# COSNER
# V.
# UMATILLA COUNTY

LUBA NO. 2011-070, 2011-071, 2011-072

Local File Number
Text Amendment, #T-10-042

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## CONSOLIDATED RECORD

## VOLUME 3 of 8, Pages 812 - 1868

McCann Appraisal, LLC

June 8, 2010

Mike McLaughlin, Chairman
Adams County Board
Adams County Courthouse
507 Vermont St
Quincy, IL 62301

Re: Wind Turbine setbacks

Dear Chairman McLaughlin
and Members of the Adams County Board:

On behalf of my clients and as a real estate valuation advisor to the elected officials of Adams County, I am hereby submitting my written testimony as a professional real estate appraiser. Having been sworn in prior to expert testimony numerous times, I am quite familiar with the serious nature of giving my oath, and you may consider this written document to be a sworn affidavit. My opinions are also certified pursuant to Illinois Appraiser Licensing law and requirements.

I understand the County is considering a 1,000 foot residential setback requirement for wind turbines, and I have read that certain committee members are contemplating a recommendation increasing that to a 1,500 foot minimum. My testimony will address the adequacy of such setbacks, based upon a synopsis of widely known, reported and/or studied effects of living in close proximity to utility scale wind turbine projects. My testimony also includes results of my own independent study of property value impacts, and my professional opinions, recommendations and supporting illustrative comment are included along with supporting data I and other appraisers and researchers have developed as well.

Finally, I have projected the likely or probable impact to residential property values in Adams County, on the basis of what independent market research indicates. When considering an ordinance for setbacks from residential lots, as well as schools and other occupied dwellings or non-industrial land uses, I believe that my specialized expertise and experience as an appraiser familiar with wind farm issues is a relevant consideration for the policy-makers in Adams County.

## Introduction

First and foremost, I understand very well that consideration of industrial scale wind energy projects is a unique situation for virtually every jurisdiction considering applications or requests from developers to build and operate such projects. They are intensive, large-scale projects with a decidedly industrial character, and most projects in

Illinois are proposed to "overlay" existing mixed-use residential and agricultural areas. This type of overlay is also sought in Adams County.

This is significant in the evaluation of land use compatibility or typical zoning standard compliance, since it is virtually impossible to introduce such a large scale project among existing low intensity residential uses without dramatically changing the character of the neighborhoods that will be encompassed by the turbine's land use overlay.

These large scale projects affect thousands of acres, and are far different than "typical" zoning variation or land use approval requests, such as a drive-through lane at a restaurant or bank, or a request to construct a gas station with a car wash. When the prudence of reviewing requests for smaller-scale, single uses is required to insure the new development does not adversely affect neighboring people or land uses, the immense scale and intensity of wind energy project development and operations demands even greater scrutiny and expert evaluation, which is often not financially feasible for smaller, rural counties.

My written testimony incorporates substantial experience with wind energy projects gained over the last 5 years, and 29 years experience as an appraiser. I have been qualified and testified in hundreds of contested and litigated land use matters, in zoning hearings, state and federal courts, and other public forums. I have been formally engaged to evaluate potential real estate impacts for 8 wind energy projects in Illinois, and have consulted with concerned citizens on a pro bono basis for several other projects throughout the United States. My qualifications and experience in this and numerous other impact studies, zoning compliance evaluations and property value damage claims is summarized within my professional biography included herein.

The ***Appraisal Institute*** has developed methodology and techniques for evaluating the effects of environmental contamination on the value of real property. The three potential effects that contamination can have on real property: cost effects, use effects, and risk (stigma) effects. All three effects are recognized as being present with utility-scale wind energy projects, as summarized in my written testimony.

**Cost effects** can include neighboring owner costs to attempt to mitigate against sound intrusion, shadow flicker, medical costs to deal with sleep deprivation related conditions, as well as, in some instances, the cost to rent substitute housing and potential legal costs incurred to protect individual owner's property rights, etc. For Agricultural property, there can be increased costs due to the loss of ability to retain aerial spraying services, which can result in increased cost for ground spraying methods and/or decreased crop yields.

**Use effects** include the loss of peaceful use and enjoyment of their homesteads for many turbine neighbors, and there is evidence that livestock has been adversely impacted by the noise from turbines, ranging from death (*goats in Taiwan*) to reproductive disorders (*See Wirtz case in Wisconsin*) and behavioral changes and irritability of horses and cattle. These may also represent cost effects, in some cases, or other forms of financial impact.

**Stigma effects** can range from loss of aesthetics, diminished views and character of neighborhoods, to fear of health issues and noise disturbance, etc. This effect is often manifest in the lack of marketability of homes in the "footprint" and nearby properties most impacted by active turbines, and to varying degrees the known and unknown cost and use effects are also contributing factors to stigma effects.

My opinions are also based on use of the recognized and generally accepted methods for valuing contaminated properties – paired sales analysis (*i.e. Appendix C*), environmental case studies analysis (*i.e. Appendices B, D, E and F*) and multiple-regression analysis. (*i.e. Appendix D*). I have also reviewed studies conducted by other appraisers, which yield similar indications of property value impacts.

In the Adams County matter, my evaluation of the proposed wind turbine setbacks is conducted from a real estate valuation perspective with a land use impact focus, since every land use has some impact upon neighboring land uses and residents. The impact can be substantially positive, negative, or so minimal as to be immeasurable in terms of property values. As I understand it, governmental policies and land use decisions are intended to prevent "significant" negative impacts on property values and the peaceful use and enjoyment of existing property by area residents.

Further, I believe the majority of my written testimony, and supporting basis thereof, is applicable to other locations characterized by residential uses interspersed with historically compatible agricultural land uses.

In order to be perfectly clear, I must also state that I have developed no professional opinion or conclusions as to the validity of the need for, or effectiveness of, industrial-scale wind energy projects for their intended purpose: the creation of renewable energy. While my research has disclosed considerable controversy on these topics as well, I leave those conclusions, opinions and corporate or governmental decisions to experts on electric utility issues and those technical aspects of these projects.

Thus, as a professional appraiser, I focus on the concept and reality of property value impacts. In order to understand the basis for any potential impacts, I have researched, collected, reviewed, studied and considered the same type of information available to anyone with an internet connected computer, which comprises the majority of the home-buying public in modern countries like the United States. I have also researched property values and value-related trends in larger wind energy project locations, to investigate whether industry claims are true or whether the neighboring citizens of such projects have valid claims regarding property value impacts.

Briefly stated, there is much to be concerned about as officials in Adams County whom are responsible for protecting the public health, safety and welfare, as well as the use and enjoyment of property and its underlying value.

As the balance of my written testimony and the supporting documentation indicates, I have developed a summary of professional expert opinions and wind energy project impact mitigation recommendations, which includes nine (9) primary opinions and ten (10) recommendations, as follows:

McCann Appraisal, LLC

## SUMMARY OF OPINIONS & RECOMMENDATIONS

### Opinions

1. Residential property values are adversely and measurably impacted by close proximity of industrial-scale wind energy turbine projects to the residential properties, with value losses measured up to 2-miles from the nearest turbine(s), in some instances.

2. Impacts are most pronounced within "footprint" of such projects, and many ground-zero homes have been completely unmarketable, thus depriving many homeowners of reasonable market-based liquidity or pre-existing home equity.

3. Noise and sleep disturbance issues are mostly affecting people within 2-miles of the nearest turbines and 1-mile distances are commonplace, with many variables and fluctuating range of results occurring on a household by household basis.

4. Real estate sale data typically reveals a range of 25% to approximately 40% of value loss, with some instances of total loss as measured by abandonment and demolition of homes, some bought out by wind energy developers and others exhibiting nearly complete loss of marketability.

5. Serious impact to the "use & enjoyment" of many homes is an on-going occurrence, and many people are on record as confirming they have rented other dwellings, either individual families or as a homeowner group-funded mitigation response for use on nights when noise levels are increased well above ambient background noise and render their existing homes untenable.

6. Reports often cited by industry in support of claims that there is no property value, noise or health impacts are often mischaracterized, misquoted and/or are unreliable. The two most recent reports touted by wind developers and completed in December 2009 contain executive summaries that are so thoroughly cross-contingent that they are better described as "disclaimers" of the studies rather than solid, scientifically supported conclusions. Both reports ignore or fail to study very relevant and observable issues and trends.

7. If Adams County approves a setback of 1,000 feet, 1,500 feet, or any distance less than 2-miles, these types of property use and property value impacts are likely to occur to the detriment of Adams County residences and citizens for which the nearest turbines are proposed to be located.

8. The approval of wind energy projects within close proximity to occupied homes is tantamount to an inverse condemnation, or regulatory taking of private property rights, as the noise and impacts are in some respects a physical invasion, an

easement in gross over neighboring properties, and the direct impacts reduce property values and the rights of nearby neighbors.

9. A market value reduction of **$6.5 million** is projected for the residential property located in the footprint and within 2-miles of the pending Prairie Mills project located in east Adams County.

## Recommendations

Therefore, if the County Board should choose to adopt the industry requested minimal setbacks, or some other setback of less than 2-miles from residential uses or occupied dwellings or structures such as schools, churches and nursing homes, I have developed a series of recommendations that would at least partially mitigate the widely experienced impacts prevalent with industrial scale wind turbines developments, as follows:

1. A Property Value Guarantee (PVG) should be required of the developer(s), significantly similar to the PVG attached hereto as **Appendix A.** A County-controlled fund or developer bond should be required to guarantee no undue delay in PVG payment(s) to legitimately affected homeowners, and/or to buy out homeowners located within 2-miles of any turbines if they elect to relocate away from the turbine project(s) and cannot sell for the pre-project market value of their properties. Such a guarantee is nominal in cost, relative to total project costs, and are used to condition high impact land use approvals such as landfills and even limestone quarries, as well as other wind energy developments (i.*e. DeKalb County, Illinois, etc.*)

2. An alternative to the bonding element of Recommendation # 1 would be to require that the developer(s) obtain a specialized insurance policy from a high-risk insurance carrier or legitimate insurer, such as Lloyds of London, if they will even insure against such impacts. If Lloyds was unwilling to provide such insurance, however, that should be compelling to the County that professional risk-management actuaries find such projects too risky for even them to insure. Under those possible circumstances the burden of risk is fairly placed with the developer, rather than the residential occupants who are being surrounded or otherwise directly impacted by close proximity of the projects.

3. If Adams County decides to permit projects, the limited evidence of impacts beyond a 2-mile setback would mitigate against the need for a PVG as cited in recommendation # 1.

4. If Adams County decides to permit projects, I recommend that the County require developer funding and a plan to constantly monitor not only sound levels in

decibels, but also in low frequency noise emissions from the turbines utilizing the best available technology, or at least homeowner reports and logs. There is significant evidence and personal accounts confirming that low frequency sound/noise is "felt" by nearby occupants, and, as I understand it, cannot be measured by decibels as audible noise is typically measured. Disclosure of the owner's actual experience to prospective buyers is necessary from both an ethical perspective and, I believe potentially under the Illinois Real Property Disclosure Act, as a "known" defect or detrimental condition. Thus, documentation should be created at the cost of the developer(s), to insure that appropriate disclosures can be made to any prospective buyer(s) of homes within the 2-mile zone.

5. Appropriate devices should be installed at the developers expense at <u>all</u> occupied dwellings and property lines within a 2-mile distance of any turbines, and the County should retain the ability to immediately enforce the shut-down of any turbines exceeding a level of 10 decibels or more above ambient background noise levels from any property/home experiencing that exceeded noise level. The proximity of constant or frequent noise sources is an adverse impact to the use and enjoyment of a residential property, and indicates a basis for loss of property value.

6. An alternative to recommendation # 5 would be to place a limit on hours of operation, requiring turbines within 2 miles of any occupied (non-participating) dwelling be shut off during normal sleeping hours (*i.e. 10 p.m. to 7 a.m.*).

7. If the County finds that the wind energy projects are desirable from a economic development goal or perspective, or for the "public good", I recommend that "footprint" and 2-mile distant neighboring homeowners (measured to lot line from the furthest span of turbine blades) be afforded the opportunity to sell to either the developer or the County, with possible use of eminent domain powers employed by the County, on behalf of and at the expense of the developer(s).

8. The financial assurance for decommissioning and reclamation of wind turbine pad sites, i.e., a bonding requirement, is also recommended as a County condition. To demonstrate solvency companies should pay the bond requirements before starting construction. It's basically insurance in case the company goes bankrupt or otherwise abandons the wind project without taking down the turbines and reclaiming the land. Coal mines, quarries, landfills and drilling companies have similar bond or financial assurance requirements.

9. An aesthetic landscaping requirement for wind project developers to plant <u>mature</u> trees or groves to shield the view between residential properties and turbines. Evergreens planted along property lines and/or other types of trees strategically planted between residential windows and turbines would partially alleviate aesthetic impacts from turbines.

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10. The County should consider a moratorium on wind energy project development(s) in Adams County, until such time as:

- A thorough and complete Wind Energy Ordinance is developed and adopted by the County, which incorporates all the protection and authority of zoning, building and health codes.
- Appropriate Conditional or Special Use standards are developed and adopted, to insure wind developers carry the burden of their for-profit projects rather than the hosting jurisdiction(s) and/or neighboring property owners.
- The actual experiences of numerous existing turbine neighbors is documented thoroughly by an impartial group of professionals with appropriate qualifications in the various relevant fields of expertise, i.e., acoustic engineers, medical sciences, valuation professionals, etc.

The preceding recommendations are not intended to be all inclusive or to address all wind energy project issues and impacts. They are intended to address issues that affect the public health, safety and welfare of area residents, as well as their property values.

The following pages summarize portions of underlying support for the preceding opinions and recommendations.

## General Impact Issues & Comment

Several Issues are relevant considerations to property value impacts. As the real estate market becomes more aware of complaints and problems attendant to living near turbines, a stigma is becoming common. Stigma issues are inextricably intertwined with property value trends, and the general public has varying but increasing levels of awareness of underlying issues and conflicts with wind energy projects.

The most measurable impact on home values is the distances from the industrial-scale turbines. The categories of impact that my research discloses as most typically related to distance include:

- Noise and "vibro-accoustic" effect.
- Aesthetics & compatibility.

Wildlife impacts, i.e., bird & bat kills, road damage, tax & fiscal impacts are also issues attendant to wind farms, but have little or no identifiable correlation to property value impacts, and are only mentioned in passing.

The following comments, excerpts and attachments attempt to summarize a representative sample of these issues, industry claims, market reactions and responses by McCann Appraisal, LLC.

First, as a part time Florida resident and homeowner, I am quite concerned about the ultimate impacts of the ongoing and catastrophic oil spill in the Gulf of Mexico. I mention this man-made disaster because I note certain parallels between the goals, claims and realities between the Gulf situation and the wind energy development trend.

One might argue that man-made disasters like the Gulf oil spill are part of the justification for pushing full steam ahead on wind energy projects, yet the parallels remain between off-shore oil drilling and wind turbine projects:

- Both project types seek to provide independent energy needs for the United States.
- Both are extremely large scale types of projects, notwithstanding the invisible & noiseless infrastructure of oil rigs to most citizens, i.e., no neighbors at sea.
- Both industries have gone on record with claims that their projects are "safe", will have very minimal impact on the environment, and include many "trust us" type statements, messages and public relations campaigns.
- Both have considerable evidence accumulated of "anecdotal", but nevertheless serious negative impacts that are long-term and affect a relatively small percentage of the population.
- Both have historically had influence on political and legislative decision makers.
- Questionable "science" is cited and utilized by the energy industry to support their PR claims and approval requests, with respect to property values and health

issues emanating from noise, and primarily the sleep interruptions. As an example, Exxon was able to obtain a written opinion that the Valdez spill did not damage coastal property values, despite the nearly complete destruction of the local fishing-based economy and the extensive environmental degradation from the oil spill.

- With accidents like the Valdez spill and now the BP Gulf catastrophe, and against the growing anecdotal list of impacts from industrial-scale wind turbine projects, it is justifiable to enforce the assurances and responsibilities of the energy industry, overall, and to place the cost of mitigating their impacts on the corporations who develop, own and operate the energy projects.

Further, when the term ***"Green Energy"*** is used, I perceive an implicit claim by the wind energy industry and even governmental policy goals that creation of such energy is (*intended to be*) of low or no impact on the environment. I consider impacts on people and their property values to be included in the term "environment".

There is however a considerable body of evidence that clearly shows there are in fact many circumstances where this intention does not match the reality, and is affecting many people, livestock, lifestyles, sleep and health issues, and the related underlying property values of wind turbine neighbors.

The Adams County consideration of a setback requirement is tantamount to a "zoning" ordinance, as it affects land use and compatibility with existing and neighboring land uses.

Zoning is defined in similar ways as:

- Dividing an area into zones or <u>sections reserved for different purposes</u> such as residence and business and manufacturing, etc.
- Legislative action for the purpose of regulating the use of property and the construction of buildings, facilities or structures within the area under the jurisdiction of the legislative body concerned.
- An exercise of police power by a municipality to regulate and control the character and use of property.
- Governmental authority over land use, intended to protect the public health, safety and welfare, while creating or preserving compatibility between land uses.

Most Zoning Ordinances require as a condition for approval of a special use, such as a wind energy generating project, that the ***"proposed use will not be injurious to the value of neighboring property"*** and/or "***will not prevent the use and enjoyment of neighboring property for uses to which it is already used or zoned"***.

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Despite the consistently reported effects on neighboring people, a typical developer's answer to this is: ***There is no "scientific" evidence of health issues.***

My response to that is there has been no legitimate study by the wind industry to determine what, if any health effects are linked to proximity to turbines.

To my knowledge there are no scientific studies that prove bricks falling from a high rise scaffold will cause injury or worse to people walking below, but there is enough "anecdotal" evidence over time to warrant building codes and ordinances that require effective barriers to **protect the public health, safety & welfare** (*which is exactly what zoning and other ordinances are supposed to accomplish*)

According to the website for Adams County, the Division of Health Protection's Environmental Health Section responsibilities include:

- reduction of food borne illnesses through restaurant and food stand inspection
- assurance of safe drinking water through private and non-community water well system permitting and inspection
- regulation of proper wastewater disposal through on-site wastewater system permitting and inspection
- permitting and annual inspection of tanning parlors
- investigation of nuisance complaints relating to the above-mentioned areas of responsibility as well as rodents and trash
- annual surveillance of mosquitoes and birds for the presence of West Nile Virus

From a land use policy perspective, which is directly related to the use and impact on homes from turbines, I anticipate the County may need to increase staff to deal with nuisance complaints from turbines located closer to homes than cited in recommendations #3, #4, #5 & #6.

To my knowledge, there are no scientific studies that prove there are ***no*** ill health effects either. The recent (December 2009) AWEA/CWEA report is merely a literature review that reads more like a "disclaimer", in its conclusions regarding review of other studies, and claims there is no scientific proof of adverse health effects. In fact, research has disclosed one of the Doctor/authors of that industry funded report has directly contradicted his prior sworn testimony regarding low frequency sound impacts so, to my mind, the report is wholly unreliable.

I may add that If citizens parked a vehicle in front of County Board member or developers homes with an audible or physically perceptible "thump-thump" low frequency beat emitted all night, with an occasional gear screeching or jet engine noise for good measure, there is little doubt that the local law enforcement department would

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be called with a disturbing the peace complaint. This complaint would also no doubt be enforceable, even if the vehicle was not actually parked on the complainant's property.

While the preceding remarks are perhaps as glib as industry claims that there are no adverse health, noise or property value effects, it is still an appropriate use of police powers of government bodies to ***prevent*** such disturbances.

But after the fact of a setback or other ordinance is approved, the noise generator has the authority of an ordinance approving the use to stand behind, and the local residents must either endure the disturbances, relocate or incur thousands of dollars in legal expenses just to be heard in a forum where the complaint is given new consideration, namely, in Court. This growing trend is costly for all involved, and can include the governmental body, participating land owners/lessors, as well as the developers and the innocent by-stander homeowners.

The alternative and, sadly, growing trend is for people to give up trying to deal with the problems of large turbines being developed in their midst, and abandon their homes (*See Wirtz family case in Wisconsin, etc).*

As a real estate appraiser with 25 years experience in evaluating zoning matters, I am unaware of any other land use in the 20 States in which I have worked that is permitted to cause such a nuisance that a property owner's rights are completely disregarded and protection of their property values marginalized to the point of meaningless and non-existent protection, via inadequate separation of incompatible uses based on industry-preferred setbacks.

I also suggest that when the governmental goal is economic development and tax revenue as the foundation for approval of these large-scale projects, they would be well advised to build in to their equation not only the cost of attorney fees to protect governmental decisions, but also the lost tax revenue from abandoned houses, potentially higher medical costs and injury claims from neighbors, road damage, and other ancillary costs that developers do not advertise, much less typically admit.

See the Canadian Hydro case for a group of neighboring homes bought out by the developer to eliminate certain vocal noise/health complaints, and note that those are not the first or last homes demolished as a direct impact of a wind energy project. Much can be read on the internet, and a summary of buy-outs is attached in **Appendix B**.

## Adams County Background

Per Wikipedia, as of the census of 2000, there were **68,277 people** (66,234 residents projected for 2010), 26,860 households, and **17,996 families** residing in the county. The population density was **80 people per square mile** (31/km$^2$). There were 29,386 housing units at an **average density of 34 per square mile.**

The median income for a household in the county was $34,784, and the median income for a family was $44,133 (Median Household Income projected for 2010 was $42,880). The per capita income for the county was $17,894. About 7.40% of families and 10.00% of the population were below the poverty line including 12.00% of those under age 18 and 8.90% of those aged 65 or over. 78% of county households earn less than $75,000 per year, leaving limited relocation options available to the majority of people in the Adams County.

**Median Home Value** for 2000 was $73,090 rising in 2005 to $106,059 and by 2010 had reached $132,445.

**Property Value Impacts**

Several physical factors, perceptions, stigma issues and concerns are reflected in the market trends used to measure property value impacts. The market trends include increased marketing time, decreased marketability and lower values for homes in relatively close proximity to new wind turbine projects. The negative factors typically include:

1. Audible sound and low frequency sound.
2. Health concerns and widely reported adverse affects at numerous project locations.
3. Sleep deprivation, which is sometimes also linked to health affects.
4. Aesthetic impacts due to introduction of large industrial-scale turbines into the immediate neighborhood, and which affects perceptions of compatibility and views from residential property.

The Appraiser has not attempted to isolate the level of value reduction related to each separate stigma issue, but has considered the sale price data to incorporate market awareness of these potential factors as a whole. Although the impacts vary from property to property, individual tolerances vary, and the distances between sale data and turbines also vary, adequate data exists to indicate that close proximity to turbines has a measureable and significant negative impact on residential property values.

I refer to **Appendix E** for a small sample of relevant sound and health concern research articles and reports, to assist the reader of this testimony in understanding the type of information still being developed regarding wind turbine noise. This sample is by no means complete or exhaustive as to the number of articles available to the general public on the internet, but it accurately reflects the trends and reported circumstances encountered by wind project neighbors.

Health concerns and impacts documented by Dr. Nina Piepont, the World Health Organization, and medical professionals from the United States, France, Canada, etc., link health impacts to noise issues primarily, and while not commonplace, there are reports of noise being heard or "felt" as far as 2-miles from the nearest turbine to residences.

Aesthetic impacts or amenity factors, while more subjective and personal, have a well established relationship to property values. An attempted objective measurement of amenities represented by property sale data with vistas ranging from premium to poor is contained in **Appendix D**, **Figure ES-2**. This data was derived from the 2009 United States Department Of Energy (DOE) funded study, prepared by researchers affiliated with an acknowledged advocate of wind energy development, thus, it is not subject to being categorized as an "objector's study". Nevertheless, it is demonstrative that poor vistas (views) typically yield property sale prices **21% lower than homes with an average vista**, and approximately **34% lower than homes with a premium vista.**

Similarly, Figure **ES-4** in **Appendix D** indicates measureable declines in property values over time, with reductions beginning after announcement of wind energy projects within a mile of home sales, and even steeper declines after the turbines have been operational for several years.

Finally, and despite the executive summary conclusions of the DOE funded study excerpted in **Appendix D, Figure ES-1** clearly shows a **5.3% to 5.5%** lower property value for homes within 1-mile of turbines, and a measured decline out to a 2 mile distance, as compared to the base-line home sales located more than 5-miles from turbines.

It is noted that this study analysis used regression analyses developed by the authors, and which has been subject to professional peer review criticism for the application of regression techniques and arguably incomplete or improper variables. Thus, this study may tend to minimize the actual impacts, as the carefully crafted language in the report's executive summary appears to indicate is the case.

What is clear is that there is a simple correlation or appropriate comparison between the data represented by Extreme Views of turbines and the Poor Vista views, as shown in the photograph appendices (D & E) within **Appendix D**, and the Poor Vista data shows a **21% lower than average value** for homes.

**Appendix C** contains data derived from Lee County Illinois Assessor records, and has in fact been used by an appraiser in Illinois for several different wind project developer zoning applications in Illinois and Wisconsin. After performing statistical analysis of select data with certain data excluded from the analysis, the appraiser was able to conclude that there was no measurable and statistically significant difference between home sales in zones within 2 miles and more than 2 miles from the nearest turbines of the Mendota Hills project.

However, there was also a 10% deviation from the mean, which indicates the conclusions are only valid beyond that deviation. In my opinion, discounting effects that lie within a 10% deviation is not indicative of appropriate consideration of value losses, as a 10% loss of home value is a significant loss to most people in the marketplace, and goes well beyond typical price reductions of negotiated sales. Regardless, both the near and far data is presumably reflective of typical negotiations, yet only the pattern from the nearby property sales shows even further declines in average sale prices.

I have analyzed the same data, as shown in **Appendix C**, on the basis most similar to how the market views residential property. On its face, the data reflects a **25% lower average** sale price per square foot for homes located within 2-miles of turbines, as compared to homes outside the 2 mile zone.

My findings are consistent with other non-industry retained appraisal studies of property values near wind turbine projects, and I submit copies of those studies as supplemental documentation to this written testimony.

**Appendix F** contains a partial list of wind turbine neighbor complaints which are mostly unresolved. However, when combined with the sample of developer buyouts caused by noise/health effects shown in Appendix B as well as other reports of home abandonment, rental of replacement housing by neighbors, and the non-anecdotal data contained in Appendices C and D, there exists adequate data to indicate market support for Recommendation 1 (Appendix A) to Adams County.

**Property Value Impact Projection – Adams County**

The pending Prairie Mills (PM) project located in east Adams County has been disclosed to the degree that a number of turbine leases are known to exist in certain sections of Clayton, Concord, Columbus and Camp Point Townships.

Via review of reported turbine lease location information and comparison with Farm Plat Maps for the preceding Townships, it has been estimated that approximately 143 homes are located within the "footprint" of the project, and Forty seven (47) Sections are identified as locations for at least one (1) turbine in each Section, which represents a 47 square mile or 30,000+ acre "footprint" for the PM project. This indicates an existing residential development density of just over 3 homes per square mile. Based on an additional 47 sections for each surrounding/abutting square mile, the 2 mile impact zone is estimated to contain approximately 94 square miles with 282 homes.
**(94 square miles X 3 homes per square mile = 282 homes)**

According to Adams County demographic data researched, the median home value was $132,445 for 2010; say $130,000. Thus, aggregate residential home values in the probable impact area for the PM project, prior to development of the project, is estimated as follows:

Footprint homes: 143 X $130,000 = $18,590,000
2-mile zone: 282 X $130,000 = <u>$36,660,000</u>

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Aggregate value: $55,250,000

Further review and disclosure of locations may increase the number of homes within the 2-mile zone, as it may incorporate higher density communities. I also recognize that the most severe impacts are realized by homes in the footprint, and those with the shortest setbacks from turbines outside the footprint. Those at the furthest points or with more effective screening afforded by topographic and landscaping features are not as likely to experience the maximum value impact. As a conservative check on the impact projections, I will utilize the 25% loss factor for homes in the footprint, and only a 5% value diminution factor as an average in the 2-mile zone. On this basis, property value losses projected due to the PM project are calculated as follows:

| | | |
|---|---|---|
| Footprint homes: | $18,590,000 X 25% = | $4,647,500 |
| 2-mile zone: | $36,660,000 X 5% = | $1,830,000 |
| Aggregate value reduction: | | $6,477,500 or **$6.5 million** |

Thus, if each and every residential Property Owner within the footprint and the 2-mile zone elected to move and sold for the appraised value, and the developer in turn sold each home for the post-project reduced value, the developer would incur a cost or loss of about $6.5 million. This is equal to the cost of 2 to 3 turbines, and is essentially a "contingency" category in their financial pro-forma, but clearly not a cost-prohibitive factor that warrants or requires abandonment of the project.

On balance, if the typical developer claims are true, then no homeowners will be disturbed to the degree that they will seek to move away from the project, and the value impact cost that is fairly absorbed by the project developer can be viewed as an unlikely worst-case scenario. However, if the market data supported basis for projecting value losses should materialize to the full extent of the projected estimate, then the developers gain should not be at the financial expense of existing homeowners and families.

Further, at least one other wind energy project is proposed for Adams County, the Rock Creek project proposed for Ellington, Mendon South, Mendon North and Ursa Townships. Rumors of a third project have been discussed to some degree, but the Appraiser does not have adequate data to evaluate the level of impact probable in the latter two projects.

A somewhat meaningful projection of the impact of 2 or 3 projects, however, can be simply calculated by doubling or tripling the value losses projected for the Prairie Mills project, and refined at a later date on a pro-rata basis when the number of proposed turbines is known and the number of affected residential properties counted more accurately.

Further, based on the residential density of Adams County, overall, with an average density of 34 homes per square mile (also equal to 18.8 acres per home average), the number of homes in the footprint is estimated without projecting value losses into nearby towns or villages.

**Closing Comment**

I trust that the preceding written testimony is useful to helping the Adams County Board in understanding better some of the issues that are commonplace with hosting wind energy project developments, and that complaints of neighbors are not just typical comment from people who don't want anything to ever change in their surroundings. There are real, tangible and discernible negative impacts and "stigma" associated with far too many wind projects to simply be an overly vocal minority.

When people react to the negative influences in ways that would normally seem extreme, such as filing lawsuits or selling their properties for steep discounts from what they should be worth on the open market, or give up on marketing attempts completely and end up abandoning homes, it is not a minor impact or "refrigerator noise" that triggers such market reactions. Those comparisons often made by wind energy representatives are disingenuous, based on virtually everything I have researched.

Market sale data analyzed not only by me, but also by proponents and highly paid consultants to the wind industry, can not hide the fact that these effects become measurably manifest in dollar terms, even if that is just one component of negative impacts.

To be sure, not every neighbor experiences the identical effects or has identical reactions, but the negative reactions are clearly widespread enough to warrant special measures, consideration and conditions to be placed on wind energy project developers, and use of setbacks that are well outside of industry preferences appears to be the single best way to avoid or minimize impacts.

I understand that my recommendation of a 2-mile setback exceeds most of the setbacks required by other communities, but then again it is not my goal to win favor with wind energy developers or to march in step with the typical community setback requirements. My setback recommendation also is fairly consistent with independent medical expert recommendations, which they have based on real-life experience in treating people suffering from closer proximity to turbines.

If it is Adams County's goal to avoid as much conflict as possible, the 2-mile setback, in my professional opinion, has the best chance of accomplishing this goal. However, if the County wants all the benefits promised by wind energy, developers will likely indicate that their projects are not feasible with that kind of requirement. I believe that my recommendations in the event of shorter setbacks are reasonable, economically justified and feasible, and will help to keep "whole" the residents who would be the real hosts to the turbines, by having them as neighbors day and night.

Wind developers are running against the clock to get the funding and tax benefits via expediting their projects as quickly as possible while it is still available, and it is reminiscent of the wild-west pioneering days of this country. Yet, we all know how that turned out for the natives of the land used for expanding the nation. It is my belief that orderly and controlled growth will be better in the long run for the economic health of host communities and their residents, and Adams County is in a position to guide this trend in such a manner by adopting reasonable low or no impact setbacks, and/or adopting the recommendations that will reduce social and financial impacts of utility scale wind energy projects proposed in Adams County.

My best wishes to the County in this difficult decision making process.

Respectfully submitted,

McCANN APPRAIISAL, LLC

Michael S. McCann

Michael S. McCann, CRA
*State Certified General Real Estate Appraiser*
*License No. 553.001252 (Expires 9/30/2009)*

# ADDENDUM

- Appraisal Testimony Certification
- Professional Biography of Appraiser
- Adams County Map
- Adams County Market Profile & Demographics
- Adams County Township Map
- **Appendix A -** Property Value Guarantee Agreement
- **Appendix B -** Canadian Hydro home buy out records
- **Appendix C -** Mendota Hills Property Value Impact Sale Data
- **Appendix D -** DOE funded Multiple Regression Analysis study of wind energy project impact on residential property values.

  Figure ES-1
  Figure ES-2
  Figure ES-4
  Appendix D - Vista rating photographs
  Appendix E – View rating photographs

00000830

Cape Vincent Realtors Report on wind project impact on marketability of homes

- **Appendix E -** Case studies and articles regarding noise impact
- 
- **Appendix F -** Representative sample of neighbor complaints

## EXHIBIT A

CONTINGENT AND LIMITING CONDITIONS OF APPRAISAL AGREEMENT

The following terms and conditions apply to this and any engagement of McCann appraisal, LLC (McCann), by the client. Written, electronic or oral authorization by the client or their attorney or agent to proceed with the assignment shall constitute acceptance of these terms by the client.

It is assumed that the title to this property is good and marketable. No title search has been made, nor have we attempted to determine ownership of the property. The value estimate is given without regard to any questions of title, boundaries, or encroachments. It is assumed that all assessments are paid. We assume the property to be free and clear of liens and encumbrances except as noted. No attempt has been made to render an opinion or determine the status of easements that may pre-exist.

The legal description, if included herein, should be verified by legal counsel before being relied upon or used in any conveyance or other document.

Any exhibits in the report are intended to assist the reader in visualizing the property and its surroundings. The drawings are not intended as surveys and no responsibility is assumed for their cartographic accuracy. Drawings are not intended to be exact in size, scale, or detail.

Areas and dimensions of the property have not been physically measured unless specifically stated by McCann in the written appraisal report. If data is furnished by the Client or from plot plans or surveys furnished by the Client, or from public records, we assume it to be reasonably accurate. In the absence of current surveys, land areas may be based upon representations made by the owner's agents or our client. No responsibility is assumed for discrepancies, which may become evident from a licensed survey of the property.

Our value estimate involves only the real estate and all normal building equipment, if any improvements are involved in this appraisal. No consideration was given to personal property (or special equipment), unless stated.

It is assumed that the property is subject to lawful, competent and informed ownership and management unless noted.

Information in this report concerning market data was obtained from buyers, sellers, brokers, and attorneys, trade publications or public records. This information is believed to be reliable. Dimensions, areas, or data obtained from others is believed correct; however, no guarantee is made in that the appraiser did not personally measure same.

Any information, in whatever form, furnished by others is believed to be reliable; however, no responsibility is assumed for its accuracy. The client specifically waives any claim of liability, which may result from reliance on information furnished by others.

The physical condition of any improvements described herein was based on visual inspection only. Electrical, heating, cooling, plumbing, sewer and/or septic system, mechanical equipment and water supply were not specifically tested but were assumed to be in good working order, and adequate, unless otherwise specified. No liability is assumed for the soundness of structural members, since no engineering tests were made of same. The roof(s) of structures described herein are assumed to be in good repair unless otherwise noted.

If the client has any concern regarding the structural, mechanical or protective components of the improvements described herein, or the adequacy or quality of sewer, water or other utilities, it is suggested that independent contractors or experts in these disciplines be retained and consulted before relying upon this appraisal, or a specific written disclosure of the defect or property condition must be made to the appraiser as part of the assignment.

We have not been provided, nor are we familiar with any engineering studies made to determine the bearing capacity of the land. It is therefore assumed that soil and subsoil conditions are stable unless specifically outlined in this report. We assume no responsibility for any such conditions, which may render the property more or less valuable. The client assumes responsibility for obtaining any engineering study necessary to determine soil and subsoil conditions. The client agrees to provide same in advance of execution of this agreement, or to waive any and all liability, which may result from undisclosed soil or subsoil conditions.

The existence of potentially hazardous material used in the construction or maintenance of the building, such as urea formaldehyde insulation and/or asbestos insulation, which may or may not be present on the property, has not been considered. In addition, no deposit of toxic wastes, unless specifically disclosed to the appraiser in advance of submittal of the appraisal report, has been considered. The appraiser is not qualified to detect such substances and suggests the client seek an expert opinion, if desired. Further, this report does not consider the potential ramifications due to the presence of Underground Storage Tanks (UST) or the possible environmental impact due to the leakage and/or soil contamination, if present.

It is specifically noted that the appraiser(s) have not conducted tests to determine the presence of, or absence of, Radon. We are not qualified to detect the presence of Radon gas, which requires special tests and therefore must suggest that if the client is concerned as to the presence of Radon or any other potentially hazardous substances, he or she should take steps to have proper testing done by qualified firms who have the equipment and expertise to determine the presence of this substance in the property.

The separate allocation between land and improvements, if applicable, represents our judgment only under the existing utilization of the property. A re-evaluation should be made if the improvements are removed or substantially altered, and the land utilized for another purpose.

All information and comments concerning the location, neighborhood, trends, construction quality and costs, loss in value from whatever cause, condition, rents, or any other data for the property appraised herein, represents the estimates and opinions of the appraiser formed after an examination and study of the property.

Any valuation analysis of the income stream had been predicated upon financing conditions as specified in the appraisal report, which we have reason to believe are currently available for this property. Financing terms and conditions other than those indicated may alter the final value conclusions.

Expenses shown in the Income Capitalization Approach, if used, are estimates only, and are based on past operating history if available, and are stabilized as generally typical over a reasonable time period.

The appraiser is not required to give testimony or appear in court because of having made this appraisal, with reference to the property in question, unless arrangements have been made previously thereto. If the appraiser(s) is subpoenaed pursuant to court order, the Client will be required to compensate said appraiser(s) for their time at their regular hourly rates plus expenses.

All opinions, as to values stated, are presented as the appraiser's considered opinion based on the information set forth in the report. We assume no responsibility for changes in market conditions or for the inability of the Client or any other party to achieve their desired results based upon the appraised value. Further, some of the assumptions made can be subject to variation depending upon evolving events. We realize some assumptions may never occur and unanticipated events or circumstances may occur. Therefore, actual results achieved during the projection period may vary from those in our report.

Appraisals made subject to satisfactory completion of construction, repairs, alterations, remodeling or rehabilitation, are contingent upon completion of such work in a timely manner using good quality materials and workmanship and in substantial conformity to plans or descriptions or attachments made hereto.

The Americans with Disability Act (ADA) of 1990, (effective January 2, 1992), as passed by the United States Congress, establishes a clear and comprehensive prohibition of discrimination on the basis of disability. This public law (Titles I-V) addresses employment (1); public services (II); public accommodations and services operated by private entitles (III); telecommunications (IV); and miscellaneous provisions (V). The law covers all "commercial facilities" intended for non-residential use whose operations affect commerce. Most private manufacturing, industrial, and warehouse facilities, are neither considered public accommodations (even though their office area may be), nor are they generally subject to Title III of the law.

The appraiser has not made a specific compliance survey and analysis of the subject property to determine whether or not it is in conformity with the various detailed requirements of the ADA. It is possible that a compliance survey of the subject property, along with a detailed analysis of the requirements of the ADA, could uncover that the subject property is not in compliance with one or more of the requirements of the Act. If this situation occurs, it could have an adverse effect upon the market value of the subject property.

Unless otherwise noted, it is assumed that the construction and use of the appraised property, if improved, complies with all public authorities having jurisdiction, including but not limited to the National Environmental Protection Act and any other applicable federal, state, municipal, and local environment impact or energy laws or regulations.

The appraisal services and appraisal report are intended and believed to be developed in compliance with the relevant requirements of the Uniform Standards of Professional Appraisal Practice (USPAP). A signatory of the appraisal report is licensed by the State of Illinois as a Certified General Real Estate Appraiser and is a Member or Associate Member of the Appraisal Institute. The Bylaws and Regulations of the Appraisal Institute require their members, candidates, or employers to control the use and distribution of each appraisal report signed by such member or candidate. Therefore, except as hereinafter provided, the party for whom the appraisal report was prepared may distribute copies of the appraisal report, in its entirety, to such third parties as may be selected by the party for whom the appraisal is prepared. Selected portions of this appraisal report, however, shall not be given to third parities without prior written consent of the signatories of this appraisal report. Further, neither all nor any part of this appraisal report shall be disseminated to the general public by the use of advertising media, public relations media, news media, sales media or other media for public communication without the prior written consent of the signatories of the appraisal report. This restriction applies particularly as to the valuation conclusions, the identity of the appraisers, or any reference to the Appraisal Institute. McCann will retain the control and confidentiality of the clients file unless legally required to release such file.

The Appraiser/ consultant responsibility is limited to the client, and use of this appraisal by third parties shall be solely at the risk of the client and/or third parties. This report should not be used or relied upon by any other party except the client to whom the report is addressed. Any party, who uses or relies upon any information in the report without the appraiser's written consent, does so at his own risk.

It is the intent of the appraiser(s) and those that retain their services, that the liability of McCann for any allegation of negligent acts, omissions, misrepresentations, or erroneous reliance upon information provided by others, is limited to and shall not exceed the cost of the services rendered. In the event of any disagreement between the parties regarding the services performed, fees and/or expenses to be paid, or any other clause in this document, it is agreed that such dispute shall be submitted to arbitration. The client waives any cause of action in the event of their failure to file such claim within one year.

McCann retains all copyrights to any work product developed by McCann on this assignment, and licenses use of the report exclusively to the client in exchange for the professional fees disclosed in the proposal.

McCann Appraisal, LLC

## CERTIFICATION

**PROPERTY LOCATION:** Adams County, Illinois
Wind Turbine Setback written testimony

The undersigned, representing McCANN APPRAISAL, LLC, do hereby certify to the best of our knowledge and belief that:

FIRST: The statements of fact contained in this written consulting testimony report are true and correct.

SECOND: The reported analyses, opinions and conclusions are limited only by the reported assumptions and limiting conditions and represents the personal, impartial and unbiased professional analyses, opinions, and conclusions of the undersigned.

THIRD: We have no present or prospective interest in the property that is the subject of this report and no personal interest with respect to any of the parties involved.

FOURTH: We have no bias with respect to the property that is the subject of this report or to the parties involved with this assignment.

FIFTH: Our engagement in this assignment was not contingent upon developing or reporting predetermined results.

SIXTH: Our compensation for completing this assignment is not contingent upon the development or reporting of a predetermined value or direction in value that favors the cause of the client, the amount of the value opinion, the attainment of a stipulated result, or the occurrence of a subsequent event directly related to the intended use of this appraisal.

SEVENTH: Our analysis, opinions, and conclusions were developed, and this report has been prepared in conformity with the Uniform Standards of Professional Appraisal Practice.

EIGHTH: No inspection was made by McCann Appraisal, LLC of the property that is the subject of this report.

NINTH: No one other than the undersigned provided significant real property appraisal assistance to the person signing this certification.

TENTH: Neither the undersigned nor McCann Appraisal, LLC has previously appraised the subject property.

IN WITNESS WHEREOF, THE UNDERSIGNED has caused these statements to be signed and attested to.

Michael S. McCann

Michael S. McCann, CRA
*State Certified General Real Estate Appraiser*
*Illinois License No.553.001252*
*(Expires 9/30/2011)*

# PROFESSIONAL BIOGRAPHY

## MICHAEL S. MCCANN, CRA

Michael S. McCann has been exclusively engaged in the real estate appraisal profession since 1980, and is the owner of McCann Appraisal, LLC.

**EXPERIENCE**

His appraisal experience has included market value appraisals in 20 states of virtually all types of commercial, office, residential, retail, industrial and vacant property, along with a wide variety of unique or special purpose real estate, such as limestone quarries, hotels, contaminated properties, etc. Appraisals have been prepared for purposes including condemnation, litigation, purchase, sale, estate planning, fractional interest valuation, leasehold and leased fee analysis, financing, divorce, damages and construction defects, easements, highway extension and widening, foreclosure, and numerous other purposes.

He has gained extensive experience in real estate zoning evaluations and property value impact studies, including analysis of gas-fired electric generating plants, shopping centers, industrial facilities, limestone quarries, sanitary landfills, transfer station, cell tower and wind farm projects. He has been retained as an independent consultant to municipalities, government agencies, corporations, attorneys, developers lending institutions and individual and private owners associations, and has completed appraisals for the States Attorney of Cook County, Illinois, for numerous downtown office buildings, major retail, hotel and commercial properties.

In addition to evaluation of eminent domain real estate acquisitions for both property owners & governmental condemning authorities, Mr. McCann has served as a Condemnation Commissioner (2000-2002) appointed by the United States District Court - Northern District, for the purpose of determining just compensation to property owners, under a federal condemnation matter for a natural gas pipeline project in Will County, Illinois.

He has been a speaker at seminars for the Appraisal Institute, the Illinois State Bar Association and Lorman Education Services on topics including the vacation of public right of ways (1986), and Property Taxation in the New Millennium (2000), Zoning and Land Use in Illinois (2005, 2006).

Related real estate expertise has been gained through negotiating transactions with a total in excess of $65 million for purchase and sales of acreage and smaller sites, commercial and residential properties, both as agent on behalf of private and governmental clients and personally.

**EXPERT TESTIMONY**

Deposition, trial and public hearing testimony has been given for assignments that include appraisals, studies and consultation regarding real estate located throughout the United States. He has qualified and testified as an expert witness in Federal Court and numerous State Circuit Courts for condemnation, property tax appeal, foreclosure, divorce, and property damage proceedings and zoning matters in the Counties of Cook, Will, DuPage, Boone, Lake, Madison, St. Clair, Iroquois, Fulton, McHenry, Ogle, Marshall, & Kendall, as well as the Chicago and Cook County Zoning Boards of Appeal, the Property Tax Appeal Board (PTAB) and tax court &

Commissions of Illinois, Wisconsin, and Ohio, Circuit Courts in New Jersey and Indiana, as well as zoning, planning, and land use and County Boards in Texas, Missouri, Idaho, Michigan, New Mexico and various metropolitan Chicago area locales. He has been certified as an expert on the Uniform Standards of Professional Appraisal Practice (USPAP) by the Cook County, Illinois Circuit Court.

**PROJECT EXPERIENCE**

Mr. McCann has substantial experience in large-scale condemnation and acquisition projects and project coordination at the request of various governmental agencies and departments. These include appraisals for land acquisition projects such as the Chicago White Sox Stadium project, the Southwest Transit (Orange Line) CTA rail extension to Chicago's Midway Airport, the United Center Stadium for the Chicago Bulls and Blackhawks, the minor league baseball league, Silver Cross Field stadium in Joliet, Illinois, I-355 tollway and numerous highway acquisition and improvement projects, railway ROW transactions, as well as many other urban renewal, acquisition and neighborhood revitalization projects.

**REAL ESTATE EDUCATION**

Specialized appraisal education includes successful completion of Real Estate Appraisal Principles, Appraisal Procedures, Residential Valuation, Capitalization Theory and Techniques Part A, Uniform Standards of Professional Appraisal Practice and USPAP update courses, Case Studies in Real Estate Valuation, Highest and Best Use and Market Analysis, Advanced Income Capitalization, Subdivision Analysis and Special Purpose Properties, Eminent Domain and Condemnation, and Valuation of Detrimental Conditions in Real Estate offered by the Appraisal Institute. In addition, he has completed the Society of Real Estate Appraisers' Marketability and Market Analysis course, the Executive Enterprises - Environmental Regulation course, and a variety of continuing education real estate classes and seminars offered by other appraisal education providers, such as Litigation Valuation, Appraising in a Changing Economy, etc. Real estate courses from state licensed appraisal education providers were all subsequent to two years of associate study at the College of DuPage for marketing and real estate, and exceed the requirements for the Illinois Certified General Real Estate Appraiser license. Michael McCann is current with all continuing education requirements.

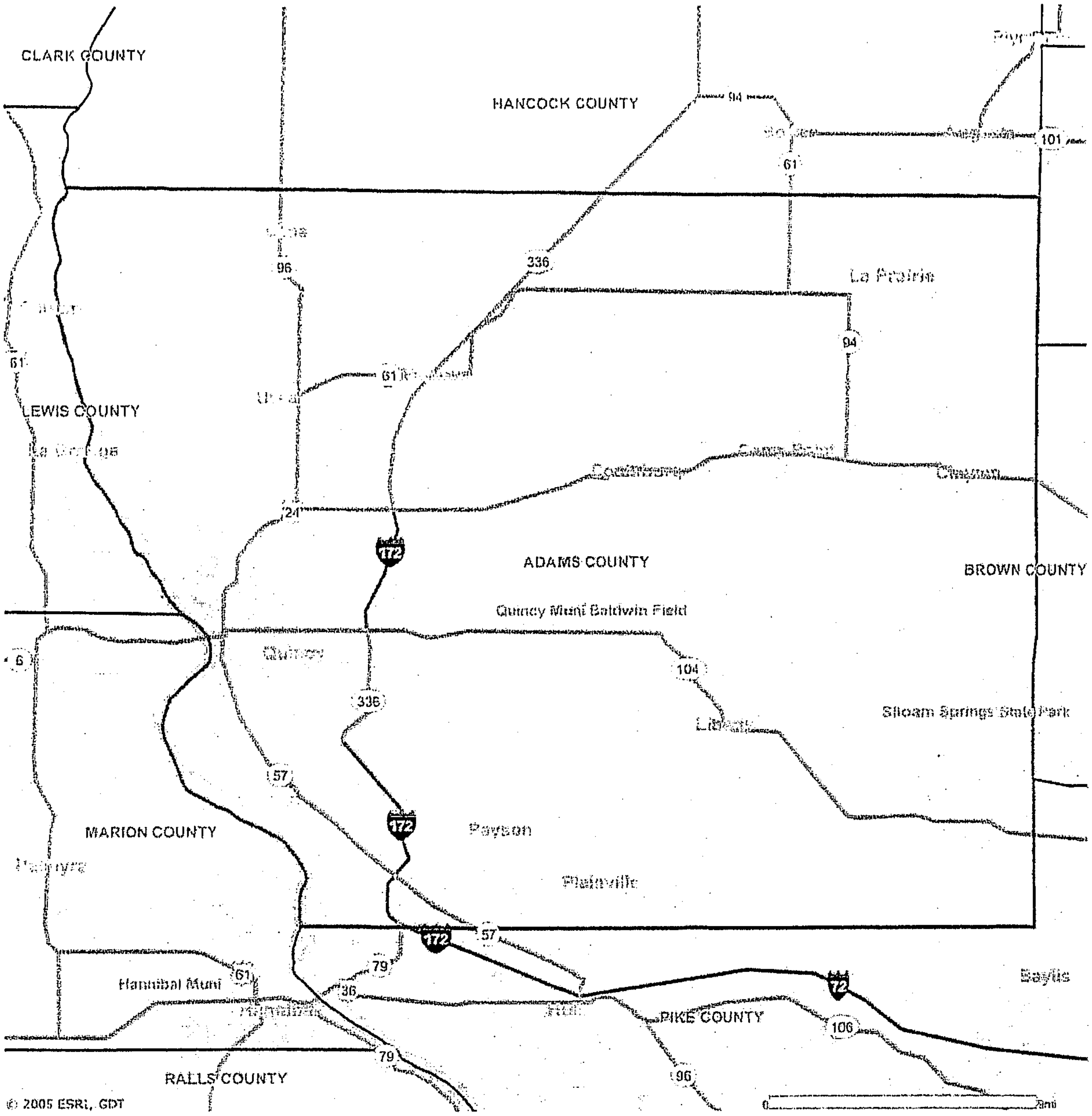
**DESIGNATIONS, PROFESSIONAL AFFILIATIONS & LICENSES**

Mr. McCann is a State Certified Associate Member of the Appraisal Institute, and the National Association of Review Appraisers & Mortgage Underwriters designated him as a Certified Review Appraiser (CRA). He was elected in 2003 as a member of Lambda Alpha International, an honorary land economics society, and he served several years as a member of the Appraiser's Council of the Chicago Board of Realtors. He has held appraisal and sales licenses in several states, and is a State Certified General Real Estate Appraiser in the State of Illinois. *(License No. 533.001252, expiration September 30, 2011)*

McCann Appraisal, LLC

## Adams County Standard Map

January 10, 2006



## Adams County Market Profile

| | |
|---|---|
| **2010 Housing Units** | 29,633 |
| Owner Occupied Housing Units | 68.9% |
| Renter Occupied Housing Units | 20.1% |
| Vacant Housing Units | 11.0% |

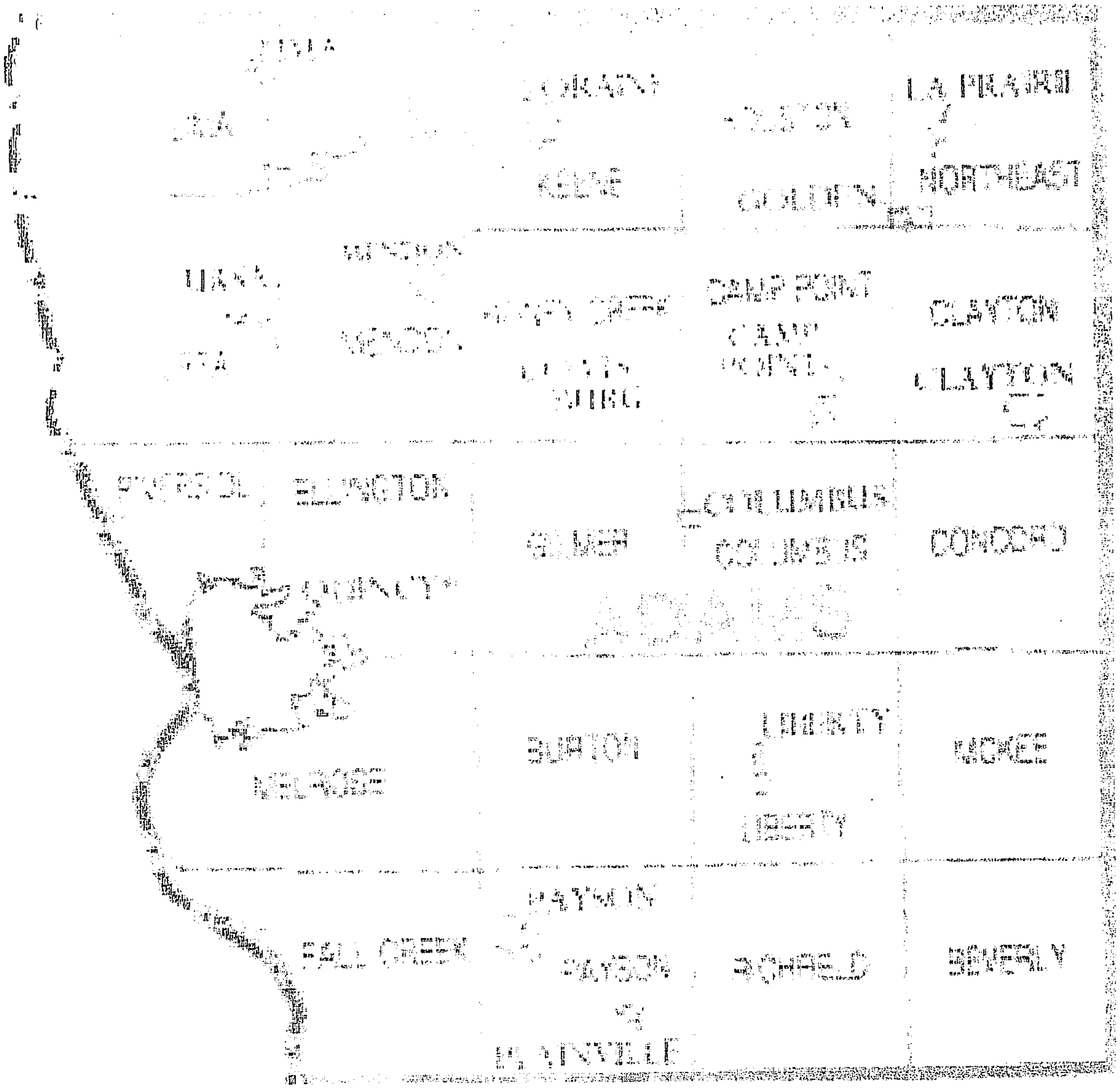
| | |
|---|---|
| 2000 Total Population | 68,277 |
| 2005 Total Population | 67,488 |
| 2010 Total Population | 66,234 |

**Median Household Income**
2000 $34,800
2005 $38,723
2010 $42,880
**Median Home Value**
2000 $73,090
2005 $106,059
**2010 $132,445**
**Per Capita Income**
2000 $17,894
2005 $20,584
2010 $23,864
**Median Age**
2000 38.2
2005 39.4
2010 40.5

**2010 Households by Income**
Household Income Base

| | |
|---|---|
| < $15,000 | 13.8% |
| $15,000 - $24,999 | 13.0% |
| $25,000 - $34,999 | 13.7% |
| $35,000 - $49,999 | 16.9% |
| $50,000 - $74,999 | 20.7% |
| $75,000 - $99,999 | 9.3% |
| $100,000 - $149,999 | 1.8% |
| $150,000 - $199,999 | 2.2% |
| $200,000+ | 2.5% |
| Average Household Income | $58,213 |

*Source:*
*U.S. Bureau of the Census, 2000 Census of Population and Housing. ESRI forecasts for 2005 and 2010.*


LA PRAIRIE
NORTHEAST
KEENE
CAMP POINT
CLAYTON
ELLINGTON
GILMER
COLUMBUS
CONCORD
QUINCY
ADAMS
BURTON
LIBERTY
MCKEE
MELROSE
PAYSON
FALL CREEK
BEVERLY
PLAINVILLE

# Appendix A

## Property Value Guarantee Agreement

This Property Value Guarantee Agreement (Agreement") made and entered into on this ___ day of ________________ , by and between *(Insert Developer Corp. Name)* ____________________________________________, having its principal offices at ____________________________________________________________("Guarantor") and ____________________________________________________, residing at (Insert address)________________________________, IL (zip)________, ("Property Owners").

**RECITALS**
WHEREAS, Property Owners own eligible Property as described herein ("Property"), that
Property having the legal description as follows:

______________________________________________________________________

______________________________________________________________________

_________________________________________________________ Adams County, Illinois.

WHEREAS, Guarantor has been granted approvals by Adams County Ordinance No. __________ for the construction and operation of a wind energy center consisting of up to #________ turbines on properties located in unincorporated ________________________________________________Townships in Adams County, Illinois ["Wind Energy Center"];

WHEREAS, Guarantor desires to alleviate concerns and guarantee preservation of Property values of all Property located in proximity to the Wind Energy Center, specifically within two (2) miles of any wind turbine (measured from furthest reach of turbine blades to the Property); and WHEREAS, Guarantor is desires to provide for either continued occupancy of existing residences by Property Owners or otherwise not financially impacting neighboring Property Owners as a result of the Wind Energy project; and WHEREAS Property Owners are desirous of preserving equity in the Property, by ensuring that if the Property described herein is either diminished in value or sold at a price less than the ASKING PRICE as a result of proximity to the Wind Energy Center, as determined by the procedures contained herein, the Guarantor will guarantee payment to the Property Owners of such difference; or if Property owner is unable to sell the Property following a reasonable marketing period, as defined herein, the Guarantor will guarantee payment to the Property Owners of the full Appraised value and purchase the Property, as defined herein.

IT IS HEREBY AGREED AS FOLLOWS:

1. EFFECTIVE DATE OF AGREEMENT. This Agreement shall become effective and binding on Guarantor when signed by both parties. Notwithstanding the foregoing, if an administrative agency or court of competent jurisdiction rules or holds that the approvals

or permits issued by Adams County for the Wind Energy Center has been in excess of or in violation of said governmental body's authority or otherwise unlawful, and Guarantor has not constructed any of the wind turbines, then Guarantor's obligations under this Agreement shall be null and void. However, the construction of any or all of the proposed turbines shall render this agreement in full force and effect, and constitute the requirement of the Guarantor to fulfill all obligations to the Property owner, as defined herein.

2. ELIGIBILITY: EXERCISE OF GUARANTEE. (a) Property that is within two (2) miles of the tip of a turbine blade that is part of the Wind Energy Center is covered by this guarantee, to the extent the property is developed or approved for development on ______________, the date Adams County voted to approve Ordinance No, ______________approving the Wind Energy Center ("Ordinance Date"). Owners of such Property who were owners of record as of the Ordinance Date ("Property Owners"), or their legitimate heirs or assigns as described in Paragraph 14, are eligible to exercise this guarantee. In the event that the Property Owners wish to sell their eligible Property, and exercise the guarantee set out in this Agreement, they shall notify Guarantor of same in writing by certified mail and thereafter they shall make a good faith effort to sell said Property by entering into a listing contract with a licensed real estate broker pursuant to the terms herein. (b) Property Owners shall have a period of ten (10) years to execute this agreement from the Ordinance date cited in paragraph 2.

3. QUALIFIED PROFESSIONAL APPRAISER. For the purposes of this Agreement, a "qualified professional appraiser" shall mean a person who is licensed by the State of Illinois as a Certified General Appraiser or Licensed Residential Appraiser who (a) holds a valid Illinois license, (b) has not been subject to any suspension or revocation of license for any prior disciplinary action regarding their Illinois License by Illinois licensing authorities or from any professional association to which Appraiser is a member or affiliated with, and (c) has not been previously retained by either the wind energy industry or any citizens or citizens groups to opine in writing or in testimony as to wind energy projects effects on property values, hereafter deemed a "Qualified Professional Appraiser" (Appraiser), (d) is not related to the Property Owners, is not an employee or prior contractor of Guarantor or its affiliates and does not otherwise have a business relationship with Guarantor or Property Owners, and (e) who is a member of at least one national appraisal association that subscribes to the requirements of USPAP, (f) has at least 5 years experience in appraising and has worked within Adams County and/or any surrounding Counties during that period. (g)All appraisal reports shall conform to the Uniform Standards of Professional Appraisal Practice (USPAP), as required by current Illinois law. (h) The appraisal fee shall be paid in advance by the Guarantor to the County, for retention of the Appraiser by the County Attorney, who shall include a copy of this agreement to the Appraiser with the required fee, and a retention letter advising the Appraiser that the County, as a neutral party, is retaining the Appraiser and they are instructed to be independent of any influence from either party to this agreement. Guarantor agrees to reimburse the County for any services required of the Appraiser subsequent to delivery of the Appraisal Report, including but not limited to time expended responding to subpoena for testimony at deposition or trial.

4. AGREED TO ASKING PRICE. The ASKING PRICE is the value of the Property at the time the Property Owner decides to sell, with Property Owner discretion to either increase or decrease the asking price by no more than 5% difference with the Appraised Value. The ASKING PRICE of the Property may, however, be mutually agreed to by the Property Owners and the Guarantor. The ASKING PRICE may be mutually amended by agreement of the Property Owners and Guarantor at any time, subject to agreement.

5. DETERMINATION OF ASKING PRICE BY APPRAISAL If the parties are unable to agree on the ASKING PRICE of the Property prior to the Property Owner listing the Property for sale, then the Guarantor shall hire, at its expense, a second Appraiser and shall notify Property Owner of such Appraiser in writing with a resume or qualification summary for the Appraiser for review by the Property Owner. If the Property Owner objects to the Guarantor's choice of appraisers, it shall state those objections to Guarantor in writing within thirty (30) days of the notification of the choice of Appraiser. In the event Property Owner reasonably objects, the Guarantor shall choose another Appraiser, and proceed as described below. When a qualified professional appraiser is hired pursuant to this Paragraph 5, he or she shall be instructed to determine the market value which will become the ASKING PRICE, subject to Property Owner 5% discretion, of the Property as follows:

a. Assume that no wind energy center or utility scale wind turbine(s) are located within two (2) miles of the Property;
b. Utilize comparable sale data of property, developed as the Property was developed as of
the Ordinance Date and located a minimum of two (2) miles distance away from the Wind Energy Center, or further so that in the opinion of the appraiser the selling price of that comparable property was not influenced by the presence of the Wind Energy Center or any other wind energy project;
c. Utilize a minimum of three (3) comparable sale property, located approximately the same distance from major population centers (such as Quincy) so that in the opinion of the appraiser the selling price of the comparable property was not influenced by its closer or more distant proximity to new or existing population or employment centers.
d. Establish the market value which is based upon the Property as developed on the Appraisal inspection date, with consideration of any normal or typical maintenance, repairs or additions made during the effective term of this agreement;
e. Prepare a written narrative appraisal or residential form report supplemented as needed with written descriptions, analysis or comments, and which conforms to the requirements of USPAP:
f. Prepare the appraisal in full compliance with any and all state standards and state regulations which pertain to the preparation of an appraisal of the Property except those standards and regulations which conflict with these instructions; and
g. The appraiser shall note the condition of the premises, both interior and exterior, at the time of the appraisal.

If Property Owner and Guarantor accept the appraised value, then such value shall constitute the ASKING PRICE, and the Property Owners shall offer the above-described Property for sale at no less or more than a 5% difference with that price. If either the Property Owner or the Guarantor does not accept the appraised value, the non-accepting party may retain a second qualified professional Appraiser, of its choice, who shall not be made aware of the first appraised value and who shall determine the market value of the above-described Property on the basis of Paragraph 5(a) through (g) above. If both parties do not accept the original appraisal, they shall agree to the second qualified professional Appraiser and Guarantor shall pay the costs. In the event a second Appraisal is obtained pursuant to this paragraph and is within ten percent (10%) of the first Appraisal, the ASKING PRICE shall be the arithmetic average of the original appraised value and the second appraised value, unless the Guarantor or the Property Owner is unsatisfied with such Appraisal with specific reason(s) given in writing for disagreement with the Appraised value. In such event, the first two appraisers shall be instructed to agree on a third qualified professional Appraiser, at the sole expense of the Guarantor or the Property Owner, whichever is unsatisfied, unless both parties are unsatisfied in which case the expense shall be equally shared, and who shall not be made aware of either the first or second appraised values, and who shall determine the market value of the Property on the basis of Paragraph 4 (a) through (g) above.. The ASKING PRICE will then be the arithmetic average of the three appraised values if the lowest value is no more than fifteen percent (15%) lower than the highest appraised value. If the fifteen percent (15%) range is exceeded the third Appraisal shall conclusively determine the ASKING PRICE for the purpose of this Agreement.

6. LISTING WITH BROKER. Property Owners shall utilize the services of a real estate broker/agent who shall be licensed in Illinois, is not financially affiliated with or related to the Appraiser, shall not be immediately related to the Property Owners or Guarantor as determined by being related no closer than second cousins and/or any history of sharing the same residence, and shall be a member of the Board of Realtors Multiple Listing Service or Exchange (Broker), unless these requirements are waived by the Guarantor upon the request of a Property Owner. Property Owners shall give Guarantor notice of the Broker with whom they wish to contract and shall obtain Guarantor's approval of said Broker within five (5) business days of written notice to Guarantor that Broker meets the no-relation requirement. Guarantor will not unreasonably withhold such approval and will confirm no relationship with Broker to the Property Owner. If the Guarantor objects to the Property Owners' choice of Broker, it shall state those objections, in writing to Property Owners. In the event Guarantor reasonably objects, the Property Owners shall choose another Broker, and proceed as described above. As sellers of the Property, Property Owners shall be responsible for the Brokerage commission or fee UNLESS the Property is purchased by Guarantor pursuant to Guarantor purchase of the Property after 180 days as provided for herein. Nothing herein shall prevent the Property Owner from selling the Property at a value higher than the ASKING PRICE as determined herein.

7.TERM OF LISTING. Property Owners shall list the Property, at the ASKING PRICE as determined in Paragraphs 4, 5 and 6, or at a higher value if agreed by Guarantor.

During the listing term, Property Owners shall accept any offer to purchase for the ASKING PRICE that is a bona-fide offer to purchase by a qualified buyer with a valid loan commitment or buyer otherwise acceptable to the Guarantor, provided that normal mortgage contingencies have been met or satisfied by buyer or waived by Property Owner and any home inspection contingency has been satisfied or waived by Property Owner. Said listing contract shall provide: (a) that the Broker shall list the Property in the multiple listing exchange; (b) that the Property will be so listed until the occurrence of either the (i) closed sale of the Property or (ii) expiration of a period of 180 days; (c) that the broker shall not be entitled to any commission after the expiration of the listing contract. The Property Owners shall cooperate with the Broker in obtaining a purchaser pursuant to the terms set forth in the listing agreement and shall make, in good faith, all reasonable efforts necessary to conclude a sale pursuant to the said terms. However, this shall not be construed as a requirement that Property Owner conceals their own experience with living in the Property, inclusive of any audible or inaudible noise effect emanating from the wind turbines.

8. OFFERS TO PURCHASE. Property Owners shall provide the Guarantor with written notification of every written contract or Offer to Purchase that they receive for the Property and agree, for a period of 180 days, not to accept any offer below the ASKING PRICE without the express and written approval of the Guarantor, provided that Guarantor responds within twenty four 24 hours of Notice from Property Owner. In no event shall the Property Owners entertain anything other than good faith, bona fide offers of purchase.

9. GUARANTOR'S CONSENT TO PURCHASE. Guarantor shall have the right to make a non-contingent counter offer(s) on any offers of purchase which are more than 5% below the ASKING PRICE, said counter offer to be tendered to the purchaser within twenty four (24) hours of notification by the Property Owner of the offer of purchase. In the event the buyer accepts or meets any such counteroffer made or requested by the Guarantor, or in the event the Guarantor otherwise consents to a sale of the Property more than 5% below the ASKING PRICE, the Guarantor shall pay the Property Owners, at closing, the difference between the ASKING PRICE and the sale price so established.

10. SALE WITHOUT GUARANTOR CONSENT. If the Property Owners have not received an offer of purchase at the ASKING PRICE within 180 days of listing the Property for sale, or the Guarantor has not consented to the sale of the Property below the ASKING PRICE, the Property Owners may sell the Property at the highest offer of purchase still pending or at the next good faith bona fide offer to purchase. It shall notify the Guarantor, in writing, of its intention to accept such offer.

11. PROPERTY OWNER'S CLAIM.
(a) If the Property has sold for less than the ASKING PRICE, as determined herein, and Property Owner believes that the reason for such lowered value is because of the Wind Energy Center's proximity to the Property, Property Owner shall make a claim to the Guarantor, requesting payment for the difference between the ASKING PRICE and the

sales price. Within thirty (30) days of such request, Guarantor shall pay the Property Owner the difference unless Guarantor, within that time, has demonstrated that the sale is not a bona-fide transaction.
(b) If the Property Owner has not received an offer of purchase at the ASKING PRICE after 180 days of listing the Property for sale, Guarantor shall, within thirty (30) days of notification in writing purchase the Property for the ASKING PRICE, unless Guarantor, within that time, has demonstrated conclusively that Property Owner did not reasonably cooperate wit the terms of a bona-fide sale contract.
© If the Property has not sold within 180 days of the Listing agreement, and Guarantor provides Multiple Listing Service statistics that demonstrate a median Marketing Time for all unincorporated Adams County residential properties is in excess of 180 days, as of the original Listing date, then Guarantor has the option of notifying the Property Owner that they must extend the Listing or enter into a separate listing agreement with a new Broker for a period of 180 days. If the extended Listing option pursuant to paragraph 11 © does not result in a bona-fide sale agreement within the second (2nd) 180 day Listing term, then Guarantor must abide by the terms of paragraph 11 (b) and buy the Property for an increased price as determined by the Appraised Value plus the most recent Consumer Price Index (CPI) multiplied by 50%.

12.AGRICULTURAL LAND. This agreement requires payment by the Guarantor to any non-participating agricultural land owners with Property located within 2 miles of the Wind Turbines, on the basis of increased costs, if any, resulting from AG property owners loss of aerial spraying services, provided that (a) Ag Property owner has utilized aerial spraying services for at least 1 of the last 3 years during crop seasons; (b) aerial spraying services either decline to continue service to the Ag Property in question as a direct result of pilot safety concerns from wind turbine structures or increase the cost of services to the Ag Property in question; (c) lower lease rates are agreed between Ag Property owner and tenant farmer as a result of tenant farmers increased costs described in paragraph 12 (a) and/or (b). Cost increases and Ag Property Owner compensation shall be based on either the actual cost increase for continued use of aerial spaying services active in Adams County or the actual contracted 3rd party cost of alternative application of AG chemicals minus the last documented cost for aerial application of AG chemicals. Guarantor shall be provided documented cost differences as soon as practical after costs are incurred by the Ag Property Owner, and shall submit payment to Ag Property Owner within 60 days of notice by Ag property Owner. However, Guarantor shall have the right to have cost information reviewed by and independent auditor during the 60 day period, and if payment due the Ag Property Owner is disputed by Guarantor, they shall have the right to submit the payment claims to arbitration In Adams County, Illinois.

13. TERMINATION OF GUARANTOR'S OBLIGATIONS. This Agreement shall terminate and Guarantor shall have no obligation to guarantee the Property value or purchase price once any wind turbines located within two (2) miles of the Property are decommissioned and demolished and operations at the Wind Energy Center have been permanently terminated as the result of any corporate decision, order, judgment, or

decree issued by a federal, state, or local agency, court, or unit of government having jurisdiction under administrative code, statute, law, or ordinances.

14.PROPERTY OWNER OPTION AND ALTERNATIVE TO RELOCATION. In the event that any Property Owner elects to remain in their home and not relocate pursuant to the preceding terms and conditions of the Property Value Guarantee, Property Owners located in the footprint or within one (1) mile of the perimeter of the footprint shall notify Guarantor within 3 years of commencement of operations of the Wind Energy Project that they are exercising their option under paragraph 14, and shall be compensated by the developer in a cash amount equal to 25% of the Appraised Value, as set forth in paragraph 5 of this agreement. Property Owners located between one (1) mile and two (2) miles of said footprint perimeter shall have 2 years to exercise the paragraph 14 option, and compensation shall be equal to 5% of the Appraised Value, as set forth in paragraph 5 of this agreement. Any exercise of the paragraph 14 Property Owner Option and payment to Property Owner by Guarantor shall constitute a full waiver and release of any future property value diminution claim or right to sell to the Guarantor as otherwise provided for in this agreement.

15. ASSIGNMENT OR TRANSFER. Neither this Agreement nor the rights under it may be assigned, conveyed, or otherwise transferred by Property Owners. The guarantee given by Guarantor to guarantee the Property value and to purchase the Property is personal, and does not run with the land; however, said Agreement shall inure to the benefit of the Property Owners, their personal representatives, trustees, guardians, custodians or their heirs; but, in all events, shall terminate after any closed sale of the Property.

16. APPLICATION OF LAW DISPUTES. This Agreement shall be construed consistent with law in the State of Illinois. Disputes concerning the application or terms of this Agreement shall be subject to the circuit court jurisdiction of Adams County.

GUARANTOR:

By ______________________________________________

Name | Title | Date

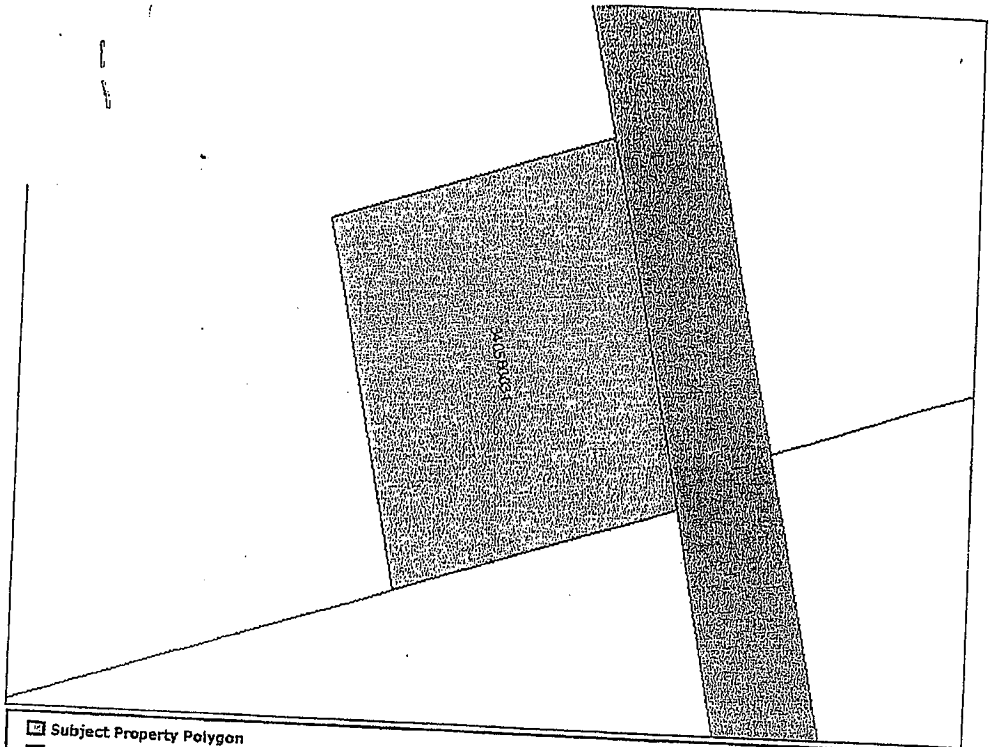
PROPERTY OWNERS:

By ______________________________________________

Name | Date

Notary ______________________________

# Appendix B



- Subject Property Polygon
- Parcel Polygons
- Roads
- Railways
- Water Limits
- Easement Limits
- Subject Property Point
- Neighbourhood Sales Points

0 10 m.

This map was compiled using plans and documents recorded in the Land Registry System and has been prepared for property indexing purposes only. This is not a Plan of Survey. For actual dimensions of property boundaries, see recorded plans and documents. Only major easements are shown.

N W E S

| SUBJECT PROPERTY IDENTIFICATION INFORMATION | |
|---|---|
| LRO | 07 |
| PIN | 340560031 |
| ASSESSMENT ROLL NUMBER | 220800000409590 |
| REGISTRATION TYPE | LT |
| LAND REGISTRY STATUS | ACTIVE |
| MUNICIPALITY | N/A |
| ADDRESS | N/A |
| AREA | 4052 m2 |
| PERIMETER | 258 m |
| | |

McCann Appraisal, LLC

| | |
|---|---|
| CRIPTION | PT LT 29 CON 7, PT 1 7R742 ; AMARANTH |
| ARTY TO: | ASHBEE, BARBARA JOAN |

SALES HISTORY

| INSTRUMENT NUMBER | REGISTRATION DATE | CONSIDERATION VALUE | INSTRUMENT TYPE | PARTY TO |
|---|---|---|---|---|
| DC43624 | 01/31/2005 | 204750 | T | ASHBEE, BARBARA JOAN |
| MF212464 | 06/30/1994 | [redacted] | T | [redacted] |

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**Coverage.** Data, information and other products and services accessed through the Land Registry Information Services are limited to land registry offices in the areas identified on the coverage map.

**Completeness of the Sales History Report.** Some Sales History Reports may be incomplete due to the amount of data collected during POLARIS title automation. Subject properties may also show nominal consideration or sales price (e.g. $2) in cases such as transfers between spouses or in tax exempt transfers.



- Subject Property Polygon
- Parcel Polygons
- Roads
- Railways
- Water Limits
- Easement Limits
- Subject Property Point
- Neighbourhood Sales Points

0 10 m.

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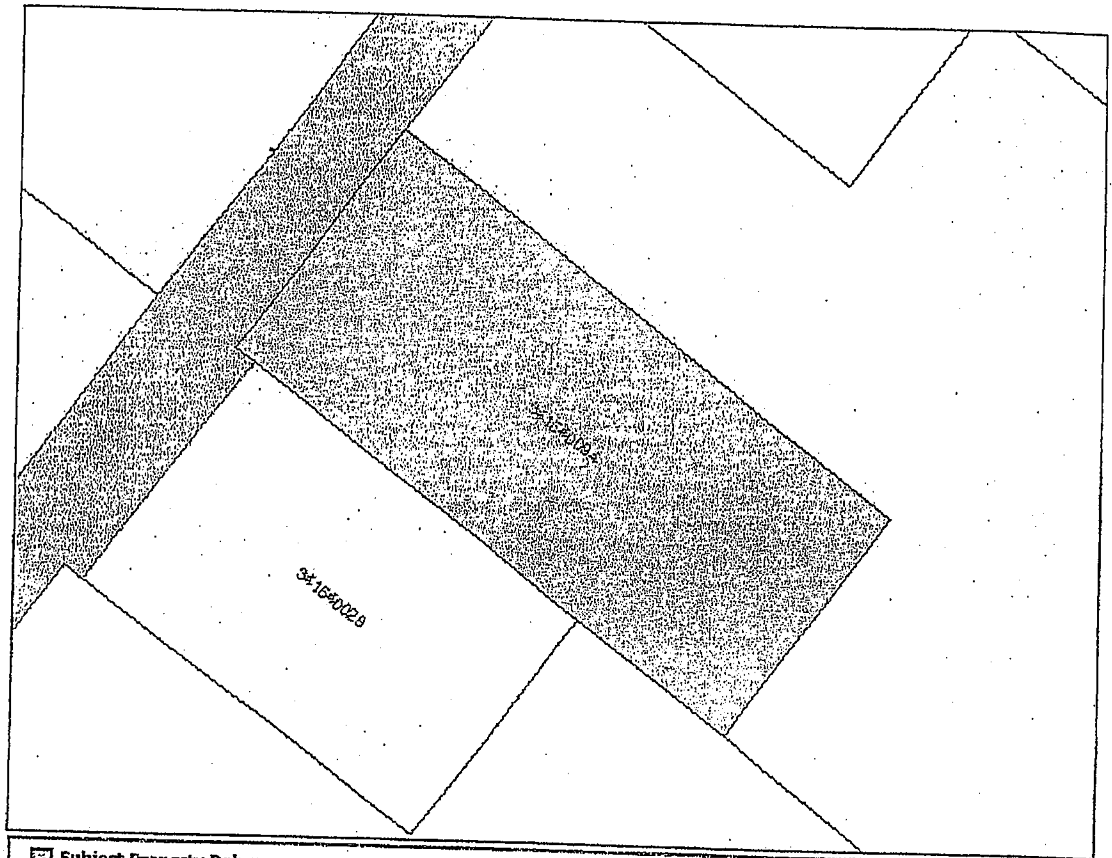
N W E S

| SUBJECT PROPERTY IDENTIFICATION INFORMATION | |
|---|---|
| LRO | 07 |
| PIN | 340560031 |
| ASSESSMENT ROLL NUMBER | 220800000409590 |
| REGISTRATION TYPE | LT |
| LAND REGISTRY STATUS | ACTIVE |
| MUNICIPALITY | N/A |
| ADDRESS | N/A |
| AREA | 4052 m2 |
| PERIMETER | 258 m |
| | |

00000852




Subject Property Polygon
Parcel Polygons
Roads
Railways
Water Limits
Easement Limits
Subject Property Point
Neighbourhood Sales Points

0 10 m.

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N W E S

| SUBJECT PROPERTY IDENTIFICATION INFORMATION | |
|---|---|
| LRO | 07 |
| PIN | 341540094 |
| ASSESSMENT ROLL NUMBER | N/A |
| REGISTRATION TYPE | LT |
| LAND REGISTRY STATUS | ACTIVE |
| MUNICIPALITY | N/A |
| ADDRESS | 58232 COUNTY ROAD, R.R. 6 |
| AREA | 8408 m2 |
| PERIMETER | 398 m |
| DESCRIPTION | PT LT 291, CON 2 SWTS, PT 2, 7R4396 ; MELANCTHON |
| PARTY TO: | CANADIAN HYDRO DEVELOPERS INC. |

**SALES HISTORY**

| INSTRUMENT NUMBER | REGISTRATION DATE | CONSIDERATION VALUE | INSTRUMENT TYPE | PARTY TO |
|---|---|---|---|---|
| DC48597 | 06/30/2005 | 299000 | T | CANADIAN HYDRO DEVELOPERS INC. |
| LTD33017 | 01/12/2001 | [redacted] | T | WILLIAMS, SANDRA MARIE BLANCHE; WILLIAMS, STEPHEN ROGER BLAINE |
| LTD11538 | 07/31/1998 | [redacted] | T | [redacted] |
| MF229782 | 08/08/1997 | [redacted] | T | [redacted] |

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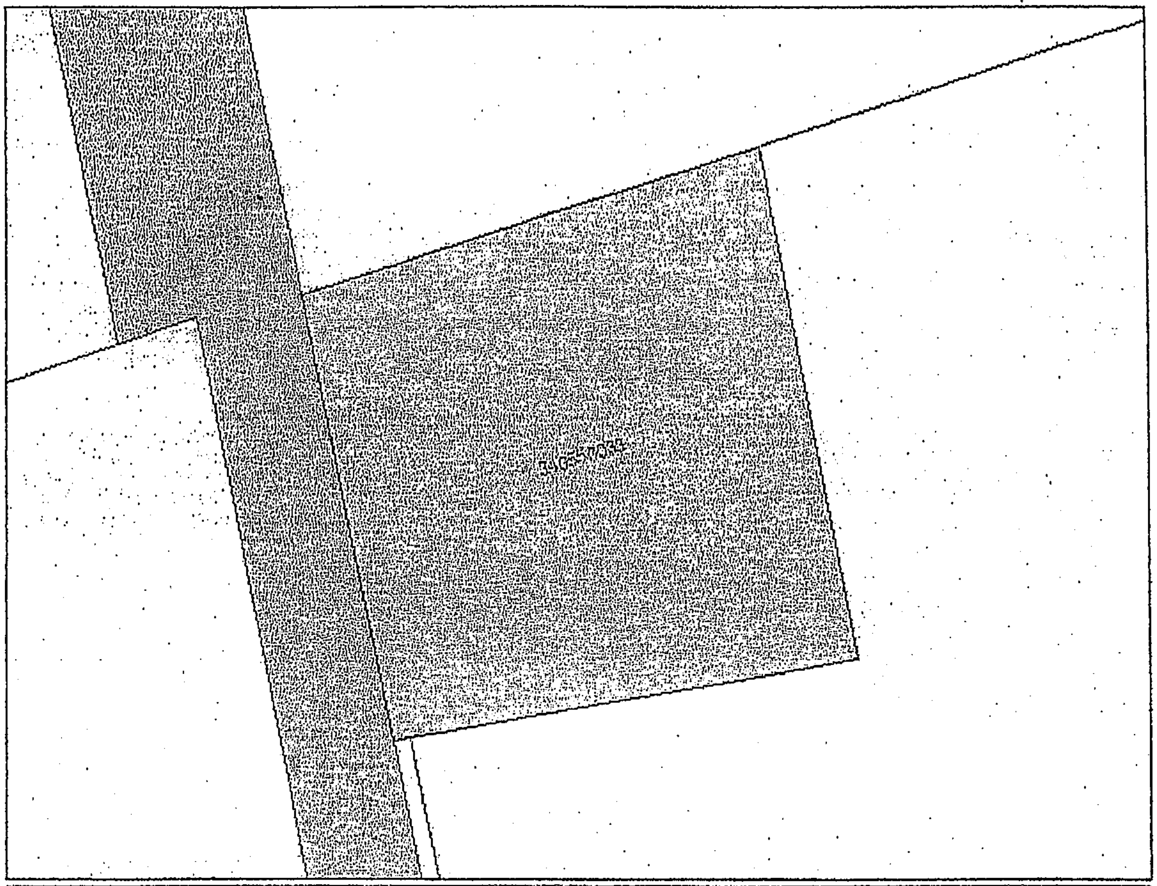

Subject Property Polygon
Parcel Polygons
Roads
Railways
Water Limits
Easement Limits
Subject Property Point
Neighbourhood Sales Points

0 10 m.

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N W E S

| SUBJECT PROPERTY IDENTIFICATION INFORMATION | |
|---|---|
| LRO | 07 |
| PIN | 340550033 |
| ASSESSMENT ROLL NUMBER | 220800000321580 |
| REGISTRATION TYPE | LT |
| LAND REGISTRY STATUS | ACTIVE |
| MUNICIPALITY | N/A |
| ADDRESS | N/A |
| AREA | 7622 m2 |
| PERIMETER | 350 m |
| DESCRIPTION | PT LT 29, CON 5, PT 1, 7R787 ; AMARANTH |
| PARTY TO: | CANADIAN HYDRO DEVELOPERS, INC. |

McCann Appraisal, LLC

SALES HISTORY

| INSTRUMENT NUMBER | REGISTRATION DATE | CONSIDERATION VALUE | INSTRUMENT TYPE | PARTY TO |
|---|---|---|---|---|
| DC81185 | 11/15/2007 | 500000 | T | CANADIAN HYDRO DEVELOPERS, INC. |
| LTD11172 | 07/20/1998 | [redacted] | T | BROWNELL, ROY; BROWNELL, TERESA |
| MF124008 | 05/15/1984 | [redacted] | T | [redacted] |

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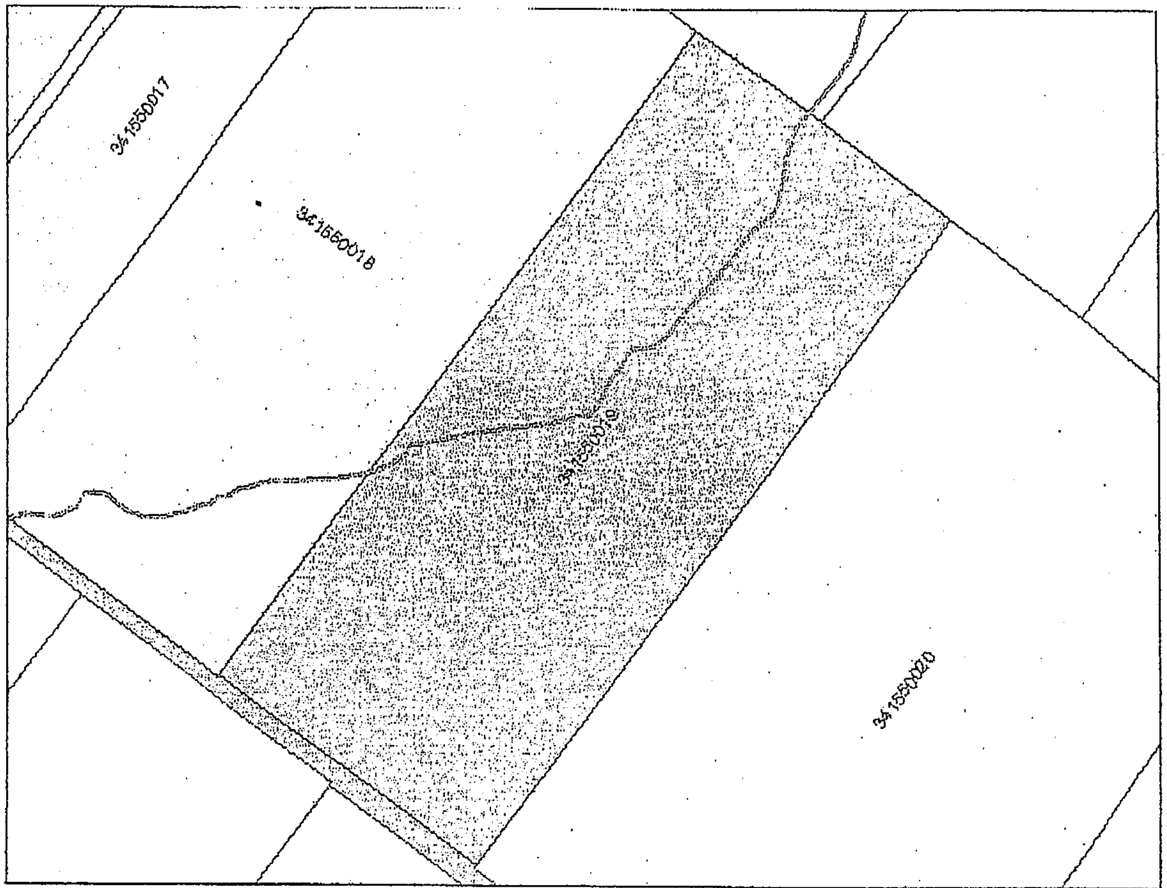
00000856




Subject Property Polygon
Parcel Polygons
Roads
Railways
Water Limits
Easement Limits
Subject Property Point
Neighbourhood Sales Points

0 100 m.

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N W E S

| SUBJECT PROPERTY IDENTIFICATION INFORMATION | |
|---|---|
| LRO | 07 |
| PIN | 341550019 |
| ASSESSMENT ROLL NUMBER | 221900000521900 |
| REGISTRATION TYPE | LT |
| LAND REGISTRY STATUS | ACTIVE |
| MUNICIPALITY | N/A |
| ADDRESS | N/A |
| AREA | 409793 m2 |
| PERIMETER | 2836 m |
| DESCRIPTION | PT LTS 284 & 285, CON 4 SWTS AS IN MF163913 ; MELANCTHON |
| PARTY TO: | CANADIAN HYDRO DEVELOPERS, INC. |

McCann Appraisal, LLC

SALES HISTORY

| INSTRUMENT NUMBER | REGISTRATION DATE | CONSIDERATION VALUE | INSTRUMENT TYPE | PARTY TO |
|---|---|---|---|---|
| DC80536 | 10/30/2007 | 350000 | T | CANADIAN HYDRO DEVELOPERS, INC. |
| MF163913 | 12/09/1988 | [redacted] | T | BENVENETE, WALTER MARK |

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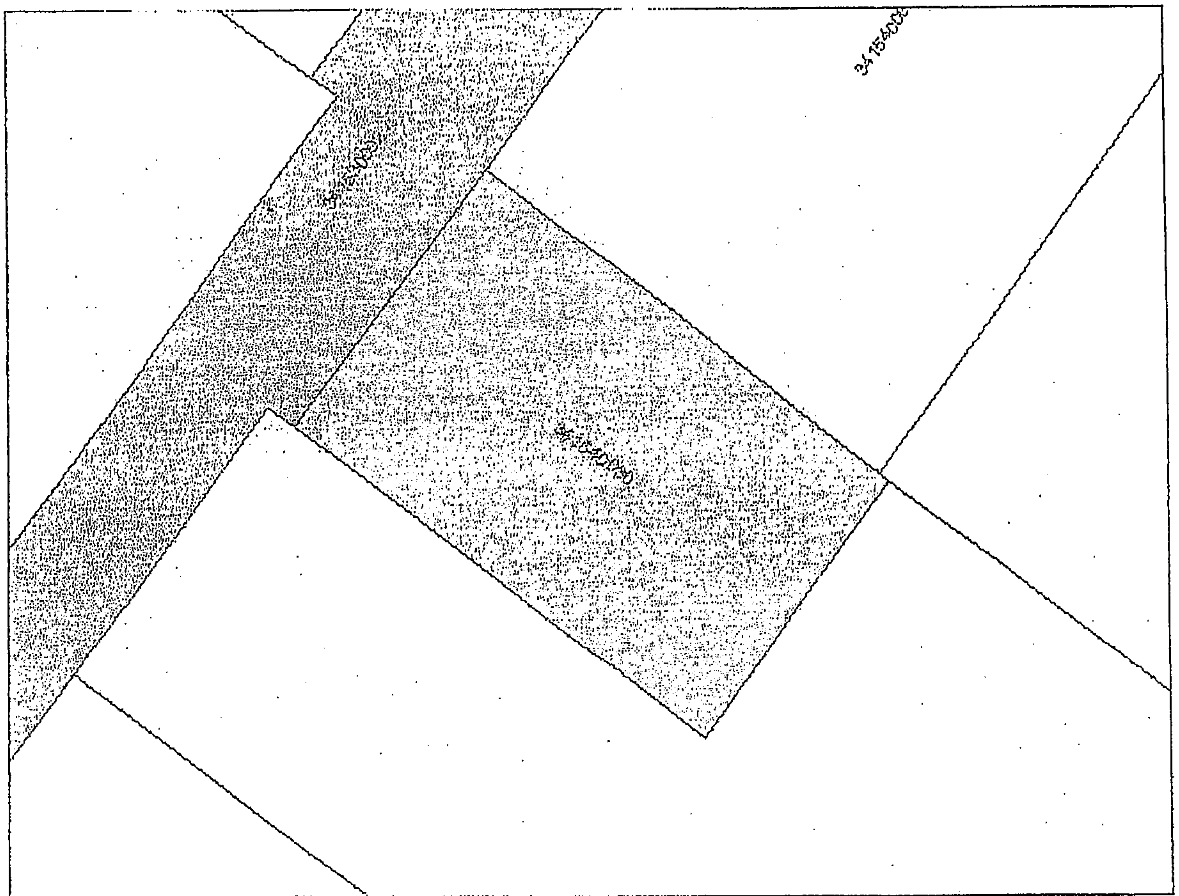
McCann Appraisal, LLC



Subject Property Polygon
Parcel Polygons
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Easement Limits
Subject Property Point
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0 10 m.

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N W E S

| SUBJECT PROPERTY IDENTIFICATION INFORMATION | |
|---|---|
| LRO | 07 |
| PIN | 341540030 |
| ASSESSMENT ROLL NUMBER | 221900000613850 |
| REGISTRATION TYPE | LT |
| LAND REGISTRY STATUS | ACTIVE |
| MUNICIPALITY | SHELBURNE |
| ADDRESS | 58234 COUNTRY ROAD 17 |
| AREA | 4048 m2 |
| PERIMETER | 262 m |
| DESCRIPTION | PT LT 291, CON 2 SWTS, PT 2, 7R924 ; MELANCTHON |
| PARTY TO: | CANADIAN HYDRO DEVELOPERS, INC. |

00000859

## SALES HISTORY

| INSTRUMENT NUMBER | REGISTRATION DATE | CONSIDERATION VALUE | INSTRUMENT TYPE | PARTY TO |
|---|---|---|---|---|
| DC77599 | 08/17/2007 | 302670 | T | CANADIAN HYDRO DEVELOPERS, INC. |
| MF68694 | 03/11/1975 | [redacted] | T | FRASER, BRUCE; FRASER HELEN |

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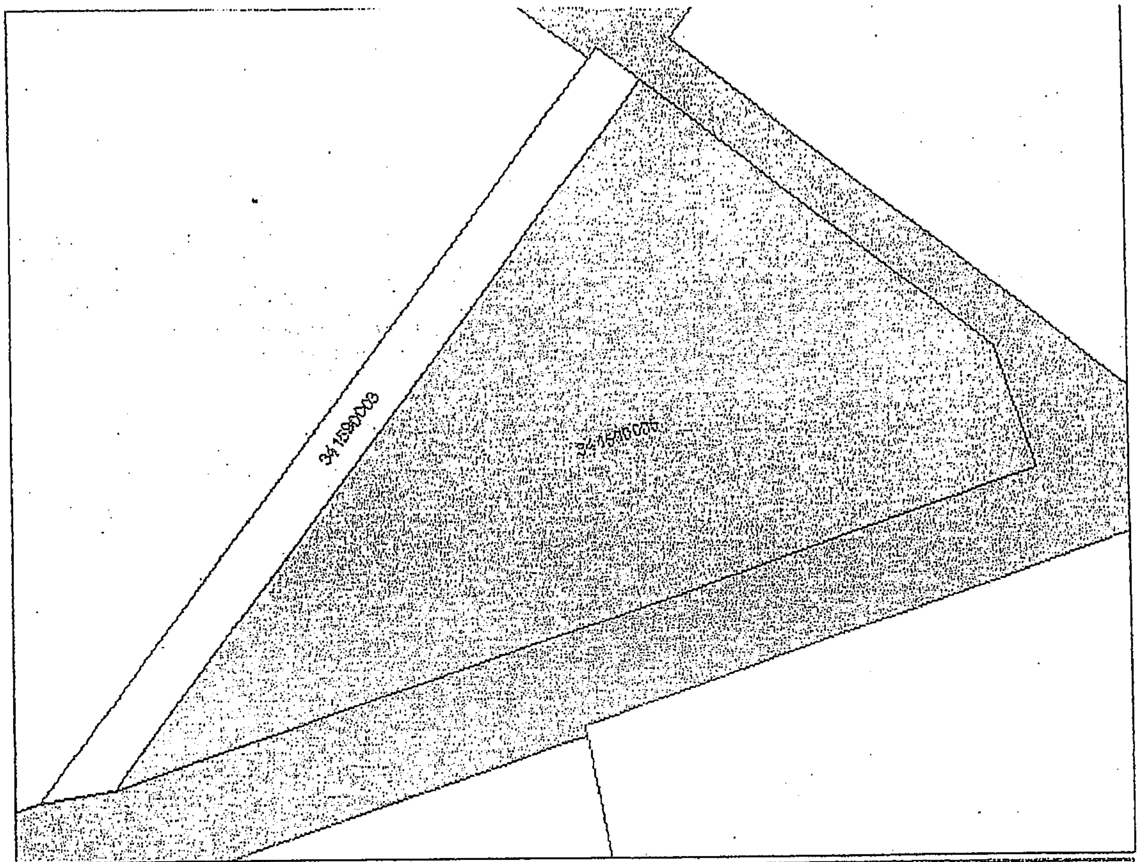


Subject Property Polygon
Parcel Polygons
Roads
Railways
Water Limits
Easement Limits
Subject Property Point
Neighbourhood Sales Points

0 100 m.

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N W E S

| SUBJECT PROPERTY IDENTIFICATION INFORMATION | |
|---|---|
| LRO | 07 |
| PIN | 341590005 |
| ASSESSMENT ROLL NUMBER | 221900000401800 |
| REGISTRATION TYPE | LT |
| LAND REGISTRY STATUS | ACTIVE |
| MUNICIPALITY | N/A |
| ADDRESS | N/A |
| AREA | 40515 m2 |
| PERIMETER | 965 m |
| DESCRIPTION | PT LT 1, CON 5 SWTS AS IN MF157736 ; MELANCTHON |
| PARTY TO: | CANADIAN HYDRO DEVELOPERS, INC. |

00000861

## ...ES HISTORY

| INSTRUMENT NUMBER | REGISTRATION DATE | CONSIDERATION VALUE | INSTRUMENT TYPE | PARTY TO |
|---|---|---|---|---|
| DC70069 | 01/31/2007 | 305000 | T | CANADIAN HYDRO DEVELOPERS, INC. |
| LTD9504 | 05/15/1998 | [redacted] | T | BARLOW, DAVID CHARLES; BARLOW, SHERYL ANN |
| MF157736 | 06/15/1988 | [redacted] | T | [redacted] |

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# Appendix C

McCann Appraisal, LLC

## Mendota Hills Wind Energy Project

| Sale # | Address | Sale Date | Price | Grantor | Grantee | Style | Size SF | $/SF |
|---|---|---|---|---|---|---|---|---|
| 1 | 629 W. Chestnut | Oct 2003 | $37,000 | Estes | Lipe | 1.5 | 1,161 | $31.87 |
| 2 | 323 W. Chestnut | Oct 2004 | $40,000 | Reed | Hovious | 1.5 | 1,425 | $28.07 |
| 3 | 1019 Steward Rd. | May 2003 | $40,000 | Houle-Ward | Reyns | 2 | 1,408 | $28.41 |
| 4 | 91143 Paw Paw | Mar 2005 | $187,000 | Zaylik | Pachero | 2 | 1,571 | $119.03 |
| 5 | 1224 IL Rte. 251 | Jun 2003 | $138,000 | Gittleson | Kowalski | 2 | 1,272 | $108.49 |
| 6 | 339 Chestnut St. | Jan 2003 | $72,000 | White | Flynn | 2 | 1,684 | $42.76 |
| 7 | 630 W. Chestnut | Sep 2003 | $126,000 | Eddy | Morath, Sr. | 1.5 | 1,728 | $72.92 |
| 8 | 427 Chestnut St | Oct 2003 | $87,000 | Hesik | Rourke, Jr. | 1.5 | 1,380 | $63.04 |
| 9 | 138 Cherry St. | Sep 2004 | $80,000 | Hammond | Alexander | 1.5 | 1,326 | $60.33 |
| 10 | 536 W. Cherry | Oct 2004 | $63,500 | Johnson | Fitzpatrick | 1.5 | 999 | $63.56 |
| 11 | 885 Compton Rd. | Oct 2004 | $68,900 | Boysen | Geilings | 1 | 480 | $143.54 |
| 12 | 518 W. Cherry St. | Apr 2003 | $87,500 | Allen | Beckman | 1 | 927 | $94.39 |
| 13 | 222 Maple St | Dec 2004 | $150,000 | Clark | Cummings | 1 | 1,852 | $80.99 |
| 14 | 444 W. Main St. | Mar 2005 | $109,900 | Miller | Michaels | 1 | 1,402 | $78.39 |
| 15 | 2874 Beemerville | Jul 2003 | $367,000 | Finkboner | DGNB TRT | 1 | 2,201 | $166.74 |
| | | | | | | Average sale price | | $78.84 |
| 16 | 1310 Melugins Grove | Apr 2004 | $179,000 | Lyons | Overton | 2 | 1,952 | $91.70 |
| 17 | 2612 Shady Oaks Rd. | Apr 2003 | $131,000 | Smith | Papiech | 1.5 | 1,208 | $108.44 |
| 18 | 3448 Cyclone Rd. | Mar 2003 | $105,900 | Munyon | Pippenger | 2 | 1,456 | $72.73 |
| 19 | 2524 Johnson St. | Aug 2004 | $61,800 | Copeland | Lampson | 1.5 | 948 | $65.19 |
| 20 | 741 Third St. | Feb 2004 | $63,500 | Eckhardt | Rosales | 1.5 | 868 | $73.16 |
| 21 | 613 Church Rd. | May 2003 | $115,000 | Merkel | Parpart | 1.5 | 1,458 | $78.88 |
| 22 | 3435 Willow Creek | Jun 2003 | $118,000 | Swiatek | Bryoun | 2 | 884 | $133.48 |
| 23 | 3021 Cottage Hill | Mar 2005 | $182,000 | Russ | Curtis | 1.5 | 1,239 | $146.89 |
| 24 | 3395 Willow Creek | Mar 2003 | $180,000 | McCoy | Carver | 2 | 2,840 | $63.38 |
| 25 | 745 Second St. | Dec 2004 | $59,000 | Wilson | Calderon | 1.5 | 1,161 | $50.82 |
| 26 | 761 4th St. | Mar 2003 | $68,000 | Stewart | Eisinger | 1 | 724 | $93.92 |
| 27 | 2774 Welland Rd. | Apr 2003 | $93,000 | Batha | Crumpton | 1.5 | 1,104 | $84.24 |
| 28 | 558 Earlville Rd. | Jan 2003 | $145,000 | Hodge | Ikeler | 2 | 1,280 | $113.28 |
| 29 | 2505 Wood St. | Aug 2004 | $105,000 | Janiak | Bullock | 2 | 1,812 | $57.95 |
| 30 | 385 Earlville Rd. | Aug 2004 | $280,000 | Rago | Diehl | 2 | 2,142 | $130.72 |
| 31 | 3095 Cyclone Rd. | Dec 2004 | $169,900 | Summerhill | Rainbolt | 2 | 2,048 | $82.96 |
| 32 | 742 Second St. | Jan 2003 | $103,000 | Delhotal | Stewart | 2 | 1,876 | $54.90 |
| 33 | 395 Angling Rd. | Mar 2005 | $119,000 | BMV Prop. | Herendeen | 1 | 680 | $175.00 |
| 34 | 2515 Wood St. | Apr 2004 | $80,000 | Jones | Sarver | 1 | 912 | $87.72 |
| 35 | 1218 Locust Rd. | Jan 2005 | $169,000 | Wachowski | Gembeck | 1 | 1,040 | $162.50 |
| 36 | 901 Melugens Grove | Aug 2003 | $228,000 | Kidd | Rajan | 1 | 2,000 | $114.00 |
| 37 | 1490 German Rd. | Aug 2004 | $85,000 | Firlit | Challand | 2 | 2,144 | $39.65 |
| 38 | 603 Ogee Rd. | Apr 2004 | $285,000 | Anderson | Miller | 1 | 1,920 | $148.44 |
| 39 | 546 Carnahan Rd. | Jan 2005 | $110,000 | Coley | Sarabia | 1 | 1,296 | $84.88 |
| 40 | 1353 County Line | Nov 2003 | $185,000 | Vallejo | Bozaeth | 1.5 | 1,338 | $138.27 |
| 41 | 2512 Johnson St. | Feb 2005 | $123,000 | Montavon | Sutton | 2 | 2,232 | $55.11 |
| 42 | 2509 Herman Rd. | Apr 2004 | $142,900 | Bresson | Arjes | 1 | 1,404 | $101.78 |
| 43 | 955 Woodlawn | Jul 2003 | $265,000 | Swan | LaRosa | 1.5 | 1,918 | $138.16 |
| 44 | 1279 Locust Rd. | Mar 2003 | $270,000 | Witte | olin | 1 | 2,156 | $125.23 |
| 45 | 648 Ogee | Nov 2003 | $225,000 | Fickenscher | Rojas | 1 | 1,768 | $127.26 |
| 46 | 1339 Woodlawn Rd. | Sep 2003 | $230,000 | Howell | Barnhill | 1 | 1,701 | $135.21 |
| 47 | 1349 Woodlawn Rd. | May 2003 | $207,500 | Howell | Wiskari | 1 | 1,809 | $114.70 |
| 48 | 711 O'Gee Rd. | Aug 2004 | $185,000 | Groevengoed | Carabal | 1 | 1,352 | $136.83 |
| 49 | 1295 Locust Rd. | May 2004 | $300,000 | Hagan | Lowe | 1 | 2,672 | $112.28 |
| 50 | 860 Paw Paw Rd. | May 2004 | $185,000 | Wiskur | Pogreba | 1 | 1,148 | $161.15 |
| 51 | 3011 Honeysuckle | Mar 2005 | $355,000 | Abbott | Brandt | 2 | 3,655 | $97.13 |
| 52 | 489 Earlville Rd. | Nov 2004 | $165,000 | Schlaffke | Fromherz | 2 | 1,400 | $127.86 |
| 53 | 2512 Shaw Rd. | Jun 2004 | $153,500 | Hlavin | Kapinski | 2 | 1,639 | $93.71 |
| | | | | | | Average sale price | | $104.72 |

| | | |
|---|---|---|
| Sales 17 - 53 located > 2 miles from turbines | $104.72 | sq ft |
| Sales 1 - 16 located within 2 miles of turbines | $78.84 | sq ft |
| Difference in sale price per square foot | $25.89 | sq ft |
| Average Value diminution within 2 miles of turbines | 25% | |

00000864

# Appendix D

McCann Appraisal, LLC

LBNL-2829E

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

# The Impact of Wind Power Projects on Residential Property Values in the United States: A Multi-Site Hedonic Analysis

Ben Hoen, Ryan Wiser, Peter Cappers,
Mark Thayer, and Gautam Sethi

Environmental Energy
Technologies Division

December 2009



The work described in this report was funded by the Office of Energy Efficiency and Renewable Energy (Wind & Hydropower Technologies Program) of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

This report was prepared by the above authors for the U.S. Department of Energy under Contract No. DE-AC02- 05CH1123.

It has been reported that the contractors payment for the report was $500,0000.

The following Figures ES-1, ES-2, ES-4 and photograph Appendix D & E were copied from this report without any editing by McCann Appraisal, LLC.

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Figure ES-1: Base Model Results: Area and Nuisance Stigma

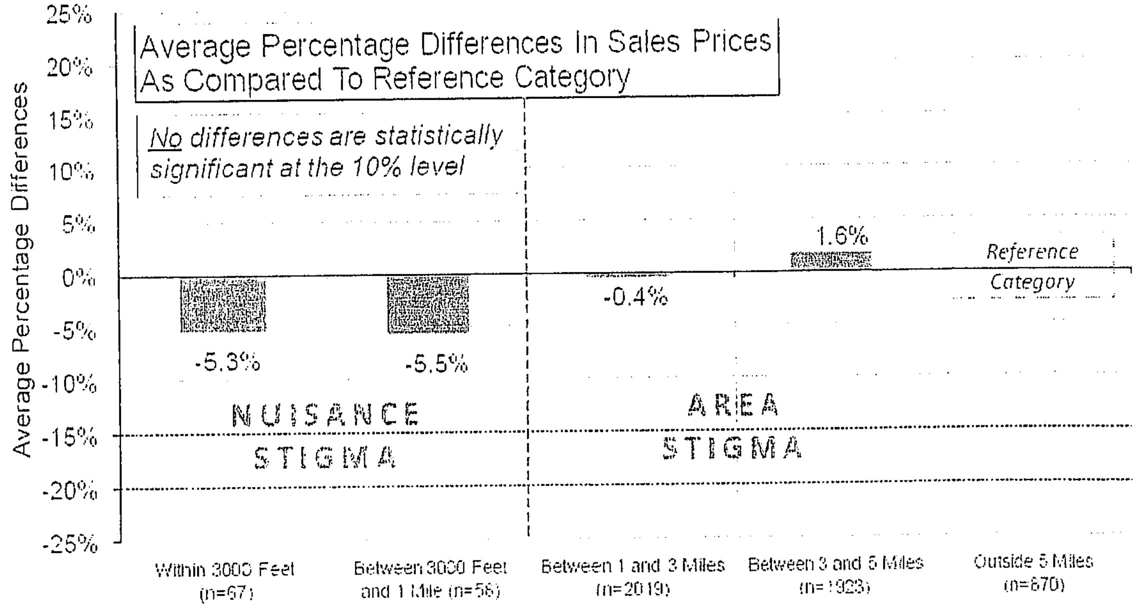
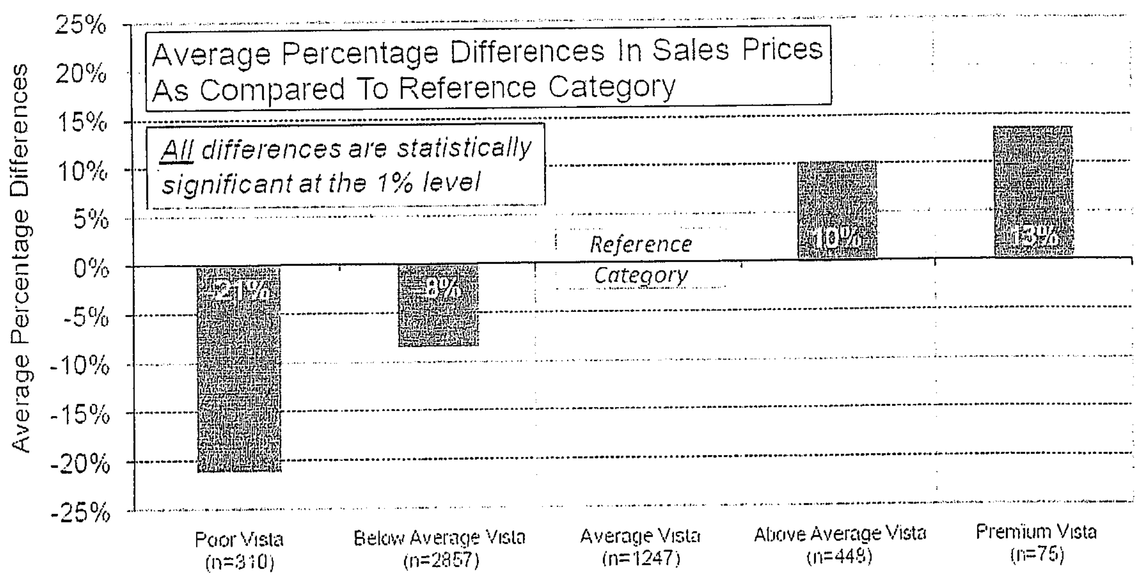
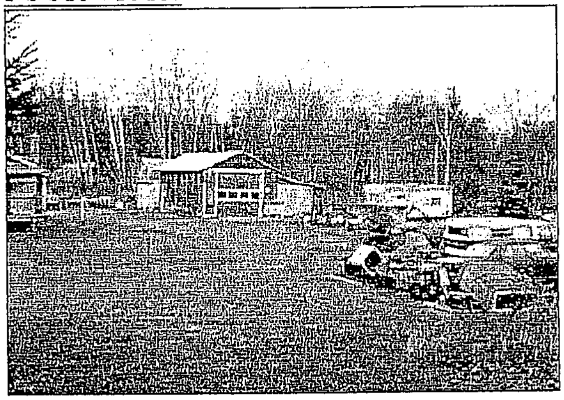



Figure ES-2: Base Model Results: Scenic Vista

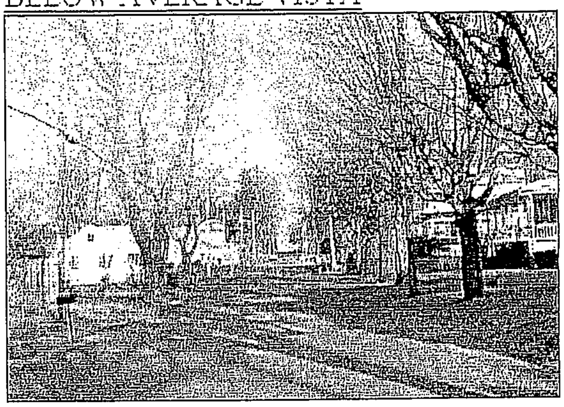


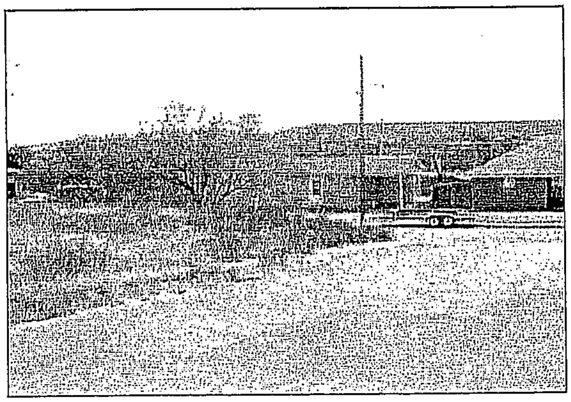
# Appendix D: Vista Ratings with Photos

POOR VISTA

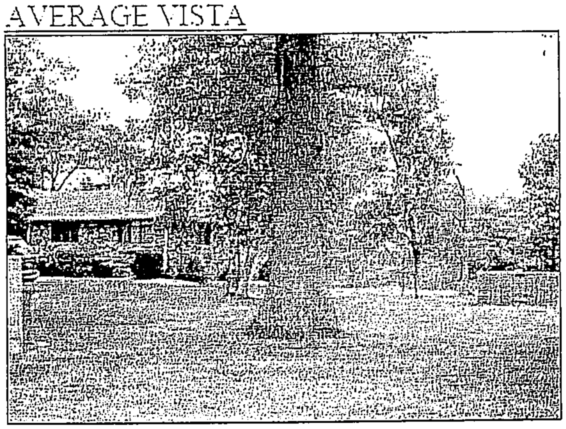


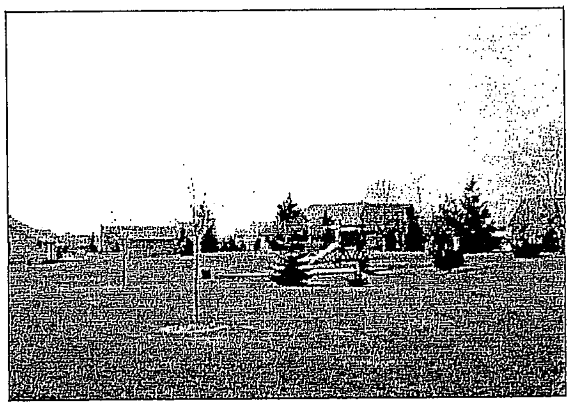
BELOW AVERAGE VISTA





AVERAGE VISTA





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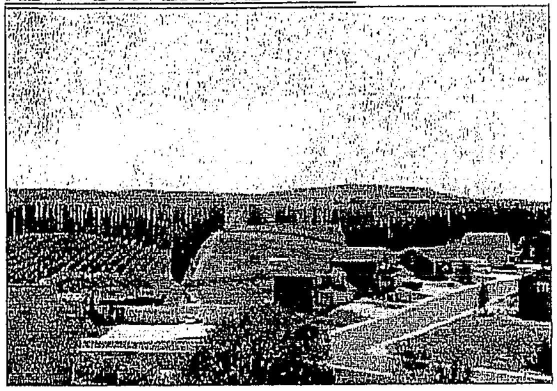
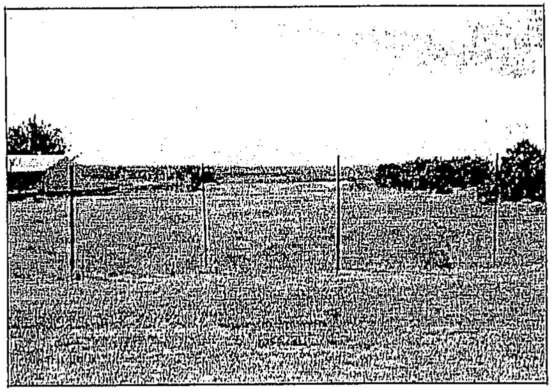
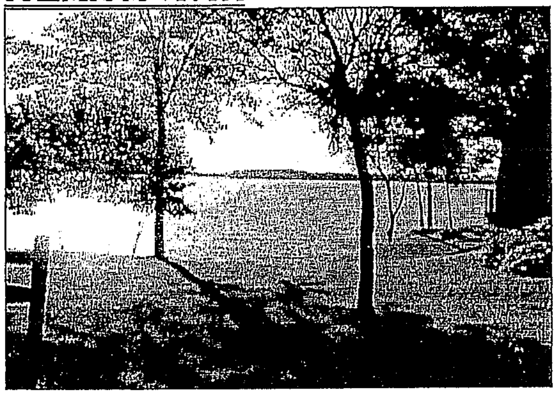
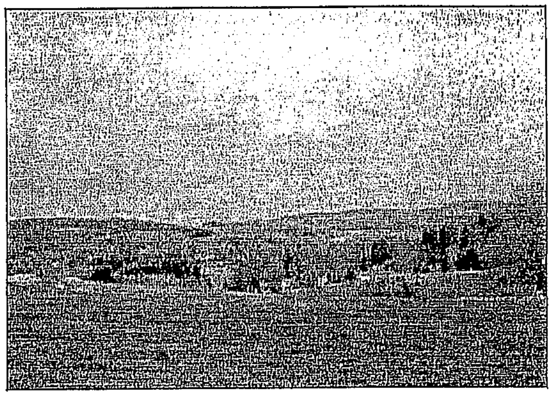
ABOVE AVERAGE VISTA





PREMIUM VISTA





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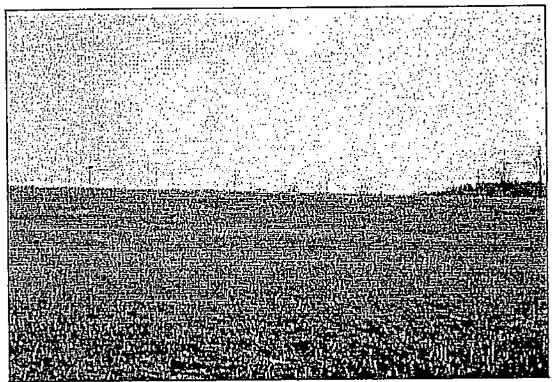
# Appendix E: View Ratings with Photos

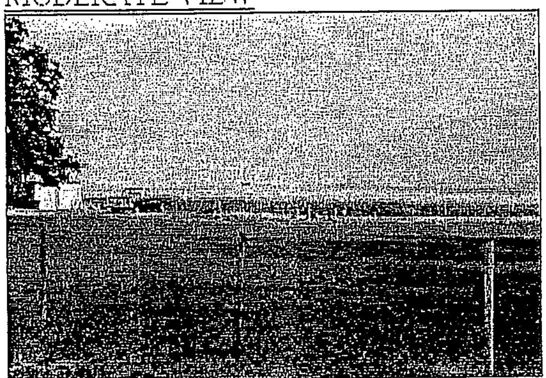
MINOR VIEW

*3 turbines visible from front orientation, nearest 1.4 miles (TXHC)*

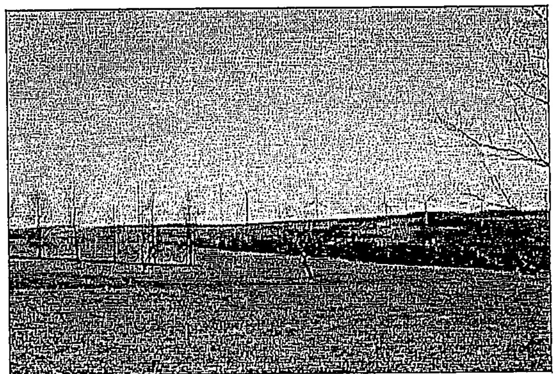


*5 turbines visible from front orientation, nearest 0.9 miles (NYMC)*

MODERATE VIEW

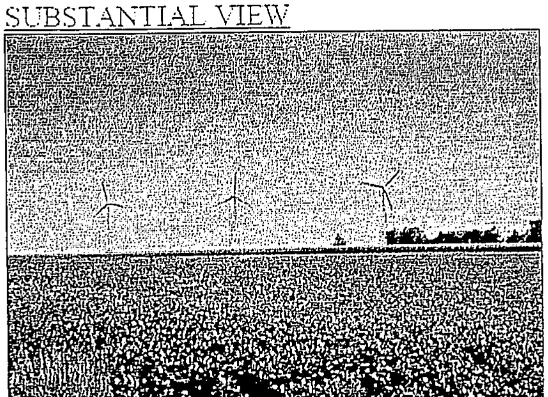


*18 turbines visible from back orientation, nearest 1.6 miles (ILLC)*

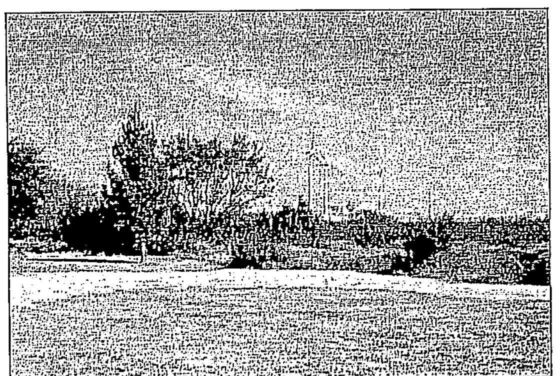


*6 turbines visible from back orientation, nearest 0.8 miles (PASC)*

SUBSTANTIAL VIEW



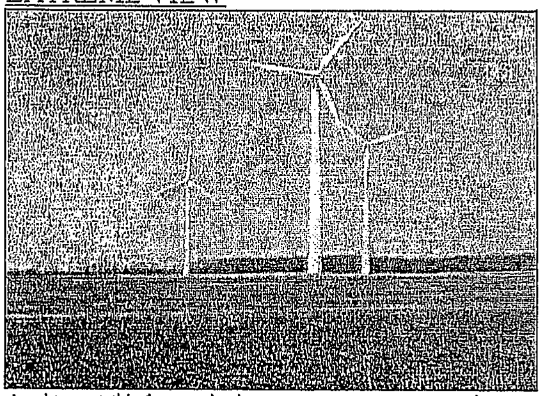
*90 turbines visible from all orientations, nearest 0.6 miles (IABV)*



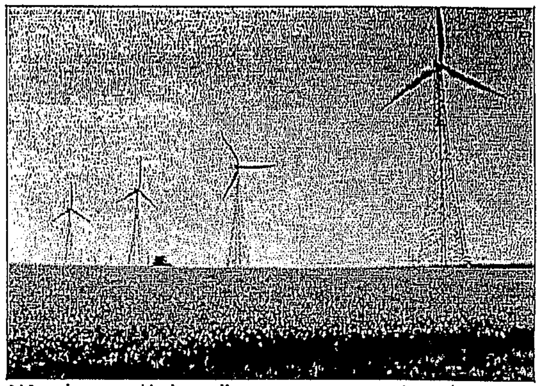
*27 turbines visible from multiple orientations, nearest 0.6 miles (TXHC)*

00000870

EXTREME VIEW



*6 turbines visible from multiple orientations, nearest 0.2 miles (WIKCDC)*



*212 turbines visible from all orientations, nearest 0.4 miles (IABV)*

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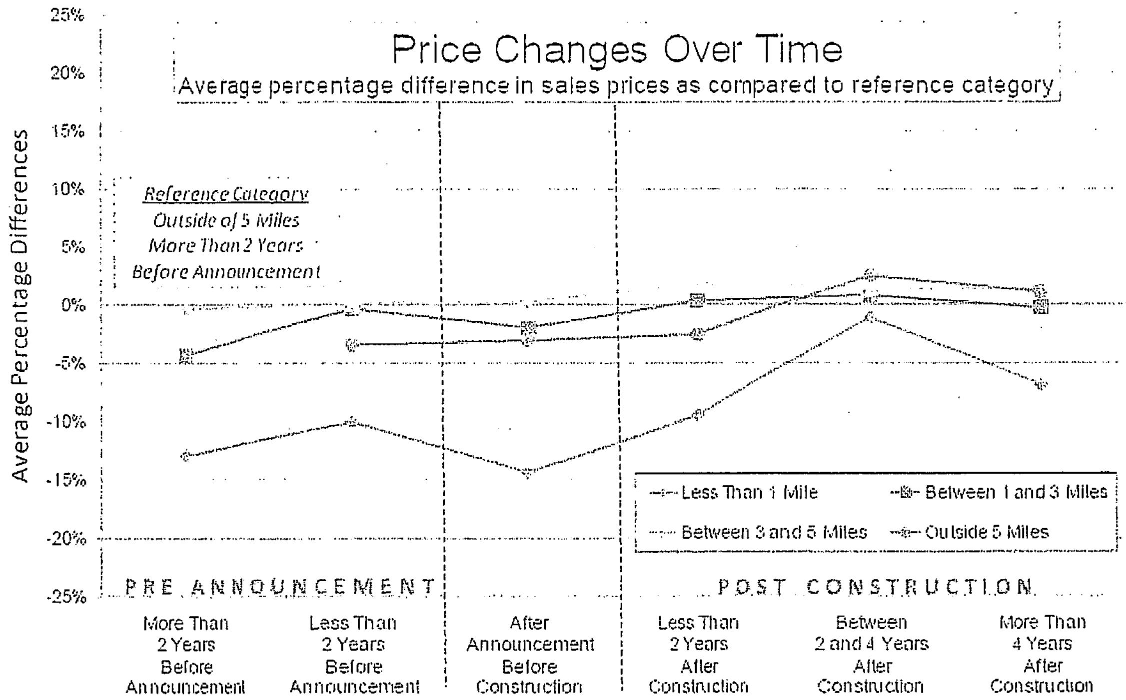
McCann Appraisal, LLC

Figure ES - 4: Temporal Aspects Model Results: Area and Nuisance Stigma




00000872

# Property values blowing in the wind

REALTOR'S REPORT: Proposed turbine projects put damper on residential property sales in Cape Vincent
By NANCY MADSEN
TIMES STAFF WRITER
WEDNESDAY, APRIL 7, 2010

Sales records show that Cape Vincent has had a steeper decline in residential property sales than its neighbors and real estate professionals are starting to blame proposed wind power developments.

"People do not want to buy near windmills," said Amanda J. Miller, owner of Lake Ontario Realty, Dexter, who specializes in waterfront property sales. "They avoid purchasing in towns like Cape Vincent."

She presented her views and a report on property values to the Jefferson County Board of Legislators on Tuesday night.

In other countries that have had wind power development for a while, they have seen 40 percent to 60 percent drops in resale values, she said. Closer to home, she's had clients pull out of deals and refuse to consider areas that are possible sites for wind turbines.

"Even if people don't mind looking at it, they're not going to put their investment in an area where they're going to have turbines depreciate it," Ms. Miller said in a phone interview on Monday. "They don't want to look at them, see them, and others don't want to buy because they don't know what the wind turbines will do for property values."

National studies have gone both ways, some saying that wind turbines have no effect on property values and others saying the projects hurt property values.

Data on the local real estate trends were compiled by Clifford J. Schneider, a Cape Vincent resident and former fisheries biologist with the state Department of Environmental Conservation.

The analysis compared Cape Vincent sales, closing prices and days on market to those in Alexandria Bay, Brownville, Clayton and Lyme from 2000 through 2009. The analysis included houses of more than 1,000 square feet on the Jefferson-Lewis Board of Realtors Multiple Listing Service.

Both overall residential sales and a subset of waterfront residential sales were analyzed.

Closings for the 2006-09 period declined 8.4 percent in the other four towns and 15.4 percent in Cape Vincent, though that was not statistically significant.

In waterfront properties over the last decade, closings fell 12 percent in Cape Vincent and 4.6 percent in the four-town average. In the more recent 2006-09 period, closings fell 10 percent per year for the four-town average and 25 percent in Cape Vincent. The difference in the decline was statistically significant.

Cape Vincent had 10 residential property closings in 2009, three of which were waterfront.

"This should be a good wake-up call to people," Ms. Miller said.

Average days on market declined for the four towns by 9.5 percent per year through the decade. Through the decade, the trend was a drop by 7.3 percent per year in Cape Vincent, but in 2006-09 the days on market increased 58.5 percent per year, while the four-town average increased 10 percent.

"There is some evidence that the Cape Vincent housing market is in a slump, more so than what would normally be credited to the decline in the general economy," the report said.

The economy is playing some role in the decreased number of sales.

"Things are slow partly because the overall economy is so bad," said Brooks J. Bragdon, a real estate sales agent and Cape Vincent councilman. "But things are even slower in areas overdeveloped by wind turbines."

Some local wind farm opponents are pushing for a property value assurance agreement, in which a developer would pay the difference between a property's sale price and the value of comparable property outside of a wind power development if the property loses value.

The two real estate professionals said that won't be enough.

"I don't put too much stock into it because the aesthetics of the area are so valuable that you can't put a dollar figure onto it," Mr. Bragdon said. "We should address the setbacks and make them reasonable according to the zoning law and comprehensive plan and state and federal rules without getting into compensating people for lost value."

Ms. Miller agreed.

"It doesn't take care of the tourism economy," she said. "There's no way to solve that."

# Appendix E

00000875

On ABC's Stateline, Lane Crockett of the wind industry said, "There is no evidence whatsoever in any peer-reviewed article or medical assessment that says there's any health effect from wind farms."

Worldwide, people are experiencing noise problems from wind farms, Nina Pierpont's research has been published with peer review, and the wind industry's story that people are not affected by noise from wind turbine noise is far from the truth.

The noise problem was experienced by residents near the Toora wind farm more than 4 years ago.

Early in 2007, Stanwell, Queensland Government, owners of the Toora wind farm, bought Les Osbourne's house which was about 600 metres or so from the nearest turbine and then bulldozed the house. Les was originally in favour of Stanwell building turbines all around him, believing the spin about there not being any noise problems. In fact he signed the petition in favour of the windfarm 5 times. Once the wind farm was built he started to suffer from the noise.

00000876

The house, being demolished in the photos, is just across the road from Jayne & Steve's place who also suffered from the low frequency noise so much it affected their health and the company was required to institute temporary shutdowns of turbines.

And why is it the Brumby government does not want to use current noise standards and the wind industry is reacting so strongly against a national code for wind farm.development?

### Acoustic Ecology Institute

# Wind Farm Noise: 2009 in Review

In the most extreme cases, families are forced to move from their homes to escape the effects of the ongoing noise disturbances. These are not necessarily people living extremely close to turbines; such unlivable situations have occurred from 1000 feet to over a half-mile from the closest turbines. Some wind farm developers have actually bought out neighbors that were especially impacted[7], though most are left to make the best they can with a piece of property that will be difficult, if not impossible[8], to sell. I have not seen any comprehensive listing of residents who had to move, but such reports are becoming more common in the US, Canada, and the UK, totaling perhaps three to six per year.

## Oregon wind farm ruled too loud: six months to find fix

Human impacts, News, Wind turbines No Comments »

The Morrow County Planning Board ruled this week that the Willow Creek Energy Center, an 80-turbine wind farm, is producing noise levels that violate Oregon's noise limits, and gave Invenergy, the wind farm's owner, six months to get the turbines into compliance. The wind farm began operating in January 2009, and by March, several neighbors within a half mile had raised serious concerns about the noise (see this article for details), including regularly having difficulty sleeping. Noise monitoring then took place, and in January of this year, the Planning Board received the results, which showed that noise levels at four homes sometimes exceeded the limit of 37dB. There was some contention at that meeting, as neighbors had hired independent noise monitoring consultants, whose records showed more consistent violations than those of the Invenergy-hired consultant; the differences were pegged to the fact that the Invenergy consultant did not record in high wind speeds, contending that the noise gets no louder above wind speeds of 9m/s. It is unclear from initial news reports whether the wind farm will be required to comply with the noise limits based on the Invenergy sound monitoring protocol, which found excess noise just 10% of the time at one house, and less frequent slight violations at three others, or whether they'll use the more comprehensive techniques used by the local citizens, which found violations more consistently at two homes (one just over the limit, the other often over 40dB), with one home experiencing excess noise on 22 out of 37 nights.

Carla McLane, Planning Director for Morrow County, noted that while the commission did rule the wind farm was violating state regulations, it found the turbines only crossed the noise threshold at certain times of day and under certain conditions. "Some would want to view it in black and white and if it's a violation then you have to shut them down," McLane said. "Others would want to view it in terms of shade of gray and say it's not an ongoing and continuous violation. It's an intermittent violation."

"I'm not sure how someone can say this is an unusual, infrequent event," said Kerrie Standlee, one of the neighbors' noise consultants. "To me, 59 percent (of nights with excess noise) is not occasional or unusual." Standlee's noise study also went beyond Invenergy's in that he gave the residents a sheet of paper to log their experiences with time and date. He then overlaid those comments on the data and showed that when the residents reported high noise, the wind was blowing from a particular direction or at a particular speed. This last bit of information may offer Invenergy some direction about when they might shut down turbines if they want to avoid the worst of the noise issues, during the six months they have to get into compliance.

00000878

The Planning Board struggled with the conflicting approaches, according the the East Oregonian (article archived here). "I have a very hard time coming to a concrete conclusion on which study I feel is accurate," Commissioner Pamela Schmidt said. "I'm not a licensed engineer in acoustics myself and there's been so much information I can't make a decision." Invenergy claimed that the background ambient noise varies, so that in higher wind periods, it should be allowed to exceed 36dB; yet, in its permit, it used the 26dB ambient standard, which is the state's default if measurements are not made ahead of time. Complicating matters more is the fact that, as the East Oregonian noted, "the rule does not direct agencies on how to administer the rule or decide conflicts such as the one between Invenergy and its neighbors. The agency that originally enforced the rule, the Oregon Department of Environmental Quality, has since defunded and destaffed its noise program."

It's worth noting that the noise issues seem to be quite pronounced even at sound levels of 40dB. Oregon's 36dB limit is among the most conservative in the country; it's based on being 10dB above average night time ambient noise levels, which have been measured at 26dB. It appears that noise issues may well be present even when the measured sound levels are at or very near 36dB; this is in synch with reports from elsewhere, which suggest that people accustomed to quiet rural night time soundscapes are quite easily disturbed when turbine noise becomes one of the loudest local sounds, even when absolute noise levels are not extreme. In general, acousticians consider a sound to become readily audible when it is 5dB above ambient, with disturbance considered likely when it reaches 10dB above ambient.

26

## Clifton Maine considers 4000 foot setbacks for wind turbines

Human impacts, News, Wind turbines No Comments »

A private landowner in Clifton, Maine, is hoping to erect four commercial wind turbines on a small ridge known as Pisgah Mountain, and sell the energy to the local utility, Bangor Hydro. Hearing of negative experiences in other Maine towns, including Mars Hill and Vinalhaven, some local residents are concerned about noise impacts and effects on wildlife. The town of Clifton has drafted a new ordinance that sets 4000 feet as the minimum distance between a turbine and a neighboring house; this ordinance will go before voters on June 8. In both other towns, affected families live within 3500 feet of the local turbines.

"What we have on this site is setbacks to the closest residence of a little over 4,300 feet," says Paul Fuller, who owns the 240 acres where the turbines would be built. "I think we could boast that that is the farthest setback of any wind farm in the state of Maine at this point." Several other homes are within a mile to mile and a half of the location.

If this project moves ahead, it would be one of the first to do so with regulatory setbacks of over 1500-1700 feet, which are commonly used in Maine and elsewhere in the US, as developers aim to reach a 45dB limit at homes. The ordinance allows sound levels of up to 50dB during the day and 40dB at night; past experience would suggest that at this distance, these sound levels are unlikely to be reached, though it is entirely possible that the turbines will be somewhat audible up to a mile or so away at times (night time noise levels in rural areas can be as low as 20-25db). Some community advocates urge setbacks of a mile or mile and a quarter, to more surely eliminate

audible noise issues; this project would be a valuable "guinea pig" for the helping answer the crucial question of where the proper balance lies between wind development and respecting the rural soundscape of small towns.
Read more and see a news clip at WLBZ2.com

22

## UK addresses challenges in assessing wind farm noise

Human impacts, News, Wind turbines No Comments »

England's primary environmental agency, the Department for Environment, Food, and Rural Affairs (DEFRA), has commissioned a study to improve techniques for assessing wind farm noise. "There is a possibility that local authorities are not currently investigating complaints about noise from wind farms due to the absence of any formal technical guidance," an internal document reads. "Defra wishes to let a contract to provide local authorities with a methodology by which to investigate noise from wind farms, to support local authority enforcement of statutory nuisance legislation." According to the Telegraph, the report is due out later this year, and should make it easier for local councils to respond to noise complaints. A recent survey suggests that about one in seven UK wind farms have spurred noise complaints; noise campaigners contend that many people who are bothered do not file formal complaints, since they are rarely acted upon.

Meanwhile, also in the UK, the Bradford Planning Inspector upheld a ruling by the city Council to deny a permit for building a single large turbine at a factory in town. The applicant had appealed the denial, since its noise studies showed that that the turbine would be in compliance with the federal noise code ETSU-R-97, which is the only code named in the statutes. However, the investigating Bradford Council Environmental Health officer used several other noise level methodologies when he visited a similar turbine in Norfolk. Using World Health Organisation and British Standard guidelines and codes of practice, as well as ETSU-R-97, he came to the conclusion that the Princes Soft Drinks turbine would cause a noise nuisance for nearby residents. The Planning ruling noted that even according to the company's modeling, "for some dwellings under certain conditions, the emitted turbine noise is likely to lead to complaints. Furthermore, according to WHO standards, there would be times when this noise could result in sleep disturbance, or prove to be a serious annoyance to residents. I find this to be unacceptable."

Councillor John Ruding said: "I am delighted that the inspector agreed with the local community and their voices have been heard. "These proposals were an experiment on people's lives which was not acceptable." Earlier, at the time that the company appealed the initial denial, another Councillor, James Cairns, had noted, "The Council has done its best. Its officers didn't believe it was feasible in the area. Bradford is not against wind turbines - if you go up onto the moors, you will see them. But turbines of this size have not been tried and tested in urban areas."

14

## Third of a mile setback doesn't prevent wind turbine noise issues in Falmouth

Human impacts, News, Wind turbines No Comments »

00000880

When the town-owned wind turbine began operating at the Falmouth, MA wastewater treatment facility in March, most townspeople saw it as the most striking example of the town's far-reaching commitment to sustainability. Since then, it's generated about a third of the town's electricity needs, and a second turbine is being readied for installation nearby this summer. As noted at a forum on the town's many energy-savings initiatives, in discussing the second turbine: "The special thing about the site is it's remote. The nearest home is about 1/3 mile away, which is important in terms of noise and appearance." (This is just under 1800 feet, or 600 yards.)

But over the few weeks since the first turbine began operating, residents are finding the noise much more disruptive than they'd imagined. According to the Cape Cod Times, some neighbors who live in the sparsely populated, wooded area around the treatment facility were horrified when they heard the noise. "It's destroyed our capacity to enjoy our homes," Kathy Elder said. Elder said the noise surrounds her residence, alternating between a jet's whine, thunder and a thumping that sometimes can be felt.

The town has received formal complaints from six residents, one of whom, Annie Hart Cool, has gathered over 40 names of people within a mile or so who say they are affected. She notes that her husband enjoys working in their yard after work, "but when he comes back inside and his head is hurting, you know something's wrong."

Assistant Town Manager Heather Harper says that the town has asked Vestas, the turbine manufacturer, to come check whether there are any mechanical issues that may be causing elevated noise levels, and is asking residents to compile records of when the sound is worst, to help the town figure out how to respond. "This has been a community project from the beginning," Harper said. "We're genuinely concerned and we take the complaints very seriously." At the same time, Harper noted that "We didn't expect no sound, but it should meet all governmental standards." This is, indeed, often the issue: governmental noise standards, which tend to range from 40-50dB, are not always sufficient to avoid negative impacts on the nearest neighbors.

UPDATE: Another local newspaper covers the brewing controversy.

03

## South Dakota residents fail to get half-mile wind farm setbacks

Human impacts, News, Wind turbines 1 Comment »

An excellent 3-part series on wind farm development ran this week in the Bismark Tribune. It has a good balance of the excitement and economic benefits that attract farmers to the industry, and well-stated concerns from those who want larger setbacks in order to protect neighbors from noise. The grey area around health impacts is navigated quite well, with a well-grounded emphasis on sleep disruption; and most strikingly, the piece includes acknowledgement that there is individual variability in how easily people can adapt to a new and potentially intrusive noise source.

Interestingly, there are repeated indications that in this community, as in others, a half mile setback was seen as the "sweet spot" that could accommodate both industry and neighbors; in initial community meetings, there was significant support for a one-mile setback, while a general consensus emerged that a half mile would be tolerable to most people. Nonetheless, the county decided to go with a third of a mile (1750-foot) setback, which has some community members concerned that the turbines will be audible enough to be disruptive at times.

25

## Maine towns keep wind farms at arm's length as state looks to far offshore sites

Human impacts, News, Ocean, Wind turbines No Comments »

"As goes Maine, so goes the Nation?" While this old political truism has faded in recent decades, the State of Maine is currently blazing trails in carefully considered wind power development. At the local level, small towns continue to pass moratoriums and strict setback standards. Most recently, Thorndike became the third town to set a one-mile setback, with the neighboring town of Dixmont taking up a similar ordinance at this week's town meeting. Meanwhile, two more towns, Avon and New Vineyard, joined four others who have hit the pause button on any wind farm developments by adopting moratoriums on any permits. These actions come in the wake of three projects that have generated significant noise issues for neighbors out to as far as 3000-3500 feet; thus, half-mile setbacks are being seen as not enough to avoid risk of disrupting rural lifestyles.

While these towns see the state as being overly aggressive in supporting ridgetop wind farms (abetted by the fact that a former Governor is one of the state's leading wind developers), when it comes to offshore wind development, the state's goals will be much more welcome for most coastal communities. Instead of opening Maine state waters to windfarm leasing, the legislature's Committee on Utilities and Energy is redrafting controversial ocean windfarm bill LD 1810 to do the very opposite. Under changes to be finalized today at the committee's 2nd worksession on the bill, "An Act To Implement the Recommendations of the Governor's Ocean Energy Task Force" will focus Maine instead on constructing floating deepwater windmills on land, and then deploying them at locations ten miles offshore and further, where wind speeds and higher and more consistent and fisheries are less impacted.

The plan received an enthusiastic response from the Maine Lobstermens Association, which has been very concerned about the impacts of any traditional bottom-mounted wind turbines on their activities near shore. Habib Dagher, who leads the University of Maine's offshore wind project, offered a timeline for getting deepwater wind energy going off Maine. "Our goal is build our first demonstration floating turbine - a third-scale turbine about 120 feet above the water - next year, and place it in the water the year after in the Monhegan site," Dagher said. "In 2013 we would build the first 4 or 5 megawatt unit, In 2014 and 2015, a 25 megawatt farm." He predicted that offshore wind would keep growing: "The next phase is development of a large scale 500 to 1,000 megawatt farm. We have at least one developer interested to do that and have it operational in 2020"

22

## UK: Noise complaints at 37 of 255 wind farms

Human impacts, News, Wind turbines 1 Comment »

Here's a bit of news that might be spun either way, depending on your predilection. Jane Davis, who was driven from her home by wind farm noise, has been compiling information on English wind farms and noise complaints; she has found that 37 wind farms have spurred some sort of noise complaints nationwide. This amounts to about 1 in 7 UK wind farms, in contrast to an oft-repeated mantra that "only four" UK wind farms had noise issues, and they'd been "resolved." The new numbers could support those cautioning that wind farm noise issues are more widespread than generally acknowledged, AND those who claim that noise issues are the exception rather than the rule; it certainly reinforces AEI's theme that we need to acknowledge that a minority of people are affected by noise around wind farms, and that we must come to grips with how to address this.

This article in the Telegraph details some of the information shared at a gathering of wind farm noise campaigners, WindCon2010. Gillian Haythornthwaite, who lives near the wind farm in Askam with her partner Barry Moon, said it has been a "devastating" experience. "It is a dreadfully irritating whoosh, whoosh noise," she said. "It is unbearable to be outside in the garden when there is the noise."

Read the rest of this entry »

23

## Ontario wind tech and health research chair named-background is solid in tech, weak on health

Health, Wind turbines No Comments »

Electrical engineer Siva Sivoththaman has been named to the newly-created Ontario provincial Research Chair in Renewable Energy Technologies and Health. Local activist groups that have raised concerns about the effects of wind farm noise on neighbors had hoped that this position, created as part of Ontario's new Green Energy Act, would take the lead in formally investigating the negative health effects some neighbors of wind farms have reported. However, the choice appears to be more oriented toward the technology aspect of the Chair's responsibilities. As noted in the request for proposals: "The Chair in Renewable Energy Technologies and Health will focus first on emerging science and technology related to wind turbines, and then will explore the potential health effects from renewable energy."

According to a news release, "Dr. Sivoththaman will bring focus to multi-disciplinary activities in renewable energy technologies and health, ensuring that health and safety are top priorities in the induction of new technologies. His research program will develop new technical approaches and will provide guidelines in setting standards to ensure health and safety in the manufacturing, use, and end-of-life phases of renewable energy technologies." Sivoththaman's research centres on silicon-based crystalline and thin-film photovoltaic devices, and he serves as director of the Centre for Photovoltaic Systems and Devices, which occupies much of the photovoltaic research building beside Matthews Hall. His interest extends to nanocrystalline semiconductors, and he was the first director of the University of Waterloo's nanotechnology engineering program when it was launched in 2004.

Two leading Ontario wind activist groups expressed their disappointment with the choice; Wind Concerns Ontario said "We have no faith in any meaningful body of evidence being produced on health effects from wind turbines by this government-funded non expert and Ontarians will suffer for it," while the Society for Wind Vigilance chair Dr. Robert McMurtry said the choice missed the mark in that "the lead and expertise of this Research Chair would more appropriately have been a clinician scientist. We strongly encourage the new Chair to seek the appropriate collaborators as the research program is established."

It is as yet unclear what the Chair's timeline will be in addressing the dual (and quite distinct) topics he is charged with overseeing. Given the widespread concern about health effects, and the role this concern is playing in the wind development process in Ontario and elsewhere, we hope that the two topics will be pursued simultaneously. And indeed, as McMurtry suggests, it is clear that the Chair will need to bring in some experts in health and acoustics to effectively address the health aspects; in the spirit of collaboration and inclusiveness, we can also hope that his research/investigative team draws from qualified experts who have expressed concerns about wind noise, as well as those who have previously worked on reports that found few health effects.

11

## Vinalhaven begins month-long "experiment" in reducing noise issues

Human impacts, News, Wind turbines 4 Comments »

The Fox Islands Electrical Cooperative on Vinalhaven, an island off the coast of Maine, has begun a month-long experiment as a first step in trying to come up with a local solution to noise issues from three wind turbines that began operating in November. About two dozen people within a half-mile of the turbines have reported annoying levels of noise, with six property owners claiming that their lives are severely impacted. Others in the same area who can hear the turbines are not particularly bothered by the noise.

Shortly after the turbines started operating, and some residents (including some who were excited about the wind farm, and some who had been skeptical) reported unexpected noise issues, neighbors began noting the times that the sound was most troublesome, in an effort to identify what wind directions or atmospheric conditions might be most to blame. At its January meeting the Board of the electric coop decided to conduct a month-long "experiment" during February, in which the turbines would be slowed down in random patterns. Sound measurements will be made throughout the month, and the 38 households within a half-mile are being asked to log their sense of the noise on a regular basis (half these households are summer people, so are unlikely to be participating). In a letter to coop members, the board said the experiment "will enable us, as a community, to figure out what to do and come to a solution that works, as well as possible, for everyone."

A very detailed article in The Working Waterfront, a local paper, features a variety of comments from a locals about the process that is underway to find a community-based solution to the noise problems. Some find that the noise is moderate enough to be tolerable, easily drowned out by other sounds such as the TV or a car passing by, or being no more bothersome than a dishwasher running in another room; one person remembers the noisy generator that used to provide power to the town in the 60s and 70s, which people got used to. Some who have been disturbed share their perceptions, as well; Ethan Hall notes that "I've never heard anything in my life that sounds like it." Both he and Lindgren (another neighbor being affected) believe that current sound measurement standards do not take into account the complexity of turbine noise and its true impact. "The nature of the sound is so unique, that to try and quantify or qualify it with a strict dBa [decibel] measurement is an entirely inadequate way of describing the effect on people and surroundings," Hall feels. An hour-long radio interview with Hall and others being affected, recorded this past December, is available on the WERU website.

## Lawsuits begin to crop up, challenging nearby wind farms

In recent months, several lawsuits and formal complaints have been filed, claiming unlawful nuisance and/or impacts on property values and quality of life near wind farms. Most recently, sixteen residents sued the Michigan Wind I wind farm and its developers, laying out a series of complaints, including (as detailed in the Huron Daily Tribune):

- Private nuisance from, among other things, sustained and highly annoying audible noise and amplitude modulation in both audible and sub-audible frequencies

- Negligent design of a wind farm, including a noise assessment that estimated only audible noise levels within the dBA range, and did not consider low frequency noise or impulse noise

- Negligent misrepresentation, claiming the wind companies made false representations in board of commissioner and planning commissioner meetings and public hearings when company representatives said the wind farm's operations would not result in a noise nuisance or cause adverse health effects to adjacent landowners. "(The defendants) were negligent in making these misrepresentations because, as the parties seeking approval to construct a wind turbine farm in Huron County, they had a duty to use reasonable care to provide Huron County and its citizens with both accurate and complete information," the lawsuit states. The plaintiffs claim the wind companies provided inaccurate and/or incomplete information about the audible turbine noise levels, and no information about low frequency noise, infrasound and/or impulse noise emitted from the turbines.

In Pennsylvania, the Allegheny Ridge Wind Farm settled out of court this week as a lawsuit brought by Todd and Jill Stull was moving toward a jury trial in July. The suit alleged that the company misrepresented the noise levels that would be generated by assuring residents the noise would e minimal. The agreement is bound by confidentiality, so no details are available. See earlier coverage of the lawsuit here.

Meanwhile, in neighboring Wisconsin, a family that abandoned their home near the Forward Energy Wind Center, is assessing their options after the state Public Service Commission dismissed a complaint they filed, seeking compensation from the wind developer for business losses from their alpaca farm, health impacts and property value losses. The PSC determined that they did not have jurisdiction to consider the complaint, and recommended the family seek relief in circuit court. Read more on this in the Milwaukee Daily Reporter.

In Maine, neighbors of the Mars Hill wind farm filed suit in August, seeking compsensation for what they say is a resulting drop in their property values along with emotional and physical distress.

In 2006, residents near a Texas wind farm were rebuffed by courts in their region, which ruled that noise issues were aesthetic claims, and did not qualify for relief under nuisance laws. There, turbine noise averaged 28 dBA at a distance of 1.7 miles from the wind turbines, and 44 dBA at 1,700 feet; it's worth noting that night time ambient sound levels are likely between 20 and 30dB in this ranch land.

Across the pond, a court in France responded to a noise complaint by ordering 8 wind turbines shut down from 10pm to 7am.

And, while not a court challenge, residents in Massachusetts have asked the state public health commissioner to assess the health and well-being effects of living near wind farms. Since a single turbine began operating in Falmouth, over forty nearby residents have struggled with noise issues; one, an air traffic controller, is concerned that sleep disruptions he's experiencing will affect his job performance.

http://aeinews.org/archives/926

McCann Appraisal, LLC

Interview with Ann and Jason Wirtz
N1157 Hwy YY
Oakfield, WI 53065
902 960 5246
Dodge County, Wisconsin
Conducted on the evening of May 2, 2009 by Lynda Barry

**WIND TURBINE NOISE FORCES WISCONSIN FAMILY TO ABANDON HOME**

TOWN OF OAKFIELD- While lawmakers in Madison consider a bill which will override local government and give the Public Service Commission of Wisconsin siting authority for wind farms throughout the state, one Dodge County family already living in a wind farm approved by the PSC has decided to abandon their home due to turbine noise.

Ann and Jason Wirtz have a pretty Wisconsin farmhouse near the Town of Oakfield. It's the kind of place that had people stopping by to ask if the family would consider selling it.

"They'd just pull into our driveway," says Ann. "There were people who said if we ever decided to sell it, we should call them."

Although turn-of-the-century house needed a lot of work when they bought it, they didn't mind. The Wirtz family planned to stay. They both grew up in the area and wanted to raise their children there.

"I thought we were going to live here for the rest of our lives." says Ann, a mother of four. "I thought one of our kids was going to live here after us."

This was before 86 industrial wind turbines went up around their home as part of the Forward Energy wind project which began operation in March of 2008. The closest turbine is to the Wirtz home is less than 1300 feet from their door.

"Last night it was whining," said Ann. "It wasn't just the whoosh whoosh whoosh or the roaring. It was a high pitched whine. And I don't just hear them, I can feel them."
She describes a feeling like a beat in her head, a pulse that matches the turbine's rhythm.
"Last night was really bad," she said.

She says she knows which nights are going to be loud by which way the turbine blades are facing, and her family dreads the nights when the wind is out of the west. "That's when they are the loudest."

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Jason said he found out there was a wind farm planned for his area from a neighbor he ran into at the post office. "He asked me if I knew anything about the turbines coming in. I didn't." Jason came home and mentioned it to Ann.

"When I first heard about it I wasn't that alarmed." says Ann, "People were saying how bad they could be, but I just didn't believe them at first."

She assumed the turbines would be sited much further away from her home, unaware of the controversy over the setbacks approved by the Public Service Commission of Wisconsin which allows turbines to be sited close as 1000 feet to the homes of people like the Wirtzes.

"All those orange flags they put in were way back there. I was thinking it wouldn't be too bad. And then when that access road started coming in so close I said, 'what the heck is going on?'

Meanwhile, Jason had been attending town meetings and learning more about the project. The more he learned, the more worried he became. Five months before the turbines went up, the Wirtz family decided to sell their house.

They called people who had let them know they'd be interested in buying it. "When they found out about the turbines," said Ann, "They weren't interested anymore."

Wirtz family prepared the house to put on the market. In November of 2007, the home, sitting on eight acres, was appraised for $320,000. But this once sought-after property could find no buyers. "As soon as people found out about the wind farm coming in," says Ann. "That was it. And once they started building the roads to the turbines, forget it. They'd ask what that road was for, we'd tell them and we'd never hear from them again."

After the turbines went up, interested buyers stopped showing up altogether.

"We tried to find another realtor," said Ann, "They'd ask 'is it near the wind turbines?' and when they found out it was, they wouldn't even bother to come out to the house to look at it. One realtor told me it wasn't worth her marketing dollars to even list it because if it was in the wind farm she knew she couldn't sell it. I mean have you ever heard of a real estate agent turning down a chance to sell a house?"

Another realtor said they would have to price it well under $200,000 to get anyone to even look at it. "At that price we were going to be $50,000 worse than when we started, " said Ann. "And that didn't include the 12 years of work we put into the place."

But the Wirtzes were increasingly anxious to get away from the turbines. While Jason, who works nights, wasn't having much trouble with the turbine noise, it was keeping Ann and her children from sleeping well at night. They were tired all the time. They were also getting frequent headaches.

And there was trouble with their animals as well. The Wirtz family raise alpaca and have a breeding herd. Ann says the Alpaca became jumpy the first day the turbines went on line. "Normally they are so calm. But the day the towers started up, they seemed to panic. They were on their back legs right away."

Ann says the herd had always been docile and healthy, with no breeding problems. Since the wind farm started up, their temperament has changed and none of the females have been able to carry a pregnancy to full term. " They're nervous all the time now. I can't prove anything but I do know my animals. And I really felt something was wrong. All the years we've had them we've never had a problem."

At night herd shelters in the large metal shed behind the Wirtz home. When the turbines are loud, Ann says the sound echoes inside the shed and the metal vibrates and hums. "The noise in here gets just unbelievable. When the tin starts to vibrate in here, they can't stand it. I have to find them a better home. This is torture for them."

The same turbine noise has driven Ann out of her own bedroom "I can't stand to be in that room anymore. I don't sleep at all. My sleep has been terrible." Instead she sleeps on the couch where a fan on their pellet stove helps counter the turbine noise. "My number one complaint is how tired I am all the time," says Ann, "I never had that before, ever."

Says Jason, "We don't have air conditioning, we didn't want it and we didn't need it. In the summer we just opened the windows and let cross breezes cool the house. But the first summer with the turbine noise we had to shut the windows and turn on the fan. We couldn't stand it."

After one of the children was recently diagnosed with a severe stress-related illness, the Wirtzes decided they'd had enough. They decided the health of their family was more important than keeping their home, and they are abandoning it.

"Now, after all the trouble we've had living here" said Ann, " If a family showed up and wanted to buy the place and they had kids, I don't think I could sell it to them. Knowing what I know about living here, I just don't think I could put another family through this."

They are now looking for a place in a nearby village. "We were born and raised in the country but we're thinking of moving to Oakfield because they aren't going to plop a 400 foot turbine in the middle of the village, says Jason. "And I know I'm going to have to drive by this place every day on my way to work. It's going to make me sick to see it, but I can't stay here anymore."

Ann adds, "I say we move near whoever it is that decides on the setbacks because you know they'll never have a turbine by their place"

Jason and Ann sit at the dining room table and point out the elaborate woodwork they'd stripped and re-finished by hand. Jason holds a picture of the farmhouse from happier times. Earlier that day they'd met with the people at the bank to let them know they were giving up their home.

Jason says, "At least we're young enough to start over. My mom, she doesn't have much money and now she has turbines around her house. She said, 'This house was my retirement,' Her and my dad put everything into that house. Now I don't know what she's going to do." Jason says, " The quality of life we had here is just gone. I grew up here and I loved it here. But I don't anymore. "

# Appendix F

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## Representative Sample of Neighbor Complaints

| Name | State | Project | MW | Turbine Setback | Notes |
|---|---|---|---|---|---|
| Rene Taylor | IL | Twin Grove | 396 | 1500 | sued over substation near home; suit dropped but can be brought again |
| David & Stephanie Hulthen | IL | Illinois Wind | | 1500 | complained |
| Patty Spalding | MA | Newburyport | | | complained; worked to get ordinance changed |
| Sharon Eddy | MA | Falmouth | | | complained |
| Todd Family | ME | Mars Hill | 42 | 2500 | sued town and company |
| Carol Cowperthwaith | ME | Mars Hill | 42 | 2500 | sued town and company |
| Phil Bloomstein | ME | Freedom | | 1000 | no action |
| Ethan Hall | ME | Vinalhaven | | 2500 | threatening suit. Wind company claims they are trying to fix the problem |
| David and Sally Wylie | ME | Vinalhaven | | 2500 | threatening suit. Wind company claims they are trying to fix the problem |
| Art and Cherly Lindgren | ME | Vinalhaven | 42 | 2500 | threatening suit. Wind company claims they are trying to fix the problem |
| Fletcher Family | ME | Mars Hill | 42 | 2500 | sued town and company |
| Boyd Family | ME | Mars Hill | 42 | 2500 | sued town and company |
| Harris Family | ME | Mars Hill | 42 | 2500 | sued town and company |
| Burchell Family | ME | Mars Hill | 42 | 2500 | sued town and company |
| Gene Champagne | MI | Harvest Wind Farm | | | registered complaint |
| Charlie Porter | MO | | | | sued wind company; case dropped |
| Daniel & Carolyn d'Entremont | Nova Scotia | Pubnico Point | | 1000 | abandoned home |
| Tim Yancey | NY | Maple Ridge | | | filed complaints |
| Jessica | NY | Sheldon Wind | | | no action |
| Jim and Judi Hall | NY | Cohocton Wind | | | filed complaints |
| Hal Graham | NY | Cohocton Wind | | 1000 | has turbine on land; came out against wind company |
| Colette McLean | Ont | | | 1000 | developer purchased her home |
| Barbara Ashbee-Lormand | Ont. | | | 1000 | abandoned home |
| Dale Rankin | TX | Horse Hollow | | | sued but lost in court |
| John Ruggiero | TX | Barton Chapel | | 2500 | complained to county |
| Tom Shea | VT | Searburg | | 1000 | complained; asked for property value reduction |
| Larry Wausch | WI | | | 1500 | complained |
| Gerry Meyer | WI | Forward Wind | | 1100 | complained |
| Ann and Jason Wirtz | WI | Forward Wind | | 1000 | abandoned home; filed suit |
| Tony S. Moyer | WI | Cedar Ridge | | 1320 | complained |
| Barbara Aper | IL | Rail Splitter | | 1500 | sued; settled; sold at reduced price. Horizon wind guarenteed property value |
| Todd and Jill Stules | PA | Allegheny Ridge | | 2000 | sued over noise; case accepted in court and pending |

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**Why did the people who once lived in this house have to abandon it?**

The home in the photo above was made uninhabitable by wind turbine noise and vibration. The family who once lived here were forced to abandon their home in 2006. Three years later, it remains empty and unsold. To read more about this story, http://www.windaction.org/news/3003

00000893

Real Estate Appraisers & Consultants

McCann Appraisal, LLC

January 6, 2011

Christopher Senie
Attorney at Law
5 East Main Street, 2nd Floor
Westborough, MA 01581

Re: Property Value Impact & Zoning evaluation
Cape & Vineyard Electric Cooperative (CVEC)
Freeman's Way Municipal Wind Project
Commerce Park Road
Brewster, Massachusetts

Dear Mr. Senie:

As requested, I am submitting this real estate impact evaluation for your consideration and use in addressing the compliance of the proposed CVEC facility with the Town of Brewster Zoning Code, as described for Special Permit approval of Wind Energy Turbines.

The approval criteria I have specifically evaluated are codified under **§179-40.2. J. (2) (a) & (b)**, as follows:

***(a) The proposed WET will not have an undue adverse impact on historic resources, scenic views, natural resources, and/or residential property values;***

***(b) The applicant has agreed to implement all reasonable measures to mitigate the potential adverse safety, environmental, and aesthetic impacts of the WET.***

Further Special Permit criteria have been evaluated pursuant to **§179-51.A.(5) (a) [2]**, as follows:

***The location, type, character and size of the use/ building, or other structure in connection therewith, will be in harmony with the visual character of the neighborhood, including views and vistas and, where applicable, the historic character of the neighborhood.***

500 North Michigan Avenue, Suite 300 Chicago, Illinois 60611
PHONE: (312) 644-0621 FAX: (312) 644-9244

Also applicable from a real estate, land use and zoning perspective are the requirements for a Special Permit described under **§179-67.E.(6)**, and all uses requiring a special permit under this Article shall meet the following standards as a condition of approval.

***(6)Buildings and architectural design shall be compatible with the character and scale of the adjacent roadway and surrounding neighborhood.***

**Professional Opinions**
My professional opinions are effective as of the current date. My evaluation and this Consulting Report have been prepared and submitted pursuant to applicable licensing laws that mandate compliance with the Uniform Standards of Professional Appraisal Practice (USPAP), and my opinions are certified accordingly.

Briefly stated, based upon my review of the proposed CVEC facility, location, the density, height, type and intensity of the proposed utility scale turbines, the proposed use does not comply with the applicable Brewster Code (Code), as it is not compatible with adjacent and nearby residential uses and, specifically, will have a significant averse effect on the market value of the neighboring residential property.

Further, the Applicant has failed to even attempt to mitigate the impact on aesthetics and values of residential properties, as could have been accomplished to some degree with the provision for an owner/developer Property Value Guarantee (PVG).

While the Brewster Code focuses on undue adverse impact criterion for residential property values, I am also aware of potential impacts on the ability to continue to use a radio transmission facility, a municipal golf course and two (2) facilities nearby that are currently used for elderly housing and care; the Pleasant Bay nursing home and the Woodlands assisted living facility, which are less than ½ mile from the nearest proposed turbine..

My specialized and unique experience with utility scale wind energy developments, as well as 30 years of real estate, land use evaluation and appraisal background has enabled and qualified me to evaluate whether the proposed CVEC facility meets the criteria described in the Brewster Code. The basis for my professional opinions are described and summarized herein.

**CVEC Facility - Background**
The developers for the CVEC facility seek to locate two (2) turbines of approximately 410 feet in height each (tip of blade) adjacent to single family homes, nursing/assisted living facilities, a municipal golf course, athletic fields, etc. The underlying land for the turbines is reportedly owned by the Town of Brewster, and comprises two (2) lots, ( 1 & 32) on Assessor's Map # 131. The site itself is zoned industrial, within the partially occupied Freeman's Way Commerce park development.

In order to better understand the character of the subject neighborhood and subject property setting therein, I have reviewed maps, photographs, the Special Permit Application prepared by Weston & Sampson dated October 18, 2010 and which has been submitted to the Brewster Planning Board Members, inclusive of the site plan photo simulations of the subject location, noise study, etc. I have also reviewed the CVEC website and documents, maps and photographs contained therein.

The issue of impact from industrial scale turbines on the property value of residential owners is the primary focus of the following property value evaluation, as property values are an objective measure of the desirable characteristics of any community.

The Brewster community, overall, and land uses nearest the subject property are also the focus of this evaluation, as the impacts from existing turbines are well documented as being present at residential homes and some impacts have been measured as distant as 2 to 3 miles from turbines.

The contrast of such man made towers with natural views and the highly valued amenity derived from views is analyzed herein, with focus on ratings of the view from, or "Vista" of residential properties.

It is important to understand that high quality or natural views are an asset to real estate market values and, in particular, residential property and land. Other types of "value" can be identified and described in non-real estate terminology, but my focus as an appraiser is on the market value of property.

Similarly, detraction from such premium views can and does have a measurable adverse effect on residential property values. This is well studied in the real estate appraisal profession, and in fact by proponents of wind energy funded by the USDOE such as:

- ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY The Impact of Wind Power Projects on Residential Property Values in the United States: Ben Hoen, Ryan Wiser, et al, Environmental Energy Technologies Division December 2009. (LBNL)

This USDOE funded study is often cited by wind energy developers to claim there is no value impact from such projects, even though the ***study acknowledges that nearby properties may experience losses*** and further recommends that more study in the immediate project areas is needed. This study is useful to understanding the probable impact from the CVEC turbine facility.

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## VISTA IMPAIRMENT

In the LBNL study, the authors attempt to analyze the impact of wind projects on residential property values. They also separately address the statistically measured impact on residential values from scenic vistas, or views based on ***regression analysis of over 4,700 sale transactions,*** for this component of the study.

As graphically depicted within the LBNL report (pg xiii) on Figure ES-2, the following observations are prima facie evidence that impairment of scenic views results in a measurable loss of property values, as follows:

- A premium Vista adds 13% of value over and above the value of an average vista.
- A poor vista results in values 21% below the base-line average vista.
- An above average vista adds 10% to the value of an average vista.
- A below average vista reflects values 8% lower than an average vista.

To illustrate examples of the LBNL findings as it applies to the impairment of vistas for residential property, it is first acknowledged that the vista of any given residential property is going to be rated differently before introduction of a utility scale wind energy facility which will later have a view of the facility, albeit at varied distances.

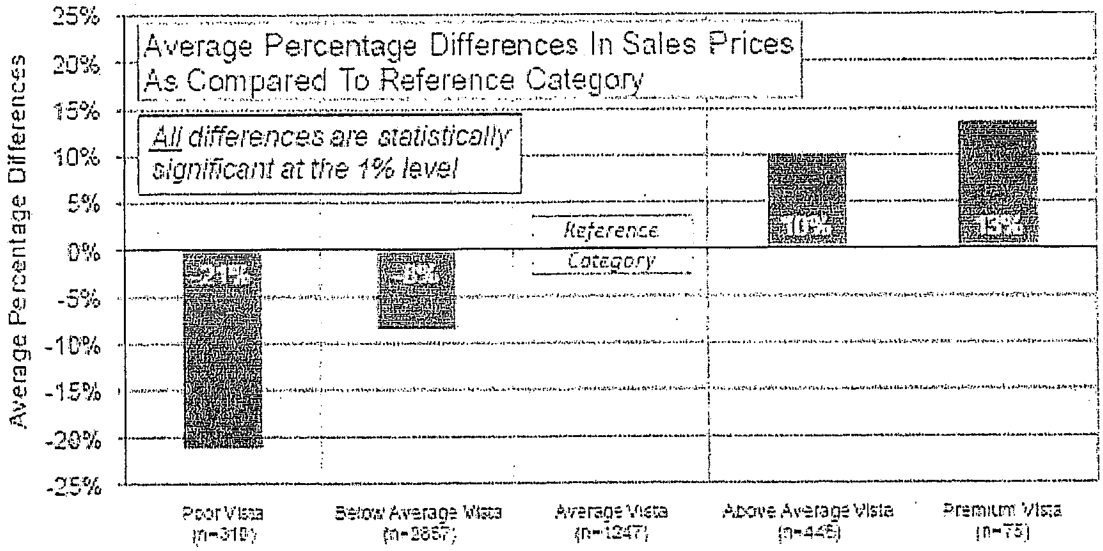
My review of photographic evidence of existing vistas in the immediate subject property location adjacent to the project area indicates similarity with premium, above average and average vistas, as defined and characterized in the LBNL report. On balance, the LBNL report provides examples of premium, above average, average, below average and poor vistas.

Less natural, industrialized vistas have inferior ratings, and the extremely close proximity of a 410 foot turbine, as represented by a distance of 1,800 feet to the nearest residence (McCann Exhibit C), and other distances to residential and senior housing/care uses of well under 1 mile, represents an extreme impairment of the existing neighborhood vista, and the character of the neighborhood that pre-exists the CVEC project.

In my opinion, below average and poor vista ratings are consistent with the impairment of vistas that will be caused by the CVEC facility itself. ***(see McCann Exhibit A)***

McCann Appraisal, LLC

Figure ES-2: Base Model Results: Scenic Vista




*The reference category consists of transactions for homes with an Average Vista, and that occurred after construction began on the wind facility*

*Source: December 2009 LBNL report*

Thus, in project area residential locations with a premium vista, a turbine facility downgrading the amenity to a poor or below average vista will result in a **value loss of 21% to 34%.** Similarly, residential property possessing a current average vista, if downgraded to poor or below average vista from the CVEC facility will suffer **between 8% and 21% value diminution.**

At approximately 410 feet in height, the view of the FGWP facility will be present at considerable distances that extend beyond the nearest residential property, particularly if a blinking light is required at night for aviation safety purposes.

In addition to the findings of the LBNL research report, I have also considered several peer reviewed studies published in The Appraisal Journal, that relate to value losses and impairment caused by other industrial "towers", such as cell towers, high voltage transmission lines, as well as the higher values that are derived from premium views from residential property.

Each of these studies generally confirms the findings summarized by the data reflected in LBNL Figure ES-2, and are maintained in the appraiser's work file for future reference.

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## NUISANCE IMPAIRMENT

For many residents, the introduction of a utility scale turbine facility will constitute a nuisance, based on the unprecedented height and the impairment of aesthetics related thereto, the blinking aviation light in the night sky, if required by the FAA, etc.

Nuisances are also created by noise from wind generators, and have been well documented by the "market" as being highly disruptive to the peaceful use and enjoyment of residential homes at levels well below the 10 dBa above ambient standard cited in the Brewster Code. In short, compliance with noise codes does NOT insure against nuisances being created by actual noise levels.

The complaints, personal accounts and factual experiences described by hundreds of individual "neighbors" to turbines comport with the technical descriptions and medical studies of sub-audible noise, also referred to as ultra-sound, infra-sound, low frequency noise, and which is not audible to the typical human ear in the normally expressed manner.

These real-life (not "modeled") nuisance descriptions are typically ignored, discounted or denied by wind developers, even though there are numerous examples of developers buying out or settling with nearby homeowners who have suffered from the same range of effects commonly known as "Wind Turbine Syndrome". These noise effects and nuisances related thereto have been documented in excess of 2 to 3 miles from the nearest turbines.

The LBNL study attempts to separately isolate the impact of nuisance on value, as depicted in the following Figure ES-1 from the LBNL study.

This figure separates the nuisance by distance from residential property, and clearly reveals that properties in the 3,000 feet and less, and 3,000 feet to 1-mile range **suffer value loss of 5.3% to 5.5%,** respectively.

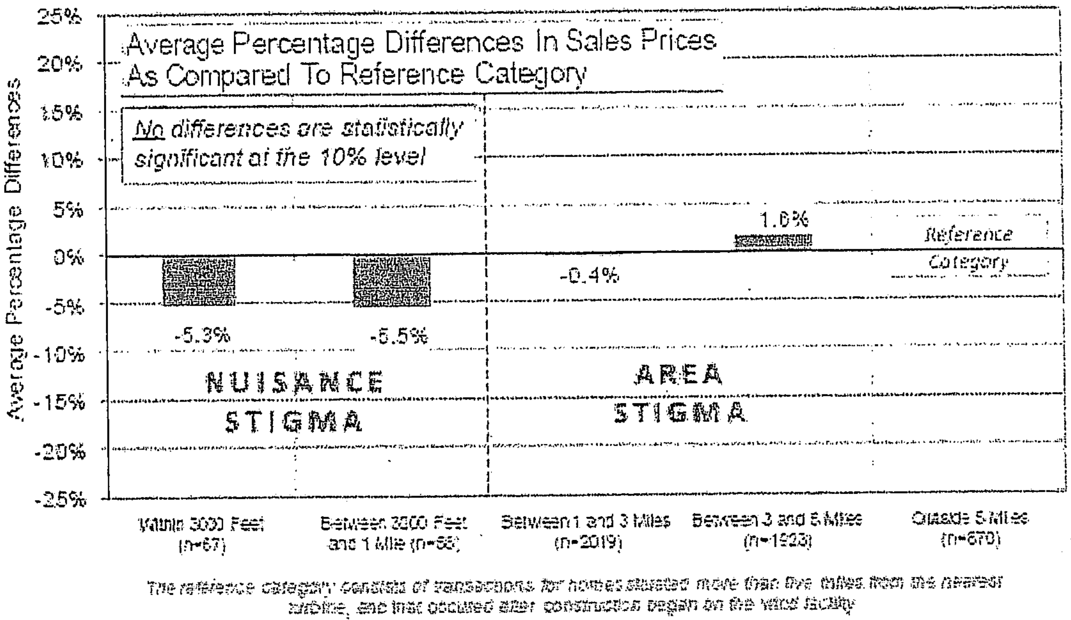
While the LBNL report author discounts the statistical significance of their own findings, this dismissal of relevance must be understood in the context of the largely irrelevant data from greater distances having provided the baseline property characteristics in a disproportionately sized data pool or sample, and which "waters down" the statistical indications.

The LBNL report must also be understood as a study commissioned with the intent of furthering the government policy of expanding wind energy development in the United States.

Nevertheless, even exclusion of certain impacted property data, or the disproportionate inclusion of data from 5 to 10 miles distant, did not eliminate the downward indication of value resulting from proximity to a nuisance, as depicted in the following figure:

00000899

Figure ES-1: Base Model Results: Area and Nuisance Stigma

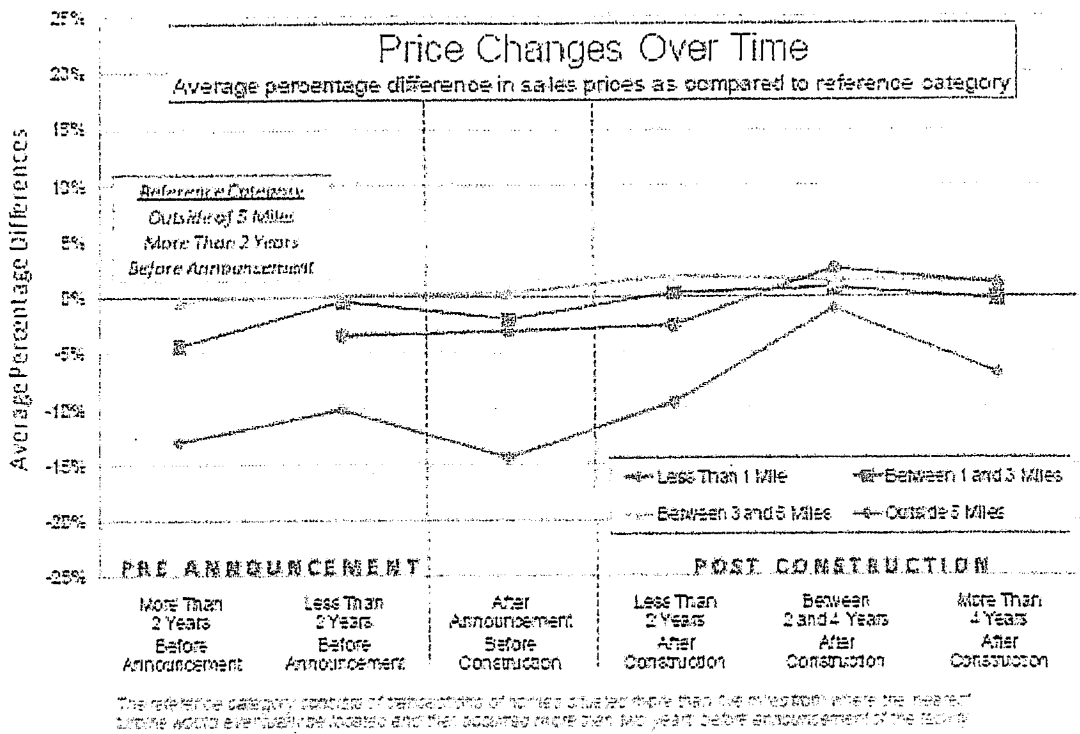



Source: December 2009 LBNL report

00000900

**Pre-Construction "Constructive Notice" of Turbine Facilities**
Further, the following LBNL study Figure ES-4 depicts value changes over time, at varied distance from wind turbines. The applicability of this focus of the LBNL study to the subject CVEC facility can be understood in the post-announcement but pre-construction phase of turbine projects, at which point "constructive notice" has been served on surrounding neighbors and property owners. Properties within 1-mile of such projects reflect the largest decline in value, and **confirm that a utility scale wind energy facility has measurable negative impact on property values within 1-mile**. Even the 3 to 5 mile range shows that values did not increase post-construction, when the control group of home sales outside 5 miles were increasing in value, nothing located within 5 miles indicated comparable value increases.

Figure ES - 4: Temporal Aspects Model Results: Area and Nuisance Stigma




The LBNL study is not the only pro-wind study that refutes the claims of developers regarding property value loss, due to their utility scale wind energy projects. A recent study focuses more on the pre-construction or "constructive notice" phase of development, as characterized by the pending application for the CVEC facilities.

00000901

A separate academic study conducted by Jennifer L. Hinman, Illinois State University, WIND FARM PROXIMITY AND PROPERTY VALUES: A POOLED HEDONIC REGRESSION ANALYSIS OF PROPERTY VALUES IN CENTRAL ILLINOIS

The background of this study author is a Master's Thesis, prepared by the author in partial fulfillment of degree requirements. ISU is heavily funded by wind energy developers, the American Wind Energy Association, the USDOE and other grant programs that are decidedly "pro-wind", and which seek to refute the actual experience of many neighbors to such projects.

In fact, ISU newsletters disclose that "corporate partners" that include wind energy development companies have access to the renewable energy programs, include advising on research direction and the right to review any applied research developed by ISU.

An excerpt of the Hinman report is presented as follows:

*This study uses 3,851 residential property transactions from January 1, 2001 through December 1, 2009 from McLean and Ford Counties, Illinois. This is the first wind farm proximity and property value study to adopt pooled hedonic regression analysis with difference-in-differences estimators. This methodology significantly improves upon many of the previous methodologies found in the wind farm proximity and property value literature.* ***The estimation results provide evidence that a "location effect" exists such that before the wind farm was even approved, properties located near the eventual wind farm area were devalued in comparison to other areas****. Additionally, the results show that property value impacts vary based on the different stages of wind farm development. These stages of wind farm development roughly correspond to the different levels of risk as perceived by local residents and potential homebuyers. Some of the estimation results support the existence of "wind farm anticipation stigma theory," meaning that* ***property values may have diminished in "anticipation" of the wind farm*** *after the wind farm project was approved by the McLean County Board. Wind farm anticipation stigma is likely due to the impact associated with a fear of the unknown, a general uncertainty surrounding a proposed wind farm project regarding the aesthetic impacts on the landscape, the actual noise impacts from the wind turbines, and just how disruptive the wind farm will be*

**Property Value Guarantee (PVG)**

Approval of wind energy facilities have served as constructive notice of future plans for development of wind turbine projects, and property values have been shown to decline based on pre-construction anticipation of wind projects. As such, there is ample evidence to either deny such related projects within 1 to 3 miles of homes or require a PVG.

00000962

I note the CVEC application is devoid of any such guarantee for any home or property owner, much less the Town of Brewster residents who live within 1, 2 or 3 miles from the proposed turbines.

Despite all the industry claims to the contrary, significant value impacts have in fact occurred, and have even resulted in the abandonment of homes, as well as nuisances, health problems, etc. A sampling of nuisance and health testimonials from people living near turbines is included in **McCann Exhibit D,** which contains web page and news links.

As a personal observation, in 30 years of appraising and studying real estate values, damages claims, zoning and land use issues, I have never before observed such a widespread and consistent series of similar, negative reports coming from residents living by any other type of facility. It is an observable trend in the market, both for owner-occupants and the home-buying market.

Even the principal author of the LBNL study, Ben Hoen, now recommends implementation of Property Value Guarantees (PVG's) in the context of wind energy project mitigation of impacts.

(see page 32 of linked webinar)
http://www.windpoweringamerica.gov/newengland/pdfs/2010/webinar_neweep_property_values_hoen.pdf

# Property Value Risks Will Persist Unless They Are Measured, Mitigated and Managed

## Manage

Manage risks in the short term for homeowners through tenable/workable measures

- Offer some combination of neighbor agreements/incentives and/or property value guarantees (e.g., Dekalb County, IL) to nearby homeowners as are economically tenable and legally workable
- Conduct follow up studies (e.g., surveys, appraisals)
- Realize that cumulative impacts may exist
- Realize that real or perceived risks may increase/decrease as more/better information become available

Nuisance can be manifest by close proximity of the CVEC facility to homes of less than 1 mile, and for other reasons. Distance includes visual impacts but that has more of an impact on marketing, and also leaves homeowners wishing to sell with the ethical dilemma of making full disclosure of known nuisances to potential buyers, or facing possible legal repercussions and financial liability for failing to make such a disclosure.

Despite the limited number of the (2) CVEC turbine developments, they will have a negative impact or "nuisance" due to the circumstances that the project and use has a dominant presence, impairs aesthetics, negatively changes the character of the neighboring residential property settings or perception thereof (single or multiple properties).

Any number of potential variable impacts has a demonstrable adverse impact on the use, enjoyment, marketability or value of the subject property neighboring use, and it creates a man-made detriment to neighboring property and results in a negative impact for any homes that "got in the way". This is exactly why adequate setbacks are important. To mitigate against adverse impacts on neighboring property.

**McCann Value Impact Study**

Additional sale data studied by McCann for home values in a rural Illinois location adjacent to the Mendota Hills wind turbine project in Lee County is included in **Exhibit B** of this report. Despite the booming market conditions represented by the 2003-early 2005 sale dates, the homes within 2 miles of the nearest turbine reflect an average sale price per square foot that is 25% lower than homes located outside that 2-mile perimeter.

Thus an impaired view, inadequate setback, and stigma associated with noise and health impacts and concerns, measured to project value loss from a property possessing a "premium" vista, indicates that a 13% premium could become a 21% reduction, or a net property value reduction of 34%. This is well supported by the range of property case studies of value loss for individual homes that range from 20% to 40%, and in some instances a complete loss of equity when homes are completely unmarketable, or are acquired by wind developers and re-sold for losses up to 80%, or even demolition of the otherwise livable homes.

This range of value loss for the nearest residential properties is fairly classified as significant, preventable and "undue". The probability of damages to the value of homes and other property is quantified with empirical data rather than speculation, and is clearly indicated to a high degree of professional certainty.

Further, the two property value studies cited in the CVEC website (Hoen & Hinman) were prepared by researchers who hold no appraisal licenses, designations, credentials or even any background in property sales or development. The industry-sponsored studies have also been selectively & partially quoted by the CVEC, to the extent that it would tend to mislead the public as to the conclusions of the study authors. A brief interview with Ben Hoen, which is available on the web, is contained in **McCann Exhibit E**. This exhibit contains a printed version of the Hoen comments about his study, as well as a link to listen to the audio recording.

**Conclusion**

After completing my review of the subject location, it is clear that numerous homes in the Town of Brewster will be adversely impacted, and the best available evidence indicates that **value loss of 25% or more will occur to homes within approximately 2 miles of the turbines.** This impact is not expected to be uniform, and some losses may well be lower and others higher.

The close proximity of the proposed turbines cannot meet the zoning requirements stated previously. The basis for this conclusion is the failure of the project to meet certain Special Permit and other approval criteria, as follows:

- ***It will have an undue adverse impact on scenic views and residential property values.*** This is supported by both industry studies, post publication author updates, and McCann independent study of property values. The LBNL study isolates and identifies value contribution to residential property when good or premium vistas are present, and the loss of such amenity is documented as the basis for lower values.

- ***The applicant has not agreed to implement any reasonable measures to mitigate the aesthetic impacts of the WET that result in value loss.*** Property Value Guarantees are effective tools, if carefully designed to leave property owners "whole", and even the LBNL author now recognizes the validity of a PVG.

- ***The two (2) turbine structures will NOT be in harmony with the visual character of the neighborhood, including views and vistas and, the historic character of the neighborhood.*** There is nothing built in Brewster that is the height of a 40 story building, and the turbines will become the dominant presence within at least a mile of any other land use. Views and vistas create value for property, and impairment of vistas with non-compatible, immense, spinning machines simply can not blend in to any residential area or community.

- ***The turbines architectural design will not be compatible with the character and scale of the adjacent and surrounding neighborhoods.*** Turbines are not architecturally designed but, rather, utilitarian by design. Large steel poles and the spinning (or still) blades are completely disproportionate in scale and contrary to the character of small towns and neighborhoods. Despite the denial

00000966

of wind industry spokespeople of low-frequency or sub-audible noise impacts, the fact remains that a significant number of people are highly disturbed by this type of turbine impact, which clearly demonstrates a lack of compatibility for turbines to be placed in close proximity to residential uses. The design of turbines can not avoid the noise impacts, including sub-audible, amplitude modulation noise.

The CVEC Facility, does not comply with the relevant Brewster Code, as it fails to avoid or even to minimize impact on property value, impact on the character of the neighborhood, and is highly questionable as to safety of setbacks that do not even meet manufacturer guidelines for safety zone, or the code requirement for distances safe from "ice throw". The proximity to Route 6 is several hundred feet closer to the turbine project than the 1,300 feet minimum to prevent ice throw hazards to this public roadway. [illegible] Roads

However, the preceding range of value and value damages is considered to be reasonably reliable for the purpose of determining whether the CVEC Facility meets Code requirements as to minimizing adverse impact on property values or on adverse impact to the character of the neighborhood.

**Related Issues**

Other property has been identified which, in my opinion, is likely to experience significant value loss.

- A nearby radio station will reportedly experience significant impact to its broadcast capabilities, which would have a significant detrimental effect on the continued use for that purpose and its underlying value. Radio Broadcast Interference
- The Pleasant Bay nursing home is within shadow-flicker and noise distances, and the resulting disturbance to high-risk residents is likely to cause some residents to be relocated, or even to suffer health impacts. With 135 beds and a reported approximate revenue base of $300 per day per bed, a drop in occupancy of only 10% would represent a $1.48 million per year loss of revenue, which in turn would decrease the property value and the value of the nursing home business. Nursing Home
- The Woodlands assisted living facility consists of 59 units that reportedly rent for $4,000 - $6,000 per month. A 10% drop in occupancy would indicate a gross revenue loss of approximately $354,000 annually, and the corresponding property value would also be impaired. Assisted Living Facility
- A municipal golf course, which depends on a peaceful, serene setting, will now have visual and sometimes audible disturbances, and is likely to realize a loss of patronage from golfers who have other options and require a peaceful course. Golf Course
- The Town Of Brewster's assessed values are likely to experience justification for a significant decrease, as values and prices of residential property in Brewster

begin to decline due to the close proximity and the resulting impacts of the turbines.

- Liability issues for the Town, as owner of the project, are likely to begin if the turbines are developed, as nuisance, health and property value damage claims are litigated. The fiscal impact to the Town of Brewster could very well suffer in the long-term, despite revenue and grant benefits cited by the CVEC.

City Liability

Additional documents, facts, data and studies and market trend information is retained in the appraiser's work file, in the event expert opinions expressed herein and the basis for the opinions must be refined or given in testimony in any future legal proceedings.

I reserve the right to supplement my opinions at a later date, if the need arises and/or if additional information becomes available. Further, McCann's ongoing study of wind energy projects and their impacts may result in future disclosures and market information relevant to wind energy development issues.

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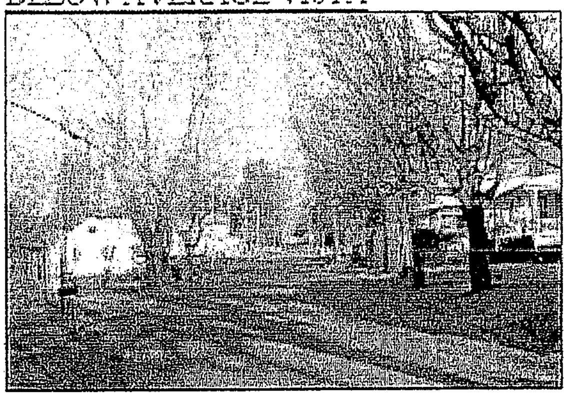
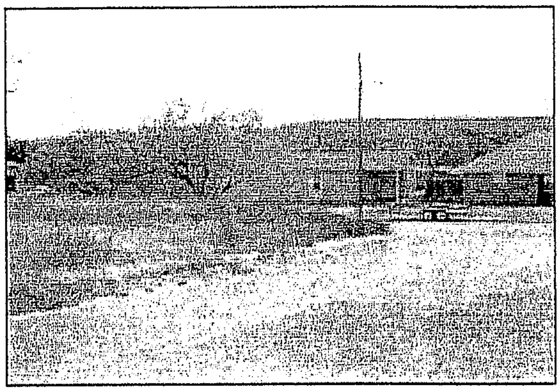
# McCann Exhibit A

## Appendix D: Vista Ratings with Photos

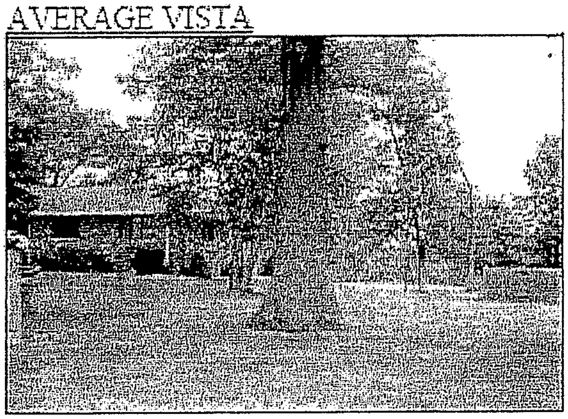
POOR VISTA

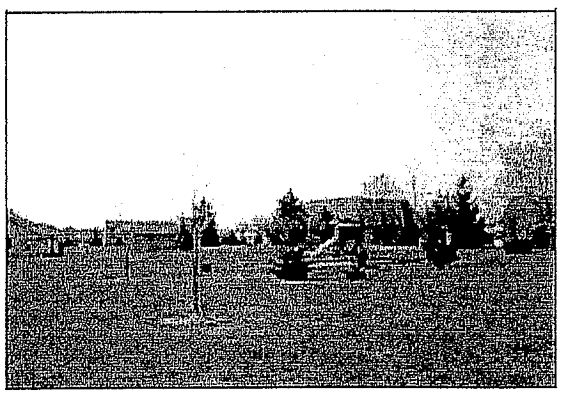
BELOW AVERAGE VISTA





AVERAGE VISTA







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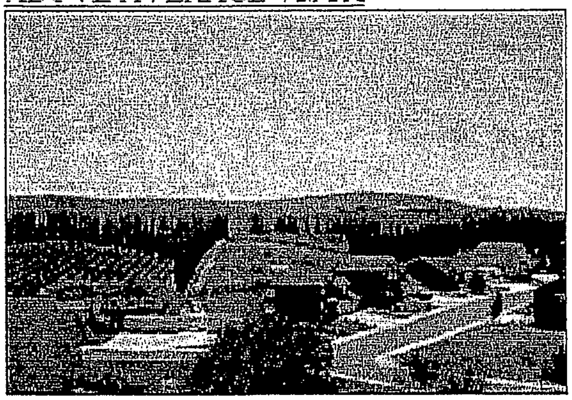
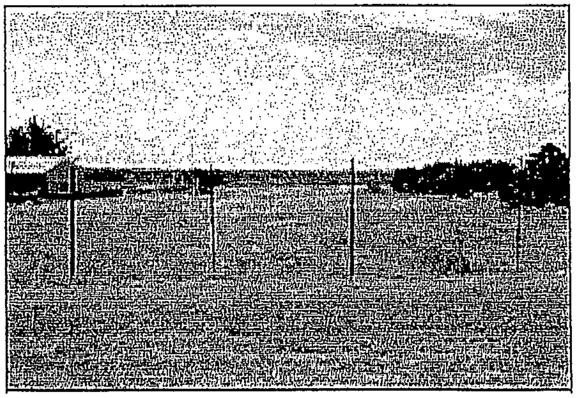
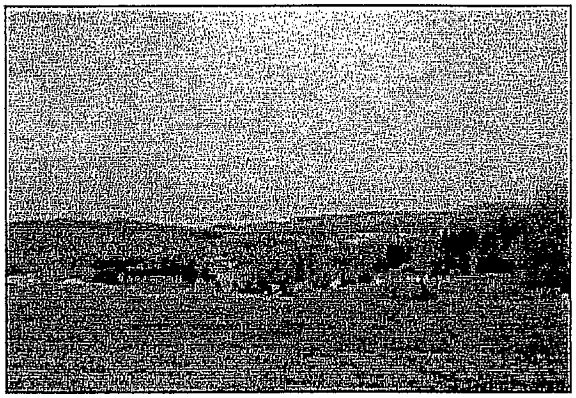
ABOVE AVERAGE VISTA





PREMIUM VISTA



*Source: LBNL Appendix D, report page 120 & 121*

McCann Appraisal, LLC

# McCann Exhibit B

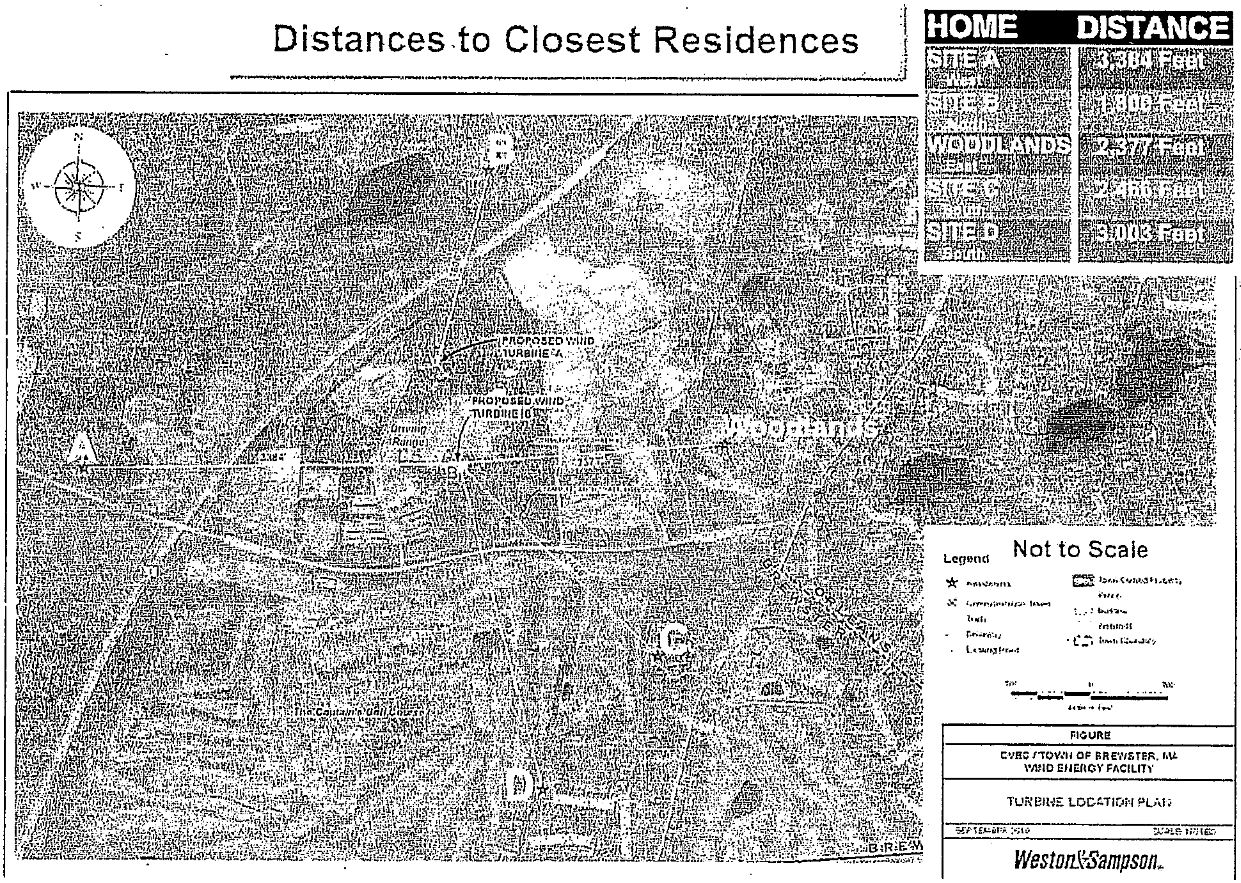
## Mendota Hills Wind Energy Project

| Sale # | Address | Sale Date | Price | Grantor | Grantee | Style | Size SF | $/SF |
|---|---|---|---|---|---|---|---|---|
| 1 | 629 W. Chestnut | Oct 2003 | $37,000 | Estes | Lipe | 1.5 | 1,161 | $31.87 |
| 2 | 323 W. Chestnut | Oct 2004 | $40,000 | Reed | Hovious | 1.5 | 1,425 | $28.07 |
| 3 | 1019 Steward Rd. | May 2003 | $40,000 | Houle-Ward | Reyns | 2 | 1,408 | $28.41 |
| 4 | 91143 Paw Paw | Mar 2005 | $187,000 | Zaylik | Pachero | 2 | 1,571 | $119.03 |
| 5 | 1224 IL Rte. 251 | Jun 2003 | $138,000 | Gittleson | Kowalski | 2 | 1,272 | $108.49 |
| 6 | 339 Chestnut St. | Jan 2003 | $72,000 | White | Flynn | 2 | 1,684 | $42.76 |
| 7 | 630 W. Chestnut | Sep 2003 | $126,000 | Eddy | Morath, Sr. | 1.5 | 1,728 | $72.92 |
| 8 | 427 Chestnut St. | Oct 2003 | $87,000 | Hesik | Rourke, Jr. | 1.5 | 1,380 | $63.04 |
| 9 | 138 Cherry St | Sep 2004 | $80,000 | Hammond | Alexander | 1.5 | 1,326 | $60.33 |
| 10 | 536 W. Cherry | Oct 2004 | $63,500 | Johnson | Fitzpatrick | 1.5 | 999 | $63.56 |
| 11 | 885 Compton Rd. | Oct 2004 | $66,900 | Boysen | Gellings | 1 | 480 | $143.54 |
| 12 | 518 W. Cherry St. | Apr 2003 | $87,500 | Allen | Beckman | 1 | 927 | $94.39 |
| 13 | 222 Maple St. | Dec 2004 | $150,000 | Clark | Cummings | 1 | 1,852 | $80.99 |
| 14 | 444 W. Main St. | Mar 2005 | $109,900 | Miller | Michaels | 1 | 1,402 | $78.39 |
| 15 | 2874 Beemerville | Jul 2003 | $367,000 | Finkboner | DGNB TRT | 1 | 2,201 | $166.74 |
| | | | | | | Average sale price | | $78.84 |
| 16 | 1310 Melugins Grove | Apr 2004 | $179,000 | Lyons | Overton | 2 | 1,952 | $91.70 |
| 17 | 2612 Shady Oaks Rd. | Apr 2003 | $131,000 | Smith | Paplech | 1.5 | 1,208 | $108.44 |
| 18 | 3448 Cyclone Rd. | Mar 2003 | $105,900 | Munyon | Pippenger | 2 | 1,456 | $72.73 |
| 19 | 2524 Johnson St. | Aug 2004 | $61,800 | Copeland | Lampson | 1.5 | 948 | $65.19 |
| 20 | 741 Third St. | Feb 2004 | $63,500 | Eckhardt | Rosales | 1.5 | 868 | $73.16 |
| 21 | 613 Church Rd. | May 2003 | $115,000 | Merkel | Parpart | 1.5 | 1,458 | $78.88 |
| 22 | 3435 Willow Creek | Jun 2003 | $118,000 | Swiatek | Brydun | 2 | 884 | $133.48 |
| 23 | 3021 Cottage Hill | Mar 2005 | $182,000 | Russ | Curtis | 1.5 | 1,239 | $146.89 |
| 24 | 3385 Willow Creek | Mar 2003 | $180,000 | McCoy | Carver | 2 | 2,840 | $63.38 |
| 25 | 745 Second St. | Dec 2004 | $59,000 | Wilson | Calderon | 1.5 | 1,161 | $50.82 |
| 26 | 761 4th St. | Mar 2003 | $68,000 | Stewart | Etsinger | 1 | 724 | $93.92 |
| 27 | 2774 Welland Rd. | Apr 2003 | $93,000 | Batha | Crumpton | 1.5 | 1,104 | $84.24 |
| 28 | 558 Earlville Rd. | Jan 2003 | $145,000 | Hodge | Ikeler | 2 | 1,280 | $113.28 |
| 29 | 2505 Wood St. | Aug 2004 | $105,000 | Janiak | Bullock | 2 | 1,812 | $57.95 |
| 30 | 385 Earlville Rd. | Aug 2004 | $280,000 | Rago | Diehl | 2 | 2,142 | $130.72 |
| 31 | 3095 Cyclone Rd. | Dec 2004 | $169,900 | Summerhill | Rainbolt | 2 | 2,048 | $82.96 |
| 32 | 742 Second St. | Jan 2003 | $103,000 | Delhotal | Stewart | 2 | 1,876 | $54.90 |
| 33 | 395 Angling Rd. | Mar 2005 | $119,000 | BMV Prop. | Herendeen | 1 | 680 | $175.00 |
| 34 | 2515 Wood St. | Apr 2004 | $80,000 | Jones | Sarver | 1 | 912 | $87.72 |
| 35 | 1218 Locust Rd | Jan 2005 | $169,000 | Wachowski | Gembeck | 1 | 1,040 | $162.50 |
| 36 | 901 Melugens Grove | Aug 2003 | $228,000 | Kidd | Rajan | 1 | 2,000 | $114.00 |
| 37 | 1490 German Rd. | Aug 2004 | $85,000 | Firlit | Chailand | 2 | 2,144 | $39.65 |
| 38 | 603 Ogee Rd. | Apr 2004 | $285,000 | Anderson | Miller | 1 | 1,920 | $148.44 |
| 39 | 546 Carnahan Rd. | Jan 2005 | $110,000 | Coley | Sarabia | 1 | 1,296 | $84.88 |
| 40 | 1353 County Line | Nov 2003 | $185,000 | Vallejo | Bozaeth | 1.5 | 1,338 | $138.27 |
| 41 | 2512 Johnson St. | Feb 2005 | $123,000 | Montavon | Sutton | 2 | 2,232 | $55.11 |
| 42 | 2509 Herman Rd | Apr 2004 | $142,900 | Bresson | Arjes | 1 | 1,404 | $101.78 |
| 43 | 955 Woodlawn | Jul 2003 | $265,000 | Swan | LaRosa | 1.5 | 1,918 | $138.16 |
| 44 | 1279 Locust Rd. | Mar 2003 | $270,000 | Witte | olin | 1 | 2,156 | $125.23 |
| 45 | 648 Ogee | Nov 2003 | $225,000 | Fickenscher | Rojas | 1 | 1,768 | $127.26 |
| 46 | 1339 Woodlawn Rd. | Sep 2003 | $230,000 | Howell | Barnhill | 1 | 1,701 | $135.21 |
| 47 | 1349 Woodlawn Rd | May 2003 | $207,500 | Howell | Wiskari | 1 | 1,809 | $114.70 |
| 48 | 711 O'Gee Rd | Aug 2004 | $185,000 | Groevengoed | Carabal | 1 | 1,352 | $136.83 |
| 49 | 1295 Locust Rd | May 2004 | $300,000 | Hagan | Lowe | 1 | 2,672 | $112.28 |
| 50 | 660 Paw Paw Rd. | May 2004 | $185,000 | Wiskur | Pogreba | 1 | 1,148 | $161.15 |
| 51 | 3011 Honeysuckle | Mar 2005 | $355,000 | Abbott | Brandt | 2 | 3,655 | $97.13 |
| 52 | 489 Earlville Rd. | Nov 2004 | $165,000 | Schlafke | Fromherz | 2 | 1,400 | $127.86 |
| 53 | 2512 Shaw Rd. | Jun 2004 | $153,500 | Hlavin | Kapinski | 2 | 1,638 | $93.71 |
| | | | | | | Average sale price | | $104.72 |

| | | |
|---|---|---|
| Sales 17 - 53 located > 2 miles from turbines | $104.72 | sq ft |
| Sales 1 - 16 located within 2 miles of turbines | $78.84 | sq ft |
| Difference in sale price per square foot | $25.89 | sq ft |
| Average Value diminution within 2 miles of turbines | 25% | |

McCann Appraisal, LLC

# McCann Exhibit C




*Source: CVEC website*

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# McCann Exhibit D

*Author:* National Wind Watch

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# McCann Exhibit E

*posted:* December 21, 2010 •

## Ben Hoen on need for Property Value Guarantee

*Author:* Schneider, Clif

The following is an excerpt from a conversation I had in April 2010 with Ben Hoen, whose work with property value impacts associated with wind projects is widely referenced by developers, including those developers hoping to have wind projects approved here in Jefferson and St. Lawrence Counties. Hoen's comments below are very different from the spin suggested by Madden of BP Alternative Energy and Acciona's FEIS. Hoen indicates if developers believe turbines won't devalue neighboring property they should guarantee it, and he's right:

"You know we are very cautious about what happens close to the turbines. We really don't know what's going on there (e.g., 1,250 ft from turbines). I just spoke in Illinois about this. You might know about a Property Value Guarantee. It's a dicey situation and complicated, but I think homes that are very close, there is just too much unknown right now; that seems reasonable. I think **one of the things that often happens is that (wind) developers put our report forward and say look property values aren't affected, and that's not what we would say specifically.** On the other hand, they have little ground to stand on if they say we won't guarantee that. I think for homes that are close we have a lot more ambiguity and real issues. If we are talking about views that's one thing, if we are hearing it or shadow flicker that might be really regular, the kind of things that happen at night. …

"I'm not a lawyer and I'm not the developer, these (PVGs) are just options in the tool kit. I don't know whether it's reasonable to put together, I have looked at one, I don't know if there is a better way to write it or whether the one I read from Illinois is good or bad. They have to be thought about, they all probably have cost implications, so the developer is not going to give away the house if they were too generous; on the other hand if they are not generous enough they don't have any impact. That's just one of the tools available, there are neighbor agreements that may be more applicable whether folks nearby get compensation, if they are not a participating land owner. One of the things I've always hoped is somebody would offer one or the other and see what landowners would do."

*Reported by:*
Clif Schneider
April 12, 2010

Listen to the recording of Hoen's comment:

McCann Appraisal, LLC

## CERTIFICATION

The undersigned, representing McCANN APPRAISAL, LLC, do hereby certify to the best of our knowledge and belief that:

FIRST: The statements of fact contained in this consulting report are true and correct.

SECOND: The reported analyses, opinions and conclusions are limited only by the reported assumptions and limiting conditions and represents the personal, impartial and unbiased professional analyses, opinions, and conclusions of the undersigned.

THIRD: We have no present or prospective interest in the property that is the subject of this report and no personal interest with respect to any of the parties involved.

FOURTH: We have no bias with respect to the property that is the subject of this report or to the parties involved with this assignment.

FIFTH: Our engagement in this assignment was not contingent upon developing or reporting predetermined results.

SIXTH: Our compensation for completing this assignment is not contingent upon the development or reporting of a predetermined value or direction in value that favors the cause of the client, the amount of the value opinion, the attainment of a stipulated result, or the occurrence of a subsequent event directly related to the intended use of this appraisal.

SEVENTH: Our analysis, opinions, and conclusions were developed, and this report has been prepared in conformity with the Uniform Standards of Professional Appraisal Practice.

EIGHTH: No physical inspection was made by McCann Appraisal, LLC of the property that is the subject of this report. The undersigned utilized photographs, maps and property record card data for characterizing and understanding the character of the subject property:

NINTH: No one other than the undersigned provided significant real property appraisal assistance to the person signing this certification.

TENTH: Neither the undersigned nor McCann Appraisal, LLC has previously appraised the subject property.

IN WITNESS WHEREOF, THE UNDERSIGNED has caused these statements to be signed and attested to.

Michael S. McCann

Michael S. McCann, CRA
*State Certified General Real Estate Appraiser*
*License No.553.001252 (Expires 9/30/2011)*

00000920

# PROFESSIONAL BIOGRAPHY
# MICHAEL S. MCCANN, CRA

Michael S. McCann has been exclusively engaged in the real estate appraisal profession since 1980, and is the owner of McCann Appraisal, LLC.

## EXPERIENCE

His appraisal experience has included market value appraisals of various types of commercial, office, residential, retail, industrial and vacant property, along with a wide variety of unique or special purpose real estate, such as limestone quarries, hotels, contaminated properties, etc. He has gained a wide variety of experience in real estate zoning evaluations and property value impact studies, including analysis of utility scale wind turbine generating facilities, gas-fired electric generating plants, shopping centers, industrial facilities, limestone quarries, sanitary landfills and transfer station waste disposal facilities. He has been retained as an independent consultant to municipalities, government agencies, corporations, attorneys, developers lending institutions and private owners, and has spoken at seminars for the Appraisal Institute, the Illinois State Bar Association and Lorman Education Services on topics including the vacation of public right of ways (1986), and Property Taxation in the New Millennium (2000), Zoning and Land Use in Illinois (2005, 2006).

In addition to evaluation of eminent domain real estate acquisitions for a wide variety of property owners & condemning authorities, Mr. McCann has served as a Condemnation Commissioner (2000-2002) appointed by the United States District Court - Northern District, for the purpose of determining just compensation to property owners, under a federal condemnation matter for a natural gas pipeline project in Will County, Illinois.

## EXPERT TESTIMONY

Assignments include appraisals, studies and consultation regarding real estate located in 21 states. He has qualified and testified as an expert witness in Federal Court, and for condemnation, property tax appeal and zoning matters in the Counties of Cook, Will, Boone, Lake, Madison, St. Clair, Iroquois, Fulton, McHenry, Ogle & Kendall Circuit Courts, as well as the Chicago and Cook County Zoning Boards of Appeal, the Property Tax Appeal Board (PTAB) and tax court & Commissions of Illinois, Wisconsin, and Ohio, Circuit Courts in New Jersey and Indiana, as well as zoning, planning, and land use and County Boards in Texas, Missouri, Idaho, Michigan, New Mexico and various metropolitan Chicago area locales. He has also been certified as an expert on the Uniform Standards of Professional Appraisal Practice (USPAP) by the Cook County, Illinois Circuit Court. Mr. McCann has substantial experience in large-scale condemnation and acquisition projects and project coordination at the request of various governmental agencies and departments. These include appraisals for land acquisition projects such as the Chicago White Sox Stadium project, the Southwest Transit (Orange Line) CTA rail extension to Chicago's Midway Airport, the United Center Stadium for the Chicago Bulls and Blackhawks, the minor league baseball league, Silver Cross Field stadium in Joliet, Illinois , as well as many other urban renewal, acquisition and neighborhood revitalization projects.

## REAL ESTATE EDUCATION

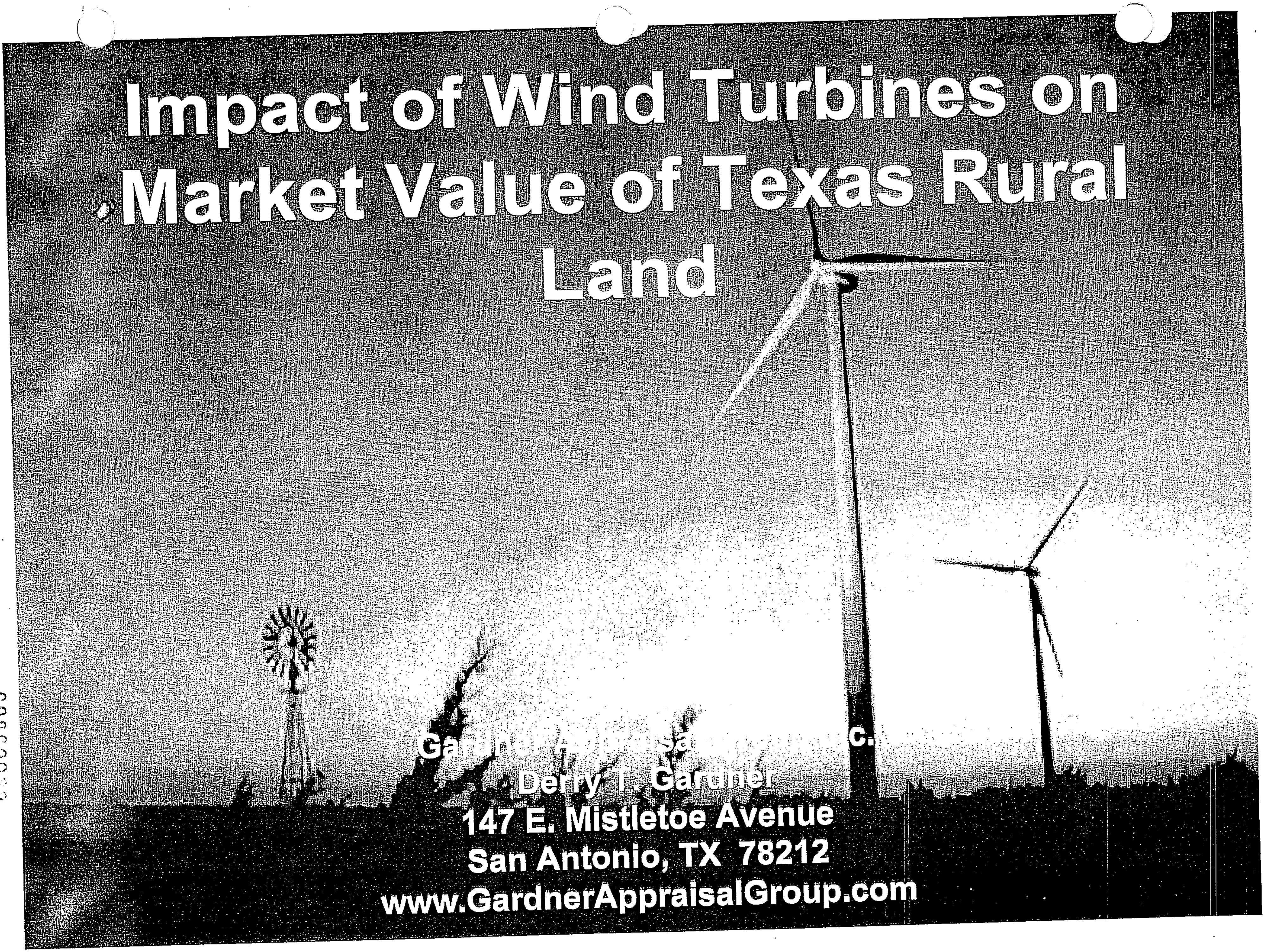
Specialized appraisal education includes successful completion of Real Estate Appraisal Principles, Appraisal Procedures, Residential Valuation, Capitalization Theory and Techniques Part A, Standards of Professional Practice Parts A, B and C, Case Studies in Real Estate Valuation, Highest and Best Use and Market Analysis, Advanced Income Capitalization, Subdivision Analysis and Special Purpose Properties, Eminent Domain and Condemnation, and Valuation of Detrimental Conditions in Real Estate offered by the Appraisal Institute. In addition, he has completed the Society of Real Estate Appraisers' Marketability and Market Analysis course, the Executive Enterprises - Environmental Regulation course, and a variety of continuing education real estate seminars.

## DESIGNATIONS & PROFESSIONAL AFFILIATIONS

Mr. McCann is a State Certified Associate Member of the Appraisal Institute, and the National Association of Review Appraisers & Mortgage Underwriters designated him as a Certified Review Appraiser (CRA). He was elected in 2003 as a member of Lambda Alpha International, an honorary land economics society, and he served several years as a member of the Appraiser's Council of the Chicago Board of Realtors.

## LICENSES

State Certified General Real Estate Appraiser in the State of Illinois (License No. 533.001252) and is current with all continuing education requirements.


Impact of Wind Turbines on
Market Value of Texas Rural
Land
Derry T. Gardner
147 E. Mistletoe Avenue
San Antonio, TX 78212
www.GardnerAppraisalGroup.com

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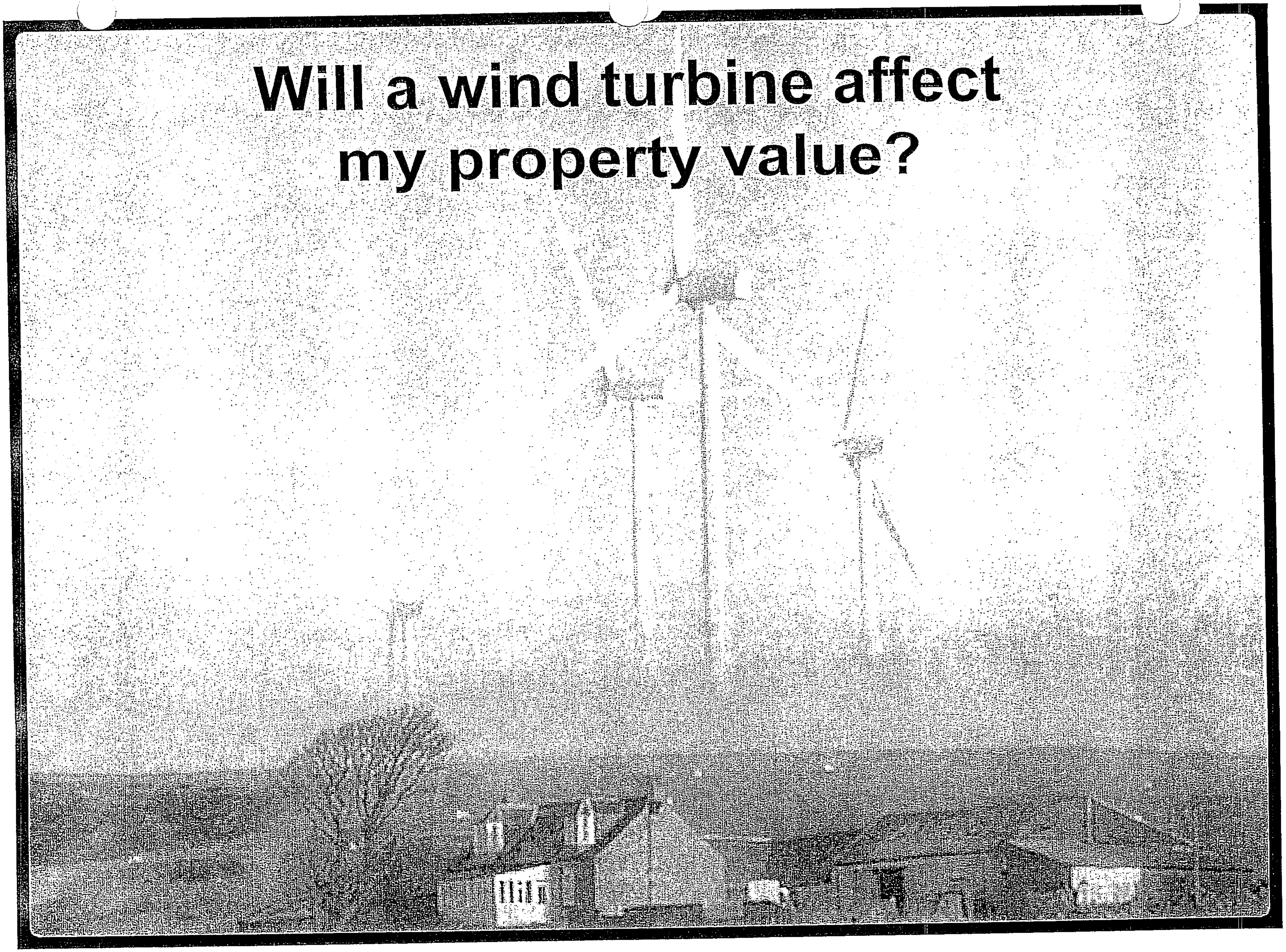
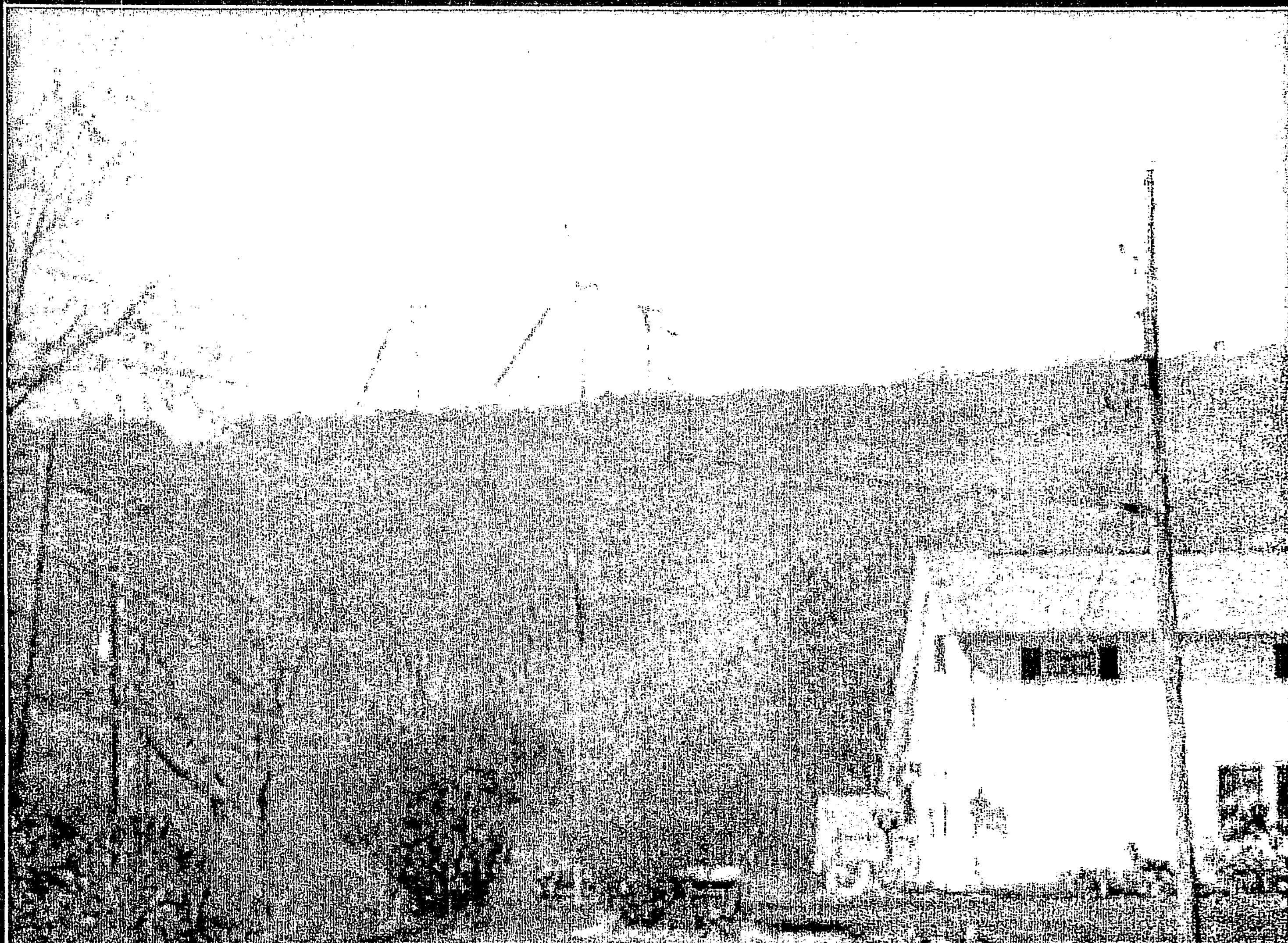
Prepared for the South Texas Plains
Agriculture Wind & Wildlife Conference
February 13, 2009
American Wind Power Center & Museum,
Lubbock, Texas


Will a wind turbine affect
my property value?

# WILL A WIND TURBINE ON MY PROPERTY EFFECT THE MARKET VALUE OF MY NEIGHBOR'S PROPERTY?

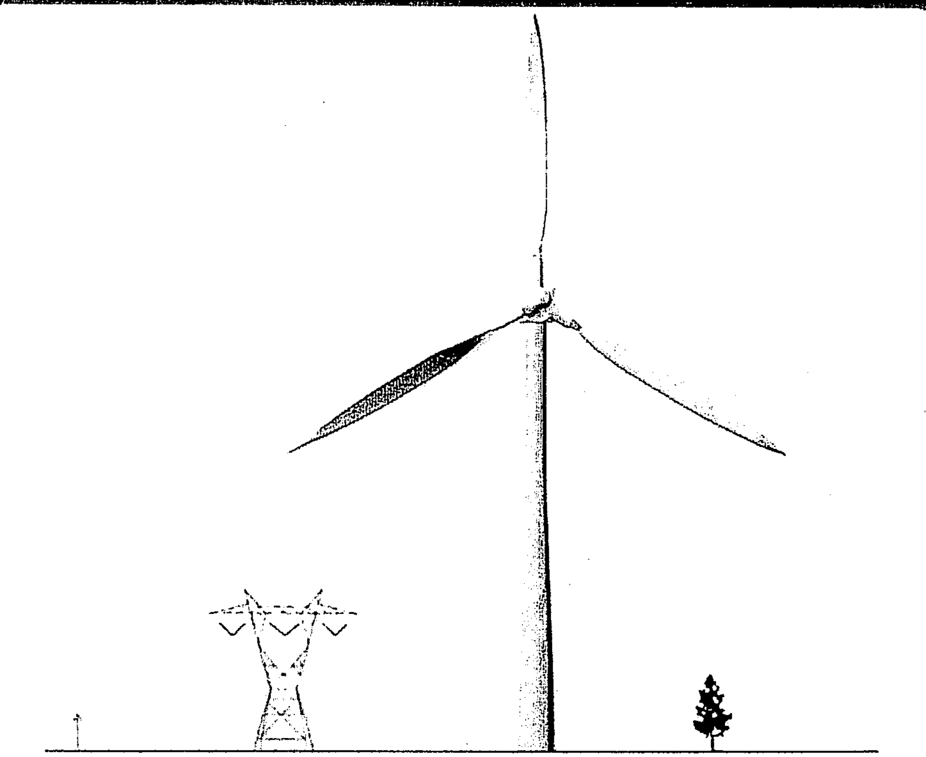


WOULD YOU PAY THE SAME PRICE FOR THIS LAND
*__AFTER__* WIND FARM AS *__BEFORE__* WIND FARM?

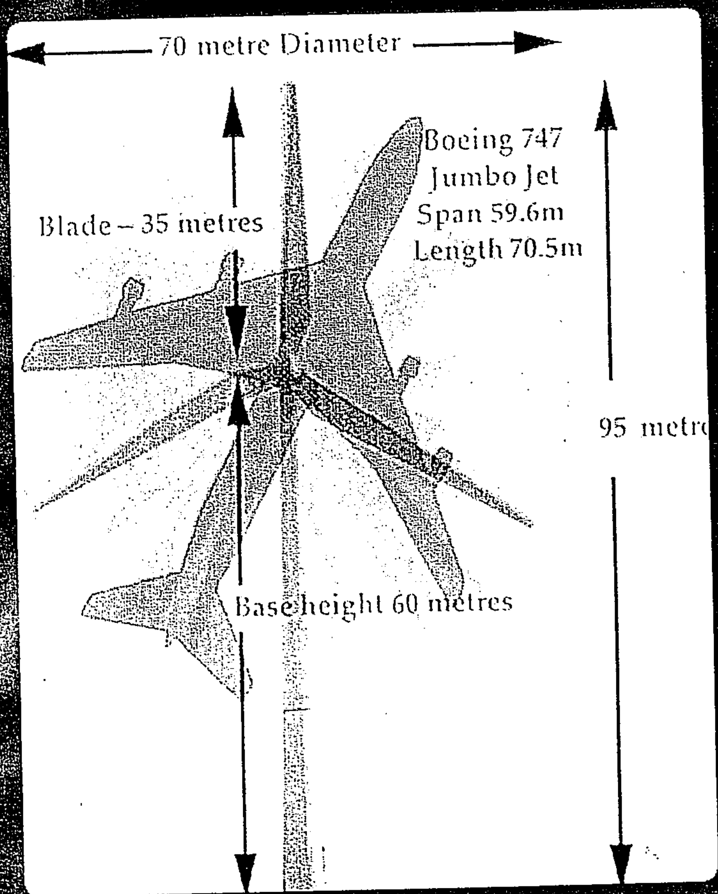
BEFORE

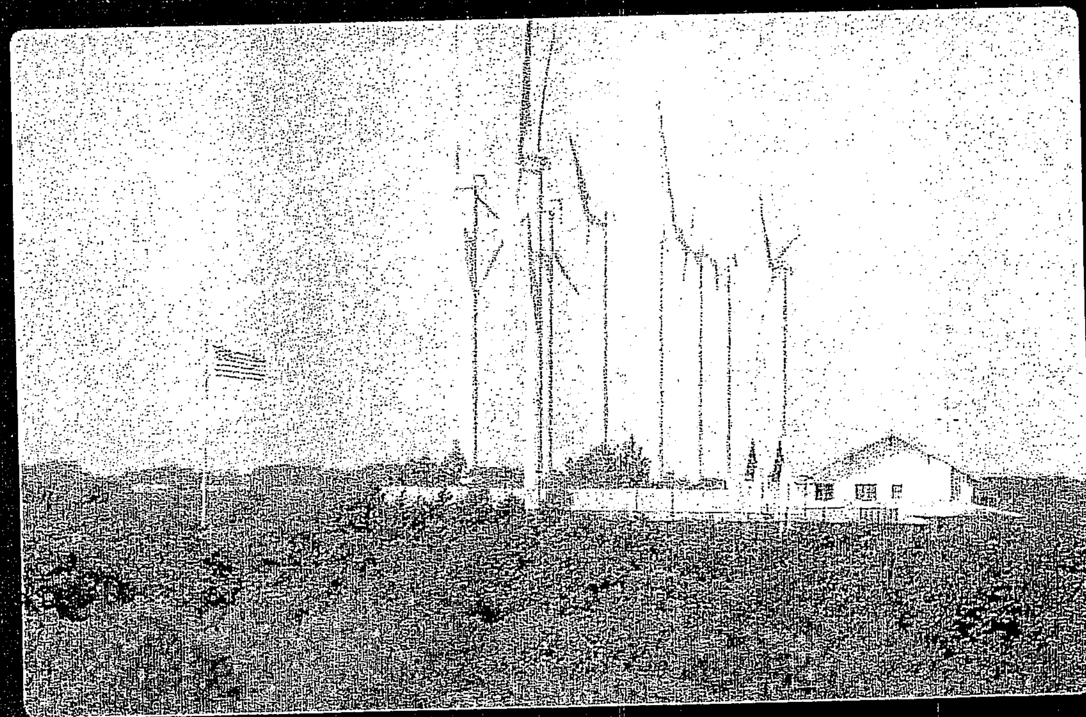
AFTER

# Do you know how big they really are?



# THIS IS HOW BIG THEY ARE!



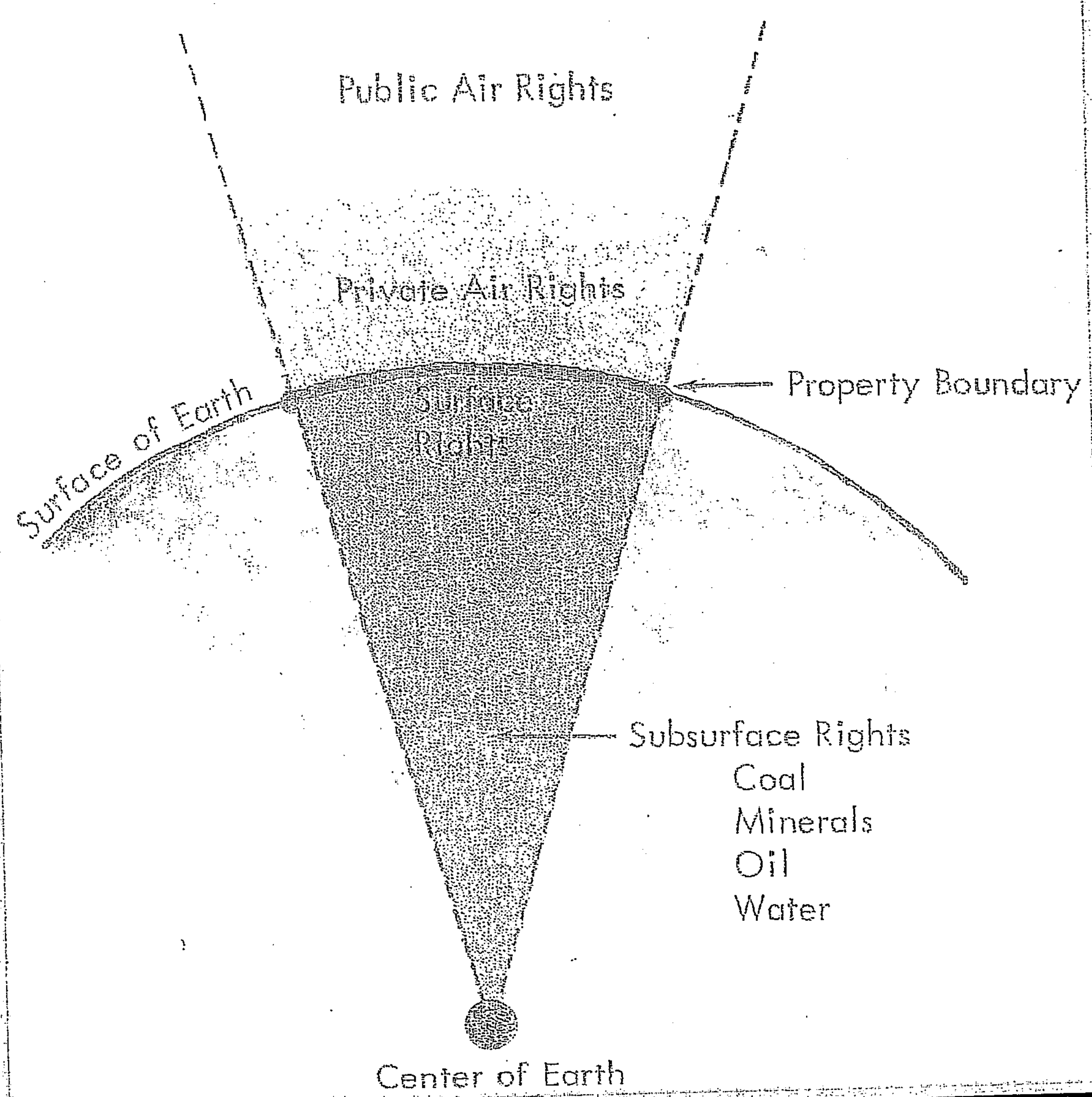



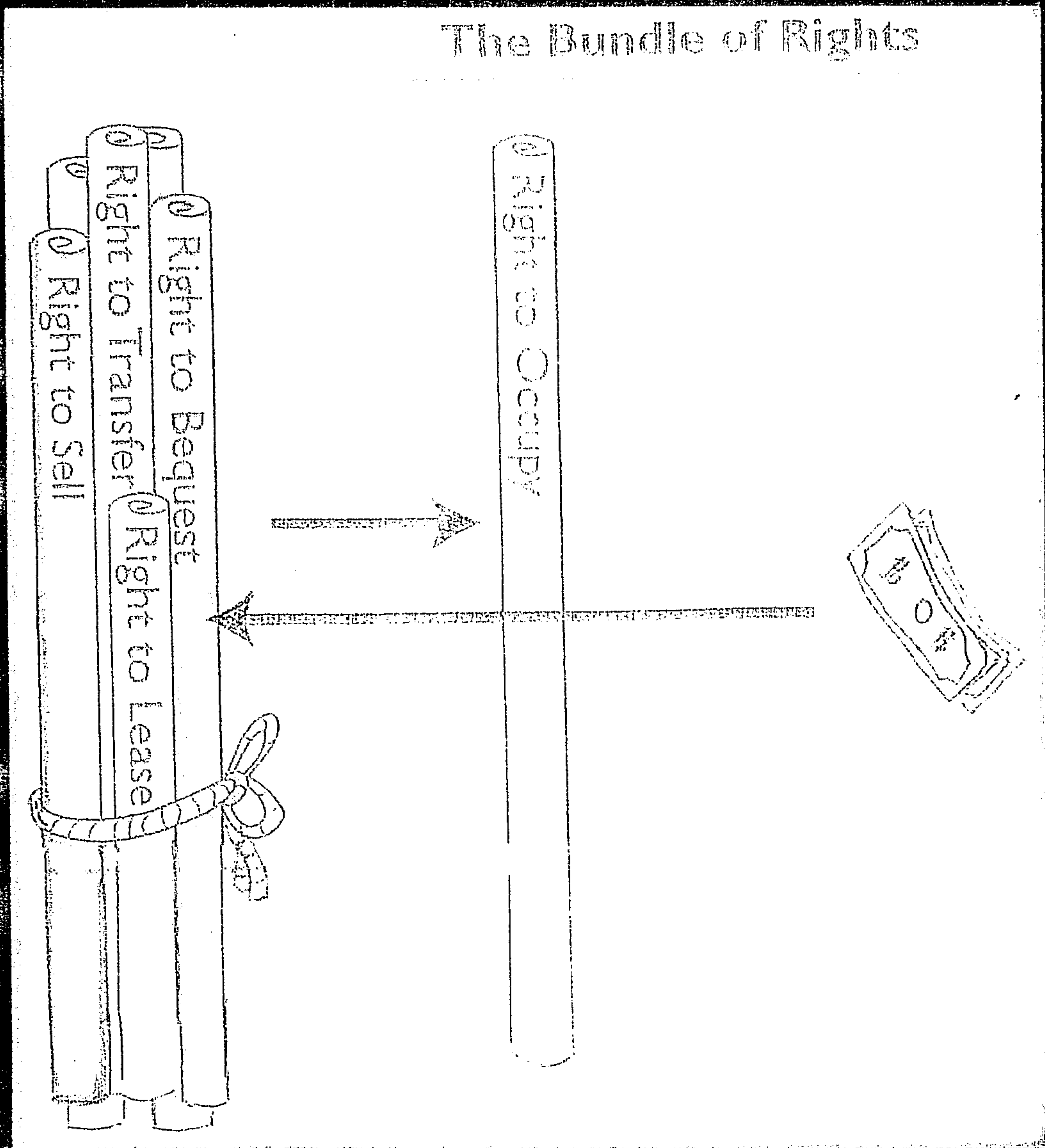
**When valuing real property, first determine the property rights to be appraised; the most complete form of ownership is "title in fee" or FEE SIMPLE INTEREST**

- ❑ Most complete form of ownership
- ❑ Unencumbered by any other interest or estate
- ❑ Only subject to limitations imposed by the government

  (taxation, eminent domain, police power, escheat)

## Property Rights Associated with Fee Ownership






- Ownership of a fee simple interest = ownership of the complete bundle of rights;
- Each right represents a partial interest in the whole

# BUNDLE OF RIGHTS

- Real property ownership includes a bundle of rights – each with a value:
- right to sell/lease/mortgage an interest
- right to occupy the property
- right to convey
- right to do nothing at all
- unlike mineral rights, Texas is UNDECIDED as to **"wind rights"** – can they be <u>conveyed</u>? can they be <u>retained?</u>

Market forces create value; same market forces have a bearing on the

# HIGHEST AND BEST USE OF LAND

HIGEST AND BEST USE MEANS THE USE OF THE PROPERTY THAT

RESULTS IN THE HIGHEST VALUE THAT IS ALSO

LEGAL; REASONABLY PROBABLE PHYSICALLY POSSIBLE

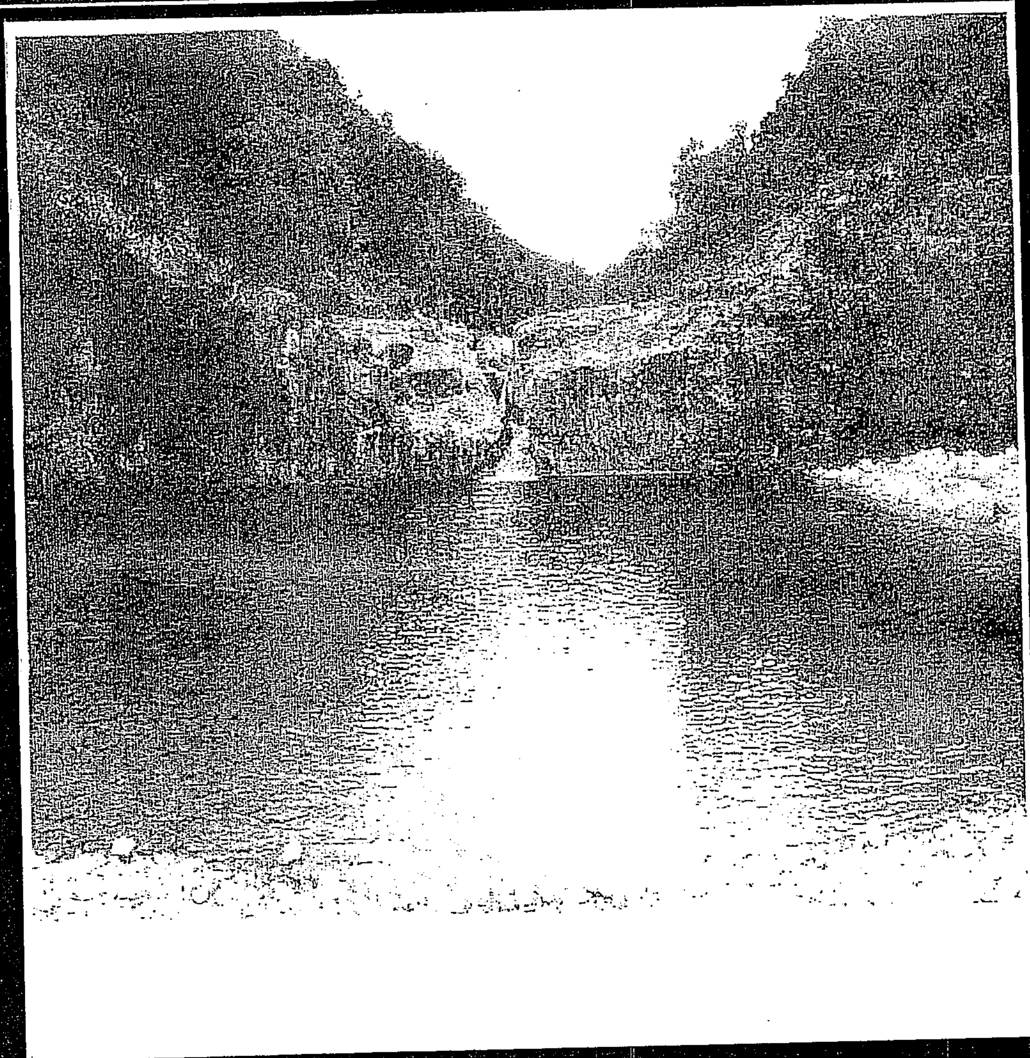
AND

FINANACIALLY FEASIBLE

HIGEST AND BEST USE IS THE FOUNDATION

UPON

**IN THE PAST 25 YEARS THE HIGHEST & BEST USE OF TEXAS RANGELAND HAS CHANGED FROM *AG RICULTURAL USE TO R ECREATIONAL USE***



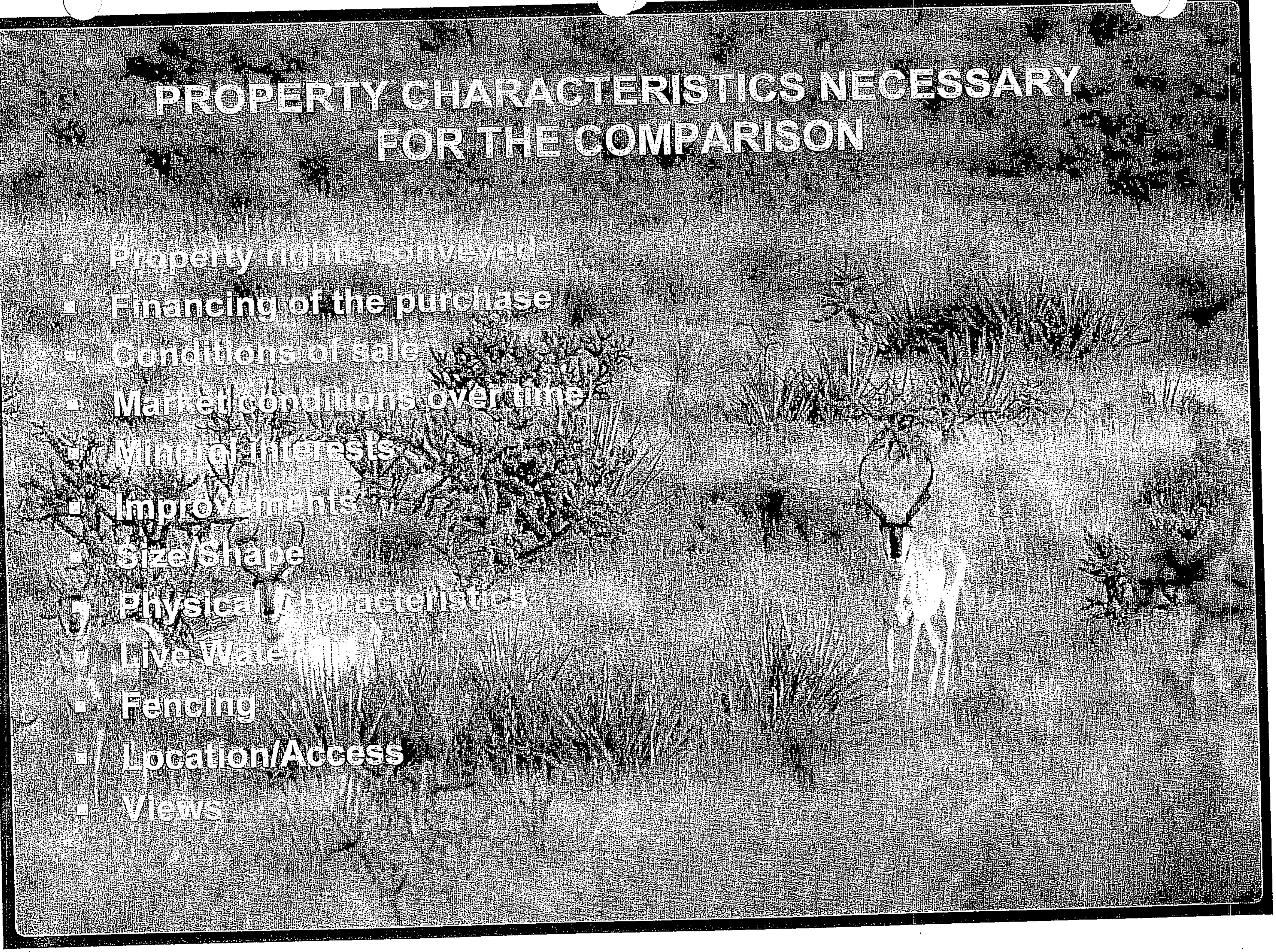
TAYLOR COUNTY **HUNTING (RECREATIONAL) LEASES BRING $12.00 TO $18.00 PER ACRE…** COMPARED TO **GRAZING LEASE S BRING $2.50 TO $3.50 PER ACRE…**

**RECREATIONAL USE INCLUDES:**

HUNTING, FISHING, CAMPING, HIKING, , ETC… WILDLIFE RESOURCES & CONSERVATION, LIVE WATER, WEEKEND PLACE, PEACE & QUIET

# DIRECT SALES COMPARISON APPROACH;
## MOST WIDELY USED AND ACCEPTED APPROACH TO VALUEING RURAL PROPERTY

- Defined as an estimate of value of recent sales of similar property in the surrounding or competing areas - as compared to the subject property


PROPERTY CHARACTERISTICS NECESSARY
FOR THE COMPARISON
Property rights conveyed
Financing of the purchase
Conditions of sale
Market conditions over time
Mineral Interests
Improvements
Size/Shape
Physical Characteristics
Live Water
Fencing
Location/Access
Views

00000337

# NOT COMPARABLE

RESIDENCE

RURAL

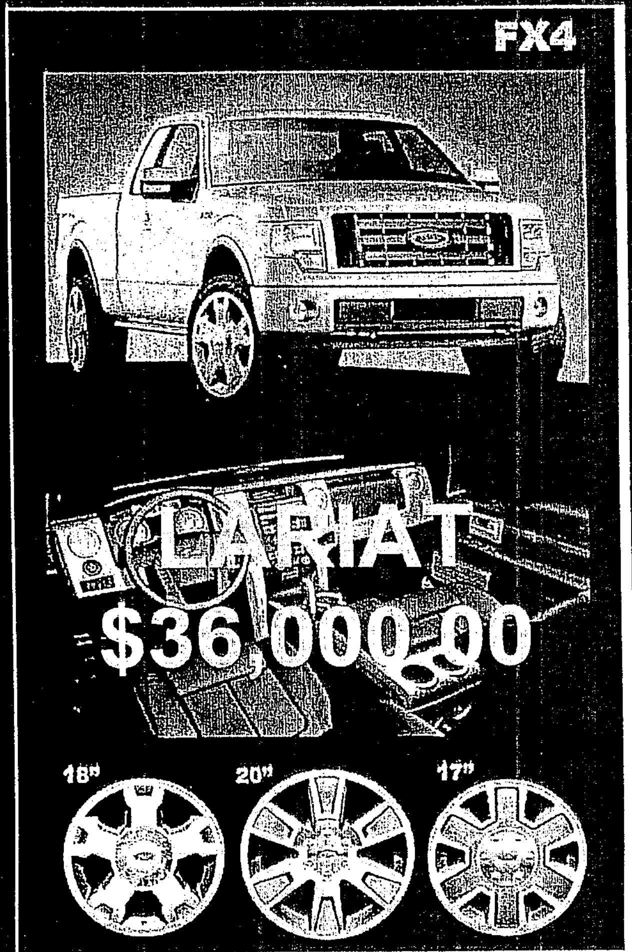
# PAIRED SALES ANALYSIS

Within the direct sales comparison approach - several techniques are used to quantify adjustments - most commonly used technique is that of *paired sales*:

When two properties are in all other respects equal, a single difference can be measured to determine the difference in price between the two.

TWO TRUCKS – **BOTH** FORDS; **BOTH** F-150; **BOTH** FOUR WHEEL DRIVE; **BOTH** 2009 MODELS – ***ONE DIFFERENCE***

**LARIET PCKGE VS KING RANCH PCKGE**





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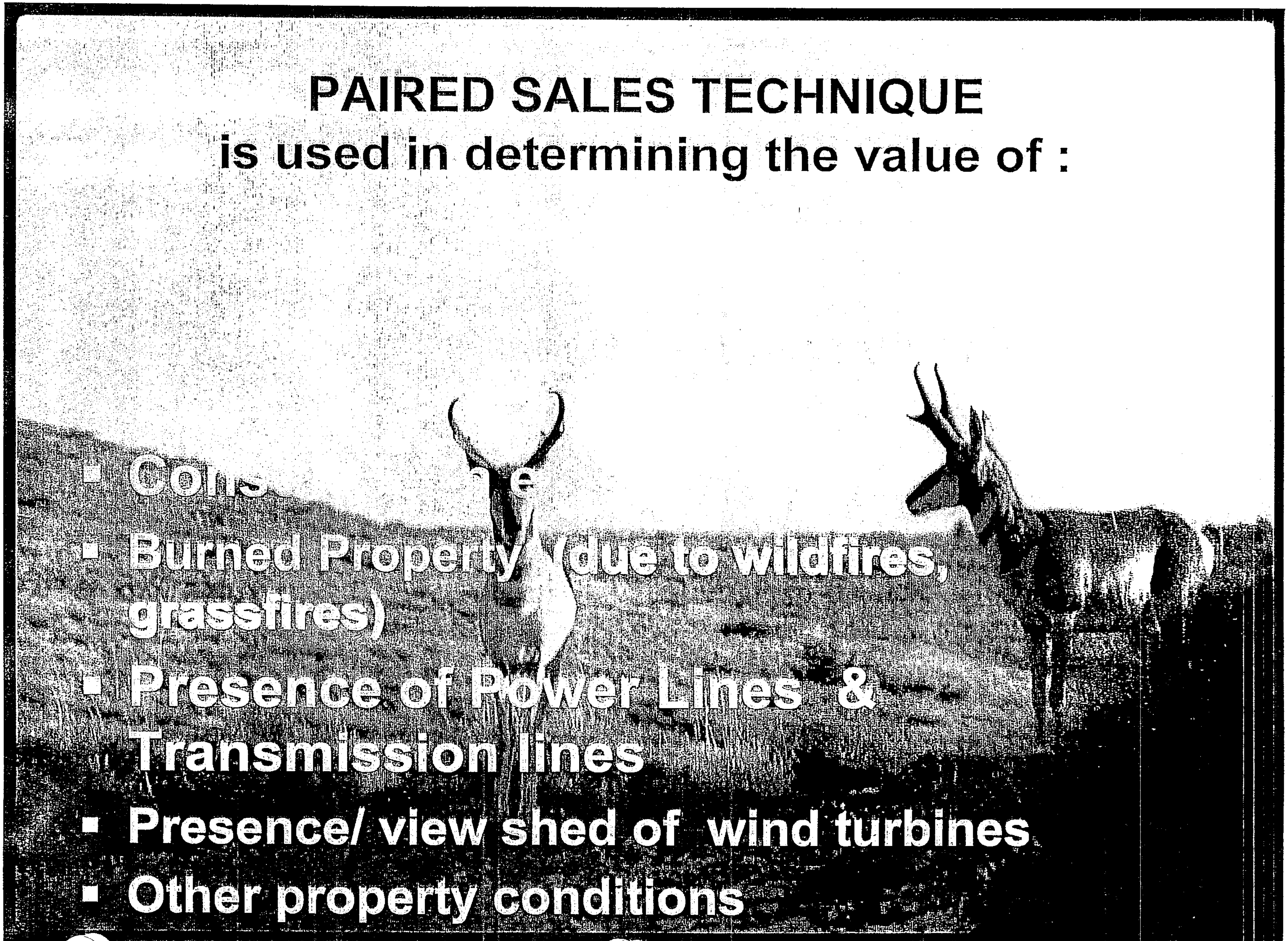
**COMPARING THESE TWO TRUCKS UNDER PAIRED SALES TECHNIQUE:**

KING RANCH PCKGE

CONTRIBUTES $9,000 IN VALUE

OVER THE LARIAT PCKGE


PAIRED SALES TECHNIQUE
is used in determining the value of :
Cons e
Burned Property (due to wildfires, grassfires)
Presence of Power Lines & Transmission lines
Presence/ view shed of wind turbines
Other property conditions

00000942

# WHAT WE KNOW ABOUT WIND TURBINES
## common sense stuff

- Up to 600' feet tall
- constant noise
- shadow/flicker
- view shed effect -

  turbines tower over horizon , changing the view
- construction ; transmission lines ; substations
- turbines forever change the aesthetics; a more industrial feeling
- loss of native wildlife habitat

# Renewable Energy Policy Project (REPP)
# May, 2003

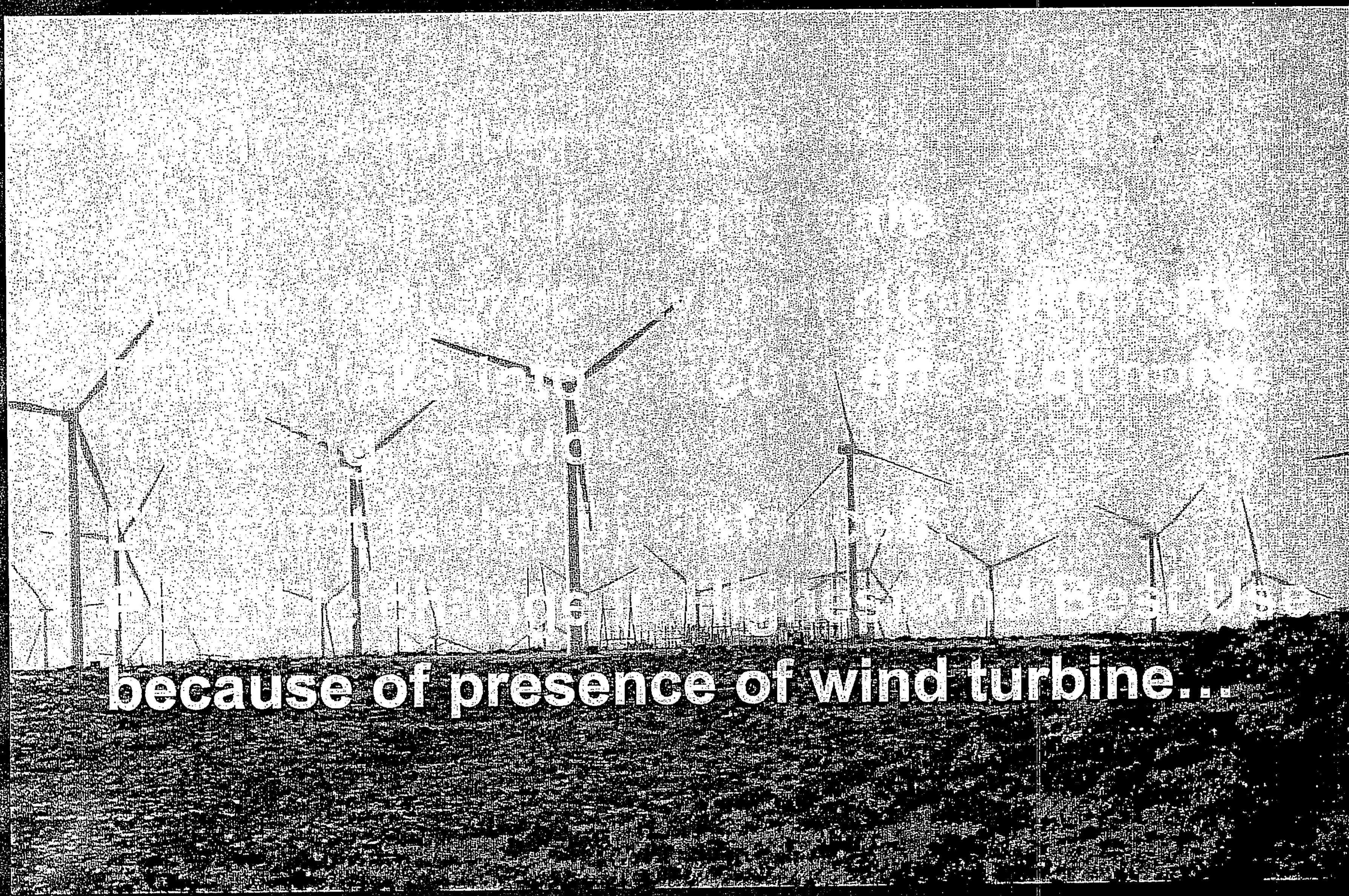
**Findings:**

wind turbines will not diminish Property Values, but will enhance Property Values

**Flaws:**

1. funded by proponents of wind power built in bias in conclusions...
2. methodology used lacks necessary variables for analysis...

# VARIABLES NOT USED IN REPP



# Appraisal Research Shows:

- A **VIEW adds value** to rural property
- Take view away – added value goes away
- Brokers in rural areas confirm that property values in areas of wind facilities are **10% - 30% less** than property not in areas of wind facilities.
- Wind energy development creates an income stream, increasing property's production value; increased production value does not necessarily result in increased market value

# Case Study One - 2007

- **350 acres in Erath County** – top end ranch purchased for retirement homestead….
- **27 wind turbines** within 1 ½ mile radius
- For sale for $2,100,000.00
- Prospective buyer agreed to sales price
- **Disclosure of wind turbine** project to buyer
- Buyer **backed out of offer**
- Seller agreed to 25% discount to Buyer
- Buyer **declined discounted offer**
- Currently little interest in property in spite of other characteristics of property

# Case Study Two - 2007

- Using paired sales analysis - Sales of Seven large tracts of rural land with **varying proximity to wind turbines** in Taylor County, Texas….
- Sales 1, 2, and 3 compared to Sales 4-7
- Sales occurred between 3-06 & 8-07
- No time adjustment
- Contributory value of improvements deducted from each sale
- All other characteristics considered similar

# Wind turbine on the property

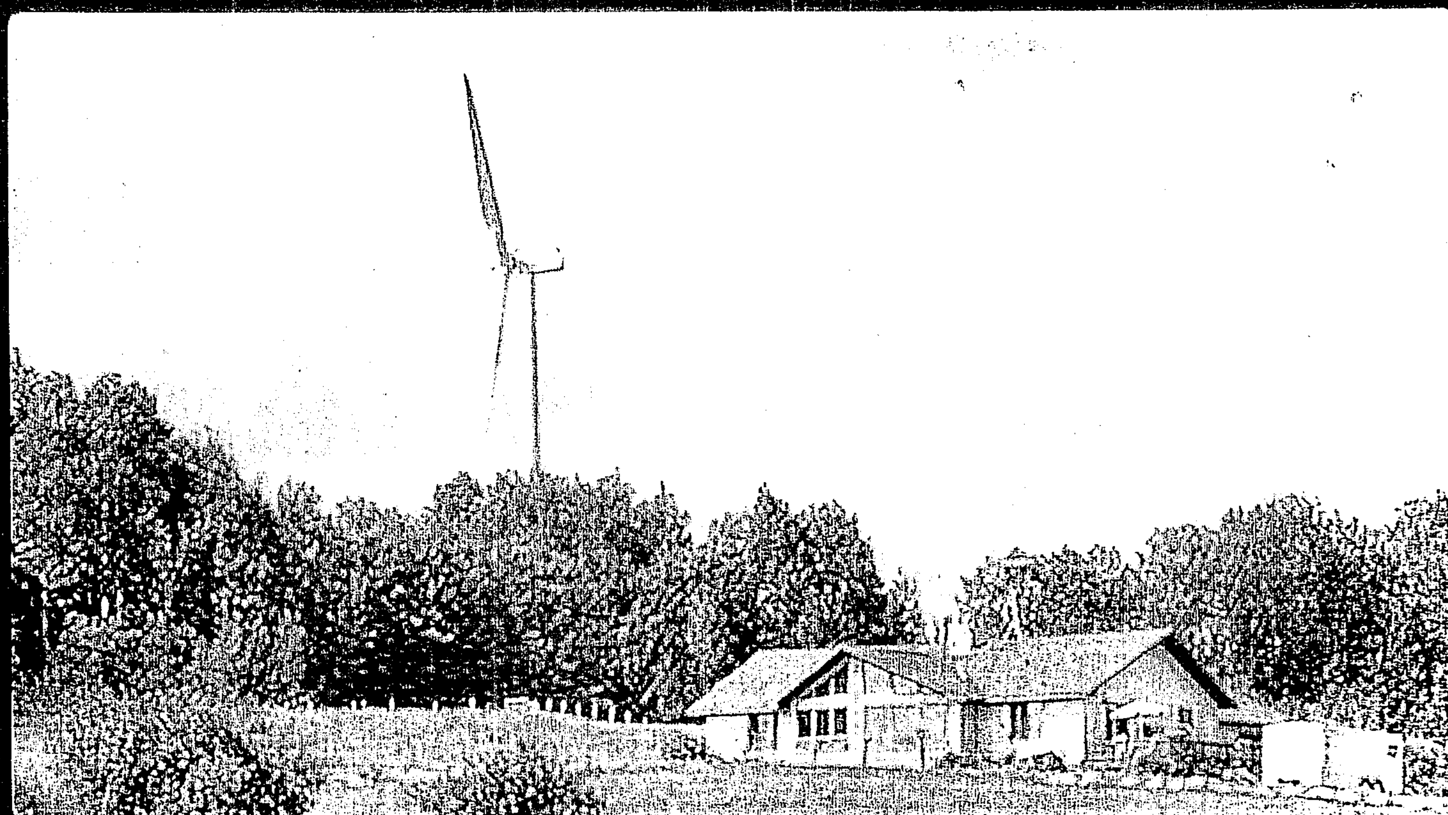
| Sale Number | Wind Turbine Presence (western Taylor County; 1700+ acres; 3 wind turbines on property; seller reserved "wind | Price/Acre | Diminutio n Value |
|---|---|---|---|
| One | Turbines on property | $850.00 | |
| Four | No wind turbines in visual | $1,290.00 | 34% |
| Five | No wind turbines in visual | $1,536.00 | 45% |
| Six | No wind turbines in visual | $1,200.00 | 29% |
| Seven | No wind turbines in visual | $1,416.00 | 40% |

# TURBINES ON PROPERTY

Diminution in value

29%-45%

37% average



# Wind turbine within .2 - .4 miles

| Sale Number | Wind Turbine Presence (1,110+ acres ; Taylor County; 2 wind turbines in within .2 & .4 miles | Price/Acre | Diminution Value |
|---|---|---|---|
| Two | Turbines within .2 - .4 miles | $1,000.00 | |
| Four | No wind turbines in visual | $1,290.00 | 22% |
| Five | No wind turbines in visual | $1,536.00 | 35% |
| Six | No wind turbines in visual | $1,200.00 | 17% |
| Seven | No wind turbines in visual | $1,416.00 | 29% |

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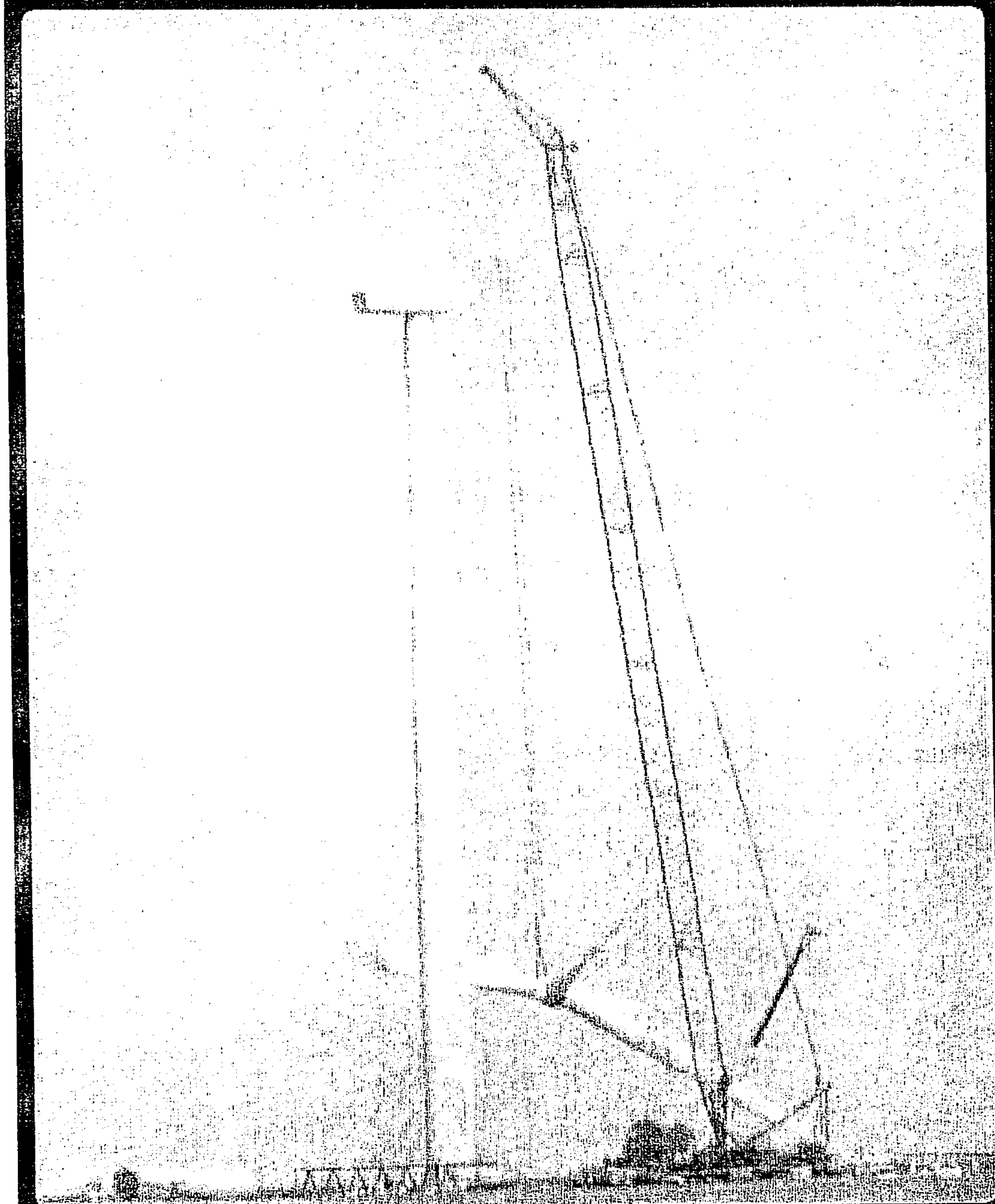


# TURBINES WITHIN .2 - .4 MILES

Diminution in value is 17%- 35%

26% Average

# Wind turbine within 1.8 miles

| Sale Number | Wind Turbine Presence (550+ acres in Taylor County, 1 turbine 1.8 miles away) | Price/Acre | Diminution Value |
|---|---|---|---|
| Three | Turbines within 1.8 miles | $1,016.00 | |
| Four | No wind turbines in visual range | $1,290.00 | 21% |
| Five | No wind turbines in visual range | $1,536.00 | 34% |
| Six | No wind turbines in visual range | $1,200.00 | 15% |
| Seven | No wind turbines in visual range | $1,416.00 | 28% |

# TURBINES WITHIN 1.8 MILES

Diminution in value is 15%- 34%

25% Average

# Diminution in Value Summary

Turbines on property

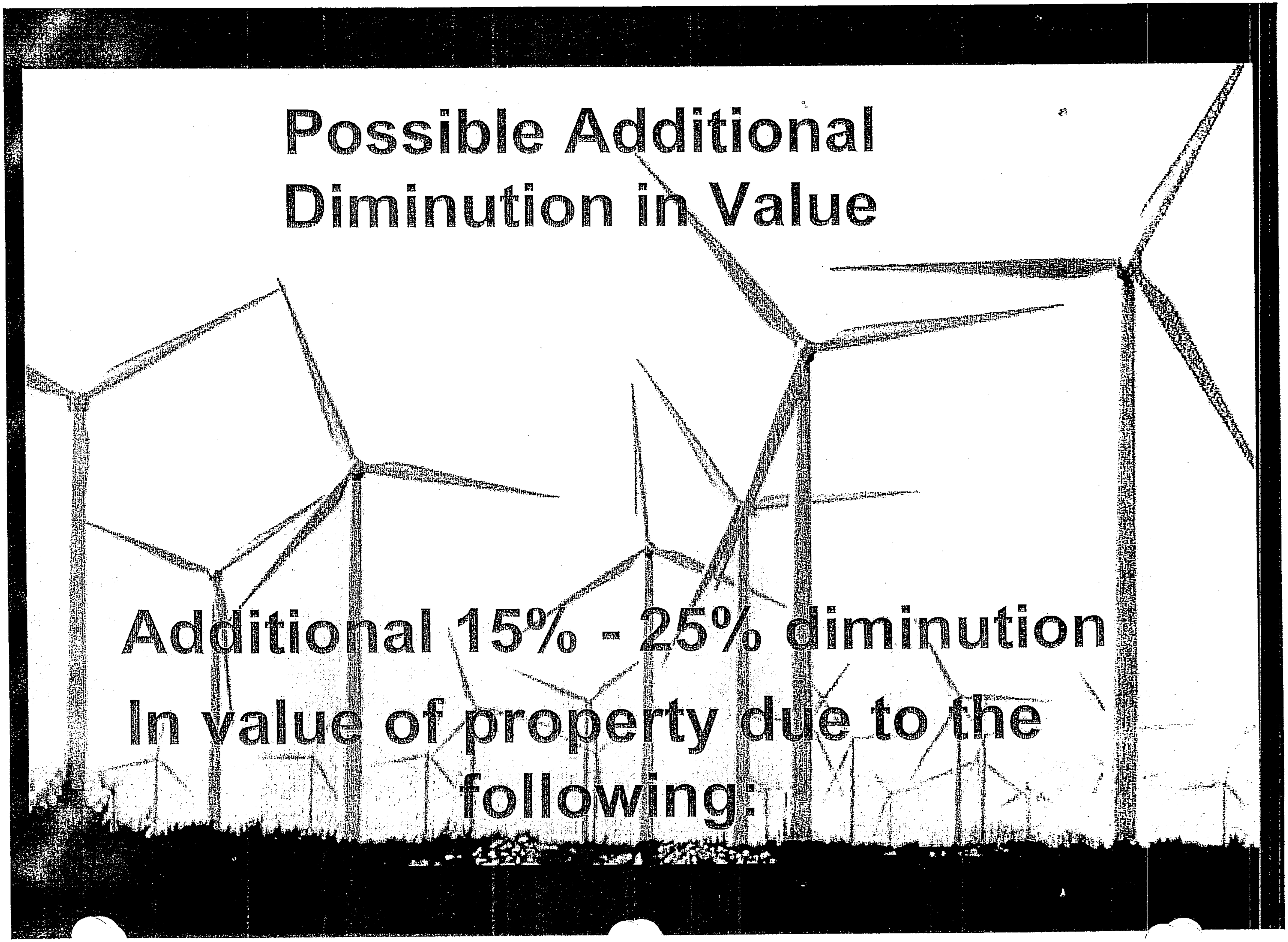
Average 37%

Turbines within .2 -.4 miles

Average 26%

Turbines within 1.8 miles

Average 25%


Possible Additional
Diminution in Value
Additional 15% - 25% diminution
In value of property due to the
following: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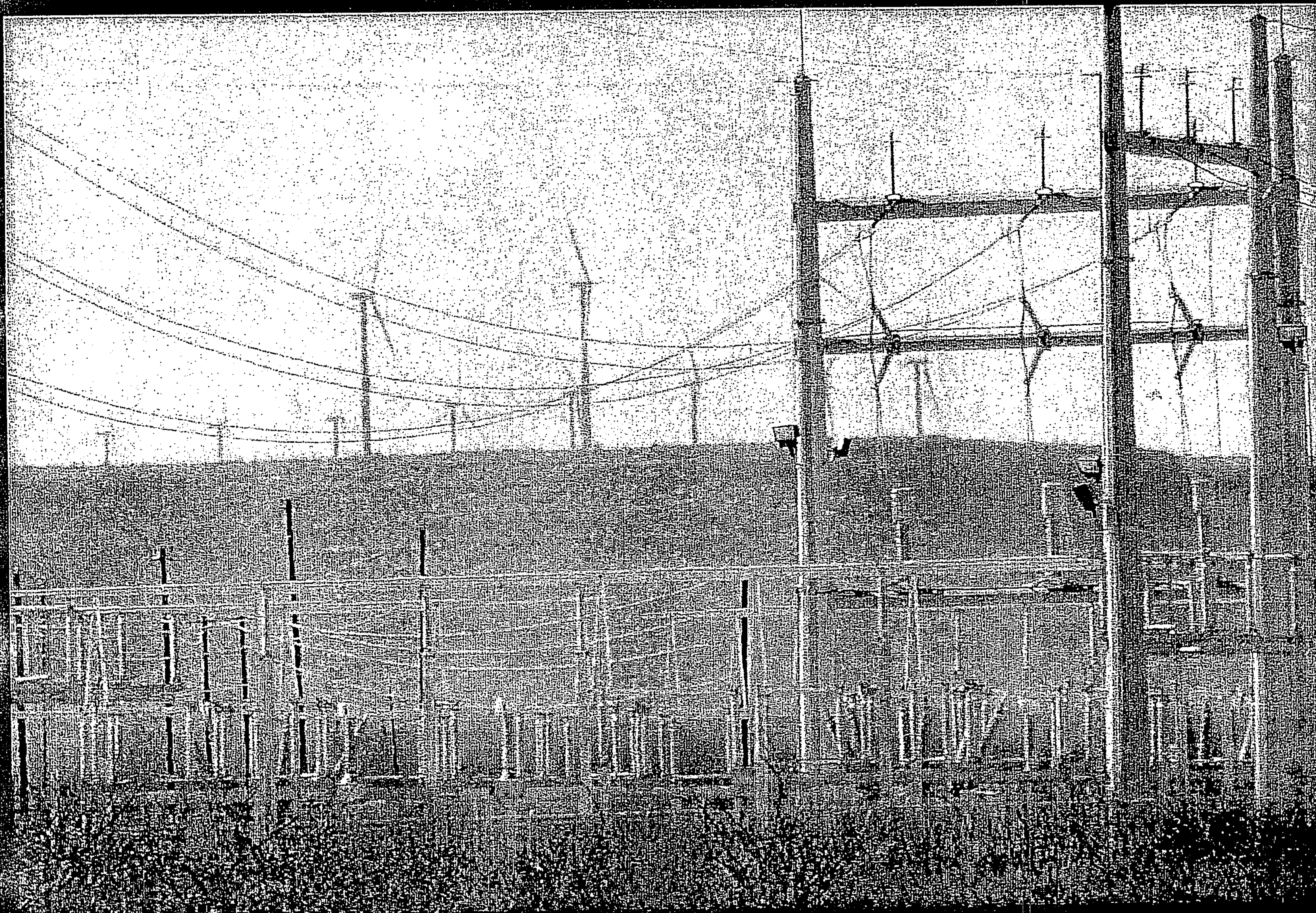
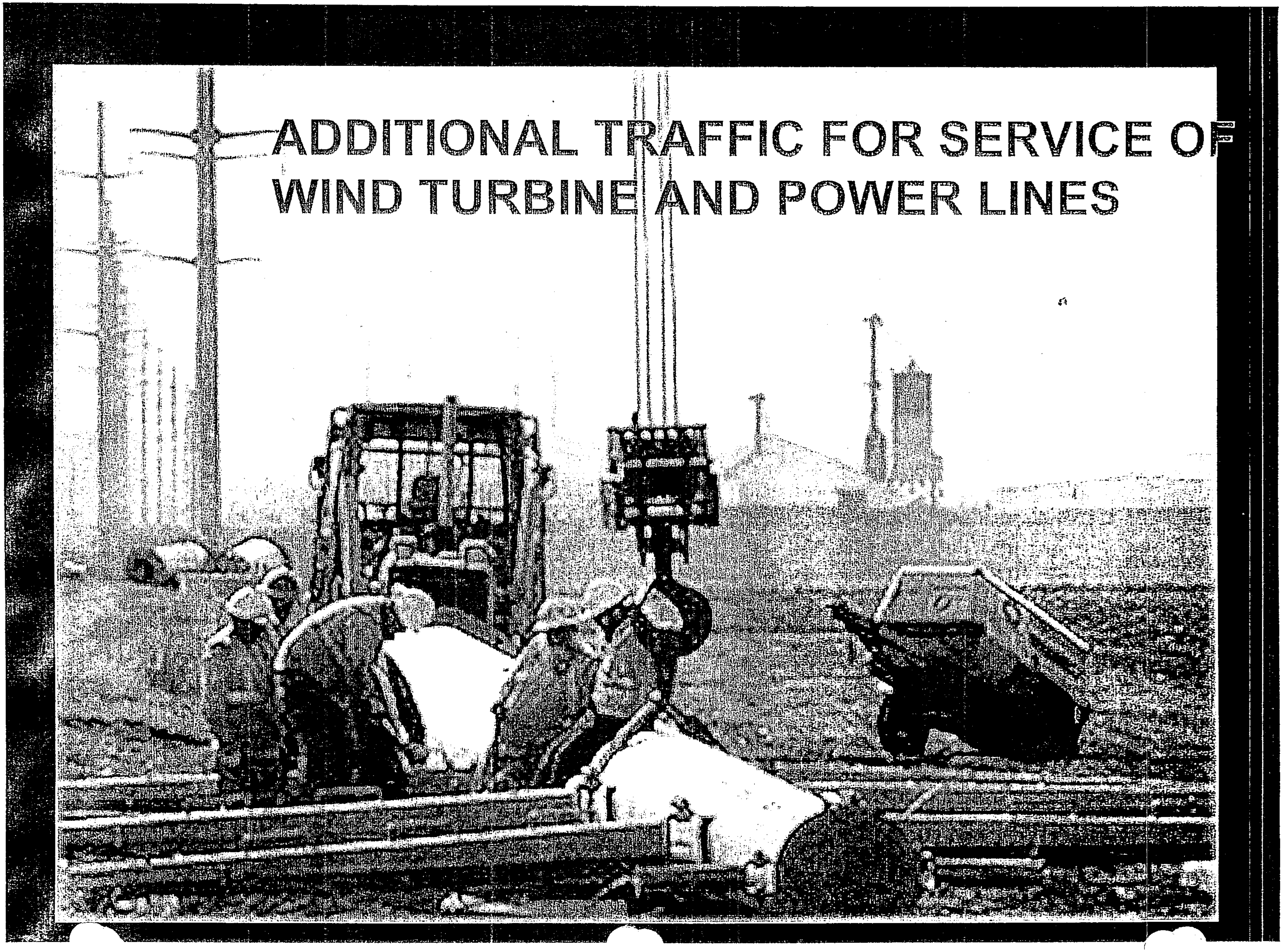
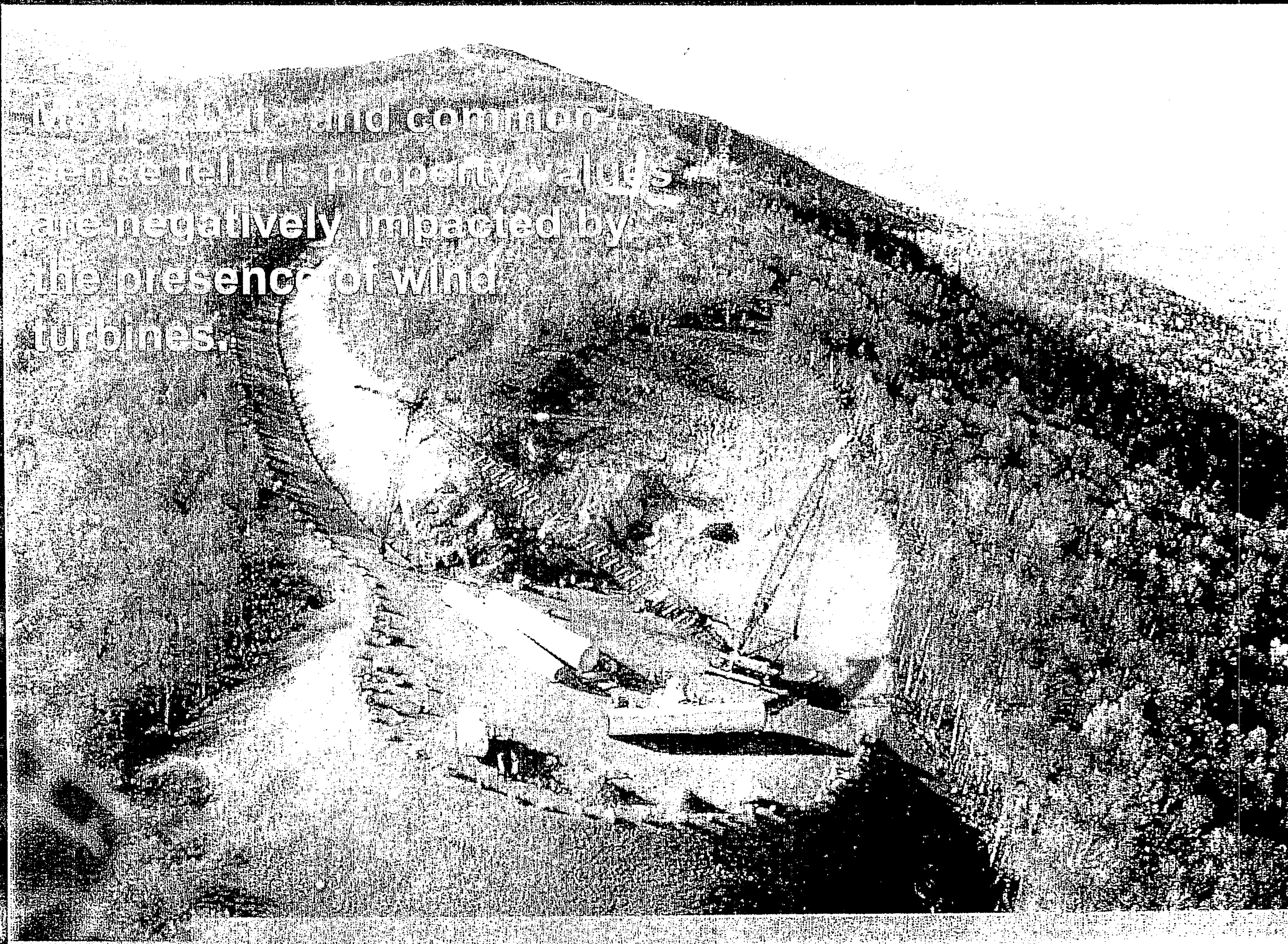
MISSION LINES

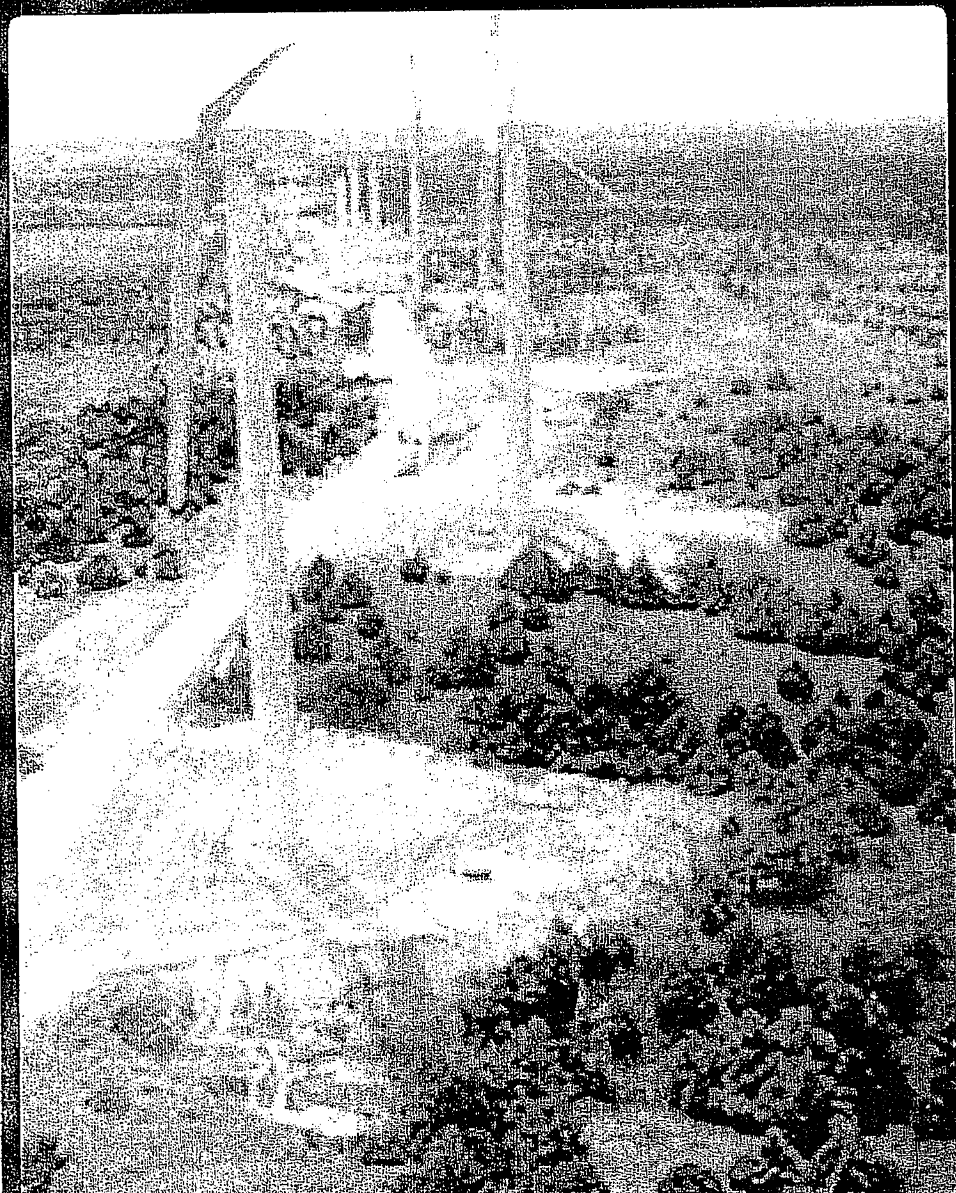
# SUBSTATIONS




ADDITIONAL TRAFFIC FOR SERVICE OF
WIND TURBINE AND POWER LINES

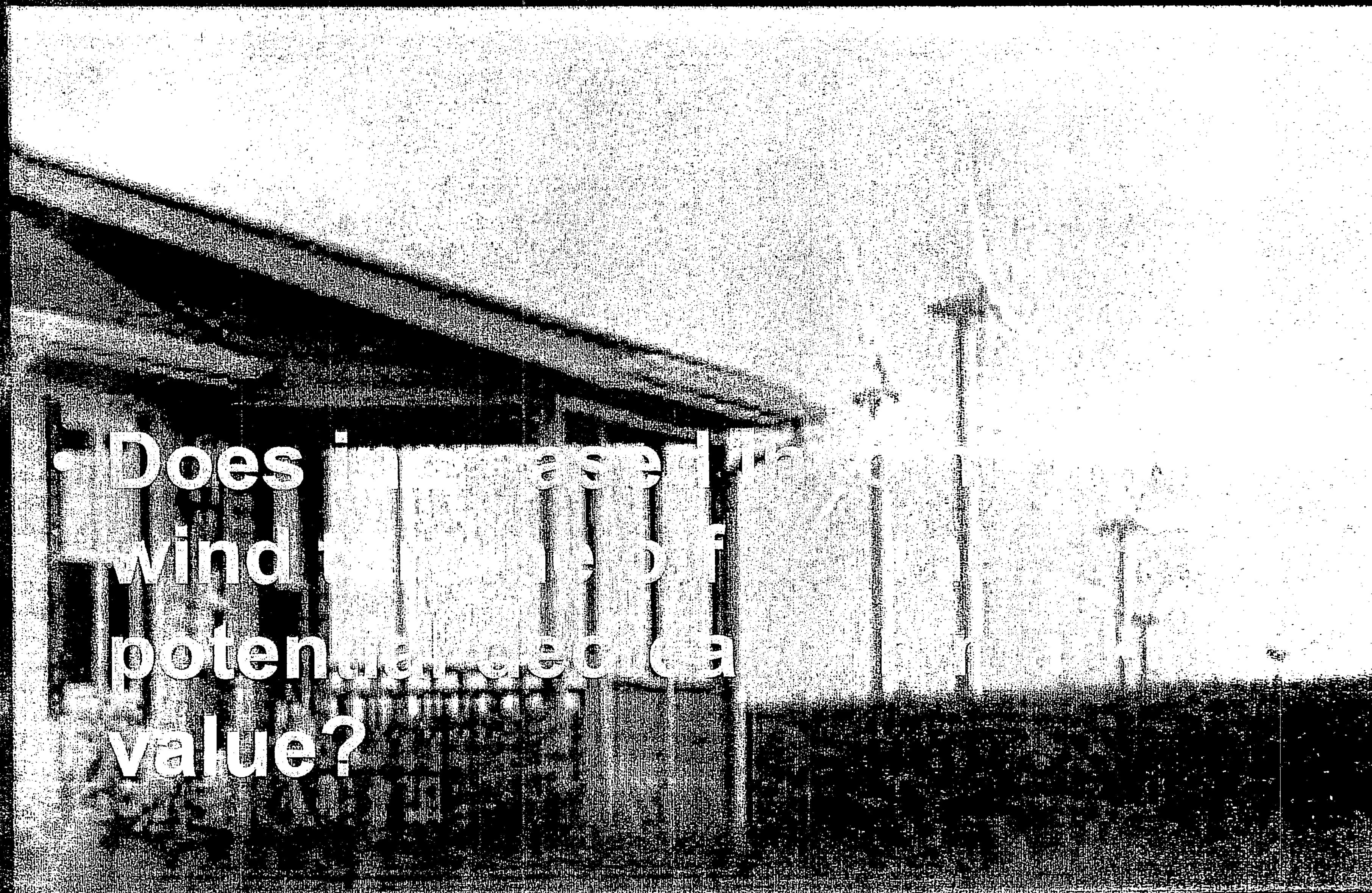
# ADDITIONAL ROADS


and common-
sense tell us property values
are negatively impacted by
the presence of wind
turbines.

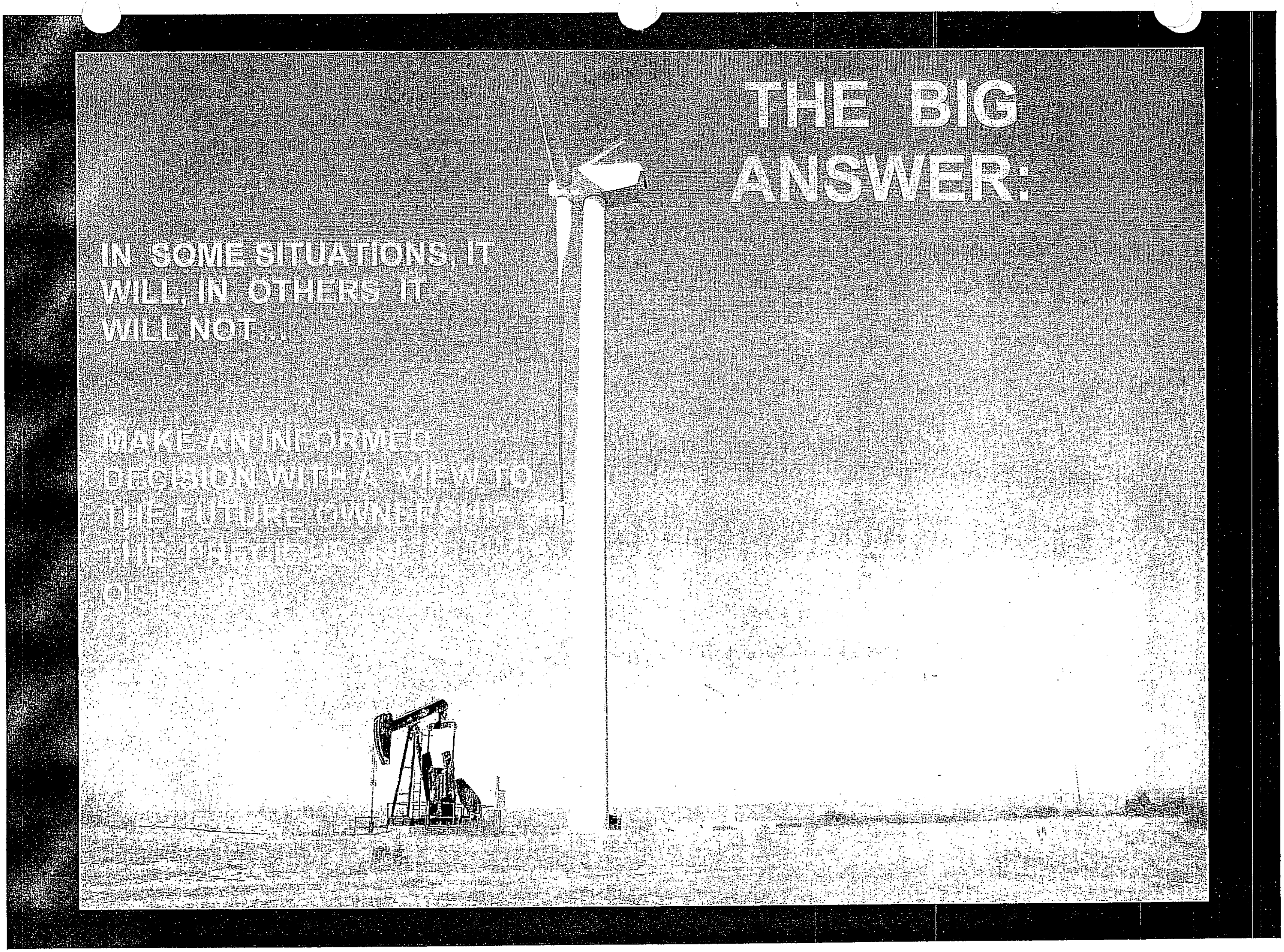


Consider & weigh impact on your property's overall value when leasing for wind turbines…

# THE BIG QUESTION



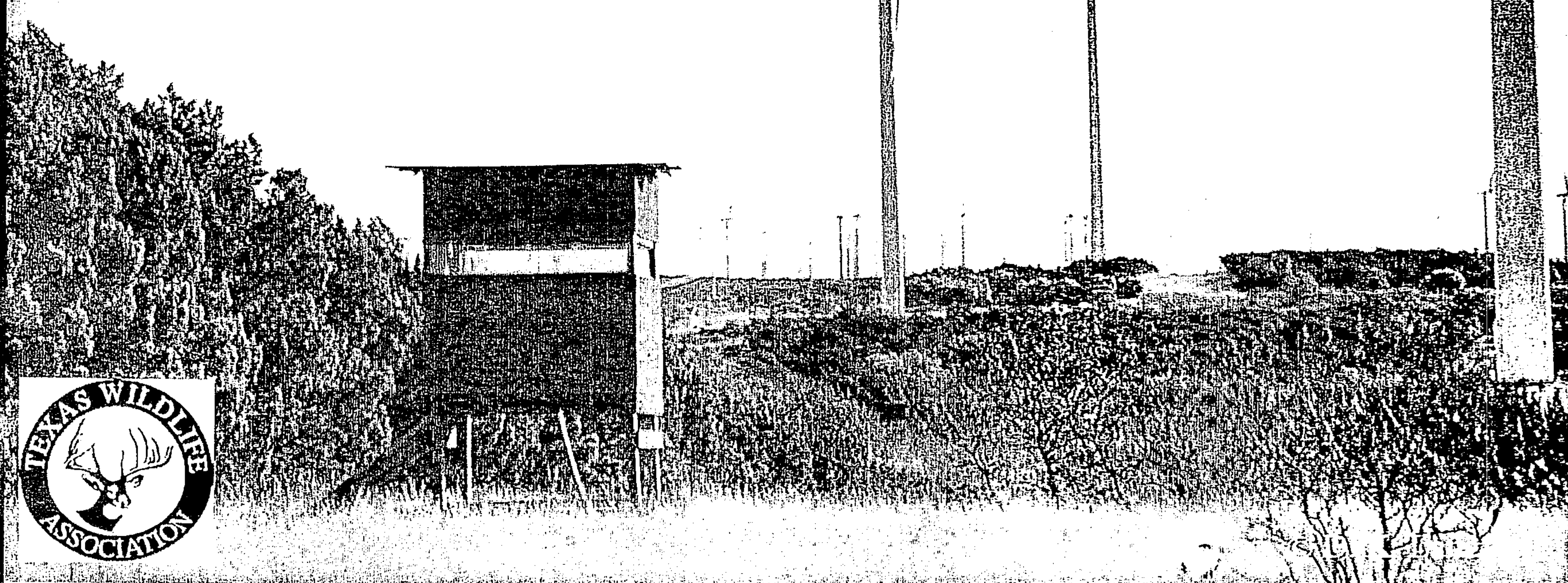
- Does [illegible] wind [illegible] potential [illegible] value?


THE BIG
ANSWER:
IN SOME SITUATIONS, IT
WILL, IN OTHERS IT
WILL NOT...
MAKE AN INFORMED
DECISION WITH A VIEW TO
THE FUTURE

00000365

# Studies Developed by:

- Gardner Appraisal Group, Inc.
- Austin Valuation Consultants
- Various real estate appraisers and brokers



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# The Impact of Wind Power Projects on Residential Property Values in the United States: A Multi-Site Hedonic Analysis

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Mark Thayer, and Gautam Sethi

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December 2009 (revision #1)

*This analysis was funded by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Wind & Hydropower Technologies Program*

# The Impact of Wind Power Projects on Residential Property Values in the U.S.

- Motivation and Study Methods
  - Motivation
  - Overview and Methods
  - Data Summary
- Summary of Analysis Results
- Conclusions and Further Research

00000969

# Proximity to and Views of Environmental (Dis)Amenities Can Impact Property Values

| Highway | Transmission Lines | Average Home | Green Space | Ocean Front |
|---|---|---|---|---|
| ↓$ | ↓ $ |  | ↑$ | ↑$ |



This linkage is well studied generally, but not for wind power facilities

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# Aesthetics and Property Values Rank as Key Concerns for Wind Stakeholders

"Aesthetic perceptions, both positive and negative, are the strongest single influence on individuals' attitudes towards wind power projects." (Warren, 2005, p. 853)

US developers rank aesthetics & property values as the #1 and #3 concerns of those in opposition to wind development (Paul, 2006)

100% and 85% of those opposed to offshore wind development believe aesthetics and property values, respectively, will be adversely impacted (Firestone et. al., 2007 )

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Having structures on the Vermont hilltops was considered a "big disadvantage" by the majority of those surveyed before the Searsburg, VT wind facility was erected (Palmer, 1997)

# Property Value Concerns for Wind Energy Fall Into Three Potential Categories

1. **Area Stigma:** Concern that rural areas will appear more developed

   No one will move here!

2. **Scenic Vista Stigma:** Concern over decrease in quality of scenic vistas from homes

   It will ruin my view!

3. **Nuisance Stigma:** Concern that factors that occur in close proximity will have unique impacts

   I won't be able to live in my home!

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Each of these effects could impact property values; none are mutually exclusive

# Relatively Few Existing Wind and Property Studies: A List of the Most Publicized

- **Variety of methods used**, from surveys to sales analyses, with varying levels of sophistication

- **Results are diverse**, and in many instances unpersuasive due to limitations in data and methodology

| Document Type Author(s) | Year | Number of Transactions or Respondents | Before or After Wind Facility Construction Commenced | Area Stigma | Scenic Vista Stigma | Nuisance Stigma |
|---|---|---|---|---|---|---|
| **Homeowner Survey** | | | | | | |
| Haughton et al. | 2004 | 501 | Before | - * | - * | |
| Goldman | 2006 | 50 | After | none | | |
| Firestone et al. | 2007 | 504 | Before | - * | - * | |
| Bond | 2008 | ~300 | After | | - ? | - ? |
| **Expert Survey** | | | | | | |
| Grover | 2002 | 13 | After | none | | none |
| Haughton et al. | 2004 | 45 | Before | - * | - * | |
| Khatri | 2004 | 405 | Before‡ | - ? | | - ? |
| Goldman | 2006 | 50 | After | none | | none |
| Kielisch | 2009 | 57 | Before‡ | | | - ? |
| **Transaction Analysis - Simple Statistics** | | | | | | |
| Jerabek | 2001 | 25 | After | | | none |
| Jerabek | 2002 | 7 | After | | | none |
| Sterzinger et al. | 2003 | 24,000 | After | none | | |
| Beck | 2004 | 2 | After | | | none |
| Poletti | 2005 | 187 | After | none | | none |
| DeLacy | 2005 | 21 | Before† | none | | |
| Goldman | 2006 | 4 | After | none | | |
| Poletti | 2007 | 256 | After | none | | none |
| McCann | 2008 | 2 | After | | | - ? |
| Kielisch | 2009 | 103 | After | | | - ? |
| **Transaction Analysis - Hedonic Model** | | | | | | |
| Jordal-Jorgensen | 1996 | ? | After | | | - ? |
| Hoen | 2006 | 280 | After | | none | |
| Sims & Dent | 2007 | 919 | After | | | - * |
| Sims et al. | 2008 | 199 | After | | -/+ * | |

*"none" indicates the majority of the respondents do not believe properties have been affected (for surveys) or that no effect was detected at 10% significance level (for transaction analysis)*

*"- ?" indicates a negative effect without statistical significance provided*

*"- *" indicates statistically significant negative effect at 10% significance level*

*"-/+ *" indicates positive and negative statistically significant effects at 10% significance level*

*† Sales were collected after facility announcement but before construction*

*‡ Some respondents had experience with valuations near facilities while others did not*

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# Limitations of Existing Research

- **Many studies have relied on surveys** of homeowners or real estate professionals, rather than quantifying real impacts based on market data
- **Most studies have relied on simple statistical techniques** that have limitations and that can be dramatically influenced by small numbers of sales transactions or survey respondents
- **Most studies have used small datasets** that are concentrated in only one wind project study area, making it difficult to extrapolate findings
- **Many studies have not reported the statistical significance** of their results, making it difficult to determine if those results are meaningful
- **Many studies have concentrated on Area Stigma**, and have ignored Scenic Vista and/or Nuisance Stigma
- **Only a few studies have included field visits** to homes to determine wind turbine visibility and collect other important information
- **Only two studies have been published** in peer-reviewed journals

# The Impact of Wind Power Projects on Residential Property Values in the U.S.

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00000975

# Be◌keley Lab Project Involves Most Da◌a-Rich and Comprehensive Analysis To Date

## Research Questions

1) Is there evidence that views of turbines measurably affect sales prices?
2) Is there evidence that proximity to turbines measurably affect sales prices?
3) Do the results change over time, and are there other observable impacts?

## Relevance

Provides stakeholders in siting/permitting processes greater confidence in the likely effects of proposed wind energy facilities, allowing greater consensus on often-contentious setback requirements and viewshed valuations

## Team

B. Hoen (Subcontractor to LBNL), R. Wiser (LBNL), P. Cappers (LBNL), M. Thayer (San Diego State University), G. Sethi (Bard College)

## Funder

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Wind & Hydropower Technologies Program

# Research Approach Responds to Limitations of Previous Work

- **Conduct literature review** of previous wind / property value studies and wind facility public acceptance surveys, as well as potentially analogous studies on other disamenities (e.g. roads, power lines, power plants)
- **Collect large amount of data** on residential sales transactions occurring both pre- and post-construction surrounding a **representative sample** of wind facilities at **multiple locations** in the U.S.
- **Visit each home** to determine wind turbine visibility and to collect other important information about the home (e.g., the quality of the scenic vista)
- **Use multiple statistical models** to explore magnitude and statistical significance of potential effects, relying primarily on **hedonic model**
- **Test for the presence of all three stigmas** – Area Stigma, Scenic Vista Stigma, and Nuisance Stigma
- **Rigorously analyze** the data, culminating in an LBNL report and at least one journal paper

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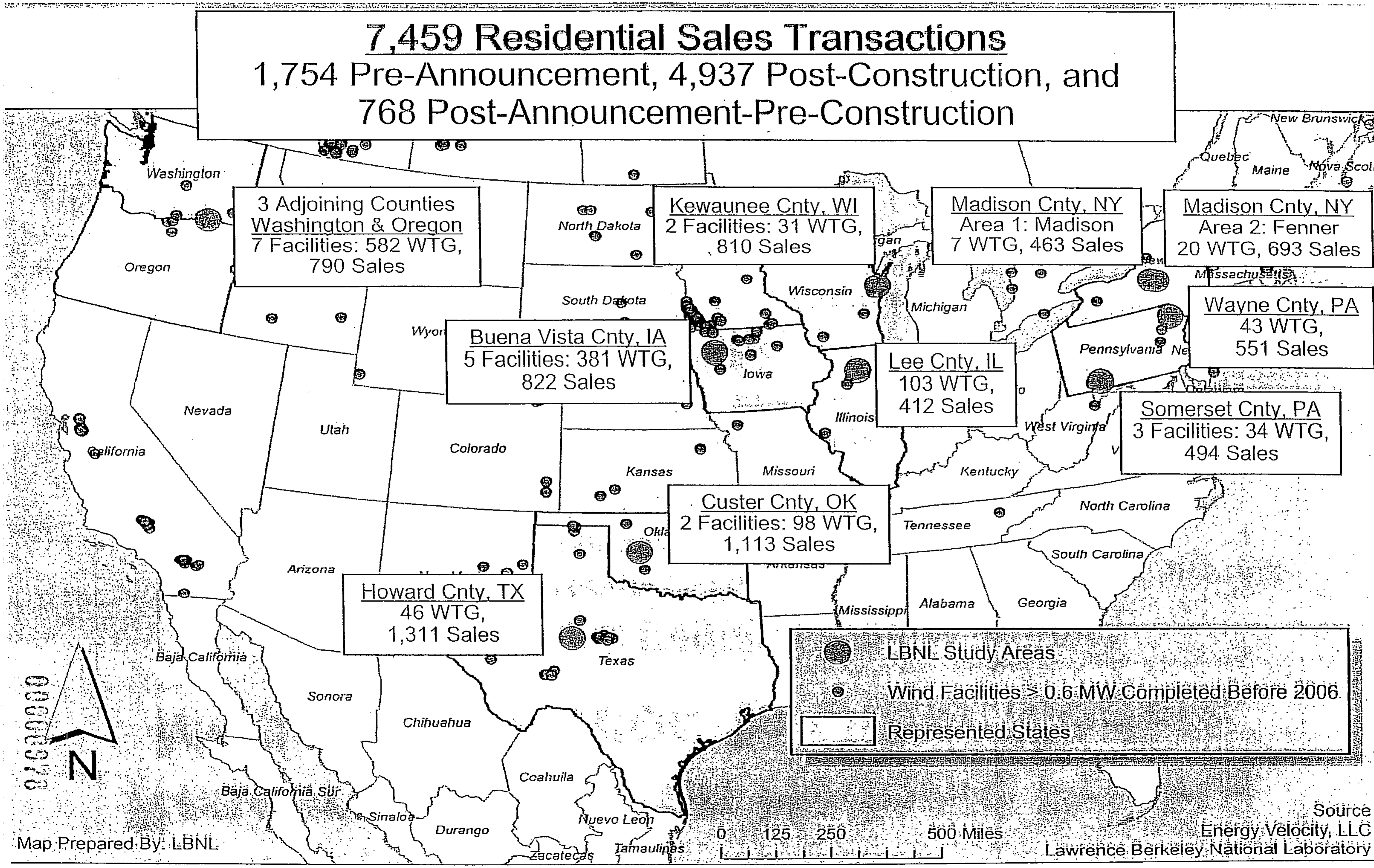
# Collected Sales Data from 10 Study Areas Surrounding 24 Wind Facilities in 9 States

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# Research Relies on Hedonic Pricing Model in Addition to Other Models

| | Coef. | SE | p Value | n |
|---|---|---|---|---|
| Intercept | 7.62 | 0.18 | 0.00 | |
| Nbr LN SalePrice96 hat | 0.29 | 0.02 | 0.00 | 4,937 |
| AgeatSale | -0.006 | 0.0004 | 0.00 | 4,937 |
| AgeatSale Sqrd | 0.00002 | 0.000003 | 0.00 | 4,937 |
| Sqft 1000 | 0.28 | 0.01 | 0.00 | 4,937 |
| Acres | 0.02 | 0.00 | 0.00 | 4,937 |
| Baths | 0.09 | 0.01 | 0.00 | 4,937 |
| ExtWalls Stone | 0.21 | 0.02 | 0.00 | 1,486 |
| CentralAC | 0.09 | 0.01 | 0.00 | 2,575 |
| Fireplace | 0.11 | 0.01 | 0.00 | 1,834 |
| FinBsmt | 0.08 | 0.02 | 0.00 | 673 |
| Cul De Sac | 0.10 | 0.01 | 0.00 | 992 |
| Water Front | 0.33 | 0.04 | 0.00 | 87 |
| Cnd Low | -0.45 | 0.05 | 0.00 | 69 |
| Cnd BAvg | -0.24 | 0.02 | 0.00 | 350 |
| Cnd Avg | Omitted | Omitted | Omitted | 2,727 |
| Cnd AAvg | 0.14 | 0.01 | 0.00 | 1,445 |
| Cnd High | 0.23 | 0.02 | 0.00 | 337 |
| Vista Poor | -0.21 | 0.02 | 0.00 | 310 |
| Vista BAvg | -0.08 | 0.01 | 0.00 | 2,857 |
| Vista Avg | Omitted | Omitted | Omitted | 1,247 |
| Vista AAvg | 0.10 | 0.02 | 0.00 | 448 |
| Vista Prem | 0.13 | 0.04 | 0.00 | 75 |
| WAOR | Omitted | Omitted | Omitted | 519 |
| TXHC | -0.75 | 0.03 | 0.00 | 1,071 |
| OKCC | -0.44 | 0.02 | 0.00 | 476 |
| IABV | -0.24 | 0.02 | 0.00 | 605 |
| ILLC | -0.09 | 0.03 | 0.00 | 213 |
| WIKCDC | -0.14 | 0.02 | 0.00 | 725 |
| PASC | -0.31 | 0.03 | 0.00 | 291 |
| PAWC | -0.07 | 0.03 | 0.01 | 222 |
| NYMCOC | -0.20 | 0.03 | 0.00 | 346 |
| NYMC | -0.15 | 0.02 | 0.00 | 469 |
| Post Con NoView | Omitted | Omitted | Omitted | 4,207 |
| View Minor | -0.01 | 0.01 | 0.40 | 561 |
| View Mod | 0.02 | 0.03 | 0.58 | 106 |
| View Sub | -0.01 | 0.07 | 0.94 | 35 |
| View Extrm | 0.02 | 0.09 | 0.80 | 28 |
| Mile Less 0 57 | -0.05 | 0.06 | 0.40 | 67 |
| Mile 0 57to1 | -0.05 | 0.05 | 0.30 | 58 |
| Mile 1to3 | 0.00 | 0.02 | 0.80 | 2,019 |
| Mile 3to5 | 0.02 | 0.01 | 0.23 | 1,923 |
| Mile Gtr5 | Omitted | Omitted | Omitted | 870 |

*"Omitted" = reference category for fixed effects variables*
*"n" indicates number of cases in category when category = "1"*

Model Information

| | |
|---|---|
| Model Equation Number | 1 |
| Dependent Variable | LN SalePrice96 |
| Number of Cases | 4937 |
| Number of Predictors (k) | 37 |
| F Statistic | 442.8 |
| Adjusted R Squared | 0.77 |

## What Is a Hedonic Pricing Model?

- **Well respected model** used by economists and real estate practitioners for over 40 years
- **Heterogeneous** residential sales data are used
- **Measures marginal price differences** between homes that vary by the variables of interest, after controlling for other characteristics
- **Controlling characteristics** include square feet, acres, bathrooms, fireplaces, age, condition and scenic vista of the home, location, etc.
- **Variables of interest** include view of turbines, distance from turbines, and development period (e.g. before or after construction began)
- **Results <u>and</u> significance levels** are important

## Other Models Used in Analysis

Repeat Sales and Sales Volume Models

# To Test for Scenic Vista Stigma, Scenic Vista Itself Is Controlled For

They might pull in two directions...

↑ $

By separating out scenic vista,
a potential bias is removed from
measurements of the effects of
the view of wind turbines

↓ $

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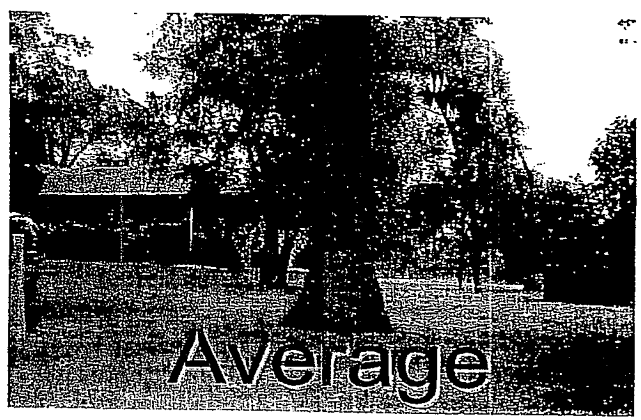
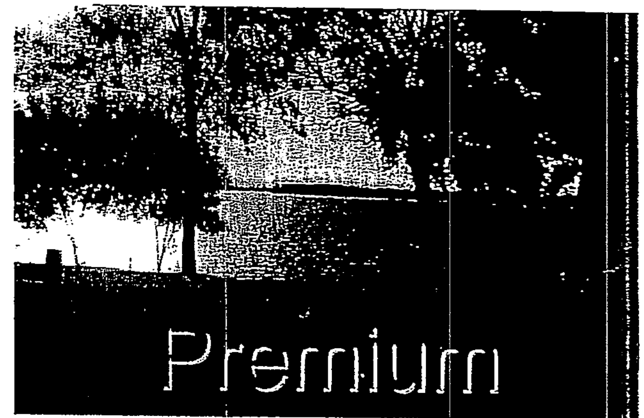
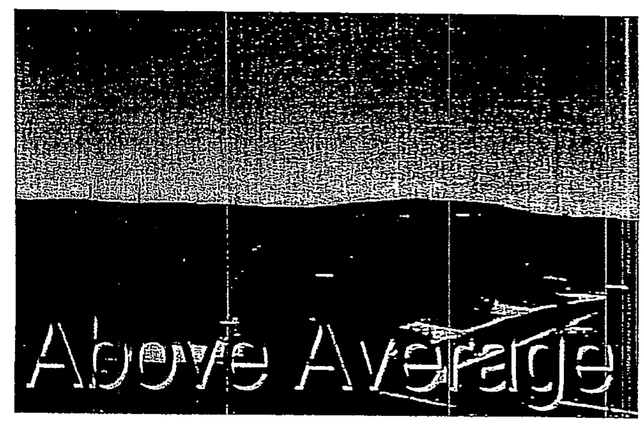
# Five Qualitative Ratings Are Used for Quality of Scenic Vista



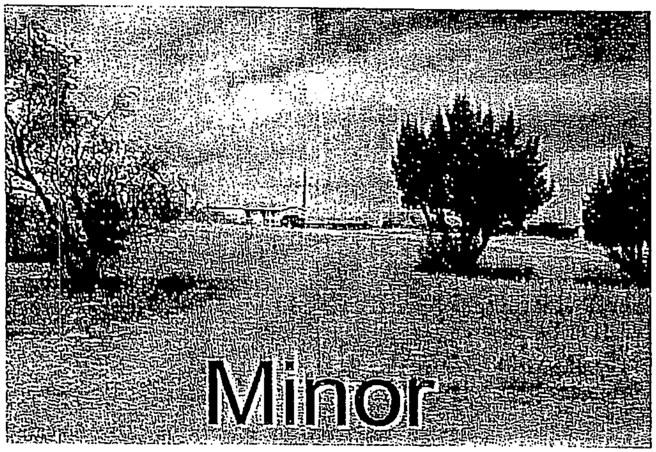
Each home is given a scenic vista rating, based on field visits



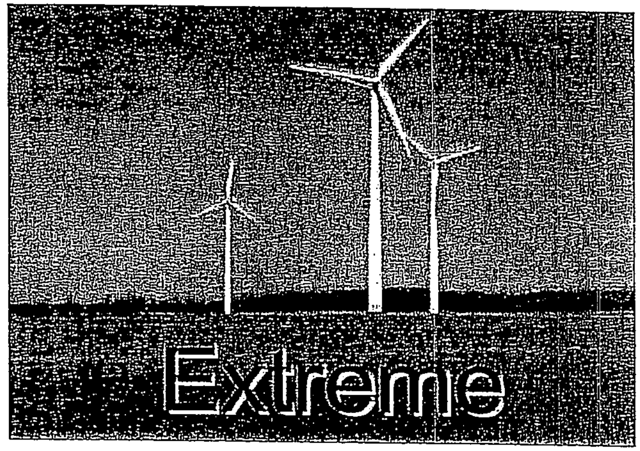



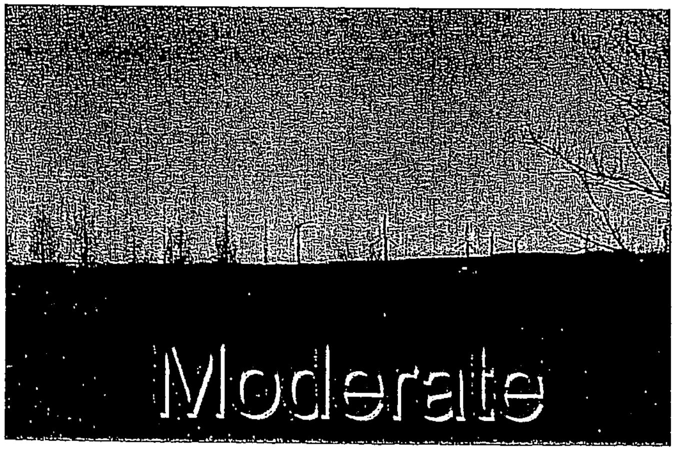



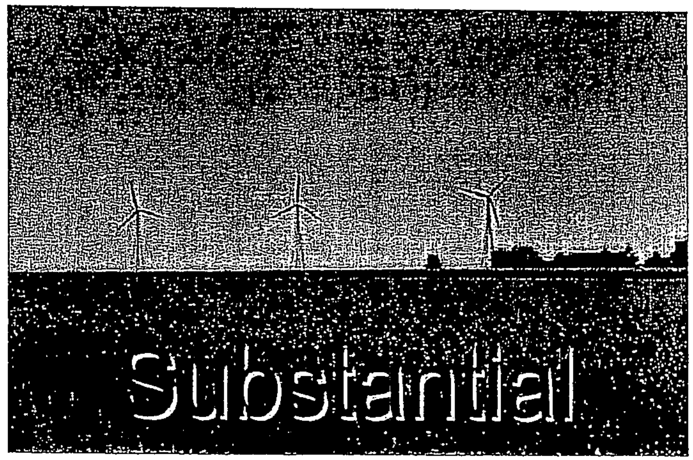
# Four Qualitative Ratings Are Used for Dominance of View of Wind Turbines




Each home is given a view of turbines dominance rating, based on field visits

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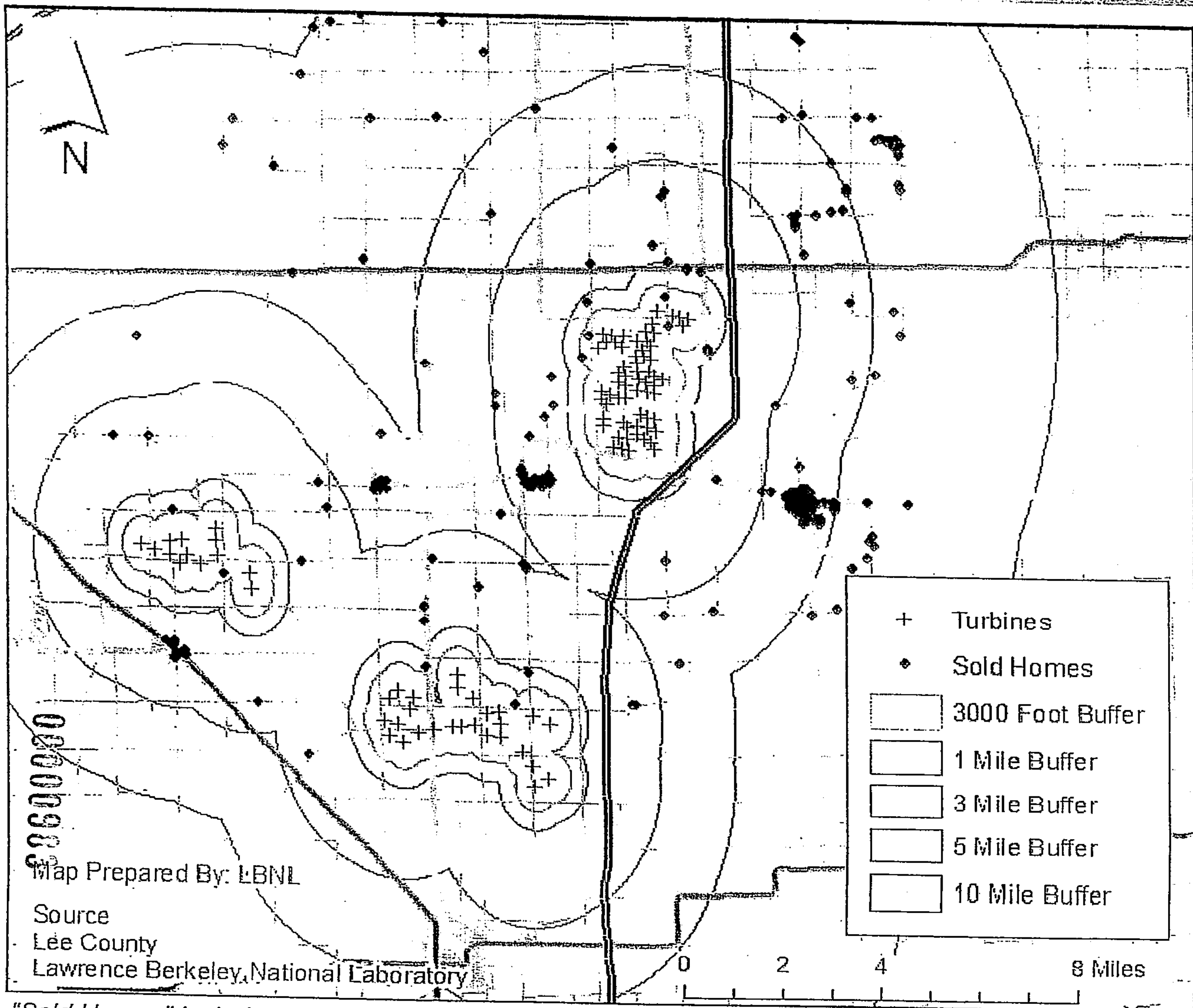
# To Test for Area and Nuisance Stigmas,

## Distance to Nearest Turbine at Time of Sale Is Determined




"Sold Homes" include all homes sold both before and after construction of the wind facility

**Five Distance Bands Are Created**

**Nuisance Stigma**

- Inside of 3000 Feet
- Between 3000 Feet and 1 Mile

**Area Stigma**

- Between 1 and 3 Miles
- Between 3 and 5 Miles
- Outside of 5 Miles

# The Impact of Wind Power Projects on Residential Property Values in the U.S.

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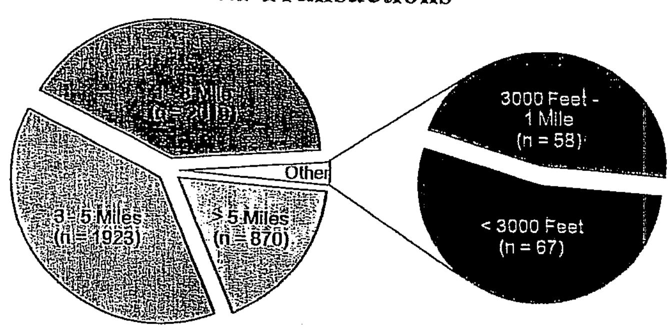
# Data Summary: Development Period, and Distance from and View of Wind Facilities

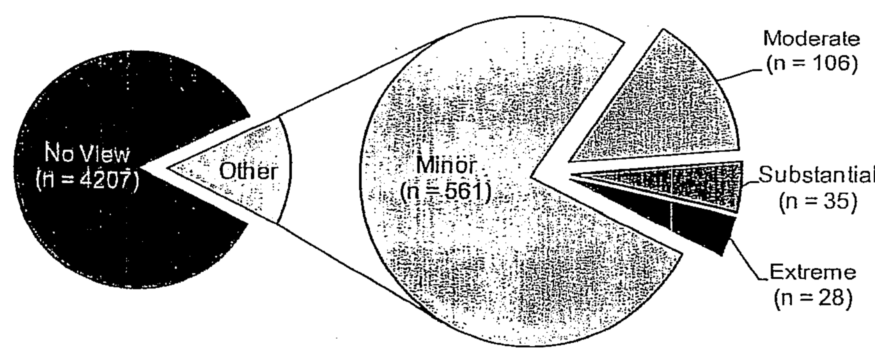
## Summary of Transactions across Study Areas and Development Periods

| | Pre Announcement | Post Announcement Pre Construction | 1st Year After Construction | 2nd Year After Construction | 2+ Years After Construction | Total |
|---|---|---|---|---|---|---|
| Benton/Walla Walla, WA & Umatilla, OR (WAOR) | 226 | 45 | 76 | 59 | 384 | 790 |
| Howard, TX (TXHC) | 169 | 71 | 113 | 131 | 827 | 1311 |
| Custer, OK (OKCC) | 484 | 153 | 193 | 187 | 96 | 1113 |
| Buena Vista, IA (IABV) | 152 | 65 | 80 | 70 | 455 | 822 |
| Lee, IL (ILLC) | 115 | 84 | 62 | 71 | 80 | 412 |
| Kewaunee/Door, WI (WIKCDC) | 44 | 41 | 68 | 62 | 595 | 810 |
| Somerset, PA (PASC) | 175 | 28 | 46 | 60 | 185 | 494 |
| Wayne, PA (PAWC) | 223 | 106 | 64 | 71 | 87 | 551 |
| Madison/Oneida, NY (MYMCOC) | 108 | 9 | 48 | 30 | 268 | 463 |
| Madison, NY (NYMC) | 59 | 165 | 74 | 70 | 325 | 693 |
| TOTAL | 1755 | 767 | 824 | 811 | 3302 | 7459 |

**Frequency of DISTANCE Ratings for Post-Construction Transactions**




**Frequency of VIEW Ratings for Post-Construction Transactions**

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# The Impact of Wind Power Projects on Residential Property Values in the U.S.

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00000987

# Eight Hedonic Models Used, as Well as Repeat Sales and Sales Volume Analyses

- Variety of models used to investigate reliability of "Base Hedonic Model" results and to explore myriad of other potential effects from variety of perspectives
- Data across study areas are pooled in this analysis; many other hedonic model specifications, including those with no pooling of data, are investigated

| Statistical Model | Description |
|---|---|
| **Base Hedonic Model** | Using only "post-construction" transactions (those that occurred after the wind facility was built), this model investigates all three stigmas in a straightforward manner |
| **Alternative Hedonic Models** | |
| View Stability | Using only post-construction transactions, this model investigates whether the Scenic Vista Stigma results from the Base Model are independent of the Nuisance and Area Stigma results |
| Distance Stability | Using only post-construction transactions, this model investigates whether the Nuisance and Area Stigma results from the Base Model are independent of the Scenic Vista Stigma results |
| Continuous Distance | Using only post-construction transactions, this model investigates Area and Nuisance Stigmas by applying a continuous distance parameter as opposed to the categorical variables for distance used in the previous models |
| All Sales | Using all transactions, this model investigates whether the results for the three stigmas change if transactions that occurred before the announcement and construction of the wind facility are included in the sample |
| Temporal Aspects | Using all transactions, this model further investigates Area and Nuisance Stigmas and how they change for homes that sold more than two years pre-announcement through the period more than four years post-construction |
| Orientation | Using only post-construction transactions, this model investigates the degree to which a home's orientation to the view of wind turbines affects sales prices |
| Overlap | Using only post-construction transactions, this model investigates the degree to which the overlap between the view of a wind facility and a home's primary scenic vista affects sales prices |
| **Repeat Sales Model** | Using paired transactions of homes that sold once pre-announcement and again post-construction, this model investigates the three stigmas, using as a reference transactions of homes located outside of five miles of the nearest wind turbine and that have no view of the turbines |
| **Sales Volume Model** | Using both pre-announcement and post-construction transactions, this model investigates whether the rate of home sales (not the price of those sales) is affected by the presence of nearby wind facilities |

**Data collection, cleaning, validity, and regression tests are all discussed in detail in the full report**

# Each Model Fails to Uncover Conclusive Evidence of Any of the Three Stigmas

## Home Prices in Sample Are Not Measurably Impacted by Either the View of or Distance to Wind Facilities

| Statistical Model | Is there statistical evidence of: Area Stigma? | Scenic Vista Stigma? | Nuisance Stigma? | Section Reference |
|---|---|---|---|---|
| Base Model | No | No | No | *Section 4* |
| View Stability | Not tested | No | Not tested | *Section 5.1* |
| Distance Stability | No | Not tested | No | *Section 5.1* |
| Continuous Distance | No | No | No | *Section 5.2* |
| All Sales | No | No | Limited | *Section 5.3* |
| Temporal Aspects | No | No | No | *Section 5.4* |
| Orientation | No | No | No | *Section 5.5* |
| Overlap | No | Limited | No | *Section 5.6* |
| Repeat Sales | No | Limited | No | *Section 6* |
| Sales Volume | No | Not tested | No | *Section 7* |

*"No"………………… No statistical evidence of a negative impact*
*"Yes"………………… Strong statistical evidence of a negative impact*
*"Limited"……………. Limited and inconsistent statistical evidence of a negative impact*
*"Not tested"………… This model did not test for this stigma*

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# The Impact of Wind Power Projects on Residential Property Values in the U.S.

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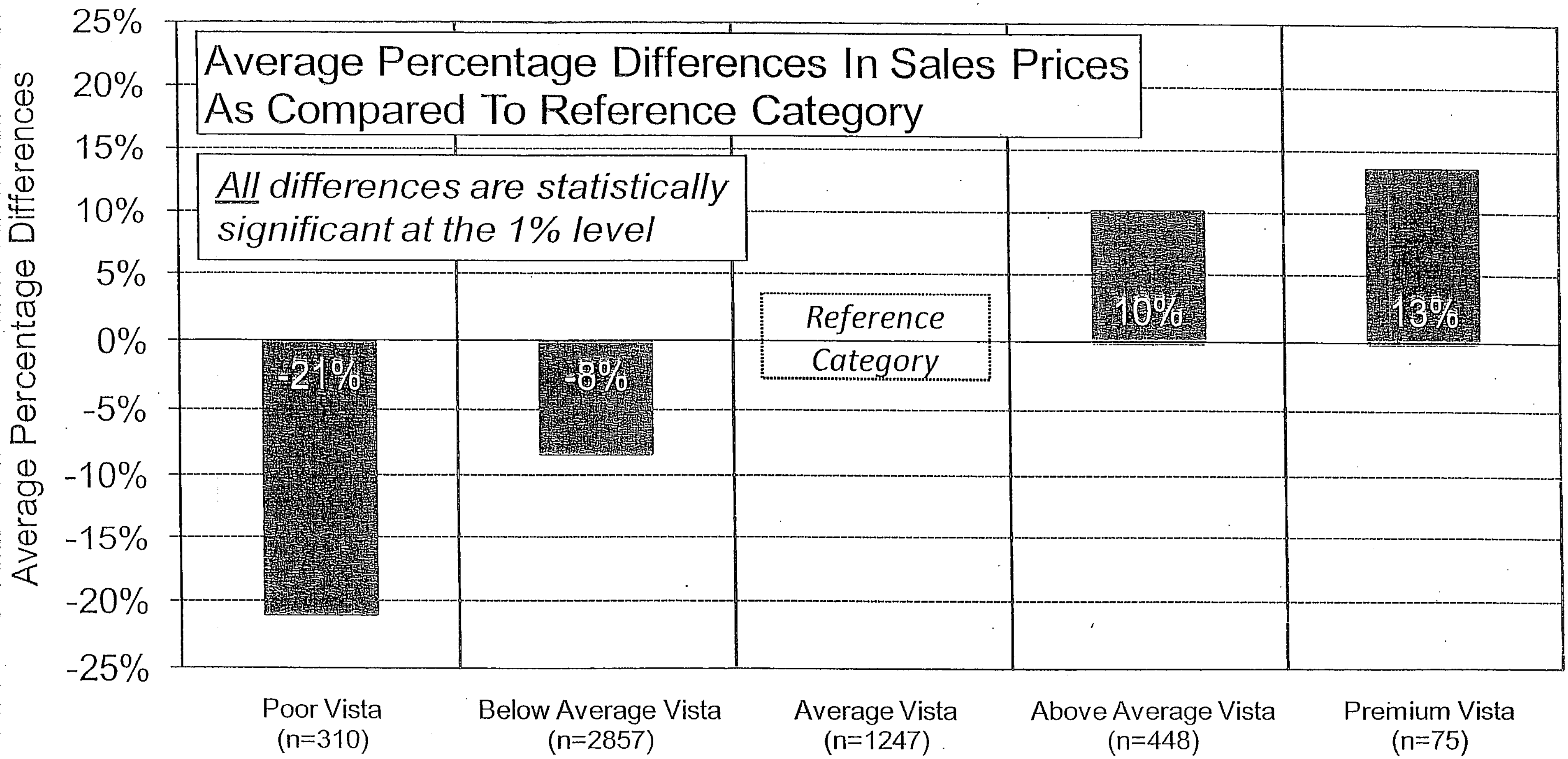
# Base Hedonic Model Results:

## There Is Strong Statistical Evidence that the Quality of the Scenic Vista Affects Sales Prices

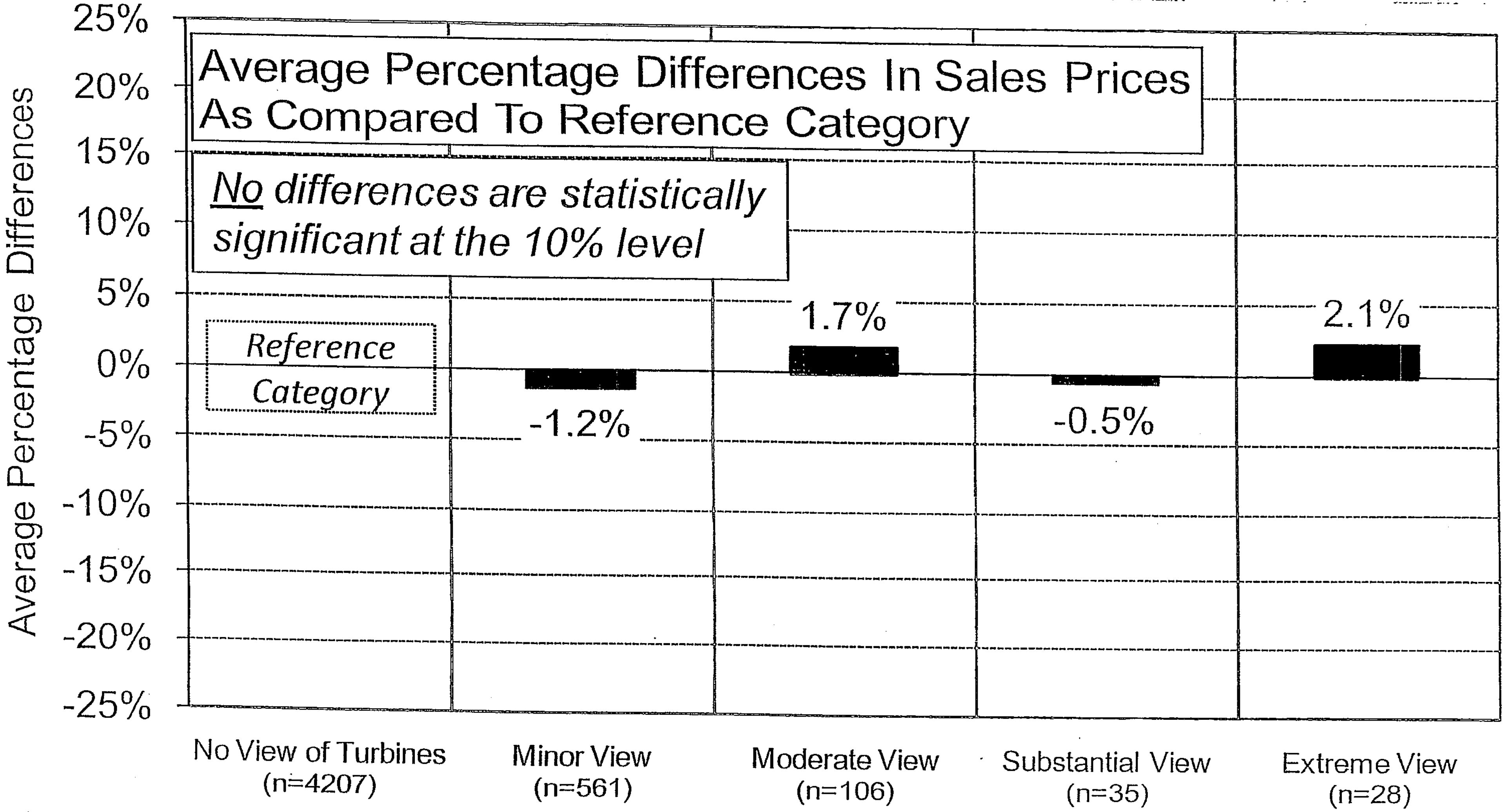



*The reference category consists of transactions for homes with an Average Vista, and that occured after construction began on the wind facility*

00000950

# Base Hedonic Model Results:

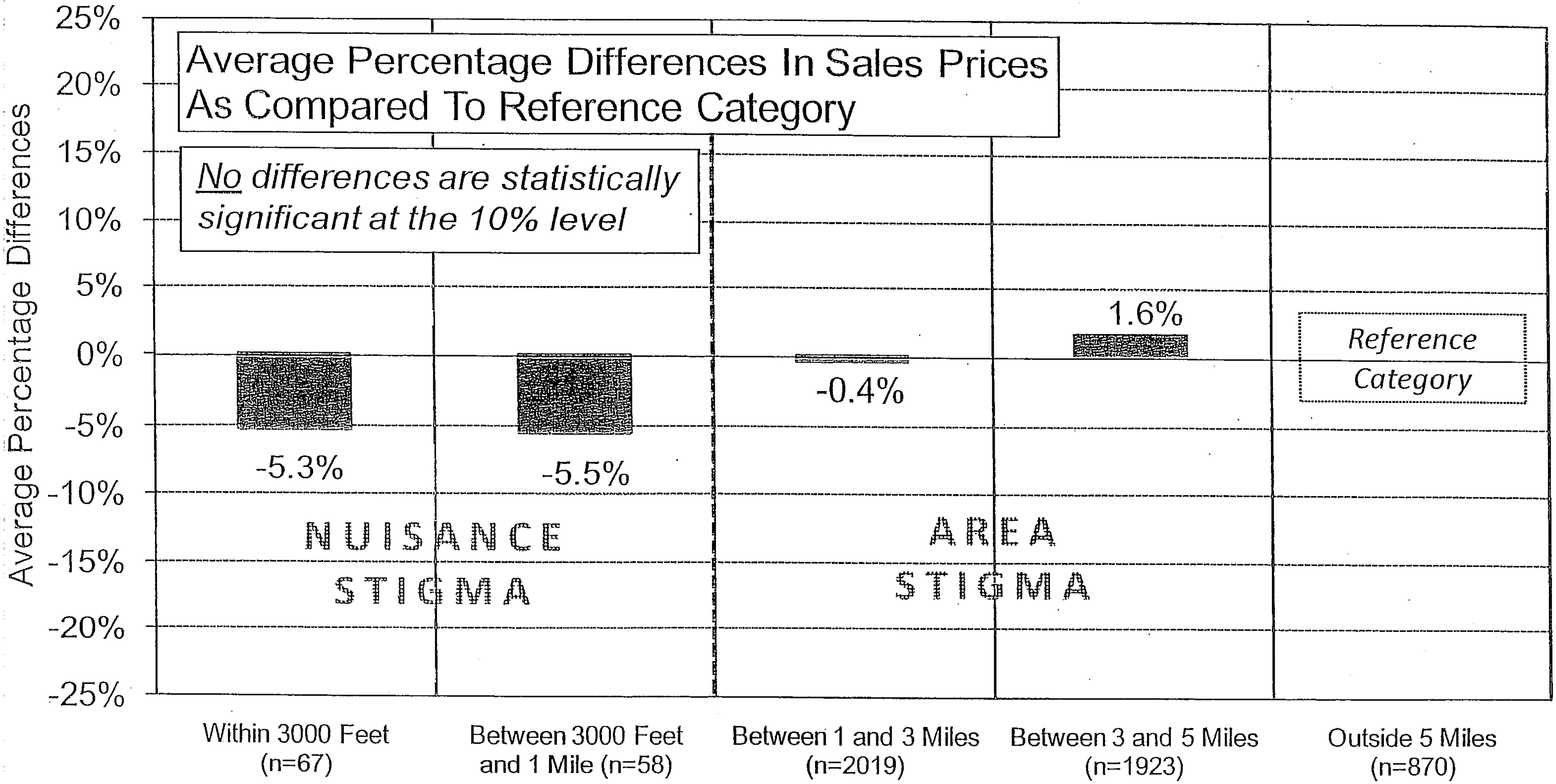
## There Is a Lack of Statistical Evidence that the Dominance of the Views of Turbines Affects Sales Prices




*The reference category consists of transactions for homes without a view of the turbines, and that occured after construction began on the wind facility*

# Base Hedonic Model Results:

## There Is a Lack of Statistical Evidence that the Distance to the Nearest Turbine Affects Sales Prices




*The reference category consists of transactions for homes situated more than five miles from the nearest turbine, and that occured after construction began on the wind facility*

00000992

# The Impact of Wind Power Projects on Residential Property Values in the U.S.

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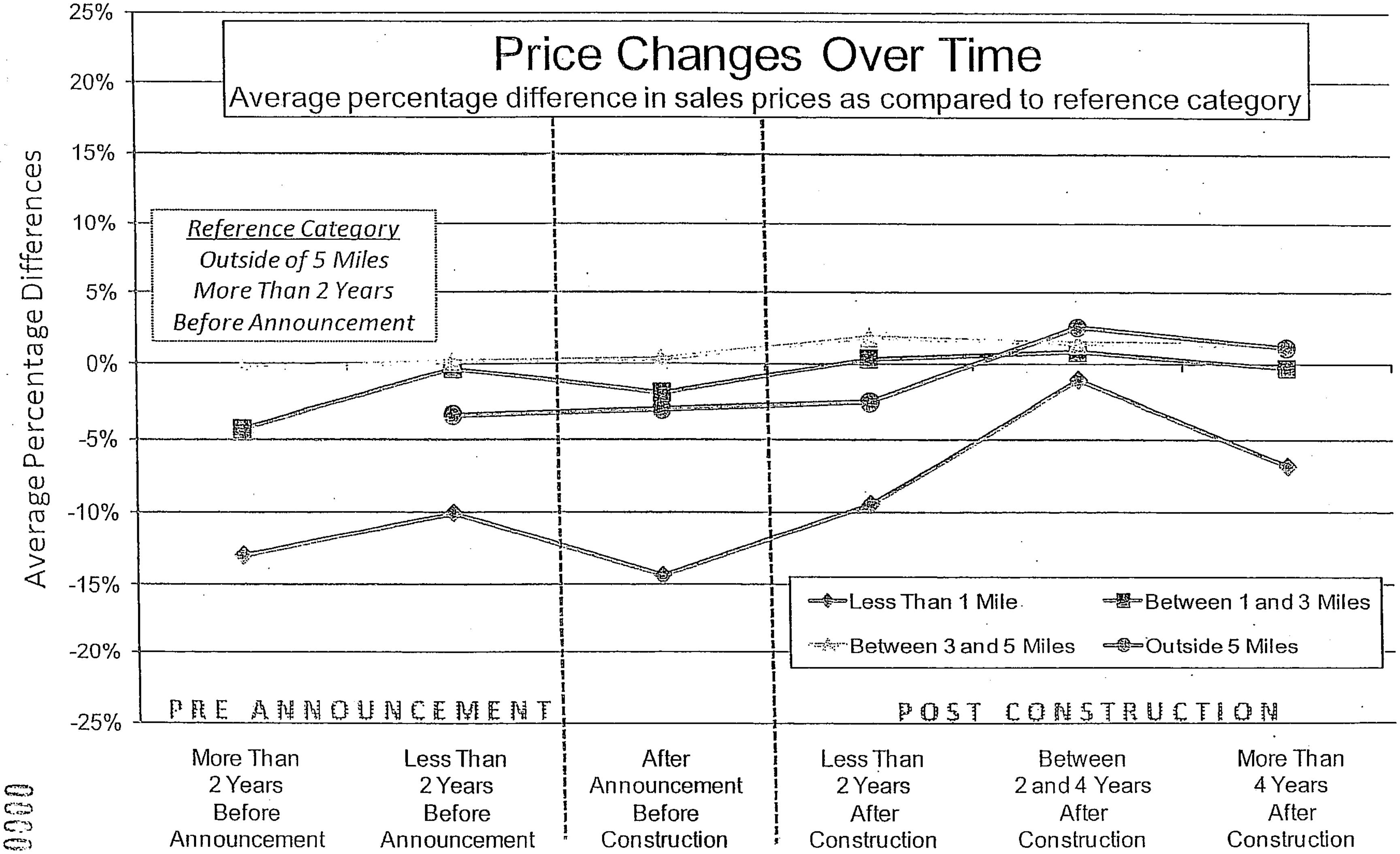
00000993

# Temporal Aspects Model Results:

## Homes Nearest the Turbines Were Depressed in Value Before Construction and Appreciated the Most After Construction While Homes Further Away Were Largely Unchanged Over Time




*The reference category consists of transactions of homes situated more than five miles from where the nearest turbine would eventually be located and that occurred more than two years before announcement of the facility*

00003354

# The Impact of Wind Power Projects on Residential Property Values in the U.S.

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  - Key Model Results
    - Base Model [illegible]
    - Temporal Aspects Model [illegible]
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# Results from Other Models Support Basic Conclusions from Base Hedonic Model

<u>Some examples are…</u>

**Repeat Sales Model:** Investigated appreciation rates between houses that sold twice with various views of and distances from turbines

**Sales Volume Model:** Investigated the numbers of homes that sold as a percentage of those that were available to sell at various distances from the turbines

**Hedonic Orientation Model:** Investigated whether a home's orientation to the view of turbines has an effect on selling price

**Hedonic Overlap Model:** Investigated whether the degree to which the view of the turbines overlaps the scenic vista has an effect

The results are consistent across all models in that none uncovers conclusive evidence of the existence of any widespread property value impacts for any of the three stigmas

00000996

# The Impact of Wind Power Projects on Residential Property Values in the U.S.

- Motivation and Study Methods
- Summary of Analysis Results
- **Conclusions and Further Research**

00000997

# Conclusions

Although the analysis cannot dismiss the possibility that individual homes have been or could be negatively impacted, the Berkeley Lab research finds that if these impacts do exist in the sample of homes analyzed, they are either too small and/or too infrequent to result in any widespread, statistically observable effect

- **Area Stigma:** Homes in the study areas analyzed do not appear to be measurably stigmatized by the arrival of a wind facility
- **Scenic Vista Stigma:** None of the various models finds strong statistical evidence that the view of a nearby wind facility impacts sales prices in a significant and consistent manner
- **Nuisance Stigma:** Homes in the sample that are within a mile of the nearest wind facility, where various nuisance effects have been posited, have not been broadly and measurably affected by the presence of those wind facilities

00000938

# Further Research Recommendations

- **Complete "primer"** to summarize findings, place results into broader literature of disamenities, and outline options to measure, mitigate, and manage property value risks
- **Survey homeowners** living close to existing wind facilities especially those who have bought and sold homes in proximity to wind facilities after facility construction
- **Conduct more detailed analysis on sales volume** impacts including time on the market prior to sale
- **Revisit hedonic analysis** when more data are available for homes located particularly close to and having dominating view of wind facilities

# For More Information...

See full report for additional findings, a discussion of the sources of data used, etc.

- **http://eetd.lbl.gov/ea/ems/re-pubs.html**

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This analysis was funded by the Office of Energy Efficiency and Renewable Energy, Wind & Hydropower Technologies Program of the U.S. DOE under Contract No. DE-AC02-05CH11231

LBNL-2829E

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# The Impact of Wind Power Projects on Residential Property Values in the United States: A Multi-Site Hedonic Analysis

Ben Hoen, Ryan Wiser, Peter Cappers,
Mark Thayer, and Gautam Sethi

Environmental Energy
Technologies Division

December 2009



The work described in this report was funded by the Office of Energy Efficiency and Renewable Energy (Wind & Hydropower Technologies Program) of the U.S. Department of Energy under Contract No. DE-AC02-05CH1123.

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# The Impact of Wind Power Projects on Residential Property Values in the United States: A Multi-Site Hedonic Analysis

Prepared for the

Office of Energy Efficiency and Renewable Energy
Wind & Hydropower Technologies Program
U.S. Department of Energy
Washington, D.C.

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## Abstract

With wind energy expanding rapidly in the U.S. and abroad, and with an increasing number of communities considering wind power development nearby, there is an urgent need to empirically investigate common community concerns about wind project development. The concern that property values will be adversely affected by wind energy facilities is commonly put forth by stakeholders. Although this concern is not unreasonable, given property value impacts that have been found near high voltage transmission lines and other electric generation facilities, the impacts of wind energy facilities on residential property values had not previously been investigated thoroughly. The present research collected data on almost 7,500 sales of single-family homes situated within 10 miles of 24 existing wind facilities in nine different U.S. states. The conclusions of the study are drawn from eight different hedonic pricing models, as well as both repeat sales and sales volume models. The various analyses are strongly consistent in that none of the models uncovers conclusive evidence of the existence of any widespread property value impacts that might be present in communities surrounding wind energy facilities. Specifically, neither the view of the wind facilities nor the distance of the home to those facilities is found to have any consistent, measurable, and statistically significant effect on home sales prices. Although the analysis cannot dismiss the possibility that individual homes or small numbers of homes have been or could be negatively impacted, it finds that if these impacts do exist, they are either too small and/or too infrequent to result in any widespread, statistically observable impact.

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## Acknowledgements

The work described in this report was funded by the Office of Energy Efficiency and Renewable Energy (Wind & Hydropower Technologies Program) of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231. The authors would particularly like to thank Megan McCluer, Patrick Gilman, Jim Ahlgrimm, Michele Desautels, and Steve Lindenberg, all of the U.S. Department of Energy, for their long-term support of this work. For reviewing drafts of this report and/or for providing comments that helped shape the early thinking on this project, the authors thank Mark Bolinger, Galen Barbose, and Larry Dale (Berkeley Lab), Alejandro Moreno (US DOE), Larry Flowers and Eric Lantz (NREL), Peter Dent and Sally Sims (Oxford Brookes University), Sandy Bond (Curtin Business School), Randy Winter, Dave Loomis, and Jennifer Hinman (Illinois State University), Thomas Priestley (CH2M Hill), Barton DeLacy (Cushman & Wakefield), Dave Maturen (Maturen Appraisal), Mike McCann (McCann Appraisal), Tom Hewson (Energy Ventures Analysis), Kimberly Centera (AES), Jeff Peterson (NYSERDA), Charles Kubert (Clean Energy Group), Lisa Linowes (Industrial Wind Action), Chris Taylor (Element Power), Sam Enfield (MAP Royalty, Inc.), and Laurie Jodziewicz (AWEA). Of course, any remaining omissions or inaccuracies are those of the authors.

## Executive Summary

### Overview

Wind power development in the United States has expanded dramatically in recent years. If that growth is to continue it will require an ever-increasing number of wind power projects to be sited, permitted, and constructed. Most permitting processes in the U.S. require some form of environmental impact assessment as well as public involvement in the siting process. Though public opinion surveys generally show that acceptance towards wind energy is high, a variety of concerns with wind power development are often expressed on the local level during the siting and permitting process. One such concern is the potential impact of wind energy projects on the property values of nearby residences.

Concerns about the possible impact of wind power facilities on residential property values can take many forms, but can be divided into the following non-mutually exclusive categories:

- Area Stigma: A concern that the general area surrounding a wind energy facility will appear more developed, which may adversely affect home values in the local community regardless of whether any individual home has a view of the wind turbines.
- Scenic Vista Stigma: A concern that a home may be devalued because of the view of a wind energy facility, and the potential impact of that view on an otherwise scenic vista.
- Nuisance Stigma: A concern that factors that may occur in close proximity to wind turbines, such as sound and shadow flicker, will have a unique adverse influence on home values.

Although concerns about the possible impact of wind energy facilities on the property values of nearby homes are reasonably well established, the available literature[1] that has sought to quantify the impacts of wind projects on residential property values has a number of shortcomings:

1) Many studies have relied on surveys of homeowners or real estate professionals, rather than trying to quantify real price impacts based on market data;
2) Most studies have relied on simple statistical techniques that have limitations and that can be dramatically influenced by small numbers of sales transactions or survey respondents;
3) Most studies have used small datasets that are concentrated in only one wind project study area, making it difficult to reliably identify impacts that might apply in a variety of areas;
4) Many studies have not reported measurements of the statistical significance of their results, making it difficult to determine if those results are meaningful;
5) Many studies have concentrated on an investigation of the existence of Area Stigma, and have ignored Scenic Vista and/or Nuisance Stigmas;
6) Only a few studies included field visits to homes to determine wind turbine visibility and collect other important information about the home (e.g., the quality of the scenic vista); and
7) Only two studies have been published in peer-reviewed academic journals.

[1] This literature is briefly reviewed in Section 2 of the full report, and includes: Jordal-Jorgensen (1996); Jerabek (2001); Grover (2002); Jerabek (2002); Sterzinger et al. (2003); Beck (2004); Haughton et al. (2004); Khatri (2004); DeLacy (2005); Poletti (2005); Goldman (2006); Hoen (2006); Firestone et al. (2007); Poletti (2007); Sims and Dent (2007); Bond (2008); McCann (2008); Sims et al. (2008); and Kielisch (2009).

This report builds on the previous literature that has investigated the potential impact of wind projects on residential property values by using a hedonic pricing model and by avoiding many of the shortcomings enumerated above. The hedonic pricing model is one of the most prominent and reliable methods for identifying the marginal impacts of different housing and community characteristics on residential property values (see side bar). This approach dates to the seminal work of Rosen (1974) and Freeman (1979), and much of the available literature that has investigated the impacts of potential disamenities on property values has relied on this method.[2]

**What Is a Hedonic Pricing Model?**
Hedonic pricing models are frequently used by economists and real estate professionals to assess the impacts of house and community characteristics on property values by investigating the sales prices of homes. A house can be thought of as a bundle of characteristics (e.g., number of square feet, number of bathrooms). When a price is agreed upon by a buyer and seller there is an implicit understanding that those characteristics have value. When data from a large number of residential transactions are available, the individual marginal contribution to the sales price of each characteristic for an average home can be estimated with a hedonic regression model. Such a model can statistically estimate, for example, how much an additional bathroom adds to the sale price of an average home. A particularly useful application of the hedonic model is to value non-market goods – goods that do not have transparent and observable market prices. For this reason, the hedonic model is often used to derive value estimates of amenities such as wetlands or lake views, and disamenities such as proximity to and/or views of high-voltage transmission lines, roads, cell phone towers, and landfills. It should be emphasized that the hedonic model is not typically designed to appraise properties (i.e., to establish an estimate of the market value of a home at a specified point in time), as would be done with an automated valuation model. Instead, the typical goal of a hedonic model is to estimate the marginal contribution of individual house or community characteristics to sales prices.

To seed the hedonic model with appropriate market data, this analysis collects information on a large quantity of residential home sales (i.e., transactions) ($n = 7{,}459$) from ten communities surrounding 24 existing wind power facilities spread across multiple parts of the U.S. (e.g., nine states). Homes included in this sample are located from 800 ft to over five miles from the nearest wind energy facility, and were sold at any point from before wind facility announcement to over four years after the construction of the nearby wind project. Each of the homes that sold was visited to determine the degree to which the wind facility was likely to have been visible at the time of sale and to collect other essential data.

To assess the potential impacts of all three of the property value stigmas described earlier, a base hedonic model is applied as well as seven alternative hedonic models each designed to investigate the reliability of the results and to explore other aspects of the data (see Table ES - 1 below). In addition, a repeat sales model is analyzed, and an investigation of possible impacts on sales volumes is

[2] Many of these studies are summarized in the following reviews: Kroll and Priestley (1992); McCann (1999); Bateman et al. (2001); Boyle and Kiel (2001); Jackson (2001); Simons and Saginor (2006); and Leonard et al. (2008). For further discussion of the hedonic model and its application to the quantification of environmental stigmas see Jackson (2005) and Simons (2006a).

conducted. Though some limitations to the analysis approach and available data are acknowledged, the resulting product is the most comprehensive and data-rich analysis to date in the U.S. or abroad on the impacts of wind projects on nearby property values.

## Analysis Findings

Table ES - 1 describes the ten resulting statistical models that are employed to investigate the effects of wind facilities on residential sales prices, and the specific stigmas that those models investigate. Though all models test some combination of the three possible stigmas, they do so in different ways. For instance, the Base Model asks the question, "All else being equal, do homes near wind facilities sell for prices different than for homes located farther away?", while the All Sales Model asks, "All else being equal, do homes near wind facilities that sell after the construction of the wind facility sell for prices different from similar homes that sold before the announcement and construction of the facility?" Each model is therefore designed to not only test for the reliability of the overall results, but also to explore the myriad of potential effects from a variety of perspectives. Table ES-2 summarizes the results from these models.

**Table ES - 1: Description of Statistical Models**

| Statistical Model | Description |
|---|---|
| **Base Hedonic Model** | Using only "post-construction" transactions (those that occurred after the wind facility was built), this model investigates all three stigmas in a straightforward manner |
| **Alternative Hedonic Models** | |
| View Stability | Using only post-construction transactions, this model investigates whether the Scenic Vista Stigma results from the Base Model are independent of the Nuisance and Area Stigma results |
| Distance Stability | Using only post-construction transactions, this model investigates whether the Nuisance and Area Stigma results from the Base Model are independent of the Scenic Vista Stigma results |
| Continuous Distance | Using only post-construction transactions, this model investigates Area and Nuisance Stigmas by applying a continuous distance parameter as opposed to the categorical variables for distance used in the previous models |
| All Sales | Using all transactions, this model investigates whether the results for the three stigmas change if transactions that occurred before the announcement and construction of the wind facility are included in the sample |
| Temporal Aspects | Using all transactions, this model further investigates Area and Nuisance Stigmas and how they change for homes that sold more than two years pre-announcement through the period more than four years post-construction |
| Orientation | Using only post-construction transactions, this model investigates the degree to which a home's orientation to the view of wind turbines affects sales prices |
| Overlap | Using only post-construction transactions, this model investigates the degree to which the overlap between the view of a wind facility and a home's primary scenic vista affects sales prices |
| **Repeat Sales Model** | Using paired transactions of homes that sold once pre-announcement and again post-construction, this model investigates the three stigmas, using as a reference transactions of homes located outside of five miles of the nearest wind turbine and that have no view of the turbines |
| **Sales Volume Model** | Using both pre-announcement and post-construction transactions, this model investigates whether the rate of home sales (not the price of those sales) is affected by the presence of nearby wind facilities |

Table ES-2: Impact of Wind Projects on Property Values: Summary of Key Results

| Statistical Model | Is there statistical evidence of: Area Stigma? | Scenic Vista Stigma? | Nuisance Stigma? | Section Reference |
|---|---|---|---|---|
| Base Model | No | No | No | *Section 4* |
| View Stability | Not tested | No | Not tested | *Section 5.1* |
| Distance Stability | No | Not tested | No | *Section 5.1* |
| Continuous Distance | No | No | No | *Section 5.2* |
| All Sales | No | No | Limited | *Section 5.3* |
| Temporal Aspects | No | No | No | *Section 5.4* |
| Orientation | No | No | No | *Section 5.5* |
| Overlap | No | Limited | No | *Section 5.6* |
| Repeat Sales | No | Limited | No | *Section 6* |
| Sales Volume | No | Not tested | No | *Section 7* |

*"No"…………………* *No statistical evidence of a negative impact*
*"Yes"…………………* *Strong statistical evidence of a negative impact*
*"Limited"……………* *Limited and inconsistent statistical evidence of a negative impact*
*"Not tested"…………* *This model did not test for this stigma*

*Base Model Results*

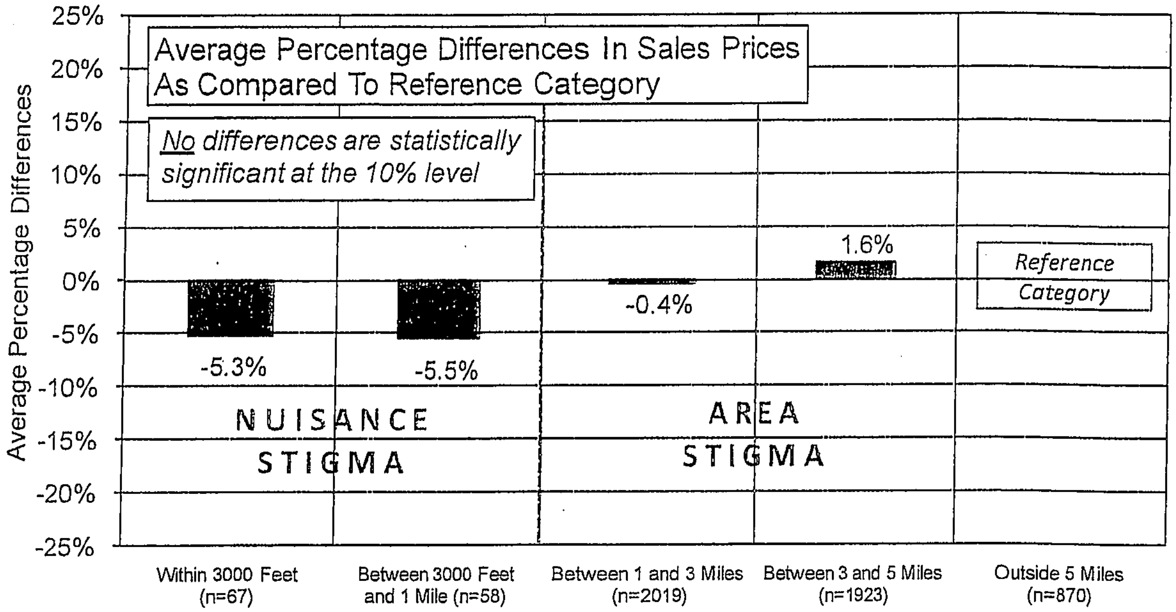
The Base Model serves as the primary model and allows all three stigmas to be explored. In sum, this model finds no persuasive evidence of any of the three potential stigmas: neither the view of the wind facilities nor the distance of the home to those facilities is found to have any consistent, measurable, and statistically significant effect on home sales prices.

- Area Stigma: To investigate Area Stigma, the model tests whether the sales prices of homes situated anywhere outside of one mile and inside of five miles of the nearest wind facility are measurably different from the sales price of those homes located outside of five miles. No statistically significant differences in sales prices between these homes are found (see Figure ES-1).
- Scenic Vista Stigma: For Scenic Vista Stigma, the model is first used to investigate whether the sales prices of homes with varying scenic vistas - absent the presence of the wind facility - are measurably different. The model results show dramatic and statistically significant differences in this instance (see Figure ES-2); not surprisingly, home buyers and sellers consider the scenic vista of a home when establishing the appropriate sales price. Nonetheless, when the model tests for whether homes with minor, moderate, substantial, or extreme views of wind turbines have measurably different sales prices, no statistically significant differences are apparent (see Figure ES-3).
- Nuisance Stigma: Finally, for Nuisance Stigma, the model is used to test whether the sales prices of homes situated inside of one mile of the nearest wind energy facility are measurably different from those homes located outside of five miles. Although sample size is somewhat limited in this case,[3] the model again finds no persuasive statistical evidence that wind

[3] 125 homes were located inside of one mile of the nearest wind facility and sold post-construction.

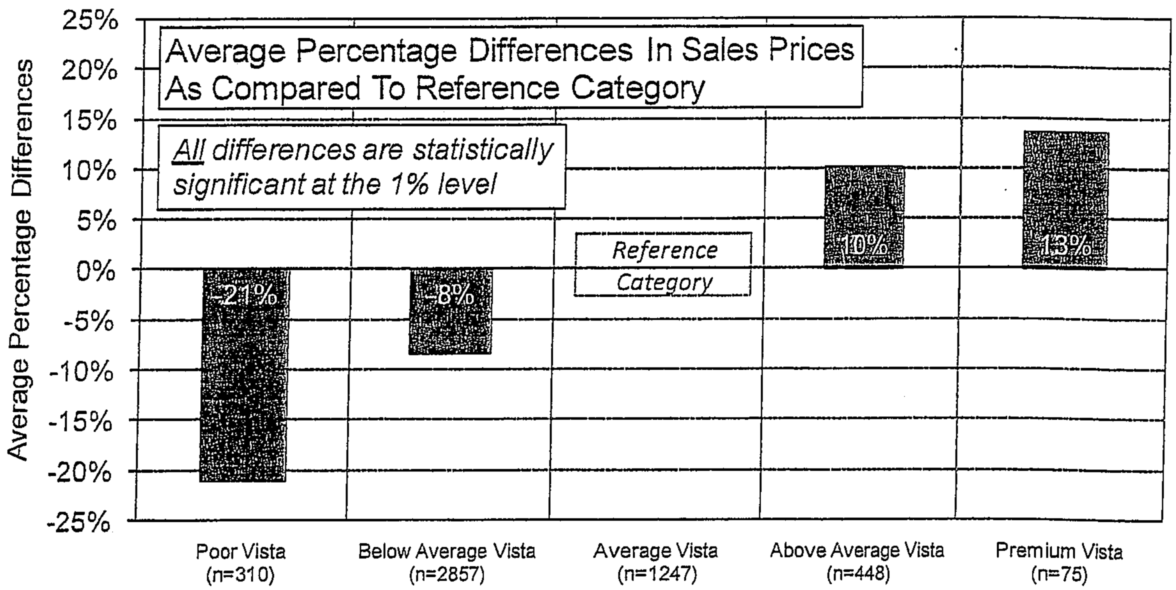
facilities measurably and broadly impact residential sales prices (see Figure ES-1 and later results).

**Figure ES-1: Base Model Results: Area and Nuisance Stigma**



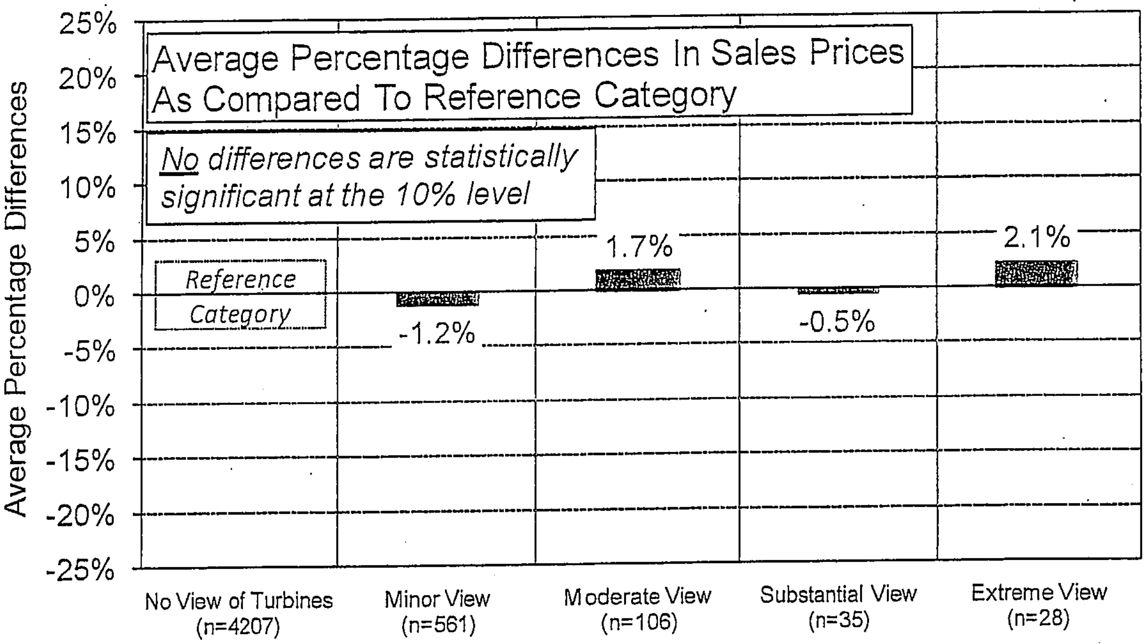

*The reference category consists of transactions for homes situated more than five miles from the nearest turbine, and that occured after construction began on the wind facility*

**Figure ES-2: Base Model Results: Scenic Vista**




*The reference category consists of transactions for homes with an Average Vista, and that occured after construction began on the wind facility*

**Figure ES-3: Base Model Results: Scenic Vista Stigma**




*The reference category consists of transactions for homes without a view of the turbines, and that occured after construction began on the wind facility*

The seven alternative hedonic models and the additional analysis contained in the Repeat Sales and Sales Volume Models (see Table ES-2) provide a fuller picture of the three stigmas and the robustness of the Base Model results.

*Area Stigma: Other Model Results*

Concentrating first on Area Stigma, the results from all of the models are similar: there is no statistical evidence of a widespread Area Stigma among the homes in this sample. Homes in the study areas analyzed here do not appear to be measurably stigmatized by the arrival of a wind facility, regardless of when those homes sold in the wind project development process and regardless of whether the homes are located one mile or five miles away from the nearest facility.

In the All Sales Model, for example, after adjusting for inflation,[4] homes that sold after wind facility construction and that had no view of the turbines are found to have transacted for higher prices - not lower - than those homes that sold prior to wind facility construction. Moreover, in the Temporal Aspects Model, homes that sold more than two years prior to the announcement of the wind facility and that were located more than five miles from where the turbines were eventually located are found to have transacted for lower prices - not higher - than homes situated closer to the turbines and that sold at any time after the announcement and construction of the wind facility (see Figure ES - 4). Further, in the Repeat Sales Model, homes located near the wind facilities that transacted more than once were found to have appreciated between those sales by an amount that was no different from that experienced by homes located in an area

[4] All sales prices in all models are adjusted for inflation, but because this model (and the Temporal Aspects Model) deals with time explicitly, it is mentioned specifically here.

many miles away from the wind facilities. Finally, as shown in Table ES-2, none of the other models identified evidence of a broadly negative and statistically significant Area Stigma.

*Scenic Vista Stigma: Other Model Results*

With respect to Scenic Vista Stigma, the seven alternative hedonic models and the additional analysis contained in the Repeat Sales Model find little consistent evidence of a broadly negative and statistically significant impact. Although there are 730 residential transactions in the sample that involve homes that had views of a wind facility at the time of sale, 160 of which had relatively significant views (i.e., a rating higher than Minor), none of the various models finds strong statistical evidence that the view of a nearby wind facility impacts sales prices in a significant and consistent manner.

When concentrating only on the view of the wind facilities from a home (and not testing for Area and Nuisance Stigmas simultaneously), for example, the results from the View Stability Model are very similar to those derived from the Base Model, with no evidence of a Scenic Vista Stigma. Similarly, the All Sales Model finds that homes that sold after wind facility construction and that had a view of the facility transacted for prices that are statistically indistinguishable from those homes that sold at any time prior to wind facility construction. The Orientation Model, meanwhile, fails to detect any difference between the sales prices of homes that had either a front, back, or side orientation to the view of the wind facility. As shown in Table ES-2, the Continuous Distance and Temporal Aspects models also do not uncover any evidence of a broadly negative and statistically significant Scenic Vista Stigma.

In the Repeat Sales Model, some limited evidence is found that a Scenic Vista Stigma may exist, but those effects are weak, fairly small, somewhat counter-intuitive, and are at odds with the results of other models. This finding is likely driven by the small number of sales pairs that are located within one mile of the wind turbines and that experience a dramatic view of those turbines. Finally, in the Overlap Model, where the degree to which a view of the wind facility overlaps the primary scenic vista from the home is accounted for, no statistically significant differences in sales prices are detected between homes with somewhat or strongly overlapping views when compared to those homes with wind turbine views that did not overlap the primary scenic vista. Though this model produces some weak evidence of a Scenic Vista Stigma among homes with Minor views of wind facilities, the same model finds that the sales prices of those homes with views that barely overlap the primary scenic vista are positively impacted by the presence of the wind facility. When these two results are combined, the overall impact is negligible, again demonstrating no persuasive evidence of a Scenic Vista Stigma.

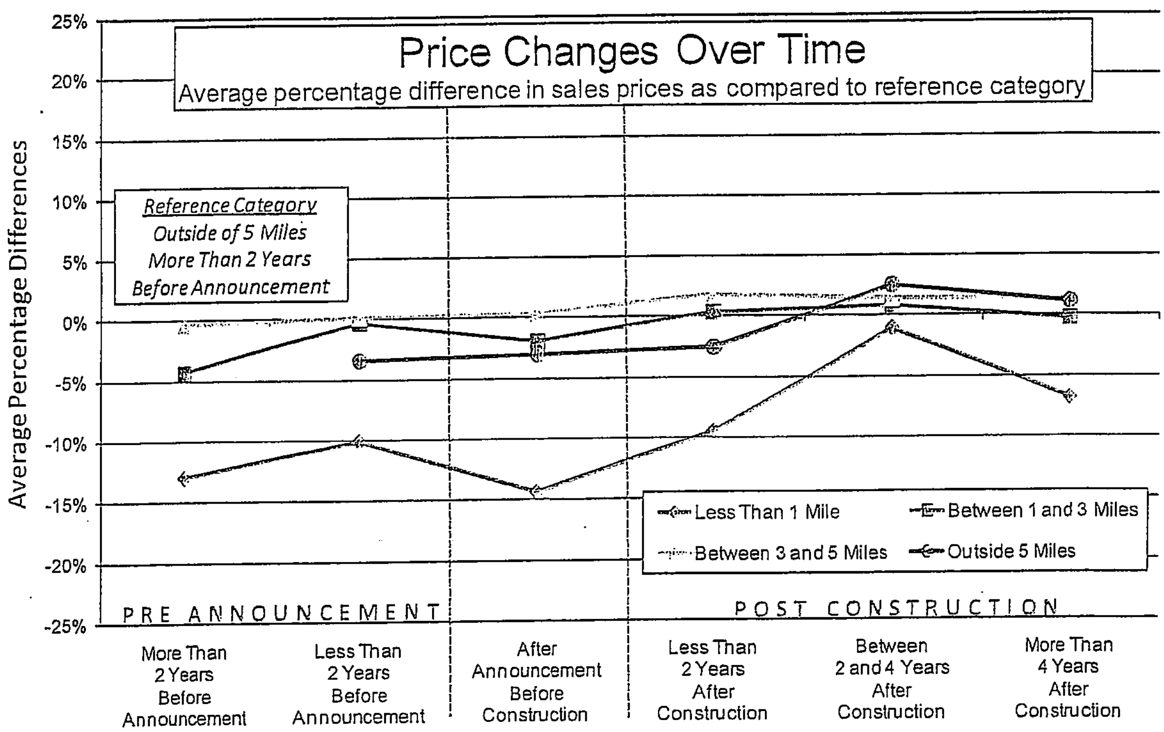
*Nuisance Stigma: Other Model Results*

Results for Nuisance Stigma from the seven alternative hedonic models and the additional analysis contained in the Repeat Sales and Sales Volume Models support the Base Model results. Taken together, these models present a consistent set of results: homes in this sample that are within a mile of the nearest wind facility, where various nuisance effects have been posited, have not been broadly and measurably affected by the presence of those wind facilities. These results imply that Nuisance Stigma effects are either not present in this sample, or are too small and/or infrequent to be statistically distinguished.

In the Distance Stability Model, for example, when concentrating only on the distance from homes to the nearest wind turbine (and not testing for Scenic Vista Stigma simultaneously), the results are very similar to those derived from the Base Model, with no statistical evidence of a Nuisance Stigma. These results are corroborated by the Continuous Distance, Orientation, Overlap, and Repeat Sales Models, none of which find a statistically significant relationship between distance and either sales prices or appreciation rates. Relatedly, the Sales Volume analysis finds no evidence that homes located within one mile of the nearest wind turbine are sold any more or less frequently than homes located farther away from the wind facilities.

In the All Sales Model, a weakly significant difference is found between the sales prices of homes located between 3000 feet and one mile of the nearest wind facility and the homes that sold before the announcement of the wind facility. This effect, however, is largely explained by the results of the Temporal Aspects Model, shown in Figure ES - 4. The Temporal Aspects Model finds that homes located within one mile of where the wind turbines would eventually be located sold for depressed prices well before the wind facility was even announced or constructed. In all time periods following the commencement of wind facility construction, however, inflation-adjusted sales prices increased - not decreased - relative to pre-announcement levels, demonstrating no statistical evidence of a Nuisance Stigma. The results from the All Sales Model (and, for that matter, the negative, albeit statistically insignificant coefficients inside of one mile in the Base Model, see Figure ES-1) are therefore an indication of sales price levels that preceded wind facility announcement construction, and that are not sustained after construction.

**Figure ES - 4: Temporal Aspects Model Results: Area and Nuisance Stigma**




*The reference category consists of transactions of homes situated more than five miles from where the nearest turbine would eventually be located and that occurred more than two years before announcement of the facility*

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## Conclusions and Further Research Needs

Though each of the analysis techniques used in this report has strengths and weaknesses, the results as a whole are strongly consistent in that none of the models uncovers conclusive evidence of the presence of any of the three property value stigmas that might be present in communities surrounding wind power facilities. Therefore, based on the data sample and analysis presented here, no evidence is found that home prices surrounding wind facilities are consistently, measurably, and significantly affected by either the view of wind facilities or the distance of the home to those facilities. Although the analysis cannot dismiss the possibility that individual homes or small numbers of homes have been or could be negatively impacted, it finds that if these impacts do exist, they are either too small and/or too infrequent to result in any widespread, statistically observable impact. Moreover, to the degree that homes and wind facilities in this sample are similar to homes and facilities in other areas of the United States, the results presented here are expected to be transferable to other areas.

This work builds on the existing literature in a number of respects, but there remain a number of areas for further research. The primary goal of subsequent research should be to concentrate on those homes located closest to wind facilities, where the data sample herein was the most limited. Additional research of the nature reported in this paper could be pursued, but with a greater number of transactions, especially for homes particularly close to wind facilities. A more detailed analysis of sales volume impacts may also be fruitful, as would an assessment of the potential impact of wind facilities on the length of time homes are on the market in advance of an eventual sale. Finally, it would be useful to conduct a survey of those homeowners living close to existing wind facilities, and especially those residents who have bought and sold homes in proximity to wind facilities after facility construction, to assess their opinions on the impacts of wind project development on their home purchase and sales decisions.

# 1. Introduction

Wind power development has expanded dramatically in recent years (GWEC, 2009). Although the percent of electricity supplied to the U.S. and globally from wind power projects installed through 2008 remains relatively low (1.9% and 1.5%, respectively) (Wiser and Bolinger, 2009), there are expectations that those percentages will rise and that wind energy could contribute a significant percentage of future electricity supply (GWEC, 2008; Wiser and Hand, 2010). Most recently, President Obama, in his 2009 State of the Union address, called for a doubling of renewable energy in three years (by 2012), and in 2008 the U.S. Department of Energy produced a report that analyzed the feasibility of meeting 20% of U.S. electricity demand with wind energy by 2030 (US DOE, 2008).

To meet these goals, a significant amount of wind project development activity would be required. The average size of wind power projects built in the U.S. in 2007 and 2008 was approximately 100 MW (Wiser and Bolinger, 2009) and the total amount of capacity required to reach 20% wind electricity is roughly 300,000 MW (US DOE, 2008). Therefore, to achieve 20% wind electricity by 2030, a total of 3,000 wind facilities may need to be sited and permitted. Most permitting processes in the U.S. require some form of environmental impact assessment, and some form of public involvement in the siting process. Though surveys show that public acceptance is high in general for wind energy (e.g., Wolsink, 2000; Firestone and Kempton, 2006), a variety of concerns are often expressed on the local level that can impact the length and outcome of the siting and permitting process. These concerns range from the potential impacts of wind projects on wildlife habitat and mortality, radar and communications systems, ground transportation and historic and cultural resources, to aesthetic and property value concerns as well as potential nuisance and health impacts. As a result, a variety of siting and permitting guidelines (AWEA, 2008) and impact assessments (NAS, 2007) have been completed.

Surveys of local communities considering wind facilities have consistently ranked adverse impacts on aesthetics and property values in the top tier of concerns (e.g., BBC R&C, 2005; Firestone and Kempton, 2006). Developers of wind energy echo this assessment: they ranked aesthetics and property values as two of the top concerns (first and third respectively) for individuals or communities opposed to wind power development (Paul, 2006). Local residents have even brought suit against a developer over property values (Dale Rankin v. FPL, 2008), and some developers have responded to these concerns by offering "neighbor agreements" that compensate nearby homeowners for the potential impacts of wind projects.

The two concerns of aesthetics and property values are intrinsically linked. It is well established that a home's value will be increased if a high-quality scenic vista is enjoyed from the property (e.g., Seiler et al., 2001). Alternatively, it is reasonable to assume that if a home's scenic vista overlaps with a view of a disamenity, the home might be devalued, as has been found for high-voltage transmission lines (HVTL) (Kroll and Priestley, 1992; Des-Rosiers, 2002). Whether a view of wind turbines similarly impacts home values is a key topic of debate in local siting decisions. Aesthetics alone, however, is not the only pathway through which wind projects might impact residential property values. Distance to the nearest wind turbine, for example, might also have an impact if various nuisance effects are prominent, such as turbine noise, shadow flicker,[5] health or safety concerns, or other impacts, real or perceived. In this way, property values near wind turbines might be impacted in the same way as homes near roads might be devalued (Bateman et al., 2001). Additionally, there is evidence that proximity to a disamenity, even if that disamenity is not visible and is not so close as to have obvious nuisance effects, may still decrease a home's sales price, as has been found to be the case for landfills (Thayer et al., 1992).

Taken together, these general concerns about the possible impacts of wind projects on residential property values can be loosely categorized into three potential stigmas:

- Area Stigma: A concern that the general area surrounding a wind energy facility will appear more developed, which may adversely affect home values in the local community regardless of whether any individual home has a view of the wind turbines.
- Scenic Vista Stigma: A concern that a home may be devalued because of the view of a wind energy facility, and the potential impact of that view on an otherwise scenic vista.
- Nuisance Stigma: A concern that factors that may occur in close proximity to wind turbines, such as sound and shadow flicker, will have a unique adverse influence on home values.

These three potential stigmas are not mutually exclusive and could, in theory, be present in part or in combination for any single home. Consequently, all three potential impacts must be considered when analyzing the effects of wind facilities on residential sales prices.

Although concerns about the potential impact of wind projects on residential property values are often mentioned in siting cases, the state of the existing literature on this topic leaves much to be desired. To some extent, the growing body of research investigating this topic has come to opposing conclusions. The most recent and comprehensive of these studies have often concluded that no widespread impacts of wind projects on residential property values are apparent (Hoen, 2006; Sims and Dent, 2007; Sims et al., 2008). At the same time, pre-construction surveys of both homeowners and real estate experts have sometimes found an expectation of negative impacts (e.g. Haughton et al., 2004), and post-construction appraisals have sometimes come to similar conclusions (McCann, 2008; Kielisch, 2009). Given the state of the literature, it is not uncommon for local siting and permitting processes to involve contradicting testimony from experts, as occurred in 2004 when the Public Service Commission of Wisconsin heard opposing conclusions from two studies conducted by experienced home valuation experts (Poletti, 2005; Zarem, 2005).

This report contains the most comprehensive and data-rich analysis to date on the potential impacts of wind projects on nearby residential sales prices. Data from 7,459 residential transactions were collected from the surrounding communities of 24 individual wind projects in nine states and 14 counties in the United States.[6] Because of the large sample size, the diversity of wind projects included in the analysis, and the depth of information collected, a number of different analyses were possible. Specifically, this report relies heavily on a hedonic regression

[5] Shadow flicker occurs when the sun shines through the wind turbine blades when at a low angle to the horizon and shadows are cast on a window or interior wall of a residence (NAS, 2007).

[6] The majority of the analysis only includes homes that sold after wind facility construction began, totaling 4,937 transactions.

model[7] and uses various forms of that model to investigate potential effects and to confirm the robustness of the resulting findings. To further investigate the robustness of the results, a repeat sales model[8] and a sales volume model[9] are also utilized. In sum, this work builds and improves on the previous literature, and provides an in-depth assessment of the question of whether residential property values in the United States have been affected, in a statistically measurable way, by views of and proximity to wind power facilities.

The remainder of this report is structured as follows. The next section discusses the hedonic model in general, its application to environmental disamenities research, and some potentially analogous results drawn from these studies. This is followed by a summary of the existing literature that has investigated the effects of wind energy on residential property values. The report then turns to the data used in the analysis, a discussion of the primary (or "base") hedonic model, and an analysis of the results from that statistical model. Following that, a set of alternative hedonic models are estimated, as well as a repeat sales model and sales volume model, to test for the robustness of the "base" model results and to explore other aspects of the data. Taking into account the full set of results presented earlier, the report then discusses the three stigmas that may lead to wind projects impacting residential property values, and summarizes how the analysis informs the existence and magnitude of these potential effects. The report ends with a brief conclusion, and a discussion of future research possibilities. A number of appendices follow the conclusion, and contain detailed information on each wind project study area, the data collection instrument and qualitative rating systems used in the field research, the investigation of the best "base" model, the hedonic model assumptions and related tests, and full results from all of the additional statistical models estimated in the report.

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7 The hedonic regression model, which was briefly described in a sidebar in the Executive Summary, is described in detail in Section 2.1.

8 A repeat sales model uses, as its dataset, only those homes that have sold more than once. By comparing annual appreciation rates of homes that sold once before facility announcement, and again after construction, it can be tested, in an alternative fashion, if home values are affected by the distance to or view of nearby wind turbines.

9 Sales volume can be defined as the percentage of homes that fit a certain criteria (e.g. single family, on less than 25 acres, zoned residential, assessed for more than $10,000) that actually did sell. By comparing sales volumes at various distances to wind facilities, before and after the facility was built, a further robustness test is possible.

## 2. Previous Research

Hedonic pricing models are frequently used to assess the marginal impacts of house and community characteristics on sales prices and by extension on property values in general. Because the hedonic model is the primary statistical method used in this report, this section begins by describing the model in more detail and providing some relevant examples of its use. The section then reviews the existing literature on the effects of wind energy facilities on surrounding property values, highlights the shortcomings of that literature, and outlines how the present research addresses those shortcomings.

### 2.1. Hedonic Models and Environmental Disamenities

A house can be thought of as a bundle of characteristics (e.g., number of square feet, number of bathrooms, number of fireplaces, and amount of acreage). When a price is agreed upon between a buyer and seller there is an implicit understanding that those characteristics have value. When data from a number of sales transactions are available, the individual marginal contribution to the sales price of each characteristic can be estimated with a hedonic regression model (Rosen, 1974; Freeman, 1979). This relationship takes the basic form:

Sales price = *f*(house structural characteristics, other factors)

where "house structural characteristics" might include, but are not limited to, the number of square feet of living area, bathrooms, and fireplaces, the presence of central AC and the condition of the home, and "other factors" might include, but are not limited to, home site characteristics (e.g., number of acres), neighborhood characteristics (e.g., school district), market conditions at the time of sale (e.g., prevailing mortgage interest rates), and surrounding environmental conditions (e.g., proximity to a disamenity or amenity).

The relationship between the sales price of homes and the house characteristics and other factors can take various forms. The most common functional form is the semi-log construction where the dependent variable is the natural log of the inflation adjusted sales price, and the independent variables are unadjusted (not transformed) home characteristics and other factors. The usefulness of this form of hedonic model is well established (Malpezzi, 2003; Sirmans et al., 2005b; Simons and Saginor, 2006) assuming that certain threshold assumptions are met.[10] The model is used commonly by academics, real estate assessors, appraisers, and realtors when large datasets are available on past residential sales transactions, and when estimates of the marginal impact of certain house characteristics and other factors on sales prices are desired.[11]

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[10] These assumptions, which are discussed in greater detail in Section 4.2 and Appendix G, include absence of outliers and/or influencers, presence of homoskedastic variances, absence of spatial and temporal autocorrelation, and absence of collinearity between the variables of interest and other independent variables.

[11] It should be emphasized that a hedonic model is not designed to appraise properties (i.e., to establish an estimate of the market value of a home at a specified point in time), as would be done with an automated valuation model (AVM). Rather, hedonic models are designed to estimate the marginal contribution of individual house or community characteristics to sales prices, which requires hedonic models to rely upon large data sets with a sizable number of explanatory variables. Appraisal models, on the other hand, are generally based on small, localized data sets (i.e., "comps") and a limited number of explanatory variables that pertain to nearby properties. Due to their higher level of accuracy through the use of significantly more information (e.g., diverse spatial, temporal, and

A particularly useful application of the hedonic regression model is to value non-market goods – goods that do not have transparent and observable market prices. For this reason, the hedonic model is often used to derive value estimates of amenities such as wetlands (e.g., Mahan et al., 2000) or lake views (e.g., Seiler et al., 2001), and disamenities, such as proximity to and/or views of high-voltage transmission lines (HVTLs) (e.g. Des-Rosiers, 2002), fossil fuel power plants (Davis, 2008), roads (e.g. Bateman et al., 2001), cell phone towers (e.g. Bond and Wang, 2007), and landfills (e.g., Thayer et al., 1992; Ready and Abdalla, 2005).

There are a number of useful reviews that describe the application of hedonic models in these circumstances (Kroll and Priestley, 1992; Farber, 1998; McCann, 1999; Bateman et al., 2001; Boyle and Kiel, 2001; Jackson, 2001; Ready and Abdalla, 2005; Simons and Saginor, 2006; Simons, 2006b; Leonard et al., 2008).[12] The large number of studies covered in these reviews demonstrate that hedonic models are regularly used to investigate the interplay between home values and distance to potential disamenities, teasing out if and how sales prices are adversely affected depending on the distance of a typical home from a disamenity. For example, Carroll et al. (1996) use a hedonic model to estimate a devaluation of 16% for homes "close to" a chemical plant, with a 6.5% increase in sales price per mile away out to 2.5 miles, at which point effects fade entirely. Dale et al. (1999) find a maximum effect of -4% near a lead smelter, with sales prices increasing 2% for each mile away out to two miles, where effects again fade. Ready and Abdalla (2005) find maximum effects near landfills of -12.4%, which fade entirely outside 2,400 feet, and maximum effects near confined animal feeding operations of -6.4%, which fade entirely outside of 1,600 feet. Meanwhile, studies of other energy infrastructure, such as HVTLs, find maximum effects of -5.7% for homes adjacent to a HVTL tower, and an increase in prices of 0.018% per foot away from the tower out to 300 feet (Hamilton and Schwann, 1995), and maximum effects of -14% for homes within 50 feet of a HVTL, but no effect for similar homes at 150 feet (Des-Rosiers, 2002). Further, for fossil fuel power plants, Davis (2008) finds average adverse effects of between 3 and 5% inside of two miles but that those effects fade entirely outside of that distance range.

In addition to investigating how sales prices change with distance to a disamenity, hedonic models have been used to investigate how prices have changed over time. For instance, sales prices have sometimes been found to rebound after the removal of a disamenity, such as a lead smelter (Dale et al., 1999), or to fade over time, as with HVTLs (Kroll and Priestley, 1992) or spent fuel storage facilities (Clark and Allison, 1999). Finally, hedonic models have been used to estimate how views of a disamenity affect sales prices. Des-Rosiers (2002), for example, finds that homes adjacent to a power line and facing a HVTL tower sell for as much as 20% less than similar homes that are not facing a HVTL tower.

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characteristic information) and rigorous methodology, hedonic models can also be used as appraisal models. Automated valuation models cannot, however, be reliably used to measure marginal effects because they do not employ sufficient information to do so, and, more importantly, AVMs do not hold controlling characteristics constant, which could bias any resulting estimates of marginal effects.

[12] For further discussion of the hedonic model and its application to the quantification of environmental stigmas in comparison to other methods see Jackson (2005).

It is unclear how well the existing hedonic literature on other disamenities applies to wind turbines, but there are likely some similarities. For instance, in general, the existing literature seems to suggest that concerns about lasting health effects provide the largest diminution in sales prices, followed by concerns for one's enjoyment of the property, such as auditory and visual nuisances, and that all effects tend to fade with distance to the disamenity - as the perturbation becomes less annoying. This might indicate that property value effects from wind turbines are likely to be the most pronounced quite close to them, but fade quickly as their auditory and visual impacts fade. The existing hedonic literature also, in general, finds that effects fade with time as self-selecting buyers without prejudice towards the disamenity move into the area, or as the real or perceived risks of the disamenity are lessoned (Jackson, 2001). This implies that any stigmas related to wind turbines might also fade over time as local communities come to accept their presence.

## 2.2. Impacts of Wind Projects on Property Values

Turning to the literature that has investigated the potential property value effects from wind facilities directly, it deserves note that few studies have been academically peer-reviewed and published; in some cases, the work has been performed for a party on one side or the other of the permitting process (e.g., the wind developer or an opposition group). Nonetheless, at a minimum, a brief review of this existing literature will set the stage for and motivate the later discussion of the methods and results of the present work. The literature described below is summarized in Table 1. To frame this discussion, where possible, the three potential stigmas discussed earlier are used:

- Area Stigma: A concern that the general area surrounding a wind energy facility will appear more developed, which may adversely affect home values in the local community regardless of whether any individual home has a view of the wind turbines.
- Scenic Vista Stigma: A concern that a home may be devalued because of the view of a wind energy facility, and the potential impact of that view on an otherwise scenic vista.
- Nuisance Stigma: A concern that factors that may occur in close proximity to wind turbines, such as sound and shadow flicker, will have a unique adverse influence on home values.

In one of the most recent studies, Sims et al. (2008) used a hedonic model to investigate Scenic Vista Stigma using 199 residential transactions within ¼ of a mile of the 16-turbine Bears Down wind facility in Cornwall, UK. They found both large positive and smaller negative significant relationships between views of the turbines and sales prices depending on whether the view is seen from the front or rear of the home, respectively, but found no relationship between the number of wind turbines visible and sales prices. Previously, Sims and Dent (2007) used a hedonic model to investigate Nuisance and Scenic Vista Stigma with 919 transactions for homes within five miles of two wind facilities in the UK, finding only limited evidence of a relationship between proximity to and views of turbines and sales prices, which local real estate experts attributed to other causes. Hoen (2006) investigated Scenic Vista Stigma using a hedonic model to analyze 280 residential transactions occurring near a wind facility in Madison County, NY, and found no evidence that views of turbines significantly affects prices. Jordal-Jorgensen (1996) investigated Nuisance Stigma in Denmark, and found an adverse effect for homes located "close" to the turbines, but no statistical significance was reported.[13]

[13] A copy of this report could not be obtained and therefore its findings are reported based on other citations.

Using different statistical methods, Poletti (2005; 2007) used a $t$-Test to investigate Nuisance and Area Stigma by comparing the mean sales prices of 187 and 256 homes in Illinois and Wisconsin, respectively, located near wind facilities (target group) to those further away (control group).[14, 15] He split these target and control groups into respective smaller and more-homogenous sub-groups, such as large and small tracts, with and without homes, finding no statistical evidence that homes near the wind facilities sold for different prices than those farther away. Sterzinger et al. (2003) analyzed roughly 24,000 residential transactions, which were divided between those within five miles of a wind facility and those outside of five miles in an effort to assess Area Stigma. They compared residential appreciation rates over time, and found no apparent difference between those homes within and outside of five miles from a wind facility, but the statistical significance of this comparison was not reported.

Other authors have used smaller samples of residential transactions and a variety of simple statistical techniques, without reporting statistical significance, and have found a lack of evidence of effects from Nuisance Stigma (Jerabek, 2001; Jerabek, 2002; Beck, 2004) and Area Stigma (DeLacy, 2005; Goldman, 2006). These results, however, are somewhat contrary to what one appraiser has found. In his investigation of Nuisance Stigma around a wind facility in Lee County, IL, McCann (2008) found that two homes nearby a wind facility had lengthy selling periods that, he believes, also adversely affected transaction prices. Additionally, Kielisch (2009) investigated Nuisance Stigma by comparing twelve transactions of undeveloped land near two wind facilities in Wisconsin (Blue Sky Green Field and Forward) to undeveloped land transactions farther away. He found that land tracts near the wind facilities sold for dramatically lower prices ($/acre) than the comparable group, but the statistical significance of the comparison was not reported.

In addition to these revealed preference studies, a number of stated preference surveys (e.g., contingent valuation) and general opinion surveys have investigated the existence of potential effects.[16] A survey of <u>local residents</u>, conducted after the wind facilities were erected, found no evidence of Area Stigma (Goldman, 2006), while another found limited evidence of these stigmas (Bond, 2008).[17] Similarly, some surveys of <u>real estate experts</u> conducted after facility

[14] A $t$-Test is used to compare two sample means by discerning if one is significantly different from the other.

[15] The 2007 study used the data contained in the 2005 study in combination with new data consisting of transactions that occurred in the interim period.

[16] Contingent valuation is a survey based technique to value non-market goods (e.g., an environmental disamenity) that asks respondents what their "willingness to pay" (or "willingness to accept") is to have, for instance, a disamenity removed from (or to have it remain in) their neighborhood. This technique is distinct from a general opinion survey, which might ask whether respondents believe property values have been impacted by an environmental disamenity and, if so, "by how much." Although there are important distinctions between the two techniques, with the contingent valuation method often preferred by economic practitioners, for simplicity no distinction is made here between these two approaches. Finally, another subset of the survey literature focuses on public acceptance (i.e., opinion). Though these public acceptance surveys sometimes cover possible impacts on property values, those impacts are not quantified in economic terms. As a result, public acceptance survey results are not reported here.

[17] Bond (2008) asked respondents to declare if the wind facility, which is located roughly 7 miles away, would effect what they would be willing to pay for their house and 75% said either they would pay the same or more for their house, while the remainder would pay less. When those latter respondents were asked to estimate the percentage difference in value, their estimates averaged roughly 5%.

construction have found no evidence of Area or Nuisance Stigmas (Grover, 2002; Goldman, 2006). These results, however, are contrary to the expectations for Area, Scenic Vista, and Nuisance Stigma effects predicted by local residents (Haughton et al., 2004; Firestone et al., 2007) and real estate experts (Haughton et al., 2004; Khatri, 2004; Kielisch, 2009) prior to construction found elsewhere.[18] The difference between predicted and actual effects might be attributable, at least in part, to the fear of the unknown. For instance, Wolsink (1989) found that public attitudes toward wind power, on average, are at their lowest for local residents during the wind project planning stage, but return almost to pre-announcement levels after the facilities are built. This result is echoed by Exeter-Enterprises-Ltd. (1993) and Palmer (1997), whose post-construction surveys found higher approval than those conducted pre-construction. Others, however, have found that perceptions do not always improve, attributing the lack of improvement to the perceived "success" or lack therefore of the project, with strong disapproval forming if turbines sit idle (Thayer and Freeman, 1987) or are perceived as a waste of taxpayer dollars (Devine-Wright, 2004).

When this literature is looked at as a whole, it appears as if wind projects have been predicted to negatively impact residential property values when pre-construction surveys are conducted, but that sizable, widespread, and statistically significant negative impacts have largely failed to materialize post-construction when actual transaction data become available for analysis. The studies that have investigated Area Stigma with market data have failed to uncover any pervasive effect. Of the studies focused on Scenic Vista and Nuisance Stigmas, only one is known to have found statistically significant adverse effects, yet the authors contend that those effects are likely driven by variables omitted from their analysis (Sims and Dent, 2007). Other studies that have relied on market data have sometimes found the possibility of negative effects, but the statistical significance of those results have rarely been reported.

Despite these findings, the existing literature leaves much to be desired. First, many studies have relied on surveys of homeowners or real estate professionals, rather than trying to quantify real price impacts based on market data. Second, a number of studies conducted rather simplified analyses of the underlying data, potentially not controlling for the many drivers of residential sales prices. Third, many of the studies have relied upon a very limited number of residential sales transactions, and therefore may not have had an adequate sample to statistically discern any property value effects, even if effects did exist. Fourth, and perhaps as a result, many of the studies did not conduct, or at least have not published, the statistical significance of their results. Fifth, when analyzed, there has been some emphasis on Area Stigma, and none of the studies have investigated all three possible stigmas simultaneously. Sixth, only a few of the studies (Hoen, 2006; Sims and Dent, 2007; Sims et al., 2008; Kielisch, 2009) conducted field visits to the homes to assess the quality of the scenic vista from the home, and the degree to which the wind facility might impact that scenic vista. Finally, with two exceptions (Sims and Dent, 2007; Sims et al., 2008), none of the studies have been academically peer-reviewed and published.

[18] It should be noted that the samples used by both Khatri and Kielisch contained a subset of respondents who did have some familiarity with valuing homes near wind facilities.

Table 1: Summary of Existing Literature on Impacts of Wind Projects on Property Values

| Document Type<br>Author(s) | Year | Number of Transactions or Respondents | Before or After Wind Facility Construction Commenced | Area Stigma | Scenic Vista Stigma | Nuisance Stigma |
|---|---|---|---|---|---|---|
| **Homeowner Survey** | | | | | | |
| Haughton et al. | 2004 | 501 | Before | - * | - * | |
| Goldman | 2006 | 50 | After | none | | |
| Firestone et al. | 2007 | 504 | Before | - * | - * | |
| Bond | 2008 | ~300 | After | | - ? | - ? |
| **Expert Survey** | | | | | | |
| Grover | 2002 | 13 | After | none | | none |
| Haughton et al. | 2004 | 45 | Before | - * | - * | |
| Khatri | 2004 | 405 | Before‡ | - ? | | - ? |
| Goldman | 2006 | 50 | After | none | | none |
| Kielisch | 2009 | 57 | Before‡ | | | - ? |
| **Transaction Analysis - Simple Statistics** | | | | | | |
| Jerabek | 2001 | 25 | After | | | none |
| Jerabek | 2002 | 7 | After | | | none |
| Sterzinger et al. | 2003 | 24,000 | After | none | | |
| Beck | 2004 | 2 | After | | | none |
| Poletti | 2005 | 187 | After | none | | none |
| DeLacy | 2005 | 21 | Before† | none | | |
| Goldman | 2006 | 4 | After | none | | |
| Poletti | 2007 | 256 | After | none | | none |
| McCann | 2008 | 2 | After | | | - ? |
| Kielisch | 2009 | 103 | After | | | - ? |
| **Transaction Analysis - Hedonic Model** | | | | | | |
| Jordal-Jorgensen | 1996 | ? | After | | | - ? |
| Hoen | 2006 | 280 | After | | none | |
| Sims & Dent | 2007 | 919 | After | | | - * |
| Sims et al. | 2008 | 199 | After | | -/+ * | |

*"none" indicates the majority of the respondents do not believe properties have been affected (for surveys) or that no effect was detected at 10% significance level (for transaction analysis)*

*"- ?" indicates a negative effect without statistical significance provided*

*"- *" indicates statistically significant negative effect at 10% significance level*

*"-/+ *" indicates positive and negative statistically significant effects at 10% significance level*

*† Sales were collected after facility announcement but before construction*

*‡ Some respondents had experience with valuations near facilities while others did not*

## 3. Data Overview

The methods applied in the present work are intended to overcome many of the limitations of the existing literature. First, a large amount of data is collected from residential transactions within 10 miles of 24 different wind projects in the U.S., allowing for a robust statistical analysis across a pooled dataset that includes a diverse group of wind project sites. Second, all three potential stigmas are investigated by exploring the potential impact of wind projects on home values based both on the distance to and view of the projects from the homes. Third, field visits are made to every home in the sample, allowing for a solid assessment of the scenic vista enjoyed by each home and the degree to which the wind facility can be seen from the home, and to collect other value-influencing data from the field (e.g., if the home is situated on a cul-de-sac). Finally, a number of hedonic regression models are applied to the resulting dataset, as are repeat sales and sales volume analyses, in order to assess the robustness of the results.

Testing for the three potential stigmas requires a significant sample of residential transactions within close proximity to existing wind facilities. Unfortunately for the study, most wind power projects are not located near densely populated areas. As a result, finding a single wind project site with enough transaction data to rigorously analyze was not possible. Instead, the approach was to collect data from multiple wind project sites, with the resulting data then pooled together to allow for robust statistical analyses.[19] The remainder of this section describes the site selection process that is used, and provides a brief overview of both the selected study areas and the data that were collected from these areas. Also provided is a description of how scenic vista, views of turbines, and distances from turbines were quantified for use in the hedonic analysis, and a summary of the field data collection effort. The section ends with a brief summary of the resulting dataset.

### 3.1. Site Selection

For the purpose of this study, an ideal wind project area would:

1) Have a large number of residential transactions both before and, more importantly, after wind facility construction, and especially in close proximity (e.g., within 2 miles) of the facility;
2) Have comprehensive data on home characteristics, sales prices, and locations that are readily available in electronic form; and
3) Be reasonably representative of the types of wind power projects being installed in the United States.

To identify appropriate sites that met these criteria, and that also provided a diversity of locations, the authors obtained from Energy Velocity, LLC a set of Geographic Information System (GIS) coordinates representing 241 wind projects in the U.S. that each had a total nameplate capacity greater than 0.6 megawatts (MW) and had gone online before 2006.[20] Also provided were facility capacity, number of turbines, and announcement, construction, and operational dates. These data were cross-checked with a similar dataset provided by the American Wind Energy Association (AWEA), which also included some turbine hub-height information.

[19] A thorough discussion of this "pooled" approach is contained in Section 4.2 and in Appendix F.

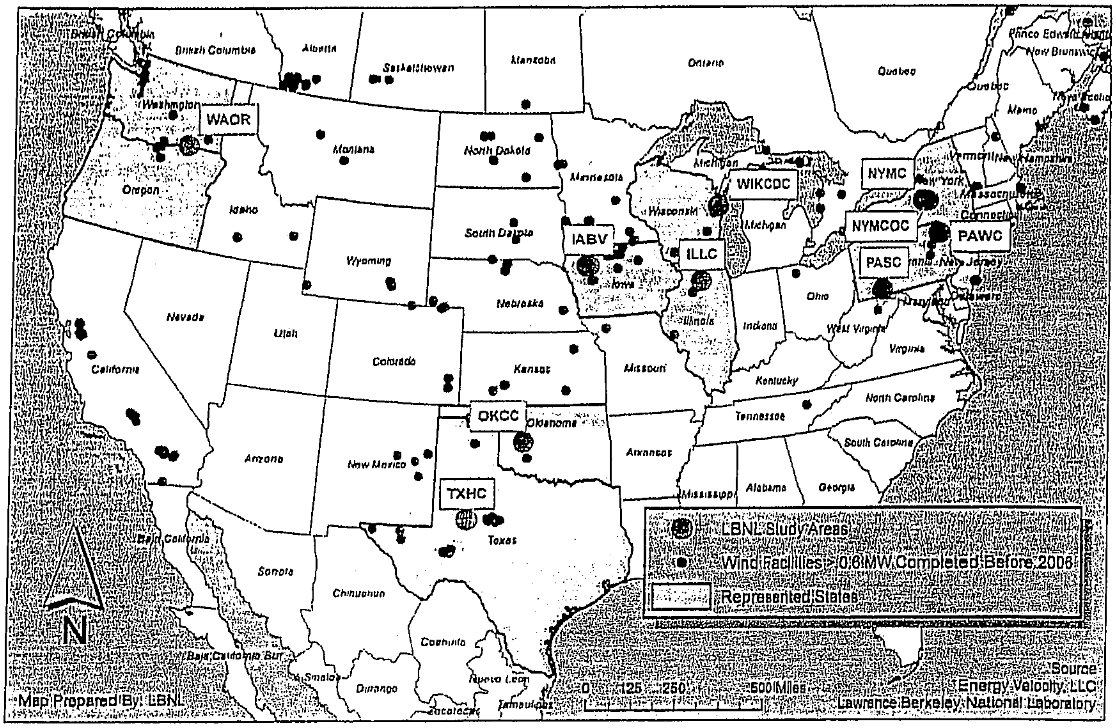
[20] Energy Velocity, LLC was owned at the time by Global Energy Decisions, which was later purchased by Ventyx. The dataset is available as Velocity Suite 2008 from Ventyx.

By using a variety of different GIS sorting techniques involving nearby towns with populations greater than, for example, 2,500 people, using census tract population densities, and having discussions with wind energy stakeholders, a prospective list of 56 possible study areas was generated, which were then ranked using two scales: "highly desirable" to "least desirable," and "feasible" to "potentially unfeasible."[21] Then, through an iterative process that combined calls to county officials to discuss the number of residential transactions and data availability, with investigations using mapping software to find the location of individual wind turbines, and, in some cases, preliminary visits, a list of 17 prospective study areas were chosen as both "highly desirable" and "feasible." Ultimately, three of these proved to be "unfeasible" because of data availability issues and four "undesirable" because the study area was considered not representative. This effort ultimately resulted in a final set of ten study areas that encompass a total of 24 distinct wind facilities (see Figure 1 and Table 2).[22] A full description of each study area is provided in Appendix A.

[21] "Desirability" was a combination of a number of factors: the wind facility having more than one turbine; the study area having greater than 350 sales within 5 miles and within 10 years, 250 of which transacted following construction of the facility; having some transaction data old enough to pre-date facility announcement; having data on the core home and site characteristics (e.g., square feet, acres); and, where possible, having a concentration of sales within 1 mile of the facility. "Feasibility" was also a combination of factors: having home characteristic and sales data in electronic form; having GIS shapefiles of the parcel locations; and being granted ready access to this information.

[22] The "unfeasible" study areas were Cerro Gordo County, IA, Bennington County, VT, and Atlantic County, NJ. Cerro Gordo County, IA contained multiple wind projects totaling 140 MW. Although the data at this site were available in electronic form, the county only agreed to share data in paper form, which would have created an enormous data entry burden. Because another site in the sample was considered similar to the Cerro Gordo site (IABV), Cerro Gordo County was dropped from the prospective sites. Bennington County, VT contained the 11 turbine Searsburg Wind Project (6 MW) but had no electronic records. Atlantic County, NJ contained the five turbine Jersey Atlantic Wind Farm (7.5 MW), but had data in paper records only and the county was unresponsive to inquiries regarding the study. The "undesirable" study areas were Plymouth County, MA, Wood County, OH, Cascade County, MT, and Riverside County, CA. Although the data in Plymouth County, MA were more than adequate, this small, on-land, yet coastal Hull Wind facility (2 turbines, 2.5 MW) was not considered to be particularly representative of wind development across the US. Wood County's four turbine Bowling Green facility (7 MW) met the appropriate data requirements, but ultimately it was decided that this facility was too small and remote to be representative. Cascade County's six turbine Horseshoe Bend Wind Park (9 MW) did not have enough transactions to justify study. Riverside, CA, where roughly 2500 turbines are located, had less-than-desired home characteristic data, had transactions that came more than 10 years after large scale development began, and despite having homes that were within 1 mile of the turbines, those homes typically had limited views because of high subdivision walls.

Figure 1: Map of Study Areas and Potential Study Areas




## Table 2: Summary of Study Areas

| Study Area Code | Study Area Counties, States | Facility Names | Number of Turbines | Number of MW | Max Hub Height (meters) | Max Hub Height (feet) |
|---|---|---|---|---|---|---|
| WAOR | Benton and Walla Walla Counties, WA and Umatilla County, OR | Vansycle Ridge, Stateline, Nine Canyon I & II, Combine Hills | 582 | 429 | 60 | 197 |
| TXHC | Howard County, TX | Big Spring I & II | 46 | 34 | 80 | 262 |
| OKCC | Custer County, OK | Weatherford I & II | 98 | 147 | 80 | 262 |
| IABV | Buena Vista County, IA | Storm Lake I & II, Waverly, Intrepid I & II | 381 | 370 | 65 | 213 |
| ILLC | Lee County, IL | Mendota Hills, GSG Wind | 103 | 130 | 78 | 256 |
| WIKCDC | Kewaunee and Door Counties, WI | Red River, Lincoln | 31 | 20 | 65 | 213 |
| PASC | Somerset County, PA | Green Mountain, Somerset, Meyersdale | 34 | 49 | 80 | 262 |
| PAWC | Wayne County, PA | Waymart | 43 | 65 | 65 | 213 |
| NYMCOC | Madison and Oneida Counties, NY | Madison | 7 | 12 | 67 | 220 |
| NYMC | Madison County, NY | Fenner | 20 | 30 | 66 | 218 |
| | | TOTAL | 1345 | 1286 | | |

These 10 study areas and 24 projects are located in nine separate states, and include projects in the Pacific Northwest, upper Midwest, the Northeast, and the South Central region. The wind projects included in the sample total 1,286 MW, or roughly 13% of total U.S. wind power capacity installed at the time (the end of 2005). Turbine hub heights in the sample range from a minimum of 164 feet (50 meters) in the Washington/Oregon (WAOR) study area, to a maximum of 262 (80 meters) (TXHC, OKCC and PASC), with nine of the ten study areas having hub heights of at least 213 feet (65 meters). The sites include a diverse variety of land types, including combinations of ridgeline (WAOR, PASC, and PAWC), rolling hills (ILLC, WIKCDC, NYMCOC, and NYMC), mesa (TXHC), and windswept plains (OKCC, IABV).[23]

## 3.2. Data Collection

In general, for each study area, residential transaction data in as close proximity to the wind turbines as possible was sought, from both before and after wind facility construction. To balance the cost and quantity of data collection in each study area with the desire to cover as many study areas as possible, the research effort sought to collect data on 400 to 1,250 transactions in each study area.[24] In some instances, this meant including all residential transactions within ten miles of the wind turbines. In others, only transactions within five miles were included. In some extreme instances, when the number of transactions inside of five miles far exceeded the 1,250 limit, all transactions in close proximity to the wind turbines (e.g., inside three miles) were included in combination with a random sample of transactions outside of that distance band (e.g., between three and five miles).[25] The data selection processes for each Study Area are contained in Appendix A.

Three primary sets of data are used in the analysis: tabular data, GIS data, and field data, each of which is discussed below. Following that, this subsection highlights the two qualitative variables that are essential to this analysis and that therefore require special attention, scenic vista and views of turbines, and then discusses the field data collection process.

### 3.2.1. Tabular Data

Berkeley Lab obtained tabular transaction data from participating counties[26] containing 7,459 "valid"[27] transactions of single family residential homes, on less than 25 acres,[28] which were

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[23] Some areas, such as PASC, had both a ridgeline and rolling hills on which wind facilities were located.

[24] This range was chosen to ensure that a minimum of data were present in each study area to allow for a robust analysis, and yet not too much so as to make data collection (e.g., the visiting of each home) inordinately time and resource consuming in any individual study area.

[25] An alternative method would have been to collect data on every sale that occurred. Although in most cases this would be preferred, in ours it would not have added one additional transaction within close proximity or with dramatic views of wind turbine, the focus of the study. Rather, it would have added an overwhelming majority of transactions of homes without views and at distances outside of three miles from the turbines, all of which would have come at considerably cost and, more importantly, would not likely have influenced the results significantly while perhaps necessitating a reduction in the total number of study areas that could be included in the sample.

[26] In some cases, the county officials, themselves, extracted data from their database, and in some cases a company engaged to manage a county's data provided the necessary information. In either case the provider is referred to as "county." Detailed descriptions of the providers are presented in Appendix A.

[27] Validity was determined by each individual county data provider. A sale that is considered "valid" for county purposes would normally meet the minimum requirements of being arm's length; being a transfer of all rights and warrants associated with the real estate; containing an insignificant amount of personal property so as not to affect the price; demonstrating that neither party in the sale acting under duress or coercion; not being the result of a liquidation of assets or any other auction, a mortgage foreclosure, a tax sale, or a quit claim; and being appropriate for use in calculating the sales price to assessed value ratios that are reported to the state. Due to the formal requirements associated with this calculation, "validity" is often defined by a state's Department of Revenue, as shown, for example, here: http://www.orps.state.ny.us/assessor/manuals/vol6/rfv/index.htm. In addition, though the

sold for a price of more than $10,000,[29] which occurred after January 1, 1996,[30] and which had fully populated "core" home characteristics. These core characteristics are: number of square feet of the living area (not including finished basement), acres of land, bathrooms, and fireplaces, the year the home was built,[31] if the home had exterior wallsthatwere stone, a central air conditioning unit, and/or a finished basement, and the exterior condition of the home. The 7,459 residential transactions in the sample consist of 6,194 homes (a number of the homes in the sample sold more than once in the selected study period). Because each transaction had a corresponding set of the core home characteristic data, they could all be pooled into a single model. In addition to the home characteristic data, each county provided, at a minimum, the home's physical address and sales price. The counties often also provided data on homes in the study area that did not sell in the study period.[32] Finally, market-specific quarterly housing inflation indexes were obtained from Freddie Mac, which allowed nominal sales prices to be adjusted to 1996 dollars.[33]

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sample originally contained 7,498 sales, 34 homes sold twice in a 6 month period and, after discussions with local officials, these transactions were considered likely to have been "invalid" despite the county coding them to the contrary. Additionally, five transactions produced standardized residuals that were more than six standard deviations away from the mean, indicating that these sales were abnormal and likely not valid. Both of these sets of transactions, totaling 39, were removed from the final dataset. Of the 39 sales, 32 sold following construction, 10 were concentrated in IABV and nine in TXHC with the others spread between seven of the remaining eight study areas. One of the homes was inside of one mile from the turbines at the time of sale, and two had views of the turbines (both of which were MINOR). The home that was located within one mile was surrounded by a number of other homes – at similar distances from the turbines - that transacted both before and after the wind facilities were built and were included in the sample. A more thorough discussion of the screening techniques used to ensure the appropriateness of the final data set are presented in detail in Appendix G under "Outliers/Influencers." Finally, it should be noted that the authors are aware of four instances in the study areas when homes were sold to wind developers. In two cases the developer did not resell the home; in the other two, the developer resold the home at a lower price than which it was purchased. But, because the sales were to a related party, these transactions were not considered "valid' and are therefore not included here. One might, however, reasonably expect that the property values of these homes were impacted by the presence of the wind turbines.

[28] Single family residences on more than 25 acres were considered to be likely candidates for alternative uses, such as agricultural and recreational, which could have an influence on sales price that was outside of the capabilities of the model to estimate. Because all records were for parcels that contained a residence, the model did not contain any "land-only" transactions. Further, none of the transactions provided for this research were for parcels on which a turbine was located.

[29] A sales price of $10,000 was considered the absolute minimum amount an improved parcel (one containing a residential structure) would sell for in any of the study areas and study periods. This provided an additional screen over and above the "valid" screen that the counties performed.

[30] This provided a maximum of 12 years of data. Some counties did not have accessible data back to 1996 but in all cases these countries had data on transactions that occurred before the wind facilities were erected.

[31] "Year Built" was used to construct a variable for the age of the home at the time of the sale.

[32] These data were used to calculate the "Sales Volume" percentages referred to in Section 7.

[33] Freddie Mac Conventional Mortgage Home Price Index: municipal statistical area (MSA) series data are available from the following site: http://www.freddiemac.com/finance/cmhpi/. Because most of the study areas do not fall within the MSAs, a collection of local experts was relied upon, including real estate agents, assessors, and appraisers, to decide which MSA most-closely matched that of the local market. In all cases the experts had consensus as to the best MSA to use. In one case (NYMCOC) the sample was split between two MSAs. These indexes are adjusted quarterly, and span the entire sample period. Therefore, during the housing boom, insofar as a boom occurred in the sample areas, the indexes increased in value. Subsequently when the market began falling, the index retracted.

### 3.2.2. GIS Data

GIS data on parcel location and shape were also required, and were obtained from the counties. The counties also often provided GIS layers for roads, water courses, water bodies, wind turbines (in some cases), house locations, and school district and township/town/village delineations. GIS data on census tract and school district delineations were obtained from the U.S. Census Bureau, if not provided by the county.[34] GIS data were obtained on water courses, water bodies, land elevations, and satellite imagery, as was necessary, from the U.S. Department of Agriculture.[35] Combined, these data allowed each home to be identified in the field, the construction of a GIS layer of wind turbine locations for each facility, and the calculation of the distance from each home to the nearest wind turbine.[36] Determining the distance from each home to the nearest wind turbine was a somewhat involved process, and is discussed in detail in Appendix B. Suffice it to say that each transaction had a unique distance ("DISTANCE")[37] that was determined as the distance between the home and nearest wind turbine at the time of sale, and that these distances are grouped into five categories: inside of 3000 feet (0.57 miles), between 3000 feet and one mile, between one and three miles, between three and five miles, and outside of five miles.[38] Finally, the GIS data were used to discern if the home was situated on a cul-de-sac and had water frontage, both of which were corroborated in the field.

### 3.2.3. Field Data

Additional data had to be collected through field visits to all homes in the sample. Two qualitative measures in particular – for scenic vista and for view of the wind turbines – are worth discussing in detail because each is essential to the analysis and each required some amount of professional judgment in its creation.

The impact or severity of the view of wind turbines ("VIEW") [39] may be related to some combination of the number of turbines that are visible, the amount of each turbine that is visible (e.g., just the tips of the blades or all of the blades and the tower), the distance to the nearest turbines, the direction that the turbines are arrayed in relation to the viewer (e.g., parallel or perpendicular), the contrast of the turbines to their background, and the degree to which the turbine arrays are harmoniously placed into the landscape (Gipe, 2002). Recent efforts have made some progress in developing quantitative measures of the aesthetic impacts of wind turbines (Torres-Sibillea et al., 2009),[40] but, at the time this project began, few measures had

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[34] These data were sourced from the U.S. Census Bureau's Cartographic Boundary Files Webpage: http://www.census.gov/geo/www/cob/bdy_files.html.

[35] These data were sourced from the USDA Geospatial Data Gateway: http://datagateway.nrcs.usda.gov/GatewayHome.html.

[36] Although in some cases the county provided a GIS layer containing wind turbine points, often this was not available. A description of the turbine mapping process is provided in Appendix B.

[37] Distance measures are collectively and individually referred to as "DISTANCE" from this point forward.

[38] The minimum distance of "inside 3000 feet" was chosen because it was the closest cutoff that still provided an ample supply of data for analysis.

[39] View of turbines ratings are collectively and individually referred to as "VIEW" from this point forward.

[40] In addition to these possible field techniques, previous studies have attempted to use GIS to estimate wind turbine visibility using "line-of-sight" algorithms. For example, Hoen (2006) used these algorithms after adding ground cover to the underlying elevation layer. He found that the GIS method differed substantially from the data collected in the field. Seemingly, small inaccuracies in the underlying elevation model, errors in the software's algorithm, and the existence of ground cover not fully accounted for in the GIS, substantially biased GIS-based assessments of

been developed, and what had been developed was difficult to apply in the field (e.g., Bishop, 2002). As a result, the authors opted to develop an ordered qualitative VIEW rating system that consisted of placing the view of turbines into one of five possible categories: NO VIEW, MINOR, MODERATE, SUBSTANTIAL, and EXTREME. These ratings were developed to encompass considerations of distance, number of turbines visible, and viewing angle into one ordered categorical scale, and each rating is defined in Table 3:[41]

**Table 3: Definition of VIEW Categories**

| | |
|---|---|
| NO VIEW | The turbines are not visible at all from this home. |
| MINOR VIEW | The turbines are visible, but the scope (viewing angle) is narrow, there are many obstructions, or the distance between the home and the facility is large. |
| MODERATE VIEW | The turbines are visible, but the scope is either narrow or medium, there might be some obstructions, and the distance between the home and the facility is most likely a few miles. |
| SUBSTANTIAL VIEW | The turbines are dramatically visible from the home. The turbines are likely visible in a wide scope and most likely the distance between the home and the facility is short. |
| EXTREME VIEW | This rating is reserved for sites that are unmistakably dominated by the presence of the wind facility. The turbines are dramatically visible from the home and there is a looming quality to their placement. The turbines are often visible in a wide scope or the distance to the facility is very small. |

*Photographic examples of each of the categories are contained in Appendix E.*

visibility. This was corroborated elsewhere by Maloy and Dean (2001) and Riggs and Dean (2007). As a result of these findings, it was determined that field collection of VIEW data was essential.

[41] In addition to the qualitative rating system that was ultimately used in this study, a variety of quantitative data were collected that might describe the nature of the view of wind turbines, including the total number of turbines visible, the distance of the home to the nearest wind turbine, and the view scope/viewing angle (i.e., the degree to which the turbines spread out in front of the home: narrow, medium, or wide). To explore the validity of the qualitative rating scale two tests were conducted. First, a pre-study survey was conducted by showing 10 different off-site respondents 15 randomly selected photographs from the field representing the various rated VIEW categories. The higher VIEW ratings were oversampled to create a roughly equal distribution among the categories. The respondents rated the views into one of the qualitative categories. The on-site / field collected ratings matched the off-site responses 65% of the time, with 97% of the rankings differing by no more than one category. Ninety-eight percent of the on-site-ranked MINOR VIEWs and 89% of the EXTREME VIEWs were similarly ranked by off-site respondents. The on-site rankings were less than the off-site rankings 97% of the time; it is assumed that this is because on-site ratings took into account a greater portion of the panorama than were captured in the photos, which translated into a lower ranking. Secondly, a post hoc Multinomial Logistic Regression model was created that used the qualitative on-site VIEW ratings as the dependent variable and the quantitative measures of distance to nearest turbine, number of turbines visible, and view scope as the independent variables. This model produced high Pseudo $R^2$ statistics (Cox and Snell 0.88, Nagelkerke 0.95, and McFadden 0.79) and predicted values that were highly correlated with the actual qualitative rating (Pearson's 0.88). Therefore, both tests corroborated the appropriateness of the simpler qualitative VIEW rankings used herein.

In addition to the qualitative VIEW measurements, a rating for the quality of the scenic vista ("VISTA")[42] from each home, absent the existence of the wind facilities, was also collected in the field. An assessment of the quality of the VISTA from each home was needed because VIEW and VISTA are expected to be correlated; for example, homes with a PREMIUM VISTA are more likely to have a wide viewing angle in which wind turbines might also be seen. Therefore, to accurately measure the impacts of the VIEW of wind turbines on property values a concurrent control for VISTA (independent of any views of turbines) is required. Drawing heavily on the landscape-quality rating system developed by Buhyoff et al. (1994) and to a lesser degree on the systems described by others (Daniel and Boster, 1976; USDA, 1995), an ordered VISTA rating system consisting of five categories was developed: POOR, BELOW AVERAGE, AVERAGE, ABOVE AVERAGE, and PREMIUM, with each rating defined in Table 4:[43]

**Table 4: Definition of VISTA Categories**

| | |
|---|---|
| POOR VISTA | These vistas are often dominated by visually discordant man-made alterations (not considering turbines), or are uncomfortable spaces for people, lack interest, or have virtually no recreational potential. |
| BELOW AVERAGE VISTA | These scenic vistas contain visually discordant man-made alterations (not considering turbines) but are not dominated by them. They are not inviting spaces for people, but are not uncomfortable. They have little interest or mystery and have minor recreational potential. |
| AVERAGE VISTA | These scenic vistas include interesting views that can be enjoyed often only in a narrow scope. These vistas may contain some visually discordant man-made alterations (not considering turbines), are moderately comfortable spaces for people, have some interest, and have minor recreational potential. |
| ABOVE AVERAGE VISTA | These scenic vistas include interesting views that often can be enjoyed in a medium to wide scope. They might contain some man-made alterations (not considering turbines), yet still possess significant interest and mystery, are moderately balanced and have some potential for recreation. |
| PREMIUM VISTA | These scenic vistas would include "picture postcard" views that can be enjoyed in a wide scope. They are often free or largely free of any discordant man made alterations (not considering turbines), possess significant interest, memorable qualities, and mystery and are well balanced and likely have a high potential for recreation. |

*Photographic examples of each of the categories are contained in Appendix D.*

[42] Scenic vista ratings are individually and collectively referred to as "VISTA" from this point forward.

[43] The appropriateness of these rankings were tested in two ways. First, a set of 34 pictures taken on-site and representing various categories of VISTA were shown to 10 off-site respondents who were asked to rank them using the same categories, and then explain why they rated them as such. Although the off-site ratings matched the on-site ratings only 51% of the time, 94% of on- and off-site rankings differed by no more than one category, with 17% of the off-site rankings below the on-site and 26% ranked above. The descriptions of why the rankings where chosen by the off-site respondents illuminated the fact that off-site ratings did not take into account a number of aspects that were not adequately captured in the photos, but that were apparent in the field. This finding was borne out by a second test that had five individuals visit seven homes in the field to rank their scenic vistas. When all respondents were on-site, they similarly ranked the vista 72% of the time, with a rankingthat differed by no more than one category occurring one hundred percent of the time.

In addition to the VIEW and VISTA ratings, it was assumed that the orientation of the home to the view of turbines (e.g., front, back, or side) ("ORIENTATION"), and the degree to which the view of the turbines overlapped the primary scenic vista (e.g., not at all, barely, somewhat or strongly) ("OVERLAP"), might influence residential property values. As such, information on ORIENTATION and OVERLAP were also collected in the field.

### 3.2.4. Field Data Collection

Field data collection was conducted on a house-by-house basis. Each of the 6,194 homes was visited by the same individual to remove bias among field ratings. Data collection was conducted in the fall of 2006, and the spring, summer, and fall of 2007 and 2008. Each house was photographed and, when appropriate, so too were views of turbines and the prominent scenic vista.[44] Data on VIEW were collected only for those homes that sold after at least one wind power facility had been erected in the study area. When multiple wind facilities, with different construction dates, were visible from a home, field ratings for VIEW were made by taking into account which turbines had been erected at the time of sale. Additionally, if the season at the time of sale differed from that of data collection and, for example, if leaves were off the trees for one but on for the other, an effort was made to modulate the VIEW rating accordingly if necessary.[45]

Both VIEW and VISTA field ratings were arrived at through a Q-Sort method (Pitt and Zube, 1979), which is used to distinguish relatively similar rankings. For views of turbines, the rater first determined if the ranking was MINOR or EXTREME. If neither of these two rankings was appropriate, then only a choice between MODERATE and SUBSTANTIAL was required. Similarly, for VISTA rankings, first POOR and PREMIUM were distinguished from the others; if neither applied then BELOW AVERAGE or ABOVE AVERAGE could be selected. If neither of those were appropriate the VISTA, by default, was considered AVERAGE. In all cases, if wind turbines were visible from the home, the VISTA rankings were made as if those turbines did not exist.

## 3.3. Data Summary

The final dataset consists of 7,459 valid and screened residential transactions occurring between January 2, 1996 and June 30, 2007. Those transactions are arrayed across time and the ten wind project study areas as shown in Table 5. The sample of valid residential transactions ranges from 412 in Lee County, Illinois (ILLC) to 1,311 in Howard County, Texas (TXHC).[46] Of the total 7,459 transactions, 4,937 occurred after construction commenced on the relevant wind facilities. More specifically, 23% of the transactions ($n$=1,755) took place before any wind facility was announced and 10% occurred after announcement but before construction commenced ($n$=767),

[44] In many cases the prominent VISTA was homogenous across groups of home, for instance urban homes on the same road. In those cases a picture of the VISTA of one home was applied to all of the homes. All pictures were taken with a Canon EOS Rebel XTi Single Lens Reflex Camera with a 18-55mm lens. VIEW and VISTA pictures were taken with the lens set to 18mm, with the camera at head height, and with the center of the camera pointed at the center of the prominent VISTA or VIEW. Examples of the various VISTA and VIEW categories are contained in Appendices D and E respectively.

[45] This "modulation" occurred only for trees in the foreground, where, for instance, a single tree could obscure the view of turbines; this would not be the case for trees nearer the horizon.

[46] See description of "valid" in footnote 27 on page 13.

with the rest of the transactions occurring after construction commenced (66%, $n$=4,937).[47] Of that latter group, 17% ($n$=824, 11% of total) sold in the first year following the commencement of construction, 16% in the second year ($n$=811, 11% of total), and the remainder (67%) sold more than two years after construction commenced ($n$=3,302, 44% of total).

**Table 5: Summary of Transactions across Study Areas and Development Periods**

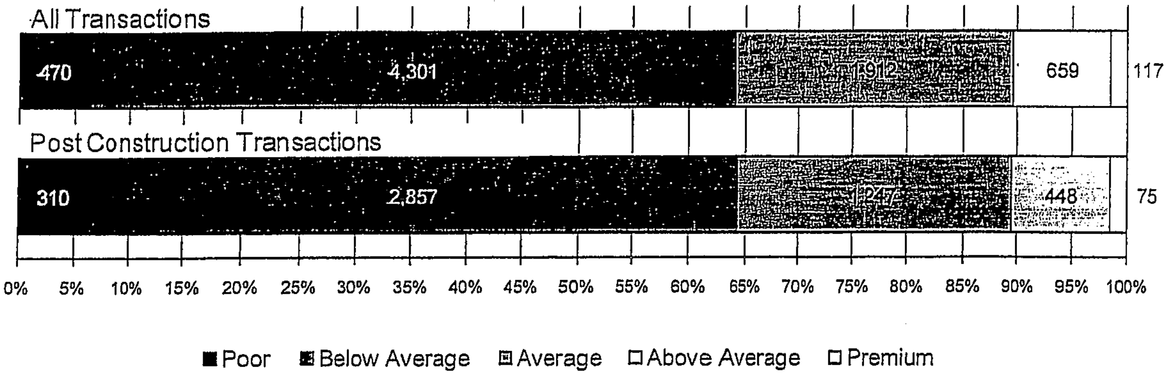
| | Pre Announcement | Post Announcement Pre Construction | 1st Year After Construction | 2nd Year After Construction | 2+ Years After Construction | Total |
|---|---|---|---|---|---|---|
| Benton/Walla Walla, WA & Umatilla, OR (WAOR) | 226 | 45 | 76 | 59 | 384 | 790 |
| Howard, TX (TXHC) | 169 | 71 | 113 | 131 | 827 | 1311 |
| Custer, OK (OKCC) | 484 | 153 | 193 | 187 | 96 | 1113 |
| Buena Vista, IA (IABV) | 152 | 65 | 80 | 70 | 455 | 822 |
| Lee, IL (ILLC) | 115 | 84 | 62 | 71 | 80 | 412 |
| Kewaunee/Door, WI (WIKCDC) | 44 | 41 | 68 | 62 | 595 | 810 |
| Somerset, PA (PASC) | 175 | 28 | 46 | 60 | 185 | 494 |
| Wayne, PA (PAWC) | 223 | 106 | 64 | 71 | 87 | 551 |
| Madison/Oneida, NY (MYMCOC) | 108 | 9 | 48 | 30 | 268 | 463 |
| Madison, NY (NYMC) | 59 | 165 | 74 | 70 | 325 | 693 |
| TOTAL | 1755 | 767 | 824 | 811 | 3302 | 7459 |

A basic summary of the resulting dataset, including the many independent variables used in the hedonic models described later, is contained in Table 6 and Table 7. These tables present summary information for the full dataset (7,459 transactions) as well as the post-construction subset of that dataset (4,937 transactions); the latter is provided because much of the analysis that follows focuses on those homes that sold after wind facility construction. The mean nominal residential transaction price in the sample is $102,968, or $79,114 in 1996 dollars. The average house in the sample can be described as follows: it is 46 years old, has 1,620 square feet of finished living area above ground, is situated on 1.13 acres, has 1.74 bathrooms, and has a

[47] The announcement date (as well as construction and online dates) was provided by Energy Velocity with the GIS files as described in footnote 20 on page 10. The date corresponds to the first time the facility appears in the public record, which was often the permit application date. This constitutes the first well established date when the existing wind facility would have been likely known by the public, and therefore is appropriate to use for this analysis, but there remain a number of areas for potential bias in this date. First, the permit application date might be preceded by news reports of the impending application; alternatively, if the public record was not published online (that Energy Velocity used to establish their date), the "announcement" date – as used here - could, in fact, follow the permit application date. To address this, when possible, the authors had discussions with the developer of the facility. In most cases, the Energy Velocity dates were found to be accurate, and when they were not they were adjusted to reflect the dates provided by the developer. A second potential source of bias is the possibility that a different project was proposed but never built, but that influenced the residential market in the study area prior to the "announcement" date. Although this is likely rarer, we are aware of at least a few projects that fit that description in the study areas. A final source of bias might revolve around the likelihood that awareness of a project could occur even before the facility is formally announced. For example, a community member might know that a wind facility is being considered because they had been approached by the wind development company well ahead of a public announcement. In turn, they might have had private discussions regarding the facility with other members of the community. Taken together, it is appropriate to assume that there is some bias in the "announcement" date, and that awareness of the project might precede the date used in this analysis. How this bias might affect the results in this report is addressed further in Section 5.3 and footnote 74 on page 38.

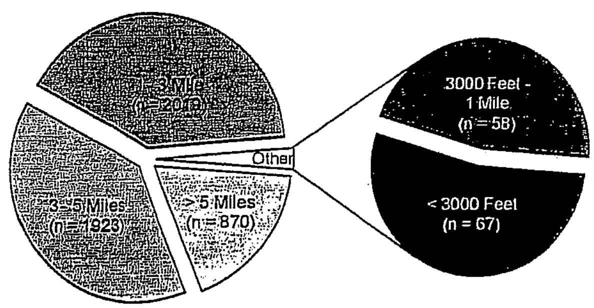
slightly better than average condition.[48] Within the full sample, 6% and 58% of homes had a poor or below average VISTA rating, respectively; 26% of homes received an average rating on this scale, with 9% above average and 2% experiencing premium vistas (see Figure 2).

**Figure 2: Frequency of VISTA Ratings for All and Post-Construction Transactions**




With respect to the variables of interest, among the post-construction subset of 4,937 transactions, the frequency of the DISTANCE categories is found to follow geometry with the smallest numbers of transactions occurring near the wind turbines and ever increasing numbers further away (see Figure 3). 67 transactions (1%) are situated inside of 3,000 feet (< 0.57 Miles), 58 (1%) are between 3,000 feet and one mile (0.57-1 mile), 2,019 (41%) occur outside of one mile but inside of three miles (1-3 miles), 1,923 (39%) occur between three and five miles (3-5 miles), and 870 (18%) occur outside of five miles (>5 miles).[49] In this same post-construction group, a total of 730 homes that sold (15%) have a view of the wind turbines (see Figure 4). A large majority of those homes have MINOR view ratings ($n$ = 561, 11% of total), with 2% having MODERATE ratings ($n$=106) and the remaining transactions roughly split between SUBSTANTIAL and EXTREME ratings ($n$=35, 0.6%, and $n$=28, 0.5%, respectively). A full description of the variables of interest and how they are arrayed at the study area level is contained in Appendix A.

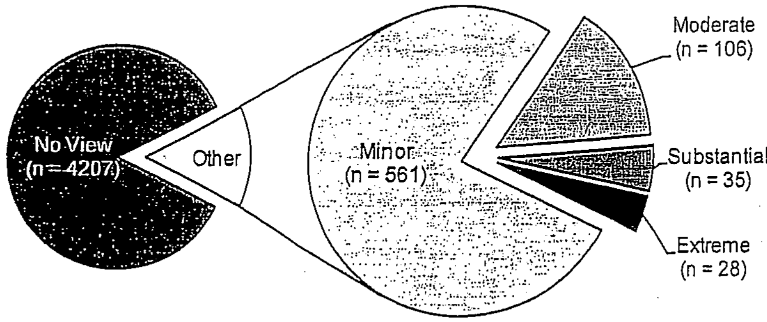
**Figure 3: Frequency of DISTANCE Ratings for Post-Construction Transactions**




[48] The variable for the condition of the home was not uniform across study areas because, in some cases, it took into account construction grade while in others it did not.

[49] These numbers and percentages are skewed slightly from the overall population of transactions because homes outside of three miles were often under-sampled to reduce field data collection burdens. Further, higher numbers of homes fall into each of the categories when the post-announcement-pre-construction transactions are included, as they are in some models. These additional transactions are described below in Table 7 under "All Sales."

## Figure 4: Frequency of VIEW Ratings for Post-Construction Transactions




## Table 6: Summary Statistics: All Sales and Post-Construction Sales

| | | All Sales | | | Post Construction Sales | | |
|---|---|---|---|---|---|---|---|
| Variable Name | Description | Freq. * | Mean | Std. Dev. | Freq. * | Mean | Std. Dev. |
| SalePrice | The unadjusted sale price of the home (in US dollars) | 7,459 | 102,968 | 64,293 | 4,937 | 110,166 | 69,422 |
| SalePrice96 | The sale price of the home adjusted to 1996 US dollars | 7,459 | 79,114 | 47,257 | 4,937 | 80,156 | 48,906 |
| LN_SalePrice96 | The natural log transformation of the sale price of the home adjusted to 1996 US dollars | 7,459 | 11.12 | 0.58 | 4,937 | 11.12 | 0.60 |
| AgeatSale | The age of the home at the time of sale | 7,459 | 46 | 37 | 4,937 | 47 | 36 |
| AgeatSale_Sqrd | The age of the home at the time of sale squared | 7,459 | 3,491 | 5,410 | 4,937 | 3,506 | 5,412 |
| Sqft_1000 | The number of square feet of above grade finished living area (in 1000s) | 7,459 | 1.623 | 0.59 | 4,937 | 1.628 | 0.589 |
| Acres | The number of Acres sold with the residence | 7,459 | 1.13 | 2.42 | 4,937 | 1.10 | 2.40 |
| Baths | The number of Bathrooms (Full Bath = 1, Half Bath = 0.5) | 7,459 | 1.74 | 0.69 | 4,937 | 1.75 | 0.70 |
| ExtWalls_Stone | If the home has exterior walls of stone, brick or stucco (Yes = 1, No = 0) | 2,287 | 0.31 | 0.46 | 1,486 | 0.30 | 0.46 |
| CentralAC | If the home has a Central AC unit (Yes = 1, No = 0) | 3,785 | 0.51 | 0.50 | 2,575 | 0.52 | 0.50 |
| Fireplace | The number of fireplace openings | 2,708 | 0.39 | 0.55 | 1,834 | 0.40 | 0.55 |
| Cul_De_Sac | If the home is situated on a cul-de-sac (Yes = 1, No = 0) | 990 | 0.13 | 0.34 | 673 | 0.14 | 0.34 |
| FinBsmt | If finished basement square feet is greater than 50% times first floor square feet (Yes = 1, No = 0) | 1,472 | 0.20 | 0.40 | 992 | 0.20 | 0.40 |
| Water_Front | If the home shares a property line with a body of water or river (Yes = 1, No = 0) | 107 | 0.01 | 0.12 | 87 | 0.02 | 0.13 |
| Cnd_Low | If the condition of the home is Poor (Yes = 1, No = 0) | 101 | 0.01 | 0.12 | 69 | 0.01 | 0.12 |
| Cnd_BAvg | If the condition of the home is Below Average (Yes = 1, No = 0) | 519 | 0.07 | 0.25 | 359 | 0.07 | 0.26 |
| Cnd_Avg | If the condition of the home is Average (Yes = 1, No = 0) | 4,357 | 0.58 | 0.49 | 2,727 | 0.55 | 0.50 |
| Cnd_AAvg | If the condition of the home is Above Average (Yes = 1, No = 0) | 2,042 | 0.27 | 0.45 | 1,445 | 0.29 | 0.46 |
| Cnd_High | If the condition of the home is High (Yes = 1, No = 0) | 440 | 0.06 | 0.24 | 337 | 0.07 | 0.25 |
| Vista_Poor | If the Scenic Vista from the home is Poor (Yes = 1, No = 0) | 470 | 0.06 | 0.24 | 310 | 0.06 | 0.24 |
| Vista_BAvg | If the Scenic Vista from the home is Below Average (Yes = 1, No = 0) | 4,301 | 0.58 | 0.49 | 2,857 | 0.58 | 0.49 |
| Vista_Avg | If the Scenic Vista from the home is Average (Yes = 1, No = 0) | 1,912 | 0.26 | 0.44 | 1,247 | 0.25 | 0.44 |
| Vista_AAvg | If the Scenic Vista from the home is Above Average (Yes = 1, No = 0) | 659 | 0.09 | 0.28 | 448 | 0.09 | 0.29 |
| Vista_Prem | If the Scenic Vista from the home is Premium (Yes = 1, No = 0) | 117 | 0.02 | 0.12 | 75 | 0.02 | 0.12 |
| SaleYear | The year the home was sold | 7,459 | 2002 | 2.9 | 4,937 | 2004 | 2.3 |

* *"Freq." applies to the number of cases the parameter's value is not zero*



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## Table 7: Summary of Variables of Interest: All Sales and Post-Construction Sales

| | | All Sales | | | Post Construction Sales | | |
|---|---|---|---|---|---|---|---|
| Variable Name | Description | Freq. * | Mean | Std. Dev. | Freq. * | Mean | Std. Dev. |
| View_None | If the home sold after construction began and had no view of the turbines (Yes = 1, No = 0) | 4,207 | 0.56 | 0.50 | 4,207 | 0.85 | 0.36 |
| View_Minor | If the home sold after construction began and had a Minor View of the turbines (Yes = 1, No = 0) | 561 | 0.08 | 0.26 | 561 | 0.11 | 0.32 |
| View_Mod | If the home sold after construction began and had a Moderate View of the turbines (Yes = 1, No = 0) | 106 | 0.01 | 0.12 | 106 | 0.02 | 0.15 |
| View_Sub | If the home sold after construction began and had a Substantial View of the turbines (Yes = 1, No = 0) | 35 | - | 0.07 | 35 | 0.01 | 0.08 |
| View_Extrm | If the home sold after construction began and had a Extreme View of the turbines (Yes = 1, No = 0) | 28 | - | 0.06 | 28 | 0.01 | 0.08 |
| DISTANCE † | Distance to nearest turbine if the home sold after facility "announcement", otherwise 0 | 5,705 | 2.53 | 2.59 | 4,895 | 3.57 | 1.68 |
| Mile_Less_0.57 † | If the home sold after facility "announcement" and was within 0.57 miles (3000 feet) of the turbines (Yes = 1, No = 0) | 80 | 0.01 | 0.09 | 67 | 0.01 | 0.12 |
| Mile_0.57to1 † | If the home sold after facility "announcement" and was between 0.57 miles (3000 feet) and 1 mile of the turbines (Yes = 1, No = 0) | 65 | 0.01 | 0.09 | 58 | 0.01 | 0.11 |
| Mile_1to3 † | If the home sold after facility "announcement" and was between 1 and 3 miles of the turbines (Yes = 1, No = 0) | 2,359 | 0.27 | 0.44 | 2,019 | 0.41 | 0.49 |
| Mile_3to5 † | If the home sold after facility "announcement" and was between 3 and 5 miles of the turbines (Yes = 1, No = 0) | 2,200 | 0.26 | 0.44 | 1,923 | 0.39 | 0.49 |
| Mile_Gtr5 † | If the home sold after facility "announcement" and was outside 5 miles of the turbines (Yes = 1, No = 0) | 1,000 | 0.12 | 0.32 | 870 | 0.18 | 0.38 |

* *"Freq." applies to the number of cases the parameter's value is not zero*

† *"All Sales" freq., mean and standard deviation DISTANCE and DISTANCE fixed effects variables (e.g., Mile_1to3) include transactions that occurred after facility "announcement" and before "construction" as well as those that occured post-construction*

# 4. Base Hedonic Model

This section uses the primary hedonic model ("Base Model") to assess whether residential sales prices are affected, in a statistically measurable way, by views of and proximity to wind power facilities. In so doing, it simultaneously tests for the presence of the three potential property value stigmas associated with wind power facilities: Area, Scenic Vista, and Nuisance. This section begins with a discussion of the dataset that is used and the form of the model that is estimated, and then turns to the results of the analysis. Various alternative hedonic models are discussed and estimated in Section 5, with Sections 6 and 7 providing a discussion of and results from the repeat sales and sales volume models.

## 4.1. Dataset

The data used for the Base Model were described in Section 3.3. A key threshold question is whether or not to include the residential transactions that pre-date the relevant wind facility. Specifically, though the complete dataset consists of 7,459 residential transactions, a number of these transactions ($n = 2{,}522$) occurred before the wind facility was constructed. Should these homes which, at the time of sale, would not have had any view of or distance to the wind facility, be included? Two approaches could be applied to address this issue. First, pre-construction transactions could be included in the hedonic model either as part of the reference category within which no wind-project property value impacts are assumed to exist, or instead by specifically identifying these pre-construction transactions through an indicator variable. Second, and alternatively, pre-construction transactions could simply be excluded from the analysis altogether.

For the purpose of the Base Model, the latter approach is used, therefore relying on only the post-construction subset of 4,937 residential transactions. This approach, as compared to the others, results in somewhat more intuitive findings because all homes have a distance greater than zero and have a possibility of some view of the turbines. More importantly, this approach minimizes the chance of inaccuracies that may otherwise exist due to inflation adjustment concerns or outdated home characteristics information.[50] Nonetheless, to test for the implications of this choice of datasets, alternative hedonic models that use the full dataset were estimated, and are discussed in detail in Sections 5.3 and 5.4.

[50] Home characteristics were obtained as of the last property assessment. The timing of that assessment relative to the timing of the home sale transaction dictates how representative the assessed home characteristics are of the subject home when it was sold. For example, if a home sold early in the study period but subsequently had significant improvements made that are reflected in the current assessment data used in the analysis, the model would assign value to these home characteristics at the time of sale when, in fact, those characteristics were inaccurate. Additionally, the inflation adjustment index used in this analysis to translate home values to real 1996 dollars came from the nearest or more appropriate municipal statistical area (MSA). Many of the wind projects in the analysis are located in relatively rural parts of the country, and the housing market in the nearest metropolitan area could be different than the market surrounding wind projects. Although these areas have – in many instances – recently begun to attract home buyers willing to commute back to the metropolitan areas on which the index is based, the older index adjustments are likely less accurate than the more recent adjustments. Using a subset of the data for the majority of the analyses that removes the older, pre-construction, homes minimizes both of these biases.

## 4.2. Model Form

A standard semi-log functional form is used for the hedonic models (as was discussed in Section 2.1), where the dependent variable (sales price in inflation-adjusted 1996 dollars) is transformed to its natural log form and the independent variables (e.g., square feet and acres) are not transformed. Using this form to examine the effect that views of, and distance to, wind facilities have on sales prices, the following basic model is estimated:

$$\ln(P) = \beta_0 + \beta_1 N + \sum_s \beta_2 S + \sum_k \beta_3 X + \sum_v \beta_4 \mathrm{VIEW} + \sum_d \beta_5 \mathrm{DISTANCE} + \varepsilon \quad (1)$$

where

P represents the inflation-adjusted sales price,
N is the spatially weighted neighbors' predicted sales price,
S is the vector of *s* Study Area fixed effects variables (e.g., WAOR, OKCC, etc.),
X is a vector of *k* home and site characteristics (e.g., acres, square feet, number of bathrooms, condition of the home, age of home, VISTA, etc.),
VIEW is a vector of *v* categorical view of turbine variables (e.g., MINOR, MODERATE, etc.),
DISTANCE is a vector of *d* categorical distance to turbine variables (e.g., less than 3000 feet, between one and three miles, etc.),
$\beta_0$ is the constant or intercept across the full sample,
$\beta_1$ is a parameter estimate for the spatially weighted neighbor's predicted sales price,
$\beta_2$ is a vector of *s* parameter estimates for the study area fixed effects as compared to homes sold in the Washington/Oregon (WAOR) study area,
$\beta_3$ is a vector of *k* parameter estimates for the home and site characteristics,
$\beta_4$ is a vector of *v* parameter estimates for the VIEW variables as compared to homes sold with no view of the turbines,
$\beta_5$ is a vector of *d* parameter estimates for the DISTANCE variables as compared to homes sold situated outside of five miles, and
$\varepsilon$ is a random disturbance term.

As such, this model, and all subsequent hedonic models, has four primary groups of parameters: variables of interest, spatial adjustments, study-area fixed effects, and home and site characteristics.

The variables of interest, VIEW and DISTANCE, are the focus of this study, and allow the investigation of the presence of Area, Scenic Vista, and Nuisance Stigmas. These variables were defined in Section 3, and are summarized in Table 8. Both VIEW and DISTANCE appear in the model together because a home's value may be affected in part by the magnitude of the view of the wind turbines, and in part by the distance from the home to those turbines, and both variables appear in the Base Model as ordered categorical values. The coefficients associated with these two vectors of variables ($\beta_4$ and $\beta_5$) represent the marginal impact of views of, and distances to, wind turbines on sales prices, as compared to a "reference" category of residential transactions, and should be ordered monotonically from low to high.[51] This form of variable was used to

[51] "Reference category" refers to the subset of the sample to which other observations are compared, and is pertinent when using categorical or "fixed effect" variables.



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impose the least structure on the underlying data.[52] For the purpose of the Base Model, the reference category for the DISTANCE variables are those transactions of homes that were situated outside of five miles from the nearest wind turbine. The reference category for the VIEW variables are those transactions of homes that did not have a view of the wind facility upon sale. Among the post-construction sample of homes, these reference homes are considered the least likely to be affected by the presence of the wind facilities.[53]

Table 8: List of Variables of Interest Included in the Base Model

| Variable Name | Description | Type | Expected Sign |
|---|---|---|---|
| View_None | If the home sold after construction began and had no view of the turbines (Yes = 1, No = 0) | Reference | n/a |
| View_Minor | If the home sold after construction began and had a Minor View of the turbines (Yes = 1, No = 0) | OC | - |
| View_Mod | If the home sold after construction began and had a Moderate View of the turbines (Yes = 1, No = 0) | OC | - |
| View_Sub | If the home sold after construction began and had a Substantial View of the turbines (Yes = 1, No = 0) | OC | - |
| View_Extrm | If the home sold after construction began and had an Extreme View of the turbines (Yes = 1, No = 0) | OC | - |
| Mile_Less_0.57 | If the home sold after facility "construction" and was within 0.57 miles (3000 feet) of the turbines (Yes = 1, No = 0) | OC | - |
| Mile_0.57to1 | If the home sold after facility "construction" and was between 0.57 miles (3000 feet) and 1 mile of the turbines (Yes = 1, No = 0) | OC | - |
| Mile_1to3 | If the home sold after facility "construction" and was between 1 and 3 miles of the turbines (Yes = 1, No = 0) | OC | - |
| Mile_3to5 | If the home sold after facility "construction" and was between 3 and 5 miles of the turbines (Yes = 1, No = 0) | OC | - |
| Mile_Gtr5 | If the home sold after facility "construction" and was outside 5 miles of the turbines (Yes = 1, No = 0) | Reference | n/a |

*"OC" Ordered Categorical (1 = yes, 0 = no) values are interpreted in relation to the reference categorical case and are expected to have a monotonic order from low to high.*

The three stigmas are investigated though these VIEW and DISTANCE variables. Scenic Vista Stigma is investigated through the VIEW variables. Area and Nuisance Stigmas, on the other hand, are investigated through the DISTANCE variables. To distinguish between Area and

[52] In place of the ordered categorical DISTANCE variables, practitioners often rely on a continuous DISTANCE form (e.g., Sims et al., 2008). Similar to ordered categorical variables, continuous variables have a natural ordering, either ascending or descending, but, unlike categorical variables, these "continuous" values are on a scale. Therefore, given any two of its values $X_1$ and $X_2$ and a specific functional form, the ratio "$X_1/X_2$" and the distance "$X_1 - X_2$" have a fixed meaning. Examples of continuous variables other than DISTANCE that are commonly used include the number of square feet of living area (in 1000s) in a home (SQFT_1000) or the acres in the parcel (ACRES). A continuous functional form of this nature "imposes structure" because practitioners must decide how price is related to the underlying variables through the selection of a specific functional relationship between the two. For instance, in the case of DISTANCE, is there a linear relationship (which would imply a similar marginal difference between two distances both near and far from the turbines), does it decay slowly as distance grows, or does it fade completely at some fixed distance? Because of the lack of literature in this area, no *a priori* expectations for which functional form is the best were established, and therefore unstructured categorical variables are used in the Base Model. Nonetheless, a continuous DISTANCE form is explored in Section 5.2.

[53] It is worth noting that these reference homes are situated in both rural and urban locales and therefore are not uniquely affected by influences from either setting. This further reinforces their worthiness as a reference category.

Nuisance Stigma, it is assumed that Nuisance effects are concentrated within one mile of the nearest wind turbine, while Area effects will be considered for those transactions outside of one mile. Any property value effects discovered outside of one mile and based on the DISTANCE variables are therefore assumed to indicate the presence of Area Stigma, while impacts within a mile may reflect the combination of Nuisance and Area Stigma.

The second set of variables in the Base Model - spatial adjustments - correct for the assumed presence of spatial autocorrelation in the error term ($\varepsilon$). It is well known that the sales price of a home can be systematically influenced by the sales prices of those homes that have sold nearby. Both the seller and the buyer use information from comparable surrounding sales to inform them of the appropriate transaction price, and nearby homes often experience similar amenities and disamenities. This lack of independence of home sale prices could bias hedonic regression results and, to help correct for this bias, a spatially (i.e., distance) weighted neighbors' sales price (N) is included in the model. Empirically, the neighbors' price has been found to be a strong (and sometimes even the strongest) predictor of home values (Leonard and Murdoch, forthcoming), and the coefficient $\beta_1$ is expected to be positive, indicating a positive correlation between the neighbors' and subject home's sales price. A more-detailed discussion of the importance of this variable, and how it was created, is contained in Appendix G.

The third group of variables in the Base Model - study area fixed effects - control for study area influences and the differences between them. The vector's parameters $\beta_2$ represent the marginal impact of being in any one of the study areas, as compared to a reference category. In this case, the reference category is the Washington/Oregon (WAOR) study area.[54] The estimated coefficients for this group of variables represent the combined effects of school districts, tax rates, crime, and other locational influences across an entire study area. Although this approach greatly simplifies the estimation of the model, because of the myriad of influences captured by these study-area fixed effects variables, interpreting the coefficient can be difficult. In general, though, the coefficients simply represent the mean difference in sales prices between the study areas and the reference study area (WAOR). These coefficients are expected to be strongly influential, indicating significant differences in sales prices across study areas.

The fourth group of variables in the Base Model are the core home and site characteristics (X), and include a range of continuous ("C"),[55] discrete ("D"),[56] binary ("B"),[57] and ordered categorical ("OC") variables. The specific home and site variables included in the Base Model are listed in Table 9 along with the direction of expected influence.[58] Variables included are age

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[54] Because there is no intent to focus on the coefficients of the study area fixed effect variables, the reference case is arbitrary. Further, the results for the other variables in the model are completely independent of this choice.

[55] See discussion in footnote 52 on previous page.

[56] Discrete variables, similar to continuous variables, are ordered and the distance between the values, such as $X_1$ and $X_2$, have meaning, but for these variables, there are only a relatively small number of discrete values that the variable can take, for example, the number of bathrooms in a home (BATHROOMS).

[57] Binary variables have only two conditions: "on" or "off" (i.e., "1" or "0" respectively). Examples are whether the home has central air conditioning ("CENTRAL_AC") or if the home is situated on a cul-de-sac ("CUL_DE_SAC"). The coefficients for these variables are interpreted in relation to when the condition is "off."

[58] For those variables with a "+" sign it is expected that as the variable increases in value (or is valued at "1" as would be the case for fixed effects variables) the price of the home will increase, and the converse is true for the variables with a "-" sign. The expected signs of the variables all follow conventional wisdom (as discussed in

of the home, home and lot size, number of bathrooms and fireplaces, the condition of the home, the quality of the scenic vista from the home, if the home has central AC, a stone exterior, and/or a finished basement, and whether the home is located in a cul-de-sac and/or on a water way.[59]

Table 9: List of Home and Site Characteristics Included in the Base Model

| Variable Name | Description | Type | Expected Sign |
|---|---|---|---|
| AgeatSale | The age of the home at the time of sale in years | C | - |
| AgeatSale_Sqrd | The age of the home at the time of sale squared | C | + |
| Sqft_1000 | The number of square feet of above grade finished living area (in 1000s) | C | + |
| Acres | The number of Acres sold with the residence | C | + |
| Baths | The number of Bathrooms (Full Bath = 1, Half Bath = 0.5) | D | + |
| ExtWalls_Stone | If the home has exterior walls of stone, brick or stucco (Yes = 1, No = 0) | B | + |
| CentralAC | If the home has a Central AC unit (Yes = 1, No = 0) | B | + |
| Fireplace | The number of fireplace openings | D | + |
| Cul_De_Sac | If the home is situated on a cul-de-sac (Yes = 1, No = 0) | B | + |
| FinBsmt | If finished basement sqft > 50% times first floor sqft (Yes = 1, No = 0) | B | + |
| Water_Front | If the home shares a property line with a body of water or river (Yes = 1, No = 0) | B | + |
| Cnd_Low | If the condition of the home is Poor (Yes = 1, No = 0) | OC | - |
| Cnd_BAvg | If the condition of the home is Below Average (Yes = 1, No = 0) | OC | - |
| Cnd_Avg | If the condition of the home is Average (Yes = 1, No = 0) | Reference | n/a |
| Cnd_AAvg | If the condition of the home is Above Average (Yes = 1, No = 0) | OC | + |
| Cnd_High | If the condition of the home is High (Yes = 1, No = 0) | OC | + |
| Vista_Poor | If the Scenic Vista from the home is Poor (Yes = 1, No = 0) | OC | - |
| Vista_BAvg | If the Scenic Vista from the home is Below Average (Yes = 1, No = 0) | OC | - |
| Vista_Avg | If the Scenic Vista from the home is Average (Yes = 1, No = 0) | Reference | n/a |
| Vista_AAvg | If the Scenic Vista from the home is Above Average (Yes = 1, No = 0) | OC | + |
| Vista_Prem | If the Scenic Vista from the home is Premium (Yes = 1, No = 0) | OC | + |

*"C" Continuous, "D" Discrete, and "B" Binary (1 = yes, 0 = no) values are interpreted in relation to "No"*

*"OC" Ordered Categorical (1 = yes, 0 = no) values are interpreted in relation to the reference categorical case and are expected to have a monotonic order from low to high.*

Sirmans et al., 2005a), save AgeatSale and AgeatSale_Sqrd, which are expected to be negative and positive, respectively. The magnitude of the coefficient of AgeatSale is expected to be larger than that of AgeatSale_Sqrd indicating an initial drop in value as a home increases in age, and then an increase in value as the home becomes considerably older and more "historic."

[59] Some characteristics, such as whether the home had a deck, a pool, or is located on a public sewer, are not available consistently across the dataset and therefore are not incorporated into the model. Other characteristics, such as the number of bedrooms, the number of stories, or if the home had a garage, are available but are omitted from the final model because they are highly correlated with characteristics already included in the model and therefore do not add significantly to the model's explanatory power. More importantly, and as discussed in Appendix G, when their inclusion or exclusion are tested, the results are stable with those derived from the Base Model.

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It should be emphasized that in the Base Hedonic Model - equation (1) - and in all subsequent models presented in Section 5, all variables of interest, spatial adjustments, and home and site characteristics are pooled, and therefore their estimates represent the average across all study areas. Ideally, one would have enough data to estimate a model at the study area level - a fully unrestricted model - rather than pooled across all areas. This fully unrestricted model form, along with 15 other model forms (with some variables restricted and others not), are discussed in detail in Appendix F. In total, these 16 different models were estimated to explore which model was the most parsimonious (had the fewest parameters), performed the best (e.g., had the highest adjusted $R^2$ and the lowest Schwarz information criterion[60]), and had the most stable coefficients and standard errors. The basic pooled model described by equation (1) is found to fit that description, and that model is therefore chosen as the Base Model to which others are compared. By making this choice the effort concentrates on identifying the presence of potential property value impacts across all of the study areas in the sample as opposed to any single study area.[61]

Finally, to assure that the model produces the best linear unbiased parameter estimates, the underlying assumptions of Ordinary Least Squares (OLS) regression techniques must be verified:

1) Homoskedastic error term;
2) Absence of temporal serial correlation;
3) Reasonably limited multicollinearity; and
4) Appropriate controls for outliers and influencers.[62]

These assumptions, and the specific approaches that are used to address them, are discussed in detail in Appendix G.

### 4.3. Analysis of Results

Table 10 (on page 32) presents the results of the Base Model (equation 1).[63] The model performs well, with an adjusted $R^2$ of 0.77.[64] The spatial adjustment coefficient ($\beta_1$) of 0.29 (*p* value 0.00) indicates that a 10% increase in the spatially weighted neighbor's price increases the subject home's value by an average of 2.9%. The study-area fixed effects ($\beta_2$) variables are all significant at the one percent level, demonstrating important differences in home valuations

[60] The Schwarz information criterion measures relative parsimony between similar models (Schwarz, 1978).

[61] Because effects might vary between study areas, and the models estimate an average across all study areas, the full range of effects in individual study areas will go undetermined. That notwithstanding, there is no reason to suspect that effects will be completely "washed out." For that to occur, an effect in one study area would have to be positive while in another area it would have to be negative, and there is no reason to suspect that sales prices would increase because of the turbines in one community while decreasing in other communities.

[62] The absence of spatial autocorrelation is often included in the group of assumptions, but because it was discussed above (and in Appendix G), and is addressed directly by the variable ($N_i$) included in the model, it is not included in this list.

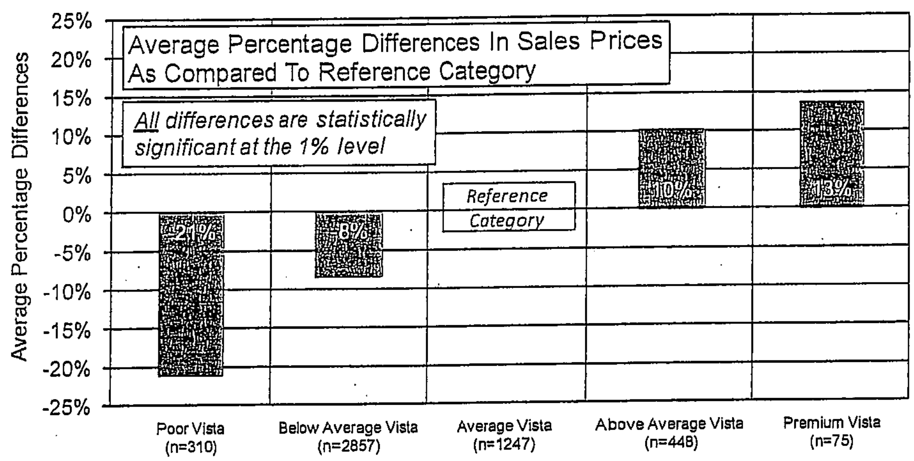
[63] This model and all subsequent models were estimated using the PROC REG procedure of SAS Version 9.2 TS1M0, which produces White's corrected standard errors.

[64] The appropriateness of the $R^2$ of 0.77 for this research is validated by the extensive hedonic literature that precedes it (see e.g., Kroll and Priestley, 1992; Boyle and Kiel, 2001; Simons, 2006b).

between the reference study area (WAOR) and the other nine study areas.[65] The sign and magnitudes of the home and site characteristics are all appropriate given the *a priori* expectations, and all are statistically significant at the one percent level.[66]

Of particular interest are the coefficient estimates for scenic vista (VISTA) as shown in Figure 5. Homes with a POOR vista rating are found, on average, to sell for 21% less (*p* value 0.00) than homes with an AVERAGE rating, while BELOW AVERAGE homes sell for 8% less (*p* value 0.00). Conversely, homes with an ABOVE AVERAGE vista are found to sell for 10% more (*p* value 0.00) than homes with an AVERAGE vista, while PREMIUM vista homes sell for 13% more than AVERAGE homes (*p* value 0.00). Based on these results, it is evident that home buyers and sellers capitalize the quality of the scenic vista in sales prices.[67]

**Figure 5: Results from the Base Model for VISTA**




*The reference category consists of transactions for homes with an Average Vista, and that occured after construction began on the wind facility*

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[65] The reference category WAOR study area has the highest mean and median house values in the sample (as shown in Appendix A) so the negative coefficients for all the study area fixed effect variables are appropriate.

[66] To benchmark the results against those of other practitioners the research by Sirmans et al. (2005a; 2005b) was consulted. They conducted a meta-analysis of 64 hedonic studies carried out in multiple locations in the U.S. during multiple time periods, and investigated the coefficients of ten commonly used characteristics, seven of which were included in the model. The similarities between their mean coefficients (i.e., the average across all 64 studies) and those estimated in the present Base Model are striking. The analysis presented here estimates the effect of square feet (in 1000s) on log of sales price at 0.28 and Sirmans et al. provide an estimate of 0.34, while ACRES was similarly estimated (0.02 to 0.03, Base Model and Sirmans et al., respectively). Further, AGEATSALE (age at the time of sale) (-0.006 to -0.009), BATHROOMS (0.09 to 0.09), CENTRALAC (0.09 to 0.08), and FIREPLACE (0.11 to 0.09) all similarly compare. As a group, the Base Model estimates differ from Sirmans et al. estimates in all cases by no more than a third of the Sirmans et al. mean estimate's standard deviation. This, taken with the relatively high adjusted $R^2$ of the Base Model, demonstrates the appropriateness of the model's specification.

[67] To benchmark these results they are compared to the few studies that have investigated the contribution of inland scenic vistas to sales prices. Benson et al. (2000) find that a mountain vista increases sales price by 8%, while Bourassa et al. (2004) find that wide inland vistas increase sales price by 7.6%. These both compare favorably to the 10% and 14% above average and premium rated VISTA estimates. Comparable studies for below average and poor VISTA were not found and therefore no benchmarking of those coefficients is conducted. Finally, it should again be noted that a home's scenic vista, as discussed in Section 3.2.3, was ranked without taking the presence of the wind turbines into consideration, even if those turbines were visible at the time of home sale.



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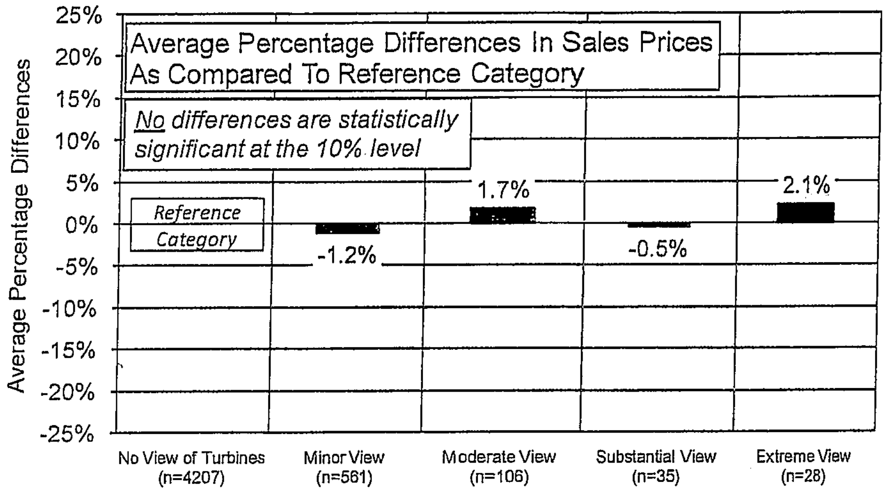
Despite this finding for scenic vista, however, no statistically significant relationship is found between views of wind turbines and sales prices.[68] The coefficients for the VIEW parameters ($\beta_4$) are all relatively small, none are statistically significant, and they are not monotonically ordered (see Figure 6). Homes with EXTREME or SUBSTANTIAL view ratings, for which the Base Model is expected to find the largest differences, sell for, on average, 2.1% more (*p* value 0.80) and 0.5% less (*p* value 0.94) than NO VIEW homes that sold in the same post-construction period. Similarly, homes with MODERATE or MINOR view ratings sell, on average, for 1.7% more (*p* value 0.58) and 1.2% less (*p* value 0.40) than NO VIEW homes, respectively. None of these coefficients are sizable, and none are statistically different from zero. These results indicate that, among this sample at least, a statistically significant relationship between views of wind turbines and residential property values is not evident. In other words, there is an absence of evidence of a Scenic Vista Stigma in the Base Model.

**Figure 6: Results from the Base Model for VIEW**




*The reference category consists of transactions for homes without a view of the turbines, and that occured after construction began on the wind facility*

The coefficients for the DISTANCE parameters ($\beta_5$) are also all relatively small and none are statistically significant (see Figure 7). Homes that are situated within 3000 feet (0.57 miles) of the nearest wind turbine, at the time of sale, are found to sell for 5.3% less (*p* value 0.40), on average, than homes outside of 5 miles that sold in the same "post-construction" period. Meanwhile, homes between 3000 feet and 1 mile sold for 5.5% less (*p* value 0.30), on average, than homes more than 5 miles away. Homes that are within 1 to 3 miles of the nearest turbine, as compared to homes outside of 5 miles, sold for essentially the same, on average (coefficient = 0.004, *p* value 0.80), while homes between 3 and 5 miles sold for 1.6% more (*p* value 0.23).

[68] A significance level of 10% is used throughout this report, which corresponds to a *p*-value at or above 0.10. Although this is more liberal than the often used 5% (*p*-value at or above 0.05), it was chosen to give more opportunities for effects that might be fairly weak to be considered significant.



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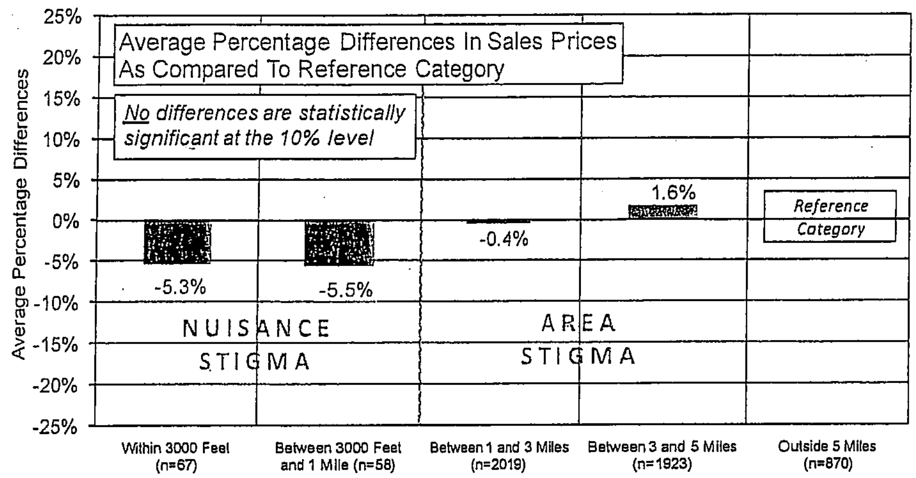
**Figure 7: Results from the Base Model for DISTANCE**




*The reference category consists of transactions for homes situated more than five miles from the nearest turbine, and that occured after construction began on the wind facility*

Looking at these results as a whole, a somewhat monotonic order from low to high is found as homes are situated further away from wind facilities, but all of the coefficients are relatively small and none are statistically different from zero. This suggests that, for homes in the sample at least, there is a lack of statistical evidence that the distance from a home to the nearest wind turbine impacts sales prices, and this is true regardless of the distance band.[69] As such, an absence of evidence of an Area or Nuisance Stigma is found in the Base Model. That notwithstanding, the -5% coefficients for homes that sold within one mile of the nearest wind turbine require further scrutiny. Even though the differences are not found to be statistically significant, they might point to effects that exist but are too small for the model to deem statistically significant due to the relatively small number of homes in the sample within 1 mile of the nearest turbine. Alternatively, these homes may simply have been devalued even before the wind facility was erected, and that devaluation may have carried over into the post construction period (the period investigated by the Base Model). To explore these possibilities, transactions that occurred well before the announcement of the wind facility to well after construction are investigated in the Temporal Aspects Model in the following "Alternative Models" section.

[69] It is worth noting that the number of cases in each of these categories (e.g., $n = 67$ for homes inside of 3000 feet and $n = 58$ between 3000 feet and one mile) are small, but are similar to the numbers of cases for other variables in the same model (e.g., LOW CONDITION, $n = 69$; PREMIUM VISTA, $n = 75$), the estimates of which were found to be significant above the 1% level.

Table 10: Results from the Base Model

| | Coef. | SE | p Value | *n* |
|---|---|---|---|---|
| Intercept | 7.62 | 0.18 | 0.00 | |
| Nbr LN SalePrice96 hat | 0.29 | 0.02 | 0.00 | 4,937 |
| AgeatSale | -0.006 | 0.0004 | 0.00 | 4,937 |
| AgeatSale Sqrd | 0.00002 | 0.000003 | 0.00 | 4,937 |
| Sqft 1000 | 0.28 | 0.01 | 0.00 | 4,937 |
| Acres | 0.02 | 0.00 | 0.00 | 4,937 |
| Baths | 0.09 | 0.01 | 0.00 | 4,937 |
| ExtWalls Stone | 0.21 | 0.02 | 0.00 | 1,486 |
| CentralAC | 0.09 | 0.01 | 0.00 | 2,575 |
| Fireplace | 0.11 | 0.01 | 0.00 | 1,834 |
| FinBsmt | 0.08 | 0.02 | 0.00 | 673 |
| Cul De Sac | 0.10 | 0.01 | 0.00 | 992 |
| Water Front | 0.33 | 0.04 | 0.00 | 87 |
| Cnd Low | -0.45 | 0.05 | 0.00 | 69 |
| Cnd BAvg | -0.24 | 0.02 | 0.00 | 350 |
| Cnd Avg | Omitted | Omitted | Omitted | 2,727 |
| Cnd AAvg | 0.14 | 0.01 | 0.00 | 1,445 |
| Cnd High | 0.23 | 0.02 | 0.00 | 337 |
| Vista Poor | -0.21 | 0.02 | 0.00 | 310 |
| Vista BAvg | -0.08 | 0.01 | 0.00 | 2,857 |
| Vista Avg | Omitted | Omitted | Omitted | 1,247 |
| Vista AAvg | 0.10 | 0.02 | 0.00 | 448 |
| Vista Prem | 0.13 | 0.04 | 0.00 | 75 |
| WAOR | Omitted | Omitted | Omitted | 519 |
| TXHC | -0.75 | 0.03 | 0.00 | 1,071 |
| OKCC | -0.44 | 0.02 | 0.00 | 476 |
| IABV | -0.24 | 0.02 | 0.00 | 605 |
| ILLC | -0.09 | 0.03 | 0.00 | 213 |
| WIKCDC | -0.14 | 0.02 | 0.00 | 725 |
| PASC | -0.31 | 0.03 | 0.00 | 291 |
| PAWC | -0.07 | 0.03 | 0.01 | 222 |
| NYMCOC | -0.20 | 0.03 | 0.00 | 346 |
| NYMC | -0.15 | 0.02 | 0.00 | 469 |
| Post Con NoView | Omitted | Omitted | Omitted | 4,207 |
| View Minor | -0.01 | 0.01 | 0.40 | 561 |
| View Mod | 0.02 | 0.03 | 0.58 | 106 |
| View Sub | -0.01 | 0.07 | 0.94 | 35 |
| View Extrm | 0.02 | 0.09 | 0.80 | 28 |
| Mile Less 0 57 | -0.05 | 0.06 | 0.40 | 67 |
| Mile 0 57to1 | -0.05 | 0.05 | 0.30 | 58 |
| Mile 1to3 | 0.00 | 0.02 | 0.80 | 2,019 |
| Mile 3to5 | 0.02 | 0.01 | 0.23 | 1,923 |
| Mile Gtr5 | Omitted | Omitted | Omitted | 870 |

*"Omitted" = reference category for fixed effects variables*
*"n" indicates number of cases in category when category = "1"*

## Model Information

| | |
|---|---|
| Model Equation Number | 1 |
| Dependent Variable | LN SalePrice96 |
| Number of Cases | 4937 |
| Number of Predictors (k) | 37 |
| F Statistic | 442.8 |
| Adjusted R Squared | 0.77 |

# 5. Alternative Hedonic Models

The Base Hedonic Model presented in Section 4 found that residential property values have, on average, not been measurably affected by the presence of nearby wind facilities. To test the robustness of this result and to test for other possible impacts from nearby wind projects, the report now turns to a number of other hedonic models. These Alternative Models were created to investigate different approaches to exploring the impact of the variables of interest (#1 and #2, below) and to assess the presence of impacts that are not otherwise fully captured by the Base Model (#3 through #6, below).

1) **View and Distance Stability Models:** Using only post-construction transactions (the same as the Base Model) these models investigate whether the Scenic Vista Stigma (as measured with VIEW) results are independent of the Nuisance and Area Stigma results (as measured by DISTANCE) and vice versa.[70]
2) **Continuous Distance Model:** Using only post-construction transactions, this model investigates Area and Nuisance Stigmas by applying a continuous distance parameter as opposed to the categorical variables for distance used in the previous models.
3) **All Sales Model:** Using all transactions, this model investigates whether the results for the three stigmas change if transactions that occurred before the announcement and construction of the wind facility are included in the sample.
4) **Temporal Aspects Model:** Using all transactions, this model further investigates Area and Nuisance Stigmas and how they change for homes that sold more than two years pre-announcement through the period more than four years post-construction.
5) **Home Orientation Model:** Using only post-construction transactions, this model investigates the degree to which a home's orientation to the view of wind turbines affects sales prices.
6) **View and Vista Overlap Model:** Using only post-construction transactions, this model investigates the degree to which the overlap between the view of a wind facility and a home's primary scenic vista affects sales prices.

Each of these models is described in more depth in the pages that follow. Results are shown for the variables of interest only; full results are contained in Appendix H.

## 5.1. View and Distance Stability Models

The Base Model (equation 1) presented in Section 4 includes both DISTANCE and VIEW variables because a home's value might be affected in part by the magnitude of the view of a nearby wind facility and in part by the distance from the home to that facility. These two variables may be related, however, in-so-far as homes that are located closer to a wind facility are likely to have a more-dominating view of that facility. To explore the degree to which these two sets of variables are independent of each other (i.e. not collinear) and to further test the robustness of the Base Model results two alternative hedonic models are run, each of which includes only one of the sets of parameters (DISTANCE or VIEW). Coefficients from these models are then compared to the Base Model results.

[70] Recall that the qualitative VIEW variable incorporated the visible distance to the nearest wind facility.



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### 5.1.1. Dataset and Model Form

The same dataset is used as in the Base Model, focusing again on post-construction transactions ($n$ = 4,937). To investigate DISTANCE effects alone the following model is estimated:

$$\ln(\mathrm{P}) = \beta_0 + \beta_1\mathrm{N} + \sum_s \beta_2\mathrm{S} + \sum_k \beta_3\mathrm{X} + \sum_d \beta_5\mathrm{DISTANCE} + \varepsilon \qquad (2)$$

where

P represents the inflation-adjusted sales price,

N is the spatially weighted neighbors' predicted sales price,

S is the vector of $s$ Study Area fixed effects variables (e.g., WAOR, OKCC, etc.),

X is a vector of $k$ home and site characteristics (e.g., acres, square feet, number of bathrooms, condition of the home, age of home, VISTA, etc.),

DISTANCE is a vector of $d$ categorical distance variables (e.g., less than 3000 feet, between one and three miles, etc.),

$\beta_0$ is the constant or intercept across the full sample,

$\beta_1$ is a parameter estimate for the spatially weighted neighbor's predicted sales price,

$\beta_2$ is a vector of $s$ parameter estimates for the study area fixed effects as compared to transactions of homes in the WAOR study area,

$\beta_3$ is a vector of $k$ parameter estimates for the home and site characteristics,

$\beta_5$ is a vector of $d$ parameter estimates for the DISTANCE variables as compared to transactions of homes situated outside of five miles, and

$\varepsilon$ is a random disturbance term.

The parameters of primary interest are $\beta_5$, which represent the marginal differences between home values at various distances from the wind turbines as compared to the reference category of homes outside of five miles. These coefficients can then be compared to the same coefficients estimated from the Base Model.

Alternatively, to investigate the VIEW effects alone, the following model is estimated:

$$\ln(\mathrm{P}) = \beta_0 + \beta_1\mathrm{N} + \sum_s \beta_2\mathrm{S} + \sum_k \beta_3\mathrm{X} + \sum_v \beta_4\mathrm{VIEW} + \varepsilon \qquad (3)$$

where

VIEW is a vector of $v$ categorical view variables (e.g., MINOR, MODERATE, etc.),

$\beta_4$ is a vector of $v$ parameter estimates for the VIEW variables, and

all other components are as defined in equation (2).

The parameters of primary interest in this model are $\beta_4$, which represent the marginal differences between home values for homes with varying views of wind turbines at the time of sale as compared to the reference category of homes without a view of those turbines. Again, these coefficients can then be compared to the same coefficients estimated from the Base Model.

Our expectation for both of the models described here is that the results will not be dramatically different from the Base Model, given the distribution of VIEW values across the DISTANCE values, and vice versa, as shown in Table 11. Except for EXTREME view, which is concentrated inside of 3000 feet, all view ratings are adequately distributed among the distance categories.

Table 11: Frequency Crosstab of VIEW and DISTANCE Parameters

| | Inside 3000 Feet | Between 3000 Feet and 1 Mile | Between 1 and 3 Miles | Between 3 and 5 Miles | Outside 5 Miles | Total |
|---|---|---|---|---|---|---|
| No View | 6 | 12 | 1653 | 1695 | 841 | 4207 |
| Minor View | 14 | 24 | 294 | 202 | 27 | 561 |
| Moderate View | 8 | 13 | 62 | 21 | 2 | 106 |
| Substantial View | 11 | 9 | 10 | 5 | 0 | 35 |
| Extreme View | 28 | 0 | 0 | 0 | 0 | 28 |
| TOTAL | 67 | 58 | 2019 | 1923 | 870 | 4937 |

### 5.1.2. Analysis of Results

Summarized results for the variables of interest from the Base Model and the two Alternative Stability Models are presented in Table 12. (For brevity, the full set of results for the models is not shown in Table 12, but is instead included in Appendix H.) The adjusted $R^2$ for the View and Distance Stability Models is the same as for the Base Model, 0.77. All study area, spatial adjustment, and home and site characteristics are significant at or above the one percent level and are similar in magnitude to the estimates presented earlier for the Base Model.

The DISTANCE and VIEW coefficients, $\beta_5$ and $\beta_4$, are stable, changing no more than 3%, with most (7 out of 8) not experiencing a change greater than 1%. In all cases, changes to coefficient estimates for the variables of interest are considerably less than the standard errors. Based on these results, there is confidence that the correlation between the VIEW and DISTANCE variables is not responsible for the findings and that these two variables are adequately independent to be included in the same hedonic model regression. As importantly, no evidence of Area, Scenic Vista, or Nuisance Stigma is found in the sample, as none of the VIEW or DISTANCE variables are found to be statistically different from zero.

Table 12: Results from Distance and View Stability Models

| | | Base Model | | | Distance Stability | | | View Stability | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variables of Interest | *n* | Coef | SE | p Value | Coef | SE | p Value | Coef | SE | p Value |
| No View | 4207 | Omitted | Omitted | Omitted | | | | Omitted | Omitted | Omitted |
| Minor View | 561 | -0.01 | 0.01 | 0.39 | | | | -0.02 | 0.01 | 0.24 |
| Moderate View | 106 | 0.02 | 0.03 | 0.57 | | | | 0.00 | 0.03 | 0.90 |
| Substantial View | 35 | -0.01 | 0.07 | 0.92 | | | | -0.04 | 0.06 | 0.45 |
| Extreme View | 28 | 0.02 | 0.09 | 0.77 | | | | -0.03 | 0.06 | 0.58 |
| Inside 3000 Feet | 67 | -0.05 | 0.06 | 0.31 | -0.04 | 0.04 | 0.25 | | | |
| Between 3000 Feet and 1 Mile | 58 | -0.05 | 0.05 | 0.20 | -0.06 | 0.05 | 0.17 | | | |
| Between 1 and 3 Miles | 2019 | 0.00 | 0.02 | 0.80 | -0.01 | 0.02 | 0.71 | | | |
| Between 3 and 5 Miles | 1923 | 0.02 | 0.01 | 0.26 | 0.01 | 0.01 | 0.30 | | | |
| Outside 5 Miles | 870 | Omitted | Omitted | Omitted | Omitted | Omitted | Omitted | | | |

*"Omitted" = reference category for fixed effects variables. "n" indicates number of cases in category when category = "1"*

Model Information

| Model Information | | | |
|---|---|---|---|
| Model Equation Number | 1 | 2 | 3 |
| Dependent Variable | LN_SalePrice96 | LN_SalePrice96 | LN_SalePrice96 |
| Number of Cases | 4937 | 4937 | 4937 |
| Number of Predictors (k) | 37 | 33 | 33 |
| F Statistic | 442.8 | 496.7 | 495.9 |
| Adjusted R Squared | 0.77 | 0.77 | 0.77 |

## 5.2. Continuous Distance Model

The potential impact of wind facilities on residential property values based on Area and Nuisance effects was explored with the Base Model by using five ordered categorical DISTANCE variables. This approach was used in order to impose the least restriction on the functional relationship between distance and property values (as discussed in footnote 52 on page 25). The literature on environmental disamenities, however, more commonly uses a continuous distance form (e.g., Sims et al., 2008), which imposes more structure on this relationship. To be consistent with the literature and to test if a more rigid structural relationship might uncover an effect that is not otherwise apparent with the five distance categories used in the Base Model, a hedonic model that relies upon a continuous distance variable is presented here. One important benefit of this model is that a larger amount of data (e.g., $n = 4{,}937$) is used to estimate the continuous DISTANCE coefficient then was used to estimate any of the individual categorical estimates in the Base Model (e.g., $n = 67$ inside 3000 feet, $n = 2019$ between one and three miles). The Continuous Distance Model therefore provides an important robustness test to the Base Model results.

### 5.2.1. Dataset and Model Form

A number of different functional forms can be used for a continuous DISTANCE variable, including linear, inverse, cubic, quadratic, and logarithmic. Of the forms that are considered, an inverse function seemed most appropriate.[71] Inverse functions are used when it is assumed that any effect is most pronounced near the disamenity and that those effects fade asymptotically as distance increases. This form has been used previously in the literature (e.g., Leonard et al., 2008) to explore the impact of disamenities on home values, and is calculated as follows:

$$\text{InvDISTANCE} = 1 / \text{DISTANCE} \tag{4}$$

where
DISTANCE is the distances to the nearest turbine from each home as calculated at the time of sale for homes that sold in the post-construction period.

For the purpose of the Continuous Distance Model, the same dataset is used as in the Base Model, focusing again on post-construction transactions ($n = 4{,}937$). InvDISTANCE has a maximum of 6.67 (corresponding to homes that were 0.15 miles, or roughly 800 feet, from the nearest wind turbine), a minimum of 0.09 (corresponding to a distance of roughly 11 miles), and a mean of 0.38 (corresponding to a distance of 2.6 miles). This function was then introduced into the hedonic model in place of the DISTANCE categorical variables as follows:

$$\ln(\text{P}) = \beta_0 + \beta_1\text{N} + \sum_s \beta_2\text{S} + \sum_k \beta_3\text{X} + \sum_v \beta_4\text{VIEW} + \beta_5\text{InvDISTANCE} + \varepsilon \tag{5}$$

where
$\text{InvDISTANCE}_i$ is the inverse of the distance to the nearest turbine,
$\beta_5$ is a parameter estimate for the inverse of the distance to the nearest turbine, and

[71] The other distance functions (e.g., linear, quadratic, cubic & logarithmic) were also tested. Additionally, two-part functions with interactions between continuous forms (e.g., linear) and categorical (e.g., less than one mile) were investigated. Results from these models are briefly discussed below in footnote 72.

all other components are as defined in equation (1).

The coefficient of interest in this model is $\beta_5$, which, if effects exist, would be expected to be negative, indicating an adverse effect from proximity to the wind turbines.

### 5.2.2. Analysis of Results

Results for the variables of interest in the Continuous Distance Model and the Base Model are shown in Table 13. (For brevity, the full set of results for the model is not shown in Table 13, but is instead included in Appendix H.) The model performs well with an adjusted $R^2$ of 0.77. All study area, spatial adjustment, and home and site characteristics are significant at the one percent level. The coefficients for VIEW are similar to those found in the Base Model, demonstrating stability in results, and none are statistically significant. These results support the previous findings of a lack of evidence of a Scenic Vista Stigma.

Our focus variable InvDISTANCE produces a coefficient ($\beta_5$) that is slightly negative at -1%, but that is not statistically different from zero (*p* value 0.41), implying again that there is no statistical evidence of a Nuisance Stigma effect nor an Area Stigma effect and confirming the results obtained in the Base Model.[72]

**Table 13: Results from Continuous Distance Model**

| | Base Model | | | | Continuous Distance | | | |
|---|---|---|---|---|---|---|---|---|
| Variables of Interest | Coef | SE | p Value | *n* | Coef | SE | p Value | *n* |
| No View | Omitted | Omitted | Omitted | 4,207 | Omitted | Omitted | Omitted | 4,207 |
| Minor View | -0.01 | 0.01 | 0.39 | 561 | -0.01 | 0.01 | 0.32 | 561 |
| Moderate View | 0.02 | 0.03 | 0.57 | 106 | 0.01 | 0.03 | 0.77 | 106 |
| Substantial View | -0.01 | 0.07 | 0.92 | 35 | -0.02 | 0.07 | 0.64 | 35 |
| Extreme View | 0.02 | 0.09 | 0.77 | 28 | 0.01 | 0.10 | 0.85 | 28 |
| Inside 3000 Feet | -0.05 | 0.06 | 0.31 | 67 | | | | |
| Between 3000 Feet and 1 Mile | -0.05 | 0.05 | 0.20 | 58 | | | | |
| Between 1 and 3 Miles | 0.00 | 0.02 | 0.80 | 2,019 | | | | |
| Between 3 and 5 Miles | 0.02 | 0.01 | 0.26 | 1,923 | | | | |
| Outside 5 Miles | Omitted | Omitted | Omitted | 870 | | | | |
| InvDISTANCE | | | | | -0.01 | 0.02 | 0.41 | 4,937 |

*"Omitted" = reference category for fixed effects variables. "n" = number of cases in category when category = "1"*

**Model Information**

| | | |
|---|---|---|
| Model Equation Number | 1 | 5 |
| Dependent Variable | LN_SalePrice96 | LN_SalePrice96 |
| Number of Cases | 4937 | 4937 |
| Number of Predictors (k) | 37 | 34 |
| F Statistic | 442.8 | 481.3 |
| Adjusted R Squared | 0.77 | 0.77 |

## 5.3. All Sales Model

The Base Model presented earlier relied on only those transactions that occurred after the construction of the relevant wind facility. This approach, however, leaves open two key questions. First, it is possible that the property values of all of the post-construction homes in the

[72] As mentioned in footnote 71 on page 36, a number of alternative forms of the continuous distance function were also explored, including two-part functions, with no change in the results presented here. In all cases the resulting continuous distance function was not statistically significant.

sample have been affected by the presence of a wind facility, and therefore that the reference homes in the Base Model (i.e., those homes outside of five miles with no view of a wind turbine) are an inappropriate comparison group because they too have been impacted.[73] Using only those homes that sold before the announcement of the wind facility (pre-announcement) as the reference group would, arguably, make for a better comparison because the sales price of those homes are not plausibly impacted by the presence of the wind facility.[74] Second, the Base Model does not consider homes that sold in the post-announcement but pre-construction period, and previous research suggests that property value effects might be very strong during this period, during which an assessment of actual impacts is not possible and buyers and sellers may take a more-protective and conservative stance (Wolsink, 1989). This subsection therefore presents the results of a hedonic model that uses the full set of transactions in the dataset, pre- and post-construction.

### 5.3.1. Dataset and Model Form

Unlike the Base Model, in this instance the full set of 7,459 residential transactions is included. The following model is then estimated:

$$\ln(P) = \beta_0 + \beta_1 N + \sum_s \beta_2 S + \sum_k \beta_3 X + \sum_v \beta_4 \text{VIEW} + \sum_d \beta_5 \text{DISTANCE} + \varepsilon \quad (6)$$

where

VIEW is a vector of $v$ categorical view variables (e.g., NONE, MINOR, MODERATE, etc.),

DISTANCE is a vector of $d$ categorical distance variables (e.g., less than 3000 feet, between one and three miles, outside of five mile, etc.),

$\beta_4$ is a vector of $v$ parameter estimates for the VIEW variables as compared to pre-construction transactions,

$\beta_5$ is a vector of $d$ parameter estimates for the DISTANCE variables as compared to pre-announcement transactions, and

all other components are as defined in equation (1).

It is important to emphasize that the VIEW and DISTANCE parameters in equation (6) have different reference categories than they do in the Base Model - equation (1). In the Base Model, DISTANCE and VIEW are estimated in the post-construction period in reference to homes that sold outside of five miles and with no view of the turbines respectively.[75] In the All Sales Model, on the other hand, the coefficients for VIEW ($\beta_4$) are estimated in reference to all <u>pre-construction</u> transactions (spanning the pre-announcement and post-announcement-pre-construction periods) and the coefficients for DISTANCE ($\beta_5$) are estimated in reference to all <u>pre-announcement</u> transactions. In making a distinction between the reference categories for VIEW and DISTANCE, it is assumed that awareness of the view of turbines and awareness of

[73] This might be the case if there is an Area Stigma that includes the reference homes.

[74] As discussed in footnote 47 on page 19, it is conceivable that awareness might occur prior to the "announcement" date used for this analysis. If true, this bias is likely to be sporadic in nature and less of an issue in this model, when all pre-announcement transactions are pooled (e.g., both transactions near and far away from where the turbines were eventually located) than in models presented later (e.g., temporal aspects model). Nonetheless, if present, this bias may weakly draw down the pre-announcement reference category.

[75] See Section 4.1 and also footnote 51 on page 24 for more information on why the post-construction dataset and five-mile-no-view homes reference category are used in the Base Model.

the distance from them might not occur at the same point in the development process. Specifically, it is assumed that VIEW effects largely occur after the turbines are erected, in the post-construction period, but that DISTANCE effects might occur in the post-announcement-pre-construction timeframe. For example, after a wind facility is announced, it is not atypical for a map of the expected locations of the turbines to be circulated in the community, allowing home buyers and sellers to assess the distance of the planned facility from homes. Because of this assumed difference in when awareness begins for VIEW and DISTANCE, the DISTANCE variable is populated for transactions occurring in the post-announcement-pre-construction period as well as the post-construction period (see Table 14 below), but the VIEW variable is populated only for transactions in the post-construction period – as they were in the Base Model.[76]

**Table 14: Frequency Summary for DISTANCE in All Sales Model**

| | < 0.57 Miles | 0.57 - 1 Miles | 1 - 3 Miles | 3 - 5 Miles | > 5 Miles | Total |
|---|---|---|---|---|---|---|
| Post-Construction | 67 | 58 | 2019 | 1923 | 870 | 4937 |
| Post-Announcement-Pre-Construction | 13 | 7 | 340 | 277 | 130 | 767 |
| TOTAL | 80 | 65 | 2359 | 2200 | 1000 | 5704 |

One beneficial consequence of the differences in reference categories for the VIEW and DISTANCE variables in this model, as opposed to the Base Model, is that this model can accommodate all of the possible VIEW and DISTANCE categories, including NO VIEW transactions and transactions of homes outside of five miles. Because of the inclusion of these VIEW and DISTANCE categories, the tests to investigate Area, Scenic Vista, and Nuisance Stigmas are slightly different in this model than in the Base Model. For Area Stigma, for example, how homes with no view of the turbines fared can now be tested; if they are adversely affected by the presence of the wind facility, then this would imply a pervasive Area Stigma impact. For Scenic Vista Stigma, the VIEW coefficients (MINOR, MODERATE, etc.) can be compared (using a *t*-Test) to the NO VIEW results; if they are significantly different, a Scenic Vista Stigma would be an obvious culprit. Finally, for Nuisance Stigma, the DISTANCE coefficients inside of one mile can be compared (using a *t*-Test) to those outside of five miles; if there is a significant difference between these two categories of homes, then homes are likely affected by their proximity to the wind facility.

### 5.3.2. Analysis of Results

Results for the variables of interest for this hedonic model are summarized in Table 15, and Base Model results are shown for comparison purposes. (For brevity, the full set of results for the model is not shown in Table 15, but is instead included in Appendix H.) The adjusted $R^2$ for the model is 0.75, down slightly from 0.77 for the Base Model, and indicating that this model has slightly more difficulty (i.e. less explanatory power) modeling transactions that occurred pre-

[76] It is conceivable that VIEW effects could occur before the turbines are constructed. In some cases, for example, developers will simulate what the project will look like after construction during the post-announcement but pre-construction timeframe. In these situations, home buyers and sellers might adjust home values accordingly based on the expected views of turbines. It is assumed, however, that such adjustments are likely to be reasonably rare, and VIEW effects are therefore estimated using only post-construction sales.

construction.[77] All study area, spatial adjustment, and home and site characteristics are significant at or above the one percent level and are similar in sign and magnitude to the estimates derived from the post-construction Base Model.

The VIEW coefficients ($\beta_4$) are clearly affected by the change in reference category. All of the VIEW parameter estimates are higher than the Base Model estimates for the same categories. Of particular interest is the NO VIEW coefficient, which represents the values of homes without a view of the turbines and that sold in the post-construction period, as compared to the mean value of homes that sold in the pre-construction period, all else being equal. These homes, on average, are estimated to sell for 2% ($p$ value 0.08) more than similar pre-construction homes. If an Area Stigma existed, a negative coefficient for these NO VIEW homes would be expected. Instead, a positive and statistically significant coefficient is found.[78] It is outside the ability of this study to determine whether the increase is directly related to the wind turbines, or whether some other factor is impacting these results, but in either instance, no evidence of a pervasive Area Stigma associated with the presence of the wind facilities is found.

To test for the possibility of Scenic Vista Stigma, the coefficients for MINOR, MODERATE, SUBSTANTIAL, and EXTREME views can be compared to the NO VIEW coefficient using a simple $t$-Test. Table 16 presents these results. As shown, no significant difference is found for any of the VIEW coefficients when compared to NO VIEW transactions. This reinforces the findings earlier that, within the sample at least, there is no evidence of a Scenic Vista Stigma.

The DISTANCE parameter estimates ($\beta_5$) are also found to be affected by the change in reference category, and all are lower than the Base Model estimates for the same categories. This result likely indicates that the inflation-adjusted mean value of homes in the pre-announcement period is slightly higher, on average, than for those homes sold outside of five miles in the post-construction period. This difference could be attributed to the inaccuracy of the inflation index, a pervasive effect from the wind turbines, or to some other cause. Because the coefficients are not systematically statistically significant, however, this result is not pursued further. What is of interest, however, is the negative 8% estimate for homes located between 3000 feet and one mile of the nearest wind turbine ($p$ value 0.03). To correctly interpret this result, and to compare it to the Base Model, one needs to discern if this coefficient is significantly different from the estimate for homes located outside of five miles, using a $t$-Test.

The results of this $t$-Test are shown in Table 17. The coefficient differences are found to be somewhat monotonically ordered. Moving from homes within 3000 feet (-0.06, $p$ value 0.22), and between 3000 feet and one mile (-0.08, $p$ value 0.04), to between one and three miles (0.00, $p$ value 0.93) and between three and five miles (0.01, $p$ value 0.32) the DISTANCE coefficients are found to generally increase. Nonetheless, none of these coefficients are statistically significant except one, homes that sold between 3000 feet and one mile. The latter finding suggests the possibility of Nuisance Stigma. It is somewhat unclear why an effect would be found in this model, however, when one was not evident in the Base Model. The most likely

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[77] This slight change in performance is likely due to the inaccuracies of home and site characteristics and the inflation adjustment for homes that sold in the early part of the study period. This is discussed in more detail in footnote 50 on page 23.

[78] For more on the significance level used for this report, see footnote 68 on page 30.

explanation is that the additional homes that are included in this model, specifically those homes that sold post-announcement but pre-construction, are driving the results. A thorough investigation of these "temporal" issues is provided in the next subsection.

In summation, no evidence is found of an Area or Scenic Vista Stigma in this alternative hedonic model, but some limited not-conclusive evidence of a Nuisance Stigma is detected. To further explore the reliability of this latter result, the analysis now turns to the Temporal Aspects Model.

Table 15: Results from All Sales Model

| | Base Model | | | | All Sales | | | |
|---|---|---|---|---|---|---|---|---|
| Variables of Interest | Coef | SE | p Value | *n* | Coef | SE | p Value | *n* |
| Pre-Construction Sales | n/a | n/a | n/a | n/a | Omitted | Omitted | Omitted | 2,522 |
| No View | Omitted | Omitted | Omitted | 4,207 | 0.02 | 0.01 | 0.08 | 4,207 |
| Minor View | -0.01 | 0.01 | 0.39 | 561 | 0.00 | 0.02 | 0.77 | 561 |
| Moderate View | 0.02 | 0.03 | 0.57 | 106 | 0.03 | 0.03 | 0.41 | 106 |
| Substantial View | -0.01 | 0.07 | 0.92 | 35 | 0.03 | 0.07 | 0.53 | 35 |
| Extreme View | 0.02 | 0.09 | 0.77 | 28 | 0.06 | 0.08 | 0.38 | 28 |
| Inside 3000 Feet | -0.05 | 0.06 | 0.31 | 67 | -0.06 | 0.05 | 0.18 | 80 |
| Between 3000 Feet and 1 Mile | -0.05 | 0.05 | 0.20 | 58 | -0.08 | 0.05 | 0.03 | 65 |
| Between 1 and 3 Miles | 0.00 | 0.02 | 0.80 | 2,019 | 0.00 | 0.01 | 0.80 | 2,359 |
| Between 3 and 5 Miles | 0.02 | 0.01 | 0.26 | 1,923 | 0.01 | 0.01 | 0.59 | 2,200 |
| Outside 5 Miles | Omitted | Omitted | Omitted | 870 | 0.00 | 0.02 | 0.78 | 1,000 |
| Pre-Announcement Sales | n/a | n/a | n/a | n/a | Omitted | Omitted | Omitted | 1,755 |

*"Omitted" = reference category for fixed effects variables. "n" = number of cases in category when category = "1"*

Model Information

| | Base Model | All Sales |
|---|---|---|
| Model Equation Number | 1 | 6 |
| Dependent Variable | LN_SalePrice96 | LN_SalePrice96 |
| Number of Cases | 4937 | 7459 |
| Number of Predictors (k) | 37 | 39 |
| F Statistic | 442.8 | 579.9 |
| Adjusted R Squared | 0.77 | 0.75 |

Table 16: Results from Equality Test of VIEW Coefficients in the All Sales Model

| | No View | Minor View | Moderate View | Substantial View | Extreme View |
|---|---|---|---|---|---|
| *n* | 4,207 | 561 | 106 | 35 | 28 |
| Coefficient | 0.02 | 0.00 | 0.03 | 0.03 | 0.06 |
| Coefficient Difference * | Reference | -0.02 | 0.00 | 0.01 | 0.04 |
| Variance | 0.0001 | 0.0003 | 0.0009 | 0.0030 | 0.0050 |
| Covariance | n/a | 0.00011 | 0.00010 | 0.00009 | 0.00008 |
| Df | n/a | 7419 | 7419 | 7419 | 7419 |
| *t*-Test | n/a | -1.20 | 0.17 | 0.23 | 0.58 |
| Significance | n/a | 0.23 | 0.87 | 0.82 | 0.57 |

** Differences are rounded to the nearest second decimal place.*
*"n" = number of cases in category when category = "1"*

Table 17: Results from Equality Test of DISTANCE Coefficients in the All Sales Model

| | Inside 3000 Feet | Between 3000 Feet and 1 Mile | Between 1 and 3 Miles | Between 3 and 5 Miles | Outside 5 Miles |
|---|---|---|---|---|---|
| *n* | 80 | 65 | 2,359 | 2,200 | 1,000 |
| Coefficient | -0.06 | -0.08 | 0.00 | 0.01 | 0.00 |
| Coefficient Difference * | -0.05 | -0.08 | 0.00 | 0.01 | Reference |
| Variance | 0.0019 | 0.0015 | 0.0002 | 0.0002 | 0.0003 |
| Covariance | 0.00010 | 0.00013 | 0.00013 | 0.00015 | n/a |
| Df | 7419 | 7419 | 7419 | 7419 | n/a |
| *t* Test | -1.23 | -2.06 | 0.09 | 1.00 | n/a |
| Significance | 0.22 | 0.04 | 0.93 | 0.32 | n/a |

** Differences are rounded to the nearest second decimal place.*
*"n" = number of cases in category when category = "1"*

## 5.4. Temporal Aspects Model

Based on the results of the All Sales Model, a more thorough investigation of how Nuisance and Area Stigma effects might change throughout the wind project development period is warranted. As discussed previously, there is some evidence that property value impacts may be particularly strong after the announcement of a disamenity, but then may fade with time as the community adjusts to the presence of that disamenity (e.g., Wolsink, 1989). The Temporal Aspects Model presented here allows for an investigation of how the different periods of the wind project development process affect estimates for the impact of DISTANCE on sales prices.

### 5.4.1. Dataset and Model Form

Here the full set of 7,459 residential transactions is used, allowing an exploration of potential property value impacts (focusing on the DISTANCE variable) throughout time, including in the pre-construction period. The following model is then estimated:

$$\ln(P) = \beta_0 + \beta_1 N + \sum_s \beta_2 S + \sum_k \beta_3 X + \sum_v \beta_4 VIEW + \sum_y \beta_5 (DISTANCE \cdot PERIOD) + \varepsilon \qquad (7)$$

where
DISTANCE is a vector of categorical distance variables (e.g., less than one mile, between one and three miles, etc.),
PERIOD is a vector of categorical development period variables (e.g., after announcement and before construction, etc.),
$\beta_5$ is a vector of $y$ parameter estimates for each DISTANCE and PERIOD category as compared to the transactions more than two years before announcement and outside of five miles, and
all other components are as defined in equation (1).

The PERIOD variable contains six different options:
1) More than two years before announcement;
2) Less than two years before announcement;
3) After announcement but before construction;
4) Less than two years after construction;
5) Between two and four years after construction; and

6) More than four years after construction.

In contrast to the Base Model, the two DISTANCE categories inside of one mile are collapsed into a single "less than one mile" group. This approach increases the number of transactions in each crossed subcategory of data, and therefore enhances the stability of the parameter estimates and decreases the size of the standard errors, thus providing an increased opportunity to discover statistically significant effects. Therefore, in this model the DISTANCE variable contains four different options:
1) Less than one mile;
2) Between one and three miles;
3) Between three and five miles; and
4) Outside of five miles.[79]

The number of transactions in each of the DISTANCE and PERIOD categories is presented in Table 18.

The coefficients of interest are $\beta_5$, which represent the vector of marginal differences between homes sold at various distances from the wind facility (DISTANCE) during various periods of the development process (PERIOD) as compared to the reference group. The reference group in this model consists of transactions that occurred more than two years before the facility was announced for homes that were situated more than five miles from where the turbines were ultimately constructed. It is assumed that the value of these homes would not be affected by the future presence of the wind facility. The VIEW parameters, although included in the model, are not interacted with PERIOD and therefore are treated as controlling variables.[80]

Although the comparisons of these categorical variables <u>between</u> different DISTANCE and PERIOD categories is be interesting, it is the comparison of coefficients <u>within</u> each PERIOD and DISTANCE category that is the focus of this section. Such comparisons, for example, allow one to compare how the average value of homes inside of one mile that sold two years before announcement compare to the average value of homes inside of one mile that sold in the post-announcement-pre-construction period. For this comparison, a *t*-Test similar to that in the All Sales Model is used.

---

[79] For homes that sold in the pre-construction time frame, no turbines yet existed, and therefore DISTANCE is created using a proxy: the Euclidian distance to where the turbines were eventually constructed. This approach introduces some bias when there is more than one facility in the study area. Conceivably, a home that sold in the post-announcement-pre-construction period of one wind facility could also be assigned to the pre-announcement period of another facility in the same area. For this type of sale, it is not entirely clear which PERIOD and DISTANCE is most appropriate, but every effort was made to apply the sale to the wind facility that was most likely to have an impact. In most cases this meant choosing the closest facility, but in some cases, when development periods were separated by many years, simply the earliest facility was chosen. In general, any bias created by these judgments is expected to be minimal because, in the large majority of cases, the development process in each study area was more-or-less continuous and focused in a specific area rather then being spread widely apart.

[80] As discussed earlier, the VIEW variable was considered most relevant for the post-construction period, so delineations based on development periods that extended into the pre-construction phase were unnecessary. It is conceivable, however, that VIEW effects vary in periods following construction, such as in the first two years or after that. Although this is an interesting question, the numbers of cases for the SUBSTANTIAL and EXTREME ratings – even if combined – when divided into the temporal periods were too small to be fruitful for analysis.



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Table 18: Frequency Crosstab of DISTANCE and PERIOD

| | More Than 2 Years Before Announcement | Less Than 2 Years Before Announcement | After Announcement Before Construction | Less Than 2 Years After Construction | Between 2 and 4 Years After Construction | More Than 4 Years After Construction | Total |
|---|---|---|---|---|---|---|---|
| Less Than 1 Mile | 38 | 40 | 20 | 39 | 45 | 43 | 225 |
| Between 1 and 3 Miles | 283 | 592 | 340 | 806 | 502 | 709 | 3,232 |
| Between 3 and 5 Miles | 157 | 380 | 277 | 572 | 594 | 757 | 2,737 |
| Outside of 5 Miles | 132 | 133 | 130 | 218 | 227 | 425 | 1,265 |
| TOTAL | 610 | 1,145 | 767 | 1,635 | 1,368 | 1,934 | 7,459 |

## 5.4.2. Analysis of Results

Results for the variables of interest for this hedonic model are presented in Table 19; as with previous models, the full set of results is contained in Appendix H. Similar to the All Sales Model discussed in the previous section, the adjusted $R^2$ for the model is 0.75, down slightly from 0.77 for the Base Model, and indicating that this model has slightly more difficulty (i.e., less explanatory power) modeling transactions that occurred before wind facility construction. All study area, spatial adjustment, and home and site characteristics are significant at or above the one percent level, are of the appropriate sign, and are similar in magnitude to the estimates derived from the post-construction Base Model.

All of the DISTANCE / PERIOD interaction coefficients for distances outside of one mile are relatively small ($-0.04 < \beta_5 < 0.02$) and none are statistically significant. This implies that there are no statistically significant differences in property values between the reference category homes – homes sold more than two years before announcement that were situated outside of five miles from where turbines were eventually erected – and any of the categories of homes that sold outside of one mile at any other period in the wind project development process. These comparisons demonstrate, arguably more directly than any other model presented in this report that Area Stigma effects likely do not exist in the sample.

The possible presence of a Nuisance Stigma is somewhat harder to discern. For homes that sold inside of one mile of the nearest wind turbine, in three of the six periods there are statistically significant negative differences between average property values when compared to the reference category. Transactions completed more than two years before facility announcement are estimated to be valued at 13% less (*p* value 0.02) than the reference category, transactions less than two years before announcement are 10% lower (*p* value 0.06), and transactions after announcement but before construction are 14% lower (*p* value 0.04). For other periods, however, these marginal differences are considerably smaller and are not statistically different from the reference category. Sales prices in the first two years after construction are, on average, 9% less (*p* value 0.15), those occurring between three and four years following construction are, on average, 1% less (*p* value 0.86), and those occurring more than four years after construction are, on average, 7% less (*p* value 0.37).

Table 19: Results from Temporal Aspects Model

| Variables of Interest | | Coef | SE | p Value | *n* |
|---|---|---|---|---|---|
| | | Temporal Aspects | | | |
| Inside 1 Mile | More Than 2 Years Before Announcement | -0.13 | 0.06 | 0.02 | 38 |
| | Less Than 2 Years Before Announcement | -0.10 | 0.05 | 0.06 | 40 |
| | After Announcement Before Construction | -0.14 | 0.06 | 0.04 | 21 |
| | 2 Years After Construction | -0.09 | 0.07 | 0.11 | 39 |
| | Between 2 and 4 Years After Construction | -0.01 | 0.06 | 0.85 | 44 |
| | More Than 4 Years After Construction | -0.07 | 0.08 | 0.22 | 42 |
| Between 1-3 Miles | More Than 2 Years Before Announcement | -0.04 | 0.03 | 0.18 | 283 |
| | Less Than 2 Years Before Announcement | 0.00 | 0.03 | 0.91 | 592 |
| | After Announcement Before Construction | -0.02 | 0.03 | 0.54 | 342 |
| | 2 Years After Construction | 0.00 | 0.03 | 0.90 | 807 |
| | Between 2 and 4 Years After Construction | 0.01 | 0.03 | 0.78 | 503 |
| | More Than 4 Years After Construction | 0.00 | 0.03 | 0.93 | 710 |
| Between 3-5 Miles | More Than 2 Years Before Announcement | 0.00 | 0.04 | 0.92 | 157 |
| | Less Than 2 Years Before Announcement | 0.00 | 0.03 | 0.97 | 380 |
| | After Announcement Before Construction | 0.00 | 0.03 | 0.93 | 299 |
| | 2 Years After Construction | 0.02 | 0.03 | 0.55 | 574 |
| | Between 2 and 4 Years After Construction | 0.01 | 0.03 | 0.65 | 594 |
| | More Than 4 Years After Construction | 0.01 | 0.03 | 0.67 | 758 |
| Outside 5 Miles | More Than 2 Years Before Announcement | Omitted | Omitted | Omitted | 132 |
| | Less Than 2 Years Before Announcement | -0.03 | 0.04 | 0.33 | 133 |
| | After Announcement Before Construction | -0.03 | 0.03 | 0.39 | 105 |
| | 2 Years After Construction | -0.03 | 0.03 | 0.44 | 215 |
| | Between 2 and 4 Years After Construction | 0.03 | 0.03 | 0.44 | 227 |
| | More Than 4 Years After Construction | 0.01 | 0.03 | 0.73 | 424 |

*"Omitted" = reference category for fixed effects variables.*
*"n" indicates number of cases in category when category = "1"*

Model Information

| | |
|---|---|
| Model Equation Number | 7 |
| Dependent Variable | LN_SalePrice96 |
| Number of Cases | 7459 |
| Number of Predictors (k) | 56 |
| F Statistic | 404.5 |
| Adjusted R Squared | 0.75 |

What these results suggest (as shown in Figure 8) is that homes inside of one mile in the sample, on average, were depressed in value (in relation to the reference category) before and after the announcement of the wind facility and up to the point that construction began, but that those values rebounded somewhat after construction commenced.[81] This conclusion also likely explains why a significant and negative effect for homes that sold between 3000 feet and one mile is found in the All Sales Model presented in Section 5.3: homes within this distance range that sold prior to facility construction were depressed in value and most likely drove the results for homes that sold after announcement. Regardless, these results are not suggestive of a pervasive Nuisance Stigma.

[81] As discussed in footnotes 47 (on page 19) and 74 (on page 38), the "announcement date" often refers to the first time the proposed facility appeared in the press. "Awareness" of the project in the community may precede this date, however, and therefore transactions occurring in the period "less than two years before announcement" could conceivably have been influenced by the prospective wind project, but it is considerably less likely that those in the period more than two years before announcement would have been influenced.



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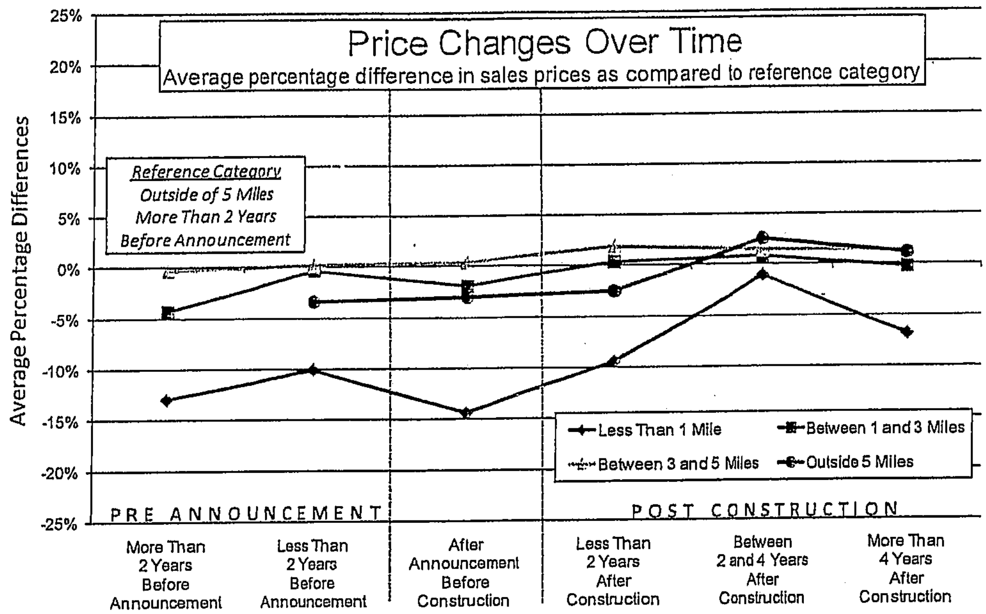
**Figure 8: Results from the Temporal Aspects Model**




*The reference category consists of transactions of homes situated more than five miles from where the nearest turbine would eventually be located and that occurred more than two years before announcement of the facility*

To explore Nuisance Stigma further, the analysis again turns to the *t*-Test and compares the coefficients for transactions that occurred more than two years before wind facility announcement (during which time the future wind facility is not expected to have any impact on sales prices) to the estimates for the DISTANCE coefficients in the periods that follow. These results are shown in Table 20. Focusing on those transactions inside of one mile, it is found that all coefficients are greater in magnitude than the reference category except during the post-announcement-pre-construction period (which is 1% less and is not statistically significant; *p* value 0.90), indicating, on average, that home values are increasing or staying stable from the pre-announcement reference period onward. These increases, however, are not statistically significant except in the period of two to four years after construction (0.12, *p* value 0.08). With respect to Nuisance Stigma, the more important result is that, relative to homes that sold well before the wind facility was announced, no statistically significant adverse effect is found in any period within a one mile radius of the wind facility. Therefore, the -5% (albeit not statistically significant) average difference that is found in the Base Model, and the -8% (statistically significant) result that is found in the All Sales Model (for homes between 3000 feet and one mile) appear to both be a reflection of depressed home prices that preceded the construction of the relevant wind facilities. If construction of the wind facilities were downwardly influencing the sales prices of these homes, as might be deduced from the Base or All Sales Models alone, a diminution in the inflation adjusted price would be seen as compared to pre-announcement levels. Instead, an increase is seen. As such, no persuasive evidence of a Nuisance Stigma is evident among this sample of transactions.[82]

[82] It should be noted that the numbers of study areas represented for homes situated inside of one mile but in the periods "more than two years before announcement" and "more than four years after construction" are fewer ($n = 5$) than in the other temporal categories ($n = 8$). Further, the "more than two years before announcement – inside of one mile" category is dominated by transactions from one study area (OKCC). For these reasons, there is less

Turning to the coefficient differences for distances greater than one mile in Table 20, again, no statistical evidence of significant adverse impacts on home values is uncovered. Where statistically significant differences are identified, the coefficients are greater than the reference category. These findings corroborate the earlier Area Stigma results, and re-affirm the lack of evidence for such an effect among the sample of residential transactions included in this analysis.

Table 20: Results from Equality Test of Temporal Aspects Model Coefficients

| | More Than 2 Years Before Announcement | Less Than 2 Years Before Announcement | After Announcement Before Construction | Less Than 2 Years After Construction | Between 2 and 4 Years After Construction | More Than 4 Years After Construction |
|---|---|---|---|---|---|---|
| Less Than 1 Mile | Reference | 0.03 (0.45) | -0.01 (-0.13) | 0.04 (0.56) | 0.12 (1.74)* | 0.06 (0.88) |
| Between 1 and 3 Miles | Reference | 0.04 (1.92)* | 0.02 (0.86) | 0.05 (2.47)** | 0.05 (2.27)** | 0.04 (1.82)* |
| Between 3 and 5 Miles | Reference | 0.01 (0.37) | 0.01 (0.34) | 0.02 (0.77) | 0.02 (0.78) | 0.02 (0.79) |
| Outside of 5 Miles † | Reference | -0.04 (-0.86) | -0.03 (-0.91) | -0.03 (-0.77) | 0.03 (0.81) | 0.01 (0.36) |

*Numbers in parenthesis are t-Test statistics. Significance = *** 1% level, ** 5% level, * 10% level, <blank> below the 10% level.*

† *For homes outside of 5 miles, the coefficient differences are equal to the coefficients in the Temporal Aspects Model, and therefore the t-values were produced via the OLS.*

## 5.5. Orientation Model

All of the hedonic models presented to this point use a VIEW variable that effectively assumes that the impact of a view of wind turbines on property values will not vary based on the orientation of the home to that view; the impact will be the same whether the view is seen from the side of the home or from the back or front. Other literature, however, has found that the impact of wind projects on property values may be orientation-dependent (Sims et al., 2008). To investigate this possibility further a parameter for orientation is included in the model.

### 5.5.1. Dataset and Model Form

The same dataset is used as in the Base Model, focusing on post-construction transactions ($n$ = 4,937). To investigate whether the orientation of a home to the turbines (ORIENTATION) has a marginal impact on residential property values, over and above that of the VIEW impacts alone, the following hedonic model is estimated:[83]

---

confidence in these two estimates (-13% and -7% respectively) than for the estimates for other temporal periods inside of one mile. Based on additional sensitivity analysis not included here, it is believed that if they are biased, both of these estimates are likely biased downward. Further, as discussed in footnote 47 on page 19, there is a potential for bias in the "announcement" date in that awareness of a project may precede the date that a project enters the public record (i.e., the "announcement" date used for this analysis). Taken together, these two issues might imply that the curve shown in Figure 8 for "less than one mile" transactions, instead of having a flat and then increasing shape, may have a more of an inverse parabolic (e.g., "U") shape. This would imply that a relative minimum in sales prices is reached in the period after awareness began of the facility but before construction commenced, and then, following construction, prices recovered to levels similar to those prior to announcement (and awareness). These results would be consistent with previous studies (e.g., Wolsink, 1989; Devine-Wright, 2004) but cannot be confirmed without the presence of more data. Further research on this issue is warranted. In either case, such results would not change the conclusion here of an absence of evidence of a pervasive Nuisance Stigma in the post-construction period.

[83] The various possible orientations of the home to the view of turbines will be, individually and collectively, referred to as "ORIENTATION" in this report.

$$\ln(P) = \beta_0 + \beta_1 N + \sum_s \beta_2 S + \sum_k \beta_3 X + \sum_v \beta_4 VIEW + \sum_d \beta_5 DISTANCE + \sum_o \beta_6 ORIENTATION + \varepsilon \quad (8)$$

where
ORIENTATION is a vector of $o$ ORIENTATION variables (e.g., SIDE, FRONT, and BACK),
$\beta_6$ is a vector of $o$ parameter estimates for ORIENTATION variables, and
all other components are as defined in equation (1).[84]

The ORIENTATION categories include FRONT, BACK, and SIDE, and are defined as follows:

- SIDE: The orientation of the home to the view of the turbines is from the side.
- FRONT: The orientation of the home to the view of the turbines is from the front.
- BACK: The orientation of the home to the view of the turbines is from the back.

The orientation of the home to the view of the wind facilities was determined in the course of the field visits to each home. If more than one orientation to the turbines best described the home (e.g., back and side, or front, back, and side) they were coded as such (e.g., turbines visible from back and side: SIDE = 1; BACK = 1; FRONT = 0).[85]

Not surprisingly, ORIENTATION is related to VIEW. Table 21 and Table 22 provide frequency and percentage crosstabs of ORIENTATION and VIEW. As shown, those homes with more dramatic views of the turbines generally have more ORIENTATION ratings applied to them. For instance, 25 out of 28 EXTREME VIEW homes have all three ORIENTATION ratings (i.e., FRONT, BACK, and SIDE). Virtually all of the MINOR VIEW homes, on the other hand, have only one ORIENTATION. Further, MINOR VIEW homes have roughly evenly spread orientations to the turbines across the various possible categories of FRONT, BACK, and SIDE. Conversely, a majority of the MODERATE and SUBSTANTIAL VIEW ratings coincide with an ORIENTATION from the back of the house.[86]

[84] Ideally, one would enter ORIENTATION in the model through an interaction with VIEW. There are two ways that could be accomplished: either with the construction of multiple fixed effects ("dummy") variables, which capture each sub-category of VIEW and ORIENTATION, or through a semi-continuous interaction variable, which would be created by multiplying the ordered categorical variable VIEW by an ordered categorical variable ORIENTATION. Both interaction scenarios are problematic, the former because it requires increasingly small subsets of data, which create unstable coefficient estimates, and the latter because there are no *a priori* expectations for the ordering of an ordered categorical ORIENTATION variable and therefore none could be created and used for the interaction. As a result, no interaction between the two variables is reported here.

[85] An "Angle" orientation was also possible, which was defined as being between Front and Side or Back and Side. An Angle orientation was also possible in combination with Back or Front (e.g., Back-Angle or Front-Angle). In this latter case, the orientation was coded as one of the two prominent orientations (e.g., Back or Front). An Angle orientation, not in combination with Front or Back, was coded as Side.

[86] The prevalence of BACK orientations for MODERATE and SUBSTANTIAL VIEW homes may be because BACK views might more-frequently be kept without obstruction, relative to SIDE views.

Table 21: Frequency Crosstab of VIEW and ORIENTATION

| | | VIEW | | | | |
|---|---|---|---|---|---|---|
| | | Minor | Moderate | Substantial | Extreme | Total |
| ORIENTATION | Front | 217 | 33 | 17 | 27 | 294 |
| | Back | 164 | 67 | 24 | 25 | 280 |
| | Side | 194 | 17 | 15 | 27 | 253 |
| | Total | 561 | 106 | 35 | 28 | 730 |

*Note: Total of ORIENTATION does not sum to 730 because multiple orientations are possible for each VIEW.*

Table 22: Percentage Crosstab of VIEW and ORIENTATION

| | | VIEW | | | | |
|---|---|---|---|---|---|---|
| | | Minor | Moderate | Substantial | Extreme | Total |
| ORIENTATION | Front | 39% | 31% | 49% | 96% | 40% |
| | Back | 29% | 63% | 69% | 89% | 38% |
| | Side | 35% | 16% | 43% | 96% | 35% |

*Note: Percentages are calculated as a portion of the total for each VIEW ratings (e.g., 24 of the 35 SUBSTANTIAL rated homes have a BACK ORIENTATION = 69%). Columns do not sum to 100% because multiple orientations are possible for each VIEW.*

The parameter estimates of interest in this hedonic model are those for ORIENTATION ($\beta_6$) and VIEW ($\beta_4$). $\beta_6$ represent the marginal impact on home value, over and above that of VIEW alone, of having a particular orientation to the turbines. In the Base Model the VIEW coefficients effectively absorb the effects of ORIENTATION, but in this model they are estimated separately. Because a home's surrounding environment is typically viewed from the front or back of the house, one would expect that, to the extent that wind facility VIEW impacts property values, that impact would be especially severe for homes that have FRONT or BACK orientations to those turbines. If this were the case, the coefficients for these categories would be negative, while the coefficient for SIDE would be to be close to zero indicating little to no incremental impact from a SIDE ORIENTATION.

### 5.5.2. Analysis of Results

Results for the variables of interest for this hedonic model are shown in Table 23; as with previous models, the full set of results is contained in Appendix H. The model performs well with an adjusted $R^2$ of 0.77. All study area, spatial adjustment, and home and site characteristics are significant at or above the one percent level, are of the appropriate sign, and are similar in magnitude to the estimates derived from the post-construction Base Model. The coefficients for DISTANCE and VIEW are stable, in sign and magnitude, when compared to the Base Model results, and none of the marginal effects are statistically significant.

The coefficients for the variables of interest ($\beta_6$) do not meet the *a priori* expectations. The estimated effect for SIDE ORIENTATION, instead of being close to zero, is -3% ($p$ value 0.36), while BACK and FRONT, instead of being negative and larger, are estimated at 3% ($p$ value 0.37) and -1% ($p$ value 0.72), respectively. None of these variables are found to be even marginally statistically significant, however, and based on these results, it is concluded that there is no evidence that a home's orientation to a wind facility affects property values in a measurable way. Further, as with previous models, no statistical evidence of a Scenic Vista Stigma is found among this sample of sales transactions.

**Table 23: Results from Orientation Model**

| | Base Model | | | | Orientation Model | | | |
|---|---|---|---|---|---|---|---|---|
| **Variables of Interest** | Coef | SE | p Value | *n* | Coef | SE | p Value | *n* |
| No View | Omitted | Omitted | Omitted | 4207 | Omitted | Omitted | Omitted | 4207 |
| Minor View | -0.01 | 0.01 | 0.39 | 561 | -0.01 | 0.06 | 0.88 | 561 |
| Moderate View | 0.02 | 0.03 | 0.57 | 106 | 0.00 | 0.06 | 0.96 | 106 |
| Substantial View | -0.01 | 0.07 | 0.92 | 35 | -0.01 | 0.09 | 0.85 | 35 |
| Extreme View | 0.02 | 0.09 | 0.77 | 28 | 0.02 | 0.17 | 0.84 | 28 |
| Inside 3000 Feet | -0.05 | 0.06 | 0.31 | 67 | -0.04 | 0.07 | 0.46 | 67 |
| Between 3000 Feet and 1 Mile | -0.05 | 0.05 | 0.20 | 58 | -0.05 | 0.05 | 0.26 | 58 |
| Between 1 and 3 Miles | 0.00 | 0.02 | 0.80 | 2019 | 0.00 | 0.02 | 0.83 | 2019 |
| Between 3 and 5 Miles | 0.02 | 0.01 | 0.26 | 1923 | 0.02 | 0.01 | 0.26 | 1923 |
| Outside 5 Miles | Omitted | Omitted | Omitted | 870 | Omitted | Omitted | Omitted | 870 |
| Front Orientation | | | | | -0.01 | 0.06 | 0.72 | 294 |
| Back Orientation | | | | | 0.03 | 0.06 | 0.37 | 280 |
| Side Orientation | | | | | -0.03 | 0.06 | 0.36 | 253 |

*"Omitted" = reference category for fixed effects variables. "n" = number of cases in category when category = "1"*

**Model Information**

| | Base Model | Orientation Model |
|---|---|---|
| Model Equation Number | 1 | 8 |
| Dependent Variable | LN_SalePrice96 | LN_SalePrice96 |
| Number of Cases | 4937 | 4937 |
| Number of Predictors (k) | 37 | 40 |
| F Statistic | 442.8 | 410.0 |
| Adjusted R Squared | 0.77 | 0.77 |

## 5.6. Overlap Model

The Orientation Model, presented above, investigated, to some degree, how the potential effects of wind turbines might be impacted by how a home is oriented to the surrounding environment. In so doing, this model began to peel back the relationship between VIEW and VISTA, but stopped short of looking at the relationship directly. It would be quite useful, though, to understand the explicit relationship between the VISTA and VIEW variables. In particular, one might expect that views of wind turbines would have a particularly significant impact on residential property values when those views strongly overlap ("OVERLAP") the prominent scenic vista from a home. To investigate this possibility directly, and, in general, the relationship between VIEW and VISTA, a parameter for OVERLAP is included in the model.

### 5.6.1. Dataset and Model Form

Data on the degree to which the view of wind turbines overlaps with the prominent scenic vista from the home (OVERLAP) were collected in the course of the field visits to each home.[87] The categories for OVERLAP included NONE, BARELY, SOMEWHAT, and STRONGLY, and are described in Table 24: [88]

Table 24: Definition of OVERLAP Categories

| | |
|---|---|
| OVERLAP - NONE | The scenic vista does not contain any view of the turbines. |
| OVERLAP - BARELY | A small portion (~ 0 - 20%) of the scenic vista is overlapped by the view of turbines, and might contain a view of a few turbines, only a few of which can be seen entirely. |
| OVERLAP - SOMEWHAT | A moderate portion (~20-50%) of the scenic vista contains turbines, and likely contains a view of more than one turbine, some of which are likely to be seen entirely. |
| OVERLAP - STRONGLY | A large portion (~50-100%) of the scenic vista contains a view of turbines, many of which likely can be seen entirely. |

A crosstab describing the OVERLAP designations and the VIEW categories is shown in Table 25. As would be expected, the more dramatic views of wind turbines, where the turbines occupy more of the panorama, are coincident with the OVERLAP categories of SOMEWHAT or STRONGLY. Nonetheless, STRONGLY are common for all VIEW categories. Similarly, SOMEWHAT is well distributed across the MINOR and MODERATE rated views, while BARELY is concentrated in the MINOR rated views.

The same dataset is used as in the Base Model, focusing on post-construction transactions ($n$ = 4,937). To investigate whether the overlap of VIEW and VISTA has a marginal impact on residential property values, over and above that of the VIEW and VISTA impacts alone, the following hedonic model is estimated:[89]

$$\ln(P) = \beta_0 + \beta_1 N + \sum_s \beta_2 S + \sum_k \beta_3 X + \sum_v \beta_4 \text{VIEW} + \sum_d \beta_5 \text{DISTANCE} + \sum_t \beta_6 \text{VISTA} + \sum_p \beta_7 \text{OVERLAP} + \varepsilon \quad (9)$$

where

VIEW is a vector of $v$ categorical view variables (e.g., MINOR, MODERATE, etc.),
VISTA is a vector of $t$ categorical scenic vista variables (e.g., POOR, BELOW-AVERAGE, etc.),
OVERLAP is a vector of $p$ categorical overlap variables (e.g., BARELY, SOMEWHAT, etc.),

[87] Scenic vista was rated while taking into account the entire panorama surrounding a home. But, for each home, there usually was a prominent direction that offered a preferred scenic vista. Often, but not always, the home was orientated to enjoy that prominent scenic vista. Overlap is defined as the degree to which the view of the wind facility overlaps with this prominent scenic vista.

[88] "...can be seen entirely" refers to being able to see a turbine from the top of the sweep of its blade tips to below the nacelle of the turbine where the sweep of the tips intersects the tower.

[89] Although VISTA appears in all models, and is usually included in the vector of home and site characteristics represented by X, it is shown separately here so that it can be discussed directly in the text that follows.

$\beta_4$ is a vector of $v$ parameter estimates for VIEW fixed effects variables as compared to transactions of homes without a view of the turbines,
$\beta_6$ is a vector of $t$ parameter estimates for VISTA fixed effect variables as compared to transactions of homes with an AVERAGE scenic vista,
$\beta_7$ is a vector of $o$ parameter estimates for OVERLAP fixed effect variables as compared to transactions of homes where the view of the turbines had no overlap with the scenic vista, and all other components are as defined in equation (1).

The variables of interest in this model are VIEW, VISTA and OVERLAP, and the coefficients $\beta_4$, $\beta_6$, and $\beta_7$ are therefore the primary focus. Theory would predict that the VISTA coefficients in this model would be roughly similar to those derived in the Base Model, but that the VIEW coefficients may be somewhat more positive as the OVERLAP variables explain a portion of any negative impact that wind projects have on residential sales prices. In that instance, the OVERLAP coefficients would be negative, indicating a decrease in sales price when compared to those homes that experience no overlap between the view of wind turbines and the primary scenic vista.

**Table 25: Frequency Crosstab of OVERLAP and VIEW**

| | | VIEW | | | | | |
|---|---|---|---|---|---|---|---|
| | | None | Minor | Moderate | Substantial | Extreme | Total |
| OVERLAP | None | 4,207 | 317 | 3 | 0 | 0 | 4,527 |
| OVERLAP | Barely | 0 | 139 | 10 | 1 | 0 | 150 |
| OVERLAP | Somewhat | 0 | 81 | 42 | 7 | 2 | 132 |
| OVERLAP | Strongly | 0 | 24 | 51 | 27 | 26 | 128 |
| | Total | 4,207 | 561 | 106 | 35 | 28 | 4,937 |

### 5.6.2. Analysis of Results

Results for the variables of interest for this hedonic model are shown in Table 26; as with previous models, the full set of results is contained in Appendix H. The model performs well with an adjusted $R^2$ of 0.77. All study area, spatial adjustment, and home and site characteristics are significant at or above the one percent level, are of the appropriate sign, and are similar in magnitude to the estimates derived from the post-construction Base Model.

As expected from theory, the VISTA parameters are stable across models with no change in coefficient sign, magnitude, or significance. Counter to expectations, however, the VIEW coefficients, on average, decrease in value. MINOR VIEW is now estimated to adversely affect a home's sale price by 3% ($p$ value 0.10) and is weakly significant, but none of the other VIEW categories are found to be statistically significant. Oddly, the OVERLAP rating of BARELY is found to significantly increase home values by 5% ($p$ value 0.08), while none of the other OVERLAP ratings are found to have a statistically significant impact.

Taken at face value, these results are counterintuitive. For instance, absent any overlap of view with the scenic vista (NONE), a home with a MINOR view sells for 3% less than a home with no view of the turbines. If, alternatively, a home with a MINOR view BARELY overlaps the prominent scenic vista, it not only enjoys a 2% increase in value over a home with NO VIEW of the turbines but a 5% increase in value over homes with views of the turbines that do not overlap with the scenic vista. In other words, the sales price increases when views of turbines overlap the prominent scenic vista, at least in the BARELY category. A more likely explanation for these results are that the relatively high correlation (0.68) between the VIEW and OVERLAP parameters is spuriously driving one set of parameters up and the other down. More importantly, when the parameters are combined, they offer a similar result as was found in the Base Model. Therefore, it seems that the degree to which the view of turbines overlaps the scenic vista has a negligible effect on sales prices among the sample of sales transactions analyzed here.[90]

Despite these somewhat peculiar results, other than MINOR, none of the VIEW categories are found to have statistically significant impacts, even after accounting for the degree to which those views overlap the scenic vista. Similarly, none of the OVERLAP variables are simultaneously negative and statistically significant. This implies, once again, that a Scenic Vista Stigma is unlikely to be present in the sample. Additionally, none of the DISTANCE coefficients are statistically significant, and those coefficients remain largely unchanged from the Base Model, reaffirming previous results in which no significant evidence of either an Area or a Nuisance Stigma was found.

[90] An alternative approach to this model was also considered, one that includes an interaction term between VIEW and VISTA. For this model it is assumed that homes with higher rated scenic vistas might have higher rated views of turbines, and that these views of turbines would decrease the values of the scenic vista. To construct the interaction, VISTA, which can be between one and five (e.g., POOR=1,...PREMIUM=5), was multiplied by VIEW, which can be between zero and four (e.g. NO VIEW=0, MINOR=1,...EXTREME=4). The resulting interaction (VIEW*VISTA) therefore was between zero and sixteen (there were no PREMIUM VISTA homes with an EXTREME VIEW), with zero representing homes without a view of the turbines, one representing homes with a POOR VISTA and a MINOR VIEW, and sixteen representing homes with either a PREMIUM VISTA and a SUBSTANTIAL VIEW or an ABOVE AVERAGE VISTA and an EXTREME VIEW. The interaction term, when included in the model, was relatively small (-0.013) and weakly significant ($p$ value 0.10 – not White's corrected). The VISTA estimates were unchanged and the VIEW parameters were considerably larger and positive. For instance, EXTREME was 2% in the Base Model and 16% in this "interaction" model. Similarly, SUBSTANTIAL was -1% in the Base Model and 13% in this model. Therefore, although the interaction term is negative and weakly significant, the resulting VIEW estimates, to which it would need to be added, fully offset this negative effect. These results support the idea that the degree to which a VIEW overlaps VISTA has a likely negligible effect on sales prices, while also confirming that there is a high correlation between the interaction term and VIEW variables.

Table 26: Results from Overlap Model

| Variables of Interest | Base Model | | | | Overlap Model | | | |
|---|---|---|---|---|---|---|---|---|
| | Coef | SE | p Value | n | Coef | SE | p Value | n |
| No View | Omitted | Omitted | Omitted | 4,207 | Omitted | Omitted | Omitted | 4,207 |
| Minor View | -0.01 | 0.01 | 0.39 | 561 | -0.03 | 0.02 | 0.10 | 561 |
| Moderate View | 0.02 | 0.03 | 0.57 | 106 | -0.02 | 0.04 | 0.65 | 106 |
| Substantial View | -0.01 | 0.07 | 0.92 | 35 | -0.05 | 0.09 | 0.43 | 35 |
| Extreme View | 0.02 | 0.09 | 0.77 | 28 | -0.03 | 0.10 | 0.73 | 28 |
| Inside 3000 Feet | -0.05 | 0.06 | 0.31 | 67 | -0.05 | 0.06 | 0.32 | 67 |
| Between 3000 Feet and 1 Mile | -0.05 | 0.05 | 0.20 | 58 | -0.05 | 0.05 | 0.27 | 58 |
| Between 1 and 3 Miles | 0.00 | 0.02 | 0.80 | 2,019 | 0.00 | 0.02 | 0.82 | 2,019 |
| Between 3 and 5 Miles | 0.02 | 0.01 | 0.26 | 1,923 | 0.02 | 0.01 | 0.26 | 1,923 |
| Outside 5 Miles | Omitted | Omitted | Omitted | 870 | Omitted | Omitted | Omitted | 870 |
| Poor Vista | -0.21 | 0.02 | 0.00 | 310 | -0.21 | 0.02 | 0.00 | 310 |
| Below Average Vista | -0.08 | 0.01 | 0.00 | 2,857 | -0.08 | 0.01 | 0.00 | 2,857 |
| Average Vista | Omitted | Omitted | Omitted | 1,247 | Omitted | Omitted | Omitted | 1,247 |
| Above Average Vista | 0.10 | 0.02 | 0.00 | 448 | 0.10 | 0.02 | 0.00 | 448 |
| Premium Vista | 0.13 | 0.04 | 0.00 | 75 | 0.13 | 0.04 | 0.00 | 75 |
| View Does Not Overlap Vista | | | | | Omitted | Omitted | Omitted | 320 |
| View Barely Overlaps Vista | | | | | 0.05 | 0.03 | 0.08 | 150 |
| View Somewhat Overlaps Vista | | | | | 0.01 | 0.03 | 0.66 | 132 |
| View Strongly Overlaps Vista | | | | | 0.05 | 0.05 | 0.23 | 128 |

*"Omitted" = reference category for fixed effects variables. "n" = number of cases in category when category = "1"*

Model Information

| | | |
|---|---|---|
| Model Equation Number | 1 | 9 |
| Dependent Variable | LN_SalePrice96 | LN_SalePrice96 |
| Number of Cases | 4937 | 4937 |
| Number of Predictors (k) | 37 | 40 |
| F Statistic | 442.8 | 409.7 |
| Adjusted R Squared | 0.77 | 0.77 |



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## 6. Repeat Sales Analysis

In general, the Base and Alternative Hedonic Models presented in previous sections come to the same basic conclusion: wind power facilities in this sample have no demonstrable, widespread, sizable, and statistically significant affect on residential property values. These hedonic models contain 29 or more controlling variables (e.g., house and site characteristics) to account for differences in home values across the sample. Although these models perform well and explain nearly 80% of the variation in sales prices among homes in the sample, it is always possible that variables not included in (i.e., "omitted from") the hedonic models could be correlated with the variables of interest, therefore biasing the results.

A common method used to control for omitted variable bias in the home assessment literature is to estimate a repeat sales model (Palmquist, 1982). This technique focuses on just those homes that have sold on more than one occasion, preferably once before and once after the introduction of a possible disamenity, and investigates whether the price appreciation between these transactions is affected by the presence of that disamenity. In this section a repeat sales analysis is applied to the dataset, investigating in a different way the presence of the three possible property value stigmas associated with wind facilities, and therefore providing an important cross-check to the hedonic model results. The section begins with a brief discussion of the general form of the Repeat Sales Model and a summary of the literature that has employed this approach to investigate environmental disamenities. The dataset and model used in the analysis is then described, followed by a summary of the results from that analysis.

### 6.1. Repeat Sales Models and Environmental Disamenities Literature

Repeat sales models use the annual sales-price appreciation rates of homes as the dependent variable. Because house, home site, and neighborhood characteristics are relatively stable over time for any individual home, many of those characteristics need not be included in the repeat sales model, thereby increasing the degrees of freedom and allowing sample size requirements to be significantly lower and coefficient estimates to be more efficient (Crone and Voith, 1992). A repeat sales analysis is not necessarily preferred over a traditional hedonic model, but is rather an alternative analysis approach that can be used to test the robustness of the earlier results (for further discussion see Jackson, 2003). The repeat sales model takes the basic form:

Annual Appreciation Rate (AAR) = *f* (TYPE OF HOUSE, OTHER FACTORS)

where
TYPE OF HOUSE provides an indication of the segment of the market in which the house is situated (e.g., high end vs. low end), and
OTHER FACTORS include, but are not limited to, changes to the environment (e.g., proximity to a disamenity).

The dependent variable is the adjusted annual appreciation rate and is defined as follows:

$$AAR = \exp\left[\frac{\ln(P_1 / P_2)}{t_1 - t_2}\right] - 1 \tag{10}$$

where



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$P_1$ is the adjusted sales price at the first sale (in 1996 dollars),
$P_2$ is the adjusted sales price at the second sale (in 1996 dollars),
$t_1$ is the date of the first sale,
$t_2$ is the date of the second sale, and
$(t_1 - t_2)$ is determined by calculating the number of days that separate the sale dates and dividing by 365.

As with the hedonic regression model, the usefulness of the repeat sales model is well established in the literature when investigating possible disamenities. For example, a repeat sales analysis was used to estimate spatial and temporal sales price effects from incinerators by Kiel and McClain (1995), who found that appreciation rates, on average, are not sensitive to distance from the facility during the construction phase but are during the operation phase. Similarly, McCluskey and Rausser (2003) used a repeat sales model to investigate effects surrounding a hazardous waste site. They found that appreciation rates are not sensitive to the home's distance from the disamenity before that disamenity is identified by the EPA as hazardous, but that home values are impacted by distance after the EPA's identification is made.

## 6.2. Dataset

The 7,459 residential sales transactions in the dataset contain a total of 1,253 transactions that involve homes that sold on more than one occasion (i.e., a "pair" of sales of the same home). For the purposes of this analysis, however, the key sample consists of homes that sold once before the announcement of the wind facility, and that subsequently sold again after the construction of that facility. Therefore any homes that sold twice in either the pre-announcement or post-construction periods were not used in the repeat sales sample.[91] These were excluded because either they occurred before the effect would be present (for pre-announcement pairs) or after (for post-announcement pairs). This left a total of 368 pairs for the analysis, which was subsequently reduced to 354 usable pairs.[92]

The mean AAR for the sample is 1.0% per year, with a low of -10.5% and a high of 13.4%. Table 27 summarizes some of the characteristics of the homes used in the repeat sales model. The average house in the sample has 1,580 square feet of above-ground finished living area, sits on a parcel of 0.67 acres, and originally sold for $70,483 (real 1996 dollars). When it sold a second time, the average home in the sample was located 2.96 miles from the nearest wind turbine (14 homes were within one mile, 199 between one and three miles, 116 between three and five miles, and 25 outside of five miles). Of the 354 homes, 14% ($n = 49$) had some view of the facility (35 were rated MINOR, five MODERATE, and nine either SUBSTANTIAL or EXTREME). Because of the restriction to those homes that experienced repeat sales, the sample is relatively small for those homes in close proximity to and with dramatic views of wind facilities.

[91] 752 pairs occurred after construction began, whereas 133 pairs occurred before announcement.

[92] Of the 368 pairs, 14 were found to have an AAR that was either significantly above or below the mean for the sample (mean +/- 2 standard deviations). These pairs were considered highly likely to be associated with homes that were either renovated or left to deteriorate between sales, and therefore were removed from the repeat sales model dataset. Only two of these 14 homes had views of the wind turbines, both of which were MINOR. All 14 of the homes were situated either between one and three miles from the nearest turbine ($n = 8$) or between three and five miles away ($n = 6$).

Table 27: List of Variables Included in the Repeat Sales Model

| Variable Name | Description | Type | Sign | Freq. | Mean | Std. Dev. | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| SalePrice96_Pre | The Sale Price (adjusted for inflation into 1996 dollars) of the home as of the first time it had sold | C | + | 354 | $ 70,483 | $ 37,798 | $ 13,411 | $ 291,499 |
| SalePrice96_Pre_Sqr | SalePrice96_Pre Squared (shown in millions) | C | – | 354 | $ 6,393 | $ 8,258 | $ 180 | $ 84,972 |
| Acres | Number of Acres that sold with the residence | C | + | 354 | 0.67 | 1.34 | 0.07 | 10.96 |
| Sqft_1000 | Number of square feet of finished above ground living area (in 1000s) | C | + | 354 | 1.58 | 0.56 | 0.59 | 4.06 |
| No View | If the home had no view of the turbines when it sold for the second time (Yes = 1, No = 0) | Omitted | n/a | 305 | 0.86 | 0.35 | 0 | 1 |
| Minor View | If the home had a Minor View of the turbines when it sold for the second time (Yes = 1, No = 0) | OC | – | 35 | 0.10 | 0.30 | 0 | 1 |
| Moderate View | If the home had a Moderate View of the turbines when it sold for the second time (Yes = 1, No = 0) | OC | – | 5 | 0.01 | 0.12 | 0 | 1 |
| Substantial/Extreme View | If the home had a Substantial or Extreme View of the turbines when it sold for the second time (Yes = 1, No = 0) | OC | – | 9 | 0.03 | 0.12 | 0 | 1 |
| Less than 1 Mile | If the home was within 1 mile (5280 feet) of the turbines when it sold for the second time (Yes = 1, No = 0) | OC | – | 14 | 0.02 | 0.13 | 0 | 1 |
| Between 1 and 3 Miles | If the home was between 1 and 3 miles of the turbines when it sold for the second time (Yes = 1, No = 0) | OC | – | 199 | 0.56 | 0.50 | 0 | 1 |
| Between 3 and 5 Miles | If the home was between 3 and 5 miles of the turbines when it sold for the second time (Yes = 1, No = 0) | OC | – | 116 | 0.33 | 0.47 | 0 | 1 |
| Outside 5 Miles | If the home was outside 5 miles of the turbines when it sold for the second time (Yes = 1, No = 0) | Omitted | n/a | 25 | 0.07 | 0.26 | 0 | 1 |

*"C" Continuous, "OC" Ordered Categorical (1 = yes, 0 = no) values are interpreted in relation to the "Omitted" category. This table does not include the study area fixed effects variables that are included in the model (e.g., WAOR, TXHC, NYMC). The reference case for these variables is the WAOR study area.*

## 6.3. Model Form

To investigate the presence of Area, Scenic Vista, and Nuisance Stigmas, the adjusted annual appreciation rate (AAR) is calculated for the 354 sales pairs in the manner described in equation (10), using inflation adjusted sales prices. The following model is then estimated:

$$AAR = \beta_0 + \sum_s \beta_1 S + \sum_k \beta_2 X + \sum_v \beta_3 VIEW + \sum_d \beta_4 DISTANCE + \varepsilon \quad (11)$$

where

AAR represents the inflation-adjusted Annual Appreciation Rate for repeat sales,
S is the vector of *s* Study Area fixed effects variables (e.g., WAOR, OKCC, etc.),
X is a vector of *k* home, site and sale characteristics (e.g., acres, square feet, original sales price),
VIEW is a vector of *v* categorical view variables (e.g., MINOR, MODERATE, etc.),
DISTANCE is a vector of *d* categorical distance variables (e.g., less than one mile, between one and three miles, etc.),
$\beta_0$ is the constant or intercept across the full sample,
$\beta_1$ is a vector of *s* parameter estimates for the study area fixed effects as compared to sales that occurred in the WAOR study area,
$\beta_2$ is a vector of *k* parameter estimates for the home, site, and sale characteristics,
$\beta_3$ is a vector of *v* parameter estimates for the VIEW variables as compared to transactions of homes with no view of the turbines,
$\beta_4$ is a vector of *d* parameter estimates for the DISTANCE variables as compared to transactions of homes outside of five miles, and
$\varepsilon$ is a random disturbance term.



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Effectively, this model seeks to identify reasons that AARs vary among those sales pairs in the sample. Reasons for such differences in AARs might include variations in home and site characteristics, the study area in which the sale occurs, or the degree to which the home is in proximity to or has a dramatic view of a wind facility. As such, the model as shown by equation (11) has three primary groups of parameters: variables of interest; home, site, and sale characteristics; and study area fixed effects.

The variables of interest are VIEW and DISTANCE, and the coefficients $\beta_3$ and $\beta_4$ are therefore the primary focus of this analysis. Because of the small numbers of homes in the sample situated inside of 3000 feet and between 3000 feet and one mile, they are collapsed into a single category (inside one mile). For the same reason, homes with SUBSTANTIAL or EXTREME VIEWS are collapsed into a single category (SUBSTANTIAL/EXTREME). In this model, therefore, the influence on appreciation rates of the following variables of interest is estimated: MINOR, MODERATE, and SUBSTANTIAL/EXTREME VIEWS, and less than one mile, between one and three mile, and between three and five mile DISTANCES. For the VIEW fixed-effects variables, the reference category is NO VIEW; for DISTANCE, it is homes outside of five miles. As with previous models, if effects exist, it is expected that all of the coefficients would be negative and monotonically ordered.

The number of home, site, and sale characteristics included in a repeat sales model is typically substantially lower than in a hedonic model. This is to be expected because, as discussed earlier, the repeat sales model explores variations in AARs for sales pairs from individual homes, and home and site characteristics are relatively stable over time for any individual home. Nonetheless, various characteristics have been found by others (e.g., Kiel and McClain, 1995; McCluskey and Rausser, 2003) to affect appreciation rates. For the purposes of the Repeat Sales Model, these include the number of square feet of living space (SQFT_1000), the number of acres (ACRES), the inflation-adjusted price of the home at the first sale (SalePrice96_Pre), and that sales price squared (SalePrice96_Pre_Sqr). Of those characteristics, the SQFT_1000 and ACRES coefficients are expected to be positive indicating that, all else being equal, an increase in living area and lot size increases the relative appreciation rate. Conversely, it is expected that the combined estimated effect of the initial sales prices (SalePrice96_Pre and SalePrice96_Pre_Sqr) will trend downward, implying that as the initial sales price of the house increases the appreciation rate decreases. These expectations are in line with the previous literature (Kiel and McClain, 1995; McCluskey and Rausser, 2003).

Finally, the study-area fixed effects variables ($\beta_1$) are included in this model to account for differences in inflation adjusted appreciation rates that may exist across study areas (e.g., WAOR, TXHC, NYMC). The WAOR study area is the reference category, and all study-area coefficients therefore represent the marginal change in AARs compared to WAOR (the intercept represents the marginal change in AAR for WAOR by itself). These study area parameters provide a unique look into Area Stigma effects. Recall that the appreciation rates used in this model are adjusted for inflation by using an inflation index from the nearby municipal statistical area (MSA). These MSAs are sometimes quite far away (as much as 20 miles) and therefore would be unaffected by the wind facility. As such, any variation in the study area parameters (and the intercept) would be the result of local influences not otherwise captured in the inflation adjustment, and represent another test for Area Stigma; if effects exist, it is expected that the $\beta_0$ and $\beta_1$ coefficients will be negative.

As with the hedonic models presented earlier, the assumptions of homoskedasticity, absence of spatial autocorrelation, reasonably little multicollinearity, and appropriate controls for outliers are addressed as described in the associated footnote and in Appendix G.[93]

## 6.4. Analysis of Results

The results from the Repeat Sales Model are presented in Table 28. The model performs relatively poorly overall, with an Adjusted $R^2$ of just 0.19 (and an $F$-test statistic of 5.2). Other similar analyses in the literature have produced higher performance statistics but have done so with samples that are considerably larger or more homogenous than ours.[94] The low $R^2$ found here should not be cause for undue concern, however, given the relatively small sample spread across ten different study areas. Moreover, many of the home and site characteristics are found to be statistically significant, and of the appropriate sign. The coefficient for the adjusted initial sales price (SalePrice96_Pre), for example, is statistically significant, small, and negative (-0.000001, $p$ value 0.00), while the coefficient for the adjusted initial sales price squared (SalePrice96_Pre_Sqr) is also statistically significant and considerably smaller (<0.000000, $p$ value 0.00). These results imply, consistent with the prior literature, that for those homes in the sample, an increase in initial adjusted sales price decreases the average percentage appreciation rate. ACRES (0.002, $p$ value 0.10) and SQFT_1000 (0.02, $p$ value 0.00) are both positive, as expected, and statistically significant.

Of particular interest are the intercept term and the associated study-area fixed effect coefficients, and what they collectively say about Area Stigma. The coefficient for the intercept ($\beta_0$) is 0.005 ($p$ value 0.81), which is both extremely small and not statistically significant. Likewise, the study-area fixed effects are all relatively small (less than 0.03 in absolute terms) and none are statistically significant. As discussed above, if a pervasive Area Stigma existed, it would be expected to be represented in these coefficients. Because all are small and statistically insignificant, it can again be concluded that there is no persuasive evidence of an Area Stigma among this sample of home transactions.

---

[93] All results are produced using White's corrected standard errors to control for heteroskedasticity. Spatial autocorrelation, with this small sample, is impossible to control. Because of the small sample, an even smaller number of neighboring sales exist, which are required to construct the spatial matrix. As such, spatial autocorrelation is not addressed in the repeat sales model. As with the hedonic models, some multicollinearity might exist, but that multicollinearity is unlikely to be correlated with the variables of interest. Outliers are investigated and dealt with as discussed in footnote 91 on page 56.

[94] McCluskey and Rausser (2003) had a sample of over 30,000 repeat sales and had an $F$-test statistic of 105; Kiel and McClain (1995) produced an $R^2$ that ranged from 0.40 to 0.63 with samples ranging from 53 to 145, but all sales took place in North Andover, MA.

Table 28: Results from Repeat Sales Model

| | Coef. | SE | p Value | *n* |
|---|---|---|---|---|
| Intercept | 0.005 | 0.02 | 0.81 | 354 |
| WAOR | Omitted | Omitted | Omitted | 6 |
| TXHC | -0.01 | 0.02 | 0.63 | 57 |
| OKCC | 0.03 | 0.02 | 0.11 | 102 |
| IABV | 0.02 | 0.02 | 0.14 | 59 |
| ILLC | -0.01 | 0.02 | 0.38 | 18 |
| WIKCDC | 0.02 | 0.03 | 0.50 | 8 |
| PASC | -0.01 | 0.02 | 0.67 | 32 |
| PAWC | 0.02 | 0.02 | 0.16 | 35 |
| NYMCOC | 0.02 | 0.02 | 0.23 | 24 |
| NYMC | 0.03 | 0.02 | 0.13 | 13 |
| SalePrice96_Pre | -0.000001 | 0.0000002 | 0.00 | 354 |
| SalePrice96_Pre_Sqr | 0.0000000 | 0.0000000 | 0.00 | 354 |
| Acres | 0.002 | 0.001 | 0.10 | 354 |
| Sqft_1000 | 0.02 | 0.01 | 0.00 | 354 |
| No View | Omitted | Omitted | Omitted | 305 |
| Minor View | -0.02 | 0.01 | 0.02 | 35 |
| Moderate View | 0.03 | 0.03 | 0.29 | 5 |
| Substantial/Extreme View | -0.02 | 0.01 | 0.09 | 9 |
| Less than 1 Mile | 0.03 | 0.01 | 0.01 | 14 |
| Between 1 and 3 Miles | 0.01 | 0.01 | 0.59 | 199 |
| Between 3 and 5 Miles | 0.01 | 0.01 | 0.53 | 116 |
| Outside 5 Miles | Omitted | Omitted | Omitted | 25 |

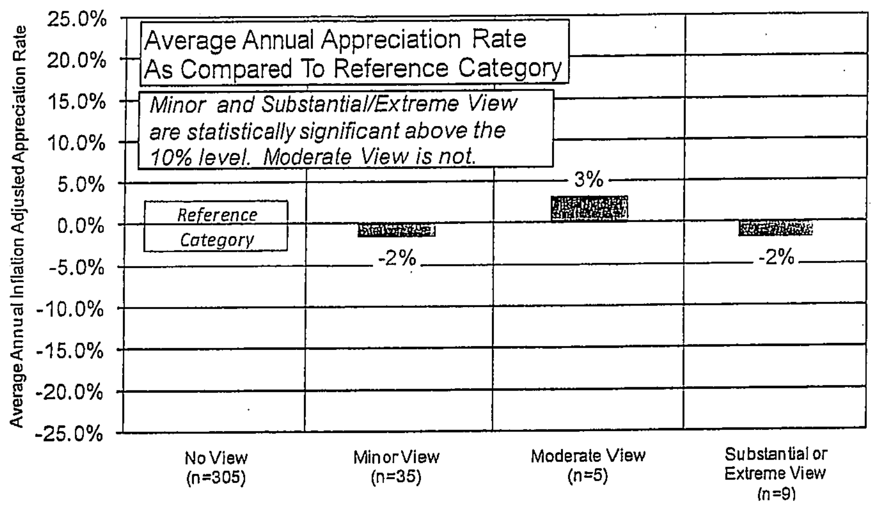
*"Omitted" = reference category for fixed effects variables*
*"n" indicates number of cases in category when category = "1"*

## Model Information

| | |
|---|---|
| Model Equation Number | 11 |
| Dependent Variable | SalePrice96_AAR |
| Number of Cases | 354 |
| Number of Predictors (k) | 19 |
| F Statistic | 5.2 |
| Adjusted R2 | 0.19 |

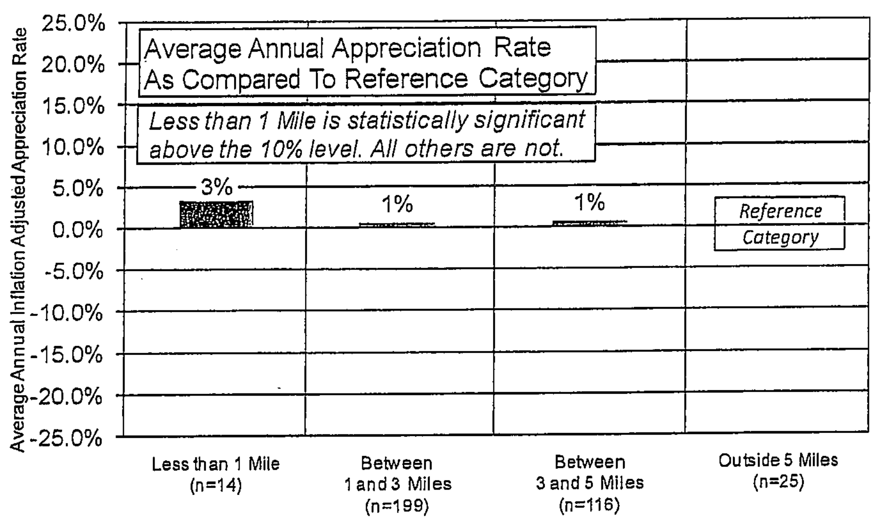
Turning to the variables of interest, mixed results (see Figure 9 and Figure 10) are found. For homes with MINOR or SUBSTANTIAL/EXTREME VIEWS, despite small sample sizes, appreciation rates after adjusting for inflation are found to decrease by roughly 2% annually (*p* values of 0.02 and 0.09, respectively) compared to homes with NO VIEW. Though these findings initially seem to suggest the presence of Scenic Vista Stigma, the coefficients are not monotonically ordered, counter to what one might expect: homes with a MODERATE rated view appreciated on average 3% annually (*p* value 0.29) compared to homes with NO VIEW. Adding to the suspicion of these VIEW results, the DISTANCE coefficient for homes situated inside of one mile, where eight out of the nine SUBSTANTIAL/EXTREME rated homes are located, is positive and statistically significant (0.03, *p* value 0.01). If interpreted literally, these results suggest that a home inside of one mile with a SUBSTANTIAL/EXTREME rated view would experience a decrease in annual appreciation of 2% compared to homes with no views of turbines, but simultaneously would experience an increase of 3% in appreciation compared to homes outside of five miles. Therefore, when compared to those homes outside of five miles and with no view of the wind facilities, these homes would experience an overall increase in AAR by 1%. These results are counterintuitive and are likely driven by the small number of sales pairs that are located within one mile of the wind turbines and experience a dramatic view of those turbines.

**Figure 9: Repeat Sales Model Results for VIEW**




*The reference category consists of tranasctions of homes that had no view of the turbines*

**Figure 10: Repeat Sales Model Results for DISTANCE**




*The reference category consists of tranasctions of homes that are situated outside of five miles from the nearest turbine*

Regardless of the reason for this result, again no persuasive evidence of consistent and widespread adverse effects is found from the presence of the wind facilities in the sample, reinforcing the findings from the previous hedonic analysis. Specifically, there is no evidence that an Area Stigma exists in that homes outside of one mile and inside of five miles do not appreciate differently than homes farther away. Similarly, there is no evidence of a Nuisance Stigma. Appreciation rates for homes inside of one mile are not adversely affected; in fact, significantly higher appreciation rates are found for these homes than for those homes located outside of five miles from the nearest wind facility. Finally, though some evidence is found that a Scenic Vista Stigma may exist in the sample of repeat sales, it is weak, fairly small, and somewhat counter-intuitive. This result is likely driven by the small number of sales pairs that are located within one mile of the wind turbines and that experience a dramatic view of those turbines.

# 7. Sales Volume Analysis

The analysis findings to this point suggest that, among the sample of sales transactions analyzed in this report, wind facilities have had no widespread and statistically identifiable impact on residential property values. A related concern that has not yet been addressed is that of sales volume: does the presence of wind facilities either increase or decrease the rate of home sales transactions? On the one hand, a decrease in sales volumes might be expected. This might occur if homeowners expect that their property values will be impacted by the presence of the wind facility, and therefore simply choose not to sell their homes as a result, or if they try to sell but are not easily able to find willing buyers. Alternatively, an increase in sales volume might be expected if homeowners that are located near to or have a dominating view of wind turbines are uncomfortable with the presence of those turbines. Though those homes may sell at a market value that is not impacted by the presence of the wind facilities, self-selection may lead to accelerated transaction volumes shortly after facility announcement or construction as homeowners who view the turbines unfavorably sell their homes to individuals who are not so stigmatized. To address the question of whether and how sales volumes are impacted by nearby wind facilities, sales volumes are analyzed for those homes located at various distances from the wind facilities in the sample, during different facility development periods.

## 7.1. Dataset

To investigate whether sales volumes are affected by the presence of wind facilities two sets of data are assembled: (1) the number of homes available to sell annually within each study area, and (2) the number of homes that actually did sell annually in those areas. Homes potentially "available to sell" are defined as all single family residences within five miles of the nearest turbine that are located on a parcel of land less than 25 acres in size, that have only one residential structure, and that had a market value (for land and improvements) above $10,000.[95] Homes that "did sell" are defined as every valid sale of a single family residence within five miles of the nearest turbine that are located on a parcel of land less than 25 acres in size, that have only one residential structure, and that sold for more than $10,000.

The sales data used for this analysis are slightly different from those used in the hedonic analysis reported earlier. As mentioned in Section 3.3, a number of study areas were randomly sampled to limit the transactions outside of 3 miles if the total number of transactions were to exceed that which could efficiently be visited in the field ($n \sim 1{,}250$). For the sales volume analysis, however, field data collection was not required, and all relevant transactions could therefore be used. Secondly, two study areas did not provide the data necessary for the sales volume analysis (WAOR and OKCC), and are therefore excluded from the sample. Finally, data for some homes that were "available to sell" were not complete, and rather than including only a small selection of these homes, these subsets of data were simply excluded from the analysis. These excluded homes include those located outside of five miles of the nearest wind turbine, and those available to sell or that did sell more than three years before wind facility announcement.[96] The resulting

[95] "Market value" is the estimated price at which a home would sell as of a given point in time.

[96] For instance, some providers supplied sales data out to ten miles, but only provided homes available to sell out to five miles. As well, data on homes that did sell were not consistently available for periods many years before announcement.

dataset spans the period starting three years prior to facility announcement and ending four years after construction. All homes in this dataset are situated inside of five miles, and each is located in one of the eight represented study areas.[97]

The final set of homes potentially "available to sell" and that actually "did sell" are then segmented into three distance categories: inside of one mile, between one and three miles, and between three and five miles. For each of these three distance categories, in each of the eight study areas, and for each of the three years prior to announcement, the period between announcement and construction, and each of the four years following construction, the number of homes that sold as a percentage of those available to sell is calculated.[98] This results in a total of 24 separate sales volume calculations in each study area, for a total of 192 calculations across all study areas. Finally, these sales volumes are averaged across all study areas into four development period categories: less than three years before announcement, after announcement but before construction, less than two years after construction, and between two and four years after construction.[99] The resulting average annual sales volumes, by distance band and development period, are shown in Table 29 and Figure 11.

**Table 29: Sales Volumes by PERIOD and DISTANCE**

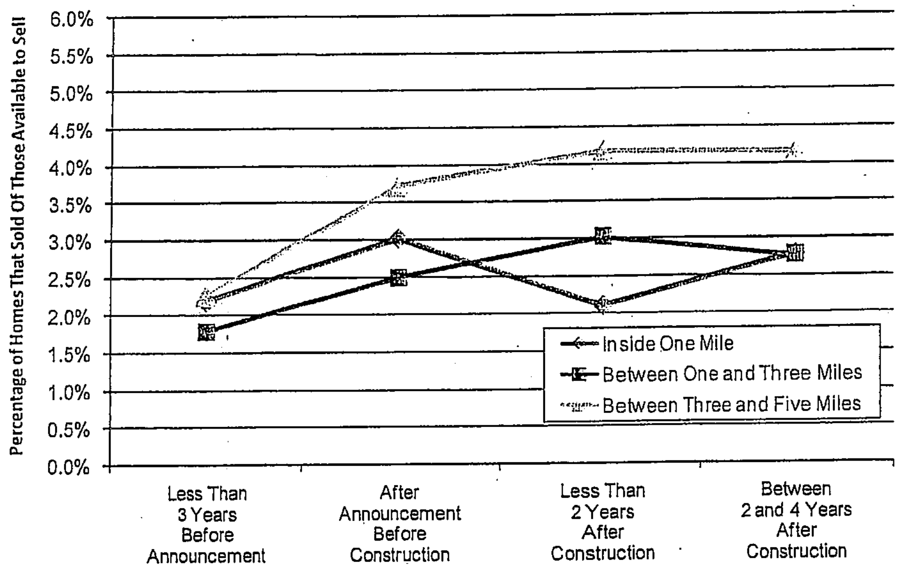
| | Inside 1 Mile | Between 1 and 3 Miles | Between 3 and 5 Miles |
|---|---|---|---|
| **Less Than 3 Years Before Announcement** | 2.2% | 1.8% | 2.3% |
| **After Announcement Before Construction** | 3.0% | 2.5% | 3.7% |
| **Less Than 2 Years After Construction** | 2.1% | 3.0% | 4.2% |
| **Between 2 and 4 Years After Construction** | 2.8% | 2.8% | 4.2% |

[97] The number of homes "available to sell" is constructed for each year after 1996 based on the year the homes in each study area were built. For many homes in the sample, the year built occurred more than three years before wind facility announcement, and therefore those homes are "available to sell" in all subsequent periods. For some homes, however, the home was built during the wind facility development process, and therefore becomes "available" some time after the first period of interest. For those homes, the build year is matched to the development dates so that it becomes "available" during the appropriate period. For this reason, the number of homes "available to sell" increases in later periods.

[98] For the period after announcement and before construction, which in all study areas was not exactly 12 months, the sales volume numbers are adjusted so that they corresponded to an average over a 12 month period.

[99] These temporal groupings are slightly different from those used in the hedonic Temporal Aspects Model. Namely, the period before announcement is not divided into two parts – more than two years before announcement and less than two years before announcement – but rather only one – less than three years before announcement. This simplification is made to allow each of the interaction categories to have enough data to be meaningful.

Figure 11: Sales Volumes by PERIOD and DISTANCE




## 7.2. Model Form

To investigate whether the rate of sales transactions is measurably affected by the wind facilities, the various resulting sales volumes shown above in Table 29 and Figure 11 are compared using a *t*-Test, as follows:

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \qquad (12)$$

where

$\bar{x}_1$ and $\bar{x}_2$ are the mean sales volumes from the two categories being compared,

$s_1^2$ and $s_2^2$ are variances of the sales volumes from the two categories being compared, and

$n_1$ and $n_2$ are numbers of representative volumes in the two categories.[100]

The degrees of freedom used to calculate the *p*-value of the *t* statistic equals the lower of $(n_1 - 1)$ or $(n_2 - 1)$.

Three sets of *t*-Tests are conducted. First, to test whether sales volumes have changed with time and are correlated with wind facility construction, the volumes for each DISTANCE group in later periods ($x_1$) are compared to the volume in that same group in the pre-announcement period ($x_2$). Second, to test whether sales volumes are impacted by distance to the nearest wind turbine, the volumes for each PERIOD group at distances closer to the turbines ($x_1$) are compared to the volume in that same group in the three to five mile distance band ($x_2$). Finally, for reasons that will become obvious later, the sales volumes for each PERIOD group at distances within one

[100] The number of representative volumes could differ between the two categories. For instance, the "less than three years before announcement" category represents three years – and therefore three volumes – for each study area for each distance band, while the "less than two years after construction" category represents two years – and therefore two volumes – for each study area for each distance band.

mile and outside of three miles of the turbines ($x_1$) are compared to the sales volume in that same group in the one to three mile distance band ($x_2$). These three tests help to evaluate whether sales volumes are significantly different after wind facilities are announced and constructed, and whether sales volumes near the turbines are affected differently than for those homes located farther away.[101]

## 7.3. Analysis of Results

Table 29 and Figure 11 above show the sales volumes in each PERIOD and DISTANCE category, and can be interpreted as the percentage of homes that are available to sell that did sell in each category, on an annual average basis. The sales volume between one and three miles and before facility announcement is the lowest, at 1.8%, whereas the sales volumes for homes located between three and five miles in both periods following construction are the highest, at 4.2%.

The difference between these two sales volumes can be explained, in part, by two distinct trends that are immediately noticeable from the data presented in Figure 11. First, sales volumes in all periods are highest for those homes located in the three to five mile distance band. Second, sales volumes at virtually all distances are higher after wind facility announcement than they were before announcement.[102]

To test whether these apparent trends are borne out statistically the three sets of *t*-Tests described earlier are performed, the results of which are shown in Table 30, Table 31, and Table 32. In each table, the difference between the subject volume ($x_1$) and the reference volume ($x_2$) is listed first, followed by the *t* statistic, and whether the statistic is significant at or above the 90% level ("*").

Table 30 shows that mean sales volumes in the post-announcement periods are consistently greater than those in the pre-announcement period, and that those differences are statistically significant in four out of the nine categories. For example, the post-construction sales volumes for homes in the three to five mile distance band in the period less than two years after construction (4.2%) and between three and four years after construction (4.2%) are significantly greater than the pre-announcement volume of 2.3% (1.9%, $t = 2.40$; 1.9%, $t = 2.31$). Similarly, the post-construction sales volumes between one and three miles are significantly greater than the pre-announcement volume. These statistically significant differences, it should be noted, could be as much related to the low reference volume (i.e., sales volume in the period less than

101 An alternative method to this model would be to pool the homes that "did sell" with the homes "available to sell" and construct a Discrete Choice Model where the dependent variable is zero (for "no sale") or one (for "sale") and the independent variables would include various home characteristics and the categorical distance variables. This would allow one to estimate the probability that a home sells dependent on distance from the wind facility. Because home characteristics data for the homes "available to sell," was not systematically collected it was not possible to apply this method to the dataset.

102 It is not entirely clear why these trends exist. Volumes may be influenced upward in areas farther from the wind turbines, where homes, in general, might be more densely sited and homogenous, both of which might be correlated with greater home sales transactions. The converse might be true in more rural areas, nearer the wind turbines, where homes may be more unique or homeowners less prone to move. The increasing sales volumes seen in periods following construction, across all distance bands, may be driven by the housing bubble, when more transactions were occurring in general.

three years before announcement), as they are to the sales volumes to which the reference category is compared. Finally, when comparing post-construction volumes inside of a mile, none are statistically different than the 2.2% pre-announcement level.

Table 30: Equality Test of Sales Volumes between PERIODS

| | Inside 1 Mile | Between 1 and 3 Miles | Between 3 and 5 Miles |
|---|---|---|---|
| Less Than 3 Years Before Announcement | Reference | Reference | Reference |
| After Announcement Before Construction | 0.8% (0.72) | 0.7% (0.99) | 1.5% (1.49) |
| Less Than 2 Years After Construction | -0.1% (-0.09) | 1.2% (2.45) * | 1.9% (2.4) * |
| Between 2 and 4 Years After Construction | 0.6% (0.54) | 1% (2.24) * | 1.9% (2.31) * |

*Numbers in parenthesis represent t-Test statistics. "*" = significantly different at or below the 10% level*

Turning to sales volumes in the same development period but between the different distance bands, consistent but less statistically significant results are uncovered (see Table 31). Although all sales volumes inside of three miles, for each period, are less than their peers outside of three miles, those differences are statistically significant in only two out of eight instances. Potentially more important, when one compares the sales volumes inside of one mile to those between one and three miles (see Table 32), small differences are found, none of which are statistically significant. In fact, on average, the sales volumes for homes inside of one mile are greater or equal to the volumes of those homes located between one and three miles in two of the three post-announcement periods. Finally, it should be noted that the volumes for the inside one mile band, in the period immediately following construction, are less than those in the one to three mile band in the same period. Although not statistically significant, this difference might imply an initial slowing of sales activity that, in later periods, returns to more normal levels. This possibility is worth investigating further and is therefore recommended for future research.

Table 31: Equality Test of Volumes between DISTANCES using 3-5 Mile Reference

| | Inside 1 Mile | Between 1 and 3 Miles | Between 3 and 5 Miles |
|---|---|---|---|
| Less Than 3 Years Before Announcement | -0.1% (-0.09) | -0.5% (-0.88) | Reference |
| After Announcement Before Construction | -0.7% (-0.56) | -1.2% (-1.13) | Reference |
| Less Than 2 Years After Construction | -2.1% (-2.41) * | -1.2% (-1.48) | Reference |
| Between 2 and 4 Years After Construction | -1.4% (-1.27) | -1.4% (-1.82) * | Reference |

*Numbers in parenthesis represent t-Test statistics. "*" = significantly different at or below the 10% level*

Table 32: Equality Test of Sales Volumes between DISTANCES using 1-3 Mile Reference

| | Inside 1 Mile | Between 1 and 3 Miles | Between 3 and 5 Miles |
|---|---|---|---|
| Less Than 3 Years Before Announcement | 0.4% (0.49) | Reference | 0.5% (0.88) |
| After Announcement Before Construction | 0.5% (0.47) | Reference | 1.2% (1.13) |
| Less Than 2 Years After Construction | -0.9% (-1.38) | Reference | 1.2% (1.48) |
| Between 2 and 4 Years After Construction | 0% (0.01) | Reference | 1.4% (1.82) * |

*Numbers in parenthesis represent t-Test statistics. "*" = significantly different at or below the 10% level*

Taken together, these results suggest that sales volumes are not conclusively affected by the announcement and presence of the wind facilities analyzed in this report. At least among this sample, sales volumes increased in all distance bands after the announcement and construction of the wind facilities. If this result was driven by the presence of the wind facilities, however, one would expect that such impacts would be particularly severe for those homes in close proximity to wind facilities. In other words, sales volumes would be the most affected inside of one mile, where views of the turbines are more frequent and where other potential nuisances are more noticeable than in areas farther away. This is not borne out in the data - no statistically significant differences are found for sales volumes inside of one mile as compared to those between one and three miles, and sales volumes outside of three miles are higher still. Therefore, on the whole, this analysis is unable to find persuasive evidence that wind facilities have a widespread and identifiable impact on overall residential sales volumes. It is again concluded that neither Area nor Nuisance Stigma are in evidence in this analysis.

# 8. Wind Projects and Property Values: Summary of Key Results

This report has extensively investigated the potential impacts of wind power facilities on the value (i.e., sales prices) of residential properties that are in proximity to and/or that have a view of those wind facilities. In so doing, three different potential impacts of wind projects on property values have been identified and analyzed: Area Stigma, Scenic Vista Stigma, and Nuisance Stigma. To assess these potential impacts, a primary (Base) hedonic model has been applied, seven alternative hedonic models have been explored, a repeat sales analysis has been conducted, and possible impacts on sales volumes have been evaluated. Table 33 outlines the resulting ten tests conducted in this report, identifies which of the three potential stigmas those tests were designed to investigate, and summarizes the results of those investigations. This section synthesizes these key results, organized around the three potential stigmas.

**Table 33: Impact of Wind Projects on Property Values: Summary of Key Results**

| | Is there statistical evidence of: | | | |
|---|---|---|---|---|
| **Statistical Model** | **Area Stigma?** | **Scenic Vista Stigma?** | **Nuisance Stigma?** | **Section Reference** |
| Base Model | No | No | No | *Section 4* |
| View Stability | Not tested | No | Not tested | *Section 5.1* |
| Distance Stability | No | Not tested | No | *Section 5.1* |
| Continuous Distance | No | No | No | *Section 5.2* |
| All Sales | No | No | Limited | *Section 5.3* |
| Temporal Aspects | No | No | No | *Section 5.4* |
| Orientation | No | No | No | *Section 5.5* |
| Overlap | No | Limited | No | *Section 5.6* |
| Repeat Sales | No | Limited | No | *Section 6* |
| Sales Volume | No | Not tested | No | *Section 7* |

*"No"*…………………… *No statistical evidence of a negative impact*
*"Yes"*………………… *Strong statistical evidence of a negative impact*
*"Limited"*…………… *Limited and inconsistent statistical evidence of a negative impact*
*"Not tested"*………… *This model did not test for this stigma*

## 8.1. Area Stigma

Area Stigma is defined as a concern that the general area surrounding a wind energy facility will appear more developed, which may adversely affect home values in the local community regardless of whether any individual home has a view of the wind turbines. Though these impacts might be expected to be especially severe at close range to the turbines, the impacts could conceivably extend for a number of miles around a wind facility. Modern wind turbines are visible from well outside of five miles in many cases, so if an Area Stigma exists, it is possible that all of the homes in the study areas inside of five miles would be affected.

As summarized in Table 33, Area Stigma is investigated with the Base, Distance Stability, Continuous Distance, All Sales, Temporal Aspects, Orientation, and Overlap hedonic models. It is also tested, somewhat differently, with the Repeat Sales and Sales Volume analyses. In each case, if an Area Stigma exists, it is expected that the sales prices (and/or sales volume) of homes located near wind facilities would be broadly affected by the presence of those facilities, with effects decreasing with distance.

The Base Model finds little evidence of an Area Stigma, as the coefficients for the DISTANCE variables are all relatively small and none are statistically different from zero. For homes in this sample, at least, there is no statistical evidence from the Base Model that the distance from a home to the nearest wind turbine impacts sales prices, regardless of the distance band. Perhaps a more direct test of Area Stigma, however, comes from the Temporal Aspects Model. In this model, homes in all distance bands that sold after wind facility announcement are found to sell, on average, for prices that are not statistically different from those for homes that sold more than two years prior to wind facility announcement. Again, no persuasive evidence of an Area Stigma is evident.

The Repeat Sales and Sales Volume Models also investigate Area Stigma. The Repeat Sales Model's 354 homes, each of which sold once before facility announcement and again after construction, show average inflation-adjusted annual appreciation rates that are small and not statistically different from zero. If homes in all study areas were subject to an Area Stigma, one would expect a negative and statistically significant intercept term. Similarly, if homes in any individual study area experienced an Area Stigma, the fixed effect terms would be negative and statistically significant. Neither of these expectations is borne out in the results. The Sales Volume Model tells a similar story, finding that the rate of residential transactions is either not significantly different between the pre- and post-announcement periods, or is greater in later periods, implying, in concert with the other tests, that increased levels of transactions do not signify a rush to sell, and therefore lower prices, but rather an increase in the level of transactions with no appreciable difference in the value of those homes.

The All Sales, Distance Stability, Continuous Distance, Orientation, and Overlap Models corroborate these basic findings. In the All Sales and Distance Stability Models, for example, the DISTANCE coefficients for homes that sold outside of one mile but within five miles, compared to those that sold outside of five miles, are very similar: they differ by no more than 2%, and this small disparity is not statistically different from zero. The same basic findings resulted from the Orientation and Overlap Models. Further, homes with No View as estimated in the All Sales Model are found to appreciate in value, after adjusting for inflation, when compared to homes that sold before wind facility construction (0.02, $p$ value 0.06); an Area Stigma effect should be reflected as a negative coefficient for this parameter. Finally, despite using all 4,937 cases in a single distance variable and therefore having a correspondingly small standard error, the Continuous Distance Model discovers no measurable relationship between distance from the nearest turbine and the value of residential properties.

Taken together, the results from these models are strikingly similar: there is no evidence of a widespread and statistically significant Area Stigma among the homes in this sample. Homes in these study areas are not, on average, demonstrably and measurably stigmatized by the arrival of a wind facility, regardless of when they sold in the wind project development process and regardless of whether those homes are located one mile or five miles away from the nearest wind facility.

Drawing from the previous literature on environmental disamenities discussed in Section 2.1, one likely explanation for this result is simply that any effects that might exist may have faded to a level indistinguishable from zero at distances outside of a mile from the wind facilities. For other disamenities, some of which would seemingly be more likely to raise concerns, effects have been found to fade quickly with distance. For example, property value effects near a chemical plant have been found to fade outside of two and a half miles (Carroll et al., 1996), near a lead smelter (Dale et al., 1999) and fossil fuel plants (Davis, 2008) outside of two miles, and near landfills and confined animal feeding operations outside of 2,400 feet and 1,600 feet, respectively (Ready and Abdalla, 2005). Further, homes outside of 300 feet (Hamilton and Schwann, 1995) or even as little as 150 feet (Des-Rosiers, 2002) from a high voltage transmission line have been found to be unaffected. A second possible explanation for these results could be related to the view of the turbines. In the sample used for this analysis, a large majority of the homes outside of one mile ($n = 4,812$) that sold after wind-facility construction commenced cannot see the turbines ($n = 4,189$, 87%), and a considerably larger portion have – at worst – a minor view of the turbines ($n = 4,712$, 98%). Others have found that the sales prices for homes situated at similar distances from a disamenity (e.g., HVTL) depend, in part, on the view of that disamenity (Des-Rosiers, 2002). Similarly, research has sometimes found that annoyance with a wind facility decreases when the turbines cannot be seen (Pedersen and Waye, 2004). Therefore, for the overwhelming majority of homes outside of a mile that have either a minor rated view or no view at all of the turbines, the turbines may simply be out of sight, and therefore, out of mind.

## 8.2. Scenic Vista Stigma

Scenic Vista Stigma is defined as concern that a home may be devalued because of the view of a wind energy facility, and the potential impact of that view on an otherwise scenic vista. It has as its basis an admission that home values are, to some degree, derived from the quality of what can be seen from the property and that if those vistas are altered, sales prices might be measurably affected. The Base, View Stability, Continuous Distance, All Sales, Temporal Aspects, Orientation, Overlap, and Repeat Sales Models each test whether Scenic Vista Stigma is present in the sample.

The Base Model, as well as subsequent Alternative Hedonic Models, demonstrates persuasively that the quality of the scenic vista – absent wind turbines – impacts sales prices. Specifically, compared to homes with an AVERAGE VISTA, those having a POOR or a BELOW AVERAGE rating are estimated to sell for 21% ($p$ value 0.00) and 8% ($p$ value 0.00) less, on average. Similarly, homes with an ABOVE AVERAGE or PREMIUM rating are estimated to sell for 10% ($p$ value 0.00) and 13% ($p$ value 0.00) more than homes with an AVERAGE vista rating. Along the same lines, homes in the sample with water frontage or situated on a cul-de-sac sell for 33% ($p$ value 0.00) and 10% ($p$ value 0.00) more, on average, than those homes that lack these characteristics. Taken together, these results demonstrate that home buyers and sellers consistently take into account what can be seen from the home when sales prices are established, and that the models presented in this report are able to clearly identify those impacts.[103]

[103] Of course, cul-de-sacs and water frontage bestow other benefits to the home owner beyond the quality of the scenic vista, such as safety and privacy in the case of a cul-de-sac, and recreational potential and privacy in the case of water frontage.

Despite this finding, those same hedonic models are unable to identify a consistent and statistically significant Scenic Vista Stigma associated with wind facilities. Home buyers and sellers, at least among this sample, do not appear to be affected in a measurable way by the visual presence of wind facilities. Regardless of which model was estimated, the value of homes with views of turbines that were rated MODERATE, SUBSTANTIAL, or EXTREME are found to be statistically indistinguishable from the prices of homes with no view of the turbines. Specifically, the 25 homes with EXTREME views in the sample, where the home site is "unmistakably dominated by the [visual] presence of the turbines," are not found to have measurably different property values, and neither are the 31 homes with a SUBSTANTIAL view, where "the turbines are dramatically visible from the home."[104] The same finding holds for the 106 homes that were rated as having MODERATE views of the wind turbines. Moreover, the Orientation and Overlap Models show that neither the orientation of the home with respect to the view of wind turbines, nor the overlap of that view with the prominent scenic vista, have measurable impacts on home prices.

The All Sales Model compares homes with views of the turbines (in the post-construction period) to homes that sold before construction (when no views were possible), and finds no statistical evidence of adverse effects within any VIEW category. Moreover, when a *t*-Test is performed to compare the NO VIEW coefficient to the others, none of the coefficients for the VIEW ratings are found to be statistically different from the NO VIEW homes. The Repeat Sales Model comes to a similar result, with homes with MODERATE views appreciating at a rate that was not measurably different from that of homes with no views (0.03, $p$ value 0.29). The same model also finds that homes with SUBSTANTIAL/EXTREME views appreciate at a rate 2% slower per year ($p$ value 0.09) than their NO VIEW peers. Homes situated inside of one mile, however, are found to appreciate at a rate 3% more ($p$ value 0.01) than reference homes located outside of five miles. Eight of the nine homes situated inside of one mile had either a SUBSTANTIAL or EXTREME view. Therefore, to correctly interpret these results, one would add the two coefficients for these homes, resulting in a combined 1% increase in appreciation as compared to the reference homes situated outside of five miles with no view of turbines, and again yielding no evidence of a Scenic Vista Stigma.

Although these results are consistent across most of the models, there are some individual coefficients from some models that differ. Specifically, homes with MINOR rated views in the Overlap and Repeat Sales Models are estimated to sell for 3% less ($p$ value 0.10) and appreciate at a rate 2% less ($p$ value 0.02) than NO VIEW homes. Taken at face value, these MINOR VIEW findings imply that homes where "turbines are visible, but, either the scope is narrow, there are many obstructions, or the distance between the home and the facility is large" are systematically impacted in a modest but measurable way. Homes with more dramatic views of a wind facility in the same models, on the other hand, are found to not be measurably affected. Because of the counterintuitive nature of this result, and because it is contradicted in the results of other models presented earlier, it is more likely that there is some aspect of these homes that was not modeled appropriately in the Overlap and Repeat Sales Models, and that the analysis is picking up the effect of omitted variable(s) rather than a systematic causal effect from the wind facilities.

[104] See Section 3.2.3 and Appendix C for full description of VIEW ratings.

Taken together, the results from all of the models and all of the VIEW ratings support, to a large degree, the Base Model findings of no evidence of a Scenic Vista Stigma. Although there are 160 residential transactions in the sample with more dramatic views than MINOR, none of the model specifications is able to find any evidence that those views of wind turbines measurably impacted average sales prices, despite the fact that those same models consistently find that home buyers and sellers place value on the quality of the scenic vista.

## 8.3. Nuisance Stigma

Nuisance Stigma is defined as a concern that factors that may occur in close proximity to wind turbines, such as sound and shadow flicker, will have a unique adverse influence on home values. If these factors impact residential sales prices, those impacts are likely to be concentrated within a mile of the wind facilities. The Base, Distance Stability, Continuous Distance, All Sales, Temporal Aspects, Orientation, Overlap, Repeat Sales, and Sales Volume Models all investigate the possible presence of a Nuisance Stigma.

The Base Model finds that those homes within 3000 feet and those between 3000 feet and one mile of the nearest wind turbine sold for roughly 5% less than similar homes located more than five miles away, but that these differences are not statistically significant (*p* values of 0.40 and 0.30, respectively). These results remain unchanged in the Distance Stability Model, as well as in the Orientation and Overlap Models. Somewhat similarly, in the All Sales Model, when all transactions occurring after wind facility announcement are assumed to potentially be impacted (rather than just those occurring after construction, as in the Base Model), and a comparison is made to the average of all transactions occurring pre-announcement (rather than the average of all transactions outside of five miles, as in the Base Model), these same coefficients grow to -6% (*p* value 0.23) and -8% (*p* value 0.08) respectively. Although only one of these coefficients was statistically significant, they are large enough to warrant further scrutiny.

The Temporal Aspects Model provides a clearer picture of these findings. It finds that homes that sold prior to wind facility announcement and that were situated within one mile of where the turbines were eventually located sold, on average, for between 10% and 13% less than homes located more than five miles away and that sold in the same period. Therefore, the homes nearest the wind facility's eventual location were already depressed in value before the announcement of the facility. Most telling, however, is what occurred after construction. Homes inside of one mile are found to have inflation-adjusted sales prices that were either statistically undistinguishable from, or in some cases greater than, pre-announcement levels. Homes sold in the first two years after construction, for example, have higher prices (0.07, *p* value 0.32), as do those homes that sold between two and four years after construction (0.13, *p* value 0.06) and more than four years after construction (0.08, *p* value 0.24). In other words, there is no indication that these homes experienced a decrease in sales prices after wind facility construction began. Not only does this result fail to support the existence of a Nuisance Stigma, but it also indicates that the relatively large negative coefficients estimated in the Base and All Sales Models are likely caused by conditions that existed prior to wind facility construction and potentially prior to facility announcement.[105]

[105] See footnote 82 on page 46 for a discussion of possible alternative explanations to this scenario.

These results are corroborated by the Continuous Distance Model, which finds no statistically significant relationship between an inverse DISTANCE function and sales prices (-0.01, sig 0.46). Similarly, in the Repeat Sales Model, homes within one mile of the nearest turbine are not found to be adversely affected; somewhat counter-intuitively, they are found to appreciate faster (0.03, *p* value 0.01) than their peers outside of five miles. Finally, the Sales Volume analysis does not find significant and consistent results that would suggest that the ability to sell one's home within one mile of a wind facility is substantially impacted by the presence of that facility.

Taken together, these models present a consistent set of results: the sales prices of homes in this sample that are within a mile of wind turbines, where various nuisance effects have been posited, are not measurably affected compared to those homes that are located more than five miles away from the facilities or that sold well before the wind projects were announced. These results imply that widespread Nuisance Stigma effects are either not present in the sample, or are too small or sporadic to be statistically identifiable.

Though these results may appear counterintuitive, it may simply be that property value impacts fade rapidly with distance, and that few of the homes in the sample are close enough to the subject wind facilities to be substantially impacted. As discussed earlier, studies of the property value impacts of high voltage transmission lines often find that effects fade towards zero at as little distance as 200 feet (see, e.g., Gallimore and Jayne, 1999; Watson, 2005). None of the homes in the present sample are closer than 800 feet to the nearest wind turbine, and all but eight homes are located outside of 1000 feet of the nearest turbine. It is therefore possible that, if any effects do exist, they exist at very close range to the turbines, and that those effects are simply not noticeable outside of 800 feet. Additionally, almost half of the homes in the sample that are located within a mile of the nearest turbine have either no view or a minor rated view of the wind facilities, and some high voltage transmission line (HVTL) studies have found a decrease in adverse effects if the towers are <u>not</u> visible (Des-Rosiers, 2002) and, similarly, decreases in annoyance with wind facility sounds if turbines cannot be seen (Pedersen and Waye, 2004). Finally, effects that existed soon after the announcement or construction of the wind facilities might have faded over time. More than half of the homes in the sample sold more than three years after the commencement of construction, while studies of HVTLs have repeatedly found that effects fade over time (Kroll and Priestley, 1992) and studies of attitudes towards wind turbines have found that such attitudes often improve after facility construction (Wolsink, 1989). Regardless of the explanation, the fact remains that, in this sizable sample of residential transactions, no persuasive evidence of a widespread Nuisance Stigma is found, and if these impacts do exist, they are either too small or too infrequent to result in any widespread and consistent statistically observable impact.

## 9. Conclusions

Though surveys generally show that public acceptance towards wind energy is high, a variety of concerns with wind development are often expressed at the local level. One such concern that is often raised in local siting and permitting processes is related to the potential impact of wind projects on the property values of nearby residences.

This report has investigated the potential impacts of wind power facilities on the sales prices of residential properties that are in proximity to and/or that have a view of those wind facilities. It builds and improve on the previous literature that has investigated these potential effects by collecting a large quantity of residential transaction data from communities surrounding a wide variety of wind power facilities, spread across multiple parts of the U.S. Each of the homes included in this analysis was visited to clearly determine the degree to which the wind facility was visible at the time of home sale and to collect other essential data. To frame the analysis, three potentially distinct impacts of wind facilities on property values are considered: Area, Scenic Vista, and Nuisance Stigma. To assess these potential impacts, the authors applied a base hedonic model, explored seven alternative hedonic models, conducted a repeat sales analysis, and evaluated possible impacts on sales volumes. The result is the most comprehensive and data-rich analysis to date on the potential impacts of wind projects on nearby property values.

Although each of the analysis techniques used in this report has strengths and weaknesses, the results are strongly consistent in that each model fails to uncover conclusive evidence of the presence of any of the three property value stigmas. Based on the data and analysis presented in this report, no evidence is found that home prices surrounding wind facilities are consistently, measurably, and significantly affected by either the view of wind facilities or the distance of the home to those facilities. Although the analysis cannot dismiss the possibility that individual or small numbers of homes have been or could be negatively impacted, if these impacts do exist, they are either too small and/or too infrequent to result in any widespread and consistent statistically observable impact. Moreover, to the degree that homes in the present sample are similar to homes in other areas where wind development is occurring, the results herein are expected to be transferable.

Finally, although this work builds on the existing literature in a number of respects, there remain a number of areas for further research. The primary goal of subsequent research should be to concentrate on those homes located closest to wind facilities, where the least amount of data are available. Additional research of the nature reported in this paper could be pursued, but with a greater number of transactions, especially for homes particularly close to wind facilities. Further, it is conceivable that cumulative impacts might exist whereby communities that have seen repetitive development are affected uniquely, and these cumulative effects may be worth investigating. A more detailed analysis of sales volume impacts may also be fruitful, as would an assessment of the potential impact of wind facilities on the length of time homes are on the market in advance of an eventual sale. Finally, it would be useful to conduct a survey of those homeowners living close to existing wind facilities, and especially those residents who have bought and sold homes in proximity to wind facilities after facility construction, to assess their opinions on the impacts of wind project development on their home purchase and sales decisions.

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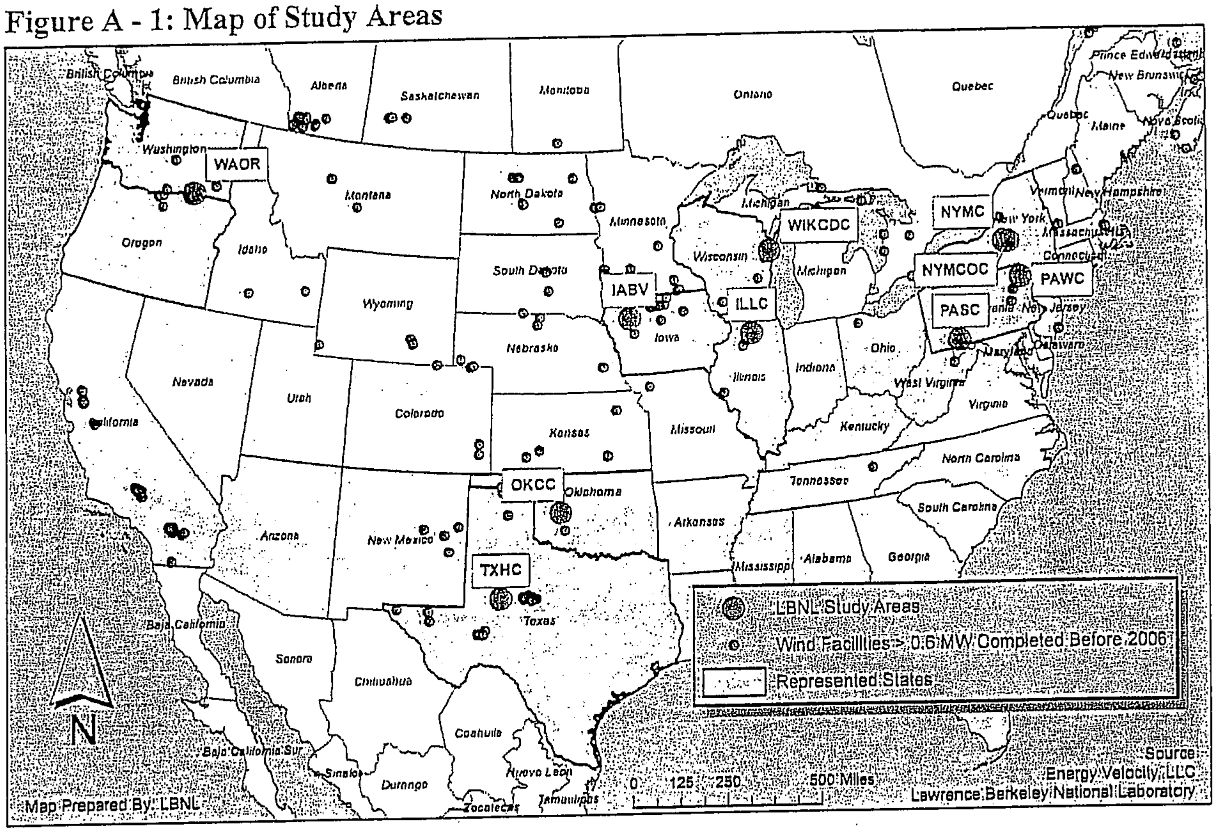
# Appendix A: Study Area Descriptions

The analysis reported in the body of the report used data from ten different wind-project study areas, across nine different states and 14 counties, and surrounding 24 different wind facilities. Each of the study areas is unique, but as a group they provide a good representation of the range of wind facility sizes, hub heights, and locations of recent wind development activity in the U.S. (see Figure A - 1 and Table A - 1). This appendix describes each of the ten study areas, and provides the following information: a map of the study area; a description of the area; how the data were collected; statistics on home sales prices in the sample and census-reported home values for the towns, county, and state that encompass the area; data on the wind facilities contained within the study area; and frequency tables for the variables of interest (i.e., views of turbines, distance to nearest turbine ,and development period).

00001100

## Figure A - 1: Map of Study Areas

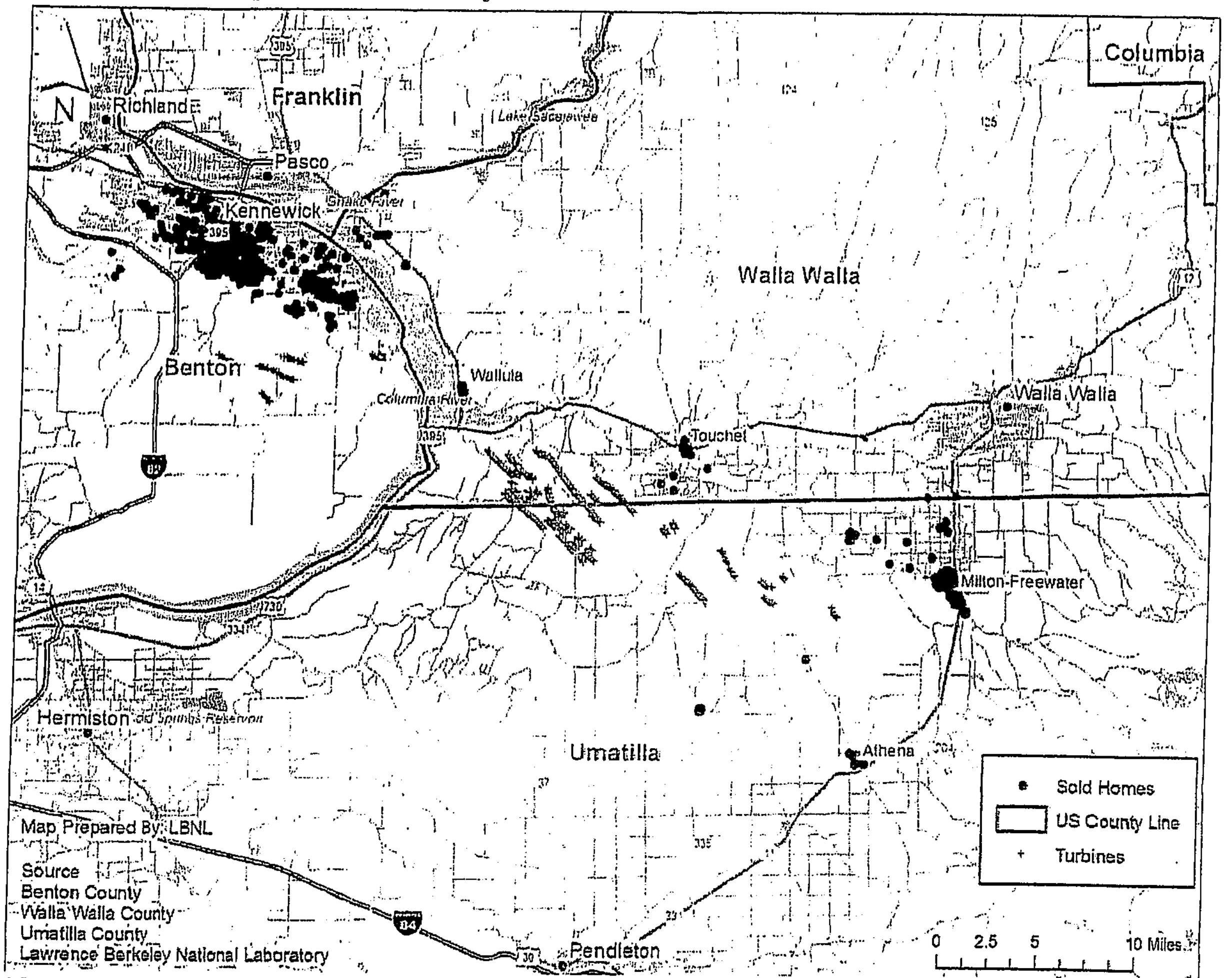



## Table A - 1: Summary of Study Areas

| Study Area Code | Study Area Counties, States | Facility Names | Number of Turbines | Number of MW | Max Hub Height (meters) | Max Hub Height (feet) |
|---|---|---|---|---|---|---|
| WAOR | Benton and Walla Walla Counties, WA and Umatilla County, OR | Vansycle Ridge, Stateline, Nine Canyon I & II, Combine Hills | 582 | 429 | 60 | 197 |
| TXHC | Howard County, TX | Big Spring I & II | 46 | 34 | 80 | 262 |
| OKCC | Custer County, OK | Weatherford I & II | 98 | 147 | 80 | 262 |
| IABV | Buena Vista County, IA | Storm Lake I & II, Waverly, Intrepid I & II | 381 | 370 | 65 | 213 |
| ILLC | Lee County, IL | Mendota Hills, GSG Wind | 103 | 130 | 78 | 256 |
| WIKCDC | Kewaunee and Door Counties, WI | Red River, Lincoln | 31 | 20 | 65 | 213 |
| PASC | Somerset County, PA | Green Mountain, Somerset, Meyersdale | 34 | 49 | 80 | 262 |
| PAWC | Wayne County, PA | Waymart | 43 | 65 | 65 | 213 |
| NYMCOC | Madison and Oneida Counties, NY | Madison | 7 | 12 | 67 | 220 |
| NYMC | Madison County, NY | Fenner | 20 | 30 | 66 | 218 |
| | | TOTAL | 1345 | 1286 | | |

## A.1 WAOR Study Area: Benton and Walla Walla Counties (Washington), and Umatilla County (Oregon)

Figure A - 2: Map of WAOR Study Area




*Note: "Sold Homes" include all sold homes both before and after construction.*

Area Description

This study area combines data from the three counties - Benton and Walla Walla in Washington, and Umatilla in Oregon - that surround the Vansycle Ridge, Stateline, Combine Hills, and Nine Canyon wind projects. Wind development began in this area in 1997 and, within the sample of wind projects, continued through 2003. In total, the wind facilities in this study area include 582 turbines and 429 MW of nameplate capacity, with hub heights that range from 164 feet to almost 200 feet. The wind facilities are situated on an East-West ridge that straddles the Columbia River, as it briefly turns South. The area consists of undeveloped highland/plateau grassland, agricultural tracks for winter fruit, and three towns: Kennewick (Benton County), Milton-Freewater (Umatilla County), and Walla Walla (Walla Walla County). Only the first two of these towns are represented in the dataset because Walla Walla is situated more than 10 miles from the nearest wind turbine. Also in the area are Touchet and Wallula, WA, and Athena, OR, all very small communities with little to no services. Much of the area to the North and South of the ridge, and outside of the urban areas, is farmland, with homes situated on small parcels adjoining larger agricultural tracts.

Data Collection and Summary

Data for this study area were collected from a myriad of sources. For Benton County, sales and home characteristic data and GIS parcel shapefiles were collected with the assistance of county officials Eric Beswick, Harriet Mercer, and Florinda Paez, while state official Deb Mandeville (Washington Department of State) provided information on the validity of the sales. In Walla Walla County, county officials Bill Vollendorff and Tiffany Laposi provided sales, house characteristic, and GIS data. In Umatilla County, county officials Jason Nielsen, Tracie Diehl, and Tim McElrath provided sales, house characteristic, and GIS data.

Based on the data collection, more than 8,500 homes are found to have sold within ten miles of the wind turbines in this study area from January 1996 to June 2007. Completing field visits to this number of homes would have been overly burdensome; as a result, only a sample of these home sales was used for the study. Specifically, all valid sales within three miles of the nearest turbine are used, and a random sample of those homes outside of three miles but inside of five miles in Benton County and inside ten miles in Walla Walla and Umatilla Counties. This approach resulted in a total of 790 sales, with prices that ranged from $25,000 to $647,500, and a mean of $134,244. Of those 790 sales, 519 occurred after wind facility construction commenced, and 110 could see the turbines at the time of sale, though all but four of these homes had MINOR views. No homes within this sample were located within one mile of the nearest wind turbine, with the majority occurring outside of three miles.

Area Statistics

| Study Period Begin | Study Period End | Number of Sales | Median Price | Mean Price | Minimum Price | Maximum Price |
|---|---|---|---|---|---|---|
| 1/23/1996 | 6/29/2007 | 790 | $ 125,803 | $ 134,244 | $ 25,000 | $ 647,500 |

Facility Statistics

| Facility Name | Number of MW | Number of Turbines | Announce Date | Construction Begin Date | Completion Date | Turbine Maker | Hub Height (Meters) |
|---|---|---|---|---|---|---|---|
| Vansycle Ridge | 25 | 38 | Aug-97 | Feb-98 | Aug-98 | Vestas | 50 |
| Stateline Wind Project, Phase I (OR) | 83 | 126 | Jun-00 | Sep-01 | Dec-01 | Vestas | 50 |
| Stateline Wind Project, Phase I (WA) | 177 | 268 | Jun-00 | Feb-01 | Dec-01 | Vestas | 50 |
| Stateline Wind Project, Phase II | 40 | 60 | Jan-02 | Sep-02 | Dec-02 | Vestas | 50 |
| Nine Canyon Wind Farm | 48 | 37 | Jun-01 | Mar-02 | Sep-02 | Bonus | 60 |
| Combine Hills Turbine Ranch I | 41 | 41 | Apr-02 | Aug-03 | Dec-03 | Mitsubishi | 55 |
| Nine Canyon Wind Farm II | 16 | 12 | Jun-01 | Jun-03 | Dec-03 | Bonus | 60 |

*Source: AWEA & Ventyx Inc.*

Variables of Interest Statistics

| Development Period | Pre Announcement | Post Announcement Pre Construction | 1st Year After Construction | 2nd Year After Construction | 2+ Years After Construction | Total |
|---|---|---|---|---|---|---|
| Benton/Walla Walla, WA & Umatilla, OR (WAOR) | 226 | 45 | 76 | 59 | 384 | 790 |

| View of Turbines | Pre Construction | None | Minor | Moderate | Substantial | Extreme | Total |
|---|---|---|---|---|---|---|---|
| Benton/Walla Walla, WA & Umatilla, OR (WAOR) | 271 | 409 | 106 | 4 | 0 | 0 | 790 |

| Distance to Nearest Turbine | Pre Construction | < 0.57 Miles | 0.57 - 1 Miles | 1 - 3 Miles | 3 - 5 Miles | > 5 Miles | Total |
|---|---|---|---|---|---|---|---|
| Benton/Walla Walla, WA & Umatilla, OR (WAOR) | 271 | 0 | 0 | 20 | 277 | 222 | 790 |

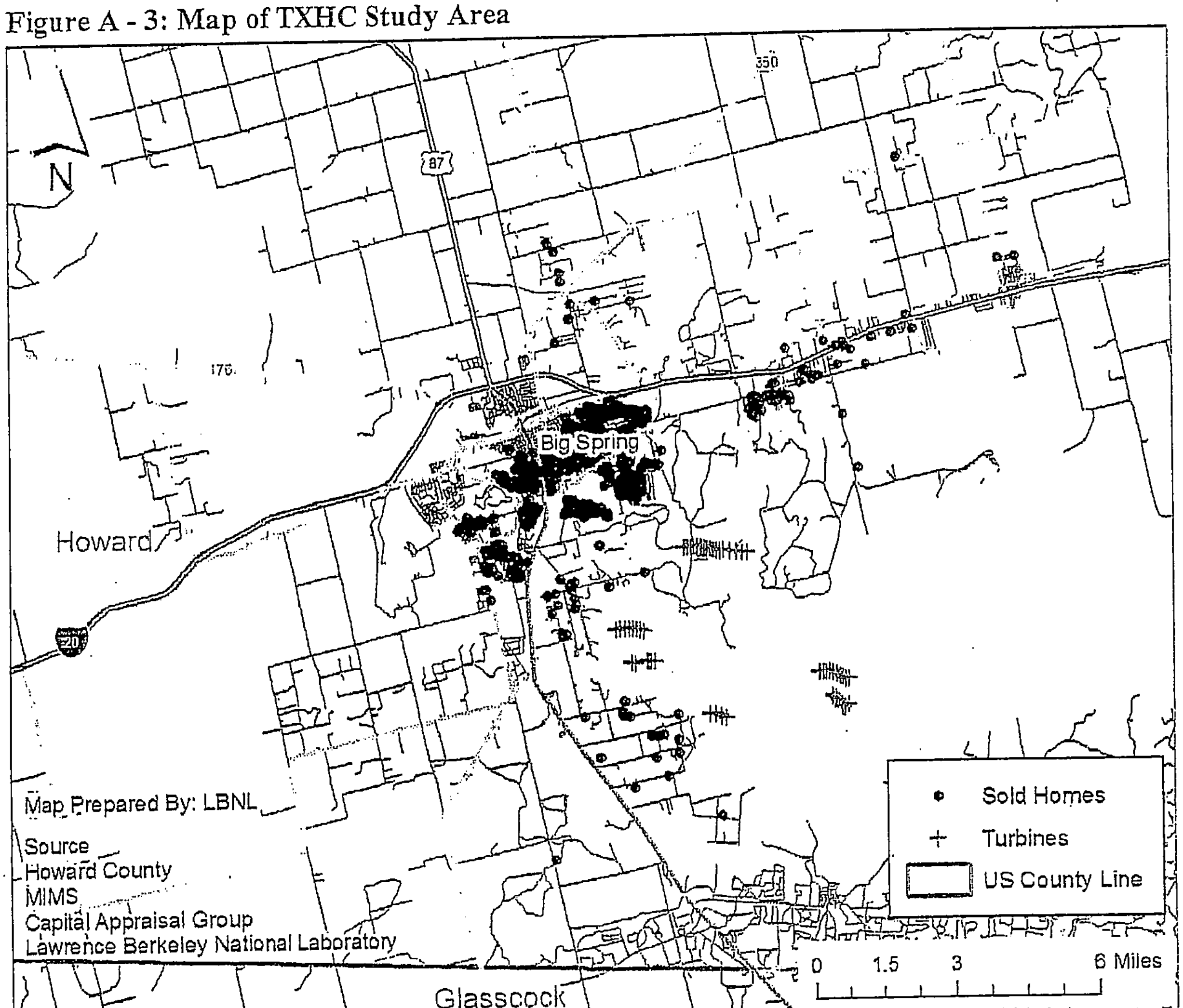
Census Statistics

| Name | Type | 2007 Population | % Change Since 2000 | Population Per Mile^2 | Median Age | Median Income | Median House 2007 | % Change Since 2000 |
|---|---|---|---|---|---|---|---|---|
| Kennewich, WA | City | 62,182 | 12.5% | 2,711 | 32.3 | $ 45,085 | $ 155,531 | 46% |
| Walla Walla, WA | City | 30,794 | 4.0% | 2,847 | 33.8 | $ 38,391 | $ 185,706 | 91% |
| Milton Freewater, OR | Town | 6,335 | -2.0% | 3,362 | 31.7 | $ 30,229 | $ 113,647 | 47% |
| Touchet, WA | Town | 413 | n/a | 340 | 33.6 | $ 47,268 | $ 163,790 | 81% |
| Benton | County | 159,414 | 3.6% | 94 | 34.4 | $ 51,464 | $ 162,700 | 46% |
| Walla Walla | County | 57,709 | 1.0% | 45 | 34.9 | $ 43,597 | $ 206,631 | 89% |
| Umatilla | County | 73,491 | 0.6% | 23 | 34.6 | $ 38,631 | $ 138,200 | 47% |
| Washington | State | 6,488,000 | 10.1% | 89 | 35.3 | $ 55,591 | $ 300,800 | 79% |
| Oregon | State | 3,747,455 | 9.5% | 36 | 36.3 | $ 48,730 | $ 257,300 | 69% |
| US | Country | 301,139,947 | 6.8% | 86 | 37.9 | $ 50,233 | $ 243,742 | 46% |

*Source: City-Data.com & Wikipedia. "% Change Since 2000" refers to the percentage change between 2000 and 2007 for the figures in the column to the left (population or median house price). "Town" signifies any municipality with less than 10,000 inhabitants. "n/a" signifies data not available.*

## A.2 TXHC Study Area: Howard County (Texas)

Figure A - 3: Map of TXHC Study Area




*Note: "Sold Homes" include all sold homes both before and after construction.*

Area Description

This study area is entirely contained within Howard County, Texas, and includes the city of Big Spring, which is situated roughly 100 miles South of Lubbock and 275 miles West of Dallas in West Texas. On top of the Northern end of the Edwards Plateau, which runs from the Southeast to the Northwest, sits the 46 turbine (34 MW) Big Spring wind facility, which was constructed in 1998 and 1999. Most of the wind turbines in this project have a hub height of 213 feet, but four are taller, at 262 feet. The plateau and the wind facility overlook the city of Big Spring which, when including its suburbs, wraps around the plateau to the South and East. Surrounding the town are modest farming tracks and arid, undeveloped land. These lands, primarily to the South of the facility towards Forsan (not shown on map), are dotted with small oil rigs. Many of the homes in Big Spring do not have a view of the wind facility, but others to the South and East do have such views.



00001105

Data Collection and Summary

County officials Brett McKibben, Sally Munoz, and Sheri Proctor were extremely helpful in answering questions about the data required for this project, and the data were provided by two firms that manage it for the county. Specifically, Erin Welch of the Capital Appraisal Group provided the sales and house characteristic data and Paul Brandt of MIMS provided the GIS data.

All valid single-family home sales transactions within five miles of the nearest turbine and occurring between January 1996 and March 2007 were included in the dataset, resulting in 1,311 sales.[106] These sales ranged in price from $10,492 to $490,000, with a mean of $74,092. Because of the age of the wind facility, many of the sales in the sample occurred after wind facility construction had commenced ($n$ = 1,071). Of those, 104 had views of the turbines, with 27 having views more dramatic than MINOR. Four homes sold within a mile of the facility, with the rest falling between one and three miles ($n$ = 584), three to five miles ($n$ = 467), and outside of five miles ($n$ = 16).

Area Statistics

| Study Period Begin | Study Period End | Number of Sales | Median Price | Mean Price | Minimum Price | Maximum Price |
|---|---|---|---|---|---|---|
| 1/2/1996 | 3/30/2007 | 1,311 | $66,500 | $74,092 | $10,492 | $490,000 |

Facility Statistics

| Facility Name | Number of MW | Number of Turbines | Announce Date | Construction Begin Date | Completion Date | Turbine Maker | Hub Height (Meters) |
|---|---|---|---|---|---|---|---|
| Big Spring I | 27.7 | 42 | Jan-98 | Jul-98 | Jun-99 | Vestas | 65 |
| Big Spring II | 6.6 | 4 | Jan-98 | Jul-98 | Jun-99 | Vestas | 80 |

*Source: AWEA & Ventyx Inc.*

Variables of Interest Statistics

| Development Period | Pre Announcement | Post Announcement Pre Construction | 1st Year After Construction | 2nd Year After Construction | 2+ Years After Construction | Total |
|---|---|---|---|---|---|---|
| Howard, TX (TXHC) | 169 | 71 | 113 | 131 | 827 | 1311 |

| View of Turbines | Pre Construction | None | Minor | Moderate | Substantial | Extreme | Total |
|---|---|---|---|---|---|---|---|
| Howard, TX (TXHC) | 240 | 967 | 77 | 22 | 5 | 0 | 1311 |

| Distance to Nearest Turbine | Pre Construction | < 0.57 Miles | 0.57 - 1 Miles | 1 - 3 Miles | 3 - 5 Miles | > 5 Miles | Total |
|---|---|---|---|---|---|---|---|
| Howard, TX (TXHC) | 240 | 0 | 4 | 584 | 467 | 16 | 1311 |

[106] If parcels intersected the five mile boundary, they were included in the sample, but were coded as being outside of five miles.

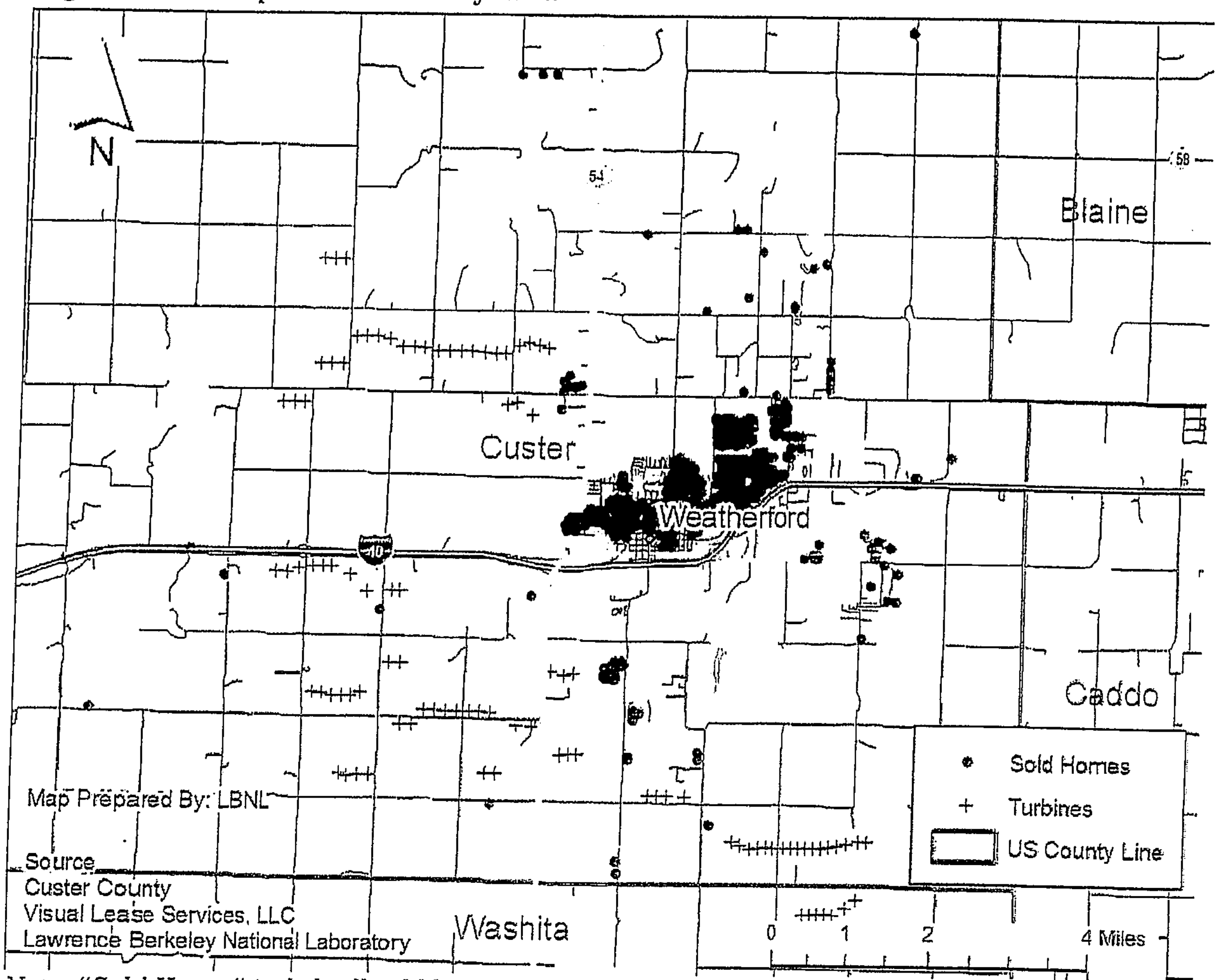
Census Statistics

| Name | Type | 2007 Population | % Change Since 2000 | Population Per Mile^2 | Median Age | Median Income | Median House 2007 | % Change Since 2000 |
|---|---|---|---|---|---|---|---|---|
| Big Spring | City | 24,075 | -5.4% | 1,260 | 35.1 | $ 32,470 | $ 54,442 | 50% |
| Forsan | Town | 220 | -4.0% | 758 | 36.8 | $ 50,219 | $ 64,277 | 84% |
| Howard | County | 32,295 | -1.9% | 36 | 36.4 | $ 36,684 | $ 60,658 | 58% |
| Texas | State | 23,904,380 | 14.6% | 80 | 32.3 | $ 47,548 | $ 120,900 | 47% |
| US | Country | 301,139,947 | 6.8% | 86 | 37.9 | $ 50,233 | $ 243,742 | 46% |

*Source: City-Data.com & Wikipedia. "% Change Since 2000" refers to the percentage change between 2000 and 2007 for the figures in the column to the left (population or median house price). "Town" signifies any municipality with less than 10,000 inhabitants.*

# A.3 OKCC Study Area: Custer County (Oklahoma)

Figure A - 4: Map of OKCC Study Area




*Note: "Sold Homes" include all sold homes both before and after construction.*

Area Description

This study area is entirely contained within Custer County, Texas, and includes the Weatherford wind facility, which is situated near the city of Weatherford, 70 miles due west of Oklahoma City and near the western edge of the state. The 98 turbine (147 MW) Weatherford wind facility straddles Highway 40, which runs East-West, and U.S. County Route 54, which runs North-South, creating an "L" shape that is more than six miles long and six miles wide. Development began in 2004, and was completed in two phases ending in 2006. The turbines are some of the largest in the sample, with a hub height of 262 feet. The topography of the study area is mostly flat plateau, allowing the turbines to be visible from many parts of the town and the surrounding rural lands. There are a number of smaller groupings of homes that are situated to the North and South of the city, many of which are extremely close to the turbines and have dramatic views of them.



00001168

Data Collection and Summary

County Assessor Debbie Collins and mapping specialist Karen Owen were extremely helpful in gathering data and answering questions at the county level. Data were obtained directly from the county and from Visual Lease Services, Inc and OKAssessor, where representatives Chris Mask, Terry Wood, Tracy Leniger, and Heather Brown helped with the request.

All valid single-family residential transactions within five miles of the nearest wind turbine and occurring between July 1996 and June 2007 were included in the dataset, resulting in 1,113 sales.[107] These sales ranged in price from $11,000 to $468,000, with a mean of $100,445. Because of the relatively recent construction of the facility, 58% of the sales ($n$ = 637) occurred before construction, leaving 476 sales with possible views of the turbines. Of those 476 sales, 25 had more-dramatic view ratings than MINOR and 17 sales occurred inside of one mile.

Area Statistics

| Study Period Begin | Study Period End | Number of Sales | Median Price | Mean Price | Minimum Price | Maximum Price |
|---|---|---|---|---|---|---|
| 7/7/1996 | 6/29/2007 | 1,113 | $91,000 | $100,445 | $11,000 | $468,000 |

Facility Statistics

| Facility Name | Number of MW | Number of Turbines | Announce Date | Construction Begin Date | Completion Date | Turbine Maker | Hub Height (Meters) |
|---|---|---|---|---|---|---|---|
| Weatherford Wind Energy Center | 106.5 | 71 | Mar-04 | Dec-04 | May-05 | GE Wind | 80 |
| Weatherford Wind Energy Center Expansion | 40.5 | 27 | May-05 | Oct-05 | Jan-06 | GE Wind | 80 |

*Source: AWEA & Ventyx Inc.*

Variables of Interest Statistics

| Development Period | Pre Announcement | Post Announcement Pre Construction | 1st Year After Construction | 2nd Year After Construction | 2+ Years After Construction | Total |
|---|---|---|---|---|---|---|
| Custer, OK (OKCC) | 484 | 153 | 193 | 187 | 96 | 1113 |

| View of Turbines | Pre Construction | None | Minor | Moderate | Substantial | Extreme | Total |
|---|---|---|---|---|---|---|---|
| Custer, OK (OKCC) | 637 | 375 | 76 | 6 | 7 | 12 | 1113 |

| Distance to Nearest Turbine | Pre Construction | < 0.57 Miles | 0.57 - 1 Miles | 1 - 3 Miles | 3 - 5 Miles | > 5 Miles | Total |
|---|---|---|---|---|---|---|---|
| Custer, OK (OKCC) | 637 | 16 | 1 | 408 | 50 | 1 | 1113 |

[107] Portions of the town of Weatherford, both North and South of the town center, were not included in the sample due to lack of available data. The homes that were mapped, and for which electronic data were provided, however, were situated on all sides of these unmapped areas and were similar in character to those that were omitted. None of the unmapped homes were within a mile of the nearest wind turbine.

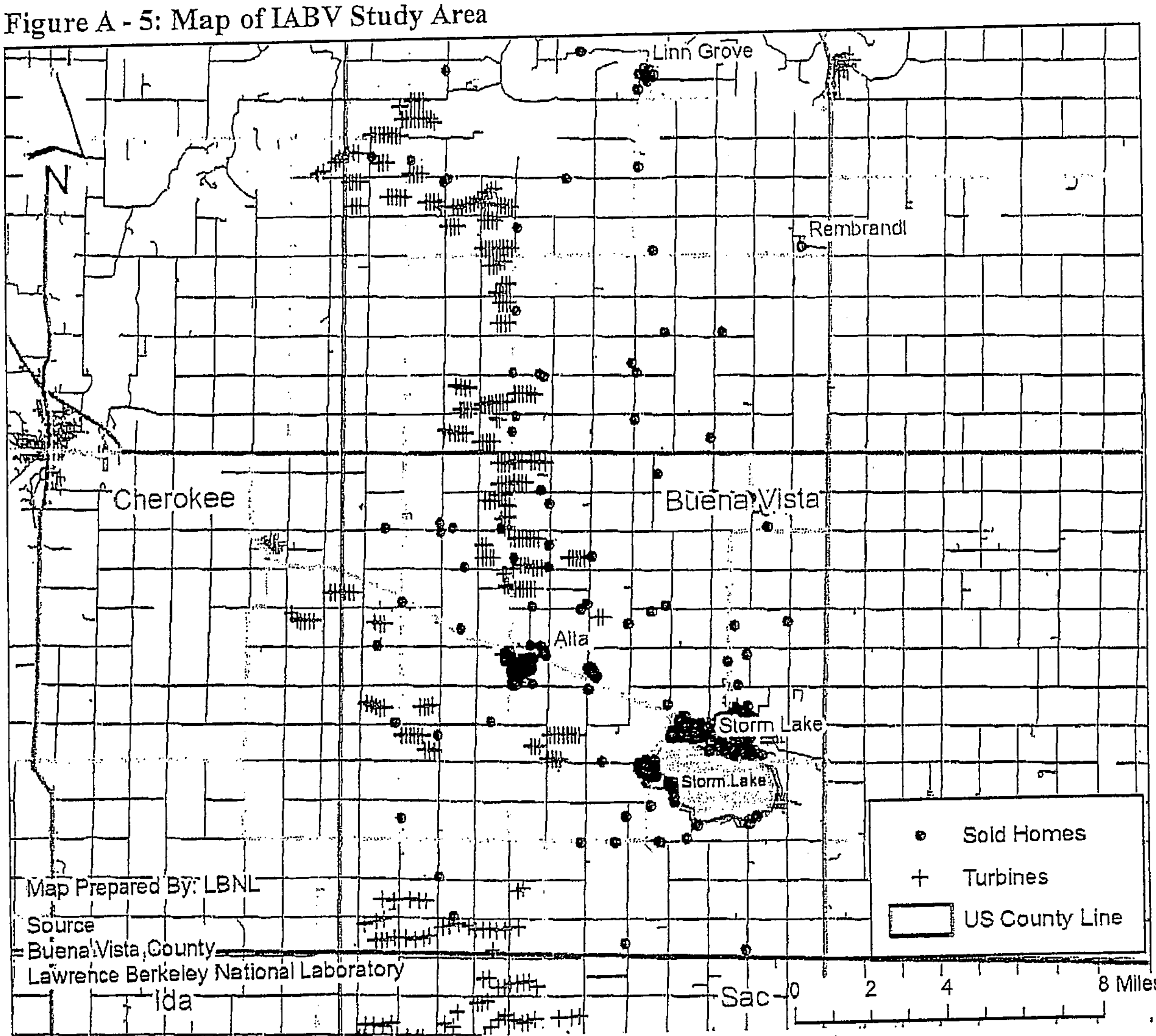
Census Statistics

| Name | Type | 2007 Population | % Change Since 2000 | Population Per Mile^2 | Median Age | Median Income | Median House 2007 | % Change Since 2000 |
|---|---|---|---|---|---|---|---|---|
| Weatherford | City | 10,097 | 1.2% | 1,740 | 24.1 | $ 32,543 | $ 113,996 | 45% |
| Hydro | Town | 1,013 | -3.7% | 1,675 | 39.2 | $ 35,958 | $ 66,365 | 68% |
| Custer | County | 26,111 | 3.6% | 26 | 32.7 | $ 35,498 | $ 98,949 | 52% |
| Oklahoma | State | 3,617,316 | 4.8% | 53 | 35.5 | $ 41,567 | $ 103,000 | 46% |
| US | Country | 301,139,947 | 6.8% | 86 | 37.9 | $ 50,233 | $ 243,742 | 46% |

*Source: City-Data.com & Wikipedia. "% Change Since 2000" refers to the percentage change between 2000 and 2007 for the figures in the column to the left (population or median house price). "Town" signifies any municipality with less than 10,000 inhabitants.*

## A.4 IABV Study Area: Buena Vista County (Iowa)

Figure A - 5: Map of IABV Study Area




*Note: "Sold Homes" include all sold homes both before and after construction.*

<u>Area Description</u>

This study area includes the sizable Storm Lake and Intrepid wind facilities, which are mostly situated in Buena Vista County, located in Northwestern Iowa, 75 miles East of Sioux City. The facilities also stretch into Sac County to the South and Cherokee County to the West. The facilities total 381 turbines (370 MW) and are more than 30 miles long North to South and eight miles wide East to West. Development began on the first Storm Lake facility in 1998 and the last of the Intrepid development was completed in 2006. The largest turbines have a hub height of 213 feet at the hub, but most are slightly smaller at 207 feet. The majority of the homes in the sample surround Storm Lake (the body of water), but a large number of homes are situated on small residential plots located outside of the town and nearer to the wind facility. Additionally, a number of sales occurred in Alta - a small town to the East of Storm Lake -thatis straddled by the wind facilities and therefore provides dramatic views of the turbines. In general, except for the depression in which Storm Lake sits, the topography is very flat, largely made up corn fields, and the turbines are therefore visible from quite far away. The housing market is driven, to some extent, by the water body, Storm Lake, which is a popular recreational tourist destination, and therefore development is occurring to the East and South of the lake. Some development is also occurring, to a lesser degree, to the East of Alta.

Data Collection and Summary

County Assessor Kathy A. Croker and Deputy Assessor Kim Carnine were both extremely helpful in answering questions and providing GIS data. Sales and home characteristic data were provided by Vanguard Appraisals, Inc., facilitated by the county officials. David Healy from MidAmerican provided some of the necessary turbine location GIS files.

The county provided data on valid single-family residential transactions between 1996 and 2007 for 1,743 homes inside of five miles of the nearest wind turbine. This sample exceeded the number for which field data could reasonably be collected; as a result, only a sample of these homes sales was used for the study. Specifically, all transactions that occurred within three miles of the nearest turbine were used, in combination with a random sample (totaling roughly 10%) of those homes between three and five miles. This approach resulted in 822 sales, with prices that ranged from $12,000 to $525,000, and a mean of $94,713. Development of the wind facilities in this area occurred relatively early in the sample period, and therefore roughly 75% of the sales (*n* = 605) occurred after project construction had commenced. Of those 605 sales, 105 had views of the turbines, 37 of which were ranked with a view rating more dramatic than MINOR, and 30 sales occurred within one mile of the nearest wind turbine.

Area Statistics

| Study Period Begin | Study Period End | Number of Sales | Median Price | Mean Price | Minimum Price | Maximum Price |
|---|---|---|---|---|---|---|
| 1/2/1996 | 3/30/2007 | 822 | $79,000 | $94,713 | $12,000 | $525,000 |

Facility Statistics

| Facility Name | Number of MW | Number of Turbines | Announce Date | Construction Begin Date | Completion Date | Turbine Maker | Hub Height (Meters) |
|---|---|---|---|---|---|---|---|
| Storm Lake I | 112.5 | 150 | Feb-98 | Oct-98 | Jun-99 | Enron | 63 |
| Storm Lake II | 80.3 | 107 | Feb-98 | Oct-98 | Apr-99 | Enron | 63 |
| Waverly | 1.5 | 2 | Feb-98 | Oct-98 | Jun-99 | Enron | 65 |
| Intrepid | 160.5 | 107 | Mar-03 | Oct-04 | Dec-04 | GE Wind | 65 |
| Intrepid Expansion | 15.0 | 15 | Jan-05 | Apr-05 | Dec-05 | Mitsubishi | 65 |

*Source: AWEA & Ventyx Inc.*

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Variables of Interest Statistics

| Development Period | Pre Announcement | Post Announcement Pre Construction | 1st Year After Construction | 2nd Year After Construction | 2+ Years After Construction | Total |
|---|---|---|---|---|---|---|
| Buena Vista, IA (IABV) | 152 | 65 | 80 | 70 | 455 | 822 |

| View of Turbines | Pre Construction | None | Minor | Moderate | Substantial | Extreme | Total |
|---|---|---|---|---|---|---|---|
| Buena Vista, IA (IABV) | 217 | 500 | 68 | 18 | 8 | 11 | 822 |

| Distance to Nearest Turbine | Pre Construction | < 0.57 Miles | 0.57 - 1 Miles | 1 - 3 Miles | 3 - 5 Miles | > 5 Miles | Total |
|---|---|---|---|---|---|---|---|
| Buena Vista, IA (IABV) | 217 | 22 | 8 | 472 | 101 | 2 | 822 |

Census Statistics

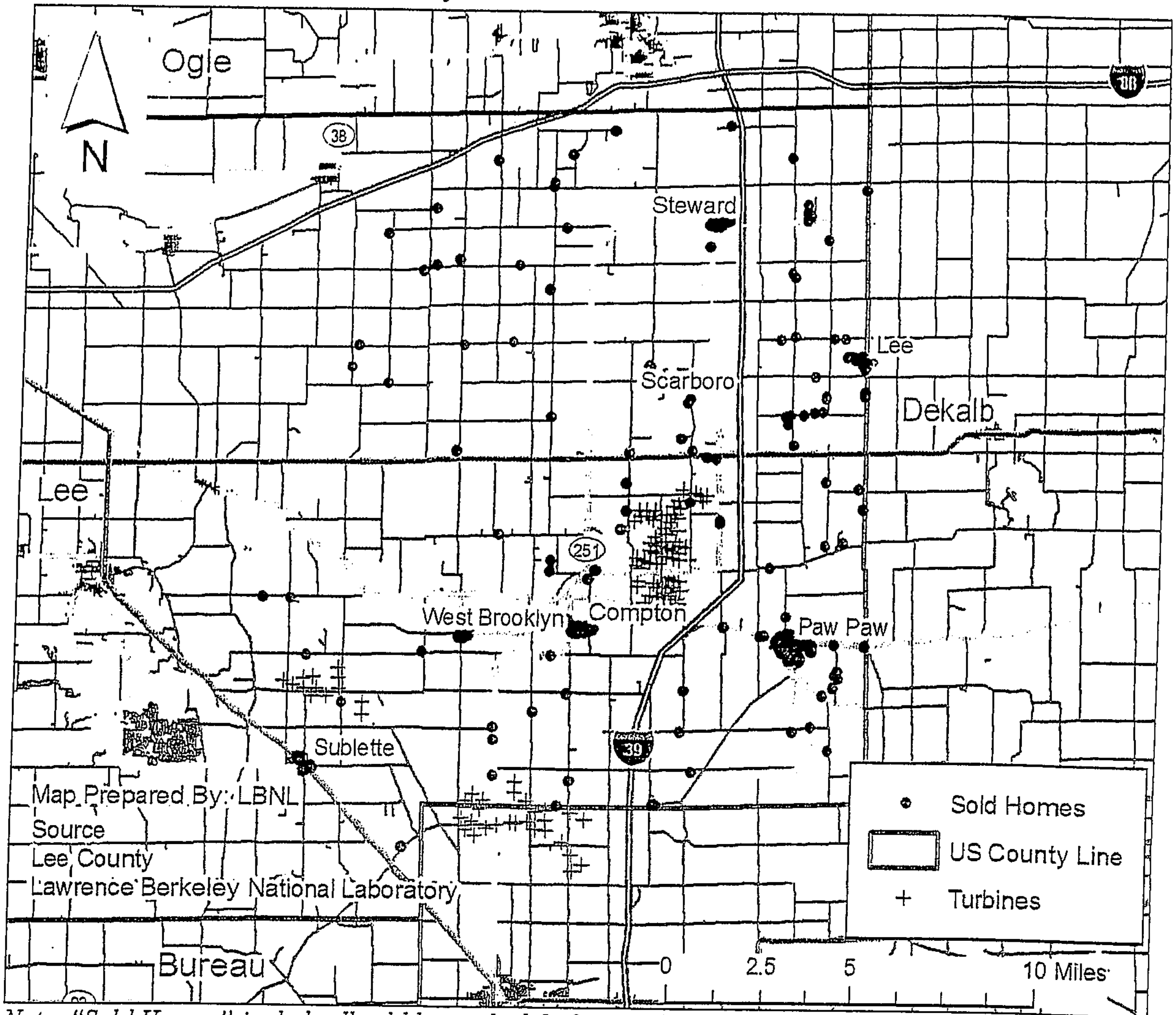
| Name | Type | 2007 Population | % Change Since 2000 | Population Per Mile^2 | Median Age | Median Income | Median House 2007 | % Change Since 2000 |
|---|---|---|---|---|---|---|---|---|
| Storm Lake | City | 9,706 | -3.9% | 2,429 | 31.7 | $ 39,937 | $ 99,312 | 41% |
| Alta | Town | 1,850 | -1.0% | 1,766 | 35.1 | $ 40,939 | $ 98,843 | 48% |
| Buena Vista | County | 19,776 | -3.1% | 36 | 36.4 | $ 42,296 | $ 95,437 | 45% |
| Iowa | State | 3,002,555 | 2.6% | 52 | 36.6 | $ 47,292 | $ 117,900 | 43% |
| US | Country | 301,139,947 | 6.8% | 86 | 37.9 | $ 50,233 | $ 243,742 | 46% |

*Source: City-Data.com & Wikipedia. "% Change Since 2000" refers to the percentage change between 2000 and 2007 for the figures in the column to the left (population or median house price). "Town" signifies any municipality with less than 10,000 inhabitants.*

00001113

## A.5 ILLC Study Area: Lee County (Illinois)

**Figure A - 6: Map of ILLC Study Area**




*Note: "Sold Homes" include all sold homes both before and after construction.*

Area Description

This study area is situated roughly 80 miles due West of Chicago, in Lee County, Illinois, and includes two wind facilities. The 63 turbine (53 MW) Mendota Hills Wind Project sits just West of North-South Highway 39, and 10 miles South of East-West Highway 88. Development began on the facility in 2001 and was completed in 2003. The second facility, the 40 turbine (80 MW) GSG Wind Farm is South and West of the Mendota Hills facility, and is broken into two parts: roughly one third of the turbines are situated two miles due north of the small town of Sublette, with the remainder located roughly six miles to the southeast and spanning the line separating Lee from La Salle County. Development began on this project in the fall of 2006 and was completed in April of the following year. The town of Paw Paw, which is East of Highway 38 and both facilities, is the largest urban area in the study area, but is further away from the



00001114

facilities than the towns of Compton, West Brooklyn, Scarboro, and Sublette. Also, to the North of the facilities are the towns of Lee, to the East of Highway 38, and Steward, just to the West. Although many home sales occurred in these towns, a significant number of additional sales occurred on small residential tracts in more-rural areas or in small developments. The topography of the area is largely flat, but falls away slightly to the East towards Paw Paw. The area enjoyed significant development during the real estate boom led by commuters from the Chicago metropolitan area, which was focused in the Paw Paw area but was also seen in semi-rural subdivisions to the Southwest and North of the wind facility.

Data Collection and Summary

County Supervisor Wendy Ryerson was enormously helpful in answering questions and providing data, as were Carmen Bollman and GIS Director, Brant Scheidecker, who also work in the county office. Wendy and Carmen facilitated the sales and home characteristic data request and Brant provided the GIS data. Additionally, real estate brokers Neva Grevengoed of LNG Realtor, Alisa Stewart of AC Corner Stone, and Beth Einsely of Einsely Real Estate were helpful in understanding the local market.

The county provided information on 412 valid single-family transactions that occurred between 1998 and 2007 within 10 miles of the nearest wind turbine, all of which were included in the sample.[108] These sales ranged in price from $14,500 to $554,148, with a mean of $128,301. Of those sales, 213 occurred after construction commenced on the wind facility and, of those, 36 had views of the turbines – nine of which were rated more dramatically than MINOR. Only two sales occurred within one mile of the nearest wind turbine.

Area Statistics

| Study Period Begin | Study Period End | Number of Sales | Median Price | Mean Price | Minimum Price | Maximum Price |
|---|---|---|---|---|---|---|
| 5/1/1998 | 3/2/2007 | 412 | $113,250 | $128,301 | $14,500 | $554,148 |

Facility Statistics

| Facility Name | Number of MW | Number of Turbines | Announce Date | Construction Begin Date | Completion Date | Turbine Maker | Hub Height (Meters) |
|---|---|---|---|---|---|---|---|
| Mendota Hills | 50.4 | 63 | Nov-01 | Aug-03 | Nov-03 | Gamesa | 65 |
| GSG Wind Farm | 80 | 40 | Dec-05 | Sep-06 | Apr-07 | Gamesa | 78 |

*Source: AWEA & Ventyx Inc.*

108 This county was not able to provide data electronically back to 1996, as would have been preferred, but because wind project development did not occur until 2001, there was ample time in the study period to establish pre-announcement sale price levels.

Variables of Interest Statistics

| Development Period | Pre Announcement | Post Announcement Pre Construction | 1st Year After Construction | 2nd Year After Construction | 2+ Years After Construction | Total |
|---|---|---|---|---|---|---|
| Lee, IL (ILLC) | 115 | 84 | 62 | 71 | 80 | 412 |

| View of Turbines | Pre Construction | None | Minor | Moderate | Substantial | Extreme | Total |
|---|---|---|---|---|---|---|---|
| Lee, IL (ILLC) | 199 | 177 | 27 | 7 | 1 | 1 | 412 |

| Distance to Nearest Turbine | Pre Construction | < 0.57 Miles | 0.57 - 1 Miles | 1 - 3 Miles | 3 - 5 Miles | > 5 Miles | Total |
|---|---|---|---|---|---|---|---|
| Lee, IL (ILLC) | 199 | 1 | 1 | 85 | 69 | 57 | 412 |

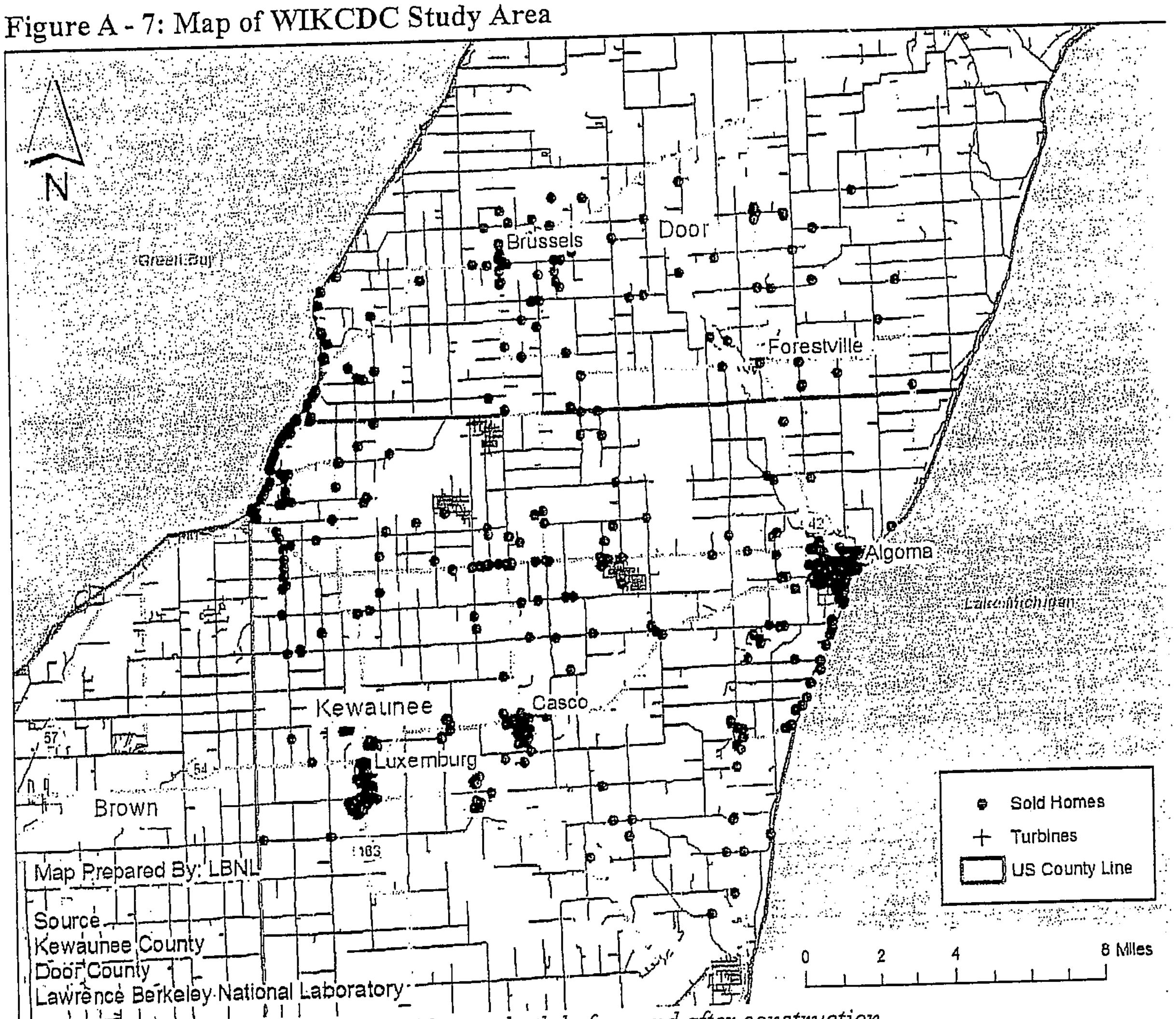
Census Statistics

| Name | Type | 2007 Population | % Change Since 2000 | Population Per Mile^2 | Median Age | Median Income | Median House 2007 | % Change Since 2000 |
|---|---|---|---|---|---|---|---|---|
| Paw Paw | Town | 884 | 2.6% | 1,563 | 38.0 | $ 48,399 | $ 151,954 | n/a |
| Compton | Town | 337 | -2.9% | 2,032 | 32.8 | $ 44,023 | $ 114,374 | n/a |
| Steward | Town | 263 | -3.0% | 2,116 | 35.2 | $ 59,361 | $ 151,791 | n/a |
| Sublette | Town | 445 | -2.4% | 1,272 | 37.7 | $ 55,910 | $ 133,328 | n/a |
| Lee | County | 35,450 | -1.7% | 49 | 37.9 | $ 47,591 | $ 136,778 | 64% |
| Illinois | State | 12,852,548 | 3.5% | 223 | 34.7 | $ 54,124 | $ 208,800 | 60% |
| US | Country | 301,139,947 | 7.0% | 86 | 37.9 | $ 50,233 | $ 243,742 | 46% |

*Source: City-Data.com & Wikipedia. "% Change Since 2000" refers to the percentage change between 2000 and 2007 for the figures in the column to the left (population or median house price). "Town" signifies any municipality with less than 10,000 inhabitants. "n/a" signifies data not available.*

# A.6 WIKCDC Study Area: Kewaunee and Door Counties (Wisconsin)

Figure A - 7: Map of WIKCDC Study Area




*Note: "Sold Homes" include all sold homes both before and after construction.*

Area Description

This study area includes the Red River (17 turbines, 14 MW) and Lincoln (14 turbines, 9 MW) wind facilities. It is situated on the "thumb" jutting into Lake Michigan, Northeast of Green Bay, Wisconsin, and spans two counties, Kewaunee and Door. There is a mix of agricultural, small rural residential, waterfront, and urban land use in this area. The three largest towns are Algoma to the East of the facilities and on the lake, Casco, which is six miles due South of the turbines, and Luxemburg, four miles West of Casco. There is a smaller village, Brussels, to the North in Door County. The remainder of the homes is situated on the water or in small rural residential parcels between the towns. Topographically, the "thumb" is relatively flat except for a slight crown in the middle, and then drifting lower to the edges. The East edge of the "thumb" ends in bluffs over the water, and the western edge drops off more gradually, allowing those parcels to



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enjoy small beaches and easy boat access. There is some undulation of the land, occasionally allowing for relatively distant views of the wind turbines, which stand at a hub height of 213 feet.

Data Collection and Summary

Kewaunee and Door Counties did not have a countywide system of electronic data storage for either sales or home characteristic data. Therefore, in many cases, data had to be collected directly from the town or city assessor. In Kewaunee County, Joseph A. Jerabek of the town of Lincoln, Gary Taicher of the town of Red River, Melissa Daron of the towns of Casco, Pierce, and West Kewaunee, Michael Muelver of the town of Ahnapee and the city of Algoma, William Gerrits of the town of Casco, Joseph Griesbach Jr. of the town of Luxemburg, and David Dorschner of the city of Kewaunee all provided information. In Door County, Scott Tennessen of the town of Union and Gary Maccoux of the town of Brussels were similarly very helpful in providing information. Additionally, Andy Pelkey of Impact Consultants, Inc., John Holton of Associated Appraisal Consultants, Andy Bayliss of Dash Development Group, and Lue Van Asten of Action Appraisers & Consultants all assisted in extracting data from the myriad of storage systems used at the town and city level. The State of Wisconsin provided additional information on older sales and sales validity, with Mary Gawryleski, James Bender, and Patrick Strabala from the Wisconsin Department of Revenue being extremely helpful. GIS data were obtained from Steve Hanson from Kewaunee County and Tom Haight from Door County.

After collecting data from each municipality, a total of 810 valid single-family home sales transactions were available for analysis, ranging in time from 1996 to 2007. These sales ranged in price from $20,000 to $780,000, with a mean of $116,698. Because development of the wind facilities occurred relatively early in the study period, a large majority of the sales transactions, 75% ($n$ = 725), occurred after project construction had commenced. Of those, 64 had views of the turbines, 14 of which had more dramatic than MINOR views, and 11 sales occurred within one mile.

Area Statistics

| Study Period Begin | Study Period End | Number of Sales | Median Price | Mean Price | Minimum Price | Maximum Price |
|---|---|---|---|---|---|---|
| 2/2/1996 | 6/30/2007 | 810 | $98,000 | $116,698 | $20,000 | $780,000 |

Facility Statistics

| Facility Name | Number of MW | Number of Turbines | Announce Date | Construction Begin Date | Completion Date | Turbine Maker | Hub Height (Meters) |
|---|---|---|---|---|---|---|---|
| Red River | 11.2 | 17 | Apr-98 | Jan-99 | Jun-99 | Vestas | 65 |
| Lincoln | 9.2 | 14 | Aug-98 | Jan-99 | Jun-99 | Vestas | 65 |

*Source: AWEA & Ventyx Inc.*

Variables of Interest Statistics

| Development Period | Pre Announcement | Post Announcement Pre Construction | 1st Year After Construction | 2nd Year After Construction | 2+ Years After Construction | Total |
|---|---|---|---|---|---|---|
| Kewaunee/Door, WI (WIKCDC) | 44 | 41 | 68 | 62 | 595 | 810 |

| View of Turbines | Pre Construction | None | Minor | Moderate | Substantial | Extreme | Total |
|---|---|---|---|---|---|---|---|
| Kewaunee/Door, WI (WIKCDC) | 85 | 661 | 50 | 9 | 2 | 3 | 810 |

| Distance to Nearest Turbine | Pre Construction | < 0.57 Miles | 0.57 - 1 Miles | 1 - 3 Miles | 3 - 5 Miles | > 5 Miles | Total |
|---|---|---|---|---|---|---|---|
| Kewaunee/Door, WI (WIKCDC) | 85 | 7 | 4 | 63 | 213 | 438 | 810 |

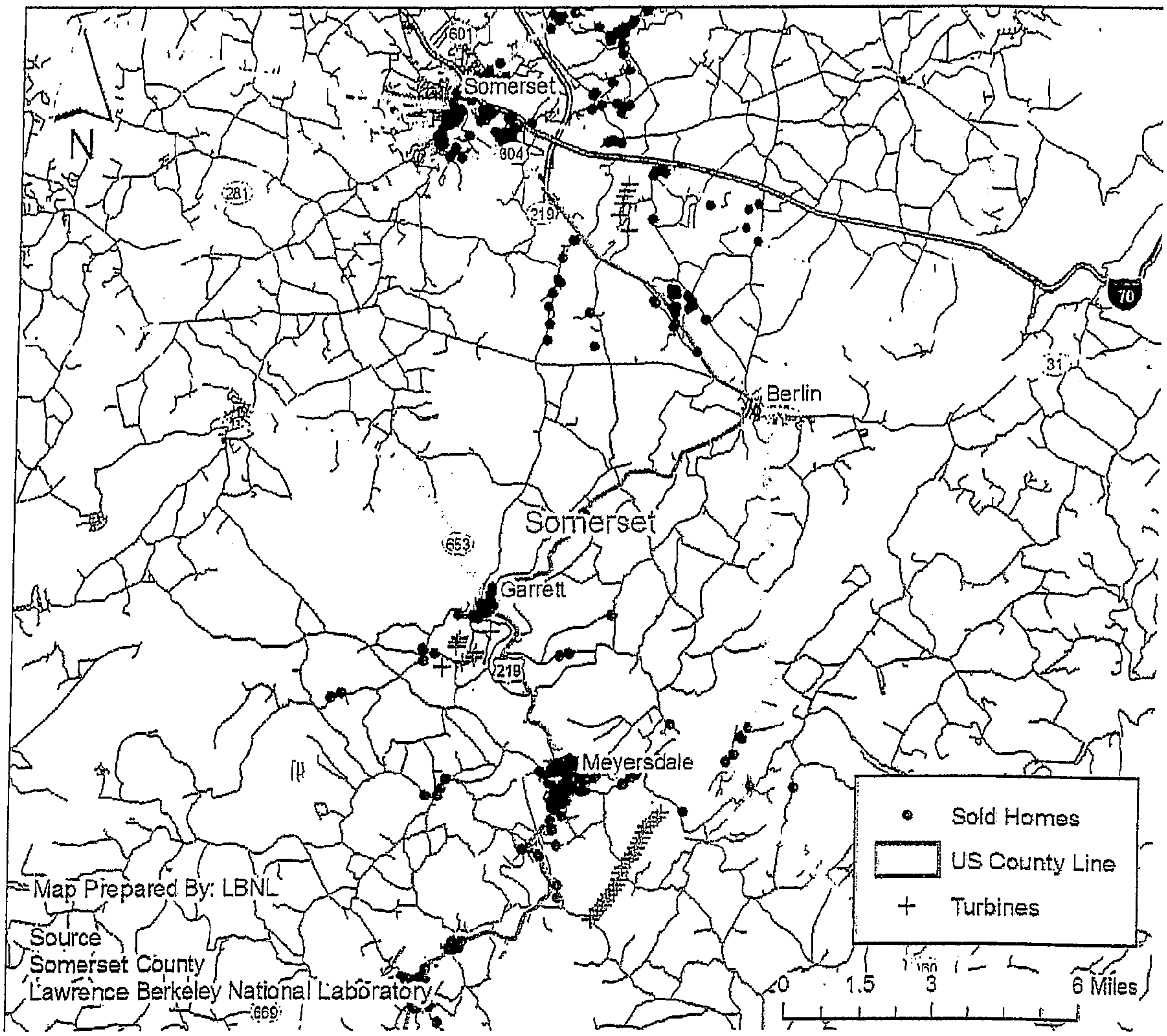
Census Statistics

| Name | Type | 2007 Population | % Change Since 2000 | Population Per Mile^2 | Median Age | Median Income | Median House 2007 | % Change Since 2000 |
|---|---|---|---|---|---|---|---|---|
| Algoma | Town | 3,186 | -4.7% | 1,305 | 41.8 | $ 39,344 | $ 112,295 | 51% |
| Casco | Town | 551 | -2.8% | 985 | 35.6 | $ 53,406 | $ 141,281 | n/a |
| Luxemburg | Town | 2,224 | 15.3% | 1,076 | 32.0 | $ 53,906 | $ 167,403 | n/a |
| Kewaunee | County | 20,533 | 1.4% | 60 | 37.5 | $ 50,616 | $ 148,344 | 57% |
| Door | County | 27,811 | 2.4% | 58 | 42.9 | $ 44,828 | $ 193,540 | 57% |
| Wisconsin | State | 5,601,640 | 0.3% | 103 | 36.0 | $ 50,578 | $ 168,800 | 50% |
| US | Country | 301,139,947 | 6.8% | 86 | 37.9 | $ 50,233 | $ 243,742 | 46% |

*Source: City-Data.com & Wikipedia. "% Change Since 2000" refers to the percentage change between 2000 and 2007 for the figures in the column to the left (population or median house price). "Town" signifies any municipality with less than 10,000 inhabitants. "n/a" signifies data not available.*

## A.7 PASC Study Area: Somerset County (Pennsylvania)

**Figure A - 8: Map of PASC Study Area**




*Note: "Sold Homes" include all sold homes both before and after construction.*

Area Description

This study area includes three wind facilities, Somerset (6 turbines, 9 MW, 210 ft hub height) to the North, Meyersdale (20 turbines, 30 MW, 262 ft hub height) to the South, and Green Mountain (8 turbines, 10 MW, 197 ft hub height) between them. All of the projects are located in Somerset County, roughly 75 miles southeast of Pittsburg in the Southwest section of Pennsylvania. None of the three facilities are separated by more than 10 miles, so all were included in one study area. To the North of the facilities is East-West U.S. Highway 70, which flanks the city of Somerset. Connecting Somerset with points South is County Route 219, which zigzags Southeast out of Somerset to the smaller towns of Berlin (not included in the data), Garret to the Southwest, and Meyersdale, which is Southeast of Garret. These towns are flanked by two ridges that run from the Southwest to the Northeast. Because of these ridges and the relatively high elevations of all of the towns, this area enjoys winter recreation, though the coal industry, which once dominated the area, is still an integral part of the community with mining occurring in many places up and down the ridges. Although many of the home sales in the sample occurred in the towns, a number of the sales are for homes situated outside of town corresponding to either rural, rural residential, or suburban land uses.

Data Collection and Summary

The County Assessor, Jane Risso, was extremely helpful, and assisted in providing sales and home characteristic data. Glen Wagner, the IT director, worked with Gary Zigler, the county GIS specialist, to extract both GIS and assessment data from the county records. Both Gary and Jane were extremely helpful in fielding questions and providing additional information as needs arose.

The county provided a total of 742 valid residential single-family home sales transactions within four miles of the nearest wind turbine. All of the sales within three miles were used ($n = 296$), and a random sample (~ 44%) of those between three and four miles were used, yielding a total of 494 sales that occurred between May 1997 and March 2007. These sales ranged in price from $12,000 to $360,000, with a mean of $69,770. 291 sales (~ 60% of the 494) occurred after construction commenced on the nearest wind facility. Of these 291 sales, 73 have views of the turbines, 18 of which are more dramatic than MINOR, and 35 sales occurred within one mile.[109]

Area Statistics

| Study Period Begin | Study Period End | Number of Sales | Median Price | Mean Price | Minimum Price | Maximum Price |
|---|---|---|---|---|---|---|
| 5/1/1997 | 3/1/2007 | 494 | $62,000 | $69,770 | $12,000 | $360,000 |

Facility Statistics

| Facility Name | Number of MW | Number of Turbines | Announce Date | Construction Begin Date | Completion Date | Turbine Maker | Hub Height (Meters) |
|---|---|---|---|---|---|---|---|
| GreenMountain Wind Farm | 10.4 | 8 | Jun-99 | Dec-99 | May-00 | Nordex | 60 |
| Somerset | 9.0 | 6 | Apr-01 | Jun-01 | Oct-01 | Enron | 64 |
| Meyersdale | 30.0 | 20 | Jan-03 | Sep-03 | Dec-03 | NEG Mico | 80 |

*Source: AWEA & Ventyx Inc.*

[109] This study area was one of the earliest to have field work completed, and therefore the field data collection process was slower resulting in a lower number of transactions than many other study areas.



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Variables of Interest Statistics

| Development Period | Pre Announcement | Post Announcement Pre Construction | 1st Year After Construction | 2nd Year After Construction | 2+ Years After Construction | Total |
|---|---|---|---|---|---|---|
| Somerset, PA (PASC) | 175 | 28 | 46 | 60 | 185 | 494 |

| View of Turbines | Pre Construction | None | Minor | Moderate | Substantial | Extreme | Total |
|---|---|---|---|---|---|---|---|
| Somerset, PA (PASC) | 203 | 218 | 55 | 15 | 2 | 1 | 494 |

| Distance to Nearest Turbine | Pre Construction | < 0.57 Miles | 0.57 - 1 Miles | 1 - 3 Miles | 3 - 5 Miles | > 5 Miles | Total |
|---|---|---|---|---|---|---|---|
| Somerset, PA (PASC) | 203 | 17 | 18 | 132 | 124 | 0 | 494 |

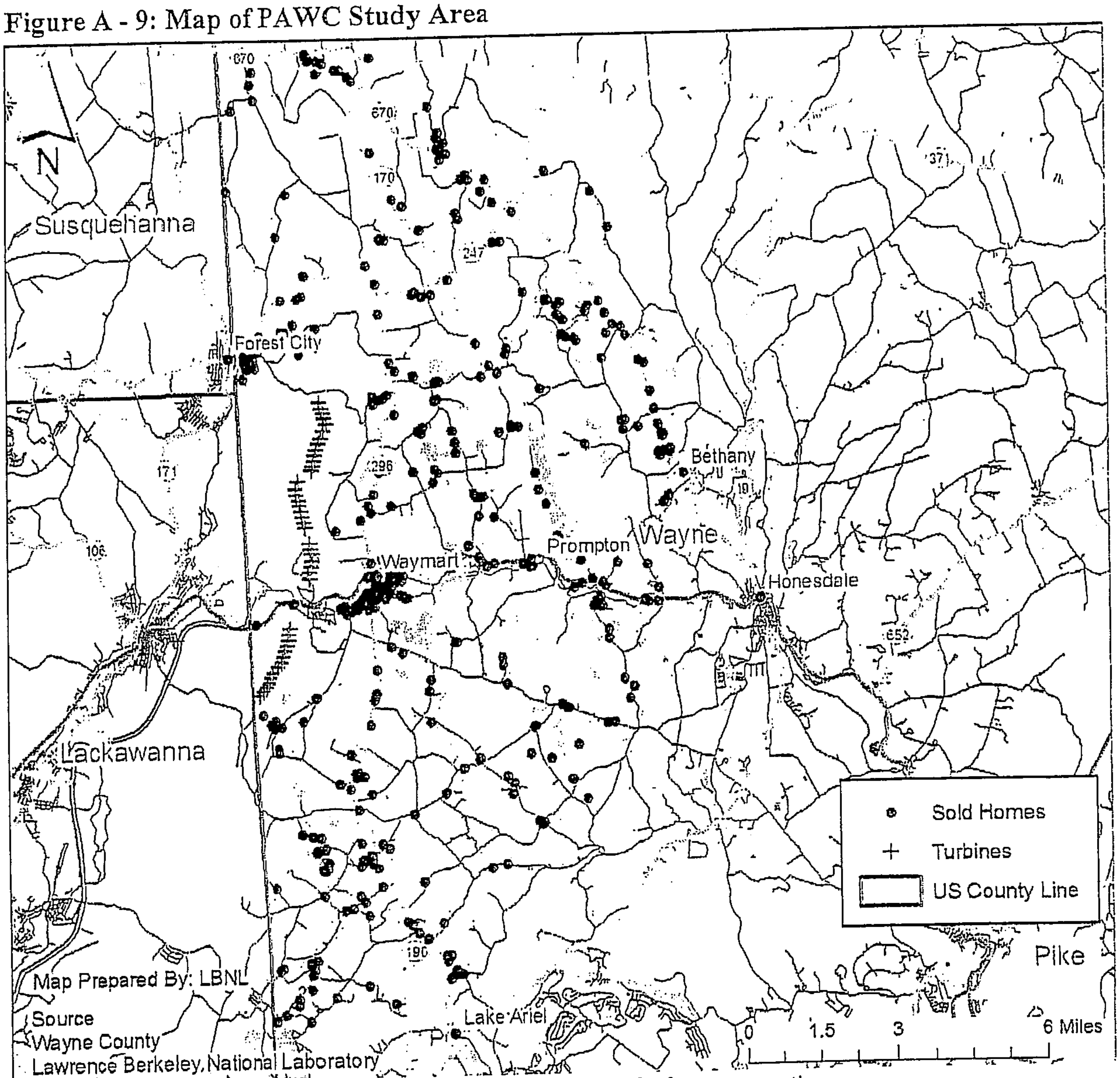
Census Statistics

| Name | Type | 2007 Population | % Change Since 2000 | Population Per Mile^2 | Median Age | Median Income | Median House 2007 | % Change Since 2000 |
|---|---|---|---|---|---|---|---|---|
| Somerset | Town | 6,398 | -4.8% | 2,333 | 40.2 | $ 35,293 | $ 123,175 | n/a |
| Berlin | Town | 2,092 | -4.0% | 2,310 | 41.1 | $ 35,498 | $ 101,704 | n/a |
| Garrett | Town | 425 | -4.7% | 574 | 34.5 | $ 29,898 | $ 54,525 | n/a |
| Meyersdale | Town | 2,296 | -6.6% | 2,739 | 40.9 | $ 29,950 | $ 79,386 | n/a |
| Somerset Co | County | 77,861 | -2.7% | 72 | 40.2 | $ 35,293 | $ 94,500 | 41% |
| Pennsylvania | State | 12,440,621 | 1.3% | 277 | 38.0 | $ 48,576 | $ 155,000 | 60% |
| US | Country | 301,139,947 | 6.8% | 86 | 37.9 | $ 50,233 | $ 243,742 | 46% |

*Source: City-Data.com & Wikipedia. "% Change Since 2000" refers to the percentage change between 2000 and 2007 for the figures in the column to the left (population or median house price). "Town" signifies any municipality with less than 10,000 inhabitants. "n/a" signifies data not available.*

## A.8 PAWC Study Area: Wayne County (Pennsylvania)

Figure A - 9: Map of PAWC Study Area




*Note: "Sold Homes" include all sold homes both before and after construction.*

Area Description

This study area includes the Waymart wind facility, which sits atop the North-South ridge running along the line separating Wayne County from Lackawanna and Susquehanna Counties in Northeast Pennsylvania. The 43 turbine (65 MW, 213 ft hub height) facility was erected in 2003, and can be seen from many locations in the study area and especially from the towns of Waymart, which sits East of the facility, and Forest City, which straddles Wayne and Susquehanna Counties North of the facility. The study area is dominated topographically by the ridgeline on which the wind turbines are located, but contains rolling hills and many streams, lakes, and natural ponds. Because of the undulating landscape, views of the wind facility can be maintained from long distances, while some homes relatively near the turbines have no view of the turbines whatsoever. The area enjoys a substantial amount of second home ownership because of the bucolic scenic vistas, the high frequency of lakes and ponds, and the proximity to larger metropolitan areas such as Scranton, roughly 25 miles to the Southwest, and Wilkes-Barre a further 15 miles Southwest.

Data Collection and Summary

John Nolan, the County Chief Assessor, was very helpful in overseeing the extraction of the data from county records. GIS specialist Aeron Lankford provided the GIS parcel data as well as other mapping layers, and Bruce Grandjean, the IT and Data Specialist, provided the sales and home characteristic data as well as fielding countless questions as they arose. Additionally, real estate brokers Dotti Korpics of Bethany, Kent Swartz of Re Max, and Tom Cush of Choice #1 Country Real Estate were instrumental providing context for understanding the local market.

The county provided data on 551 valid single-family transactions that occurred between 1996 and 2007, all of which were included in the sample. These sales ranged in price from $20,000 to $444,500, with a mean of $111,522. Because of the relatively recent development of the wind facility, only 40% ($n = 222$) of the sales transaction occurred after the construction of the facility had commenced. Of those sales, 43 (19%) had views of the turbines, ten of which had more dramatic than MINOR views, and 11 were situated within one mile.

Area Statistics

| Study Period Begin | Study Period End | Number of Sales | Median Price | Mean Price | Minimum Price | Maximum Price |
|---|---|---|---|---|---|---|
| 7/12/1996 | 9/25/2006 | 551 | $96,000 | $111,522 | $20,000 | $444,500 |

Facility Statistics

| Facility Name | Number of MW | Number of Turbines | Announce Date | Construction Begin Date | Completion Date | Turbine Maker | Hub Height (Meters) |
|---|---|---|---|---|---|---|---|
| Waymart Wind Farm | 64.5 | 43 | Feb-01 | Jun-03 | Oct-03 | GE Wind | 65 |

*Source: AWEA & Ventyx Inc.*

Variables of Interest Statistics

| Development Period | Pre Announcement | Post Announcement Pre Construction | 1st Year After Construction | 2nd Year After Construction | 2+ Years After Construction | Total |
|---|---|---|---|---|---|---|
| Wayne, PA (PAWC) | 223 | 106 | 64 | 71 | 87 | 551 |

| View of Turbines | Pre Construction | None | Minor | Moderate | Substantial | Extreme | Total |
|---|---|---|---|---|---|---|---|
| Wayne, PA (PAWC) | 329 | 179 | 33 | 8 | 2 | 0 | 551 |

| Distance to Nearest Turbine | Pre Construction | < 0.57 Miles | 0.57 - 1 Miles | 1 - 3 Miles | 3 - 5 Miles | > 5 Miles | Total |
|---|---|---|---|---|---|---|---|
| Wayne, PA (PAWC) | 329 | 1 | 10 | 95 | 55 | 61 | 551 |

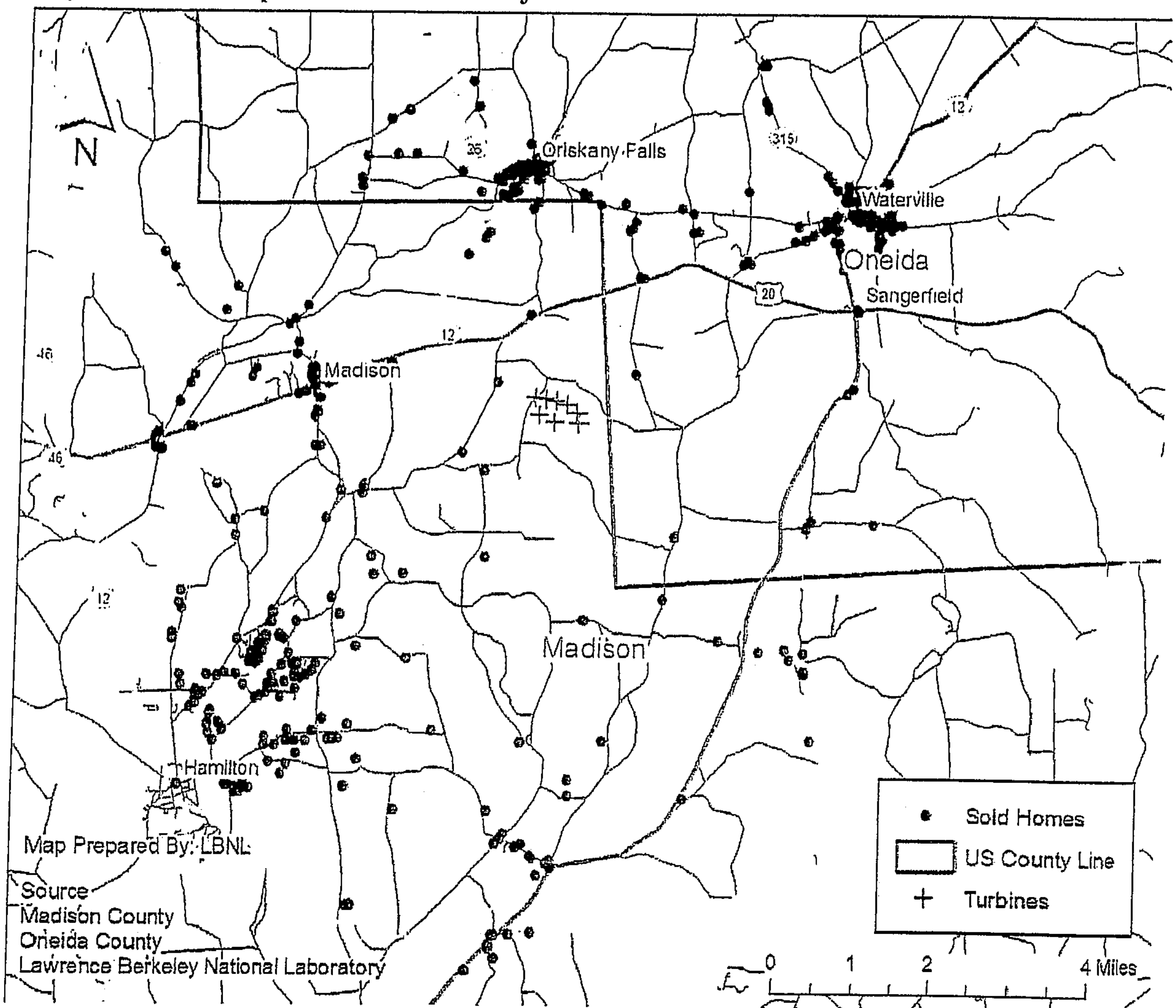
Census Statistics

| Name | Type | 2007 Population | % Change Since 2000 | Population Per Mile^2 | Median Age | Median Income | Median House 2007 | % Change Since 2000 |
|---|---|---|---|---|---|---|---|---|
| Waymart | Town | 3,075 | 116.0% | 1,111 | 41.7 | $ 43,797 | $ 134,651 | 56% |
| Forest City | Town | 1,743 | -5.2% | 1,929 | 45.6 | $ 32,039 | $ 98,937 | 67% |
| Prompton | Town | 237 | -1.6% | 149 | 41.9 | $ 30,322 | $ 162,547 | 56% |
| Wayne | County | 51,708 | 5.9% | 71 | 40.8 | $ 41,279 | $ 163,060 | 57% |
| Lackawanna | County | 209,330 | -1.9% | 456 | 40.3 | $ 41,596 | $ 134,400 | 48% |
| Pennsylvania | State | 12,440,621 | 1.3% | 277 | 38.0 | $ 48,576 | $ 155,000 | 60% |
| US | Country | 301,139,947 | 6.8% | 86 | 37.9 | $ 50,233 | $ 243,742 | 46% |

*Source: City-Data.com & Wikipedia. "% Change Since 2000" refers to the percentage change between 2000 and 2007 for the figures in the column to the left (population or median house price). "Town" signifies any municipality with less than 10,000 inhabitants.*

# A.9 NYMCOC Study Area: Madison and Oneida Counties (New York)

**Figure A - 10: Map of NYMCOC Study Area**




*Note: "Sold Homes" include all sold homes both before and after construction.*

Area Description

This study area surrounds the seven turbine (12 MW, 220 ft hub height) Madison wind facility, which sits atop an upland rise in Madison County, New York. The area is roughly 20 miles Southwest of Utica and 40 miles Southeast of Syracuse. The facility is flanked by the towns moving from the Southwest, clockwise around the rise, from Hamilton and Madison in Madison County, NY, to Oriskany Falls, Waterville, and Sangerfield in Oneida County, NY. Hamilton is the home of Colgate University, whose staff lives throughout the area around Hamilton and stretching up into the town of Madison. Accordingly, some development is occurring near the college. To the Northeast, in Oneida County, the housing market is more depressed and less development is apparent. The study area in total is a mix of residential, rural residential, and rural landscapes, with the largest portion being residential homes in the towns or immediately on their outskirts. The topography, although falling away from the location of the wind facility, does not do so dramatically, so small obstructions can obscure the views of the facility.

Data Collection and Summary

Data were obtained from both Madison and Oneida Counties for this study area. In Madison County, Kevin Orr, Mike Ellis, and Carol Brophy, all of County's Real Property Tax Services Department, were extremely helpful in obtaining the sales, home characteristic, and GIS data. In Oneida County, Jeff Quackenbush and Richard Reichert in the Planning Department were very helpful in obtaining the county data. Additionally, discussions with real estate brokers Susanne Martin of Martin Real Estate, Nancy Proctor of Prudential, and Joel Arsenault of Century 21 helped explain the housing market and the differences between Madison and Oneida Counties.

Data on 463 valid sales transactions of single family residential homes that occurred between 1996 and 2006 were obtained, all of which were located within seven miles of the wind facility. These sales ranged in price from $13,000 to $380,000, with a mean of $98,420. Roughly 75% (*n* = 346) of these sales occurred after construction commenced on the wind facility, of which 20 could see the turbines, all of which were rated as having MINOR views, except one which had a MODERATE rating; only two sales involved homes that were situated inside of one mile.

Area Statistics

| Study Period Begin | Study Period End | Number of Sales | Median Price | Mean Price | Minimum Price | Maximum Price |
|---|---|---|---|---|---|---|
| 1/6/1996 | 12/26/2006 | 463 | $77,500 | $98,420 | $13,000 | $380,000 |

Facility Statistics

| Facility Name | Number of MW | Number of Turbines | Announce Date | Construction Begin Date | Completion Date | Turbine Maker | Hub Height (Meters) |
|---|---|---|---|---|---|---|---|
| Madison Windpower | 11.6 | 7 | Jan-00 | May-00 | Sep-00 | Vestas | 67 |

*Source: AWEA & Ventyx Inc.*

Variables of Interest Statistics

| Development Period | Pre Announcement | Post Announcement Pre Construction | 1st Year After Construction | 2nd Year After Construction | 2+ Years After Construction | Total |
|---|---|---|---|---|---|---|
| Madison/Oneida, NY (MYMCOC) | 108 | 9 | 48 | 30 | 268 | 463 |

| View of Turbines | Pre Construction | None | Minor | Moderate | Substantial | Extreme | Total |
|---|---|---|---|---|---|---|---|
| Madison/Oneida, NY (MYMCOC) | 117 | 326 | 19 | 1 | 0 | 0 | 463 |

| Distance to Nearest Turbine | Pre Construction | < 0.57 Miles | 0.57 - 1 Miles | 1 - 3 Miles | 3 - 5 Miles | > 5 Miles | Total |
|---|---|---|---|---|---|---|---|
| Madison/Oneida, NY (MYMCOC) | 117 | 1 | 1 | 80 | 193 | 71 | 463 |

Census Statistics

| Name | Type | 2007 Population | % Change Since 2000 | Population Per Mile^2 | Median Age | Median Income | Median House 2007 | % Change Since 2000 |
|---|---|---|---|---|---|---|---|---|
| Madison | Town | 304 | -2.9% | 605 | 38.1 | $ 36,348 | $ 94,734 | n/a |
| Hamilton | Town | 3,781 | 7.9% | 1,608 | 20.8 | $ 48,798 | $ 144,872 | n/a |
| Orinkany Fal | Town | 1,413 | -2.9% | 1,703 | 40.8 | $ 47,689 | $ 105,934 | n/a |
| Waterville | Town | 1,735 | -3.2% | 1,308 | 37.8 | $ 46,692 | $ 104,816 | n/a |
| Sangerfield | Town | 2,626 | -1.4% | 85 | 37.6 | $ 47,563 | $ 106,213 | n/a |
| Madison | County | 69,829 | 0.6% | 106 | 36.1 | $ 53,600 | $ 109,000 | 39% |
| Oneida | County | 232,304 | -1.3% | 192 | 38.2 | $ 44,636 | $ 102,300 | 40% |
| New York | State | 19,297,729 | 1.7% | 408 | 35.9 | $ 53,514 | $ 311,000 | 109% |
| US | Country | 301,139,947 | 6.8% | 86 | 37.9 | $ 50,233 | $ 243,742 | 46% |

*Source: City-Data.com & Wikipedia. "% Change Since 2000" refers to the percentage change between 2000 and 2007 for the figures in the column to the left (population or median house price). "Town" signifies any municipality with less than 10,000 inhabitants. "n/a" signifies data not available.*

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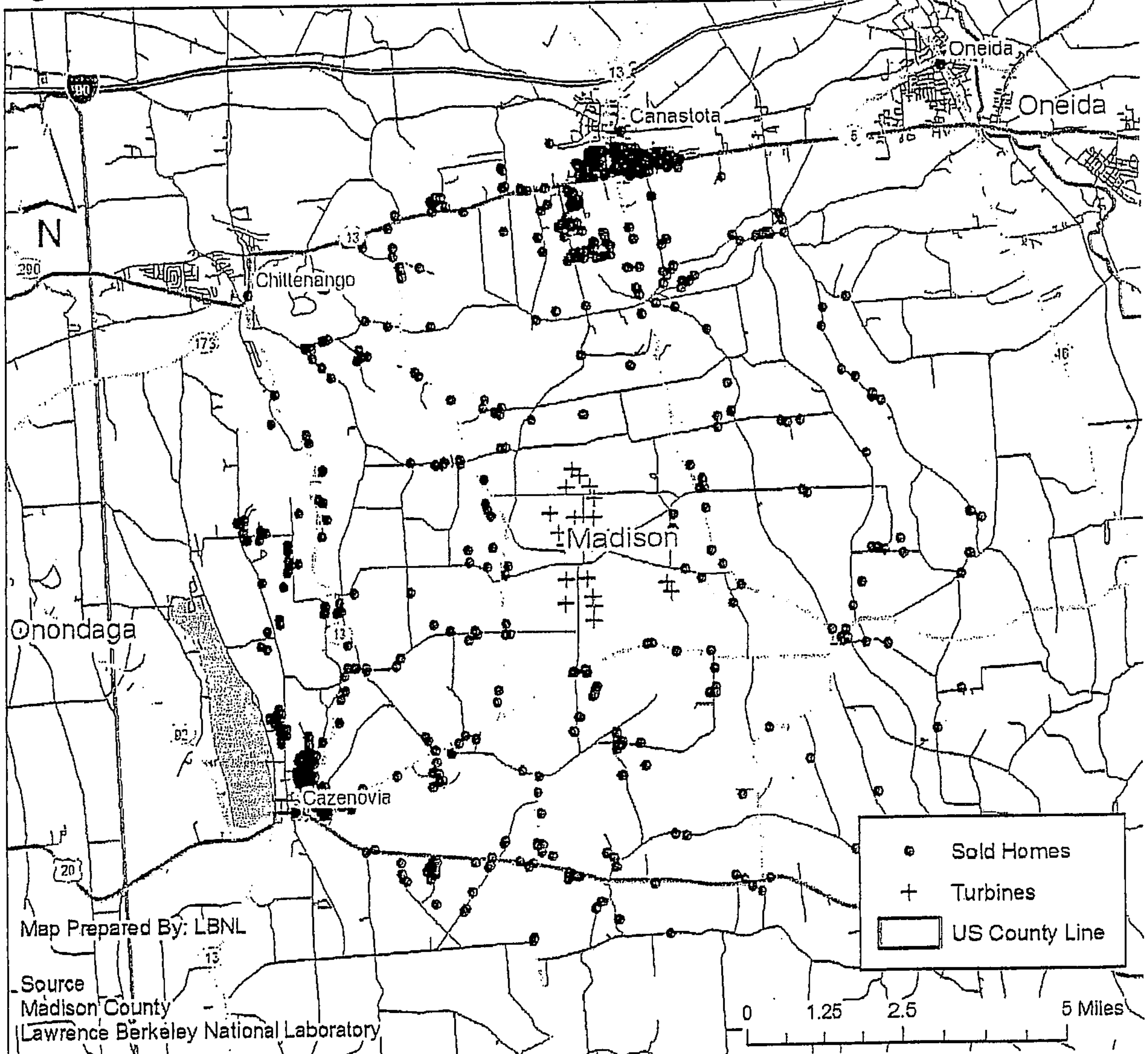
## A.10 NYMC Study Area: Madison County (New York)

Figure A - 11: Map of NYMC Study Area




*Note: "Sold Homes" include all sold homes both before and after construction.*

Area Description

This study area surrounds the 20 turbine (30 MW, 218 ft hub height) Fenner wind facility in Madison County, New York, roughly 20 miles East of Syracuse and 40 miles West of Utica in the middle of New York. The study area is dominated by two roughly parallel ridges. One, on which the Fenner facility is located, runs Southeast to Northwest and falls away towards the town of Canastota. The second ridge runs roughly North from Cazenovia, and falls away just South of the town of Chittenango. Surrounding these ridges is an undulating landscape with many water features, including the Chittenango Falls and Lake Cazenovia. A number of high-priced homes are situated along the ridge to the North of Cazenovia, some of which are afforded views of the lake and areas to the West, others with views to the East over the wind facility, and a few having significant panoramic views. The west side of the study area has a number of drivers to its real estate economy: it serves as a bedroom community for Syracuse, is the home to Cazenovia College, and enjoys a thriving summer recreational population. Canastota to the North, and Oneida to the East, are older industrial towns, both of which now serve as feeder communities for Syracuse because of easy access to Highway 90. Between the towns of Cazenovia and Canastota are many rural residential properties, some of which have been recently developed, but most of which are homes at least a half century old.

Data Collection and Summary

Data were obtained from the Madison County Real Property Tax Services department directed by Carol Brophy. As the first study area that was investigated, IT and mapping specialists Kevin Orr and Mike Ellis were subjected to a large number of questions from the study team and were enormously helpful in helping shape what became the blueprint for other study areas. Additionally, real estate brokers Nancy Proctor of Prudential, Joel Arsenault of Century 21, Don Kinsley of Kingsley Real Estate, and Steve Harris of Cazenovia Real Estate were extremely helpful in understanding the local market.

Data on 693 valid sales transactions of single family residential structures that occurred between 1996 and 2006 were obtained, most of which were within five miles of the wind facility. These sales ranged in price from $26,000 to $575,000, with a mean of $124,575. Roughly 68% of these sales ($n = 469$) occurred after construction commenced on the wind facility, 13 of which were inside of one mile, and 74 of which had views of the turbines. Of that latter group, 24 have more dramatic than MINOR views of the turbines.

Area Statistics

| Study Period Begin | Study Period End | Number of Sales | Median Price | Mean Price | Minimum Price | Maximum Price |
|---|---|---|---|---|---|---|
| 1/31/1996 | 9/29/2006 | 693 | $109,900 | $124,575 | $26,000 | $575,000 |

Facility Statistics

| Facility Name | Number of MW | Number of Turbines | Announce Date | Construction Begin Date | Completion Date | Turbine Maker | Hub Height (Meters) |
|---|---|---|---|---|---|---|---|
| Fenner Wind Power Project | 30 | 20 | Dec-98 | Mar-01 | Nov-01 | Enron | 66 |

*Source: AWEA & Ventyx Inc.*

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Variables of Interest Statistics

| Development Period | Pre Announcement | Post Announcement Pre Construction | 1st Year After Construction | 2nd Year After Construction | 2+ Years After Construction | Total |
|---|---|---|---|---|---|---|
| Madison, NY (NYMC) | 59 | 165 | 74 | 70 | 325 | 693 |

| View of Turbines | Pre Construction | None | Minor | Moderate | Substantial | Extreme | Total |
|---|---|---|---|---|---|---|---|
| Madison, NY (NYMC) | 224 | 395 | 50 | 16 | 8 | 0 | 693 |

| Distance to Nearest Turbine | Pre Construction | < 0.57 Miles | 0.57 - 1 Miles | 1 - 3 Miles | 3 - 5 Miles | > 5 Miles | Total |
|---|---|---|---|---|---|---|---|
| Madison, NY (NYMC) | 224 | 2 | 11 | 80 | 374 | 2 | 693 |

Census Statistics

| Name | Type | 2007 Population | % Change Since 2000 | Population Per Mile^2 | Median Age | Median Income | Median House 2007 | % Change Since 2000 |
|---|---|---|---|---|---|---|---|---|
| Cazenovia | Town | 2,835 | 8.6% | 1,801 | 32.3 | $ 58,172 | $ 159,553 | n/a |
| Chittenango | Town | 4,883 | -0.5% | 2,000 | 36.0 | $ 58,358 | $ 104,845 | n/a |
| Canastota | Town | 4,339 | -1.7% | 1,306 | 37.3 | $ 45,559 | $ 93,349 | n/a |
| Oneida | City | 10,791 | -1.7% | 490 | 36.9 | $ 47,173 | $ 99,305 | n/a |
| Morrisville | Town | 2,155 | 0.6% | 1,869 | 20.4 | $ 45,852 | $ 102,352 | n/a |
| Madison | County | 69,829 | 0.6% | 106 | 36.1 | $ 53,600 | $ 109,000 | 39% |
| New York | State | 19,297,729 | 1.7% | 408 | 35.9 | $ 53,514 | $ 311,000 | 109% |
| US | Country | 301,139,947 | 6.8% | 86 | 37.9 | $ 50,233 | $ 243,742 | 46% |

*Source: City-Data.com & Wikipedia. "% Change Since 2000" refers to the percentage change between 2000 and 2007 for the figures in the column to the left (population or median house price). "Town" signifies any municipality with less than 10,000 inhabitants. "n/a" signifies data not available.*

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## Appendix B: Methodology for Calculating Distances with GIS

For each of the homes in the dataset, accurate measurements of the distance to the nearest wind turbine at the time of sale were needed, and therefore the exact locations of both the turbines and the homes was required. Neither of these locations was available from a single source, but through a combination of techniques, turbine and home locations were derived. This section describes the data and techniques used to establish accurate turbine and home locations, and the process for then calculating distances between the two.

There were a number of possible starting points for mapping accurate wind turbine locations. First, the Energy Velocity data, which covered all study areas, provided a point estimate for project location, but did not provide individual turbine locations. The Federal Aviation Administration (FAA), because of permitting and aviation maps, maintains data on turbine locations, but at the time of this study, that data source did not cover all locations, contained data on structures that no longer exist, and was difficult to use.[110] Finally, in some cases, the counties had mapped the wind turbines into GIS.

In the end, because no single dataset was readily available to serve all study areas, instead the variety of data sources described above was used to map and/or confirm the location of every turbine in the 10 study areas. The process began with high-resolution geocoded satellite and aerial ortho imagery that the United States Department of Agriculture (USDA) collects and maintains under its National Agriculture Imagery Program (NAIP), and which covers virtually all of the areas in this investigation. Where needed, older ortho imagery from the USDA was used. Combining these data with the Energy Velocity data, and discussions with local officials, and maps provided by the county or the developer, locating and mapping all of the turbines in each study area was possible.

Home locations were provided directly by some counties; in other cases, a parcel centroid was created as a proxy.[111] In some situations, the centroid did not correspond to the actual house location, and therefore required further refinement. This refinement was only required and conducted if the parcel was near the wind turbines, where the difference of a few hundred feet, for example, could alter its distance rating in a meaningful fashion, or when the parcel included a considerable amount of acreage, where inaccuracy in home location could be considerable. Therefore, parcels inside of 1.5 miles of the nearest wind turbine and of any size, and parcels outside of 1.5 miles and larger than 5 acres, were both examined using the USDA NAIP imagery to determine the exact home location. In cases where the parcel centroid was not centered over the home, the location was adjusted, using the ortho image as a guide, to the actual house location.

With both turbine and home locations identified, the next step was to determine distances between the two. To do so, the date when each transaction in the sample occurred was taken into

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[110] A newer FAA database is now available that clears up many of these earlier concerns.

[111] A "parcel centroid" is the mathematical center point of a polygon, and was determined by XTools Pro (www.xtoolspro.com).

account, combined with the determination of which turbines were in existence at what time.[112] This required breaking the transactions in the sample into three categories: 1) those occurring before any wind facility was announced in the study area, 2) those occurring after the first wind facility was announced in the area but before all development was complete in the area, and 3) those occurring after all wind development in the area was complete. Any sale that occurred before wind development was announced in the study area was coded with a distance to the nearest turbine derived from the actual turbine locations after all wind development had occurred.[113] Homes that sold after all wind development had occurred were treated similarly, with distances derived from the set of turbines in place after all development had taken place. The final set of homes - those that sold after announcement of the first facility, but before the construction of the last - had to be treated, essentially, on a case by case basis. Some homes were located within five miles of one wind facility but more than five miles from another wind facility in the same study area (e.g., many homes in PASC). In this case the distance to that closer facility could be applied in a similar fashion as would be the case if only one facility was erected (e.g., NYMC or PAWC). Another group of homes, those that sold during the development of the first facility in the study area, were given the distance to that facility, regardless of distance to the other facilities in the study area. The final and most complicated group of homes consisted of those that were within five miles of multiple wind facilities, and that sold after the first facility had been erected. In those cases, the exact configuration of turbines was determined for each stage of the development process. In study areas with multiple facilities that were developed over multiple periods, there might be as many as six possible configurations (e.g., IABV). In this final scenario, the distance to the closest turbine was used, assuming it had been "announced" at the time of sale.

Once the above process was complete, the mechanics of calculating distances from the turbines to the homes was straightforward. After establishing the location of a set of turbines, for instance those constructed in the first development in the area, a euclidian distance raster was derived that encompassed every home in the study area.[114] The calculations were made using a 50-foot resolution state-plane projection and North American Datum from 1983 (NAD83). As discussed above, similar rasters were created for each period in the development cycle for each study area, depending on the turbine configuration at that time. Ultimately, a home's sale date was matched to the appropriate raster, and the underlying distance was extracted. Taking everything into account discussed above, it is expected that these measurements are accurate to

[112] It is recognized that the formal date of sale will follow the date at which pricing decisions were made. It is also recognized, as mentioned in Section 3, that wind facility announcement and construction dates are likely to be preceded by "under the radar" discussions in the community. Taken together, these two factors might have the effect, in the model, of creating some apparent lag in when effects are shown, compared to the earlier period in which effects may begin to occur. For this to bias the results, however, effects would have to disappear or dramatically lesson with time (e.g., less than one year after construction) such that the effects would not be uncovered with the models in later periods. Based on evidence from other potentially analogous infrastructure (e.g., HVTL), any fading of effects would likely occur over many years, so it is assumed that any bias is likely minimal.

[113] These distances were used to compare homes sold, for instance, within 1 mile of where the turbines were eventually erected with similar homes sold after the turbines were erected (see, for example, the Temporal Aspects Model).

[114] A "Raster" is a grid of, in this case, 50 feet by 50 feet squares, each of which contains a number representing the number of feet from the center of the square to the nearest turbine.

within roughly 150 feet inside of 1.5 miles and within a maximum of roughly 1150 feet outside of 1.5 miles.[115]

[115] The resolution of the raster is 50 feet, so the hypotenuse is 70 feet. If the home is situated in the top left of a raster cell and the turbine is situated in the bottom right of a diagonally adjacent cell, they could be separated by as much as 140 feet, yet the raster distance would only be 50 feet, a difference of 90 feet. Moreover, the resolution of the Ortho image is 40 feet so that location could additionally be off by another 55 feet along the diagonal. These two uncertainties total to roughly 150 feet for homes inside of 1.5 miles. Outside of 1.5 miles the variation between centroid and house location for parcels smaller than 5 acres could be larger still. If a 4.9 acre parcel had a highly irregular rectangular shape of 102 by 2100 feet, for instance, the centroid could be as much as 1050 feet from the property line. If the home was situated 50 feet from the property line then the actual house location could be off by as much as 1000 feet. Adding this to the 150 feet from above leads to a total discrepancy of 1150 feet (0.22 miles) for homes outside of 1.5 miles on parcels smaller than 5 acres. Of course, these extreme scenarios are highly unlikely to be prevalent.

# Appendix C: Field Data Collection Instrument

Figure A - 12: Field Data Collection Instrument

| | | | | | |
|---|---|---|---|---|---|
| House # (Control/ Key #) | | | County | | |
| House Address | | | | | |
| **Home Characteristics** | | | House Photo Number(s) | | |
| Cul-De-Sac? | No(0) / Yes(1) | | Waterfront? | | No(0) / Yes(1) |
| | | | | | |
| **Scenic Vista Characteristics** | | | Vista Photo Numbers | | |
| Overall Quality of Scenic Vista: Poor (1), Below Average (2), Average (3), Above Average (4), Premium (5) | | | | | |
| | | | | | |
| **View of Turbines Characteristics** | | | View Photo Numbers | | |
| Total # of Turbines visible | | | Orientation of Home to View: See Below | | |
| # of Turbines- blade tips only visible | | | Side (S), Front (F), Back (B), Angled (A) | | |
| # of Turbines- nacelle/hub visible | | | | | |
| # of Turbines- tower visible | | | View Scope: Narrow(1), Medium(2), Wide(3) | | |
| | | | | | |
| The Degree to which the View of Turbines Dominate the Site? Non-Existent (0), Minor (1), Moderate (2), Substantial (3), Extreme (4) | | | | | |
| Degree to which the Turbines Overlap the Prominent Scenic Vista? Not at all (0), Barely (1), Somewhat (2), Strongly (3), Entirely (4) | | | | | |
| | | | | | |
| **Notes:** | | | | | |

## Figure A - 13: Field Data Collection Instrument - Instructions - Page 1

### Home Characteristics

| | |
|---|---|
| Cul-De-Sac? No(0)/Yes(1) | Is the home situated on a cul-de-sac? |
| Waterfront? No(0)/Yes(1) | Is the home situated on the waterfront? |

### "Vista" Characteristics

| | |
|---|---|
| Overall Quality of Scenic Vista: Poor (1) | This rating is reserved for vistas of unmistakably poor quality. These vistas are often dominated by visually discordant man-made alterations (not considering turbines), or are uncomfortable spaces for people, lack interest, or have virtually no recreational potential. |
| Overall Quality of Scenic Vista: Below Average (2) | The home's vista is of the below average quality. These vistas contain visually discordant man-made alterations (not considering turbines) but are not dominated by them. They are not inviting spaces for people, but are not uncomfortable. They have little interest, mystery and have minor recreational potential. |
| Overall Quality of Scenic Vista: Average (3) | The home's vista is of the average quality. These vistas include interesting views which can be enjoyed often only a narrow scope. These vistas may contain some visually discordant man-made alterations (not considering turbines), are moderately comfortable spaces for people, have some interest, and have minor recreational potential. |
| Overall Quality of Scenic Vista: Above Average (4) | The vista from the home is of above average quality. These vistas include interesting views which often can be enjoyed in a medium to wide scope. They might contain some man made alterations (not considering turbines), yet still possess significant interest and mystery, are moderately balanced and have some potential for recreation. |
| Overall Quality of Scenic Vista: Premium (5) | This rating is reserved for vistas of unmistakably premium quality. These vistas would include "picture post card" views which can be enjoyed in a wide scope. They are often free or largely free of any discordant man made alterations (not considering turbines), possess significant interest, memorable qualities, mystery and are well balanced and likely have a high potential for recreation. |
| Degree Turbines Overlap Prominent Vista? Not at all (0)) | The vista does not contain any view of the turbines. |
| Degree Turbines Overlap Prominent Vista? Barely (1) | A small portion (~ 0 - 20%) of the vista is overlapped by the view of turbines therefore the vista might contain a view of a few turbines, only a few of which can be seen entirely (from below the sweep of the blades to the top of their tips). |
| Degree Turbines Overlap Prominent Vista? Somewhat (2) | A moderate portion (~20-50%) of the vista contains turbines, and likely contains a view of more than one turbine, some of which are likely to be seen entirely (from below the sweep of the blades to the top of their tips). |
| Degree Turbines Overlap Prominent Vista? Strongly (3) | A large portion (~50-80%) of the vista contains a view of turbines, many of which likely can be seen entirely (from below the sweep of the blades to the top of their tips). |
| Degree Turbines Overlap Prominent Vista? Entirely (4) | This rating is reserved for situations where the turbines overlap virtually the entire (~80-100%) vista from the home. The vista likely contains a view of many turbines, virtually all of which can be seen entirely (from below the sweep of the blades to the top of their tips). |

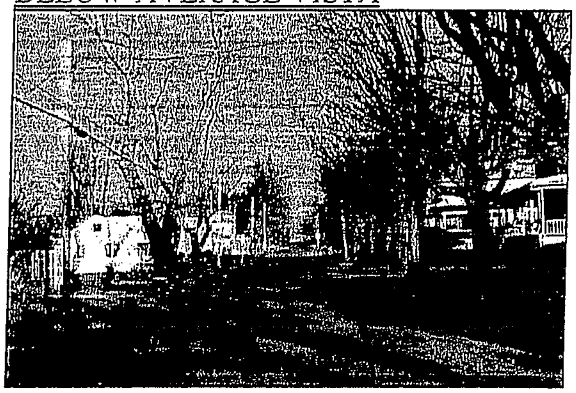
## Figure A - 14: Field Data Collection Instrument - Instructions - Page 2

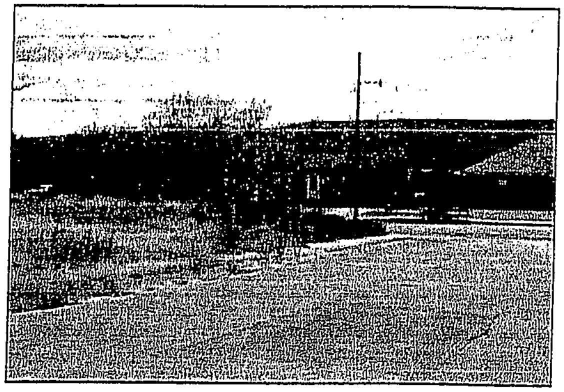
| View of Turbines Characterist | |
|---|---|
| House Orientation to View of Turbines: Side (S) | Orientation of home to the view of the turbines is from the side. |
| House Orientation to View of Turbines: Front (F) | Orientation of home to the view of the turbines is from the front. |
| House Orientation to Vista of Turbines: Back (B) | Orientation of home to the view of the turbines is from the back. |
| House Orientation to Vista of Turbines: Angled (A) | Orientation of home to the view of the turbines is from an angle. |
| View of Turbines Scope: Narrow(1) | The view of the turbines is largely blocked by trees, large shrubs or man made features in the foreground (0-300 feet) allowing 0 - 30 degrees of view of the wind facility |
| View of Turbines Scope: Medium(2) | The view of turbines is partially blocked by trees, large shrubs or man made features in the foreground (0-300 feet) allowing only 30-90 degrees of view of the wind facility. |
| View of Turbines Scope: Wide(3) | The view of the turbines is free or almost free from blockages by trees, large shrubs or man made features in the foreground (0-300 feet) allowing at least 90 degrees of view of the wind facility. |
| Degree to which View of Turbines Dominates the Site? None (0) | The turbines are not visible at all frrom this home. |
| Degree to which View of Turbines Dominates the Site? Minor (1) | The turbines are visible but either the scope is narrow, there are many obstructions, or the distance between the home and the facility is large. |
| Degree to which View of Turbines Dominates the Site? Moderate (2) | The turbines are visible but the scope is either narrow or medium, there might be some obstructions, and the distance between the home and the facility is most likely a few miles. |
| Degree to which View of Turbines Dominates the Site? Substantial (3) | The turbines are dramatically visible from the home. The turbines are likely visible in a wide scope, and most likely the distance between the home and the facility is short. |
| Degree to which View of Turbines Dominates the Site? Extreme (4) | This rating is reserved for sites that are unmistakably dominated by the presence of the windfarm. The turbines are dramatically visible from the home and there is a looming quality to their placement. The turbines are often visible in a wide scope, or the distance to the facility is very small. |

# Appendix D: Vista Ratings with Photos

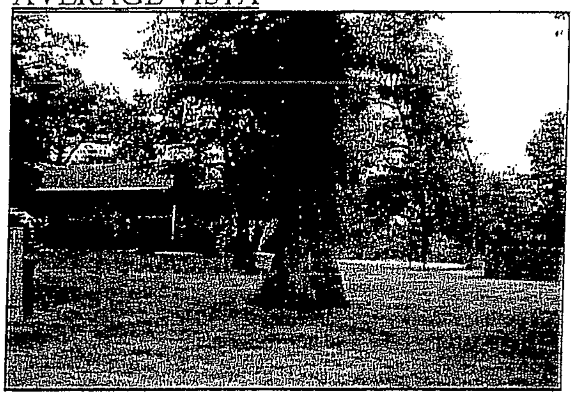
POOR VISTA

BELOW AVERAGE VISTA

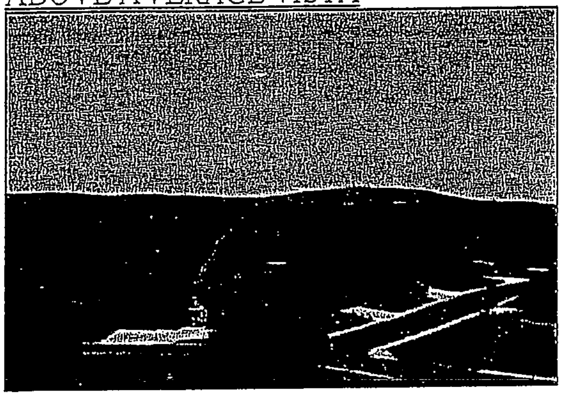


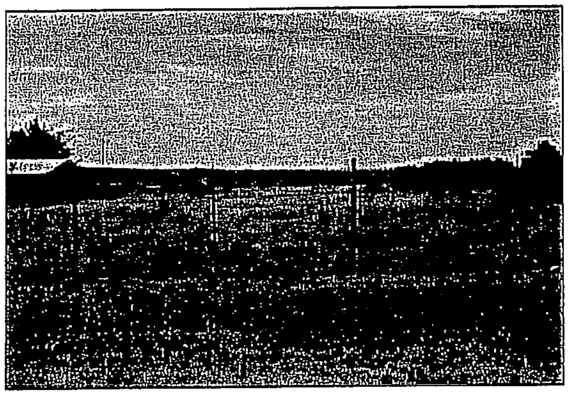


AVERAGE VISTA

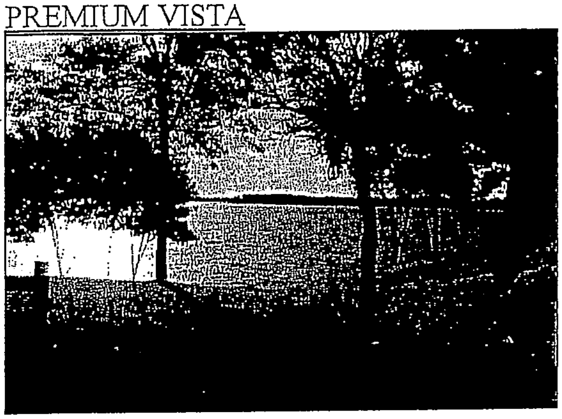


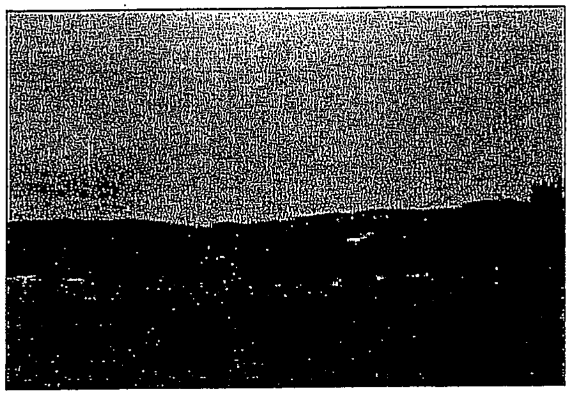
ABOVE AVERAGE VISTA





PREMIUM VISTA



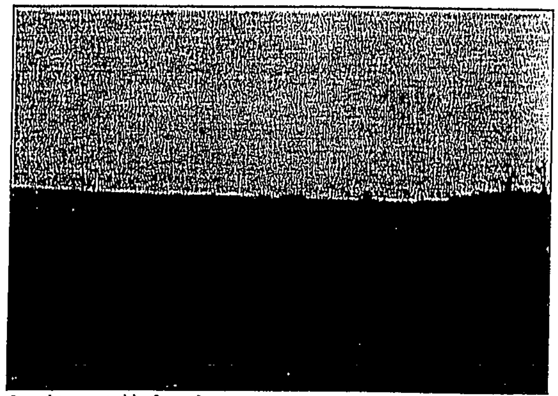


00001139

# Appendix E: View Ratings with Photos

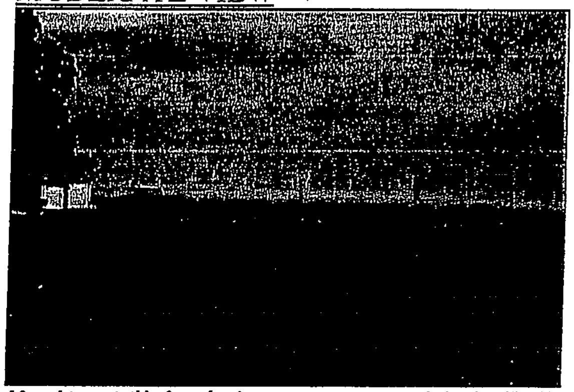
MINOR VIEW

3 turbines visible from front orientation, nearest 1.4 miles (TXHC)

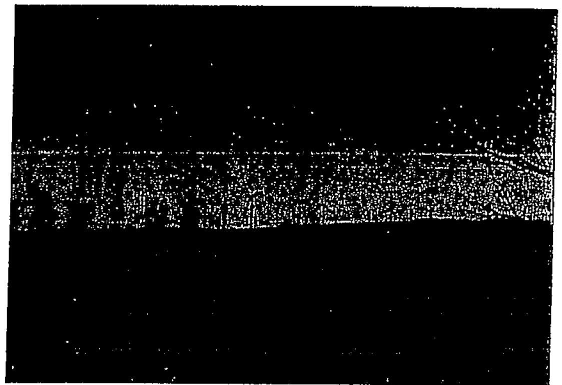


5 turbines visible from front orientation, nearest 0.9 miles (NYMC)

MODERATE VIEW

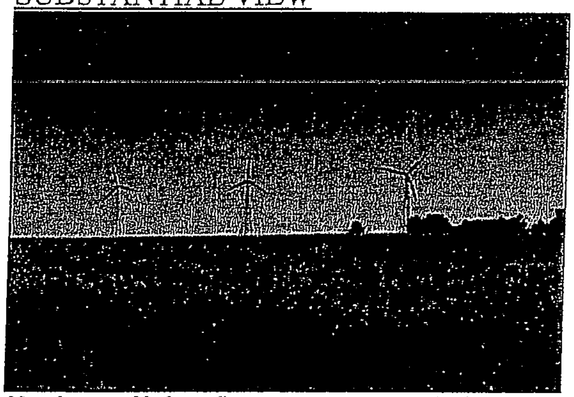


18 turbines visible from back orientation, nearest 1.6 miles (ILLC)

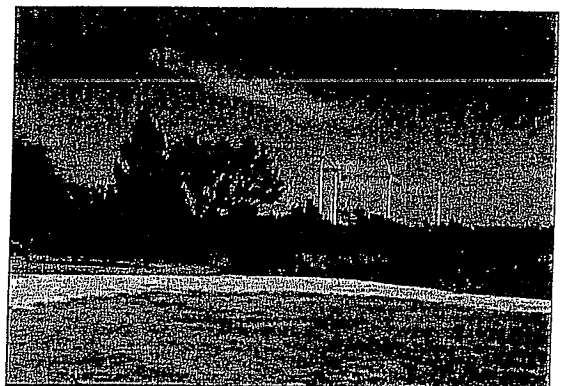


6 turbines visible from back orientation, nearest 0.8 miles (PASC)

SUBSTANTIAL VIEW

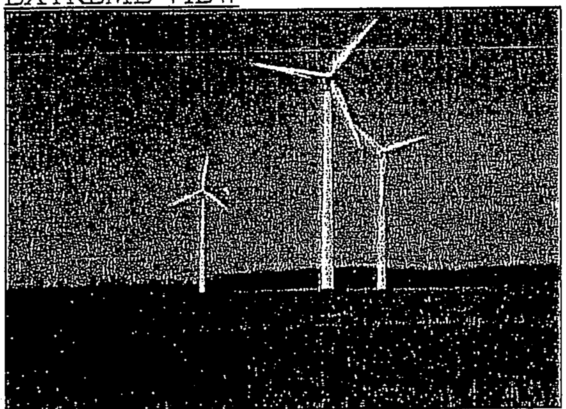


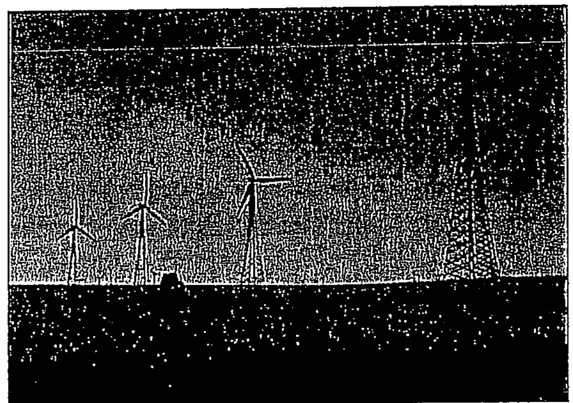
90 turbines visible from all orientations, nearest 0.6 miles (IABV)



27 turbines visible from multiple orientations, nearest 0.6 miles (TXHC)

EXTREME VIEW


6 turbines visible from multiple orientations, nearest 0.2 miles (WIKCDC)


212 turbines visible from all orientations, nearest 0.4 miles (IABV)

# Appendix F: Selecting the Primary ("Base") Hedonic Model

Equation (1) as described in Section 4.2 is presented in this report as the primary (or "Base") model to which all other models are compared. As noted earlier, in the Base Hedonic Model and in all subsequent models presented in Section 5 all variables of interest, spatial adjustments, and home and site characteristics are pooled, and therefore their estimates represent the average across all study areas. Ideally, one would have enough data to estimate a model at the study area level - a fully unrestricted model - rather than pooled across all areas. In this appendix, alternative model forms are presented that unrestrict these variables at the level of study areas. As shown here, these investigations ultimately encouraged the selection of the somewhat simpler pooled Base Model as the primary model, and to continue to use restricted or pooled models in the alternative hedonic analyses.

## F.1 Discussion of Fully Unrestricted Model Form

The Base Model described by equation (1) has variables that are pooled, and the coefficients for these variables therefore represent the average across all study areas (after accounting for study area fixed effects). An alternative (and arguably superior) approach would be to estimate coefficients at the level of each study area, thereby allowing coefficient values to vary among study areas.[116] This fully interacted – or unrestricted – model would take the following form:

$$\begin{aligned}\ln(P) = \beta_0 + \sum_s \beta_1 (N \cdot S) + \sum_c \beta_2 (Y) + \sum_k \beta_3 (X \cdot S) + \sum_v \beta_4 (VIEW \cdot S) + \\ \sum_d \beta_5 (DISTANCE \cdot S) + \varepsilon \end{aligned} \quad (F13)$$

where

P represents the inflation-adjusted sale price,
N is the spatially weighted neighbors' predicted sale price,
S is a vector of $s$ study areas (e.g., WAOR, OKCC, etc.),
Y is a vector of $c$ study area locational characteristics (e.g., census tract, school district, etc.),
X is a vector of k home and site characteristics (e.g., acres, square feet, number of bathrooms, condition of the home, age of home, VISTA, etc.),
VIEW is a vector of v categorical view of turbine variables (e.g., MINOR, MODERATE, etc.),
DISTANCE is a vector of d categorical distance to turbine variables (e.g., less than 3000 feet, between one and three miles, etc.),
$\beta_0$ is the constant or intercept across the full sample,
$\beta_1$ is a vector of $s$ parameter estimates for the spatially weighted neighbor's predicted sale price for S study areas,
$\beta_2$ is a vector of $c$ parameter estimates for the study area locational fixed effect variables,
$\beta_3$ is a vector of $k$ parameter estimates for the home and site characteristics for S study areas,
$\beta_4$ is a vector of $v$ parameter estimates for the VIEW variables as compared to homes sold with no view of the turbines for S study areas,

[116] For instance, the marginal contribution of Acres (the number of acres) to the selling price would be estimated for each study area (i.e., Acres_WAOR, Acres_TXHC etc.), as would the variables of interest: VIEW and DISTANCE.

$\beta_5$ is a vector of $d$ parameter estimates for the DISTANCE variables as compared to homes sold situated outside of five miles for S study areas, and
$\varepsilon$ is a random disturbance term.

To refresh, the fully restricted equation (1) takes the following form:

$$\ln(P) = \beta_0 + \beta_1 N + \sum_s \beta_2 S + \sum_k \beta_3 X + \sum_v \beta_4 VIEW + \sum_d \beta_5 DISTANCE + \varepsilon \qquad (1)$$

where
P represents the inflation-adjusted sale price,
N is the spatially weighted neighbors' predicted sale price,
S is the vector of $s$ Study Area fixed effects variables (e.g., WAOR, OKCC, etc.),
X is a vector of $k$ home and site characteristics (e.g., acres, square feet, number of bathrooms, condition of the home, age of home, VISTA, etc.),
VIEW is a vector of $v$ categorical view of turbine variables (e.g., MINOR, MODERATE, etc.),
DISTANCE is a vector of $d$ categorical distance to turbine variables (e.g., less than 3000 feet, between one and three miles, etc.),
$\beta_0$ is the constant or intercept across the full sample,
$\beta_1$ is a parameter estimate for the spatially weighted neighbor's predicted sale price,
$\beta_2$ is a vector of $s$ parameter estimates for the study area fixed effects as compared to homes sold in the Washington/Oregon (WAOR) study area,
$\beta_3$ is a vector of $k$ parameter estimates for the home and site characteristics,
$\beta_4$ is a vector of $v$ parameter estimates for the VIEW variables as compared to homes sold with no view of the turbines,
$\beta_5$ is a vector of $d$ parameter estimates for the DISTANCE variables as compared to homes sold situated outside of five miles, and
$\varepsilon$ is a random disturbance term.

The significant change between equations (1) and (F13) is that each of the primary groups of variables in equation (F13) is interacted with the study areas (S) so that parameters can be estimated at the study area level. For example, whereas ACRES is estimated in equation (1) across all study areas, in equation (F13) it is estimated for each study area (i.e., Acres_WAOR, Acres_TXHC, etc).[117] Similarly, when considering the possible impact of wind facilities on residential sales prices, equation (1) seeks average effects that exist over the entire sample, while equation (F13) instead looks for differential effects in each individual study area. Additionally, in equation (F13), instead of estimating fixed effects using inter-study area parameters alone (e.g., WAOR, TXHC), a set of intra-study area effects (Y) - school district and census tract delineations - are added.[118] These latter coefficients represent not only effects that are presumed

[117] This change is made because, theoretically, the contribution to sales prices of home or site characteristics may differ between study areas – for instance Central_AC in Texas vs. New York – and therefore estimating them at the study area level may increase the explanatory power of the model.

[118] In the evaluation and selection of the best model to use as the "Base Model" a set of census tract and school district delineations were used instead of the study area fixed effects. These more-granular fixed effects were extracted from GIS using house locations and census tract and school district polygons. Often, the school district and census tract delineations were not mutually exclusive. For example, in Wisconsin the WIKCDC study area contains four school districts and six census tracts, none of which completely overlap. Alternatively, in some study

to exist over each entire study area (inter-study area effects), but also intra-study area effects such as differences in home valuation due to school districts, distances to amenities, and other locationally bound influences. As with the inter-study area coefficients, because of the myriad influences captured by these variables, interpretation of any single coefficient can be difficult. However, it is expected that such coefficients would be influential, indicating significant differences in value between homes in each study area and across study areas due to school district quality and factors that differ between census tracts (e.g., crime rates).

Although the fully unrestricted model described by equation (F13) is arguably superior to the fully restricted model described in equation (1) because of its ability to resolve differences between and within study areas that are not captured by the Base Model, there are three potential drawbacks:

- Model parsimony and performance;
- Standard error magnitudes; and
- Parameter estimate stability.

Each of these potential drawbacks is discussed in turn below:

**Model parsimony and performance:** In general, econometricians prefer a simpler, more parsimonious statistical model. In this instance, variables should be added to a model only if their addition is strongly supported by theory and if the performance of the model is substantially improved by their inclusion. As such, if a model with a relatively small number of parameters performs well, it should be preferred to a model with more parameters unless the simple model can be "proven to be inadequate" (Newman, 1956). To prove the inadequacy of a simpler model requires a significant increase in performance to be exhibited from the more complex model. In this case, as presented later, performance is measured using the combination of Adjusted $R^2$, Modified $R^2$, and the Schwarz information criterion (see footnote 119 on page 127).

**Standard error magnitudes:** The magnitude of the standard errors for the variables of interest, as well as the other controlling variables, are likely to increase in the unrestricted model form because the number of cases for each variable will decrease when they are estimated at the study area level. Within each study area, there are a limited number of home transactions that meet the criteria for inclusion in the model, but even more limiting is the number of home transactions within each study area that have the characteristics of interest. For example, in Lee County, IL (ILLC), there are 205 post-construction home sales, while in Wayne County, PA (PAWC) there are 222. More importantly, in those areas, the data include a total of one and eleven sales inside of one mile, respectively, and a total of one and two homes with either EXTREME or SUBSTANTIAL rated views of turbines. With so few observations, there is increased likelihood that a single or small group of observations will strongly influence the sample mean of an independent variable. Since the standard error is derived from the variance of the parameter estimate, which in turn is derived from the summed deviation of each observation's actual level relative to its sample mean, this standard error is more likely to be larger than if a larger sample were considered. If the presence of wind facilities does have a detrimental effect on property

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areas the school district and census tracts perfectly overlapped, and in those cases either both were omitted as the reference category or one was included and the other withdrawn from the model to prevent perfect collinearity.

values, that effect seems likely to be relatively small, at least outside of the immediate vicinity of the wind turbines. The smaller sample sizes for the independent variables that come with the unrestricted model, which may decrease statistical precision by producing larger standard errors, would likely decrease the ability to accurately identify these possible effects statistically. To explore the magnitude of this concern, the difference in standard errors of the variables of interest is investigated among the restricted and unrestricted models.

**Parameter estimate stability:** In an unrestricted model, parameter estimates are more likely to be unstable because the sample of home transactions with any particular characteristic may be small and thus not representative of the population as a whole. As mentioned above, there are a limited number of transactions within each study area that have the characteristics of interest. Restricting the sample size by using an unrestricted model increases the likelihood that a limited number of observations, which in the population as a whole represent a very small segment, will drive the results in one direction or another, thereby leading to erroneous conclusions. The difference in parameter estimates is investigated by comparing the coefficients for the unrestricted variables of interest to those for the restricted variables of interest. Additionally, the sign of any significant variables will be investigated for the unrestricted models, which might help uncover potentially spurious results.

## F.2 Analysis of Alterative Model Forms

Here the spectrum of alternative models is explored, from the fully restricted equation (1) to the fully unrestricted equation (F13). To do so, not only are these two ends of the spectrum estimated, but also 14 intermediate models are estimated that consist of every combination of restriction of the four variable groups (i.e., variables of interest, spatial adjustments, study area delineations, and home and site characteristics). This produces a total of 16 models over which to assess model parsimony and performance, standard error size, and coefficient stability. This process allows for an understanding of model performance but, more importantly, to ultimately define a "Base Model" that is parsimonious (i.e., has the fewest parameters), robust (i.e., high adjusted $R^2$), and best fits the purpose of investigating wind facility impacts on home sales prices.

Table A - 2 presents the performance statistics for each of the 16 models defined above, moving from the fully restricted model equation (1) ("Model 1") to the fully unrestricted model equation (F13) ("Model 16"). In columns 2 – 5 of the table, the "R" represents a restriction for this variable group (i.e., not crossed with the study areas) and the "U" represents the case when the variable group is unrestricted (i.e., crossed with the study areas). Also shown are summary model statistics (i.e., Adjusted $R^2$, Modified $R^2$, and Schwarz information criterion - "SIC"), as well as the number of estimated parameters ($k$).[119] All models were run using the post-construction data subset of the sample of home sales transactions ($n$ = 4,937).

[119] Goldberger (1991), as cited by Gujarati (2003), suggests using a Modified $R^2 = (1 - k/n) * R^2$ to adjust for added parameters. For example, Models 1 and 14 have Modified $R^2$ of 0.76, yet Adjusted $R^2$ of 0.77 and 0.78 respectively. Therefore the Modified $R^2$ penalizes their measure of explanatory power more than the Adjusted $R^2$ when taking into account the degrees of freedom. Similarly, the Schwarz information criterion penalizes the models for increased numbers of parameters (Schwarz, 1978). More importantly, practitioners often rely on the Schwarz criterion – over the Modified or Adjusted $R^2$ statistics - to rank models with the same dependent variable by their relative parsimony (Gujarati, 2003). Therefore it will be used for that purpose here.

### Model Parsimony and Performance

Overall, the fully restricted model (1) performs well with only 37 independent variables, producing an Adjusted $R^2$ of 0.77. Despite the limited number of explanatory variables, the model explains ~77% of the variation in home prices in the sample. When the fully unrestricted model 16 (equation F13) is estimated, which lies at the other end of the spectrum, it performs only slightly better, with an Adjusted $R^2$ of 0.81, but with an additional 285 explanatory variables. It is therefore not surprising that the Modified $R^2$ is 0.76 for Model 1 and is only 0.77 for Model 16. Similarly, the Schwarz information criterion (SIC) increases from 0.088 to 0.110 when moving from model 1 to model 16 indicating relatively less parsimony. Combined, these metrics show that the improvement in the explanatory power of model 16 over model 1 is not enough to overcome the lack of parsimony. Turning to the 14 models that lie between Models 1 and 16, in general, little improvement in performance is found over Model 1, and considerably less parsimony, providing little initial justification to pursue a more complex specification than equation (1).

**Table A - 2: Summarized Results of Restricted and Unrestricted Model Forms**

| Model [1] | Study Area [2] | Spatial Adjustment | Home and Site Characteristics | Variables of Interest | Adj $R^2$ | Modified $R^2$ | SIC | $k$ † |
|---|---|---|---|---|---|---|---|---|
| 1 | R | R | R | R | 0.77 | 0.76 | 0.088 | 37 |
| 2 | U | R | R | R | 0.74 | 0.73 | 0.110 | 111 |
| 3 | R | U | R | R | 0.77 | 0.76 | 0.088 | 46 |
| 4 | R | R | U | R | 0.80 | 0.78 | 0.095 | 188 |
| 5 | R | R | R | U | 0.77 | 0.76 | 0.093 | 88 |
| 6 | U | U | R | R | 0.78 | 0.76 | 0.094 | 120 |
| 7 | R | U | U | R | 0.80 | 0.77 | 0.096 | 197 |
| 8 | R | R | U | U | 0.80 | 0.77 | 0.101 | 239 |
| 9 | U | R | U | R | 0.80 | 0.77 | 0.107 | 262 |
| 10 | U | R | R | U | 0.76 | 0.75 | 0.107 | 162 |
| 11 | R | U | R | U | 0.77 | 0.76 | 0.094 | 97 |
| 12 | U | U | U | R | 0.81 | 0.77 | 0.103 | 271 |
| 13 | R | U | U | U | 0.80 | 0.77 | 0.103 | 248 |
| 14 | U | U | R | U | 0.78 | 0.76 | 0.100 | 171 |
| 15 | U | R | U | U | 0.80 | 0.76 | 0.113 | 313 |
| 16 | U | U | U | U | 0.81 | 0.77 | 0.110 | 322 |

*"R" indicates parameters are pooled ("restricted") across the study areas.*
*"U" indicates parameters are not pooled ("unrestricted"), and are instead estimated at the study area level.*
1 - *Model numbers do not correspond to equation numbers listed in the report; equation (1) is Model 1, and equation (F1) is Model 16.*
2 - *In its restricted form "Study Area" includes only inter-study area delineations, while unrestricted "Study Area" includes intra-study area delineations of school district and census tract.*
† - *Numbers of parameters do not include intercept or omitted variables.*

The individual contributions to model performance from unrestricting each of the variable groups in turn (as shown in Models 2-5) further emphasizes the small performance gains that are earned despite the sizable increases in the number of parameters. As a single group, the unrestricted Home and Site Characteristics model (Model 4) makes the largest impact on model performance, at least with respect to the Adjusted $R^2$ (0.80), but this comes with the addition of 151 estimated parameters a slight improvement in the Modified $R^2$ (0.78) and a worsening SIC (0.095). Adding unrestricted Study Area delineations (Model 2), on the other hand, adversely affects performance (Adj. $R^2 = 0.74$, Modified $R^2 = 0.73$) and adds 74 estimated parameters (SIC = 0.110). Similarly, unrestricting the Spatial Adjustments (Model 3) offers little improvement in performance (Adj. $R^2 = 0.77$, Modified $R^2 = 0.76$) despite adding nine additional variables (SIC = 0.088). Finally, unrestricting the Variables of Interest (Model 5) does not increase model performance (Adj. $R^2 = 0.77$, Modified $R^2 = 0.76$) and adds 51 variables to the model (SIC = 0.093). This pattern of little model improvement yet considerable increases in the number of estimated parameters (i.e., less parsimony) continues when pairs or trios of variable groups are unrestricted. With an Adjusted $R^2$ of 0.77, the fully restricted equation (1) performs more than adequately, and is, by far, the most parsimonious.

**Standard Error Magnitudes**

Table A - 3 summarizes the standard errors for the variables of interest for all of the 16 models, grouped into restricted and unrestricted model categories. The table specifically compares the medians, minimums, and maximums of the standard errors for the models with restricted variables of interest (1, 2, 3, 4, 6, 7, 9 and 12) to those with unrestricted variables of interest (5, 8, 10, 11, 13, 14, 15 and 16).[120] The table demonstrates that the unrestricted standard errors for the variables of interest are significantly larger than the restricted standard errors. In fact, the minimum standard errors in the unrestricted models are often higher than the maximum standard errors produced in the restricted models. For example, the maximum standard error for an EXTREME VIEW in the restricted models is 0.09, yet the minimum in the unrestricted models is 0.12, with a maximum of 0.34. To put this result in a different light, a median standard error for the unrestricted EXTREME VIEW variable of 0.25 would require an effect on house prices larger than 50% to be considered statistically significant at the 90% level. Clearly, the statistical power of the unrestricted models is weak.[121] Based on other disamenities, as discussed in Section 2.1, an effect of this magnitude is very unlikely. Therefore, based on these standard errors, there is no apparent reason to unrestrict the variables of interest.

[120] For the restricted models, the medians, minimums, and maximums are derived across all eight models for each variable of interest. For the unrestricted models, they are derived across all study areas and all eight models for each variable of interest.

[121] At 90% confidence a standard error of 0.25 would produce a confidence interval of roughly +/- 0.42 (0.25 * 1.67). An effect of this magnitude represents a 52% change in sales prices because sales price is in a natural log form ($e$ ^ 0.42-1 = 0.52).

Table A - 3: Summary of VOI Standard Errors for Restricted and Unrestricted Models

| Standard Errors | Restricted Models Standard Errors | | | Unrestricted Models Standard Errors | | |
|---|---|---|---|---|---|---|
| | Median | Min | Max | Median | Min | Max |
| Minor View | 0.01 | 0.01 | 0.02 | 0.05 | 0.03 | 0.07 |
| Moderate View | 0.03 | 0.03 | 0.03 | 0.10 | 0.06 | 0.18 |
| Substantial View | 0.05 | 0.05 | 0.06 | 0.19 | 0.10 | 0.29 |
| Extreme View | 0.08 | 0.08 | 0.09 | 0.25 | 0.12 | 0.34 |
| Inside 3000 Feet | 0.05 | 0.05 | 0.06 | 0.21 | 0.09 | 0.33 |
| Between 3000 Feet and 1 Mile | 0.04 | 0.04 | 0.05 | 0.13 | 0.08 | 0.40 |
| Between 1 and 3 Miles | 0.02 | 0.02 | 0.02 | 0.05 | 0.02 | 0.11 |
| Between 3 and 5 Miles | 0.01 | 0.01 | 0.02 | 0.05 | 0.02 | 0.10 |

Parameter Estimate Stability

Table A - 4 summarizes the coefficient estimates for the variables of interest for all of the 16 models. The table specifically compares the medians, minimums, and maximums of the coefficients for the models with restricted variables of interest (1, 2, 3, 4, 6, 7, 9 and 12) to those with unrestricted variables of interest (5, 8, 10, 11, 13, 14, 15 and 16). As shown, the coefficients in the unrestricted models diverge significantly from those in the restricted models. For example, in the restricted models, the median coefficient for homes inside of 3000 feet is -0.03, with a minimum of -0.06 and a maximum of -0.01, yet in the unrestricted models the median coefficient is 0.06, with a minimum of -0.38 and a maximum of 0.32. Similarly, a MODERATE VIEW in the restricted models has a median of 0.00, with a minimum of -0.01 and a maximum of 0.03, whereas the unrestricted models produce coefficients with a median of -0.05 and with a minimum of -0.25 and a maximum of 0.35.

**Table A - 4: Summary of VOI Coefficients for Restricted and Unrestricted Models**

| Parameters | Restricted Models Coefficients | | | Unrestricted Models Coefficients | | |
|---|---|---|---|---|---|---|
| | Median | Min | Max | Median | Min | Max |
| Minor View | -0.02 | -0.03 | 0.00 | -0.02 | -0.16 | 0.24 |
| Moderate View | 0.00 | -0.01 | 0.03 | -0.05 | -0.25 | 0.35 |
| Substantial View | -0.01 | -0.04 | 0.02 | -0.08 | -0.31 | 0.13 |
| Extreme View | 0.03 | 0.02 | 0.05 | -0.03 | -0.23 | 0.09 |
| Inside 3000 Feet | -0.03 | -0.06 | -0.01 | 0.06 | -0.38 | 0.32 |
| Between 3000 Feet and 1 Mile | -0.04 | -0.06 | -0.01 | -0.10 | -0.44 | 0.52 |
| Between 1 and 3 Miles | -0.01 | -0.03 | 0.02 | 0.00 | -0.23 | 0.40 |
| Between 3 and 5 Miles | 0.02 | 0.01 | 0.04 | 0.05 | -0.05 | 0.32 |

Turning from the levels of the coefficients to the stability of their statistical significance and sign across models more reasons for concern are found. Table A - 5 summarizes the results of the unrestricted models, and presents the number of statistically significant variables of interest as a percent of the total estimated. The table also breaks these results down into two groups, those

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with coefficients above zero and those with coefficients below zero.[122] It should be emphasized here that it is the *a priori* expectation that, if effects exist, all of these coefficients would be less than zero, indicating an adverse effect on home prices from proximity to and views of wind turbines. Despite that expectation, when the variables of interest are unrestricted it is found that they are as likely to be above zero as they are below.[123] In effect, the small numbers of cases available for analysis at the study area level produce unstable results, likely because the estimates are being unduly influenced by either study area specific effects that are not captured by the model or by a limited number of observations that represents a larger fraction of the overall sample in that model.[124]

**Table A - 5: Summary of Significant VOI Above and Below Zero in Unrestricted Models**

| Significant Variables | Unrestricted Models | | |
|---|---|---|---|
| | Total | Below Zero | Above Zero |
| Minor View | 32% | 14% | 18% |
| Moderate View | 23% | 11% | 13% |
| Substantial View | 4% | 4% | 0% |
| Extreme View | 0% | 0% | 0% |
| Inside 3000 Feet | 23% | 15% | 8% |
| Between 3000 Feet and 1 Mile | 30% | 14% | 16% |
| Between 1 and 3 Miles | 56% | 32% | 24% |
| Between 3 and 5 Miles | 45% | 3% | 43% |

## F.3 Selecting a Base Model

To conclude, it was found that all three concerns related to the estimation and use of an unrestricted model form are borne out in practice. Despite experimenting with 16 different combinations of interactions, little overall improvement in performance is discovered. Where performance gains are found they are at the expense of parsimony as reflected in the lack of increase in the Modified $R^2$ and the relatively higher Schwartz information criterion. Further, divergent and spurious coefficients of interest and large standard errors are associated with those coefficients. Therefore the fully restricted model, equation (1), is used in this report as the "Base Model".

[122] The "Total" percentage of significant coefficients is calculated by counting the total number of significant coefficients across all 8 unrestricted models for each variable of interest, and dividing this total by the total number of coefficients. Therefore, a study area that did not have any homes in a group (for example, homes with EXTREME VIEWS) was not counted in the "total number of coefficients" sum. Any differences between the sum of "above" and "below" zero groups from the total are due to rounding errors.

[123] The relatively larger number of significant variables for the MINOR rated view, MODERATE rated view, Mile 1 to 3, and Mile 3 to 5 parameters are likely related to the smaller standard errors for those categories, which result from larger numbers of cases.

[124] Another possible explanation for spurious results in general is measurement error, when parameters do not appropriately represent what one is testing for. In this case though, the VIEW variables have been adequately "ground truthed" during the development of the measurement scale, and are similar to the VISTA variables, which were found to be very stable across study areas. DISTANCE, or for that matter, distance to any disamenity, has been repeatedly found to be an appropriate proxy for the size of effects. As a result, it is not believed that measurement error is a likely explanation for the results presented here.

## Appendix G: OLS Assumptions, and Tests for the Base Model

A number of criteria must be met to ensure that the Base Model and Alternative Hedonic Models produce unbiased coefficient estimates and standard errors: 1) appropriate controls for outliers and influencers; 2) homoskedasticity; 3) absence of serial or spatial autocorrelation; and 4) reasonably limited multicollinearity. Each of these criteria, and how they are addressed, is discussed below.

**Outliers and Influencers:** Home sale prices that are well away from the mean, also called outliers and influencers, can cause undue influence on parameter estimates. A number of formal tests are available to identify these cases, the most common being Mahalanobis' Distance ("M Distance") (Mahalanobis, 1936) and standardized residual screening. M Distance measures the degree to which individual observations influence the mean of the residuals. If any single observation has a strong influence on the residuals, it should be inspected and potentially removed. An auxiliary, but more informal, test for identifying these potentially influential observations is to see when the standardized absolute value of the residual exceeds some threshold. Both the Base Model and the All Sales Model were run using the original dataset of 7,464 transactions and the 4,940 transactions which occurred post-construction respectively. For both models the standardized residuals and the M Distance statistics were saved.[125] The histograms of these two sets of statistics from the two regressions are shown in Figure A - 15 through Figure A - 18.

[125] For the M Distance statistics all variables of interest were removed from the model. If they were left in the M-Distance statistics could be influenced by the small numbers of cases in the variables of interest. If these parameters were strongly influenced by a certain case, it could drive the results upward. Inspecting the controlling variables in the model, and how well they predicted the sale prices of the transactions in the sample, was of paramount importance therefore the variables of interest were not included.

Figure A - 15: Histogram of Standardized Residuals for Base Model

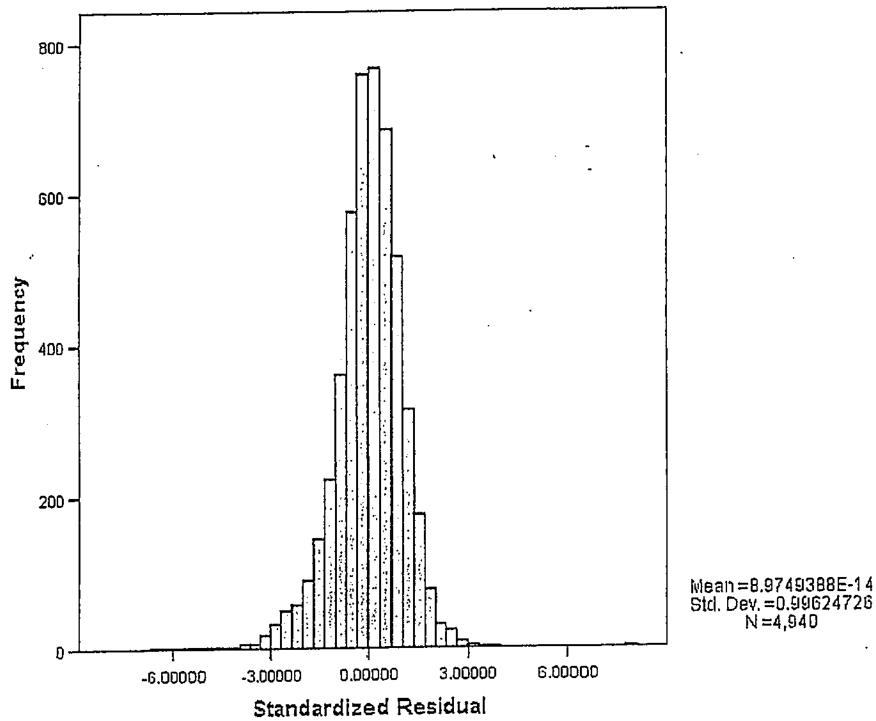


Figure A - 16: Histogram of Mahalanobis Distance Statistics for Base Model

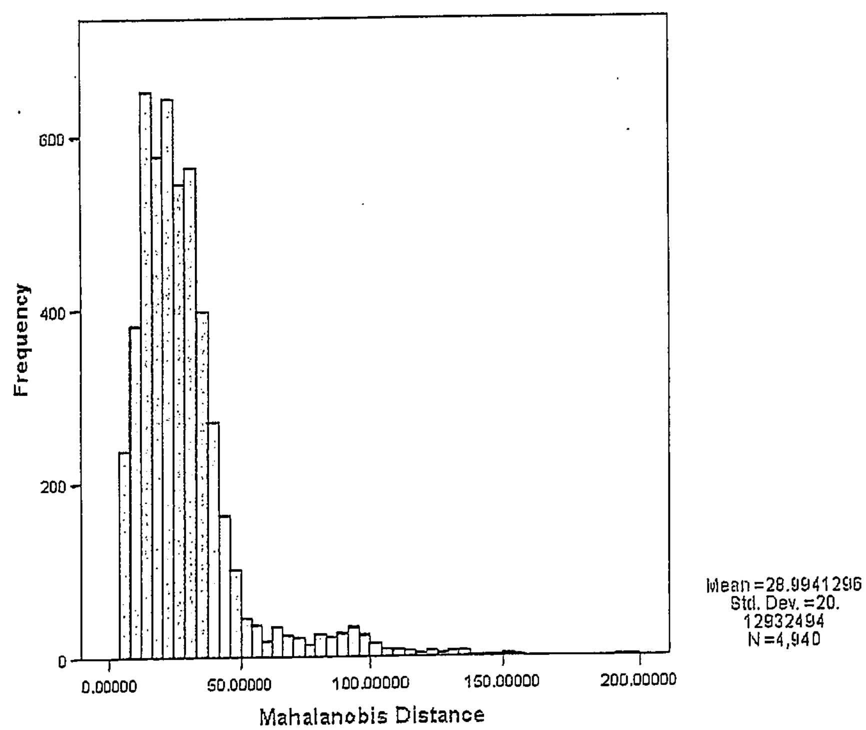




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Figure A - 17: Histogram of Standardized Residuals for All Sales Model

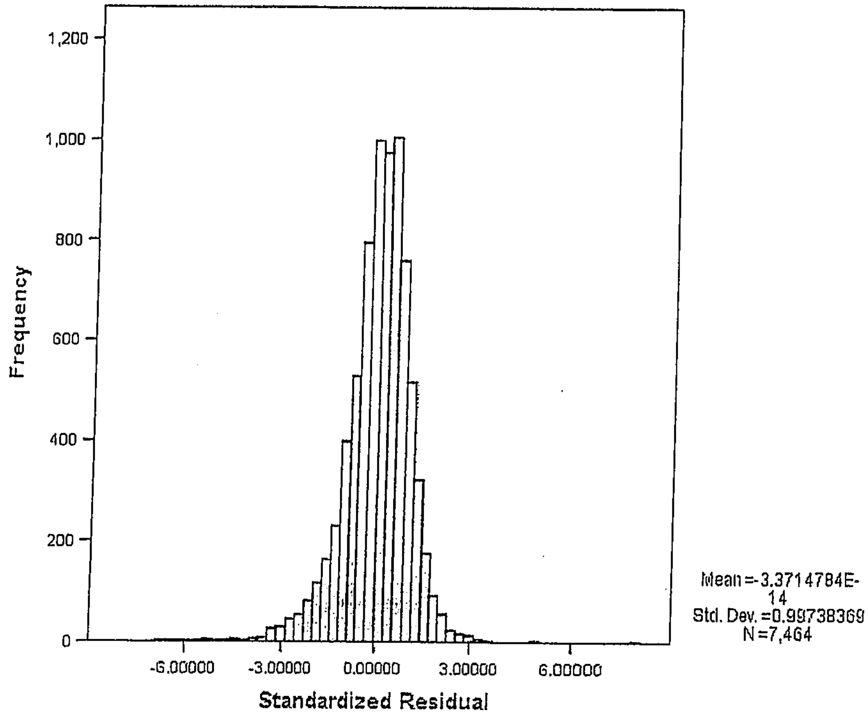
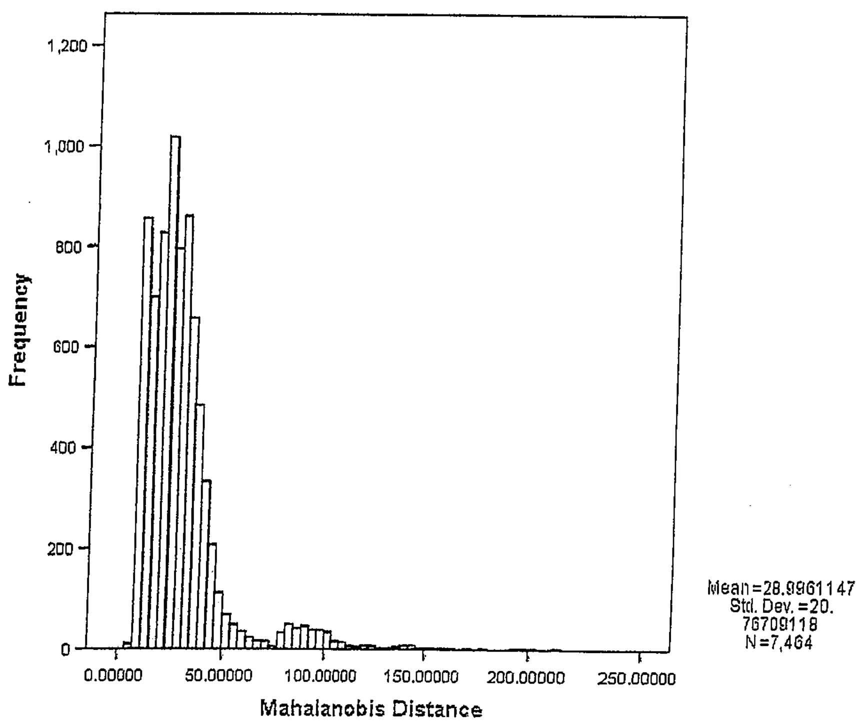



Figure A - 18: Histogram of Mahalanobis Distance Statistics for All Sales Model



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The M Distance histograms suggested that a cutoff of 150 may be appropriate, which would exclude 15 cases from the All Sales Model and seven cases from the Base Model (all of the latter of which were among the 15 outliers in the All Sales Model). The Standardized Residual histograms suggested a cutoff of 4, 5, or 6, which would exclude 13, 8, and 3 cases from the Base Model, and 22, 12, and 5 cases from the All Sales Model. A case-by-case investigation of each of these sales transactions was then conducted by comparing their home characteristics (e.g., square feet, baths, age, etc.) against their study area and panel model cohorts to ensure that none had been inappropriately coded. None of the M Distance flagged cases seemed to be inappropriately coded, and none of those cases were removed from the final dataset as a result. Five cases that were flagged from the All Sales Model (which corresponded to three cases in the Base Model) with a Standardized Residual greater than six, however, were clearly outliers. One had a sale price that was more than $200,000 more than any other transaction in the model, and the other four had exceptionally low prices, yet high numbers of corresponding characteristics that would suggest higher home sales prices (such as over 2000 square feet – all four cases – or more than two bathrooms – three cases).

As a result of these investigations, these five cases were removed from the model. One of the five cases occurred prior to announcement, one occurred after announcement and before construction, and the other three occurred after construction began. None were within three miles of the nearest wind turbine except one, which was 0.6 miles from the nearest turbine and had a MINOR view of the wind facility. The other two had no views of the turbines. Although there was hesitancy in removing any cases from the model, these transactions were considered appropriately influential and keeping them in the model would bias the results inappropriately. Further, the one home that was situated inside of one mile was surrounded by five other transactions in the same study area that also occurred after construction began and were a similar distance from the turbines, but that were not flagged by the outliers screen. Therefore, its removal was considered appropriate given that other homes in the sample would likely experience similar effects.

After removing these five cases, the sensitivity of the model results were tested to the inclusion or exclusion of the "greater than five" and "greater than four" Standardized Residuals observations and the cases flagged by the M Distance screen, finding that parameter estimates for the variables of interest moved slightly with these cases removed but not enough to change the results significantly. Because they did not show a unique grouping across the variables of interest, nor any unusual potentially inappropriate coding, and, more importantly, did not substantially influence the results, no substantive reason was found to remove any additional transactions from the sample. Therefore, the final dataset included a total of 7,459 cases, of which 4,937 occurred post-construction.

**Homoskedasticity:** A standard formal test for the presence of homoskedastic error terms is the White's statistic (White, 1980). However, the requirements to perform this test were overly burdensome for the computing power available. Instead, an informal test was applied, which plots the regression errors against predicted values and various independent variables to observe whether a "heteroskedastic pattern" is in evidence (Gujarati, 2003). Although no evidence of heteroskedasticity was found using this method, to be conservative, nonetheless all models were run with White's heteroskedasticity correction to the parameter estimates' standard errors (which will not adversely influence the errors if they are homoskedastic).

**Serial Autocorrelation:** A standard formal test for the presence of serial autocorrelation in the error term is the Durbin-Watson statistic (Durbin and Watson, 1951). Applying this test as proposed by Durbin and Watson to the full panel dataset was problematic because the test looks at the error structure based on the order that observations are included in the statistical regression model. Any ordering choice over the entire panel data set invariably involves mixing home transactions from various study areas. Ideally, one would segment the data by study area for purposes of calculating this test, but that method was not easily implemented with the statistical software package used for this analysis (i.e., SAS). Instead, study area specific regression models were run with the data chronologically ordered in each to produce twelve different Durbin-Watson statistics, one for each study area specific model. The Durbin-Watson test statistics ranged from 1.98–2.16, which are all within the acceptable range.[126] Given that serial autocorrelation was not found to be a significant concern for each study area specific model, it is assumed that the same holds for the full dataset used in the analysis presented in this report.

**Spatial Autocorrelation:** It is well known that the sales price of a home can be systematically influenced by the sales prices of those homes that have sold nearby (Dubin, 1998; LeSage, 1999). Both the seller and the buyer use information from comparable surrounding sales to inform them of the appropriate transaction price, and nearby homes often experience similar amenities and disamenities. Therefore, the price for any single home is likely to be weakly dependent of the prices of homes in close temporal and spatial proximity. This lack of independence of home sale prices could bias the hedonic results (Dubin, 1998; LeSage, 1999), if not adequately addressed. A number of techniques are available to address this concern (Case et al., 2004; Espey et al., 2007), but because of the large sample and computing limits, a variation of the Spatial Auto Regressive Model (SAR) was chosen (Espey et al., 2007).

Specifically, an independent variable is included in the models: the predicted values of the weighted nearest neighbor's natural log of sales price in 1996 dollars.[127] To construct this vector of predicted prices, an auxiliary regression is developed using the spatially weighted average natural log of sales price in 1996 dollars as the independent variable and the spatially weighted average set of home characteristics as the dependent variables. This regression was used to produce the <u>predicted</u> weighted nearest neighbor's natural log of sales price in 1996 dollars that is then included in the Base and Alternative Models. This process required the following steps:

1) Selecting the neighbors for inclusion in the calculation;
2) Calculating a weighted sales price from these neighbors' transactions;
3) Selecting and calculating the weighted neighbors home characteristics; and
4) Forecasting the weighted average neighbor's sales price.

- **Selecting the neighbors**: To select the neighbors whose home transactions would most likely have affected the sales price of the subject home under review, all of the homes that

[126] The critical values for the models were between 1.89 and 2.53, assuming 5% significance, greater than 20 variables, and more than 200 cases (Gujarati, 2003).

[127] The predicted value was used, instead of the actual value, to help correct for simultaneity or endogeneity problems that might otherwise exist.

sold within the preceding six months of a subject home's sale date in the same study area are identified and, from those, the five nearest neighbors based on Euclidian distance are selected. The inverse of each selected nearest neighbors' distance (in quarter miles) to the subject home was then calculated. Each of these values was then divided by the sum of the five nearest neighbor's inverse distance values to create a neighbor's distance weight (NDW) for each of the five nearest neighbors.[128]

- **Creating the weighted sales price:** Each of the neighbor's natural log of sales price in 1996 dollars (LN_Saleprice96) is multiplied by its distance weight (NDW). Then, each weighted neighbor's LN_Saleprice96 is summed to create a weighted nearest neighbor LN_Saleprice96 (Nbr_LN_Saleprice96).

- **Selecting and calculating the weighted neighbors home characteristics:** Nine independent variables are used from each of the neighbor's homes: square feet, age of the home at the time of sale, age of the home at the time of sale squared, acres, number of full baths, and condition (1-5, with Poor = 1, Below Average = 2, etc.). A weighted average is created of each of the characteristics by multiplying each of the neighbor's individual characteristics by their NDW, and then summing those values across the five neighbors to create the weighted average nearest neighbors' home characteristic.[129] Then each of the independent variables is interacted with the study area to allow each one to be independently estimated for each study area.

- **Forecasting the weighted average neighbors sales price:** To create the final predicted neighbor's price, the weighted nearest neighbor LN_Saleprice96 is regressed on the weighted average nearest neighbors' home characteristics to produce a predicted weighted nearest neighbor LN_Saleprice96 (Nbr_LN_SalePrice96_hat). These predicted values are then included in the Base and Alternative Models as independent variables to account for the spatial and temporal influence of the neighbors' home transactions.

In all models, the coefficient for this spatial adjustment parameter meets the expectations for sign and magnitude and is significant well above the 99% level, indicating both the presence of spatial autocorrelation and the appropriateness of the control for it.

**Multicollinearity:** There are several standard formal tests for detecting multicollinearity within the independent variables of a regression model. The Variance-Inflation Factor and Condition Index is applied to test for this violation of OLS assumptions. Specifically, a Variance-Inflation Factor (VIF) greater than 4 and/or a Condition Index of greater than 30 (Kleinbaum et al., 1988) are strong indicators that multicollinearity may exist. Multicollinearity is found in the model using both tests. Such a result is not uncommon in hedonic models because a number of characteristics, such as square feet or age of a home, are often correlated with other characteristics, such as the number of acres, bathrooms, and fireplaces. Not surprisingly, age of the home at the time of sale (AgeofHome) and the age of the home squared (AgeatHome_Sqrd)

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[128] Put differently, the weight is the contribution of that home's inverse distance to the total sum of the five nearest neighbors' inverse distances.

[129] Condition requires rounding to the nearest integer and then creating a dummy from the 1-5 integers.

exhibited some multicollinearity (VIF equaled 11.8 and 10.6, respectively). Additionally, the home condition shows a fairly high Condition Index with square feet, indicating collinearity. More importantly, though, are the collinearity statistics for the variables of interest. The VIF for the VIEW variables range from 1.17 to 1.18 and for the DISTANCE variables they range from 1.2 to 3.6, indicating little collinearity with the other variables in the model. To test for this in another way, a number of models are compared with various identified highly collinear variables removed (e.g., AgeatSale, Sqft) and found that the removal of these variables had little influence on the variables of interest. Therefore, despite the presence of multicollinearity in the model, it is not believed that the variables of interest are inappropriately influenced. Further, any corrections for these issues might cause more harm to the model's estimating efficiency than taking no further action (Gujarati, 2003); as such, no specific adjustments to address the presence of multicollinearity are pursued further.

# Appendix H: Alternative Models: Full Hedonic Regression Results

Table A - 6: Full Results for the Distance Stability Model

| | Coef. | SE | p Value | *n* |
|---|---|---|---|---|
| Intercept | 7.61 | 0.18 | 0.00 | |
| Nbr LN SalePrice96 hat | 0.29 | 0.02 | 0.00 | 4,937 |
| AgeatSale | -0.006 | 0.0004 | 0.00 | 4,937 |
| AgeatSale Sqrd | 0.00002 | 0.000003 | 0.00 | 4,937 |
| Sqft 1000 | 0.28 | 0.01 | 0.00 | 4,937 |
| Acres | 0.02 | 0.00 | 0.00 | 4,937 |
| Baths | 0.09 | 0.01 | 0.00 | 4,937 |
| ExtWalls Stone | 0.21 | 0.02 | 0.00 | 1,486 |
| CentralAC | 0.09 | 0.01 | 0.00 | 2,575 |
| Fireplace | 0.11 | 0.01 | 0.00 | 1,834 |
| FinBsmt | 0.08 | 0.02 | 0.00 | 673 |
| Cul De Sac | 0.10 | 0.01 | 0.00 | 992 |
| Water Front | 0.33 | 0.04 | 0.00 | 87 |
| Cnd Low | -0.45 | 0.05 | 0.00 | 69 |
| Cnd BAvg | -0.24 | 0.02 | 0.00 | 350 |
| Cnd Avg | Omitted | Omitted | Omitted | 2,727 |
| Cnd AAvg | 0.13 | 0.01 | 0.00 | 1,445 |
| Cnd High | 0.23 | 0.02 | 0.00 | 337 |
| Vista Poor | -0.21 | 0.02 | 0.00 | 310 |
| Vista BAvg | -0.08 | 0.01 | 0.00 | 2,857 |
| Vista Avg | Omitted | Omitted | Omitted | 1,247 |
| Vista AAvg | 0.10 | 0.02 | 0.00 | 448 |
| Vista Prem | 0.13 | 0.04 | 0.00 | 75 |
| WAOR | Omitted | Omitted | Omitted | 519 |
| TXHC | -0.75 | 0.03 | 0.00 | 1,071 |
| OKCC | -0.44 | 0.02 | 0.00 | 476 |
| IABV | -0.24 | 0.02 | 0.00 | 605 |
| ILLC | -0.08 | 0.03 | 0.00 | 213 |
| WIKCDC | -0.14 | 0.02 | 0.00 | 725 |
| PASC | -0.30 | 0.03 | 0.00 | 291 |
| PAWC | -0.07 | 0.03 | 0.01 | 222 |
| NYMCOC | -0.20 | 0.03 | 0.00 | 346 |
| NYMC | -0.15 | 0.02 | 0.00 | 469 |
| Mile Less 0 57 | -0.04 | 0.04 | 0.29 | 67 |
| Mile 0 57to1 | -0.06 | 0.05 | 0.27 | 58 |
| Mile 1to3 | -0.01 | 0.02 | 0.71 | 2,019 |
| Mile 3to5 | 0.01 | 0.01 | 0.26 | 1,923 |
| Mile Gtr5 | Omitted | Omitted | Omitted | 870 |

*"Omitted" = reference category for fixed effects variables*
*"n" indicates number of cases in category when category = "1"*

Model Information

| | |
|---|---|
| Model Equation Number | 2 |
| Model Name | Distance Stability |
| Dependent Variable | LN SalePrice96 |
| Number of Cases | 4937 |
| Number of Predictors (k) | 33 |
| F Statistic | 496.7 |
| Adjusted R Squared | 0.77 |

Table A - 7: Full Results for the View Stability Model

| | Coef. | SE | Sig | *n* |
|---|---|---|---|---|
| Intercept | 7.64 | 0.18 | 0.00 | |
| Nbr_LN_SalePrice96_hat | 0.29 | 0.02 | 0.00 | 4,937 |
| AgeatSale | -0.006 | 0.0004 | 0.00 | 4,937 |
| AgeatSale_Sqrd | 0.00002 | 0.000003 | 0.00 | 4,937 |
| Sqft_1000 | 0.28 | 0.01 | 0.00 | 4,937 |
| Acres | 0.02 | 0.00 | 0.00 | 4,937 |
| Baths | 0.09 | 0.01 | 0.00 | 4,937 |
| ExtWalls_Stone | 0.21 | 0.02 | 0.00 | 1,486 |
| CentralAC | 0.09 | 0.01 | 0.00 | 2,575 |
| Fireplace | 0.11 | 0.01 | 0.00 | 1,834 |
| FinBsmt | 0.08 | 0.02 | 0.00 | 673 |
| Cul_De_Sac | 0.10 | 0.01 | 0.00 | 992 |
| Water_Front | 0.34 | 0.04 | 0.00 | 87 |
| Cnd_Low | -0.45 | 0.05 | 0.00 | 69 |
| Cnd_BAvg | -0.24 | 0.02 | 0.00 | 350 |
| Cnd_Avg | Omitted | Omitted | Omitted | 2,727 |
| Cnd_AAvg | 0.13 | 0.01 | 0.00 | 1,445 |
| Cnd_High | 0.23 | 0.02 | 0.00 | 337 |
| Vista_Poor | -0.21 | 0.02 | 0.00 | 310 |
| Vista_BAvg | -0.08 | 0.01 | 0.00 | 2,857 |
| Vista_Avg | Omitted | Omitted | Omitted | 1,247 |
| Vista_AAvg | 0.10 | 0.02 | 0.00 | 448 |
| Vista_Prem | 0.13 | 0.04 | 0.00 | 75 |
| WAOR | Omitted | Omitted | Omitted | 519 |
| TXHC | -0.75 | 0.02 | 0.00 | 1,071 |
| OKCC | -0.45 | 0.02 | 0.00 | 476 |
| IABV | -0.25 | 0.02 | 0.00 | 605 |
| ILLC | -0.09 | 0.03 | 0.00 | 213 |
| WIKCDC | -0.14 | 0.02 | 0.00 | 725 |
| PASC | -0.31 | 0.03 | 0.00 | 291 |
| PAWC | -0.08 | 0.03 | 0.00 | 222 |
| NYMCOC | -0.20 | 0.03 | 0.00 | 346 |
| NYMC | -0.15 | 0.02 | 0.00 | 469 |
| Post_Con_NoView | Omitted | Omitted | Omitted | 4,207 |
| View_Minor | -0.02 | 0.01 | 0.25 | 561 |
| View_Mod | 0.00 | 0.03 | 0.90 | 106 |
| View_Sub | -0.04 | 0.06 | 0.56 | 35 |
| View_Extrm | -0.03 | 0.06 | 0.61 | 28 |

*"Omitted" = reference category for fixed effects variables*
*"n" indicates number of cases in category when category = "1"*

## Model Information

| | |
|---|---|
| Model Equation Number | 3 |
| Model Name | View Stability |
| Dependent Variable | LN_SalePrice96 |
| Number of Cases | 4937 |
| Number of Predictors (k) | 33 |
| F Statistic | 495.9 |
| Adjusted R Squared | 0.77 |

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## Table A - 8: Full Results for the Continuous Distance Model

| | Coef. | SE | p Value | *n* |
|---|---|---|---|---|
| Intercept | 7.64 | 0.18 | 0.00 | |
| Nbr LN SalePrice96 hat | 0.29 | 0.02 | 0.00 | 4,937 |
| AgeatSale | -0.006 | 0.0004 | 0.00 | 4,937 |
| AgeatSale Sqrd | 0.00002 | 0.000003 | 0.00 | 4,937 |
| Sqft 1000 | 0.28 | 0.01 | 0.00 | 4,937 |
| Acres | 0.02 | 0.00 | 0.00 | 4,937 |
| Baths | 0.09 | 0.01 | 0.00 | 4,937 |
| ExtWalls Stone | 0.21 | 0.02 | 0.00 | 1,486 |
| CentralAC | 0.09 | 0.01 | 0.00 | 2,575 |
| Fireplace | 0.11 | 0.01 | 0.00 | 1,834 |
| FinBsmt | 0.08 | 0.02 | 0.00 | 673 |
| Cul De Sac | 0.10 | 0.01 | 0.00 | 992 |
| Water Front | 0.34 | 0.04 | 0.00 | 87 |
| Cnd Low | -0.45 | 0.05 | 0.00 | 69 |
| Cnd BAvg | -0.24 | 0.02 | 0.00 | 350 |
| Cnd Avg | Omitted | Omitted | Omitted | 2,727 |
| Cnd AAvg | 0.13 | 0.01 | 0.00 | 1,445 |
| Cnd High | 0.23 | 0.02 | 0.00 | 337 |
| Vista Poor | -0.21 | 0.02 | 0.00 | 310 |
| Vista BAvg | -0.08 | 0.01 | 0.00 | 2,857 |
| Vista Avg | Omitted | Omitted | Omitted | 1,247 |
| Vista AAvg | 0.10 | 0.02 | 0.00 | 448 |
| Vista Prem | 0.13 | 0.04 | 0.00 | 75 |
| WAOR | Omitted | Omitted | Omitted | 519 |
| TXHC | -0.75 | 0.02 | 0.00 | 1,071 |
| OKCC | -0.44 | 0.02 | 0.00 | 476 |
| IABV | -0.25 | 0.02 | 0.00 | 605 |
| ILLC | -0.09 | 0.03 | 0.00 | 213 |
| WIKCDC | -0.14 | 0.02 | 0.00 | 725 |
| PASC | -0.31 | 0.03 | 0.00 | 291 |
| PAWC | -0.07 | 0.03 | 0.00 | 222 |
| NYMCOC | -0.20 | 0.03 | 0.00 | 346 |
| NYMC | -0.15 | 0.02 | 0.00 | 469 |
| No View | Omitted | Omitted | Omitted | 4,207 |
| Minor View | -0.01 | 0.01 | 0.33 | 561 |
| Moderate View | 0.01 | 0.03 | 0.77 | 106 |
| Substantial View | -0.02 | 0.07 | 0.72 | 35 |
| Extreme View | 0.01 | 0.10 | 0.88 | 28 |
| InvDISTANCE | -0.01 | 0.02 | 0.46 | 4,937 |

*"Omitted" = reference category for fixed effects variables*
*"n" indicates number of cases in category when category = "1"*

### Model Information

| | |
|---|---|
| Model Equation Number | 5 |
| Model Name | Continuous Distance Model |
| Dependent Variable | LN SalePrice96 |
| Number of Cases | 4937 |
| Number of Predictors (k) | 34 |
| F Statistic | 481.3 |
| Adjusted R Squared | 0.77 |

Table A - 9: Full Results for the All Sales Model

| | Coef. | SE | p Value | *n* |
|---|---|---|---|---|
| Intercept | 9.08 | 0.14 | 0.00 | |
| Nbr LN SP96 hat All OI | 0.16 | 0.01 | 0.00 | 7,459 |
| AgeatSale | -0.007 | 0.0003 | 0.00 | 7,459 |
| AgeatSale Sqrd | 0.00003 | 0.000002 | 0.00 | 7,459 |
| Sqft 1000 | 0.28 | 0.01 | 0.00 | 7,459 |
| Acres | 0.02 | 0.00 | 0.00 | 7,459 |
| Baths | 0.08 | 0.01 | 0.00 | 7,459 |
| ExtWalls Stone | 0.21 | 0.01 | 0.00 | 2,287 |
| CentralAC | 0.12 | 0.01 | 0.00 | 3,785 |
| Fireplace | 0.11 | 0.01 | 0.00 | 2,708 |
| FinBsmt | 0.09 | 0.01 | 0.00 | 990 |
| Cul De Sac | 0.09 | 0.01 | 0.00 | 1,472 |
| Water Front | 0.35 | 0.03 | 0.00 | 107 |
| Cnd Low | -0.43 | 0.04 | 0.00 | 101 |
| Cnd BAvg | -0.21 | 0.02 | 0.00 | 519 |
| Cnd Avg | Omitted | Omitted | Omitted | 4,357 |
| Cnd AAvg | 0.13 | 0.01 | 0.00 | 2,042 |
| Cnd High | 0.22 | 0.02 | 0.00 | 440 |
| Vista Poor | -0.25 | 0.02 | 0.00 | 470 |
| Vista BAvg | -0.09 | 0.01 | 0.00 | 4,301 |
| Vista Avg | Omitted | Omitted | Omitted | 1,912 |
| Vista AAvg | 0.10 | 0.01 | 0.00 | 659 |
| Vista Prem | 0.09 | 0.03 | 0.00 | 117 |
| WAOR | Omitted | Omitted | Omitted | 790 |
| TXHC | -0.82 | 0.02 | 0.00 | 1,311 |
| OKCC | -0.53 | 0.02 | 0.00 | 1,113 |
| IABV | -0.31 | 0.02 | 0.00 | 822 |
| ILLC | -0.05 | 0.02 | 0.02 | 412 |
| WIKCDC | -0.17 | 0.01 | 0.00 | 810 |
| PASC | -0.37 | 0.03 | 0.00 | 494 |
| PAWC | -0.15 | 0.02 | 0.00 | 551 |
| NYMCOC | -0.25 | 0.02 | 0.00 | 463 |
| NYMC | -0.15 | 0.02 | 0.00 | 693 |
| Pre-Construction Sales | Omitted | Omitted | Omitted | 2,522 |
| No View | 0.02 | 0.01 | 0.06 | 4,207 |
| Minor View | 0.00 | 0.02 | 0.76 | 561 |
| Moderate View | 0.03 | 0.03 | 0.38 | 106 |
| Substantial View | 0.03 | 0.07 | 0.63 | 35 |
| Extreme View | 0.06 | 0.08 | 0.43 | 28 |
| Inside 3000 Feet | -0.06 | 0.05 | 0.23 | 80 |
| Between 3000 Feet and 1 Mile | -0.08 | 0.05 | 0.08 | 65 |
| Between 1 and 3 Miles | 0.00 | 0.01 | 0.79 | 2,359 |
| Between 3 and 5 Miles | 0.01 | 0.01 | 0.58 | 2,200 |
| Outside 5 Miles | 0.00 | 0.02 | 0.76 | 1,000 |
| Pre-Announcement Sales | Omitted | Omitted | Omitted | 1,755 |

*"Omitted" = reference category for fixed effects variables*
*"n" indicates number of cases in category when category = "1"*

## Model Information

| | |
|---|---|
| Model Equation Number | 6 |
| Model Name | All Sales Model |
| Dependent Variable | LN SalePrice96 |
| Number of Cases | 7459 |
| Number of Predictors (k) | 39 |
| F Statistic | 579.9 |
| Adjusted R Squared | 0.75 |

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Table A - 10: Full Results for the Temporal Aspects Model

| | Coef. | SE | p Value | *n* |
|---|---|---|---|---|
| Intercept | 9.11 | 0.14 | 0.00 | |
| Nbr LN SP96 hat All OI | 0.16 | 0.01 | 0.00 | 7,459 |
| AgeatSale | -0.007 | 0.0003 | 0.00 | 7,459 |
| AgeatSale Sqrd | 0.00003 | 0.000002 | 0.00 | 7,459 |
| Sqft 1000 | 0.28 | 0.01 | 0.00 | 7,459 |
| Acres | 0.02 | 0.00 | 0.00 | 7,459 |
| Baths | 0.08 | 0.01 | 0.00 | 7,459 |
| ExtWalls Stone | 0.21 | 0.01 | 0.00 | 2,287 |
| CentralAC | 0.12 | 0.01 | 0.00 | 3,785 |
| Fireplace | 0.12 | 0.01 | 0.00 | 2,708 |
| FinBsmt | 0.09 | 0.01 | 0.00 | 990 |
| Cul De Sac | 0.09 | 0.01 | 0.00 | 1,472 |
| Water Front | 0.35 | 0.03 | 0.00 | 107 |
| Cnd Low | -0.43 | 0.04 | 0.00 | 101 |
| Cnd BAvg | -0.21 | 0.02 | 0.00 | 519 |
| Cnd Avg | Omitted | Omitted | Omitted | 4,357 |
| Cnd AAvg | 0.13 | 0.01 | 0.00 | 2,042 |
| Cnd High | 0.22 | 0.02 | 0.00 | 440 |
| Vista Poor | -0.25 | 0.02 | 0.00 | 470 |
| Vista BAvg | -0.09 | 0.01 | 0.00 | 4,301 |
| Vista Avg | Omitted | Omitted | Omitted | 1,912 |
| Vista AAvg | 0.10 | 0.01 | 0.00 | 659 |
| Vista Prem | 0.09 | 0.03 | 0.00 | 117 |
| WAOR | Omitted | Omitted | Omitted | 790 |
| TXHC | -0.82 | 0.02 | 0.00 | 1,311 |
| OKCC | -0.52 | 0.02 | 0.00 | 1,113 |
| IABV | -0.30 | 0.02 | 0.00 | 822 |
| ILLC | -0.04 | 0.02 | 0.05 | 412 |
| WIKCDC | -0.17 | 0.02 | 0.00 | 810 |
| PASC | -0.37 | 0.03 | 0.00 | 494 |
| PAWC | -0.14 | 0.02 | 0.00 | 551 |
| NYMCOC | -0.25 | 0.02 | 0.00 | 463 |
| NYMC | -0.15 | 0.02 | 0.00 | 693 |

*"Omitted" = reference category for fixed effects variables*
*"n" indicates number of cases in category when category = "1"*

*Note: Results for variables of interest shown on following page*

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| | Coef. | SE | p Value | *n* |
|---|---|---|---|---|
| No View | Omitted | Omitted | Omitted | 6,729 |
| Minor View | -0.02 | 0.01 | 0.20 | 561 |
| Moderate View | 0.00 | 0.03 | 0.97 | 106 |
| Substantial View | 0.01 | 0.07 | 0.87 | 35 |
| Extreme View | 0.04 | 0.07 | 0.59 | 28 |
| Pre Anc Gtr2Yr Lt1Mile | -0.13 | 0.06 | 0.02 | 38 |
| Pre Anc 2Yr Lt1Mile | -0.10 | 0.05 | 0.06 | 40 |
| Post Anc Pre Con Lt1Mile | -0.14 | 0.06 | 0.02 | 21 |
| Post Con 2Yr Lt1Mile | -0.09 | 0.07 | 0.15 | 39 |
| Post Con 2 4Yr Lt1Mile | -0.01 | 0.06 | 0.86 | 44 |
| Post Con Gtr5Yr Lt1Mile | -0.07 | 0.08 | 0.37 | 42 |
| Pre Anc Gtr2Yr 1 3Mile | -0.04 | 0.03 | 0.19 | 283 |
| Pre Anc 2Yr 1 3Mile | 0.00 | 0.03 | 0.91 | 592 |
| Post Anc Pre Con 1 3Mile | -0.02 | 0.03 | 0.53 | 342 |
| Post Con 2Yr 1 3Mile | 0.00 | 0.03 | 0.90 | 807 |
| Post Con 2 4Yr 1 3Mile | 0.01 | 0.03 | 0.78 | 503 |
| Post Con Gtr5Yr 1 3Mile | 0.00 | 0.03 | 0.93 | 710 |
| Pre Anc Gtr2Yr 3 5Mile | 0.00 | 0.04 | 0.93 | 157 |
| Pre Anc 2Yr 3 5Mile | 0.00 | 0.03 | 0.98 | 380 |
| Post Anc Pre Con 3 5Mile | 0.00 | 0.03 | 0.93 | 299 |
| Post Con 2Yr 3 5Mile | 0.02 | 0.03 | 0.56 | 574 |
| Post Con 2 4Yr 3 5Mile | 0.01 | 0.03 | 0.66 | 594 |
| Post Con Gtr5Yr 3 5Mile | 0.01 | 0.03 | 0.68 | 758 |
| Pre Anc Gtr2Yr Gtr5Mile | Omitted | Omitted | Omitted | 132 |
| Pre Anc 2Yr Gtr5Mile | -0.03 | 0.04 | 0.39 | 133 |
| Post Anc Pre Con Gtr5Mile | -0.03 | 0.03 | 0.36 | 105 |
| Post Con 2Yr Gtr5Mile | -0.03 | 0.03 | 0.44 | 215 |
| Post Con 2 4Yr Gtr5Mile | 0.03 | 0.03 | 0.42 | 227 |
| Post Con Gtr5Yr Gtr5Mile | 0.01 | 0.03 | 0.72 | 424 |

*"Omitted" = reference category for fixed effects variables*
*"n" indicates number of cases in category when category = "1"*

## Model Information

| | |
|---|---|
| Model Equation Number | 7 |
| Model Name | Temporal Aspects Model |
| Dependent Variable | LN_SalePrice96 |
| Number of Cases | 7459 |
| Number of Predictors (k) | 56 |
| F Statistic | 404.5 |
| Adjusted R2 | 0.75 |

Table A - 11: Full Results for the Orientation Model

| | Coef. | SE | p Value | n |
|---|---|---|---|---|
| Intercept | 7.62 | 0.18 | 0.00 | |
| Nbr LN SalePrice96 hat | 0.29 | 0.02 | 0.00 | 4,937 |
| AgeatSale | -0.006 | 0.0004 | 0.00 | 4,937 |
| AgeatSale Sqrd | 0.00002 | 0.000003 | 0.00 | 4,937 |
| Sqft 1000 | 0.28 | 0.01 | 0.00 | 4,937 |
| Acres | 0.02 | 0.00 | 0.00 | 4,937 |
| Baths | 0.09 | 0.01 | 0.00 | 4,937 |
| ExtWalls Stone | 0.21 | 0.02 | 0.00 | 1,486 |
| CentralAC | 0.09 | 0.01 | 0.00 | 2,575 |
| Fireplace | 0.11 | 0.01 | 0.00 | 1,834 |
| FinBsmt | 0.08 | 0.02 | 0.00 | 673 |
| Cul De Sac | 0.10 | 0.01 | 0.00 | 992 |
| Water Front | 0.33 | 0.04 | 0.00 | 87 |
| Cnd Low | -0.44 | 0.05 | 0.00 | 69 |
| Cnd BAvg | -0.24 | 0.02 | 0.00 | 350 |
| Cnd Avg | Omitted | Omitted | Omitted | 2,727 |
| Cnd AAvg | 0.13 | 0.01 | 0.00 | 1,445 |
| Cnd High | 0.24 | 0.02 | 0.00 | 337 |
| Vista Poor | -0.21 | 0.02 | 0.00 | 310 |
| Vista BAvg | -0.08 | 0.01 | 0.00 | 2,857 |
| Vista Avg | Omitted | Omitted | Omitted | 1,247 |
| Vista AAvg | 0.10 | 0.02 | 0.00 | 448 |
| Vista Prem | 0.13 | 0.04 | 0.00 | 75 |
| WAOR | Omitted | Omitted | Omitted | 519 |
| TXHC | -0.75 | 0.03 | 0.00 | 1,071 |
| OKCC | -0.44 | 0.02 | 0.00 | 476 |
| IABV | -0.24 | 0.02 | 0.00 | 605 |
| ILLC | -0.08 | 0.03 | 0.00 | 213 |
| WIKCDC | -0.14 | 0.02 | 0.00 | 725 |
| PASC | -0.31 | 0.03 | 0.00 | 291 |
| PAWC | -0.07 | 0.03 | 0.01 | 222 |
| NYMCOC | -0.20 | 0.03 | 0.00 | 346 |
| NYMC | -0.15 | 0.02 | 0.00 | 469 |
| No View | Omitted | Omitted | Omitted | 4,207 |
| Minor View | -0.01 | 0.06 | 0.92 | 561 |
| Moderate View | 0.00 | 0.06 | 0.97 | 106 |
| Substantial View | -0.01 | 0.09 | 0.87 | 35 |
| Extreme View | 0.02 | 0.17 | 0.89 | 28 |
| Inside 3000 Feet | -0.04 | 0.07 | 0.55 | 67 |
| Between 3000 Feet and 1 Mile | -0.05 | 0.05 | 0.37 | 58 |
| Between 1 and 3 Miles | 0.00 | 0.02 | 0.83 | 2,019 |
| Between 3 and 5 Miles | 0.02 | 0.01 | 0.22 | 1,923 |
| Outside 5 Miles | Omitted | Omitted | Omitted | 870 |
| Front Orientation | -0.01 | 0.06 | 0.82 | 294 |
| Back Orientation | 0.03 | 0.06 | 0.55 | 280 |
| Side Orientation | -0.03 | 0.06 | 0.55 | 253 |

*"Omitted" = reference category for fixed effects variables*
*"n" indicates number of cases in category when category = "1"*

Model Information

| | |
|---|---|
| Model Equation Number | 8 |
| Model Name | Orientation Model |
| Dependent Variable | LN SalePrice96 |
| Number of Cases | 4937 |
| Number of Predictors (k) | 40 |
| F Statistic | 410.0 |
| Adjusted R Squared | 0.77 |

Table A - 12: Full Results for the Overlap Model

| | Coef. | SE | p Value | n |
|---|---|---|---|---|
| Intercept | 7.61 | 0.18 | 0.00 | |
| Nbr LN SalePrice96 hat | 0.29 | 0.02 | 0.00 | 4,937 |
| AgeatSale | -0.006 | 0.0004 | 0.00 | 4,937 |
| AgeatSale Sqrd | 0.00002 | 0.000003 | 0.00 | 4,937 |
| Sqft 1000 | 0.28 | 0.01 | 0.00 | 4,937 |
| Acres | 0.02 | 0.00 | 0.00 | 4,937 |
| Baths | 0.09 | 0.01 | 0.00 | 4,937 |
| ExtWalls Stone | 0.21 | 0.02 | 0.00 | 1,486 |
| CentralAC | 0.09 | 0.01 | 0.00 | 2,575 |
| Fireplace | 0.11 | 0.01 | 0.00 | 1,834 |
| FinBsmt | 0.08 | 0.02 | 0.00 | 673 |
| Cul De Sac | 0.10 | 0.01 | 0.00 | 992 |
| Water Front | 0.34 | 0.04 | 0.00 | 87 |
| Cnd Low | -0.45 | 0.05 | 0.00 | 69 |
| Cnd BAvg | -0.24 | 0.02 | 0.00 | 350 |
| Cnd Avg | Omitted | Omitted | Omitted | 2,727 |
| Cnd AAvg | 0.13 | 0.01 | 0.00 | 1,445 |
| Cnd High | 0.24 | 0.02 | 0.00 | 337 |
| Vista Poor | -0.21 | 0.02 | 0.00 | 310 |
| Vista BAvg | -0.08 | 0.01 | 0.00 | 2,857 |
| Vista Avg | Omitted | Omitted | Omitted | 1,247 |
| Vista AAvg | 0.10 | 0.02 | 0.00 | 448 |
| Vista Prem | 0.13 | 0.04 | 0.00 | 75 |
| WAOR | Omitted | Omitted | Omitted | 519 |
| TXHC | -0.75 | 0.03 | 0.00 | 1,071 |
| OKCC | -0.44 | 0.02 | 0.00 | 476 |
| IABV | -0.24 | 0.02 | 0.00 | 605 |
| ILLC | -0.09 | 0.03 | 0.00 | 213 |
| WIKCDC | -0.14 | 0.02 | 0.00 | 725 |
| PASC | -0.31 | 0.03 | 0.00 | 291 |
| PAWC | -0.07 | 0.03 | 0.00 | 222 |
| NYMCOC | -0.20 | 0.03 | 0.00 | 346 |
| NYMC | -0.15 | 0.02 | 0.00 | 469 |
| No View | Omitted | Omitted | Omitted | 4,207 |
| Minor View | -0.03 | 0.02 | 0.10 | 561 |
| Moderate View | -0.02 | 0.04 | 0.67 | 106 |
| Substantial View | -0.05 | 0.09 | 0.57 | 35 |
| Extreme View | -0.03 | 0.10 | 0.77 | 28 |
| Inside 3000 Feet | -0.05 | 0.06 | 0.41 | 67 |
| Between 3000 Feet and 1 Mile | -0.05 | 0.05 | 0.38 | 58 |
| Between 1 and 3 Miles | 0.00 | 0.02 | 0.82 | 2,019 |
| Between 3 and 5 Miles | 0.02 | 0.01 | 0.22 | 1,923 |
| Outside 5 Miles | Omitted | Omitted | Omitted | 870 |
| View Does Not Overlap Vista | Omitted | Omitted | Omitted | 320 |
| View Barely Overlaps Vista | 0.05 | 0.03 | 0.09 | 150 |
| View Somewhat Overlaps Vista | 0.01 | 0.03 | 0.67 | 132 |
| View Strongly Overlaps Vista | 0.05 | 0.05 | 0.31 | 128 |

*"Omitted" = reference category for fixed effects variables*
*"n" indicates number of cases in category when category = "1"*

## Model Information

| | |
|---|---|
| Model Equation Number | 9 |
| Model Name | Overlap Model |
| Dependent Variable | LN SalePrice96 |
| Number of Cases | 4937 |
| Number of Predictors (k) | 40 |
| F Statistic | 409.7 |
| Adjusted R Squared | 0.77 |

00001164

# Critique of
# *The Impact of Wind Power Projects on Residential Property Values in the United States: A Multi-Site Hedonic Analysis*

Authors: Hoen et al

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February 16, 2010

## Introduction

The issue of wind turbines and their effect upon nearby property values has long been a contentious one, and for good reason. We generally accept the "wisdom of the market", and if wind turbines are as disruptive as opponents claim, surely this would show up in market prices of nearby properties. Opponents, politicians and wind developers can make all sorts of statements about noise, flicker, birds and so on, but talk is cheap. House prices, on the other hand, can be quite dear, and there's no easy or cheap way to hide the effect of wind turbines on house prices if in fact there is an effect. Plus house prices can serve as a single and quantitative proxy for all the effects that wind turbines may have on the neighbors.

Given the long history of the real estate industry figuring out house prices (commonly called "comps") you'd think this issue would be easily settled. Unfortunately, it is possible to arrange the data in these studies to suit the sponsor – as Mark Twain famously observed, "figures don't lie, but liars figure". But couldn't one just take the prices of houses sold "in the area" before and after a project went in? But how big should "the area" be? And if there's only a small number of sales – these are, after all, generally remote areas – what conclusions can you draw?

For the wind industry and its allies in government and academic circles, persuasive studies showing no effect would go a long way to quiet the protests of the neighbors and make wind projects easier, quicker and cheaper to install. Almost needless to say, they have been working on such studies for a number of years. A major one was the REPP study (aka Sterzinger et al), and which is available at http://amherstislandwindinfo.com/reppreport.pdf. It was not persuasive (except among wind proponents), having used a large and undefined area in which most homes were so far from the project that any effect would be minimal. In fact Hoen was one of the REPP study's most severe critics. But the REPP study did reveal the underlying argument the wind industry could use to try to convince the willing and the gullible. They justified the large study area by asserting the main problem with turbines was *how they looked.* So if you could just see them (and you can see them for miles) they ought to affect the prices and since there was no measureable effect on prices there must be no problems whatever with the turbines. Nice logic, if you can convince someone to accept it, and many politicians and reporters have done so.

This theme of the people objecting to wind projects mainly because of how they look is mentioned prominently in wind industry literature as the main reason people object to them. Never mind the noise, flicker, sleep problems and so on that are much more important for the actual close-in neighbors. The only place where serious visual objections are raised is where the scenery has a special value, like shorelines. Unfortunately, no property value study has ever been done specifically on projects in high-scenic-value locations. There's just not enough data yet – for example in this study only 117 properties, or 2%, had "premium vistas".

Regardless of what the wind industry asserts, the serious concerns for property values come from people who think they might be able to *hear* or *feel* the turbines enough so they cannot escape the noise and vibration even when they are just trying to enjoy their property, and especially when they are trying to go to sleep. For a home affected by this sort of problem the reduction in value might be very large indeed, certainly into double digits and in the worst cases approaching 100%. This is what home owners really fear.

To simplify it, there are three main ways to analyze house prices, in decreasing accuracy.

> First, you could study houses within audible distance (i.e. one mile) that sold (or perhaps independently appraised) fairly recently before the project was known about and then sold after the project went in. As long as the sales are "arms-length" and the proper adjustments made for area house price trends, this is the best indication of property value changes.
>
> Second, you could study just the house prices within audible distance of a turbine and compare them with similar houses (aka "comps") further away, like 10 miles. This technique is commonly used in the Real Estate industry to estimate property values.
>
> Third, you could use regression analysis. You start by taking all the sales within a certain distance of a wind project (5 miles is typical) and assign a series of descriptors to each house within that group – things like size of the house, number of bathrooms, distance from the wind project and so on. You then look for correlations between the different descriptors and the price, trying to assign the contribution of each. With enough computer processing you can assign the effect of each of these on the final price.

The Hoen study, published in December 2009, is the latest effort to analyze this issue and uses the third and weakest of these techniques, regression analysis. I go into more details later, of course, but in summary he found no "statistically significant" effect of turbines on house prices. Unfortunately this study has a number of significant, and in my opinion fatal problems. If you get to the bottom I've included some critiques from others that come to the same conclusions, certainly more authoritatively than I.

## The Author

The primary author of the study was Ben Hoen, and his career warrants a brief but skippable section. This is not Mr. Hoen's first study in property values around wind projects. In 2006 he completed a master's thesis that looked at the impact of the Fenner, NY wind turbines on surrounding property values. His thesis can be found at: http://amherstislandwindinfo.com/hoen-fenner-2006.pdf. A condensed version, along with a critique, is at: http://www.windaction.org/documents/3236 . That study concentrated on the relation of the visual aspects of the turbines with house prices and found no evidence of any connection. However, a close reading of that study reveals some problems. First is the acceptance of the "how they look" theme put out by the wind industry lobbyists. Second is the small number of sales inside of one mile – out of 280 sales, only about 8 were inside of that distance (the closest was 0.75 miles), and the average distance was 3.5 miles. There's a picture of the data points at http://amherstislandwindinfo.com/hoen-fenner-map.jpg. Third, while he didn't find any statistically significant evidence of an effect (and with such a small sample of the important sales, how could he?) within Fenner Township, he did find that the Township as a whole had lost some 8% of its house values relative to neighboring townships. He went into overtime to explain away this elephant in the room. I doubt he was very convincing to any disinterested party, but certainly he established whose interests he wanted to serve early on.

From windaction.org,

> "Within months of obtaining his masters, Hoen and Wiser teamed up, and since June 2007 Hoen has been broadcasting the results of this latest study even though no data or information on the study was available for others to read and challenge. In the two years leading up to the December 2 [2009, this study] release, Hoen distributed his findings to largely friendly crowds and those more interested in the outcome of his study than the legitimacy of his methodology."

It seems at least unprofessional to discuss your findings in front of those with a financial stake in the outcome before publishing the findings, but it is consistent with his own personal business plan he previously revealed at Fenner. The slides from an early presentation can be found at: http://amherstislandwindinfo.com/hoen-presentation.pdf.

## Overview of the Study

This study was funded by the U.S. DOE under a government contract at the Berkeley National Laboratory. Berkeley is a leading world center of scientific achievement, and gets its money from the Department of Energy. It would be sensible to keep in mind that the Department of Energy has a wind program that "is working to improve wind technology and increase the use of wind energy in the U.S." The study is 164 pages long and can be found at http://amherstislandwindinfo.com/hoen-property-values.pdf, with the body of the report consisting of 75 fairly densely-written pages. Upon a casual reading the study is quite impressive, full of charts and formulae, and Hoen seems to be careful in his analysis. The devil's in the details.

This study uses the third technique I listed from above - regression analysis. While it is principally concerned with Scenic and Area "stigmas" it does include a "Nuisance" stigma which hopefully promises to answer the issue of the effects on the property values of those neighbors within a mile of the projects, and who have the most to lose. I don't much value the Scenic and Area metrics as explained above, so my comments will concentrate on the Nuisance metrics.

Before I go into my comments I ought to provide some background on what is meant by the "Multi-Site Hedonic Analysis". Initially I thought the "Hedonic" had to do with some special techniques being used, but later found out that hedonic is merely an offshoot from the word "hedonism" and simply refers to analyzing intangibles – like scenic values or wind turbine nuisance. The techniques used are "simply" standard regression analyses as would be performed in any number of other fields of study.

So, what is regression analysis? From Wikipedia:

> "In statistics, regression analysis includes any techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables."

In this case the one or more independent variables are things like square footage, number of bathrooms and distance from a wind turbine, while the dependent variable is the sales price of the house.

The general process is to decide which physical areas you want to study and the questions you want to answer. Hoen ended up choosing 10 areas as shown in Figure 1 on Abode's page 30, his page 12. You then gather all the relevant information about the properties and he provides a good summary of how he did this in section 3. Once you've obtained the data – and you always end up obtaining more than you actually use – you start running the analyses, looking to show statistically that there is a relationship between, for example, distance and price. Note that statistical practitioners do not pose their quest as trying to show there is *not* a relationship between i.e. distance and price. You may recall the *null hypothesis* from your student days, where "no relationship" is the starting assumption.

One potential problem might have occurred to the alert (still awake?) reader is that house prices vary a great deal depending on a large number of often times intangible factors. This type of analysis takes a snapshot of all the sales in the study area, regardless of how big or little, nice or nasty, good shape or not. How likely is it we can accurately ferret out the factor (i.e. distance from a turbine) we are interested in? The solution is to have a large number of data points. In Hoen's case, he had 7,459 sales, making this the largest and presumably most accurate analysis to date.

Hoen worked with about 15 major independent variables, some of which were continuously variable (like square footage) while others were sorted into categories. Using these 15 independent variables in varying combinations, he then created 10 different reports that studied different relationships between them and the dependent variable – the house selling price. The reports are listed in table ES-1, Adobe's page 12 and the study's page xi. Given my interest in close-in neighbors, I will focus my comments on these most relevant 4 out of the 10 reports: Base, All Sales, Temporal, and Repeat Sales. His overall conclusions are in table ES-2, immediately following ES-1, and generally he is not able to find any statistically significant (at the 90% level) relationship between the distance from or view of the wind turbines.

## Discussion

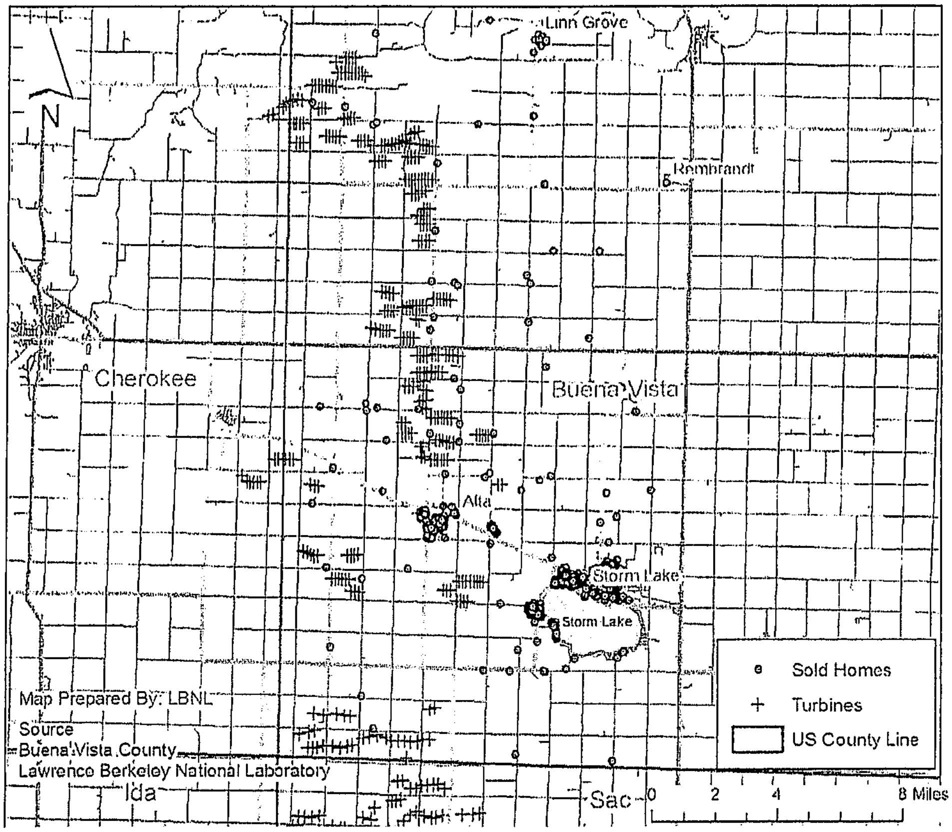
As mentioned earlier, my interest is in the close-in neighbors who can hear the turbines, labeled the "Nuisance Stigma". Fortunately, Hoen has this summary of these properties, from Abobe page 17, his page xv:

> "Taken together, these models present a consistent set of results: homes in this sample that are within a mile of the nearest wind facility, where various nuisance effects have been posited, have not been broadly and measurably affected by the presence of those wind facilities. These results imply that Nuisance Stigma effects are either not present in this sample, or are too small and/or infrequent to be statistically distinguished."

Note carefully the last sentence. He has two potential explanations for this observed lack of effect. The first one, the effects are in reality not present, is what the wind industry dwells upon, and what Mr. Hoen himself mentions most prominently. But the second explanation, too small and/or infrequent to be called statistically significant, is equally possible. Of the 7,459 sales only 80 were within 3000 feet and another 65 inside one mile, for a total of 145, or 2%. Their prices did go down relative to everything else by varying amounts depending on the study, but that wasn't enough to trigger statistical significance most of the time. However, statistical significance has two basic requirements: that (1) the numbers are different and (2) they don't vary too much among themselves (the standard deviations are relatively small). Hoen won't release his raw data so others can sift through it, but among 140 properties from across the country I'd bet the differences would be very large. As an example, for the 7,459 sales the average price was 102,968 with the standard deviation of 64,293.

To give you a sense of how the properties are spaced relative to a project, here is a picture of the sales in the area with the most post-construction sales within one mile (Buena Vista County, Iowa, with 30 out of 125).

6




This chart is typical of the other 9; if anything, it is less extreme. Note the large number of sales in the towns of Alta and Storm Lake, both of which are pretty far from any turbines. To somehow use all these remote sales to draw conclusions about the relatively few close-in sales strikes me as quite a stretch. The obvious question to ask would be what sort of prices existed before the projects versus the prices after the projects for just the close-in properties, and one study in particular – the Repeat Sales Model – promises to provide that answer. Unfortunately, that model produced conflicting results as discussed below. Just as a snarky aside, there are actually 5 projects in this area; 3 of them were by Enron.

One oddly categorized variable was 5 different distances from a turbine – why wouldn't this be continuous? Hoen goes into overtime providing the reason in footnote 52 on his page 25. I can see his point about "imposing structure" but it does give him an excellent opportunity to game the data.

I don't know if Hoen used the distance categories to game the data or not. Without the raw data it is impossible to tell. But there's other ways to warp the data to get a result you can profit from. Buried in the footnotes on page 14:

> "Finally, it should be noted that the authors are aware of four instances in the study areas when homes were sold to wind developers. In two cases the developer did not resell the home; in the other two, the developer resold the

home at a lower price than which it was purchased. But, because the sales were to a related party, these transactions were not considered "valid' and are therefore not included here. One might, however, reasonably expect that the property values of these homes were impacted by the presence of the wind turbines."

Those 2 resold properties were at the Somerset, PA project – the one you can see from the PA Turnpike. From stopillwind.org:

"...Somerset Wind...bought these properties for fair market value—one in May, 2002 for $101,049, reselling it in August to a lessor who had initially leased land to the wind company for $20,000--20% percent of the previous sale price! In May, 2002, Somerset Wind purchased the other property for $104,447, selling it in August for $65,000--62 percent of the purchase price!"

I'll concede the sales from the original owner to the developer are invalid. But the following sales are not "to a related party". The developers are presumably rational and would want to sell these 4 properties for as much as they could, and in two cases that may well have been zero. The lower prices could well reflect what the properties are now worth. Given that the close-in property sample is so small, these 4 transactions make quite a difference – by my calculations (using average values), raising the Base model's inside-a-mile decrease in property values from 5.4% to 9.2%. One wonders what the headlines would have said if those values were published. I have little doubt that difference would have been statistically significant. Hoen avoided the problem by simply discarding this inconvenient data.

Earlier I promised to discuss the 4 models that seemed to be the most germane for my close-in worries. Here they are, but Hoen has managed to eviscerate the models enough that no honest result is apparent.

**Base** (Section 4, his page 23)

This model is the centerpiece of the study, even getting its own section. It just considers the sales of properties after construction of the project begins. Hoen justifies this because of his emphasis on the visual aspects of wind turbines - after all you can't measure them until the project is built. However, it also allows Hoen to avoid discussing the large price drop experienced by the close-in properties that occurs before the project in even constructed. Even then, he found that close-in properties decrease an average of 5.4%. As mentioned above, this is not statistically significant, perhaps because the sample is small and the variability is great.

Hoen comments,

> "That notwithstanding, the -5% coefficients for homes that sold within one mile of the nearest wind turbine require further scrutiny. Even though the differences are not found to be statistically significant, they might point to effects that exist but are too small for the model to deem statistically significant due to the relatively small number of homes in the sample within 1 mile of the nearest turbine. Alternatively, these homes may simply have been devalued even before the wind facility was erected, and that devaluation may have carried over into the post construction period (the period investigated by the Base Model)."

How does Hoen explain this away? By referring us to the All Sales model, discussed below.

**All Sales** (Section 5.3, his page 37)

While the Base model uses just properties that have sold after construction has started, the All Sales model includes all the sales both before and after the announcement and construction. Because the prices of the close-in properties declined even before the project was announced, the 5% decrease noted by the Base model now becomes larger, averaging 7%. This decrease becomes big enough to now be statistically significant. How does Hoen explain this away? By referring us to the Temporal Aspects model, discussed below.

**Temporal Aspects** (section 5.4, page 42)

This model focused on the price changes over different periods both before and after the construction of a project. My interest, as always, is in the properties within one mile. As for other sections, the number of sales that are useful for my purposes is quite small, a total of 225 over the entire roughly 10-year period. How he got to 225 escapes me as I can identify only the previously-mentioned 145 properties within 1 mile, and this is too large a delta to be a rounding error. He divided the 225 sales into 6 periods and compared their prices with an average. The earlier periods show quite large drops that are statistically significant. But as the project is built and put into operation the drops lesson, never going away completely, but becoming insignificant. This allows Hoen to put "no" in the Nuisance Stigma column for Temporal Aspects in table ES-2. The most interesting result to me is that even 2 years before the formal announcement of a project the prices within a mile decrease by 13%.

**Repeat Sales Model** (Section 6, his page 55)

This study took matched pairs of sales when there was one sale before announcement of a project and another sale after construction of the project. As such it does not use regression analysis. Unfortunately, the sample I'm interested in, sales within one mile of the project, is quite small, a total of 14 properties. Curiously, it showed that these houses increased their value by 3% per year over the average. This is encouraging, but the sample size is small and there are other inconsistencies in the results in this section, so I'm not sure what to make of the results. Nor is Hoen:

> "These results are counterintuitive and are likely driven by the small number of sales pairs that are located within one mile of the wind turbines and experience a dramatic view of those turbines."

Maybe the solution to this odd result is contained in the Temporal Aspects Study. From that study, it seems that prices of houses within one mile drop a great deal beginning before the project is even announced, and then recover somewhat as time goes on. The repeat sales pairs could be reflecting this recovery from a depressed beginning.

## Other Critiques

I've bored you enough. I've even bored me enough. Here are some critiques from others, all of whom have more insight into real estate and statistics than I.

One of the reviewers was Lisa Linowes of the Industrial Wind Action Group – better known as windaction.org. She had this to say about her critique:

> "We worked closely with an appraiser experienced in regression analysis and hedonics in developing our comments. Given the flaws in Hoen's approach, we are confident that a qualified appraiser with experience in regression techniques and the problems of hedonic analysis will effectively counter Hoen's conclusion. You may be interested to know that neither Hoen or the others who were part of his research team have any experience in real estate appraisals or the correct application of regression techniques for determining house value."

Her critique is posted on their web site at http://www.windaction.org/documents/24178 and a backup copy is at http://amherstislandwindinfo.com/linowes-hoen-critique.pdf.

Albert R. Wilson is another professional real estate appraiser, and while he has (correctly) no opinion on wind turbines and property values, he eviscerates Hoen's techniques at http://www.arwilson.com/pdf/newpdfs/WindFarmsResidentialPropertyValuesandRubberRulers.pdf also saved at http://amherstislandwindinfo.com/wilson-hoen-critique.pdf.

For a shorter version and some additional commentary, visit windaction.org http://www.windaction.org/releases/25672 also saved at http://amherstislandwindinfo.com/iwa-hoen-critique.pdf.

Michael McCann, a professional appraiser in Illinois and the Midwest was another reviewer, and he had two comments. The first one mentioned that this study would likely be used in official government proceedings, and an emphasis on the disclaimer would be a good thing. Link at http://www.windaction.org/?module=uploads&func=download&fileId=1948 with a backup copy at http://amherstislandwindinfo.com/mccann-hoen-review-disclaimer.pdf.

He goes on to write a longer and in many ways a harsher critique than mine, at http://www.windaction.org/?module=uploads&func=download&fileId=1950 with a backup copy at http://amherstislandwindinfo.com/mccann-hoen-review-total.pdf.

The Acoustic Ecology Institute had the same sorts of concerns with the close-in neighbors, and noticed some of the same things I did, per http://aeinews.org/archives/529.

McCann Appraisal, LLC

December 14, 2009

Mr. Ben Hoen
Ernest Orlando Lawrence
Berkeley National Laboratory

Re: The Impact of Wind Power Projects on Residential Property Values in the United States: A Multi-Site Hedonic Analysis

Dear Mr. Hoen:

I have prepared this follow up Certified Review letter after reading your group's published study (Report). Perhaps the LBNL research team will be doing supplemental or ongoing work that will incorporate corrections, additions and shift the focus to reflect proportionate relevance, and these review comments and concerns can be given due consideration.

With all due respect, the final Report falls short of being a truly objective and reliable real estate value study of the issue at hand, in my professional opinion, the reasons for which I will begin to describe in this follow up review.

**Intended Users of Report**

As I predicted in a prior communication with you, your final Report would get a lot of exposure and probably be cited as justification for zoning and land use application approval requests for wind energy projects, on a far reaching scale.

For that reason, an abundance of caution should have been utilized to emphasize any reasonable and logical interpretation of the "nearby property" study data, even when that is contrary to, or significantly differs from, the thrust of the general conclusion that is based on the 5-mile and beyond data.

In this day and age of questionable "science" being applied regarding predictions of global warming, any appearance of omitting relevant data or painting "targets around bullet holes" does little to solve controversies or facilitate sound, well informed planning and decision making. With that preface, my review comments are, as follows:



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**Turbine Height**
First, I direct your attention to Report *Table 2*, which cites study locations and the "hub" height of turbines. This is misleading to a typical reader, as zoning standards usually include the height as fully extended by the turbine blades. The height of the structures does not peak at the "hub" and there is obviously a greater height, often approximately 400 feet and current projects proposed up to 500 feet; by any objective measure more significant than the lower hub height.

**First McCann Review of LBNL Draft report**
The Report omitted the fact that in the written review of the Draft Report, I cited to you in particular as my opinion basis for value impact 40 sales that demonstrate on their face a 25% lower value of homes in close proximity to the Mendota Hills turbines.

The two (2) "sales" you DO attribute to McCann *(Report Table 1, page 9)* as my opinion basis are, in reality, (pre-draft Report) examples I provided of inordinately long and on-going marketing times, at otherwise market-based asking prices.

The deterrent to sale of the homes directly attributable to the wind farm project is well understood by the local Realtor who had the listings and who, at the time of my communication with you, had reported to me the consistent rejection rationale of over 100 otherwise interested would-be buyers and their agents. Interest that evaporated once potential buyers visited the properties and saw the nearby and surrounding turbines.

The Report also misstated an important fact: The two (2) homes never actually sold, although the text of the Report implies it was just a long marketing time BEFORE they sold. (*See Report page 7, 2nd paragraph*) Clearly, this error distorts the market reaction indicated by the actual facts.

Such a stigma deterrent to the sale of homes, while not perhaps statistically significant or measurable via the methodology employed and data utilized in your study, is entirely significant to an owner unable to reasonably convert their home equity to cash. That real-world experience is virtually mute and is mischaracterized in the Report.

As demonstrated by the two (2) homes, if one was unable to sell their home or even elicit an offer at any price, despite reducing the asking price by 10%, 20% or more from the going in basis and/or current market rates, and if the reason for the loss of reasonable liquidity is isolated as a single factor or influence, then that impact is many things, but "insignificant" is not the phrase that comes to mind.

And while marketing experience for the two (2) homes is only *part* of the basis for opinions I have developed thus far, the Report is inaccurate since I disclosed the 40 recorded, closed sale basis to you (*see McCann review letter*) and that is not mentioned in the Report on *Table 1*, where other such outside input is shown.

I suspect I will need to go on the record at some point to clarify that Report mistake, given the opposite direction of the indication of both the Mendota Hills sale and separate unsold listing data to the Report findings.

On balance, I acknowledge that the Report gave some limited comment to the "*possibility*" that some properties "*may*" have had negative effects from proximity to turbines.

However, based on the size of the < 1 mile data sample, I am surprised that the Report does not unequivocally state that nearby properties **"have shown a discernible and measurably lower"** sale price than the base line data located > 5 miles from the projects studied.

While the qualifying words in the Report may have been intended by the authors to reflect the somewhat lower mathematical certainty of drawing the indicated adverse conclusion, vis a vis the much larger database of sales in the 5+ mile distance, the framing of the comments minimizes the real and significant impacts shown in the Report for the nearest properties sold.

In fact, the Report Executive Summary states: "....neither the view of the wind facilities ***nor the distance*** of the home to those facilities is found to have any consistent, measurable, and statistically significant effect on home sales prices". This claim simply does not comport with the data results.

**Report Results – Actual Impact**
Contrary to the study conclusions, the Report charts and data are in fact supportive of a distinctly MEASUREABLE reduction in value, on the order of **5.3% to 5.5%,** for homes up to 1 mile away from the nearest turbine(s) (*Report Figure ES-1)*.

The data within the 1 mile distance included 125 sales, compared to 870 baseline sales that were greater than 5 miles in distance. As I understand basic statistical analysis, data in excess of 50 measuring points is generally accepted and deemed statistically "significant".

In the Report, however, this difference is dismissed as "statistically insignificant". The minimization and dismissal of these facts leads the reader to the incorrect belief that wind farms do not reduce nearby property values. Further, the Report Executive Summary (*page ix*) emphasizes the word "<u>possible</u>", rather than draw attention to the factual basis of actual negative impact measured at the nearest properties.

Similarly, your report *(Figure ES-2)* reveals that 310 sales with a vista rated as poor compared to 2,857 sales with an average vista, sold for 21% lower than the average view properties.

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The poor vista measurement in the Report, however, is perfectly consistent with the Mendota Hills data I cited to you and the 25% value loss indicated. It follows then, under circumstance whereby the property in question possesses an above average vista and attendant higher than average value *(>10%, per Report)*, and will end up with a below average or poor vista post-turbine development, a value loss of 25% may very well understate the damages in those instances.

While the rating of any vista has some subjective elements to it, it is well established that the subjective rating of turbine views is disproportionately negative by residents of immediate project areas who have no turbine lease agreement or financial interest in the project(s). Again, the Report conclusions are contrary to data contained within.

While the vista or view from a given property is a well recognized value influencing factor, the Report conclusions fail to proportionately reflect the findings contained in Figures ES-1 and ES-2.

**Literature Review – Hedonic Analysis**

A true peer reviewed article (*supporting data available for peer review*) written by Dr. Sandy Bond, (*acknowledged in the Report*), found an even lower impact on residential property value from cell towers in Florida than the 5% indicated in the Report, and the Appraisal Journal indeed published those findings as being statistically significant. A different determinant standard of significance must be the explanation for these contrary conclusions.

I would also suggest that a single cell tower with a height of 80 to150 feet is far less likely to impact neighboring property use, enjoyment and value than dozens of 400 foot tall turbines with spinning blades, noise, flicker effect, etc.

Thus, the Report conclusions are completely inconsistent with an existing published study, and which was peer reviewed by the leading real estate valuation journal. At a minimum, this important conclusion difference establishes that there was some subjective determination as to what constitutes statistical significance.

Again, with all due respect, the leading real estate valuation journal must be considered as more reliable regarding property value issues than an academic study conducted by researchers untrained in professional real estate evaluation issues. At any level, an appraisal must accurately reflect the market, and any opinion related to value constitutes an appraisal opinion.

**Report Findings – Applied**

In this review, I have applied the measured proximate Report study area loss of *(rounded)* 5% into a generic (Illinois) project area, encompassing thousands of acres of land. Using simple projections, Report conclusions may not stand a reasonable test of what is or isn't significant, in the context of a zoning standard being met or failing to satisfy the legal requirement of *no substantial impact on "neighboring" property value.*

Please note that neighboring values are the relevant baseline in all zoning standards addressing this issue....not the value of homes 5 or 10 miles distant from a proposed project. Simply put, the homes located in the footprints of these projects are the real "ground zero" on this issue, and what is mathematically measured at distances beyond 1 mile, etc, is inapplicable as a basis for determining ground zero impacts.

Applying a (rounded) 5% reduction of value to a "typical" residential market value of $175,000 to homes within one (1) mile of a project footprint, and 25% impact within the project footprint, and projecting the rural housing density on the basis of 1 house per 40 acres and a 6,000 acre footprint, (10,240 acres within 1 mile) **value loss of $8.8 million** is indicated for a typical Illinois project. (*See attached McCann illustration; PROJECTED TYPICAL IMPACT)*

The actual Report measured loss of 5% includes data up to 1 mile distant but appears to be silent as far as measured value loss for the typical ground zero (footprint) residence. The direction of impact must be logically concluded as greater than 5% in the footprint.

Thus, if the Mendota data indication of 25% value loss is applied to the preceding example *(as also supported by poor vista lower values in Report Figure ES-2)*, the impact is **$8.8 million** of diminished home equity. If this is repeated for 10 new projects in rural residential areas, $88 million in losses can be reasonably forecast.

I suggest that no one could reasonably conclude the collapse of an $88 million office tower or shopping mall and complete destruction of its value would be "insignificant", even with no loss of life. I also suggest that rural residential property is no less deserving of a fair characterization of actual value loss.

As a professional appraiser, it boggles the mind to consider the total property value losses that will result if the renewable energy policy goals are completed via development of utility scale wind energy projects, in rural residential areas.

This magnitude of loss is significant on so many levels that the term "statistically insignificant" is misleading because it ignores the harsh, localized reality, when the projects are developed surrounding and interspersed with homes in rural residential areas.

In these "overlaid" locations, turbine views are not just on the distant horizon, as with the greatest majority of Report data locations and distant proximity to turbines upon which the Report conclusions focus.

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**Hole in the Doughnut**

The most impacted properties are simply not proportionately reflected in the Report, the importance of which is contrary to the Report claim that the number is again, "statistically insignificant". The "hole in the doughnut"(1) of the Report database and stated conclusions is, in my opinion, the most important indication, and it is disproportionately minimized or even misleading via the terminology used.

Any reduction of equity (value) beyond normal negotiation of price and sale commissions must be considered significant, from a land use and zoning standard perspective. Further, since the Report will be utilized for ***exactly that purpose*** rather than as an academic exercise in statistical analysis techniques, I do firmly believe more care should have been given to understanding the members of the public that the Report would be advising, influencing and affecting.

**Property Value Guarantee (PVG)**

Given the actual value loss to nearby properties shown in the Report, I must question why the Report did not even mention the prudence of Property Value Guarantees.

Such guarantees are used sometimes in high profile and controversial zoning matters such as landfills, quarries and indeed, other wind farms *(See DeKalb, Illinois record, et al)* and are certainly appropriate when value impacts are measurable and predictable with a high degree of certainty, as shown in the Report.

The Report modestly mentions homes bought out by wind farm owners/developers. And while this may be driven by health impact liability reasons, health issues are beyond the scope of the Report, this review and the reviewer's expertise. This area of neighboring owners reported experience, concern and the publicized controversy, however, has a stigma effect that is an appropriate property value issue to be considered even if the stigma effect is not measurably isolated between view and health concerns, or other nuisance-type issues.

With all the other policy and non-mathematical commentary and background cited in the Report, the "statistically insignificant" cost of implementing a property value guarantee, as measured against the huge cost of these projects, would have been a balanced and objective recommendation.

Industry may not embrace that idea nor the funding sponsor of the Report. However, there is no down-side to either of them if the *"no measurable impact on value"* Report conclusion proves out to be applicable at ground zero properties.

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(1) *A graphic depiction of this type of data "doughnut hole" is contained in the 2006 Impacts of Windmill Visibility on Property Values in Madison County, New York and attached to this review. The Lee County, Illinois study Area Map contained in the Report (Figure A-6) is another such example.*

**PVG Costs are Insignificant**
In the generic Illinois project example, value loss of homes located in the project footprint and within one (1) mile equates to $8.8 million in property value loss compensation, via a legitimate PVG. In proportion to a cost for a 100 turbine development at $3 million per turbine, a cost of 2.9% could easily be absorbed as a cost of doing business, or a simple contingency line item on the development financial pro-forma.

If 5% value loss experienced by nearby homes can be concluded in the Report as "statistically insignificant", then certainly 2.3% additional project costs is far from onerous as to the financial feasibility of wind farm development.

From a policy and planning perspective, which is apparently the intended advisory purpose of the Report, an insignificant PVG cost of that magnitude to protect property values should not have been ignored, since residential values are the fundamental issue and question at hand. The report conclusions within 1 mile and the "doughnut hole" lack of data fully warrant such a recommendation.

**Marketing Time**
Finally, and with some limited acknowledgement by Report authors of further study being needed, the Report is completely irrelevant to the issue of marketing times. This "variable" is well understood in all real estate professions as a value-related and value-influencing issue, and the opportunity to collect such data was apparently missed during the multi-year research period while LBNL was conducting the study.

The Report also does not state data I provided regarding 800+ day marketing time of a ground zero home, which commenced in the most dynamic residential market of the modern era. Other examples of ongoing marketing times beyond 2 years were omitted as well.

Beyond a property getting "stale" on the market thereby motivating inordinate price reductions, the time-value of money is easily understood, i.e., one dollar ($1) to be received in 3 months has a higher present worth (value) than $1 to be received in 3 years.

The adverse impact on marketability is only mentioned in passing in the Report as a "possibility" rather than a historic fact or trend, notwithstanding that such experience is clear and documented. Future potential research of this issue is suggested as an apparent afterthought.

The report data is not accepted under objective appraisal review as being "rich", since it is incomplete on such an important point.

00001181

**Focus of Report**
In closing, and if you will forgive my analogy, if one wishes to learn the "price of tea in China", then that is where one must look. To apply the analogy, it follows that one is not likely to find the true answer to the question of ground zero impacts if focusing on greater distances.

I suggest that the Report reflects exactly that imbalanced focus, yet leads the reader to apply the findings pretty generically to all properties, whether or not located at "ground zero".

As a statistical analyst and researcher, I hope you find the focused real estate review useful to any updated Report you may ultimately prepare, and which I believe is still warranted.

I trust that you will take my review comments in the intended spirit; that of seeking the truth for this important issue, regardless of the position or agenda of concerned parties on either side of this issue.

Respectfully submitted,

McCANN APPRAISAL, LLC

Michael S. McCann

| |
|---|
| Michael S. McCann, CRA |
| *State Certified General Real Estate Appraiser* |
| *License No. 553.001252 (Expires 9/30/2011)* |

00001182

McCann Appraisal, LLC

## PROJECTED TYPICAL IMPACT

**Combined Nearby Impact Zone**

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 16 | 1 | 2 | 3 | 6 |
| 15 | 4 | 5 | 6 | 7 |
| 14 | 7 | 8 | 9 | 8 |
| 13 | 12 | 11 | 10 | 9 |

9 = square miles in 6000 acre footprint
16 = square miles or 10,240 acres within 1 mile of footprint

Generic Wind Farm Land Area Impacted
Footprint: 6,000-acres / 640 acres per square mile = 9.375 square miles
(***Rounded to 9 square miles***)

Within 1 Mile: 16 square miles X 640 acres per square mile = 10,240 acres

Wind Farm Neighboring Homes
Footprint = 150 homes at 40 acres per home rural density (6,000 / 40 = 150)
Within 1 Mile = 256 homes at 40 acres per home rural density (10,240 / 40 = 256)

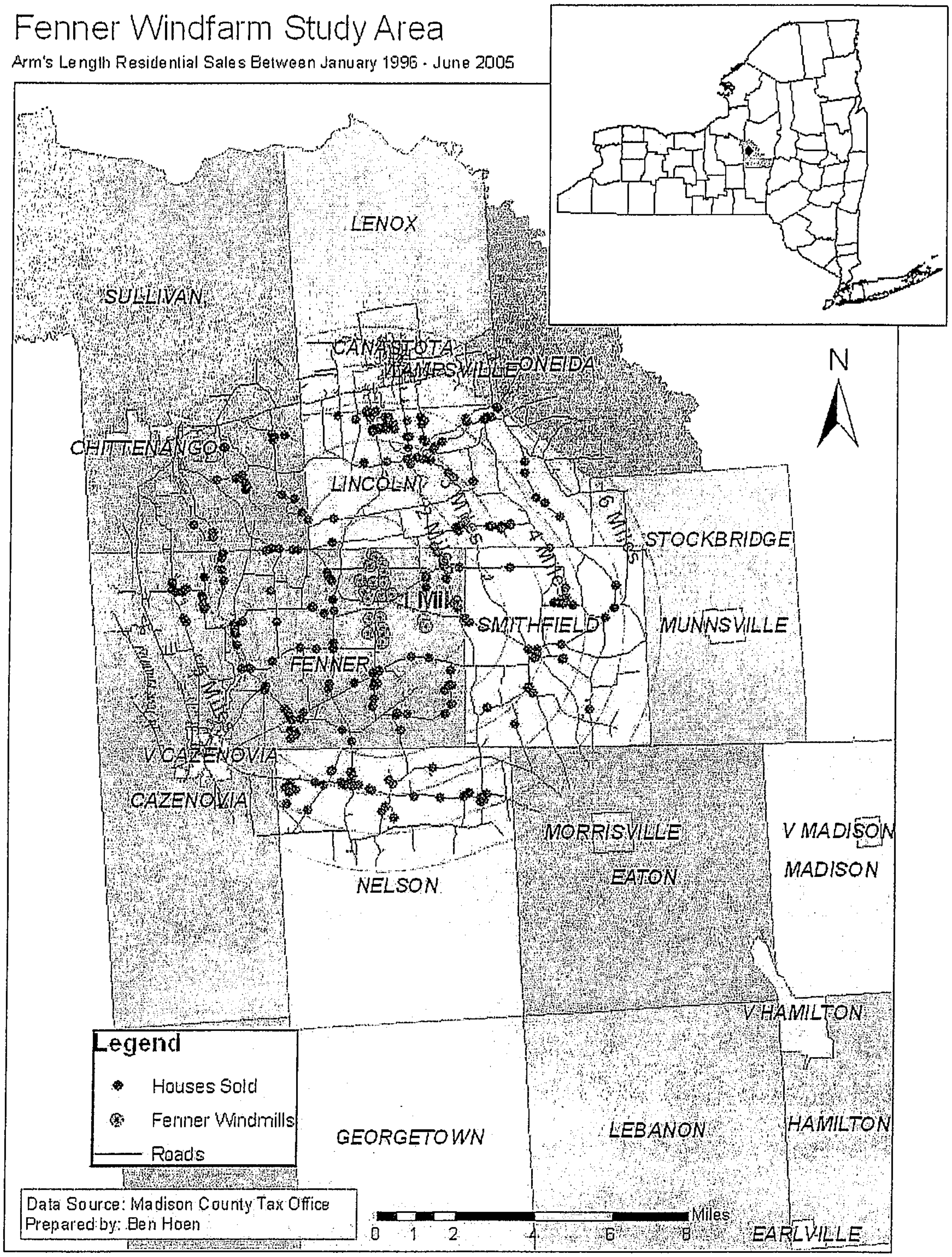
Value Baseline
Footprint = 150 homes X average value of $175,000 = $26,250,000
Within 1 Mile = 256 homes X average value of $175,000 = $44,800,000

Projected Value Impact

| | |
|---|---|
| Footprint: $26,250,000 X (1) 25% value loss = | $6,562,500 |
| Within 1 Mile: $44,800,000 X (2) 5% value loss = | $2,240,000 |
| Neighboring Properties; Total Impact = | **$8,802,500** |

(1) Per Mendota Hills data & as supported by Poor View Vista, Report figure ES-2
(2) Per Report Figure ES-1

Property Value Guarantee - Significance to Wind Farm Project Costs
Thus, if a typical 6,000 acre wind farm project with 100 turbines at cost of $3 million each, and has total project cost of $300 million, the collateral damage impact to property values of $8.8 million is equal to 2.9% of total project costs.


Fenner Windfarm Study Area
Arm's Length Residential Sales Between January 1996 - June 2005
LENOX
SULLIVAN
CANASTOTA
WAMPSVILLE
ONEIDA
CHITTENANGO
LINCOLN
STOCKBRIDGE
SMITHFIELD
MUNNSVILLE
FENNER
V CAZENOVIA
CAZENOVIA
MORRISVILLE
V MADISON
MADISON
EATON
NELSON
V HAMILTON
GEORGETOWN
LEBANON
HAMILTON
EARLVILLE
1 Mile
2 Miles
3 Miles
4 Miles
6 Miles
N
Legend
Houses Sold
Fenner Windmills
Roads
Data Source: Madison County Tax Office
Prepared by: Ben Hoen
0 1 2 4 6 8
Miles

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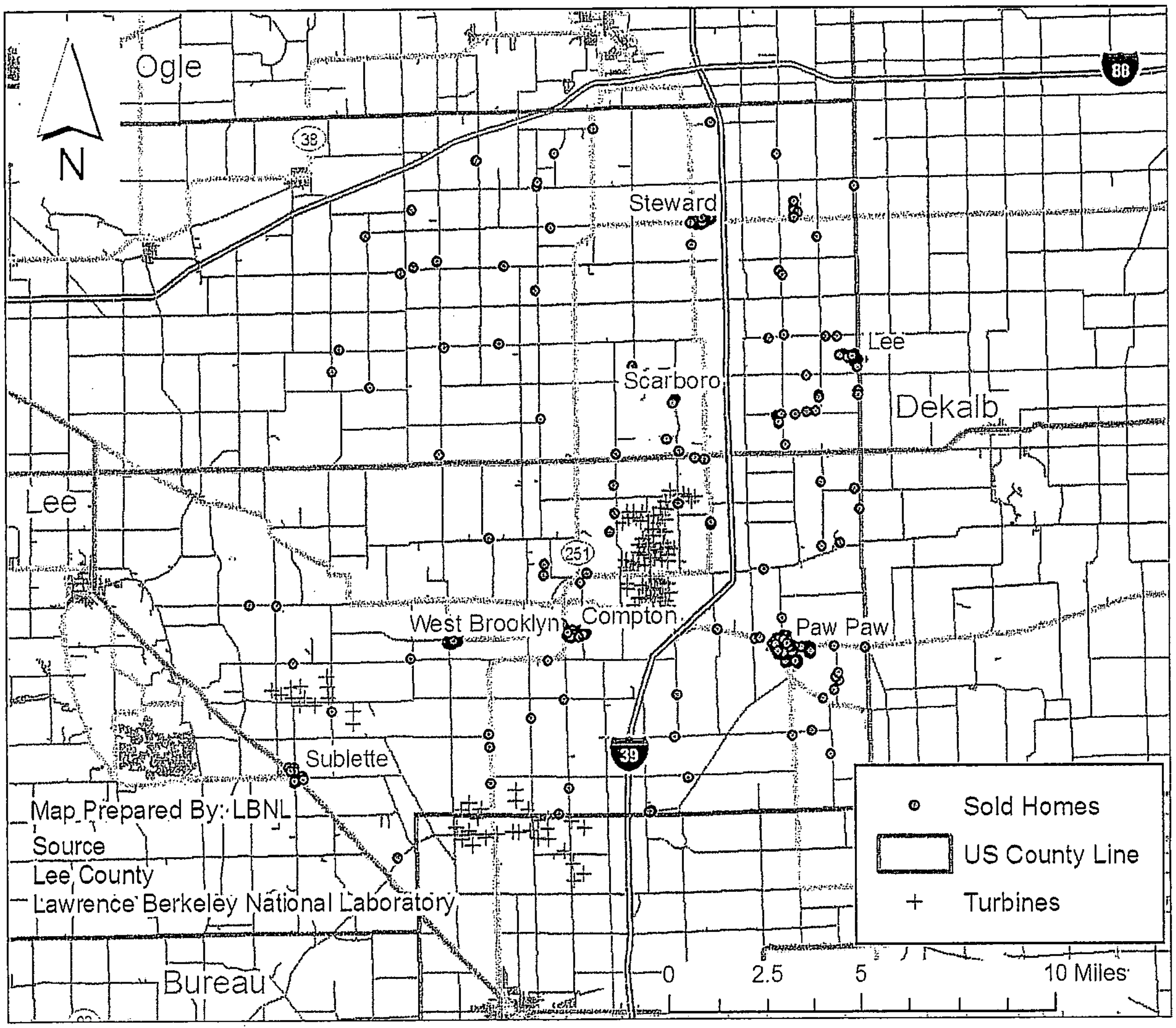
## A.5 ILLC Study Area: Lee County (Illinois)

**Figure A - 6: Map of ILLC Study Area**




00001165

McCann Appraisal, LLC

## REVIEW CERTIFICATION

**PROJECT DESCRIPTION:** Wind Farm Developments in general

**EFFECTIVE DATE OF REVIEW:** December 14, 2009

The undersigned, representing McCANN APPRAISAL, LLC, do hereby certify to the best of my knowledge and belief that:

FIRST: The statements of fact contained in this review report are true and correct.

SECOND: The reported analyses, opinions and conclusions are limited only by the reported assumptions and limiting conditions and represents the personal, impartial and unbiased professional analyses, opinions, and conclusions of the undersigned.

THIRD: I have no present or prospective interest in the property that is the subject of this report and no personal interest with respect to any of the parties involved.

FOURTH: I have no bias with respect to the property that is the subject of this report or to the parties involved with this assignment.

FIFTH: My engagement in this assignment was not contingent upon developing or reporting predetermined results.

SIXTH: My compensation for completing this assignment is not contingent upon the development or reporting of a predetermined value or direction in value that favors the cause of the client, the amount of the value opinion, the attainment of a stipulated result, or the occurrence of a subsequent event directly related to the intended use of this review report.

SEVENTH: My analysis, opinions, and conclusions were developed, and this report has been prepared in conformity with the Uniform Standards of Professional Appraisal Practice.

EIGHTH: The following person has made an exterior inspection of the public areas of the Mendota Hills project that is part of the basis for the opinions expressed in this report:

**Michael S. McCann has inspected the Mendota Hills wind farm,**
**Twin Groves, and other wind farm projects**
**on various dates beginning in 2005**

NINTH: No one other than the undersigned provided significant real property appraisal review assistance to the persons signing this certification.

IN WITNESS WHEREOF, THE UNDERSIGNED has caused these statements to be signed and attested to.

Michael S. McCann

Michael S. McCann, CRA
*State Certified General Real Estate Appraiser*
*License No.553.001252 (Expires 9/30/2011)*

00001186

The following disclaimer was copied from the LBNL Report, and is considered to be relevant to the author's ratification of the data, methodology and opinions expressed in the Report.

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## Disclaimer

/

# Critique of
## *Wind Energy Study – Effect on Real Estate Values in the Municipality of Chatham-Kent, Ontario*
Authors: Canning et al

By Wayne Gulden
wayne@amherstislandwindinfo.com
February 23, 2010

## Introduction

This introduction is very similar to what I wrote in my critique of the Hoen study, available at http://amherstislandwindinfo.com/hoen-critique.pdf, so feel free to skip this one if you've read the other.

The issue of wind turbines and their effect upon nearby property values has long been a contentious one, and for good reason. We generally accept the "wisdom of the market", and if wind turbines are as disruptive as opponents claim, surely this would show up in market prices of nearby properties. Opponents, politicians and wind developers can make all sorts of statements about noise, flicker, birds and so on, but talk is cheap. House prices, on the other hand, can be quite dear, and there's no easy or cheap way to hide the effect of wind turbines on house prices if in fact there is an effect. Plus house prices can serve as a single and quantitative proxy for all the effects that wind turbines may have on the neighbors.

Given the long history of the real estate industry figuring out house prices (commonly called "comps") you'd think this issue would be easily settled. Unfortunately, it is possible to arrange the data in these studies to suit the sponsor – as Mark Twain famously observed, "figures don't lie, but liars figure". But couldn't one just take the prices of houses sold "in the area" before and after a project went in? But how big should "the area" be? And if there's only a small number of sales – these are, after all, generally remote areas – what conclusions can you draw?

For the wind industry and its allies in government and academic circles, persuasive studies showing no effect would go a long way to quiet the protests of the neighbors and make wind projects easier, quicker and cheaper to install. Almost needless to say, they have been working on such studies for a number of years. A major one was the REPP study (aka Sterzinger et al), and which is available at http://amherstislandwindinfo.com/reppreport.pdf. It was not persuasive (except among wind proponents), having used a large and undefined area in which most homes were so far from the project that any effect would be minimal. But the REPP study did reveal the underlying argument the wind industry could use to try to convince the willing and the gullible. They justified the large study area by asserting the main problem with turbines was *how they looked.* So if you could just see them (and you can see them for miles) they ought to affect the prices and since there was no measureable effect on prices there must be no problems whatever with the turbines. Nice logic, if you can convince someone to accept it, and many politicians and reporters have done so.

This theme of the people objecting to wind projects mainly because of how they look is mentioned prominently in wind industry literature as the main reason people object to them. Never mind the noise, flicker, sleep problems and so on that are much more important for the actual close-in neighbors. The only place where serious visual objections are raised is where the scenery has a special value, like shorelines. Unfortunately, no property value study has ever been done specifically on projects in high-scenic-value locations. There's just not enough data.

Regardless of what the wind industry asserts, the serious concerns for property values come from people who think they might be able to *hear* or *feel* the turbines enough so they cannot escape the noise and vibration even when they are just trying to enjoy their property, and especially when they are trying to go to sleep. For a home affected by this sort of problem the reduction in value might be very large indeed, certainly into double digits and in the worst cases approaching 100%. This is what home owners really fear.

To simplify it, there are three main ways to analyze house prices, in decreasing accuracy.

> First, you could study houses within audible distance (i.e. one mile) that sold (or perhaps independently appraised) fairly recently before the project was known about and then sold after the project went in. As long as the sales are "arms-length" and the proper adjustments made for area house price trends, this is the best indication of property value changes.
>
> Second, you could study just the house prices within audible distance of a turbine and compare them with similar houses (aka "comps") further away, like 10 miles. This technique is commonly used in the Real Estate industry to estimate property values.
>
> Third, you could use regression analysis. You start by taking all the sales within a certain distance of a wind project (5 miles is typical) and assign a series of descriptors to each house within that group – things like size of the house, number of bathrooms, distance from the wind project and so on. You then look for correlations between the different descriptors and the price, trying to assign the contribution of each. With enough computer processing you can assign the effect of each of these on the final price.

The Canning study, published in February 2010, is the latest effort to analyze this issue and uses the third and weakest of these techniques, regression analysis. I go into more details later, of course, but in summary he found no "statistically significant" effect of turbines on house prices. Unfortunately this study has a number of significant, and in my opinion fatal problems. The complete study is available at: http://amherstislandwindinfo.com/canning-prop-values-c-k-2010.pdf.

## Overview of the Study

This study was funded by CanWEA, the Canadian Wind Energy Association. They are a trade group and lobbyist for the wind energy industry. While that in itself does not allow us to automatically discard their findings, it would be prudent to keep in mind their mission is not the discovery and dissemination of truth; rather, they are a money-making organization that makes its money by advocating for the wind energy industry.

This study uses the third technique I listed from above - regression analysis. While the Hoen Study looked at both visual and noise issues the Canning study just looks at visual aspects of wind turbines, and he provides no indication of how far his sales are from a wind energy project. He doesn't even try to answer the question that most property owners are really asking – which is how much do I lose if I can *hear* the turbines.

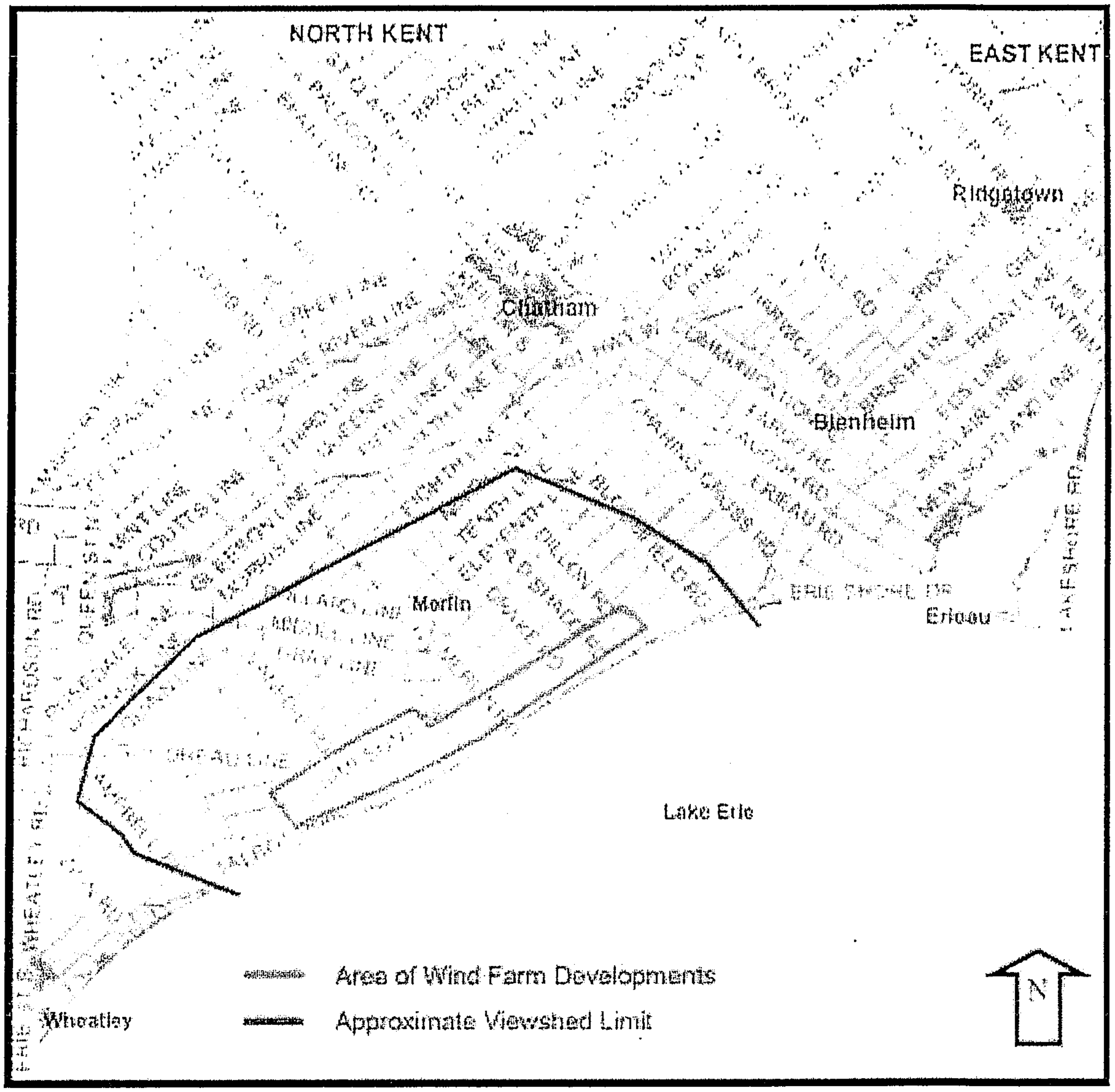
So, what is regression analysis? From Wikipedia:

> "In statistics, regression analysis includes any techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables."

In this case the one or more independent variables are things like square footage, number of bathrooms and distance from a wind turbine, while the dependent variable is the sales price of the house.

The general process is to decide which physical areas you want to study and the questions you want to answer. Canning chose the Chatham area, specifically the area around the Port Alma project. Since he was only interested in visual affects, he drew a line around the Port Alma project and any house inside that line (with some adjustments for local conditions) was in the "viz" group, and if outside was part of the "no viz", which served as a control group.

Note the picture below. To give you a sense of the scale, the "line" roads are about a mile apart, i.e. Merlin is about 5 miles from Lake Erie. Anything inside the red line was probably a "viz", so some (perhaps most, he didn't provide that data) of the "viz" sales could be further than 5 miles from a turbine. As an aside, you can clearly see the turbines from the 401, which is 3-4 miles <u>outside</u> the red line. Canning selected sales that took place within an unspecified 2-year period, coming up with 63 "no viz" sales and just 20 "viz" sales. No information was given if any of the sales involved project participants or not.




He then chose 8 relevant variables, i.e. square footage, lot size, age and so on along with the viz variable and regressed them against the sales prices He went through 4 techniques (having gotten the wrong answer the first 3) as discussed below and then came to the conclusion that viz/no viz had no effect on house prices. Quelle surprise!

One potential problem might have occurred to the alert (still awake?) reader is that house prices vary a great deal depending on a large number of often times intangible factors. This type of analysis takes a snapshot of all the sales in the study area, regardless of how big or little, nice or nasty, good shape or not. How likely is it we can accurately ferret out the factor (i.e. view of a turbine) we are interested in? The solution is to have a large number of data points. In Hoen's case, he had 7,459 sales, and he had problems with large standard deviations. Canning has a total of 83 sales.

Note that statistical practitioners do not pose their quest as trying to show there is *not* a relationship between i.e. view and price. You may recall the *null hypothesis* from your student days, where "no relationship" is the starting assumption and the quest to try to prove the relationship. Of course, when your sponsor doesn't want you to find a relationship human nature makes it more difficult to find one.

## Discussion

The number of problems with this study far exceeds those of the Hoen study. It is scary that "The following consulting report was prepared in accordance with *the Canadian Uniform Standards of Professional Appraisal Practice* for the APPRAISAL INSTITUTE OF CANADA." Even scarier is "The report, if necessary, may also form the basis of testimony at subsequent hearings.". I know that scientific competency and numeracy is dropping in our society, but to think that this report, as problematical as it is, could be used as evidence in a hearing is truly frightening.

The first problem is the reliance on the visual aspects only. This same technique has been used in all industry-sponsored property value studies to make the study size as large as possible so it would include properties that have only minor effects from the project. As mentioned in my Introduction, the big problem is the effect on houses that can hear the turbines, nominally within a mile of a turbine. With this study, the industry shows yet again they have no interest in having an honest discussion about what happens to those near-in properties.

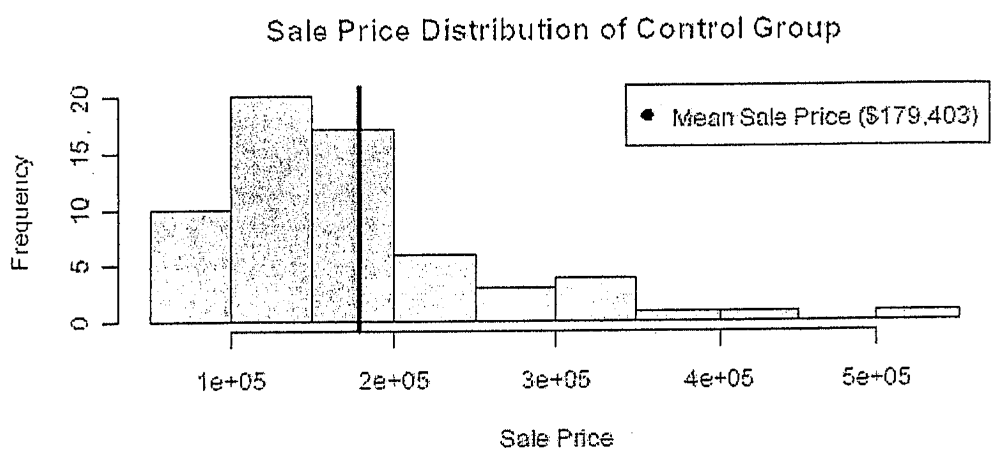
This emphasis on visual aspects only is made more problematical by Canning's simple binary measure of viz/no viz. I would think it intuitive to use the distance from the nearest turbine as the variable. Hoen, for example, grouped the distances into 5 groups so he could do regressions against properties both near and far. In fact, I have to wonder why Canning didn't also use distance in some fashion. Mysteriously, Panel B, page 47, does include "distance" as one of the independent variables along, but he never explains what it is, nor does it appear in any other part of his study. Perhaps it was inadvertently left in. Using this binary measure in place of a number allows all sorts of games to be played with the numbers, and Canning provides no details that would allow the reader to uncover this gaming.

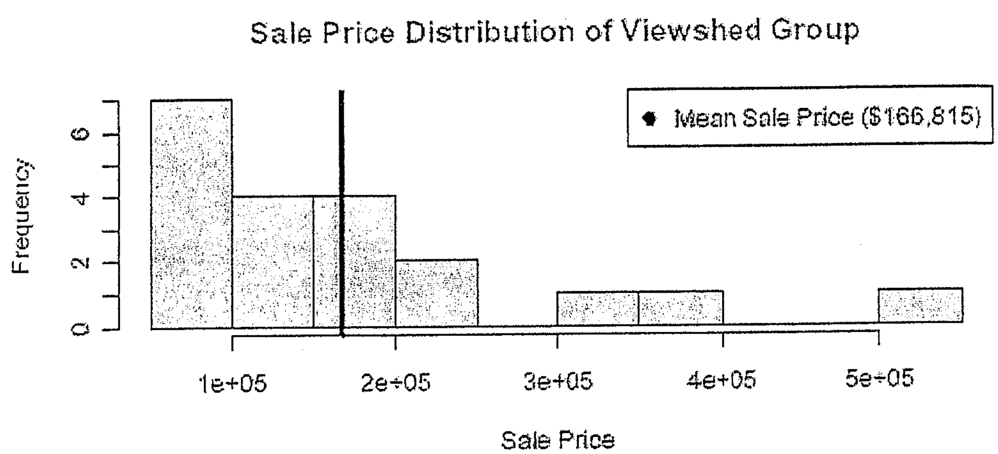
The second problem is the extraordinarily small sample size. As a quick refresher on statistics, you need to fulfill 2 basic conditions to show a relationship. First, the numbers representing the dependent variable (i.e. the sales price) and the independent variable (i.e. the viz binary value) must show some trend. Secondly, and almost as importantly, the values of the variables can't be too spread out among themselves, else you can't separate the trend from any normal random variance. Remember standard deviations? In this case the group we are interested in has just 20 members, so getting the standard deviation small enough to pick out any "statistically significant" trend is pretty much impossible. Hoen at least included some of the characteristics of the raw data, like the standard deviations of the prices of the different groups. Canning does not. This opaqueness is quite bothersome.

A third problem is that after running the analysis with all his variables, he could only explain 84% of the sales price. The International Association of Assessing Officers' standard calls for a lower limit of 90% for a study to be considered valid. This was also a problem for the Hoen study, as detailed at: http://amherstislandwindinfo.com/wilson-hoen-critique.pdf.

As an aside, one may wonder, couldn't Canning just have taken the average sales prices and compared them with no regression? He did that, and the results are shown in the picture below. The graph unnecessarily uses scientific notation along the bottom axis, the "1e+05" is just $100,000, the "2e+05 is $200,000 and so on.

Figure 2




On the face of it there appears to be a difference between the two groups, and it is not favorable to CanWEA. It comes to 7%, which seems pretty significant. Canning does not provide any raw data, but using the center point of each range I calculate the standard deviation of both groups together is $97,600, which is far larger than their separation of $12,588. A "statistically significant" result typically needs 2 SD's of separation, not the 0.13 difference we see here. Plus, as Canning correctly notes, there could be other factors, like age or lot size etc., which cause the difference. Regression analysis is one way to narrow in on the actual cause.

These problems by themselves would eliminate this study as a serious and honest attempt to find any trend. But it gets worse. Canning sings the praises of regression analyses, runs his numbers, and – quelle horreur! – comes up with viz properties selling for almost 13% less than no viz properties. And remember, this includes properties that can be more than 5 miles from the project. The standard deviation is now small enough (5%) that the margin of error (2 SD's) ranges from -3% to -23% (never getting to CanWEA's hoped-for 0%), showing that there is a statistically significant difference in the prices. I'm pretty sure that if Canning stopped here CanWEA would never have published this study.

As a theoretical exercise, if the 13% had turned out to be, say, the original 7%, the results would no longer be statistically significant. Had that been the case, does anyone really think Canning would have gone on with his additional steps?

So Canning goes to step number two. He massages the data, finding 20 no-viz homes that most closely match the 20 viz homes. He runs his numbers again, and – another quelle horreur! – the difference is 9%. At least it is less than before, and now (because the sample is even smaller than earlier) the standard deviation is so large (12%) that Canning can start to claim that 9% is just the same as 0%. I'm guessing again that if Canning stopped here CanWEA would never have published this study.

So Canning goes to step number three. Again he massages the data, this time coarsening the continuous variables such as house size so he can put them into discrete groups. The difference in price is now just 7%, still negative. The important thing, though, is that this manipulation further reduces the sample size, so the standard deviation gets even larger, now up to 21%. The idea that 7% equals 0% is even easier to justify. Maybe CanWEA would have published this, but it is hard to frame three negative numbers as anything good.

So Canning goes to step number four. He abandons regression altogether and goes to a paired sales analysis, which earlier he had disparaged. He goes outside of his 2-year window and finds 14 properties that sold twice since 2003. The idea is that if he can show the prices of the same properties didn't change during the construction and operation of the project, he'd make CanWEA very happy. I'd agree, consistent with what I wrote in my Introduction, that this would be the best way to get at the truth.

Obviously, timing here is critical. You'd have to find properties that sold before the project was even on the locals' radar and then sold again after the project was in operation. Based on information from the Port Alma project's web site, here is a rough timeline of the project.

Jan 2004 – prospecting starts.

Jan 2005 – development starts.
Jun 2006 – engineering starts.
Apr 2008 – construction starts.
Nov 2008 – operation starts.

Several studies, including Hoen, indicate that the biggest price drops in the general visual area occur early, several years before any official announcement. They then tend to recover, never getting back to parity. [This recovery may well never happen for the close-in properties.] So you'd have to, in Port Alma's case, look for "first" sales before Jan 2004 and "second" sales pretty much any time after that, as the damage has already been done. So, of the 14, how many of the first sales were before Jan 2004? The answer: 2. One of those, property B, had some updating. In neither case was the distance to the project revealed. But the prices of the 14 were mixed up enough that – voila! – Canning could now claim that the project had no effect on prices.

Did Canning offer any reasons why he did the additional studies in the first place? There are no specific reasons given in his report, aside from some general comments about the value of additional studies eliminating bias. He certainly was not looking for a more accurate assessment as the standard deviations continually increased. Maybe the increases were the goal. The additional studies did provide opportunities to manipulate the data, and additionally would tend to make the standard deviations larger, to the point where he could claim there was no "significant" difference in the prices. Without the raw data, which Canning will not publish, there's no way to know what happened behind the curtain.

In his summary, Canning states the following. Read through this paragraph carefully and you'll find a fairly good example of truth without honesty.

"The three regression models in this study returned a similar negative coefficient for the variable "viewshed" supported by a wide Standard Error and low T scores that clearly show that those coefficient results could not be relied upon as being statistically significant. It could not be said that rural residential houses located in a viewshed sold for lower prices."

It is not surprising that the wind industry will play up this report for all its worth. I understand CanWEA has been sending it around to various government agencies. I'm guessing CanWEA figures nobody will read past the summary to find out just how flawed this report is. The sad thing is, they are probably right.

That this report might be used as evidence in a court proceeding is truly scary. Judges are experts in the law, not statistics, so they rely upon testimony from people with lots of letters after names to establish "evidence". CanWEA is very good at playing this game, and sadly the courts and the media are very poor at detecting it.

# ADVERSE IMPACTS FROM WIND TURBINES IN WAUBRA, AUSTRALIA AND SURROUNDING AREA

We have spent almost one year attempting to understand the complexities of wind energy. We have researched the potential benefits and acknowledged deficiencies of industrial wind turbines. We have tried to educate citizens on Cape Cod and in Massachusetts about industrial wind energy. We have tried to foster public debate, through the formation of a Cape-wide group that has sponsored public presentations by relevant experts and has disseminated technical engineering reports, clinical medical research on adverse impacts, detailed acoustic studies of the special characteristics of wind turbine noise, relevant environmental information and numerous news reports and first-person testimonials from around the world to local, state and regional governments and agencies and to the general public.

Now after traveling to Australia and meeting with and interviewing dozens of people who have been profoundly adversely impacted by industrial wind turbines or are fighting the construction of wind turbines in their communities, we now understand with certainty that the very dramatic and real problems with wind energy are much, much worse than we had previously imagined.

What follows is a preliminary summary of our visit in Australia.

We spent the afternoon of 1/9/11 with the leaders of a country-wide organization called the Australian Landscape Guardians. They explained what is happening throughout Australia concerning the siting of industrial wind turbines. They told us that the government of Victoria, Australia is currently formulating a new policy which requires a minimum setback for all new wind turbine projects of 2 km (1.24 miles). They also informed us that the new policy includes the provision that no wind turbines can be built in National Parks, State Parks, or certain areas determined as scenic in character.

Later in the day we met Sarah Laurie, MD, Medical Director of the Waubra Foundation, who arranged this amazing journey for us. We spent time with her and she explained her work to us, which is to gather information from affected residents in order to encourage researchers to conduct appropriate independent research, to lobby for funding for such research, and to provide information and support to people who have been adversely impacted by the turbines.

That night we had dinner with a group of residents in a rural area that have organized to fight several large wind developments in their communities. They requested that we describe what has been happening on Cape Cod and in MA.

**The following day, on 1/10/11, we spent conducting interviews with some of the nicest and hardest working people we have ever met. Their stories are so incredible, emotional, and, ultimately so profound that we wanted to share our initial observations with you.** We interviewed 17 people who have been adversely impacted from a health standpoint.

## ADVERSE IMPACTS FROM WIND TURBINES IN WAUBRA, AUSTRALIA AND SURROUNDING AREA

We also interviewed a very courageous journalist who tells the stories of those in the Waubra area who are adversely impacted by industrial wind turbines.

### ONGOING RESEARCH CONCERNING ADVERSE HEALTH IMPACTS TO THOSE LIVING TOO CLOSE TO INDUSTRIAL WIND TURBINES

- Sarah Laurie, MD has been meeting with the victims of the Waubra wind power plant to gather information about their symptoms and illnesses, and to help provide information about the current knowledge of the health effects of wind turbines on human health to their General Practitioners and other doctors involved in their care. As part of her work, she has requested the victims keep track of their blood pressures throughout each day to investigate the impact of the turbines on their blood pressure. Her preliminary findings indicate that a number of the victims are experiencing dangerously elevated blood pressure since the turbines became operational, which go back down to normal levels when they are away from the turbines. Victims are tracking their blood pressure readings, and there are plans to do comprehensive investigations using 24-hour Holter Monitors, as this is the best way to measure what is going on. Some of the victims have been placed on blood pressure medications. Dr. Laurie is concerned because elevated blood pressure in the morning is an indicator of increased risk for heart attack and stroke. She has learned of several people who had normal blood pressure readings prior to the wind turbines being constructed who have now developed high blood pressure, or have had heart attacks and strokes since the turbines commenced operating. There has been one death so far due to stroke. She wants these incidents further investigated, to see if there is any connection with turbine operation when these people developed symptoms.

- Dr. Laurie also feels that it is important to investigate the impact of long-term exposure to industrial wind turbines and health. Some who have lived in the Waubra area, and are now industrial wind turbine development refugees due to adverse health impacts, have found that some of their symptoms have not gone away after permanently leaving their homes near the turbines. These people report that initially, during the first months of living near the wind turbines, their physical symptoms went away when they left the Waubra area for even a matter of hours. Several people we spoke with are concerned their health problems may be permanent. Again, these people had no problems prior to the wind turbine development.

- Some of the people living within 5 km of the wind turbines at Waubra experience what was called upper lip quiver. Two of the people we interviewed talked about this. When the wind turbine infrasound is intense, people experience a sensation in their upper lip that they can not control. Their upper lip vibrates and this twitching vibration can be seen by others. The sensation is disturbing to the people experiencing this not only because the vibration is extremely uncomfortable, but the loss of control of their own body is alarming. Dr. Laurie is gathering data on the

# ADVERSE IMPACTS FROM WIND TURBINES IN WAUBRA, AUSTRALIA AND SURROUNDING AREA

incidence of this symptom, as it appears to be highly specific with wind turbine operation. It has been reported in residents who live up to 10km adjacent to two wind developments elsewhere in Australia. She is concerned that if these symptoms are being noted at this distance, that there may be other effects on people such as elevated blood pressures, which may go undiagnosed.

- Several people living within 5 km of the wind turbines have experienced a sensation where they have woken up at night with a feeling that their heart was about to leap out of their body. Their pulse was alarmingly high. This has happened on several occasions for each of the people we spoke with who described this symptom. Dr. Laurie is gathering data that residents are noting in their personal health journals. She is also working to encourage further research in an attempt to find out more about this phenomena.

- A local Sleep Physician has agreed to carry out further research, as he is concerned about the effect the turbines are having on the health of his patients, in particular their disrupted sleep. Sleep deprivation is a major issue for the people we interviewed.

## 1. SETTING THE STAGE:

- Waubra and surrounding small towns are agricultural areas in a truly beautiful landscape of rolling hills and valleys. Many of the residents have lived in the area for many generations. Farming operations include sheep, cattle and various crops. Farming is a major source of revenue in the Waubra area. The farmers we spoke with are very concerned about the environment. Many of them use organic farming methods and all practice energy conservation. Waubra is located approximately 100 km from Melbourne.

- The people interviewed described their community life as very positive prior to the Waubra industrial wind turbine power plant development called a 'wind farm'. (They know farming and stated that the 128 wind turbines have nothing to do with farming. They call this development a wind power plant.) Parents stated the schools were very good and felt their children received good educations. Family life is very important to the people we interviewed.

- Many of the victims we interviewed were older parents. Many of their grown children who work on the farms planned to take over the family farms as their parents retired.

- Much of south eastern Australia, including Waubra, has experienced 15 consecutive years of drought. This is very important as it had a significant impact on the development of the wind power plant.

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# ADVERSE IMPACTS FROM WIND TURBINES IN WAUBRA, AUSTRALIA AND SURROUNDING AREA

- The Australian government, like the U.S., has placed a major emphasis on developing and deploying renewable sources of energy, especially wind energy. As in the U.S., Australia has set a target of 20% of its energy to come from renewal sources by 2020. The government provides generous subsidies and tax breaks to wind energy developers.

- The initial wind energy developer, Wind Power, began the process in 2003/2004. An application for a Planning Permit was submitted in 2005. The people we interviewed stated that the initial presentations were long on lofty claims and very short on facts. Some of the people we interviewed attended informational meetings and stated that the presenters claimed there were no problems with noise. The salesmen stated that the turbines sounded like leaves blowing in the wind or a stream – similar to claims we have heard in the United States that wind turbine noise is "no louder than a babbling brook, a refrigerator or a quiet conversation."

- Here is where the prolonged drought played an important role. Many farmers, especially smaller land holders, had suffered financially and they felt the wind turbine lease payments represented a life-line to help them through the difficult drought. So many signed up. IT IS IMPORTANT TO NOTE: some of the residents that did not sign up had reservations about the wind 'farm', but they did not raise their concerns because they were told by the salesmen that there were no problems and they did not want to interfere with their neighbors earning much-needed money from leasing their land to the wind energy developers. Their considerations for their neighbors would take a tragic turn following the construction of the wind energy power plant.

- Construction of the Waubra wind energy power plant occurred in stages and by June 2009 was fully operational. There are 128 industrial wind turbines covering an area of approximately 173 square kilometres.

- Many of the residents we interviewed, and presumably the people who leased their land, were shocked by the size and placement of the turbines following the construction. We were told that many residents felt lied to due to the actual size and placement of the wind turbines.

## 2. WHAT WE OBSERVED:

- All of the residents we interviewed have suffered a profound impact on their health, their relationships with family and their community, their confidence in elected officials, their financial condition and property value, and their life plans and future. They all feel betrayed and they are extremely angry. Here are the reasons why:

- *All of the people we interviewed are sick -- very PHYSICALLY ILL, as confirmed by a medical doctor, and in many cases by their family physicians.*

# ADVERSE IMPACTS FROM WIND TURBINES IN WAUBRA, AUSTRALIA AND SURROUNDING AREA

Their symptoms track with the symptoms we have heard experienced by the victims in Falmouth, MA; Vinalhaven, Maine; and many other communities globally. It was abundantly clear from these interviews, which we videotaped, that the suffering of the people has been severe. They report severe headaches, eye pain, difficulty sleeping, emotional distress, racing hearts, dangerously high blood pressure, ringing in their ears, panic attacks, feelings of hopelessness, inability to concentrate, and inability to find simple words when speaking. Children are experiencing the same symptoms as their parents. The parents we interviewed reported that their children's performance in school has radically declined since the wind plant began operation. Many we interviewed are under the care of physicians and take medication that they did not take prior to the wind turbine development. ALL THESE SYMPTOMS DEVELOPED AFTER THE TURBINES BEGAN TO OPERATE. It bears noting that the residents we interviewed, many of whom are farmers, were all healthy and hearty people who had spent their entire lives working outdoors. They are proud, and solid citizens. THEY ARE NOT COMPLAINERS...JUST THE OPPOSITE. Nonetheless, they can not ignore, nor overcome, their persistent symptoms that began to affect them, to threaten their health, and to disrupt their lives, since the arrival of the wind plant to their community.

- **REASON FOR A RED CODE ALERT: Many of the people we interviewed lived from 3 km to 10 km from the turbines. A two km (1.24 mile) setback at this wind power plant location would not have helped most of these people.**

- We were told by several that it is worse inside their home than outside because their window jambs rattle and parts of their homes vibrate.

- All the people we interviewed used similar descriptions when explaining their symptoms. They all describe feeling 'pressure' on their chest, their heart, their head, their ears and their eyes. Some have already declared themselves to be 'INDUSTRIAL REFUGEES' and have abandoned their beautiful and long-cherished homes. Others are considering leaving. Still others are determined not to leave even though their health has declined dramatically. The despair of the residents is evident as they describe this most difficult decision of whether to stay, or to abandon their homes.

- We interviewed one resident who said that she is in such pain at times she thinks that putting a bullet in her head would bring more relief than the pain she is experiencing.

- Some of the people we interviewed told us they believe that many of their neighbors who signed the leases and are hosting the turbines are suffering physical adverse health symptoms as much as they are. They stated that the land owners who signed the leases are prohibited from talking about their health problems because of the gag-clauses in the leases.

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## ADVERSE IMPACTS FROM WIND TURBINES IN WAUBRA, AUSTRALIA AND SURROUNDING AREA

- Those who have left their homes all report that their health problems have become less severe when they are away from the wind power plant. Most state that when they leave the Waubra area they feel better and that their blood pressure readings return to normal levels. But, it is very important to note, that some of the symptoms for some of the people have not gone away. Some are concerned their health problems may be permanent. The physician we talked with shares their concern.

### 3. SENSE OF COMMUNITY:

- THIS IS A TRAGEDY OF MONUMENTAL PROPORTION. According to many residents we interviewed, the Waubra area community, in their view, has disintegrated. Five generations of citizens, many life-long friends, have become adversaries. As we listened to the residents describe what has happened, we were very sad to see the emotional toll it is taking on these fine people who highly value the sense of community. One story told was that the local pub recently closed because people no longer frequented the pub because they feared who they might meet. We heard stories of violence, including an incident when one victim publicly stated his health problems and neighbors (former life-long friends) who leased land for the turbines sought revenge. Some residents told us that they now drive to near-by towns to go to the grocery store or the Post Office because they are verbally attacked in Waubra. One person stated it is their belief it will likely take a generation -- after the turbines are removed -- before the social healing can begin for their community.

### 4. IMPACT ON ANIMALS:

- The health of animals is naturally very important to farmers. Many of the residents told us that the wind turbines had an adverse impact on their animals.

- One farmer described how he had to 'put down' a blind sheep that had managed to take care of herself until the turbines began operation. After the turbines started, the sheep walked in circles and kept injuring herself walking into objects, so the farmer euthanized her.

- Others stated their dogs who are normally quite calm 'act up' when the wind turbines are loud from an audible standpoint and also when the infrasound is bad (note that dogs and other animals have a wider range of audible hearing than humans).

- When the wind farm commenced operation the usually very plentiful bats disappeared. Recently a few have been sighted. Overall there has been a decrease in the bat population.

# ADVERSE IMPACTS FROM WIND TURBINES IN WAUBRA, AUSTRALIA AND SURROUNDING AREA

## 5. IMPACT ON VIEW AND AESTHETICS OF RURAL ENVIRONMENT:

- The people we interviewed had all consciously chosen to live in the rural countryside. As previously noted, many we interviewed have maintained family farms in the area for multiple generations. Virtually all of them were heart sick at the wholesale transformation of their environment and what they characterized as the destruction of their land. Like many on Cape Cod who love the beauty of the sea, the dunes, the vistas, and the rural character of the Cape, the people we interviewed felt a profound sadness and loss regarding the industrialization of their natural and cultural heritage and community.

- One person we interviewed stated she could see 64 turbines from her land. At night the once tranquil vista now looks like an amusement park with dozens of red blinking aviation warning lights atop the turbines.

- Many of the people living in the Waubra area have powerful telescopes that they once used to enjoy the vast night sky in Australia. This was a popular hobby that used to bring great pleasure to many here, but the people in the region can no longer use their telescopes because the night sky is filled with pulsing red lights from the wind turbines.

- One resident gave us a written diary containing a day-by-day account of the noise emanating from the turbines and her observations of the adverse effects upon her health. She also wrote about the beautiful sunsets and sunrises that were spoiled by the flashing red lights – a record of observations which illustrates her love of her natural environment and her sense of permanent loss.

- One of the industrial refugees said that everywhere she looked there was movement. She couldn't stand it physically. She has motion sickness and it made her sick to her stomach and dizzy when she looked out of her windows. She reported that she found it unbearable to go outdoors and work in her garden, one of her favorite past times. In the Waubra area, every person we met had a beautiful flower garden as well as vegetable garden. They all took great pride in their garden.

- The Waubra area once was a rural, peaceful, serene location and it was evident to us from the testimonials we heard, that the hearts and souls of the residents we interviewed were tied to the land. They repeatedly described their rural location as being ruined, and turned from a peaceful countryside into an industrial zone.

- As in many similar locations around the world, including Falmouth, MA and Vinalhaven, Maine, most of the people we spoke with had supported the wind turbine development until it became operational. They now described how sad they were that their beautiful landscape is marred with the wind turbines. Some told us that this is not a place people want to come visit since its former beauty, and its sense of peace and tranquility, are now gone.

## 6. IMPACT ON LIFE GOALS:

- What can one say? The lives of many residents that we interviewed have been completely upended, even shattered, as is evident from their videotaped accounts. Like most people, they had a plan for their future. Many had taken for granted that they would continue to work their land and pass the family farm to their children.

- One resident purchased a 300 acre farm in the Waubra area to grow organic crops and livestock three years ago, about one year before the turbines began operation. Now he can not work on areas of his farm because the pain he experiences is too severe.

- Another family owns and farms a 4,000 acre property. When the wind developer offered them lease payments for eight turbines and extra income for transmission lines, they turned the offer down because they don't need or want any outside interests in their farm. They have now abandoned their beautiful home. During our videotaped interview, the mother of young children became extremely emotional when she described the decision to leave their family home and how that decision impacted her children.

## 7. THE WIND ENERGY COMPANY RESPONDING TO COMPLAINTS

- According to the residents, it would appear that the general response to a complaint by the Company is to (now, but not until continually requested) provide an Incident Reference Number. Frequently people are told 'we will look into it' and 'we will pass it to the relevant people'. Nothing happens. No investigation. When people first began to complain they did not ask for a Reference number and they felt that more than likely their complaints had not been registered.

- One resident who lives over 2 km from the nearest turbine, and who has made numerous complaints, was told that no one was responding to his complaints because he lived "too far" from the wind turbines.

## 8. PROPERTY VALUES:

- PLEASE KNOW THAT ANYONE WHO STATES THAT PROPERTY VALUES ARE NOT IMPACTED BY WIND TURBINE DEVELOPMENT IS NOT TELLING THE TRUTH. What has happened in the 18 months since the turbines began operation illustrates an impact on property values. We were told the following: Seven property owners have had properties purchased, so there are at least 7 properties, but maybe up to 10 properties that have been purchased. 4 property owners were involved pre-construction of the wind farm. 3 property owners have had properties purchased after the wind farm commenced operation. The two most recent properties to be purchased were because of noise. We were told by residents still living in Waubra that one of the property owners was bought out because of visual amenity even though she had been very outspoken in the media about her health problems. (We were told that the wind developer does not purchase properties based on health issues.)

- Further, some residents we spoke with report that there are more near-by properties coming on the market all the time. Some said there are not interested buyers in their area. One resident stated that she knows of a property that had more than 100 interested people contact the real estate agent, but when they found out the property was near the Waubra Wind Farm, not one prospective buyer has visited the property. We have heard from property owners in the Waubra area that real estate agents have said, if you can see the turbines it is very hard to sell the property.

- Many of the people we spoke with are certain that property value has dramatically declined, and some feel their properties can not be sold at any price.

- One person stated that the wind development has cost him $1,000,000 dollars in lost property value and costs incurred since the wind power plant has come to his town.

Written by:
Preston G. Ribnick and Lilli-Ann Green

Preston Ribnick is President and Lilli-Ann Green is CEO of a company in the United States, Professional Resource Group (PRG) which was was established in 1979. The company's core competencies include quality improvement, health care consulting and market research. Both Preston and Lilli speak around the United States to health care professionals on various topic related to quality improvement. PRG also develops educational programs for the health care industry. Many PRG programs are widely distributed in the U.S. and the audiences include physicians and nurses. PRG has worked with over 160,000 health care professionals throughout the United States, Canada and Puerto Rico since 1979. The main focus of PRG educational programs is quality improvement. Many of the programs center around various disease states.

version 2/9/11

Save Western NY



# Property Value

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### Wind Concerns

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The Wayward Wind, Jon Boone

Eminent Domain And Wind "Farms" In NY

A Problem With Wind Power

Hush Money From Wind Company

The Top Ten False and Misleading Claims the Windpower Industry Makes for Projects in the Eastern United States

Photo courtesy of Ed Sliwinski

**Fenner, NY. How much would YOU pay for this home?**

Whether or not wind farms adversely affect property values is a highly debated issue. The most well-known study was conducted by the Renewable Energy Policy Project (REPP); it claims that there has been no significant impact on property values from the Fenner or Madison wind farms (REPP 2003).

If you go to REPP's website and look at the report (.pdf file), which allegedly found that "property values... actually performed better than in the comparable community", you'll see that "the comparable community" was a simulated model, and the report made just one reference to noise from wind turbines in 81 pages, which was this one referring to a previous study; "However, the study concluded that while properties with wind turbines on them may increase in value, other properties may be adversely affected if within sight or audible distance of the wind turbines."

It's no wonder they put that big disclaimer at the top, absolving the government of any responsibilty for accuracy or usefullness of the report.

- **Review of REPP report:** Glenn Schleede, Reston VA..."You should be aware that REPP is an unabashed 'renewable energy' advocacy group that receives money from various liberal foundations and, unfortunately again, too many of our tax dollars via the US EPA, US Dept. of Energy, and the DOE National

Wind News

Industrial Wind Action Group

National Wind Watch

'Laboratories,' including NREL... As you have probably detected already, the basic methodology is fundamentally flawed in that it:

a. Seeks to focus on properties within a 5 mile radius of a wind farm.

b. Relies heavily on data collected from Assessors. I won't comment further on this flaw since most anyone who owns property recognizes assessors are probably the LAST place one would go for reliable data on MARKET values of property.

c. There is one VALID and RELIABLE source of market values of property: The selling price. If the property is not sold, no one knows the market value."

**Critical Review of REPP Report**: Tom Hewson, Energy Consultant..."The report was written under a "small" DOE grant that significantly limited REPP on what they could do. The author mentioned that they collected sufficient data in only 9-10 locations (each >10 MW) of the 26-30 sites in the survey. They focused their efforts on properties within 5 mile area...My concern with the REPP study is that it doesn't try to examine the nuisance effect by selecting a large 5 mile area."

- **Landowners' Rights Stop Where Neighbors' Rights Start**: Highland County Recorder Letters to the Editor, May 12, 2005: "...In real estate law and terminology, there are certain things that are guaranteed to a fee simple property owner. The term for this is the 'Bundle of Rights.' One of these rights is that you have right 'of quiet enjoyment.' Others are, the right to possess, control, encumber, and dispose... An encroachment can best be described as an unauthorized physical intrusion or an unauthorized trespass. Loud noises, bright lights, violation of the owner's air space, are some examples. These encumbrances and encroachments are illegal if the owner does not authorize it.

  The land owner can take legal action to prevent these things from happening. My discussions with a few local people frequently provoke the statement 'a person should have the right to do whatever they want with their own land.' Most everybody would agree with that opinion. However, that right stops when a person, while exercising that right, encumbers or encroaches another's 'bundle of rights'."

- **An ill wind blowing?**: Daily Telegraph UK, 14/02/2004: " "The first thing we knew about it was when we saw a notice saying that the road running past the site would be closed for the construction of a wind farm," says Barry (Moon). When the turbines were switched on, the couple realised immediately that they would be unable to live with the noise, even though it has been found to exist within the guidelines for wind farms laid down by the Department of Trade & Industry – that it should not emit more than five decibels above background noise.

  "One of the myths put out by the industry is that a wind farm sounds like a stream from 50 yards. We've got a stream running through our garden and if you stand by it, you can hear the whooshing of the turbines above the water. I've lived the same distance from the M3 and that didn't bother me anything like as much as the wind farm."

  The couple complained to Barrow Borough Council and were asked to keep detailed records of the noise, which they did for two years. After some persuasion, Powergen fitted the turbines with a system that shuts down the offending four turbines – three more are concealed behind the hill – whenever the wind blows from a certain direction and when Barry and Gillian are likely to be at home. But the system doesn't deal with the visual impact, nor with the strange flickering that the couple experience some evenings as the blades reflect the rays of the sun.

  Had they known about the wind farm, say Barry and Gillian, they would not have bought Poaka Beck House. Yet the plans did not show up in the local searches – which, contrary to what many homebuyers believe, deal only with planning applications and decisions affecting the property you are buying or adjacent

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properties. Neither were Barry and Gillian warned about the wind farm by the vendors, David and Diane Holding.

For the Holdings, this turned out to be an expensive omission. In their Sellers' Property Information Form – part of the sales contract – the couple answered "No" to the question "Have you had any negotiations or discussions with any neighbour or any other authority which affect the property in any way?" In fact, as Barry and Gillian discovered when sifting through correspondence kept by Barrow Borough Council, the Holdings had written letters of objection about the wind farm, complaining that it would reduce the value of their property by between 50 and 75 per cent. Last month, Barry and Gillian were awarded £15,000 in damages against the Holdings.

The district judge explained that he arrived at that figure by listening to the arguments of chartered surveyors employed by both sides and concluding that the wind farm reduced the value of Poaka Beck House by 20 per cent. In 1997, the property would have been worth £150,000, had there been no plans for a wind farm, he ruled. Had the farm been in place at that time, on the other hand, the property would have been worth only £120,000. As Barry and Gillian had paid £132,500, they were entitled to £12,500 in damages plus interest, bringing the total to £15,000.

The case has important repercussions because the wind-farm industry has argued for some time that turbines do not devalue homes. Indeed, until recently the website of the British Wind Energy Association (BWEA) stated, under the heading "Top 10 myths about wind farms", that "the proximity of a wind energy development does not adversely affect property prices".

The website quotes a MORI poll conducted in Scotland into the attitudes of local residents towards wind farms. The poll found that only 7 per cent of people living within 15km of a wind farm considered that it had a negative impact upon an area. Closer inspection, however, revealed that only 12 per cent of respondents could see the farm from their property. Moreover, the experience of somebody living 15km away can hardly be compared with somebody living 500 metres away.

"Barry Moon's house is one property near one wind farm," says BWEA spokeswoman Alison Hill. "There is no evidence that property values anywhere else have been affected. In fact, values of many properties near wind farms have risen. However, in the light of Mr Moon's case, we have amended our website. It is likely that we will commission a study from the Royal Institution of Chartered Surveyors or FPDSavills, which will clear up the matter for good."

- **Impact of wind farms on the value of residential property and agricultural land**: Royal Institution of Chartered Surveyors: "For those surveyors who believe that residential property values are lower as a result of wind farm developments, a majority (67%) believe that there is an impact on values as early as the planning application stage. A further 22% report that the impact is first evident at the construction phase of development."

- **Property Values and House Prices**: Country Guardian (UK) - Photo copied letters from estate agents and solicitors relating to property transaction impacted by the proximity of wind farms.

- **Blot on the landscape** Danny Buttler, Victoria (Australia) Herald Sun, 21feb04: "Bruce Richards, managing director of PBE Real Estate in South Gippsland, said Victoria's property boom was going backwards in the shadow of the giant turbines. He said selling homes within 2km of Toora's 12 wind turbines was becoming increasingly hard. 'Anywhere close to the towers is very, very difficult to sell,' he said...

  South Gippsland Shire mayor David Lewis said rate valuations had decreased on some properties near turbines, but could not confirm if it was just due to wind farms. But there was no doubt they had had depressed the immediate property market. 'My personal belief is that it does destroy property values,' he said."

- **Turbines Cast Shadow Over Land Values**: Paul Sellars, Weekly Times, 16 APR 2003... "Three prominent agents have told The Weekly Times that existing wind turbines -- and the prospect of more to come -- have turned potential buyers off properties. PBE Real Estate co-founding director John Evans said in 35 years working in South Gippsland, he had never seen a bigger threat to property values than wind farms... Wesfarmers Landmark Leongatha agent Glen Wright said wind farms were 'definitely'' having an impact on values. 'If they are near the property, buyers are staying away,'' Mr Wright said. 'If I had to put a figure on it, I would say (a reduction of) 25 to 30 per cent on the going value."

  Pat Rice Hawkins Pty Ltd sales manager Bruce Falk said potential buyers were turned off by the prospect of wind turbines... 'I would have shown 50 or 60 people through that property and I would say half of those wouldn't even look at the place once they realise it's in the vicinity of wind turbines,' Mr Falk said...The agents' claims were rejected by the Australian Wind Energy Association."

- **Tourists blow ill wind on renewable energy**: The Scottsman, Nov. 17, 2002... "four out of five (80%) of the 180 visitors who completed detailed questionnaires, said they came to Scotland for the beautiful scenery and almost all (95%) said they valued the chance to see unspoiled nature. More than half (58%) agreed that wind farms spoiled the look of the countryside and more than a quarter (28%) said they would avoid an area where they knew a wind farm was sited... The survey directly contradicts an earlier report which claimed nine out of 10 tourists said the presence of wind farms would have no bearing on whether they returned to an area for a holiday."

- **Social Assessment of Wind Power: Visual Effect and Noise from Windmills—. Quantifying and Evaluation**: Jørgensen,Jørden, Jordal, Institute of Local Government Studies, Denmark, April 1996: "The main idea of wind power is to produce electricity without air pollution and without using exhaustible natural resources. However, wind power involves certain costs. These costs are among other things due to the fact that windmills stand as a foreign element in the open landscape. Some people are of the opinion that windmills in an open landscape impinge on the recreative element of the landscape. In addition to this, windmills give off noise that, depending on the wind direction and distance from the windmill, can be a nuisance for those living in the vicinity. The purpose of this study is to evaluate how great the costs are from the visual effect and noise of the windmills. In order to make it possible to compare these costs with other costs and gains in relation to windmills, these costs are reckoned in cash terms. This has been done partly on the basis of the willingness to pay for getting rid of the windmills of people living in the vicinity (the interview method or contingent valuation), and partly using a survey of house prices in the vicinity of the windmills (the house price method or hedonic pricing) as a starting point."

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# Danes decry property depreciation by wind mills

News Type: Event — *Wed May 13, 2009 11:32 AM EDT*

technology, green, alternative-energy, denmark, alternative, wind-energy, wind-mills, adverse-impacts, property-value-loss

*By Barbara Durkin*



The Committee of the Association of Danish Landowners, Danske Torpare, on behalf of its 10,000 members, decries property value depreciation by wind mills

3/21/2009

1. Statement to the Swedish government

Monday this week the Danish association for Danes with houses in Sweden, named Danske Torpare, adressed a statement about problems with windmills to the Swedish government. A copy was sent to the Danish government. Here is this statement translated into English:

Points of view regarding wind power in Southern Sweden

Since the 1960s the Danes have bought or rented good and well
situated weekend houses in the most southerly areas of Sweden. Since the end of the 1980's the numbers have increased considerably and the Danes congregate not only in the traditional areas in the southwestern Småland, north eastern Skåne and southern Halland but have moved further north and east.

The association Danske Torpare (Danish Landowners) has since 1980 been an organization of interest to a lot of the Danes, and the association now counts app 10.000 members.

Sweden's expansion of wind power till 2020 can become a serious financial problem for many Danes with weekend houses in the country's southern forest areas. Erection of big wind mills in the locality can result in substantial depreciation of the property value and in certain cases makes it impossible for the owner to sell the property and who thus risks losing the invested capital. Apart from creating difficulties for the individual it is likely to influence the integration process in the Øresund Region. It is with increasing apprehension that the members of the association view this development. An increasing number of people contacts the association because of the predicted 150-200 meter high wind mills and the risk of a considerable noise nuisance, shadows, nocturnal flashlights and a spoilt view plus not least the economic losses of such a development. The association cannot and does not want to ignore all these many enquiries.

On November 27th 2008 the association therefore held an internal information meeting about wind power in Southern Sweden and more that 100 members participated who all one way or another are now affected by the situation. At the meeting an experienced estate agent, after having consulted many of his Swedish colleagues, informed that

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just a letter applying for erection of a wind mill in the vicinity immediately depreciated the value of the property by 30 per cent.

Wind mills that are placed closer than 2000 meters to a property can make it very difficult or impossible to sell for leisure purposes it was further informed.

It is the nature, the view, the tranquility that since the 1960's attracts still more Danish people to Sweden and through renovation and maintenance of their houses and hitherto derelict farms they contribute to the preservation of the Swedish cultural heritage.

Several Swedish councils are aware of this and have for instance on their website used this argument to attract the Danes. A good example is Klippan District council's Danish webpage. TAX Denmark has informed that in 2007 app 21.700 Danes were owners of Swedish properties. It is thus a considerable number of people that therefore can be affected by the expansion of wind power as well of course as the big number of Swedes that are in the same situation.

It is not the business of Danske Torpare to take a position for or against wind power. The association only wants to point out the concrete and very real problems to its members. We are keen to emphasize how much the association appreciates the readiness to co-operate shown by the Swedes and that on principle we do not wish to interfere in Swedish affairs.

A big number of foreign citizens who own houses in Sweden may be seriously affected economically and we therefore ask the Swedish authorities to be mindful of this predicament.

We are greatly worried about the destruction of the extraordinary beauty of the Swedish nature – not because wind mills are not all right – but because there is a danger that they are erected in the wrong places, are too big and can have a number of negative and unexpected consequences.

Danske Torpare predicts that many people will feel compelled to enter into legal proceedings about compensation with the Swedish courts of law. We would like to draw attention to the Danish compensation rules as a possible means of solving the problems.

On behalf of its members the committee of the association is willing to enter into dialogue with the Swedish authorities and politicians at all levels. We are ready – at any time and with short notice – to discuss this predicament in Sweden.

Yours sincerely,
The Committee of the Association of Danish Landowners "Danske Torpare"
Per Bonke
President

2. Danish legislation

Windmills must be situated at a minimum distance of minimum 4 x the height of the mill away from habitation.
If the mill is erected closer than 6 x the height of the mill an estimation is carried out free of charge regarding the depreciation of the property value.
If the loss is more than 1% full compensation of the loss in property value is paid out.

If the property is situated further away than 6 x the height of the mill, 4000 DKK are payable to have an evaluation of the loss in value carried out. If it is estimated that the depreciation is more than 1% the loss in value of the property is paid out and the 4000 DKK reimbursed.
If it is estimated that there is no loss in value of the property the 4000 DKK are forfeited.

Best regards

Peter Skeel Hjorth

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Mark Duchamp + 34 679 12 99 97
INCONVENIENT VIDEOS : www.iberica2000.org/Es/Articulo.asp?Id=3729

The dark side of windfarms : www.iberica2000.org/Es/Articulo.asp?Id=1228
Pictures of windfarm victims ( eagles etc. ), of turbines on fire, of collapsed turbines, of soil & water contamination etc. : http://spaces.msn.com/mark-duchamp

ESPAÑOL :
Videos inconvenientes : www.iberica2000.org/Es/Articulo.asp?Id=3729
La cara oscura de los parques eólicos: www.iberica2000.org/Es/Articulo.asp?Id=1255
Fotos de víctimas de parques eólicos ( águilas etc. ), incendios de aerogeneradores, contaminación de las aguas por sus lubricantes etc. : http://spaces.msn.com/mark-duchamp



00001211

Pro-Wind

# The Potential Health Impact of Wind Turbines

Chief Medical Officer of Health (CMOH) Report

May 2010

00001212

# Summary of Review

This report was prepared by the Chief Medical Officer of Health (CMOH) of Ontario in response to public health concerns about wind turbines, particularly related to noise.

Assisted by a technical working group comprised of members from the Ontario Agency for Health Protection and Promotion (OAHPP), the Ministry of Health and Long-Term Care (MOHLTC) and several Medical Officers of Health in Ontario with the support of the Council of Ontario Medical Officers of Health (COMOH), this report presents a synopsis of existing scientific evidence on the potential health impact of noise generated by wind turbines.

The review concludes that while some people living near wind turbines report symptoms such as dizziness, headaches, and sleep disturbance, the scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects. The sound level from wind turbines at common residential setbacks is not sufficient to cause hearing impairment or other direct health effects, although some people may find it annoying.

Common Statement in Pro-Wind Materials

# Introduction

In response to public health concerns about wind turbines, the CMOH conducted a review of existing scientific evidence on the potential health impact of wind turbines in collaboration and consultation with a technical working group composed of members from the OAHPP, MOHLTC and COMOH.

A literature search was conducted to identify papers and reports (from 1970 to date) on wind turbines and health from scientific bibliographic databases, grey literature, and from a structured Internet search. Databases searched include MEDLINE, PubMed, Environmental Engineering Abstracts, Environment Complete, INSPEC, Scholars Portal and Scopus. Information was also gathered through discussions with relevant government agencies, including the Ministry of the Environment and the Ministry of Energy and Infrastructure and with input provided by individuals and other organizations such as Wind Concerns Ontario.

In general, published papers in peer-reviewed scientific journals, and reviews by recognized health authorities such as the World Health Organization (WHO) carry more weight in the assessment of health risks than case studies and anecdotal reports.

The review and consultation with the Council of Ontario Medical Officers of Health focused on the following questions:

- What scientific evidence is available on the potential health impacts of wind turbines?
- What is the relationship between wind turbine noise and health?
- What is the relationship between low frequency sound, infrasound and health?
- How is exposure to wind turbine noise assessed?
- Are Ontario wind turbine setbacks protective from potential wind turbine health and safety hazards?
- What consultation process with the community is required before wind farms are constructed?
- Are there data gaps or research needs?

The following summarizes the findings of the review and consultation.

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# Wind Turbines and Health

## 2.1 Overview

A list of the materials reviewed is found in Appendix 1. It includes research studies, review articles, reports, presentations, and websites.

Technical terms used in this report are defined in a Glossary (Page 11).

The main research data available to date on wind turbines and health include:

- Four cross-sectional studies, published in scientific journals, which investigated the relationships between exposure to wind turbine noise and annoyance in large samples of people (351 to 1,948) living in Europe near wind turbines (see section 2.2).
- Published case studies of ten families with a total of 38 affected people living near wind turbines in several countries (Canada, UK, Ireland, Italy and USA) (Pierpont 2009). However, these cases are not found in scientific journals. A range of symptoms including dizziness, headaches, and sleep disturbance, were reported by these people. The researcher (Pierpont) suggested that the symptoms were related to wind turbine noise, particularly low frequency sounds and infrasound, but did not investigate the relationships between noise and symptoms. It should be noted that no conclusions on the health impact of wind turbines can be drawn from Pierpont's work due to methodological limitations including small sample size, lack of exposure data, lack of controls and selection bias.
- Research on the potential health and safety hazards of wind turbine shadow flicker, electromagnetic fields (EMFs), ice throw and ice shed, and structural hazards (see section 2.3).

A synthesis of the research available on the potential health impacts of exposure to noise and physical hazards from wind turbines on nearby residents is found in sections 2.2 and 2.3, including research on low frequency sound and infrasound. This is followed by information on wind turbine regulation in Ontario (section 3.0), and our conclusions (section 4.0).

## 2.2. Sound and Noise

Sound is characterized by its sound pressure level (loudness) and frequency (pitch), which are measured in standard units known as decibel (dB) and Hertz (Hz), respectively. The normal human ear perceives sounds at frequencies ranging from 20Hz to 20,000 Hz. Frequencies below 200 Hz are commonly referred to as "low frequency sound" and those below 20Hz as "infrasound," but the boundary between them is not rigid. There is variation between people in their ability to perceive sound. Although generally considered inaudible, infrasound at high-enough sound pressure levels can be audible to some people. Noise is defined as an unwanted sound (Rogers et al. 2006, Leventhall 2003).

Wind turbines generate sound through mechanical and aerodynamic routes. The sound level depends on various factors including design and wind speed. Current generation upwind model turbines are quieter than older downwind models. The dominant sound source from modern wind turbines is aerodynamic, produced by the rotation of the turbine blades through air. The aerodynamic noise is present at all frequencies, from infrasound to low frequency to the normal audible range, producing the characteristic "swishing" sound (Leventhall 2006, Colby et al. 2009).

Environmental sound pressure levels are most commonly measured using an A-weighted scale. This scale gives less weight to very low and very high frequency components that is similar to the way the human ear perceives sound. Sound levels around wind turbines are usually predicted by modelling, rather than assessed by actual measurements.

The impact of sound on health is directly related to its pressure level. High sound pressure levels (>75dB) could result in hearing impairment depending on the duration of exposure and sensitivity of the individual. Current requirements for wind turbine setbacks in Ontario are intended to limit noise at the nearest residence to 40 dB (see section 3). This is a sound level comparable to indoor background sound. This noise limit is consistent with the night-time noise guideline of 40 dB that the World Health Organization (WHO) Europe recommends for the protection of public health from community noise. According to the WHO, this guideline is below the level at which effects on sleep and health occurs. However, it is above the level at which complaints may occur (WHO 2009).

Available scientific data indicate that sound levels associated with wind turbines at common residential setbacks are not sufficient to damage hearing or to cause other direct adverse health effects, but some people may still find the sound annoying.

Studies in Sweden and the Netherlands (Pedersen et al. 2009, Pedersen and Waye 2008, Pedersen and Waye 2007, Pedersen and Waye 2004) have found direct relationships between modelled sound pressure level and self-reported perception of sound and annoyance. The association between sound pressure level and sound perception was stronger than that with annoyance. The sound was annoying only to a small percentage of the exposed people; approximately 4 to 10 per cent were very annoyed at sound levels between 35 and 45dBA. Annoyance was strongly correlated with individual perceptions of wind turbines. Negative attitudes, such as an aversion to the visual impact of wind turbines on the landscape, were associated with increased annoyance, while positive attitudes, such as direct economic benefit from wind turbines, were associated with decreased annoyance. Wind turbine noise was perceived as more annoying than transportation or industrial noise at comparable levels, possibly due to its swishing quality, changes throughout a 24 hour period, and lack of night-time abatement.

### 2.2.1 Low Frequency Sound, Infrasound and Vibration

Concerns have been raised about human exposure to "low frequency sound" and "infrasound" (see section 2.2 for definitions) from wind turbines. There is no scientific evidence, however, to indicate that low frequency sound generated from wind turbines causes adverse health effects.

Low frequency sound and infrasound are everywhere in the environment. They are emitted from natural sources (e.g., wind, rivers) and from artificial sources including road traffic, aircraft, and ventilation systems. The most common source of infrasound is vehicles. Under many conditions, low frequency sound below 40Hz from wind turbines cannot be distinguished from environmental background noise from the wind itself (Leventhall 2006, Colby et al 2009).

Low frequency sound from environmental sources can produce annoyance in sensitive people, and infrasound at high sound pressure levels, above the threshold for human hearing, can cause severe ear pain. There is no evidence of adverse health effects from infrasound below the sound pressure level of 90dB (Leventhall 2003 and 2006).

Studies conducted to assess wind turbine noise indicate that infrasound and low frequency sounds from modern wind turbines are well below the level where known health effects occur, typically at 50 to 70dB.

A small increase in sound level at low frequency can result in a large increase in perceived loudness. This may be difficult to ignore, even at relatively low sound pressures, increasing the potential for annoyance (Jakobsen 2005, Leventhall 2006).

A Portuguese research group (Alves-Pereira and Castelo Branco 2007) has proposed that excessive long-term exposure to vibration from high levels of low frequency sound and infrasound can cause whole body system pathology (vibro-acoustic disease). This finding has not been recognized by the international medical and scientific community. This research group also hypothesized that a family living near wind turbines will develop vibro-acoustic disease from exposure to low frequency sound, but has not provided evidence to support this (Alves-Pereira and Castelo Branco 2007).

### 2.2.2 Sound Exposure Assessment

Little information is available on actual measurements of sound levels generated from wind turbines and other environmental sources. Since there is no widely accepted protocol for the measurement of noise from wind turbines, current regulatory requirements are based on modelling (see section 3.0).

## 2.3 Other Potential Health Hazards of Wind Turbines

The potential health impacts of electromagnetic fields (EMFs), shadow flicker, ice throw and ice shed, and structural hazards of wind turbines have been reviewed in two reports (Chatham-Kent Public Health Unit 2008; Rideout et al 2010). The following summarizes the findings from these reviews.

- **EMFs**
  Wind turbines are not considered a significant source of EMF exposure since emissions levels around wind farms are low.

- **Shadow Flicker**
  Shadow flicker occurs when the blades of a turbine rotate in sunny conditions, casting moving shadows on the ground that result in alternating changes in light intensity appearing to flick on and off. About 3 per cent of people with epilepsy are photosensitive, generally to flicker frequencies between 5-30Hz. Most industrial turbines rotate at a speed below these flicker frequencies.

- **Ice Throw and Ice Shed**
  Depending on weather conditions, ice may form on wind turbines and may be thrown or break loose and fall to the ground. Ice throw launched far from the turbine may pose a significant hazard. Ice that sheds from stationary components presents a potential risk to service personnel near the wind farm. Sizable ice fragments have been reported to be found within 100 metres of the wind turbine. Turbines can be stopped during icy conditions to minimize the risk.

- **Structural hazards**
  The maximum reported throw distance in documented turbine blade failure is 150 metres for an entire blade, and 500 metres for a blade fragment. Risks of turbine blade failure reported in a Dutch handbook range from one in 2,400 to one in 20,000 turbines per year (Braam et al 2005). Injuries and fatalities associated with wind turbines have been reported, mostly during construction and maintenance related activities.

# Wind Turbine Regulation in Ontario

The Ministry of the Environment regulates wind turbines in Ontario. A new regulation for renewable energy projects came into effect on September 24, 2009. The requirements include minimum setbacks and community consultations.

## 3.1 Setbacks

Provincial setbacks were established to protect Ontarians from potential health and safety hazards of wind turbines including noise and structural hazards.

The minimum setback for a wind turbine is 550 metres from a receptor. The setbacks rise with the number of turbines and the sound level rating of the selected turbines. For example, a wind project with five turbines, each with a sound power level of 107dB, must have its turbines setback at a minimum 950 metres from the nearest receptor.

These setbacks are based on modelling of sound produced by wind turbines and are intended to limit sound at the nearest residence to no more than 40 dB. This limit is consistent with limits used to control noise from other environmental sources. It is also consistent with the night-time noise guideline of 40 dB that the World Health Organization (WHO) Europe recommends for the protection of public health from community noise. According to the WHO, this guideline is below the level at which effects on sleep and health occurs. However, it is above the level at which complaints may occur (WHO 2009).

Ontario used the most conservative sound modelling available nationally and internationally, which is supported by experiences in the province and in other jurisdictions (MOE 2009). As yet, a measurement protocol to verify compliance with the modelled limits in the field has not been developed. The Ministry of the Environment has recently hired independent consultants to develop a procedure for measuring audible sound from wind turbines and also to review low frequency sound impacts from wind turbines, and to develop recommendations regarding low frequency sound.

Ontario setback distances for wind turbine noise control also take into account potential risk of injury from ice throw and structural failure of wind turbines. The risk of injury is minimized with setbacks of 200 to 500 metres.

## 3.2 Community Consultation

The Ministry of the Environment requires applicants for wind turbine projects to provide written notice to all assessed land owners within 120 metres of the project location at a preliminary stage of the project planning. Applicants must also post a notice on at least two separate days in a local newspaper. As well, applicants are required to notify local municipalities and any Aboriginal community that may have a constitutionally protected right or interest that could be impacted by the project.

Before submitting an application to the Ministry of the Environment, the applicant is also required to hold a minimum of two community consultation meetings to discuss the project and its potential local impact. To ensure informed consultation, any required studies must be made available for public review 60 days prior to the date of the final community meeting. Following these meetings the applicant is required to submit as part of their application a Consultation Report that describes the comments received and how these comments were considered in the proposal.

The applicant must also consult directly with local municipalities prior to applying for a Renewable Energy Approval on specific matters related to municipal lands, infrastructure, and services. The Ministry of the Environment has developed a template, which the applicant is required to use to document project-specific matters raised by the municipality. This must be submitted to the ministry as part of the application. The focus of this consultation is to ensure important local service and infrastructure concerns are considered in the project.

For small wind projects (under 50 kW) the public meeting requirements above are not applicable due to their limited potential impacts.

## Conclusions

The following are the main conclusions of the review and consultation on the health impacts of wind turbines:

- While some people living near wind turbines report symptoms such as dizziness, headaches, and sleep disturbance, the scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects.
- The sound level from wind turbines at common residential setbacks is not sufficient to cause hearing impairment or other direct adverse health effects. However, some people might find it annoying. It has been suggested that annoyance may be a reaction to the characteristic "swishing" or fluctuating nature of wind turbine sound rather than to the intensity of sound.
- Low frequency sound and infrasound from current generation upwind model turbines are well below the pressure sound levels at which known health effects occur. Further, there is no scientific evidence to date that vibration from low frequency wind turbine noise causes adverse health effects.
- Community engagement at the outset of planning for wind turbines is important and may alleviate health concerns about wind farms.
- Concerns about fairness and equity may also influence attitudes towards wind farms and allegations about effects on health. These factors deserve greater attention in future developments.

The review also identified that sound measurements at residential areas around wind turbines and comparisons with sound levels around other rural and urban areas, to assess actual ambient noise levels prevalent in Ontario, is a key data gap that could be addressed. An assessment of noise levels around wind power developments and other residential environments, including monitoring for sound level compliance, is an important prerequisite to making an informed decision on whether epidemiological studies looking at health outcomes will be useful.

# Glossary

**A-weighted decibels (dBA)**
The sound pressure level in decibels as measured on a sound level meter using an A-weighted filter. The A-weighted filter de-emphasizes the very low and very high frequencies of the sound in a manner similar to the frequency response of the human ear.

**Decibel (dB)**
Unit of measurement of the loudness (intensity) of sound. Loudness of normal adult human voice is about 60-70 dB at three feet. The decibel scale is a logarithmic scale and it increases/decreases by a factor of 10 from one scale increment to the next adjacent one.

**Downwind model turbines**
Downwind model turbines have the blades of the rotor located behind the supporting tower structure, facing away from the wind. The supporting tower structure blocks some of the wind that blows towards the blades.

**Electromagnetic fields (EMFs)**
Electromagnetic fields are a combination of invisible electric and magnetic fields. They occur both naturally (light is a natural form of EMF) and as a result of human activity. Nearly all electrical and electronic devices emit some type of EMF.

**Grey literature**
Information produced by all levels of government, academics, business and industry in electronic and print formats not controlled by commercial publishing, i.e., where publishing is not the primary activity of the producing body.

**Hertz (Hz)**
A unit of measurement of frequency; the number of cycles per second of a periodic waveform.

**Infrasound**
Commonly refers to sound at frequencies below 20Hz. Although generally considered inaudible, infrasound at high-enough sound pressure levels can be audible to some people.

**Low frequency sound**
Commonly refers to sound at frequencies between 20 and 200 Hz.

**Noise**
Noise is an unwanted sound.

**Shadow Flicker**
Shadow flicker is a result of the sun casting intermittent shadows from the rotating blades of a wind turbine onto a sensitive receptor such as a window in a building. The flicker is due to alternating light intensity between the direct beam of sunlight and the shadow from the turbine blades.

**Sound**
Sound is wave-like variations in air pressure that occur at frequencies that can be audible. It is characterized by its loudness (sound pressure level) and pitch (frequency), which are measured in standard units known as decibel (dB) and Hertz (Hz), respectively. The normal human ear perceives sounds at frequencies ranging from 20Hz to 20,000 Hz.

**Upwind model turbines**
Upwind model turbines have the blades of the rotor located in front of the supporting tower structure, similar to how a propeller is at the front of an airplane. Upwind turbines are a modern design and are quieter than the older downwind models.

**Wind turbine**
Wind turbines are large towers with rotating blades that use wind to generate electricity.

# Appendix 1: List of Documents on Wind Turbines

## Journal Articles and Books

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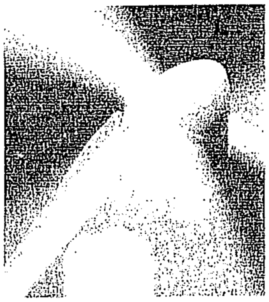
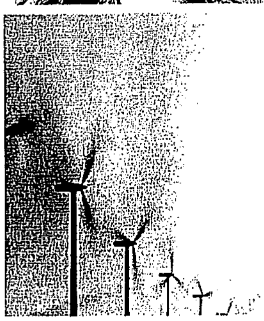
# NHMRC PUBLIC STATEMENT

JULY 2010





# Wind Turbines and Health

(Pro-Wind)

Wind power has been gaining prominence as a viable sustainable alternative to other forms of energy production. Studies have found that there is increasing population demand for 'green' energy[1,2]. In Australia, this has been encouraged by the introduction of the Renewable Energy (Electricity) Act in 2000 and the Renewable Energy Target Scheme in 2009.

As with any new technology, wind turbines are not without controversy. Those who oppose the development of wind farms contend that wind turbines can adversely impact the health of individuals living in close proximity.

## Do wind turbines impact on health?

Concerns regarding the adverse health impacts of wind turbines focus on infrasound noise, electromagnetic interference, shadow flicker and blade glint produced by wind turbines.

While a range of effects such as annoyance, anxiety, hearing loss, and interference with sleep, speech and learning have been reported anecdotally, there is no published scientific evidence to support adverse effects of wind turbines on health.

Reported health concerns primarily relate to infrasound (sound that is generally inaudible to the human ear) generated by wind turbines. The World Health Organization states that 'There is no reliable evidence that sounds below the hearing threshold produce physiological or psychological effects'[3]. A recent expert panel review in North America found no evidence that audible or subaudible sounds emitted by wind turbines have any direct adverse physiological effect[4]. The principal human response to perceived infrasound is annoyance[5].

A study of three UK wind farms also supports this conclusion, finding that sound associated with modern wind turbines is not a source which will result in noise levels which may be injurious to the health of a wind farm neighbour[6]. However, there is also the argument that if people are worried about their health they may become anxious, causing stress related illnesses which are genuine health effects arising from their worry, but not from the wind turbine itself. For this reason, NHMRC recommends that people who believe they are experiencing any health problems should consult their GP promptly.

The situation is further complicated by findings that people who benefit economically from wind turbines were less likely to report annoyance, despite exposure to similar sound levels as people who were not economically benefiting[2].

**There is currently no published scientific evidence to positively link wind turbines with adverse health effects.**

## Inside



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## How much sound do wind turbines produce?

Sound is composed of frequency expressed as hertz (Hz) and pressure level expressed as decibels (dB). Human sensitivity to sound is variable and people will exhibit variable levels of tolerance to different frequencies, including those below the normal range of human hearing[7].

Noise can be defined as any undesirable or unwanted sound. The perception of the noise is influenced by the attitude of the hearer towards the sound source[7]. A recent study found that noise annoyance was strongly associated with a negative attitude to the visual impact of wind turbines on the landscape[2].

Table 1 compares the noise produced by a ten turbine wind farm compared to noise levels from some selected activities.

**Table 1: Noise levels compared to a ten turbine wind farm**

| Activity | Sound pressure level (dBA*) |
|---|---|
| Jet aircraft at 250m | 105 |
| Noise in a busy office | 60 |
| Car travelling at 64kph at 100m | 55 |
| Wind farm (10 turbines) at 350m | 35–45 |
| Quiet bedroom | 35 |
| Background noise in rural area at night | 20–40 |

Based on these figures noise levels from wind turbines have been assessed as "negligible", that is, they appear to be no different to that found in other everyday situations[9]. Further, a survey of all known published results of infrasound from wind turbines found that wind turbines of contemporary design, where rotor blades are in front of the tower, produce very low levels of infrasound[10].

## Are there other features of wind turbines that may have effects on health?

It has been suggested that phenomena such as shadow flicker and blade glint could have effects on health. Shadow flicker describes the flicking on and off of the wind turbine's shadow as the blades rotate[1]. The primary concern with shadow flicker is the potential to cause epileptic seizures. The evidence on shadow flicker does not support a health concern[1].

Blade glint happens when the surface of wind turbine blades reflects the sun's light[11]. All major wind turbine blade manufacturers coat their blades with a low reflectivity treatment which prevents reflective glint from the surface of the blade. The risk of blade glint from modern wind turbines is considered to be very low[11].

There has been some concern about electromagnetic radiation from wind turbines however the closeness of the electrical cables counters the electromagnetic field, as does shielding with metal armour[12].

Concerns regarding the adverse health impacts of wind turbines focus on infrasound, electromagnetic radiation, shadow flicker and blade glint produced by wind turbines, as discussed above. While there is currently no evidence linking these phenomena with adverse health effects, the evidence is limited.

Therefore it is recommended that relevant authorities take a precautionary approach and continue to monitor research outcomes. Complying with standards relating to wind turbine design, manufacture, and site evaluation will minimise any potential impacts of wind turbines on surrounding areas[13].

* The "A" represents a weighting of measured sound to mimic that discernable by the human ear, which does not perceive sound at low and high frequencies to be as loud as mid range frequencies[8].



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Australian Government

National Health and Medical Research Council

# Wind Turbines and Health

A Rapid Review of the Evidence

July 2010

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## Wind Turbines and Health – A Rapid Review of the Evidence

The purpose of this paper is to present findings from a rapid review of the evidence from current literature on the issue of wind turbines and potential impacts on human health. In particular the paper seeks to ascertain if the following statement can be supported by the evidence: *There are no direct pathological effects from wind farms and that any potential impact on humans can be minimised by following existing planning guidelines.* This statement is supported by the 2009 expert review commissioned by the American and Canadian Wind Energy Associations (Colby et al. 2009).

### Context

In Australia, since the legislation of the *Renewable Energy (Electricity) Act* in 2000, wind power has been gaining prominence as a viable sustainable alternative to more traditional forms of energy production. Studies have found that there is increasing population demand for 'green' energy and that people are willing to pay a premium for renewable energy (Chatham-Kent Public Health Unit, 2008; Pedersen & Persson Waye, 2007). However as with any shift in technology, the emergence of wind farms is not without controversy.

There are two opposing viewpoints regarding wind turbines and their potential effect on human health. It is important to note that these views are frequently presented by groups or people with vested interests. For example, wind energy associations purport that there is no evidence linking wind turbines to human health concerns. Conversely, individuals or groups who oppose the development of wind farms contend that wind turbines can adversely impact the health of individuals living in proximity to wind farms.

Concerns regarding the adverse health impacts of wind turbines focus on the effects of infrasound, noise, electromagnetic interference, shadow flicker and blade glint produced by wind turbines. Does the evidence support these concerns?

### Sound and Noise from Wind Turbines

Sound is composed of frequency expressed as hertz (Hz) and pressure expressed as decibels (dB). In terms of frequency sound can be categorised as audible and inaudible. Infrasound is commonly defined as sound which is inaudible to the human ear (below 16 Hz). Despite this commonly used definition, infrasound can be audible (EPHC, 2009). There is often confusion regarding the boundary between infrasound and low frequency noise (Leventhall, 2006). Human sensitivity to sound, especially to low frequency sound, is variable and people will exhibit variable levels of tolerance to different frequencies (Minnesota Department of Health, 2009).

Noise can be defined as any undesirable or unwanted sound. The perception of the noise is also influenced by the attitude of the hearer towards the sound source. This is sometimes called the nocebo effect, which is the opposite of the better known placebo effect. If people have been preconditioned to hold negative opinions about a noise source, they are more likely to be affected by it (AusWEA, 2004).

Wind turbines produce noise that can be classified into the following categories:

1. Mechanical noise which is produced from the motor or gearbox; if functioning correctly, mechanical noise from modern wind turbines should not be an issue.
2. Aerodynamic noise which is produced by wind passing over the blade of the wind turbine (Minnesota Department of Health, 2009).

As well as the general audible range of sound emissions, wind turbines also produce noise that includes a range of Special Audible Characteristics (SACs) such as amplitude modulation, impulsivity, low frequency noise and tonality (EPHC, 2009).

Table 1 compares the noise produced by a ten turbine wind farm compared to noise levels from some selected activities.

| **Activity** | **Sound pressure level (dBA)**[1] |
|---|---|
| Jet aircraft at 250m | 105 |
| Noise in a busy office | 60 |
| Car travelling at 64kph at 100m | 55 |
| **Wind farm (10 turbines) at 350m** | **35-45** |
| Quiet bedroom | 35 |
| Background noise in rural area at night | 20-40 |

Table 1: Noise levels compared to ten turbine wind farm (SDC, 2005).

Macintosh and Downie (2006) conclude that based on these figures "noise pollution generated by wind turbines is negligible".

One of the most common assertions regarding potential adverse noise impacts of wind turbines is concerned with low frequency noise and infrasound. It should be noted that infrasound is constantly present in the environment and is caused by various sources such as ambient air turbulence, ventilation units, ocean waves, distant explosions, volcanic eruptions, traffic, aircraft and other machinery (Rogers, Manwell & Wright, 2006). In relation to wind turbines, Leventhall (2006) concludes that there is insignificant infrasound generated by wind turbines and that there is normally little low frequency noise. A survey of all known published results of infrasound from wind turbines found that wind turbines of contemporary design, where rotor blades are in front of the tower, produce very low levels of infrasound (Jakobsen, 2005). Another recent report concludes that wind farm noise does not have significant low-frequency or infrasound components (Ministry of the Environment, 2007). As discussed in further detail below the principal human response to audible infrasound is annoyance (Rogers, 2006).

**Effects of Noise from Wind Turbines on Human Health**

The health and well-being effects of noise on people can be classified into three broad categories:

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[1] The "A" represents a weighting of measured sound to mimic that discernable by the human ear, which does not perceive sound at low and high frequencies to be as loud as mid range frequencies (AusWEA, nd. a).

1. subjective effects including annoyance, nuisance and dissatisfaction;
2. interference with activities such as speech, sleep and learning; and
3. physiological effects such as anxiety, tinnitus or hearing loss (Rogers, Manwell & Wright, 2006).

Several commentators argue that noise from wind turbines only produces effects in the first two categories (Rogers, 2006; Pedersen & Persson Waye, 2007).

Various studies of wind turbine effects on health have concentrated on the self-reported perception of annoyance. There are difficulties with measuring and quantifying subjective effects of noise such as annoyance. According to the World Health Organization (WHO) (1999) annoyance is an adverse health effect, though this is not universally accepted. Kalveram proposes that annoyance is not a direct health effect but an indication that a person's capacity to cope is under threat. The person has to resolve the threat or their coping capacity is undermined, leading to stress related health effects (Kalveram 2000). Some people are very annoyed at quite low levels of noise, whilst other are not annoyed by high levels.

It has been suggested that if people are worried about their health they may become anxious, causing stress related illnesses. These are genuine health effects arising from their worry, which arises from the wind turbine, even though the turbine may not objectively be a risk to health (Chapman 2010). The measurement of health effects attributable to wind turbines is therefore very complex.

One study of wind turbine noise and annoyance found that no adverse health effects other than annoyance could be directly correlated with noise from wind turbines. The authors concluded that reported sleep difficulties, as well as feelings of uneasiness, associated with noise annoyance could be an effect of the exposure to noise, although it could just as well be that respondents with sleeping difficulties more easily appraised the noise as annoying (Pedersen & Persson Waye, 2007).

Many factors can influence the way noise from wind turbines is perceived. The aforementioned study also found that being able to see wind turbines from one's residence increased not just the odds of perceiving the sound, but also the odds of being annoyed, suggesting a multimodal effect of the audible and visual exposure from the same source leading to an enhancement of the negative appraisal of the noise by the visual stimuli (Pedersen & Persson Waye, 2007). Another study of residents living in the vicinity of wind farms in the Netherlands found that annoyance was strongly correlated with a negative attitude toward the visual impact of wind turbines on the landscape. The study also concluded that people who benefit economically from wind turbines were less likely to report noise annoyance, despite exposure to similar sound levels as those people who were not economically benefiting (Pedersen et al, 2009).

In addition to audible noise, concerns have been raised about infrasound from wind farms and health effects. It has been noted that the effects of low frequency infrasound (less than 20Hz) on humans are not well understood (NRC, 2007). However, as discussed above, several authors have suggested that low level frequency noise or infrasound emitted by wind turbines is minimal and of no consequence (Leventhall, 2006; Jakobsen, 2005). Further, numerous reports have concluded that there is no evidence of health effects arising from infrasound or low frequency noise generated by wind turbines (DTI, 2006; CanWEA, 2009; Chatham-Kent Public Health Unit, 2008; WHO, 2004; EPHC, 2009; HGC Engineering, 2007). In summary:

- 'There is no reliable evidence that infrasounds below the hearing threshold produce physiological or psychological effects' (Berglund & Lindvall 1995).

- Infrasound associated with modern wind turbines is not a source which will result in noise levels which may be injurious to the health of a wind farm neighbour (DTI, 2006).

- Findings clearly show that there is no peer-reviewed scientific evidence indicating that wind turbines have an adverse impact on human health (CanWEA, 2009).

- Sound from wind turbines does not pose a risk of hearing loss or any other adverse health effects in humans. Subaudible, low frequency sounds and infrasound from wind turbines do not present a risk to human health (Colby, et al 2009).

- The Chatham-Kent Public Health Unit (Ontario, Canada) reviewed the current literature regarding the known health impacts of wind turbines in order to make an evidence-based decision. Their report concluded that current evidence failed to demonstrate a health concern associated with wind turbines. 'In summary, as long as the Ministry of Environment Guidelines for location criteria of wind farms are followed … there will be negligible adverse health impacts on Chatham-Kent citizens. Although opposition to wind farms on aesthetic grounds is a legitimate point of view, opposition to wind farms on the basis of potential adverse health consequences is not justified by the evidence' (Chatham-Kent Public Health Unit, 2008).

- Wind energy is associated with fewer health effects than other forms of traditional energy generation and in fact will have positive health benefits (WHO, 2004).

- 'There are, at present, very few published and scientifically-validated cases of an SACs of wind farm noise emission being problematic … the extent of reliable published material does not, at this stage, warrant inclusion of SACs … into the noise impact assessment planning stage (EPHC, 2009).

- While a great deal of discussion about infrasound in connection with wind turbine generators exists in the media there is no verifiable evidence for infrasound and production by modern turbines (HGC Engineering, 2007).

The opposing view is that noise from wind turbines produces a cluster of symptoms which has been termed Wind Turbine Syndrome (WTS). The main proponent of WTS is a US based paediatrician, Dr Pierpont, who has released a book 'Wind Turbine Syndrome: A report on a Natural Experiment, presents case studies explaining WTS symptoms in relation to infrasound and low frequency noise. Dr Pierpont's assertions are yet to be published in a peer-reviewed journal, and have been heavily criticised by acoustic specialists. Based on current evidence, it can be concluded that wind turbines do not pose a threat to health if planning guidelines are followed.

### Shadow Flicker and Blade Glint

Shadow flicker occurs when the sun is located behind a wind turbine casting a shadow that appears to flick on and off as the wind turbine blades rotate (Chatham-Kent Public health Unit, 2008). It is possible to use modelling software to model shadow flicker before the finalisation of a wind farm layout and siting.

Blade glint occurs when the surface of wind turbine blades reflect the sun's light and has the potential to annoy people (EPHC, 2009).

### Effects of Shadow Flicker and Blade Glint on Human Health

Shadow flicker from wind turbines that interrupts sunlight at flash frequencies greater than 3Hz has the potential to provoke photosensitive seizures (Harding, Harding & Wilkins, 2008). As such it is recommended that to circumvent potential health effects of shadow flicker wind turbines should only be installed if flicker frequency remains below 2.5 Hz under all conditions (Harding, Harding & Wilkins, 2008).

According to the EPHC (2009) there is negligible risk of seizures being caused by modern wind turbines for the following reasons:

- less than 0.5% of the population are subject to epilepsy at any one time, and of these, approximately 5% are susceptible to strobing light;
- Most commonly (96% of the time), those that are susceptible to strobe lighting are affected by frequencies in excess of 8 Hz and the remainder are affected by frequencies in excess of 2.5 Hz. Conventional horizontal axis wind turbines cause shadow flicker at frequencies of around 1 Hz or less;
- alignment of three or more conventional horizontal axis wind turbines could cause shadow flicker frequencies in excess of 2.5 Hz; however, this would require a particularly unlikely turbine configuration.

In summary, the evidence on shadow flicker does not support a health concern (Chatham-Kent Public Health Unit, 2008) as the chance of conventional horizontal axis wind turbines causing an epileptic seizure for an individual experiencing shadow flicker is less than 1 in 10 million (EPHC, 2009). As with noise, the main impact associated with shadow flicker from wind turbines is annoyance.

In regards to blade glint, manufacturers of all major wind turbine blades coat their blades with a low reflectivity treatment which prevents reflective glint from the surface of the blade. According to the Environment Protection and Heritage Council (EPHC) the risk of blade glint from modern wind turbines is considered to be very low (EPHC, 2009).

### Electromagnetic Radiation and Interference

Electromagnetic radiation (EMR) is a wavelike pattern of electric and magnetic energy moving together. Types of EMR include X-rays, ultraviolet, visible light, infrared and radio waves (AusWEA, nd. b).

Electromagnetic interference (EMI) from wind turbines may affect electromagnetic or radiocommunication signals including broadcast radio and television, mobile phones and radar (EPHC, 2009).

As high and exposed sites are best from a wind resource perspective, it is not unusual for any of a range of telecommunications installations, radio and television masts, mobile phone base stations or emergency service radio masts to be located nearby. Care must be taken to ensure that wind turbines do not passively interfere with these facilities by directly obstructing, reflecting or refracting their radio frequency EMR signals.

**Effects of Electromagnetic Radiation and Interference from Wind Turbines on Human Health**

Electromagnetic Fields (EMF) emanate from any wire carrying electricity and Australians are routinely exposed to these fields in their everyday lives. The electromagnetic fields produced by the generation and export of electricity from a wind farm do not pose a threat to public health (Windrush Energy 2004). The closeness of the electrical cables between wind turbine generators to each other, and shielding with metal armour effectively eliminate any EMF (AusWEA, nd. b).

**Measures to Mitigate Potential Impacts of Wind Turbines**

As with the introduction of any new technology, some communities are against wind farms being located in their area. Some factors which may increase community concern include coerced or unequal exposure, industrial, exotic and/or memorable nature of the turbine, dreaded, unknown or catastrophic consequences, substantial media attention, potential for collective action and a process which is unresponsive to the community. Voluntary exposure, for example choosing to house the turbine on community land, reduces concern (Adapted by Professor Chapman from Covello et al. methodology 1986).

One review of wind turbines and noise recommends that best practice guidelines such as those identifying potential receptors of turbine noise, following established setbacks and dispelling rumours regarding infrasound which have not been supported by research, are followed in order to mitigate any potential noise issues associated with wind turbines (Howe, 2007).

Sustainable Energy Authority Victoria (2003) also recommend that complying with standards relating to turbine design and manufacturing, site evaluation and final siting of wind turbines will minimise any potential impacts on the surrounding area.

The recently released Draft National Wind Farm Development Guidelines (EPHC, 2009) include detailed methodologies at different stages of the planning and development process to assess such issues as noise and shadow flicker to mitigate any potential impact. Such processes include a range of measures such as high-level risk assessment, data collection, impact assessment, detailed technical studies and public consultation.

Therefore if planning guidelines are followed and communities are consulted with in a meaningful way, resistance to wind farms is likely to be reduced and annoyance and related health effects avoided.

## Conclusion

The health effects of many forms of renewable energy generation, such as wind farms, have not been assessed to the same extent as those from traditional sources. However, renewable energy generation is associated with few adverse health effects compared with the well documented health burdens of polluting forms of electricity generation (Markandya & Wilkinson, 2007).

This review of the available evidence, including journal articles, surveys, literature reviews and government reports, supports the statement that: *There are no direct pathological effects from wind farms and that any potential impact on humans can be minimised by following existing planning guidelines.*

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# Wind Turbine Syndrome

**Testimony before the New York State Legislature Energy Committee**

**March 7, 2006**


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I am here to talk to you today as a physician-scientist about a clinical phenomenon called Wind Turbine Syndrome. This is relevant to today's hearing because it critically affects implementation of the RPS (Renewable Portfolio Standard) in terms of the siting of industrial wind turbines. Current siting practices (which are solely industry-driven) disregard public health. The supervision of the legislature—of this committee—is needed to create siting standards to protect the citizenry, all the citizenry, including citizens who are rural, old, ill, impaired, and very young.

Federal agencies are trying to put the brakes on willy-nilly wind turbine construction, citing, for instance, wildlife issues. The GAO (Government Accountability Office) last fall told US Fish and Wildlife to get involved. The National Academy of Sciences in April 2005 initiated a 20-month study on environmental impacts whose final report is due in December this year. There also needs to be a focus on human health, and the state needs to step up to the plate in terms of regulation.

I live in Franklin County, the poorest in NY State. Two years ago, after passage of the RPS, wind energy companies showed up there in force, as they have in all the poor, rural parts of the state. They showed up with no controls whatsoever, unregulated by either the legislature or NYSERDA (New York State Energy Research & Development Authority). Our town boards, made up of farmers, teachers, corrections officers, etc., were told, "You guys handle this," by our state representatives. I got involved as a responsible citizen and physician. Over the last 1½ years I have done a lot of reading, research, and interviews. I have spoken at town board meetings and before the St. Lawrence County Legislature, and published alone or with my husband (a retired university professor) numerous editorials and letters to the editor in local newspapers. My focus has been health issues and to some degree wildlife, in which I also have credentials in my PhD.

I get a lot of slander and abuse from the wind salesmen. Their favorites are saying that my abundantly referenced and footnoted articles, like the one before you (note: a separate handout), have "no evidence," or that I think wind turbines cause mad cow disease. The latter smear came from a town meeting in Ellenburg, NY, in October 2004, when I presented information culled from the medical literature on possible effects of low frequency noise. This included a paper out of the UK linking low frequency sound to prion diseases by a complex and highly speculative mechanism. I was very clear how speculative it was, but apparently the concept of something being speculative was over their heads, including over the heads of wind salesmen in the room.

I am not for or against the RPS. I'm an intelligent person and I support renewable energy. I am not here to shoot down wind energy, which probably has its place, though that place is not near people's homes or near schools, hospitals, or other locations where people have to sleep or learn.

I would like to stress that these are not "farms." One doesn't "farm" wind any more than one "farms" water in a hydroelectric dam or "farms" neutrons in an atomic plant. These are large, industrial installations. They make large-scale, industrial noise. "Jet engines" is the most common description I hear in surveying people—a jet engine that doesn't go away and which you can't get used to.

A syndrome in medicine is a constellation of symptoms and findings which is consistent from person to person. Defining a syndrome is the first step in investigating any new disease. The symptom cluster has to make sense in terms of pathophysiology—there has to be a plausible mechanism in terms of how the body and brain work. Defining a syndrome, and making that knowledge available to the medical community, lets other doctors go from scratching their heads over weird presentations of illness which are coming through their offices, to being able to validate and name what is going on and start to do something about it. It also opens the door to epidemiologic studies to define prevalence and risk factors, which will guide prevention and treatment.

Describing and documenting symptoms is the province of physicians. So is research on the causes of diseases. Deciding whether people have significant symptoms is not within the expertise of engineers or specialists in acoustics, even when the symptoms appear to be caused by noise. We physicians appreciate the noise data which engineers provide, but this data has nothing to do with whether people have symptoms or not. One British acoustics expert, Dr. Geoff Leventhall, is especially outrageous in this regard, insisting that people "can't" have symptoms because turbines "don't," he says, produce low frequency noise. His fallback, for which he is well paid by the industry, is that people make up their complaints. But he's not trained to distinguish whether people are making up their complaints, or to know about the range of physical, psychiatric, and neurological symptoms people might have. A related point: the hallmark of a good doctor is one who takes symptoms seriously and pursues them until they are understood (and ameliorated). This includes symptoms related to the brain, our most complex organ—symptoms which may be neurologic, psychiatric, or physical.

Three doctors that I know of are studying the Wind Turbine Syndrome: myself, one in England, and one in Australia. We note the same sets of symptoms. The symptoms start when local turbines go into operation and resolve when the turbines are off or when the person is out of the area. The symptoms include:

1) Sleep problems: noise or physical sensations of pulsation or pressure make it hard to go to sleep and cause frequent awakening.
2) Headaches which are increased in frequency or severity.
3) Dizziness, unsteadiness, and nausea.
4) Exhaustion, anxiety, anger, irritability, and depression.
5) Problems with concentration and learning.
6) Tinnitus (ringing in the ears).

Not everyone near turbines has these symptoms. This does not mean people are making them up; it means there are differences among people in susceptibility. These differences are known as risk factors. Defining risk factors and the proportion of people who get symptoms is the role of epidemiologic studies. These studies are under way.

Chronic sleep disturbance is the most common symptom. Exhaustion, mood problems, and problems with concentration and learning are natural outcomes of poor sleep.

Sensitivity to low frequency vibration is a risk factor. Contrary to assertions of the wind industry, some people feel disturbing amounts of vibration or pulsation from wind turbines, and can count in their bodies, especially their chests, the beats of the blades passing the towers, even when they can't hear or see them. Sensitivity to low frequency vibration in the body or ears is highly variable in people, and hence poorly understood and the subject of much debate.

Another risk factor is a preexisting migraine disorder. Migraine is not just a bad headache; it's a complex neurologic phenomenon which affects the visual, hearing, and balance systems, and can even affect motor control and consciousness itself. Many people with migraine disorder have increased sensitivity to noise and to motion—they get carsick as youngsters, and seasick, and very sick on carnival rides. Migraine-associated vertigo (which is the spinning type of dizziness, often with nausea) is a described medical entity. Migraine occurs in 12% of Americans. It is a common, familial, inherited condition.

To keep our balance and feel steady in space, we use three types of input: from our eyes (seeing where we are in space), from stretch receptors in joints and muscles, and from balance organs in the inner ear. At least two of these systems have to be working, and agreeing, to maintain balance. If the systems don't agree, as in seasickness or vertigo, one feels both ill and unsteady. Wind turbines impinge on this system in two ways: by the visual disturbance of the moving blades and shadows, and by noise or vibration impacting the inner ear.

Other candidate risk factors for susceptibility to Wind Turbine Syndrome are age-related changes in the inner ear. Five percent (5%) of otherwise healthy people from age 57 to 91 experience dizziness, and 24% experience tinnitus or ringing. Damage to the ears or hearing from other causes, such as noise exposure, is also a potential risk factor.

Inner ear organs are closely linked, by proven neurological connections, to the brain systems which control mood, anxiety, and one's sense of well-being. Disturbing the inner ear disturbs mood, not because a person is a whiner or doesn't like turbines, but because of neurology.

Data from a number of studies and individual cases document that in rolling terrain, disturbing symptoms of the Wind Turbine Syndrome occur up to 1.2 miles from the closest turbine. In long Appalachian valleys, with turbines on ridge-tops, disturbing symptoms occur up to 1.5 miles away. In New Zealand, which is more mountainous, disturbing symptoms occur up to 1.9 miles away.

In New York State, with its mixed terrain, I recommend a setback of 1.5 miles (8000 ft.) between all industrial wind turbines and people's homes or schools, hospitals, or similar institutions. This setback should be imposed immediately for turbines not yet built.

The legislature might want to set up a panel of clinicians to review the data and medical information I refer to here, but until this happens, and as research continues, a moratorium on all wind turbine construction within 1.5 miles of homes would be appropriate.

**To recapitulate, there is in fact a consistent cluster of symptoms, the Wind Turbine Syndrome, which occurs in a significant number of people in the vicinity of industrial wind turbines. There are specific risks factors for this syndrome, and people with these risk factors include a substantial portion of the population. A setback of 1.5 miles from homes, schools, hospitals, and similar institutions will probably be adequate, in most NY State terrain, to protect people from the adverse health effects of industrial wind turbines.**

Nina Pierpont, MD PhD

Fellow of the American Academy of Pediatrics

February 8, 2006

Education

| | | |
|---|---|---|
| 1991 | M.D. | The Johns Hopkins University School of Medicine |
| 1985 | Ph.D. | Princeton University (Behavioral Ecology) |
| 1981 | M.A. | Princeton University (Behavioral Ecology) |
| 1977 | B.A. | Yale University, National Merit Scholar (cum laude) |

Post-Doctoral Training

| | | |
|---|---|---|
| 1992 to 94 | Pediatrics | Dartmouth-Hitchcock Medical Center, Lebanon, NH |
| 1991 to 92 | Pediatrics | Children's National Medical Center, Washington, DC |
| 1985 to 86 | Ornithology | American Museum of Natural History, New York, NY |

Licensure and Certification

| | |
|---|---|
| 1997 | Licensed Physician, New York |
| 1997 | Licensed Physician, New Hampshire (expired) |
| 1995 | Pediatric Advanced Life Support Instructor and Affiliate Faculty |
| 1994 | Diplomate, American Board of Pediatrics (recertified 2000, expires 2008) |
| 1994 | Licensed Physician, Alaska (expired) |

Hospital or Affiliated Institution Appointments

| | |
|---|---|
| 10/00 to 12/03 | Senior Attending in Pediatrics   Bassett Healthcare, Cooperstown, NY |
| 1997 to 00 | Attending Pediatrician   Alice Hyde Hospital, Malone, NY |
| 1995 to 96 | Chief of Pediatrics   Yukon-Kuskokwim (Yup'ik Eskimo) Delta Regional Hospital, Bethel, AK |
| 1994 to 95 | Staff Pediatrician   Yukon-Kuskokwim (Yup'ik Eskimo) Delta Regional Hospital, Bethel, AK |

Other Professional Positions

| | |
|---|---|
| 2004 to ... | Private Practice (Solo) Pediatrics (emphasizing Behavioral Peds)   Malone, NY |
| 1998 to 00 | Private Practice (Solo) Pediatrics   Malone, NY (poorest county in state) |
| 1997 to 00 | Staff Pediatrician   St. Regis Mohawk (Iroquois) Health Services, Hogansburg, NY |
| 1997 to 98 | Staff Pediatrician   North Country Children's Clinic (clinic for needy children), Malone, NY |

Academic Appointments

| | |
|---|---|
| 2000 to 03 | Assistant Clinical Professor of Pediatrics<br>Columbia University, College of Physicians and Surgeons |

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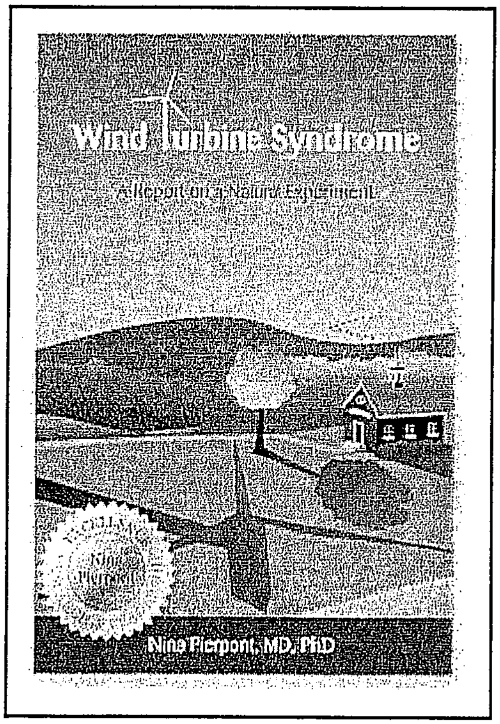


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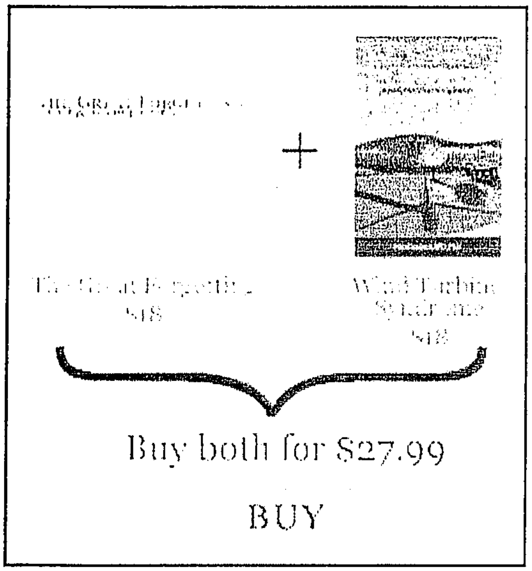


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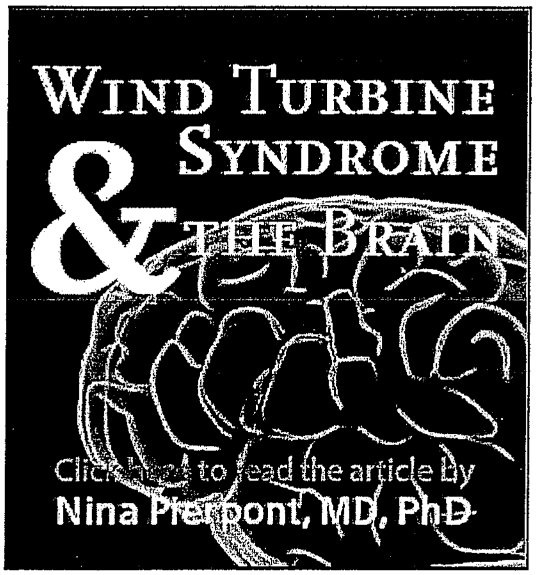


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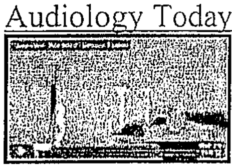
  - 

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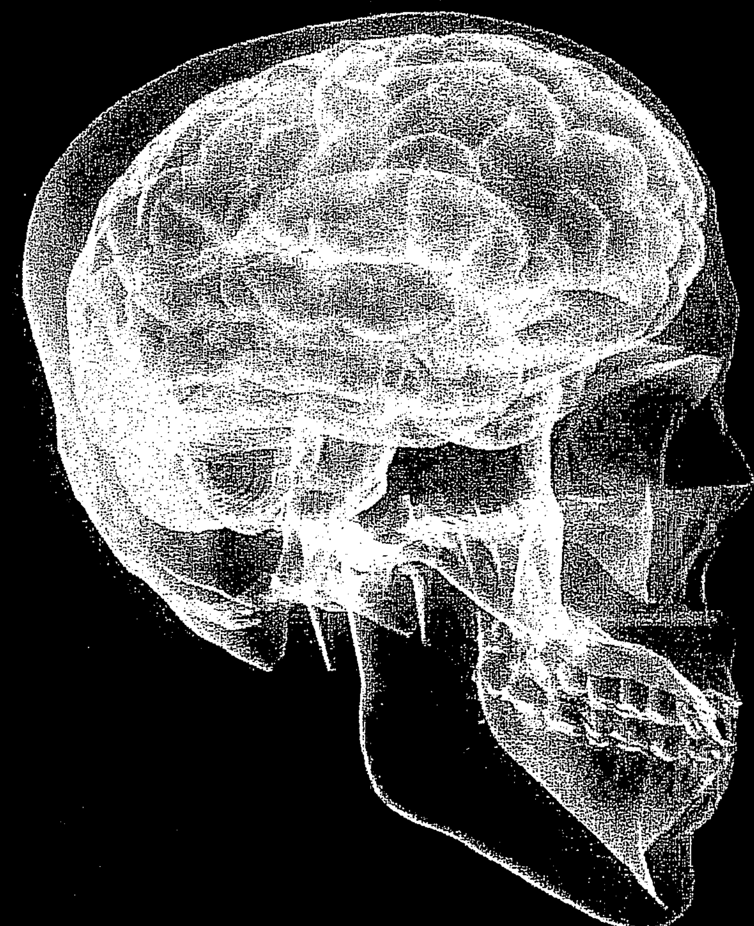
# Wind Turbine Syndrome & the Brain

Nina Pierpont, MD, PhD
November 15, 2010



*The following is the text of Pierpont's keynote address before the "First International Symposium on the Global Wind Industry and Adverse Health Effects: Loss of Social Justice?" in Picton, Ontario, Canada, October 30, 2010. It is followed by a discussion of several other relevant talks at the symposium by Drs. Alec Salt, Michael Nissenbaum, Christopher Hanning, and Mr. Richard James.

00001245

## Abstract

The latest research, as discussed below, suggests the following mechanism for Wind Turbine Syndrome: air-borne or body-borne low-frequency sound directly stimulates the inner ear, with physiologic responses of both cochlea (hearing organ) and otolith organs (saccule and utricle—organs of balance and motion detection).

Research has now proved conclusively that physiologic responses in the cochlea suppress the hearing response to low-frequency sound but still send signals to the brain, signals whose function is, at present, mostly unknown. The physiologic response of the cochlea to turbine noise is also a trigger for tinnitus and the brain-cell-level reorganization that tinnitus represents—reorganization that can have an impact on language processing and the profound learning processes related to language processing.

New research also demonstrates that the "motion-detecting" otolith organs of mammals also respond to air-borne low-frequency sound. Physiologic responses and signals from the otolith organs are known to generate a wide range of brain responses, including dizziness and nausea (seasickness, even without the movement), fear and alerting (startle, wakefulness), and difficulties with visually-based problem-solving.

Increased alerting in the presence of wind turbine noise disturbs sleep, even when people do not recall being awakened. A population-level survey in Maine now shows clear disturbances of sleep and mental well-being out to 1400 m (4600 ft) from turbines, with diminishing effects out to 5 km (3 miles).

## Sensory systems change brain functioning

I confess I have an odd medical practice. I'm a pediatrician by training, but I'm fascinated by brains and development, and essentially practice psychiatry and child development. I'm interested in how to help children's brains grow well, and, at the other end of the spectrum, in what derails normal brain functioning in normal people—like Wind Turbine Syndrome—and how to get that functioning back on track.

So much of brain function is about the sensory systems—vision, hearing, touch—and what the brain does to take basic sensory signals from all over the body and turn them into a coherent picture of where this particular creature—oneself—is at this particular time, and what needs to happen next to meet its needs. Those needs range from the basic and physiologic—like breathing and pumping blood in the right amounts to the different parts of the body—to complex social and language-based needs, like figuring out what your spouse really meant by that last thing he said. Our sensory systems mediate all of these needs.

Sensory systems change brain functioning. They affect not only what a person or animal feels or thinks at that very moment, but also how that brain will function in the future, even the near future. This is called neuroplasticity, the neural basis of learning, for which Eric Kandel won the Nobel prize in 2000.[1]

4600' out
to 3 miles

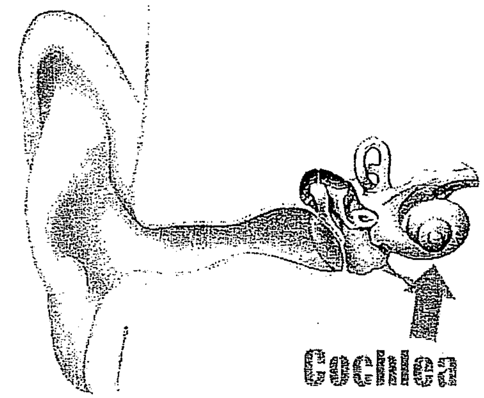
00001246

# Tinnitus:
## The brain makes up sound where no sound exists

Take, for example, tinnitus, or ringing in the ears—an important sensory problem in Wind Turbine Syndrome. Ringing, buzzing, sizzling, or waterfall noises—my study subjects described all of these, sometimes in the head as well as the ears.

58% of the adults and older teens in my sample of affected families had tinnitus. In the general population, it's 4%. People with a prior history of hearing loss or industrial noise exposure were especially likely to get tinnitus, but other people in the study also got it, without these risk factors.

Among people with tinnitus in general, many have damage to their cochlea, the snail-shaped organ of hearing in the inner ear. Because of this damage, many researchers have heretofore thought that tinnitus originates in the cochlea as distorted hearing signals—the cochlea being somehow able to produce nerve signals of sound without the sound being there in the environment.




We are now getting quite a different picture of tinnitus. People with auditory nerves (meaning the nerve from the cochlea to the brain) that have been completely cut (for example, because of a tumor on the nerve) also have tinnitus, although, again, there is no input from the cochlea to the brain at all.

Recently, functional imaging studies (like MRI or PET scans) of people with tinnitus have supported the idea that tinnitus arises not in the ear, but in the parts of the brain that process sound. The trigger is an absence of input from the cochlea or parts of the cochlea. Essentially, your brain makes up sound where no sound exists.

It's like phantom pain that people get when they have lost a limb. There is no nerve input from the limb because it's gone; nevertheless, the person experiences the limb hurting.

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The NEW ENGLAND JOURNAL of MEDICINE

Tinnitus is like this—it's phantom noise. It can be an excruciating and unpleasant sensation.

This type of change in the brain (like what happens with tinnitus) happens quickly. We learn this from a journal as unimpeachable as the *New England Journal of Medicine*, the gold standard in America for medical research. Describing the pathophysiology of tinnitus, a review article published in 2002 stated:

> Hearing loss leads to a reorganization of the pathways in the central [brain] auditory system. These changes may occur rapidly and lead to abnormal interactions between auditory and other central [brain] pathways.[2]

What's happening here is that the cells in the brain are making new connections, not good connections. It's like chaos in the brain, and the result is hearing a noise that isn't really there.

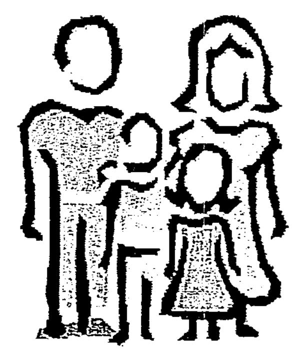
## Wind Turbine Syndrome & tinnitus

Now listen to this story from *Wind Turbine Syndrome*.[3] A real Canadian family, family A in my study. We'll call them the Smiths. We'll call them Frank, Marlene, and their 2½ year old boy, Justin.

3,300'

Frank, age 32, is a healthy fisherman who owns his own boat. Turbines, 10 in a row pointing at the house, the closest 1 km away, go online. For the first three weeks, Frank has repetitive popping in his ears, like pressure changes. After three weeks, a continuous headache starts whenever he's at home. It resolves after several hours every time he leaves the house, and comes back within several hours of coming home. Several weeks after the headache started, tinnitus starts and worsens over the duration of the 5-month exposure, until the family abandoned their home and rented a house in town.

Marlene, his wife, a 33-year-old accountant, likewise noticed repetitive popping in her ears for the first three weeks. She also noticed she couldn't hear as well as before. After three weeks, the tinnitus began. The tinnitus continued and worsened over time during the 5 months of exposure, varying according to how much she was at home and how loud the turbines were. After the exposure ended, she told me, the tinnitus resolved, but she noticed a new difficulty understanding conversation in a noisy room. She noticed she had to watch the speaker's face more closely.



During exposure, young Justin, a healthy 2½-year-old, pulled on his ears and got cranky at the same times that adults in the family noticed more headache and tinnitus. His language development was good before, during, and after exposure, but his mother noticed during exposure that the child began to confuse T with K sounds and W with L sounds, which he had not done before. This sound confusion was ongoing six weeks after exposure ended, when I interviewed the parents.

Let's match the research to the clinical account—match medical science to this real family. These two adults experienced pressure changes in their ears for some weeks, one with some loss of hearing. They then developed tinnitus. The tinnitus resolved when the noise exposure ended, but Marlene still noticed subtle differences in her own auditory processing and in her child's, Justin's.

Picking out one voice against background noise is an example of brain (or central) auditory processing, which means how your brain takes signals coming from your ears and puts them together into language, music, the song of a hermit thrush, or other recognizable and meaningful sounds.

To pick out one sound from background noise, your brain processes simultaneous signals from both ears, integrating the signals into a new type of perception that transcends what either ear can do alone. (It's sort of like depth perception with two eyes.)

Hearing in background noise is one aspect of brain auditory processing, and one that audiologists often test. Distinguishing language sounds is another critical part of how the brain processes sound, especially for children learning language.

So, what do we have? We have the *New England Journal* telling us that auditory pathways in the brain reorganize rapidly when there are deficits in the input from the ears, producing tinnitus. (Let's not ignore that this "reorganization" represents deterioration in function—not an improvement. Contrast this to the process of brain organization that occurs as a child learns language.) We have this research on the one hand, and on the other, younger healthy adults telling us their observations of their own hearing and hearing-related processes as they passed through a substantial bout of noise exposure.

Marlene described the noise, by the way, as, "Not noisy like a chainsaw; more like pulsating annoyance. To another person it wouldn't sound loud."

I suspect that in a child as young as Justin, 2½, who was removed from exposure so quickly, this process is entirely reversible. But such effects are less likely to be reversible with older age or longer exposure. That's a basic principle of how brains develop.

NOISE EXPOSURE, EVEN AT RELATIVELY LOW SOUND LEVELS, FOULS UP THE PARTS OF THE BRAIN RESPONSIBLE FOR FIGURING OUT LANGUAGE SOUNDS, AND THE PARTS RESPONSIBLE FOR UNDERSTANDING AND LEARNING AND REMEMBERING THINGS WE HEAR OR READ

I'm basing this interpretation of the Smith's experience on the tinnitus research and also on another area of research—on the effects of other types of environmental noise (like airport or traffic noise) on children's learning.

Learning to read is a language-intensive process that is especially sensitive to the effects of noise in school or at home. This effect is distinct from the effects of noise on attention or working memory,[4] and is correlated with measures of sound processing such as speech recognition.[5]

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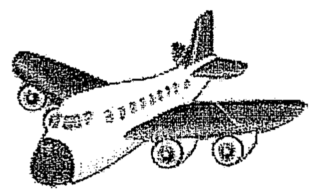
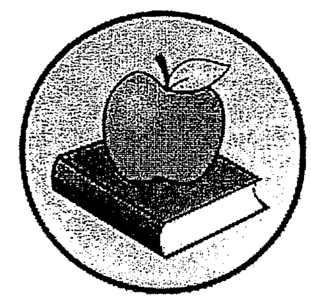


In one study, for example, a German city closed an old airport and built a new one. Researchers had the opportunity to follow the reading skills of both sets of children over time. Those living near the airport that closed showed improvement in their reading. The ones near the new airport slowed down in their learning after the airport opened.[6]

Another study looked at the effects of noise on both reading and auditory processing in children who lived in an apartment building next to a busy highway. Auditory processing, again, is what your brain does with the signals from your ears to turn them into meaningful language or other sounds.

The higher the children lived in the building, the quieter were their apartments and the better their reading and auditory discrimination scores, which means, for example, distinguishing the word *goat* from *boat*. The study factored out the effects of parent education and income, and then found that children exposed to more noise were more delayed in their reading. The amount of delay in reading was explained by how badly the children were doing distinguishing language sounds from each other, which also worsened with more noise.[7]

In other words, the presence of noise in the environment degraded how these children's brains processed language sounds, which in turn degraded their ability to learn to read. It wasn't that the noise just kept them from hearing things they needed to learn; the noise actually harmed their brain's ability to process language, even when that language was coming in through their eyes, as it does when we read.



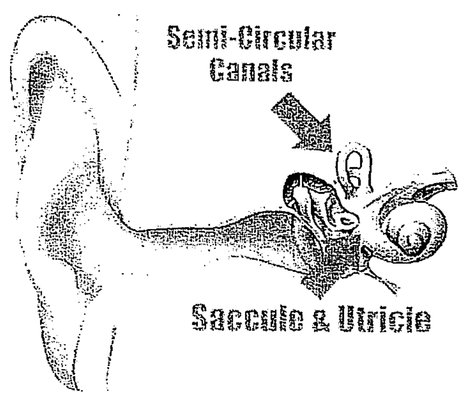
Moreover, these effects of noise on reading occur at sound levels far less than those needed to produce hearing damage.[8] Children at higher grade levels are more affected, and longer exposure produces larger deficits, other studies have shown.[9]

In my wind turbine study, 7 out of the 10 school-age children and teens did worse in school during exposure to turbines, compared to before or after, including unexpected problems in reading, math, concentration, and test performance, noticed by both teachers and parents. Teachers sent notes home asking what was wrong with the children.

Subtle as these effects are, they have serious implications. Noise exposure, even at relatively low sound levels, fouls up the parts of the brain responsible for figuring out language sounds (what we call language processing) and the parts responsible for understanding and learning and remembering things we hear or read (what we call language-based learning).

Let me emphasize: Noise exposure, even at low levels that don't damage hearing, can do this.

## The Balance Organs: A protean presence in the brain, in terms of what types of sensations they draw on and how the information is used by the brain

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There is another set of organs in the inner ear, the organs of balance (called the vestibular organs), consisting of the utricle and saccule (the two otolith or "ear rock" organs, where microscopic stones control our perception of

vestibular organs

gravity and movement in a straight line) and the semicircular canals, which detect rotations of the head in three planes.

The balance system is probably the least well known of all the senses for both the general public and physicians. It's a different kind of sense. It has some dedicated organs (the vestibular organs in the inner ear, just described), but these organs do not function on their own, not without the cooperation (and brain integration) of multiple sensory signals from all over the body.

We use this sense not just for balance (staying upright), but also for telling where we are in space and how fast and in what direction the different parts of our bodies are moving, at all times.

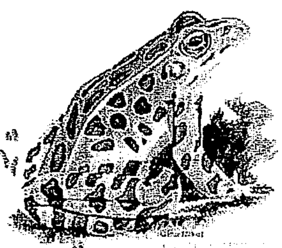
The vestibular sense feeds back instantaneously, for example, on the eye movement muscles and on posture-maintaining muscles in the neck and back. It also adapts to gravity by controlling tension in the arteries and smaller blood vessels all over the body, and how hard the heart is pumping, to keep the blood evenly distributed whether you are standing up, lying down, or standing on your head.

Balance and motion detection requires input from the eyes, from stretch receptors in the muscles and joints all over the body, from touch receptors in the skin, and, it is now known, from stretch and pressure receptors in and around internal organs and the great blood vessels in the chest and abdomen.[10] As well as requiring signals from the inner ear—the utricle, saccule, and semicircular canals.

This is a remarkable feat of brain integration, especially when the signals don't all agree with one another. The brain has to figure out which signals to downweight or ignore if they don't all agree, or if the signals from one channel are distorted.

Even fish have otolith organs and semicircular canals. The cochlea, or specialized hearing organ, evolved later, our type specifically in mammals. The brain essentially grew up, through evolution, with vestibular neurons and signals already in place. As a consequence, our systems for detecting movement, gravity, pressure, and vibration have a protean presence in the brain, going everywhere, both in terms of what types of sensations they draw on, and how the information is used by the brain.

fish & amphibians "noise", "vibration" vs "acoustical effects"



"vestibular pathology" vs brain, cognition & memory

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In fish and amphibians, the otolith organs are much better detectors of low-frequency noise and vibration than are these animals' own versions of sound-detecting organs.[11,12] We now know that even in mice—a mammal—low-frequency, air-borne sound is detected by the otolith organs.[13] In humans, detection of low frequency sound by the otolith organs has been shown only using bone-conducted sound, meaning a source of vibration placed right against the head.

"detect" vs "hear"

At 100 Hz, the tone of a moderately low note on the piano, healthy adults can detect a bone-conducted vibration at 15 dB below their own normal hearing thresholds, probably through the utricle.[14,15] "Detection" in this case means that the vibration triggers an automatic reflex in muscles around the eyes or in the neck, a response that can only be due, we know, to vestibular stimulation.

All this by way of saying that we are getting nearer to understanding the pathophysiological mechanisms causing Wind Turbine Syndrome.

## Wind Turbine Syndrome resembles inner ear pathology witnessed by otolaryngologists

The symptoms of Wind Turbine Syndrome directly mirror the symptom clusters that practicing otolaryngologists have seen for years in patients with balance problems due to vestibular inner ear pathology.[16,17] With vestibular pathology, however, the symptoms are not known to come and go with noise exposure. Very importantly, the symptoms associated with vestibular pathology are not just about balance or dizziness, as I'll review in a moment. Indeed, the symptoms clinically reveal the linkages between the balance-processing parts of the brain, and cognition and memory—linkages only now being described through experiments and functional brain imaging.

Over 90% of my sample of affected people, both adults and children, had cognitive difficulties during wind turbine exposure—problems that lingered and resolved slowly after exposure ended. These included difficulties with reading, math, spelling, writing, multitasking in kitchen and home, remembering a series of errands, maintaining a train of thought in a telephone conversation, following the plot of a TV show, following recipes, and following directions to put together furniture.

distracted concentration & memory

Balance-disordered patients in clinical practice also struggle with short-term memory, concentration, multitasking, arithmetic, and reading. Patients with inner ear fluid leakages, for example, present with symptoms of dizziness, headache, stiff neck, and disturbed sleep, accompanied by marked mental performance deficits compared to baseline.[18]

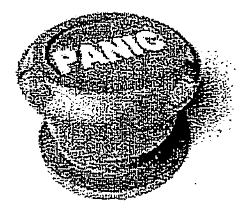
This kind of inner ear leakage can be set off by whiplash injuries, mild head trauma, or pressure trauma to the ear. The fluid leak is associated with an imbalance of fluid pressures in the inner ear, known as endolymphatic hydrops, which distorts both balance and hearing. (Ménière's disease, in which balance and hearing disturbances fluctuate, is endolymphatic hydrops that comes and goes for unknown reasons.)

Tellingly, Dr. Alec Salt, who will speak next on infrasound effects on the inner ear, has discovered experimentally that infrasound exposure causes temporary endolymphatic hydrops.[19] This is a possible mechanism for the balance disturbances, tinnitus, headache, and cognitive problems of Wind Turbine Syndrome.

## The balance system is closely linked to emotions, especially fear, anxiety, and panic

So far, I have talked about how the absence or distortion of *hearing signals* from the inner ear affects thinking and learning at the brain level, and how distortion of *balance signals* from the inner ear affects thinking, memory, and concentration at the brain level. There is one more subject in this cluster of sensory/brain-function linkages, which I would like to discuss.

Symptoms




The balance system is closely linked to emotions, especially fear, anxiety, and panic. When my foot slides on ice under some new snow and I fling my arms out to regain balance, I have a moment of panic. My husband has fear of heights for reasons directly attributable to his brain's style of balance signal integration. I don't, and love to sit on the edge of cliffs over the ocean, watching seabirds.

When he sees me doing this, or if he gets near the edge himself or goes to the top of a tall building, he feels dizzy and nauseated (which are direct balance problem symptoms) and also panicked and irrational—afraid that he or I might fall or even jump off.

(I didn't have a full sense of this until recently, he's so controlled and calm, but now I understand why he doesn't want to take me back to Newfoundland—where there are huge, wonderful seabird cliffs...)

In some studies of balance-anxiety linkages, up to 80% of people with panic disorder have measurable disorders of balance processing. The places where people panic are those in which they "lose their bearings," so to speak, due to distortion of balance signals and their own brains' particular style of dealing with distorted balance signals. Grocery stores have been always a big culprit.

Symptoms

In my wind turbine study, 2/3 of the adult subjects (14 out of 21) experienced a highly disturbing collection of symptoms when exposed to high levels of turbine noise. They felt movement inside their chests, described as quivering, jitteriness, or pulsation, and then an uncomfortable urge to flee—to get out of there. Or, if the feeling awoke them at night, panic, with racing heart, a feeling they could not breathe, or the sense that there just had been an alarming noise—like a window breaking—and that they had to get up to check the house.

## Wind Turbine Syndrome panic symptoms linked to previous history of motion sensitivity

None of these people had had panic attacks in their lives before. Several had histories of anxiety or depression, but altogether, among all the adults in the study, a previous mental health problem was not significantly associated with the presence of this panic symptom. What was associated with the panic symptom, with a highly significant statistical relationship, was a previous history of motion sensitivity.

Even a tough cowboy from Missouri, a welder who raises horses, had this symptom awakening him at night near turbines. Once he and his family moved into town, he slept like a baby. No more panic awakening. (It was his wife who had to tell me about it, however.) Even the physician in my study had this symptom. Toddlers and preschool children in my study had a similar symptom—awakening in the night in states of high alarm and unable to go back to bed or to sleep.

In short, noise impinging on the ear is not just about hearing, we are learning, but also about how the brain organizes itself around sound.

Question - Does the regularity of sound from larger, lower rpm turbines make problems worse, or not so bad?

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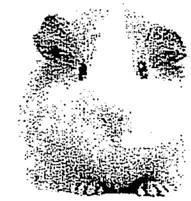
## SUMMARY

- Wind turbine noise causes tinnitus in many exposed people. Tinnitus at the physiologic level is the result of a change in sound processing by the brain.
- Other types of environmental noise have been shown to impair children's learning by changing how they process language sounds. Families exposed to wind turbines noticed deterioration in their children's thinking and learning abilities during exposure. Adults also had problems with thinking, memory, and concentration during exposure.
- Other clinical and brain studies have shown that diminished thinking and performance are tied to malfunctioning of the vestibular portion of the inner ear.
- Distorted balance signaling has a close connection with panic and anxiety in a variety of situations, a linkage that may explain how panic in the night crops up in previously non-panicked but motion-sensitive people exposed to wind turbines.





## ALEC SALT, PHD, DEMOLISHES A-WEIGHTING NOISE MEASUREMENTS, WHILE DEMONSTRATING THAT THE EAR HAS A PHYSIOLOGICAL RESPONSE TO LOW FREQUENCY NOISE AT THE INTENSITIES PRODUCED BY WIND TURBINES

Professor Alec Salt is a cochlear physiologist, a laboratory scientist in the Department of Otolaryngology at the Washington University School of Medicine in St. Louis. He and his students study the fluids and physiology of the cochlea (the hearing part of the inner ear) in guinea pigs.

For years, Salt and his colleagues have used infrasound to change the way parts of the cochlea behave—not because they were interested in infrasound, but because it has physiologic effects which are useful in their studies of cochlear fluids and cells.

In the last year or so, Dr. Salt documented that the two types of sensory cells in the cochlea, the inner and outer hair cells, react differently to infrasound. The inner hair cells, which are the ones that send hearing signals to the brain, do not respond to infrasound, but the outer hair cells do.

Infrasound, he discovered, makes the outer hair cells move in such a way that they prevent the inner hair cells from responding. The outer hair cells also send neural signals to the brain and to other outer hair cells, but it is not clear what these signals do once they reach the brain. One thing we do know is that they don't convey sound stimuli, themselves. Some evidence suggests they may play a role in mediating the perception of loud sounds in the cochlear nucleus, the first relay point for sound impulses in the brain.[20,21]

What's significant for Wind Turbine Syndrome is Dr. Salt's discovery that the cochlea does indeed respond to infrasound, and sends signals to the brain in response to infrasound, but the anatomy and cellular responses of the outer hair cells actively prevent us from hearing the infrasound.

Wondering whether these findings had any significance to people and their diseases, Dr. Salt searched the medical literature last winter and came across Wind Turbine Syndrome. He subsequently published a research article linking his findings to the symptoms or clinical manifestations of Wind Turbine Syndrome.[22]

Dr. Salt's webpage w. 3-D ear simulations

It's worth emphasizing that Professor Salt is an outstanding educator, as is clear from his website. There is a lot to be learned here about the inner ear, complete with moving, colored, 3-D simulations.

His recent research article is posted here, with a user-friendly discussion of its significance. There is also a link to the website of the National Institutes of Health, where his research is featured. He has also posted the slides from his presentation at the Picton conference on October 30.

In his presentation, Dr. Salt compared measured wind turbine sound spectra, not only to the human hearing response curve (as the wind industry consultants do), but also to the separate response curves of the inner and outer hair cells, showing that wind turbine low-frequency noise and infrasound are easily detectable by the normal cochlea. He also demonstrates how A-weighted sound level measurements specifically exclude the low frequencies significant in wind turbine health effects, effectively demolishing the credibility of A-weighted noise measurements.

A-weighted noise measurements not credible re infrasound!

Dr. Salt's research is exciting and useful because it pointedly disproves the wind industry's assertion that the infrasound produced by wind turbines is not relevant to human health because it is, they claim, below the hearing threshold of most people. On the contrary, the ear has a physiological response to low frequency noise at the intensities produced by wind turbines, even when this noise cannot be heard.

A physiologic response opens the door, of course, to clinical effects.

With regard to the mechanism of Wind Turbine Syndrome, we are now in the interesting position of having, on the one hand, a demonstrated cochlear response to infrasound without a known brain response. On the other hand, if we consider the vestibular (balance) organs in the inner ear (which share physiology and fluid connections with the cochlea), we know a lot about brain responses. There is a large scientific literature on what the brain does



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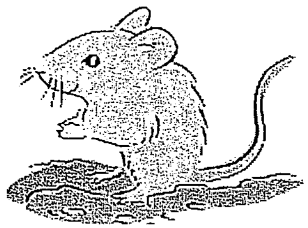
with normal or distorted vestibular signals with regard to sensations, symptoms, brain cell pathways, and functional and experimental problems.[23]

We also know that the symptom complex of Wind Turbine Syndrome is very similar to the symptoms of vestibular dysfunction.

What is lacking is direct evidence for air-borne infrasound stimulating the hair cells of the vestibular organs. Dr. Salt told us in his conference talk that the vestibular hair cells are "tuned" (meaning, have their best response) to body-borne vibrations at infrasonic frequencies, but that no one has yet looked at the responses of these cells to "acoustic" (meaning, air-borne) infrasound coming in through the outer and middle ear.

air borne vs. " body borne " infrasound (ie, "acoustic" infrasound")



## "Jumping Mice": Mammalian Balance Organs Detect Air-Borne Low-Frequency Sound Using Their Otolith Organs (Saccule & Utricle)

I suspect it's only a matter of time—and short time, at that—before some research group shows air-borne infrasound stimulating the vestibular hair cells, or shows a human vestibular response to air-borne infrasound. I base my prediction in part on a new article Dr. Salt sent to me immediately after the conference, titled, "The vestibular system mediates sensation of low-frequency sounds in mice."[24] In it, the authors explain how the "ancestral acoustic sensitivity" of the saccule has been retained not only in fish and amphibians, but also, according to recent evidence, in birds and mammals.

The authors demonstrate how mouse otolith organs respond to air-borne, low-frequency sounds below the detection range of the mouse cochlea.

Mice jump when startled by a beep. They startle more, with a more vigorous jump, in the presence of a low- or mid-frequency background sound. The authors measured this "startle response"—how much the mice jumped—quantitatively on little electronic platforms. Genetically normal mice jump more in response to either low- or mid-frequency background sound, but the authors also tested mice which, for genetic reasons, never developed the otoconia (little stones) in their otolith organs (utricle & saccule). Significantly, these otolith-deficient mice did the extra-large jumps only when the background sound stimulus fell within the frequency range of the mouse cochlea. They didn't detect the low-frequency background sound stimuli the way the mice with functioning otolith organs did.

Jumping mice. The authors of this study have demonstrated that mammalian ears, using their otolith organs of balance and motion detection, detect air-borne low-frequency sound at frequencies too low to be heard by their cochleas. This makes them startle more. Now consider "jumping people"—startled right out of bed in the middle of the night in the presence of sub-audible, low-frequency noise, or infrasound, from wind turbines.

possible wildlife effects / ?

Evidence like this suggests the following mechanism for Wind Turbine Syndrome: air-borne or body-borne low-frequency sound directly stimulates the inner ear, with physiologic responses of both cochlea and otolith organs.

Physiologic responses in the cochlea suppress the hearing response to low-frequency sound but still send some signals to the brain, signals whose function is, at present, mostly unknown. The physiologic response of the cochlea to turbine noise is also a trigger for tinnitus and the brain-cell-level reorganization that tinnitus represents—reorganization that can have an impact on language processing and the learning processes related to language processing. Physiologic responses and signals from the otolith organs tie into a wide range of known brain responses to vestibular signals, including dizziness and nausea (seasickness without the movement), fear and alerting (startle, wakefulness), and difficulties with visually-based problem-solving.

symptoms

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## Christopher Hanning, MD, and sleep arousal

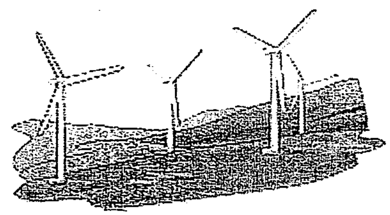
The interaction between sleep and these ear-brain mechanisms is interesting. Wind turbines create a particularly disturbing kind of noise with high alert potential, Dr. Chris Hanning, a sleep specialist, explained at the conference.

Sleep stage vs. infrasound?

Our sleep is disturbed not only when we wake up completely, but also by subclinical arousals—in which the body and brain move into a lighter phase of sleep without waking all the way up. This type of disturbance requires even less noise than full awakening, but still disrupts sleep and its restorative properties for mood, memory, thinking, alertness, and coordination.

People vary in how deeply they sleep, and how resistant they are to awakening or arousal by noise. We can reliably measure how much people are disturbed during sleep using questionnaires about their daytime functioning.

## Rick James, Noise Control Engineer: Sick Building Syndrome



Turning to noise studies around wind turbines, noise control engineer Rick James presented sound monitoring data showing the disturbing, high-alert qualities of wind turbine noise: high levels of low frequency noise and infrasound, and the pulsating quality of the low frequency noise and infrasound. Both the audible noise and the infrasound from turbines are subject to "amplitude modulation" (meaning, the loudness goes up and down)—a quality that adds markedly to its disturbing character.

"volatility" of wind Turbine infrasound?

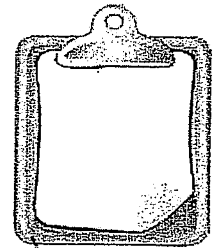
likely makes tower noise effects worse when wind direction & hence direction of Turbulence change frequently (maybe like Helix area of Oregon)

The arrangement and spacing of turbines in clusters also affects how much noise they make, because a second turbine, beating in the downwind turbulence of the first turbine, makes more noise.

Mr. James reviewed research from the 1980's and '90's on illness in office workers, induced by low-frequency noise from mal-aligned fans or vibrating ducts in the heating, ventilation, and air conditioning systems of large buildings. Research on these specialized cases of "Sick Building Syndrome" focused on the detrimental effects of low frequency noise on work productivity, and included experimental assessment of low frequency noise effects on concentration and mood.[25] "Sick Bldg Syndrome"

A word of caution, however. The term "Sick Building Syndrome" is associated most commonly with problems of indoor air quality (including particulates, allergens, infectious particles, solvent odor, and the amount of fresh air), and the syndrome includes irritation of the skin, eyes, and respiratory tract, as well as fatigue, headache, poor concentration, nausea, and dizziness.[26] The latter symptoms are commonly associated with low frequency noise exposure in other contexts, whereas skin and mucous membrane irritation are not.

In other words, although Wind Turbine Syndrome shares the noise-related aspects of Sick Building Syndrome, the two terms are not the same.



MICHAEL NISSENBAUM, MD, REPORTS THAT SURVEYED SUBJECTS UP TO 3 MILES FROM TURBINES SHOWED EFFECTS ON SLEEP AND MOOD THAT VARIED DIRECTLY WITH DISTANCE FROM THE TURBINES

Finally, Dr. Michael Nissenbaum, a Maine physician, presented results of a study of 79 adults living up to three miles from wind turbines in Maine, who completed (what are clinically called) validated questionnaires on sleep disturbance and general physical and mental well-being, divided into study and control groups based on distance from turbines.

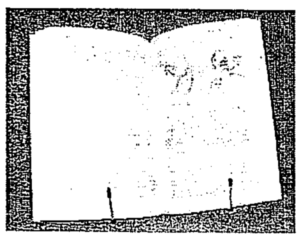
Dr. Nissenbaum found differences between the study and control groups in several sleep quality indices, and in the mental health component of the general questionnaire. Even more remarkable, when he pooled the data from study and control groups, he found a dose-response relationship out to about 5 km (3 miles) from turbines. Subjects up to 3 miles from turbines, whether they were initially considered to be in the study or control groups, showed effects on sleep and mood that varied directly with distance from the turbines, Dr. Nissenbaum reported. ≤ 3.13 miles

This is a valuable study. The surveys required information only about the sub-

7/8 mile (.875 mi) symptoms decline @ 7.875 mi (re sleep disturbance)

jects' current state of sleep and well-being, without reference to the turbines. The impact of turbine noise is apparently seen much farther away than the 1.5-2 km minimum setback proposed by many researchers (including me), although there was a drop-off in symptoms beyond 1.4 km. The questionnaires did not sample the full range of Wind Turbine Syndrome symptoms, but provide a standardized and quantified measure of one important symptom—sleep disturbance—and of general medical and mental health in relation to turbines.

.94–1.25 miles

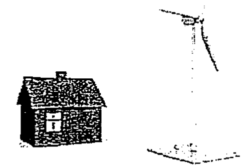


## The "Humanness" of Wind Turbine Syndrome

Such is the state of Wind Turbine Syndrome research a year after I published "Wind Turbine Syndrome: A Report on a Natural Experiment." As I said earlier, we have made substantial progress in figuring out the mechanism and other parameters of this industrial plague.

It's worth pointing out that, with one notable exception, none of this was done with government or industry or foundation support —either financial or moral support. Just the opposite, governments (at all levels) and the wind energy industry have actively tried to thwart this research. But—this pleases me immensely—it was accomplished despite their opposition.

The exception being the National Institutes of Health, which funded Dr. Salt's research. All praise to the NIH!



A final word. For me, it was both sobering and energizing to talk, again, with victims of Wind Turbine Syndrome at the conference. At times, distracted by political and journalistic "noise," I forget how serious WTS actually is.

Separately, a man and a woman from different countries told me quietly of their thoughts of committing suicide. Both are older with good marriages and productive lives and adequate resources. One has been driven from her home by relentless nausea and vomiting, and the other is made ill whenever he returns home.

While governments, the wind industry and its scientific and clinical hirelings, and the media continue to belittle and deny the experience of these individuals—Lord knows, the media is filled with denial, ridicule, and venom (Google "Wind Turbine Syndrome")—I am reminded, once more, that the physical, mental, social, and financial consequences of this perfectly correctible condition are appalling.

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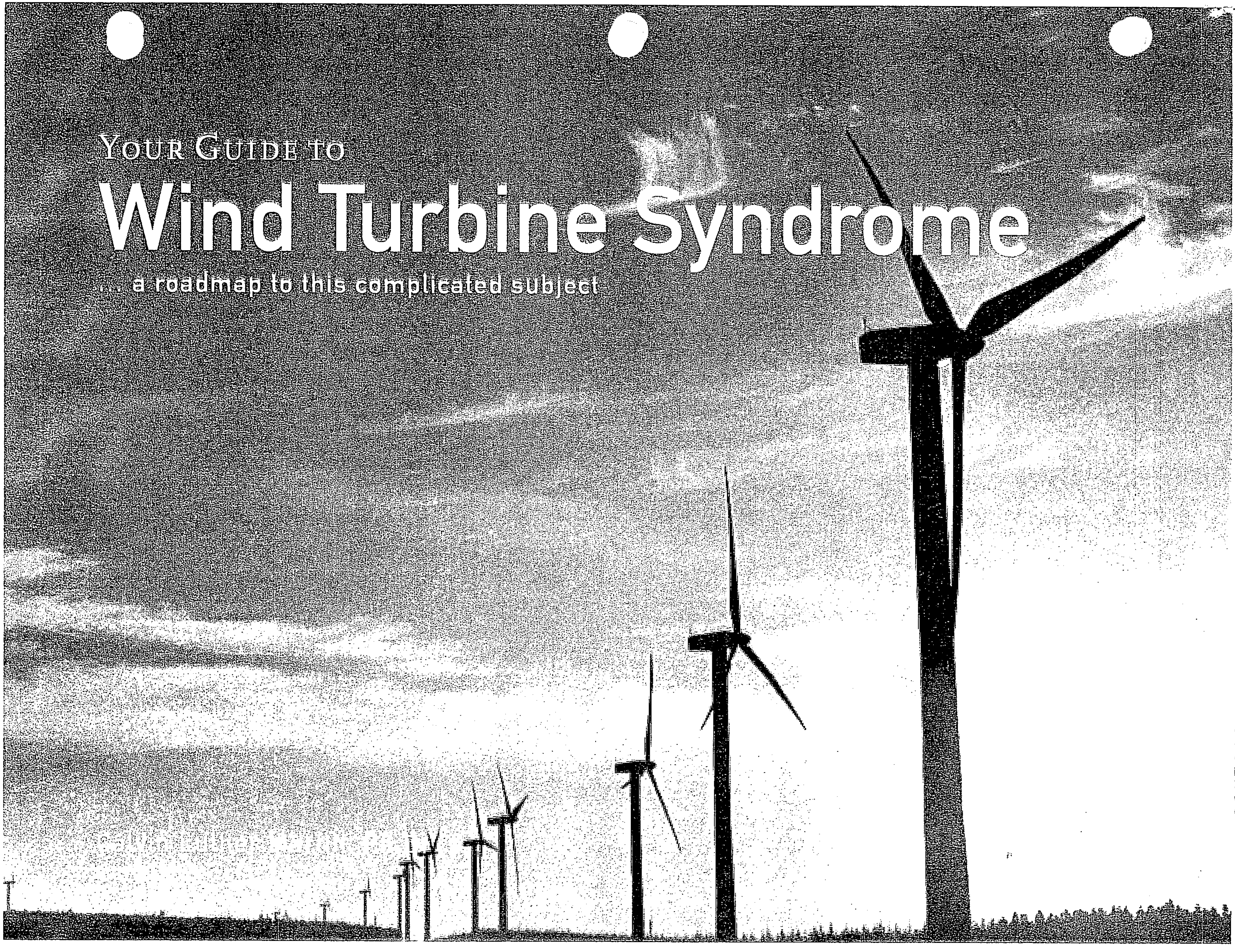

YOUR GUIDE TO
Wind Turbine Syndrome
... a roadmap to this complicated subject


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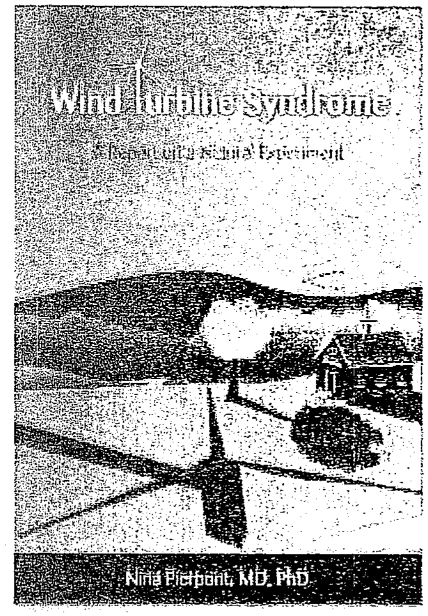
# THE SYMPTOMS

Wind Turbine Syndrome (WTS) is the clinical name Dr. Nina Pierpont has given to the constellation of symptoms experienced by many (not all) people who find themselves living near industrial wind turbines.

- sleep disturbance
- headache
- tinnitus (pronounced "tin-uh-tus": ringing or buzzing in the ears)
- ear pressure
- dizziness (a general term that includes vertigo, lightheadedness, sensation of almost fainting, etc.)
- vertigo (clinically, vertigo refers to the sensation of spinning, or the room moving)
- nausea
- visual blurring
- tachycardia (rapid heart rate)
- irritability
- problems with concentration and memory
- panic episodes associated with sensations of internal pulsation or quivering, which arise while awake or asleep




As wind turbines spring up like mushrooms around people's homes, Wind Turbine Syndrome has become an industrial plague. (See victims' Diaries & Reports and Videos). Nina Pierpont has been researching this "plague" for the past five years, and in November 2009 she published her results, *Wind Turbine Syndrome: A Report on a Natural Experiment* (Santa Fe, NM: K-Selected Books, 2009). Click on Read Peer Reviews to read the referee reports (all by medical school and university faculty). For purchase information, see Buy the book. For an in-depth radio interview with Dr. Pierpont, wherein she explains what's going on with WTS, click here. (With thanks to Radio CFCO, Ontario, Canada, 2-28-08, "Ask the Health Expert." Be sure your speakers are turned up.)

Before proceeding, a clarification. On August 2, 2009, The Independent, one of the UK's largest national newspapers, published a superb story on Nina Pierpont's research. (It's rare that the media gets WTS right. Margareta Pagano, the reporter who interviewed Pierpont, got it right.) Her article needs a correc-

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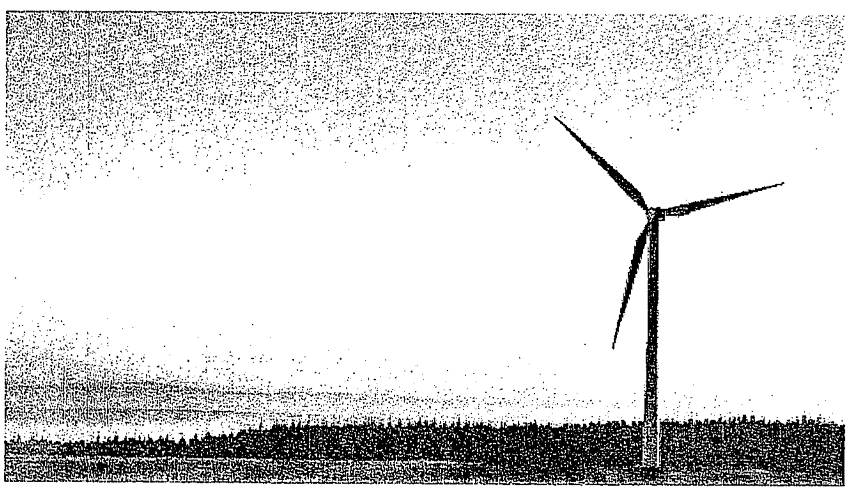
tion, however, especially since portions of her report were reprinted verbatim in scores of newspapers and blogs around the world. Ms. Pagano wrote:

> "Living too close to wind turbines can cause heart disease, tinnitus, vertigo, panic attacks, migraines and sleep deprivation, according to groundbreaking research to be published later this year by an American doctor."

The problem is the claim "wind turbines can cause heart disease." Dr. Pierpont did not say this in her interview, nor does she write this in her book. Somehow, between the interview and the printing of the article, that (erroneous) statement crept into the text. Since newspaper articles are often edited by several levels of editor, it's conceivable another editor quite innocently inserted that line, confusing tachycardia with heart disease. (After all, these people are not clinicians.)



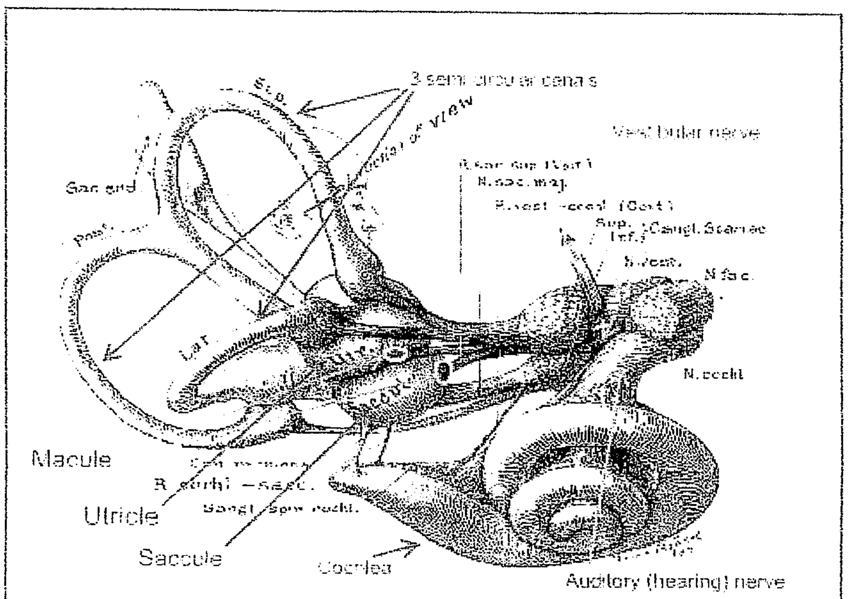
Nina Pierpont subsequently contacted Ms. Pagano to point out this needs correcting:

> "My current research does not establish a connection between heart disease and wind turbine exposure, only between a rapid heart rate as part of a panic-like response (VVVD, as described in today's article) and wind turbine exposure. However, there is a substantial body of European (including UK) research showing that environmental noise exposure in general increases the risk for cardiovascular disease. This is an area in need of further research with regard to wind turbine exposure.
>
> "Thank you to the Editors for endorsing responsible development that scrutinizes both positives and negatives of new technologies."

# The Human Ear

To understand Wind Turbine Syndrome one must first understand the function of the human vestibular system: the utricle, saccule, and semicircular canals. Three tiny organs in the inner ear. The utricle and saccule, together, constitute the otolith organs. The otolith organs and the semicircular canals are not involved in hearing per se—that would be the cochlea—but are dedicated to detecting *balance* and *motion* and *position*, with far-reaching consequences for parts of the brain controlling cognition, mood, and certain physiologic functions (such as vertigo and nausea).

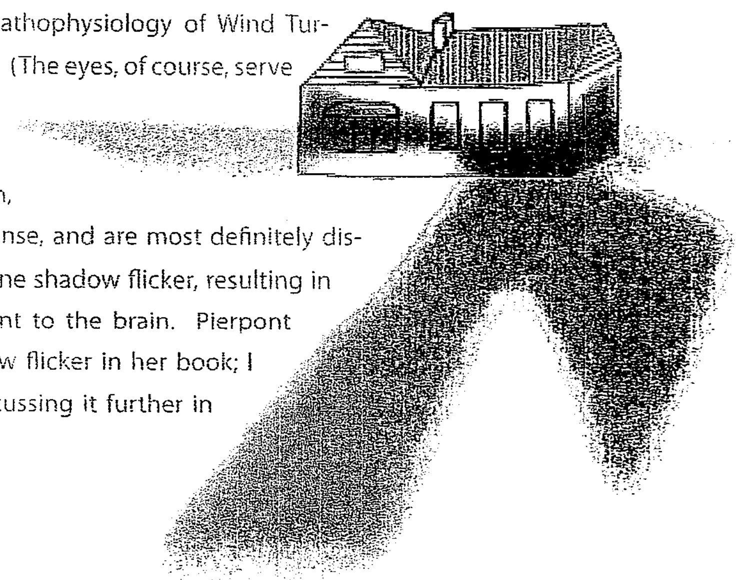
The vestibular system happens to be an ancient "command and control" center dreamed up and refined by Mother Nature over millions of years, long before there were human beings. We find a nearly identical command and control apparatus in fish and amphibians and a host of other vertebrates (back-boned animals), for whom it continues to perform important functions of cognition and behavior—just as it does in you and me.

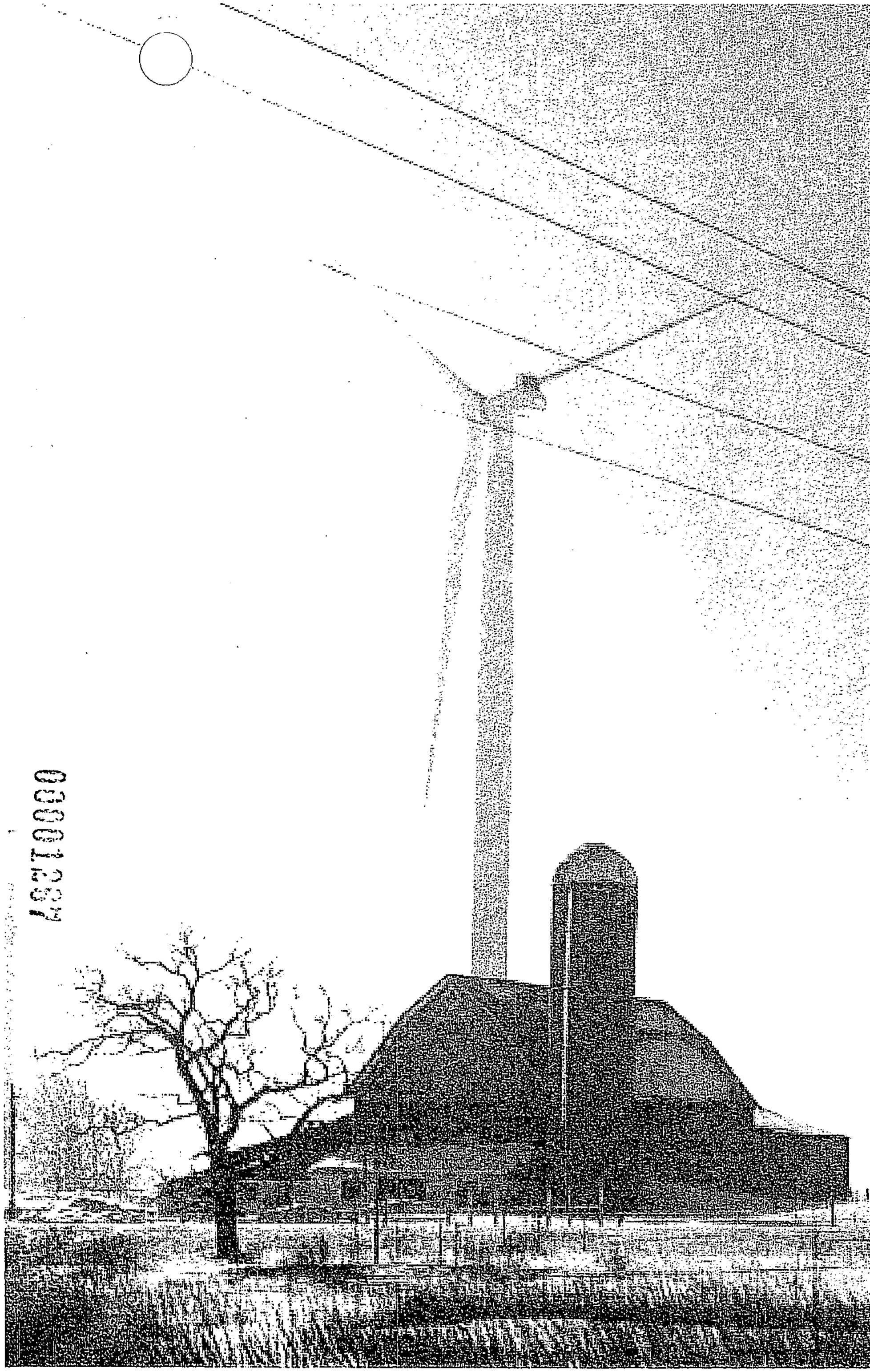



Inner Ear Illustration © Max Brödel 1934

Expose Mother Nature's vestibular command and control center to wind turbines and the result is chaos. Low frequency noise (LFN) from turbines appears to send false signals to these exquisitely sensitive structures, causing dizziness, vertigo, and nausea, along with cognitive and memory deficits, along with anxiety and panic attacks. Yes, the latter behavioral symptoms are in fact tied to the inner ear, as any up-to-date otolaryngologist (Ear, Nose, Throat surgeon) can tell you.

Bear in mind that WTS is a constellation of symptoms, including sleeplessness and tinnitus (caused by cochlear disturbance). And bear in mind that WTS appears to derail several of the body's sensory systems, besides the inner ear. Even so, the vestibular structures of the inner ear are critical to understanding the pathophysiology of Wind Turbine Syndrome. (The eyes, of course, serve as another organ of balance, motion, and position-sense, and are most definitely disturbed by turbine shadow flicker, resulting in false signals sent to the brain. Pierpont explores shadow flicker in her book; I will not be discussing it further in this overview.)





# Re-thinking Turbines

Let's stand back for a moment. We need to re-think the notion of turbines solely as electricity-producing machines and wake up to the fact that, for all practical purposes, they function equally as *low frequency noise-producing machines*. People often object vehemently to turbines because they consider them ugly and outsized for their community. (Turn up your speakers and listen to Bob Lucas's "Green Energy Blue.")

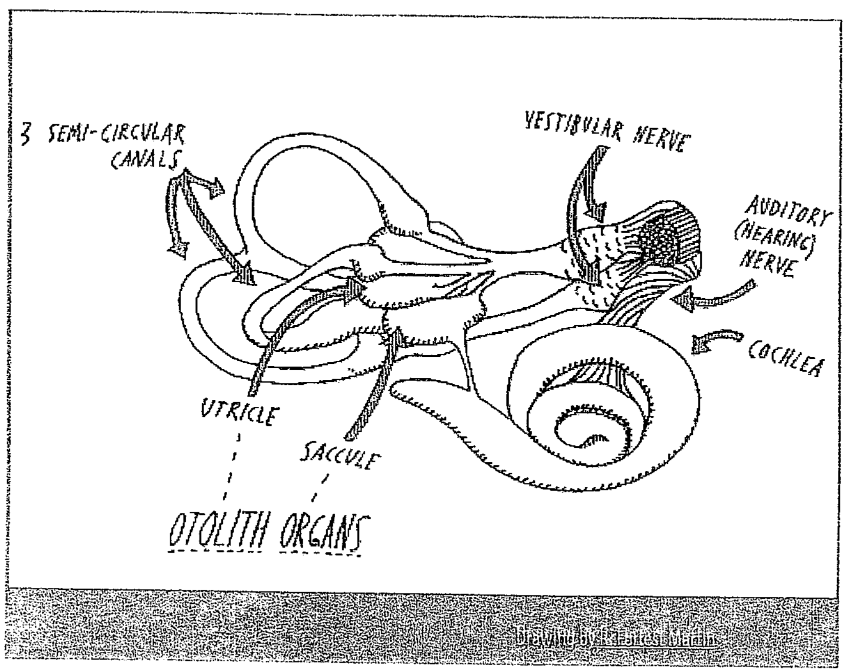
Others object because they lower property value. (That's true, they do hammer property value.)

What eclipses eyesore and property value is the low frequency noise. It's a major health issue. This is more than a "nuisance." As Nina Pierpont puts it, "People experiencing WTS are not *annoyed*, they are *sick*!"

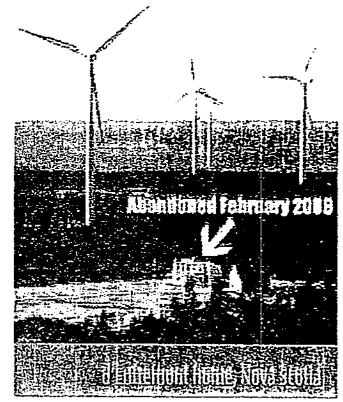

Folks who visit a wind farm and stand beneath a turbine generally have no idea that the vestibular organs of the inner ear, along with other motion, balance, and position sensors throughout the body, are being jack-hammered by a low frequency noise they can barely hear. (The amount of LFN produced during one's visit depends, of course, on whether the turbines are in fact generating, wind direction and wind speed, whether it's day or nighttime, and the degree of moisture in the air.)

Anyhow, people stand next to a turbine and exclaim, *"Gee, my cochlea [the organ within the inner ear that picks up audible sound] hears almost nothing at all! Merely a whooshing noise! Sounds like a humming refrigerator, just like the developer said! What's the problem?"*

Now for the bad news. The utricle, saccule, and semicircular canals don't register the "refrigerator-like" audible noise but, rather, the less apparent yet health-threatening sub-audible vibration. Hence, people don't say, *"Gee, despite my cochlea detecting only a mild hum, my utricle, saccule, and semicircular canals are sending weird signals! Come to think of it, my other organs of balance, motion, and position are, as well! Hey, what's going on??!!"* (Incidentally, noise and vibration are one and the same in physics.)




Organs of balance, motion, and position may (and do) respond rapidly and alarmingly in some people—for instance, when visiting a windfarm and standing, marveling, beneath a turbine for 10 minutes. But for most of us the effect takes longer to sink in—not till turbines are up and running, 1000' or 1500' or more from one's back door and exposure is 24/7. Then, for people like this Nova Scotia family (right), it's too late.



Likewise for Barbara Ashbee (a realtor, incidentally) and her husband Dennis. They used to live here. (They count themselves among the lucky ones. The wind developer bought them out, after which Barbara & Dennis had to sign a gag agreement. The developer refuses to buy out the d'Entremonts, above, who remain homeless—camping out with various relatives. Yes, their family is broken up as a result.)

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But I digress. Who is especially susceptible to WTS? That's easy to answer. "Statistically significant risk factors for symptoms during exposure include *pre-existing migraine disorder, motion sensitivity, or inner ear damage* (pre-existing tinnitus, hearing loss, or industrial noise exposure)" (Pierpont 2009). Motion sensitivity? If you got car-sick as a kid, or get seasick, you're at high risk. How many people suffer from pre-existing migraine disorder? Studies show it's a substantial proportion of the population (6% for males, 18% for females)—all human populations studied so far.

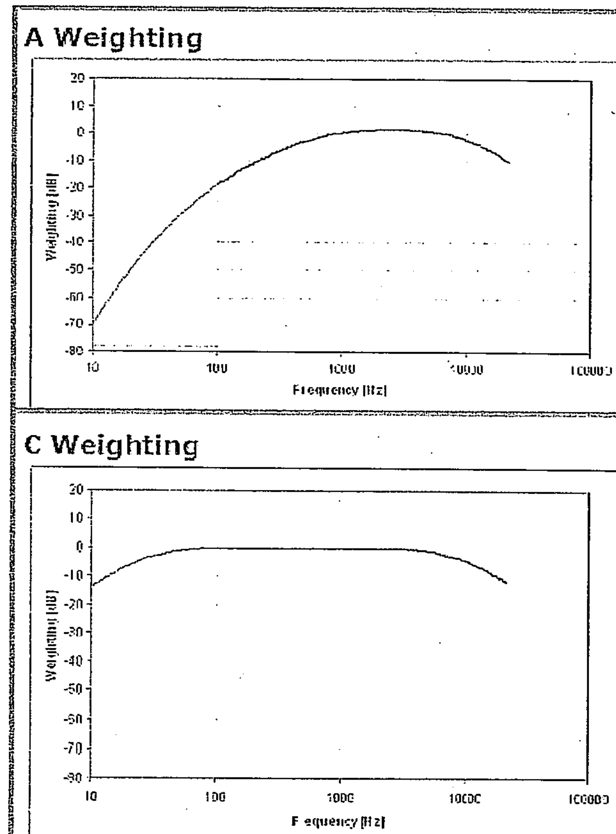
Again, the chief culprit appears to be low frequency noise.

# Noise

Tragically, most people living near turbines, or contemplating turbines for their community, fail to grasp the magnitude of all this. This happens in part because the developers get away with what are basically deceptive noise measurements. How are they deceptive? Because wind developers insist on using A-weighted (dBA) measurements. *A-weighting filters out nearly all the low frequency noise and, even lower, infrasound, both of which are produced in abundance by turbines.*

Take a look at the following graphs (right), showing the difference between dBA and dBC noise measurements.

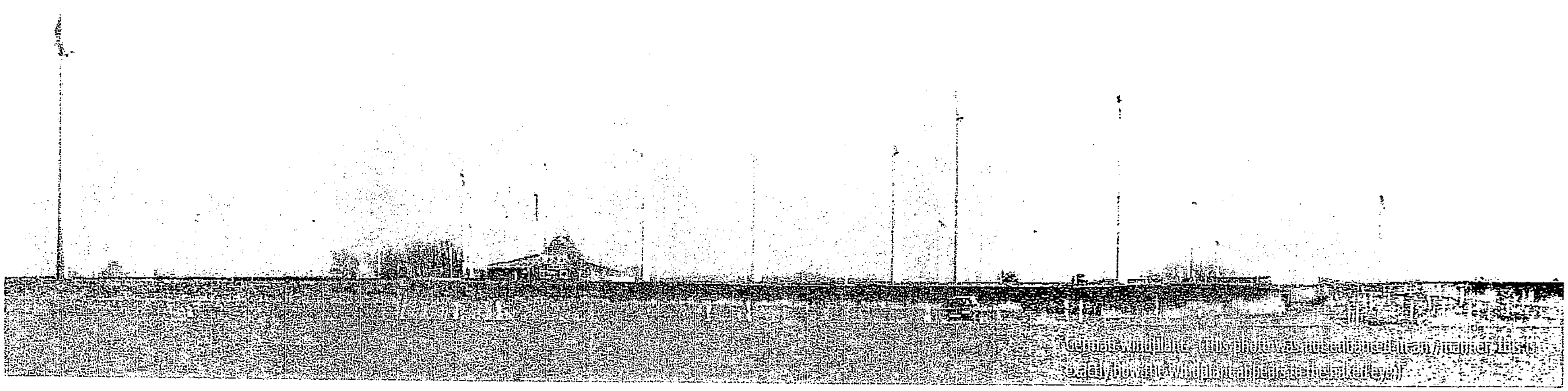
- dB = decibel
- "A" refers to *A-filtering* (also known as *A-weighting*)
- "C" refers to *C-filtering (C-weighting)*
- therefore dBA = *noise measurement with an A-filter (or A-weighted filter)*
- and dBC = *noise measurement with a C-filter (or C-weighted filter)*



It's obvious that a C-weighted filter picks up vastly more noise (literally, exponentially more) in the low frequency and infrasound range—the yellow zone on both graphs. It's equally obvious that an A-weighted filter picks up exponentially less and less LFN and infrasound as the frequency drops. (Notice that the noise data are plotted on logarithmic graph paper. This explains why the intervals between levels of frequency are unequal. Frequency is measured in Hz = Hertz.)

A-weighting is designed to pick up what the human ear normally hears in conversation. It filters out almost all the lower range of sound—the sound we barely hear (depending on how low it is), *sound that is detected as vibration by the inner ear's vestibular organs together with a variety of other motion, position, and balance sensors throughout the body.* A-weighting, in short, is designed to measure what the cochlea (the organ we hear with) detects, not what the utricle, saccule, semi-circular canals and other organs of motion, position, and balance detect.

Using A-weighted filters is a cheap trick by wind developers and the acousticians who work for them. And people suffer as a result. Rephrasing this, wind developers swindle everyone by using pseudoscience: scrupulously taking A-weighted noise measurements (dBA) without measuring for the proverbial elephant in the room—the low frequency noise. With A-weighted filters, they can get away with the claim that their turbines are no louder than a refrigerator, a library reading room, or a babbling brook—which is all technically true, but irrelevant. What their literature neglects to point out is that the 400-foot-tall whirling "refrigerator" (turbine) they just installed in your backyard is also producing major low frequency noise/vibration—something my refrigerator, local library reading room, and backyard babbling brook don't produce. And yours don't either.



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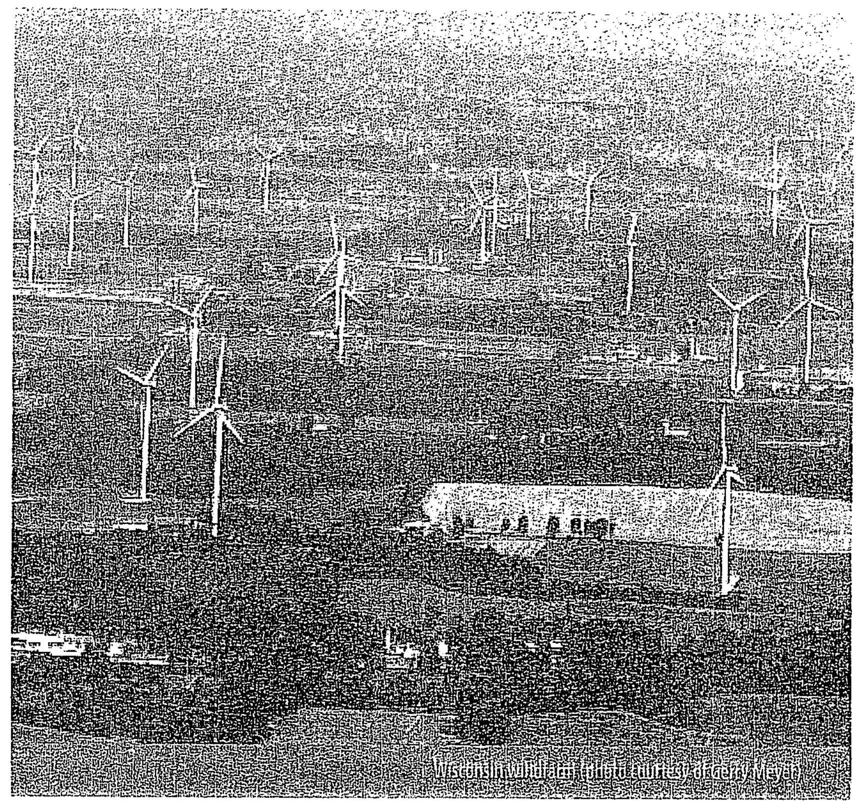
When the developers show up to do their sound measurements prior to construction or after you complain about the noise from their damn turbines, their "engineers" whip out—you guessed it!—an A-filtered noise meter. Not C-filtered. (Yes, Dorothy, this is The Land of Oz, and wind developers are that corny, childish, and sleazy.)

The good news is that LFN can be adequately detected using a C-weighted filter. However, even with a C-weighted filter combined with A-weighted readings, taking proper measurements is a tricky, highly specialized, and complicated business. Easily botched—or fudged. (See How Loud Is Too Loud?)

Fudged? Does this suggest fudging?

> "When our town council went to a windfarm [open house] hosted by the Canadian Wind Energy Association, first they were treated to gourmet snacks on the bus and given the wonderful story on wind. Then they brought them right underneath the turbines to show them how quiet they were. The councilors said the turbines were turning like crazy and yet were as quiet as a mouse.
>
> "Being suspicious, my husband checked the Sygration site and, lo and behold, for that time period the turbines were not producing any energy. Though not a turbine technician, my husband is an industrial mechanic and said this could be done very easily by just disengaging the clutch that actually runs the rotors, and it's all done from a remote computer.
>
> "We presented this information to our town council, but they wouldn't believe the nice wind fellows would do something like that."
>
> —Maureen Anderson (Ontario, Canada), 9/6/09


Wisconsin windfarm (photo courtesy of Gerry Meyer)

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"Calvin Luther Martin is correct [that] wind farm noise measurements must be obtained secretly to ensure normal wind turbine operating conditions. Rick James has made it clear that wind farm operators can and do reduce the noise emission quickly if someone is spotted measuring the wind farm noise.

"Over many decades of industrial noise emission measurements, I have learned the best atmospheric conditions (worst case for noise impacted residents) for obtaining the highest immission noise level is during an otherwise quiet night, when the atmosphere is stable. For wind farm noise immission measurements, this means a clear night with only a slight breeze (<2m/s) from the wind farm near ground level and the wind turbines operating near full power. I normally informed only the local law enforcement before my night measurements, so they could address any calls from residents concerned about my presence in the street.

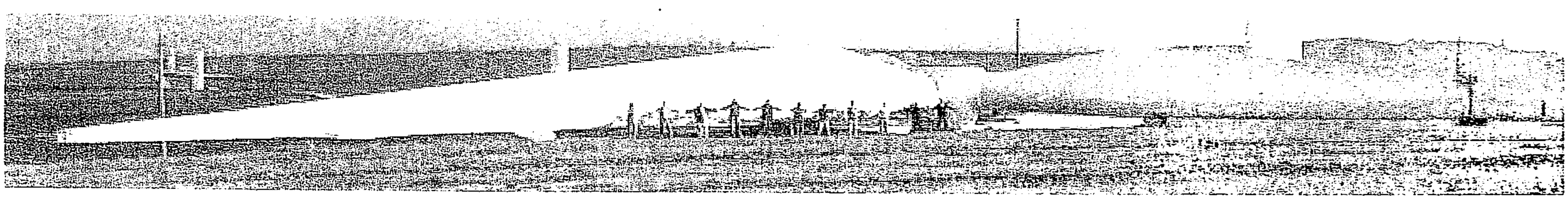
"We would be interested in any wind farm noise data you care to share with us. Please do glance through "How Loud Is Too Loud?" referenced at the end of Calvin's message, to better understand the dBA and dBC noise data we desire, to better understand the nature of the noise impact on residents. Your results would be even more valuable if you found an opportunity to also measure the noise immission environment on the same or similar night with the wind turbines not operating."

—George Kamperman, P.E., 9/6/09

Bd. Cert. Member Institute of Noise Control Engineers

Fellow Member Acoustical Society of America

Wind developers add insult to injury by flatly denying any health effects from their LFN-generating turbines. Whose LFN, I emphasize, they refuse to measure, whether properly or improperly. They refuse because (a) they either deny LFN exists, or (b) if they grudgingly acknowledge it does, they claim it's so minuscule as to be inconsequential. Their rule of thumb being, "if you can't hear it, it can't hurt you"—a notion that has been refuted by recent research. (See especially the work of Todd et al. in the attached References from Pierpont's 2009 report.)



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Indiana (with thanks to the Indianapolis Star)

"The University of Ballarat has begun investigating noise levels near Waubra Wind Farm [Australia], with residents claiming low frequency turbine sound is affecting their health. Some say they have experienced headaches, nausea and sleep deprivation since the turbines began operating. . . .

"University of Ballarat engineering lecturer Graeme Hood said previous monitoring results indicated a high level of infrasound. 'It's like having a truck going past your place constantly, although you can't hear it,' Mr Hood said. . . .

"Acciona Energy, which owns Waubra Wind Farm, says it is monitoring post-construction noise to ensure it complies with industry standards. But Mr Hood said the standards did not take infrasound into account. . . ."

In summary, WTS seems to be triggered by the organs of motion, position, and balance being commandeered by turbine low frequency noise. The result is that these organs send scrambled signals to brain centers controlling memory, concentration, learning, emotions (including panic & anxiety), sleep, balance, and so on. See the above list.

The clinical literature is clear on what frequencies cause what pathologies. For instance, Todd et al. have demonstrated that 100 Hz sets off fire alarms in the utricle and saccule (see, for example, "Tuning and sensitivity of the human vestibular system to low-frequency vibration"). One hundred (100) Hz is low-frequency. (Note that at 100 Hz, A-weighting reduces sound measurement by a factor of 1000 [30 dB]. At 31 Hz, A-weighting reduces sound measurement by a factor of 10,000 [40 dB].)

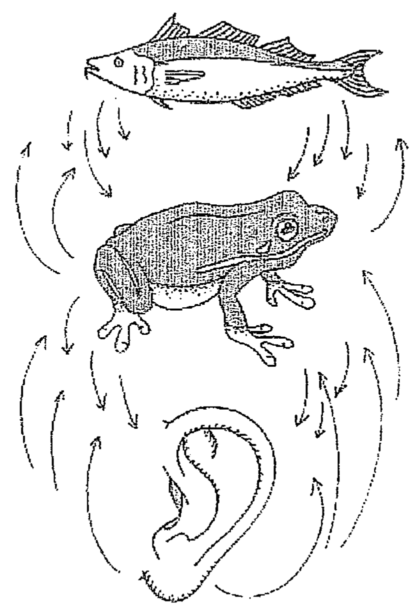
The clinical literature likewise shows symptoms down around 10 Hz and below in what is technically considered the infrasound range..

"Most exciting, Todd et al. provide direct experimental evidence that at the 100 Hz tuning peak, the vestibular organs (probably utricle) of normal humans are much more sensitive than the cochlea to low-frequency bone-conducted sound/ vibration. The researchers applied vibration directly to the skin over the bony mastoid prominence behind the subjects' ears, adjusting the power by measuring the tiny whole-head acceleration produced by each vibration force and frequency. They were able to elicit and measure neural signals of the vestibulo-ocular reflex (OVEMP) at vibration intensities 15 dB below the subjects' hearing thresholds.

"In other words, the amount of vibration/bone-conducted sound was so small that the subjects could not hear it, yet the vestibular parts of their inner ears still responded to the vibration and transmitted signals into the balance and motion networks in the brain, resulting in specific types of eye muscle activation. Since dB is a base 10 logarithmic measure, *15 dB below* means a signal 0.0316 ($10^{-1.5}$), or about 3%, of the power or amplitude of the signal these normal subjects could hear.

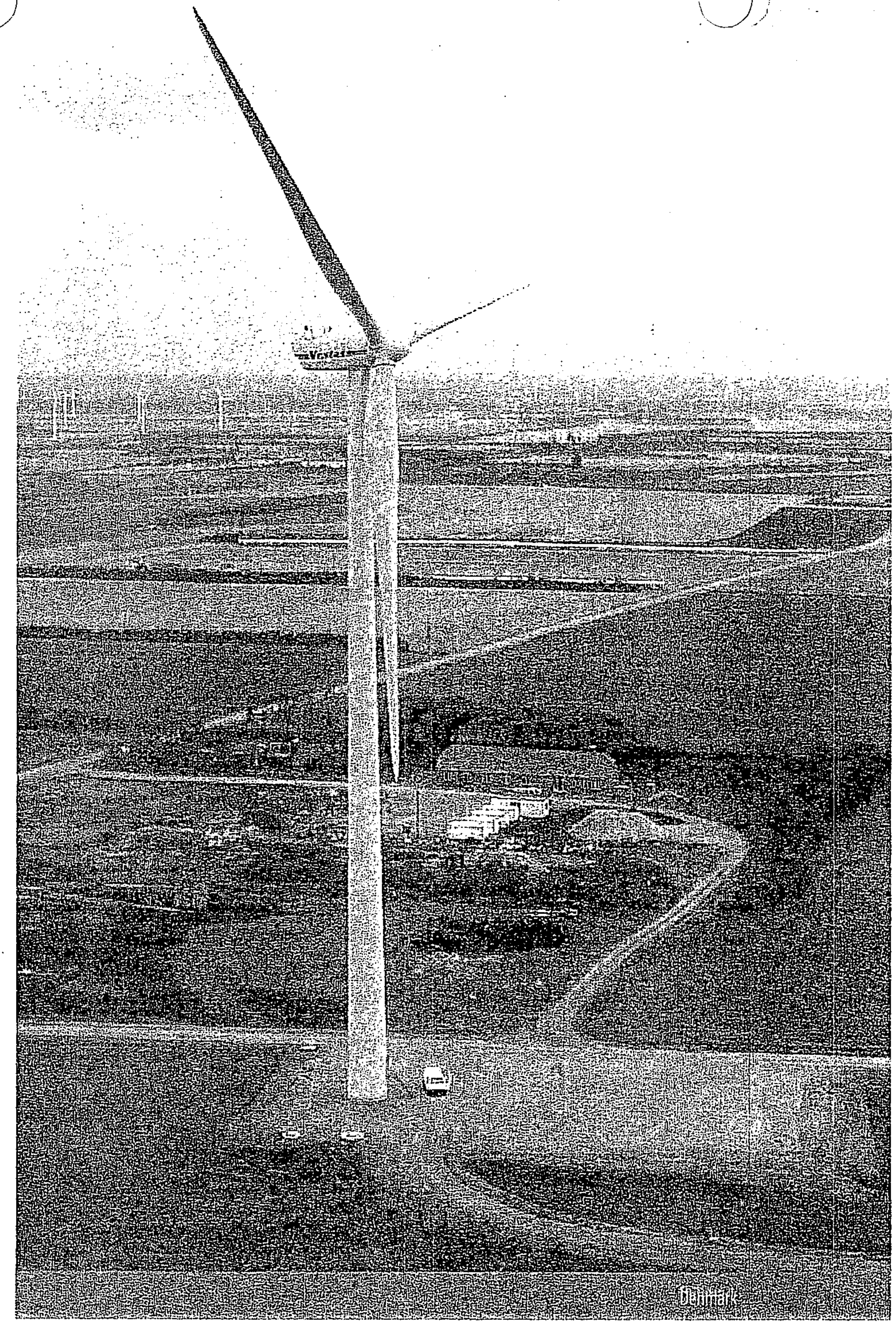
"The researchers note that 'the very low thresholds we found are remarkable as they suggest that humans possess a frog- or fish-like sensory mechanism which appears to exceed the cochlea for detection of substrate-borne low-frequency vibration and which until now has not been properly recognized.'

"Thus the potential exists, in normal humans, for stimulation of balance signals from the inner ear by low-frequency noise and vibration, even when the noise or vibration does not seem especially loud, or even cannot be heard. In the presence of pre-existing inner ear pathology, thresholds for vestibular stimulation by noise or vibration are even lower than in normal subjects.



“Each part of the body has its own resonance frequency with regard to vibration. When an object is vibrated at its resonance frequency, the vibration is amplified. The resonant frequency of the thoraco-abdominal system, as it moves vertically towards and away from the lungs, lies between 4 and 8 Hz for adult humans. Vibrations between 4 and 6 Hz set up resonances in the trunk with amplification up to 200%. Related chest and abdominal effects are found in the same frequency range. Vibrations in the 4-8 Hz range influence breathing movements, 5-7 Hz can cause chest pains, 4-10 Hz abdominal pains, and 4-9 Hz a general feeling of discomfort. In small children under 40 pounds, the vertical resonance or power absorption peaks at 7.5 Hz, as opposed to 4-5 Hz for adults.”

—Pierpont, “Report for Clinicians,” ch. 2 in *Wind Turbine Syndrome* (2009)



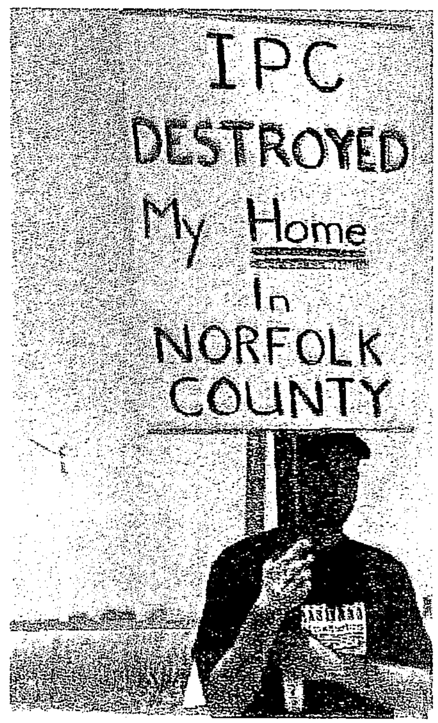
# WTS Victims

People suffering from Wind Turbine Syndrome feel desperate. Oftentimes they feel they are losing their minds. This being neither surprising nor unreasonable, given that they are losing their ability to concentrate and remember things. And they panic. (The panic is not because they're weenies, but because low frequency noise acting on vestibular organs triggers panic. Panic is an inevitable neurological response to LFN.)

Ironically, all this is a normal response to vestibular signals. Except that the vestibular signals in this instance are happening under unnatural conditions, and are sending a mish-mash of mis-information to targeted brain centers.

Consider the following diary entry by Ann Wirtz (Wisconsin).

> **"Completely exhausted, I went to bed at around 10 p.m. I fell asleep quite fast, as usual. At 12:05 I woke up and looked at the clock. I tried to think, "Sleep, sleep, sleep, and don't wake up." But it was no use; I was wide awake.**
>
> **"I had the feeling I often get of pressure in the room. I went out on our back porch. I sat down and could feel the eerie sensation even stronger outdoors. I had a feeling of pressure—the sensation you have for those few seconds when you are at the top of a rollercoaster, just before you go down. But this [feeling] is constant.**
>
> **"I also felt the swoosh, swoosh of the turbines. It was [not] real loud, yet the feeling to me was very strong. The swoosh, swoosh sensation, along with the pressure, made me feel nauseous."**



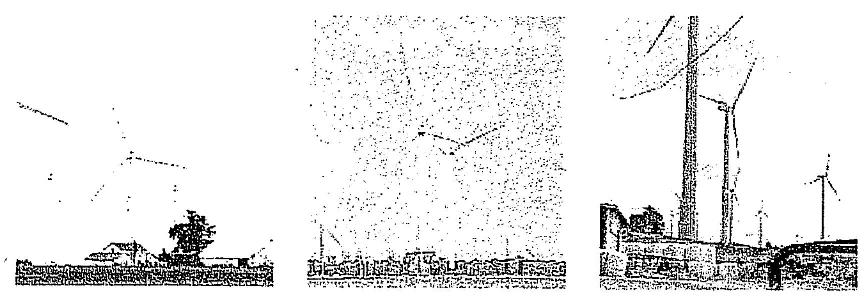

Picture it this way. Ann's utricle, saccule, and semi-circular canals are screaming at her brain, *"Oh my God, Ann is upside down and spinning!"* Alternatively, *"Oh my God, it's 1 a.m., and Ann is on a wild and crazy carnival ride!"*

In reality, Ann is sitting on her back porch in her bathrobe at 1 a.m., wondering why she can't get back to sleep. Her brain says, 'No, you're wrong! You only *think* you're sitting on your porch listening to peepers and the gentle swish of turbines. I, your brain, *know for a fact* you're on the North Atlantic in a ridiculously small boat and there's a helluva storm tossing you around like a cork, and I'm trying like the dickens to keep your motion, position, and balance in proper order."

# VVVD

As Pierpont explains in her report, Ann's weird midnight symptoms were likely a result of her vestibular apparatus being hijacked by turbine LFN, as outlined above. Alternatively, they were caused by a clinical phenomenon which Pierpont has christened *Visceral Vibratory Vestibular Disturbance* (VVVD), whereby LFN *literally vibrates internal organs*, thus setting off stretch, pressure, and vibration receptors and detectors (called visceral graviceptors, see Balaban) in and around internal organs.

Symptoms of VVVD resemble those of vestibular disturbance, with the added sensation of internal quivering or "crawling." "When the turbines get into a particular position (facing me)," reports one of Pierpont's subjects, "I get real nervous, almost like tremors going through your body. . . . It's more like a vibration from outside. . . . Your whole body feels it, as if something was vibrating me, like sitting in a vibrating chair but my body's not moving."



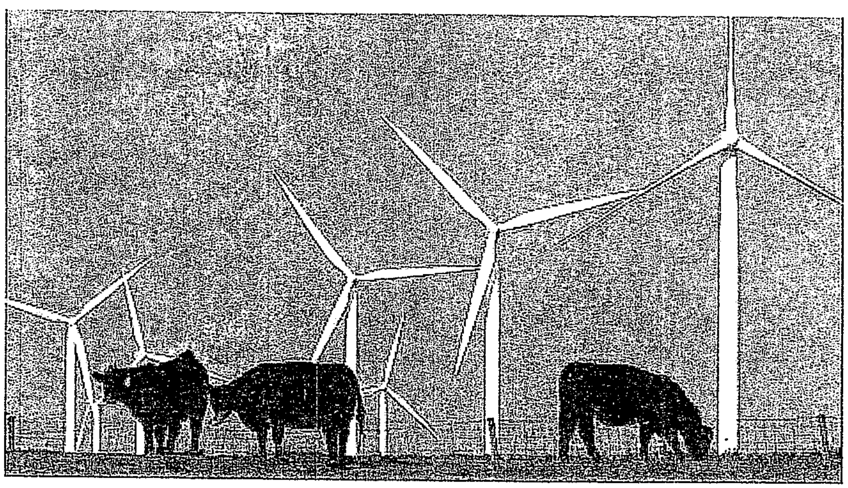
*Visceral Vibratory Vestibular Disturbance* (VVVD). For all you WTS sufferers who wonder what the heck is happening to you: What you're experiencing is a new clinical phenomenon. Yeah, you're making medical history. You're the guinea pigs for VVVD.

This is why Pierpont subtitled her book, "A Report on a Natural Experiment." *You're the experiment!* No clinician would get away with performing this outrageous experiment on people, but the wind developers pull it off because they claim ignorance. And when Pierpont and other physicians point out that they are messing with people's health, the windies have the gall simply and flatly to deny it—relying on advice from acousticians. (Hello! Acousticians and physicists are not clinicians.) Or they rely on advice from wind turbine salesmen and engineers, likewise not clinicians.

The outrage doesn't end there. The windies like to tell anyone within earshot that Pierpont's sample size (10 families, 37 people) is too small to establish any connection between the turbines next door and people's symptoms. (Wind developers are salesmen. Keep this in mind. And corporate environmentalists, for the most part, are wind developer shills. Keep this in mind, too. Neither wind developers, corporate environmentalists, politicians, public agency bureaucrats, or Barack Obama, for that matter, are clinicians.)

The windy crowd doesn't understand that *Pierpont's sample size was large enough to establish statistical significance on the question she was addressing, which was, "What aspects of a person's past medical history make him (her) susceptible to becoming sick when exposed to wind turbines?"*

This man—not a salesman, not a wind company consultant, not an acoustician or physicist, not a corporate environmentalist or politician or government job holder—grasps the significance of the statistical significance Pierpont has demonstrated. Unlike the above list of "nots," this man is an expert on the subject of LFN and vestibular dysfunction. Unlike the above crowd, he is worth listening to. Dr. Black is an Ear, Nose, Throat (ENT) physician. In fact, he's more than that; he's considered by fellow physicians to be the gold standard in otolaryngology and neuro-otology (ENT) research. Ironically, the American government also considers him the gold standard, for he regularly consults for the US Navy and NASA on vestibular disorders in astronauts and deep sea navy divers. (See F. Owen Black, MD, FACS.[1])



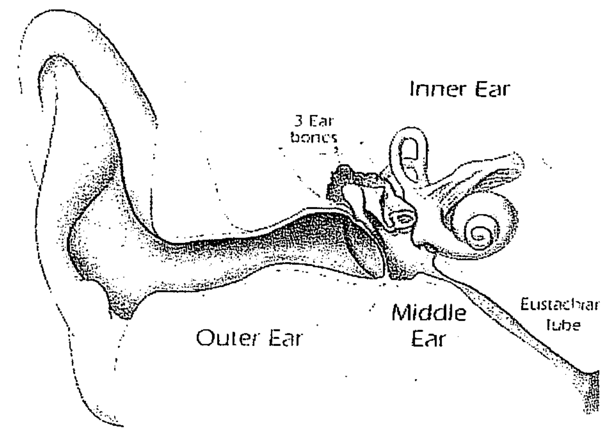
**"Dr. Pierpont has clinically defined a new group of human subjects who respond to low frequency, relatively high amplitude forces acting upon the sensory and other body systems. Her rigorous clinical observations are consistent with reports of the deleterious effects of infrasound on humans, including, but not limited to, the low frequency sonar effects on divers. There are clinical conditions (such as dehiscent superior semicircular canals) that might explain some of Dr. Pierpont's clinical symptom review, but this relatively rare condition cannot explain all of her observations.**

**"Dr. Pierpont's astute collection of observations should motivate a well-controlled, multi-site, multi-institutional prospective study."**

**—F. Owen Black, MD, FACS,** Senior Scientist and Director **of Neuro-Otology Research, Legacy Health System, Portland, Oregon. Dr. Black is widely considered to be one of the foremost balance, spatial orientation, and equilibrium clinical researchers in America.**

After reading this, you'd think responsible setbacks *à la* Nina Pierpont would be a no-brainer. The fact that clinically responsible setbacks are ignored by the above crowd is a scandal of large proportions. And getting larger by the

"I believe [Pierpont's] study is an important initial contribution to understanding the effects of low frequency pressures on the inner ear and other organs."




day, as Barack Obama and Congress pour billions of dollars into the pockets of this completely unregulated industry.

Yes, Dorothy, this is The Land of Oz, and wind developers and their shills are that brazen, sleazy and, if I understand the Geneva Convention's definition of torture, criminal.[2]

Torture? Here's what a woman named Nikki was doing at 10:42 pm on June 28, 2009. Tell me if this meets the definition.

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"... I began to feel a periodic vibration. It was strange. I even looked through the bed to see if a toy was vibrating or a cell phone was left there. Okay here is the part that may sound very strange and quite frankly has me very worried. Today the windmills were very loud and turning quickly. It is dark now so I can't see them, but they are loud this evening. Gerred [my husband] is still awake from the sound (he had a bad day today because he took the boys outside to play and swim and he said it felt like living next to an airport! Talk about Loss of Enjoyment of your property) ... Anyway, I am feeling a vibration-like feeling just above my pelvic bone. It literally feels like when your cell phone vibrates but it is within my body. ... I cannot describe it well, and even as I type I am having a hard time believing it myself. I wasn't even thinking about the turbines, I was just watching the movie with the kids when it started but now it's not stopping .... It feels very invasive ... I don't like it at all .... I remember one of the doctors saying that vibration can be conducted in gaps between bones, like at the jaw below the ear or something like that. ... I wonder if this could be happening at the top of the pelvic bone? If anyone can provide me with any information, it would be greatly appreciated .... This is the most unnerving thing that has happened so far . . . If anyone can let me know any possible cause it would be greatly appreciated . . . . I hope you don't all think I am crazy, I know it sounds strange, but it is definitely happening . . . . I just timed it out with the turbines and it seems to be following the same pattern . . . . I will definitely be seeking medical advice on this one."

Nikki lives in Ontario. Canada. You can read her daily diary here, My Next Door Neighbour Is a Wind Turbine. Ann Wirtz lives in Wisconsin. You can read about her hellish life, here.

Ann's wild ride and Nikki's vibrating guts—the stories of two human guinea pigs—this is what Nina Pierpont's report is all about. Except that her report features 10 families, not just 2, from Europe and North America, analyzed in painstaking clinical detail. Ten families who have either abandoned their homes for good, or simply moved away to temporary lodging and hope someday to return. To this the wind developers and their acoustician & physicist hirelings respond, *"Nonsense!"*

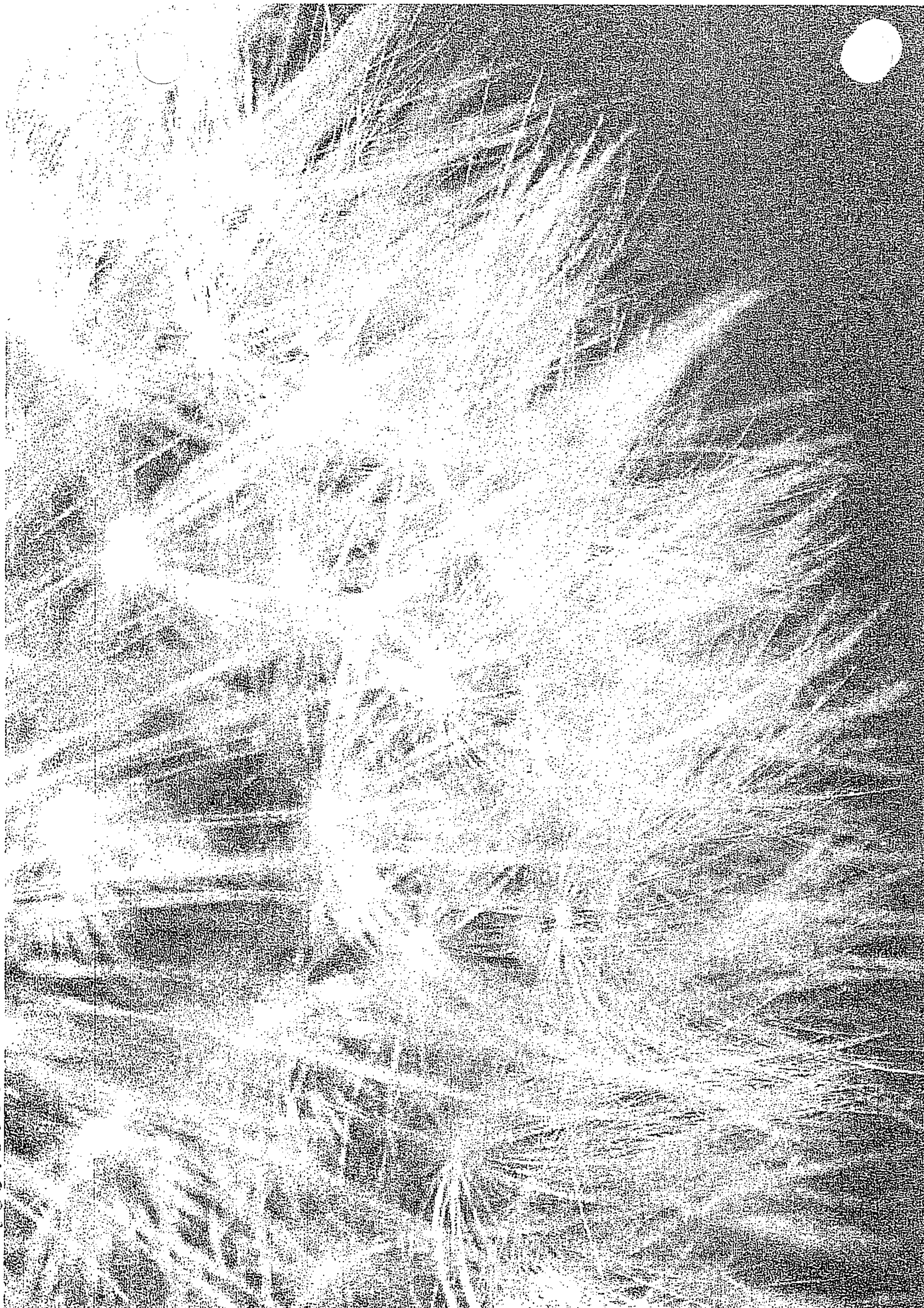
"On Friday night Julian and I went to a meeting in a local village hall to give a presentation on our experiences of having turbines as neighbours. The developers were there also. To our horror and absolute amazement, one of the directors of the company proposing the development said that it couldn't be true that the noise from the turbines was louder at our home 930m away from the turbines than it was 100m away or underneath them. *And she laughed at us* [emphasis added].

"It is so worrying when someone purporting to be a chartered engineer with 15 years experience of building wind farms, has absolutely no understanding of how large, moving structures (330+ feet high) create sound waves, and how those waves propagate. As at the Wind Turbine Noise 2009 Conference [we attended] in Aalborg, Denmark, June 17-19, 2009, we found that many (not all) who spoke had no experience of wind turbine noise in the raw, real world. No experience of the swish, the whoomph, the roar, the ever present hum, the lash, the grinding—none at all—and yet they purport to be able to predict what "noise" the nearest receptors (that's "homes" to you and me) will suffer from.

"They do not understand and seemingly do not care, either!"

—Jane Davis, Lincolnshire, England, 7/5/09. (Listen to Jane's account, "We've Now Abandoned Our Home.")

And your government, dear reader, lets the wind industry get away with all this. (Yes, Alice, you are now in Windfarmland.)



I am a physician and scientist; my expertise lies in clinical and environmental matters. Whether or not wind proves to be a viable source of power, it is absolutely essential that windmills not be sited any closer than 1.25 miles (2 km) from people's homes or anywhere else people regularly congregate. (Highways are also a problem for motorists with seizure and migraine disorders and motion sensitivity, from the huge spinning blades and landscape-sweeping shadow flicker.)

I consider a 1.25 mile set back a minimum figure. In hilly or mountainous topographies, where valleys act as natural channels for noise, this 1.25 mile set back should be extended anywhere from 2-3 miles from homes.

Let me be clear. There is nothing, absolutely nothing, in the wind energy proposition that says windmills must be sited next door to people's homes. Siting, after all, is the crux of the issue.

Irresponsible siting is what most of the uproar is about. Corporate economics favors building wind turbines in people's backyards; sound clinical medicine, however, does not.

Nina Pierpont, MD, PhD
Fellow of the American Academy of Pediatrics

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# References

1 Dr. Black's clinical resumé:

F. Owen Black MD FACS

**Senior Scientist**
**Director of Neurotology Research**
Telephone: 503-233-6068 (Clinic); 503-413-5332 (Research)

Dr. Owen Black is the Director of Neurotology Research for Legacy. An internationally known neurotologist and human vestibular physiologist, he received his MD degree from the University of Missouri in 1963. After completing a residency in otolaryngology at the University of Colorado and an NIH-sponsored fellowship in otology, he served as a combat surgeon in Vietnam with the US Navy.

Dr. Black completed his research training in 1974 through the assistance of an NIH Research Career Development Award, and held appointments at the University of Florida and University of Pittsburgh before joining the Robert S. Dow Neurological Sciences Institute in Portland in 1982. He established his lab with Legacy in 1997. Dr. Black has received continuous funding from the NIH and NASA for his research for over twenty years. In addition to his research pursuits, Dr. Black has an active clinical practice at Balance and Hearing Northwest.

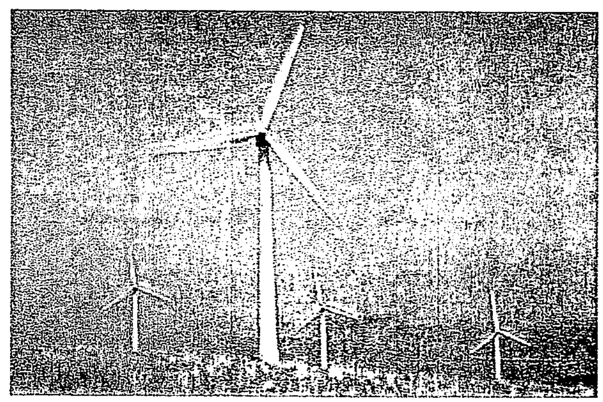
*Research Interests*

Dr. Black's research focuses on disorders of the human vestibular system and the effects of microgravity on human postural control, with a major emphasis on the role played by otolith function. His recent studies are centered on determining how trauma, disease and certain drugs adversely affect vestibular function, and in quantitatively assessing the consequences of vestibular placticity. A component of his work is investigating how visual cues the brain receives from the eyes work with the inner ear to help control balance.

His NASA-funded research involves the impact that the zero gravity of space has on astronaut balance control. Weightlessness adversely affects how the brain interprets information received from the inner ear, causing space motion sickness and difficulties in regaining a sense of balance once returning to Earth. He regularly travels to the JohnsonSpace Center in Houston and the Kennedy Space Center in Florida to meet with his NASA collaborators, and serves on the medical advisory team for the space shuttle program.

These studies are leading to a further understanding of the human vestibular system and its role in spatial orientation, equilibrium, balance, and debilitating disorders such as motion sickness that will lead to new diagnostic and therapeutic methods.

2 Part I, Article 1 of the Convention against Torture and Other Cruel, Inhuman or Degrading Treatment or Punishment: *"For the purposes of this Convention, torture means any act by which severe pain or suffering, whether physical or mental, is intentionally inflicted on a person … for any reason based on discrimination of any kind, when such pain or suffering is inflicted by or at the instigation of or with the consent or acquiescence of a public official or other person acting in an official capacity." And Article 16: "Each State Party shall undertake to prevent in any territory under its jurisdiction other acts of cruel, inhuman or degrading treatment or punishment which do not amount to torture as defined in Article 1, when such acts are committed by or at the instigation of or with the consent or acquiescence of a public official or other person acting in an official capacity. In particular, the obligations contained in articles 10, 11, 12 and 13 shall apply with the substitution for references to torture or references to other forms of cruel, inhuman or degrading treatment or punishment."*



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# Wind-Turbine NOISE

## What Audiologists Should Know

A Peer Reviewed Review of Peer Reviewed Materials (Michigan State U.)

BY JERRY PUNCH, RICHARD JAMES, AND DAN PABST

Noise from modern wind turbines is not known to cause hearing loss, but the low-frequency noise and vibration emitted by wind turbines may have adverse health effects on humans and may become an important community noise concern.



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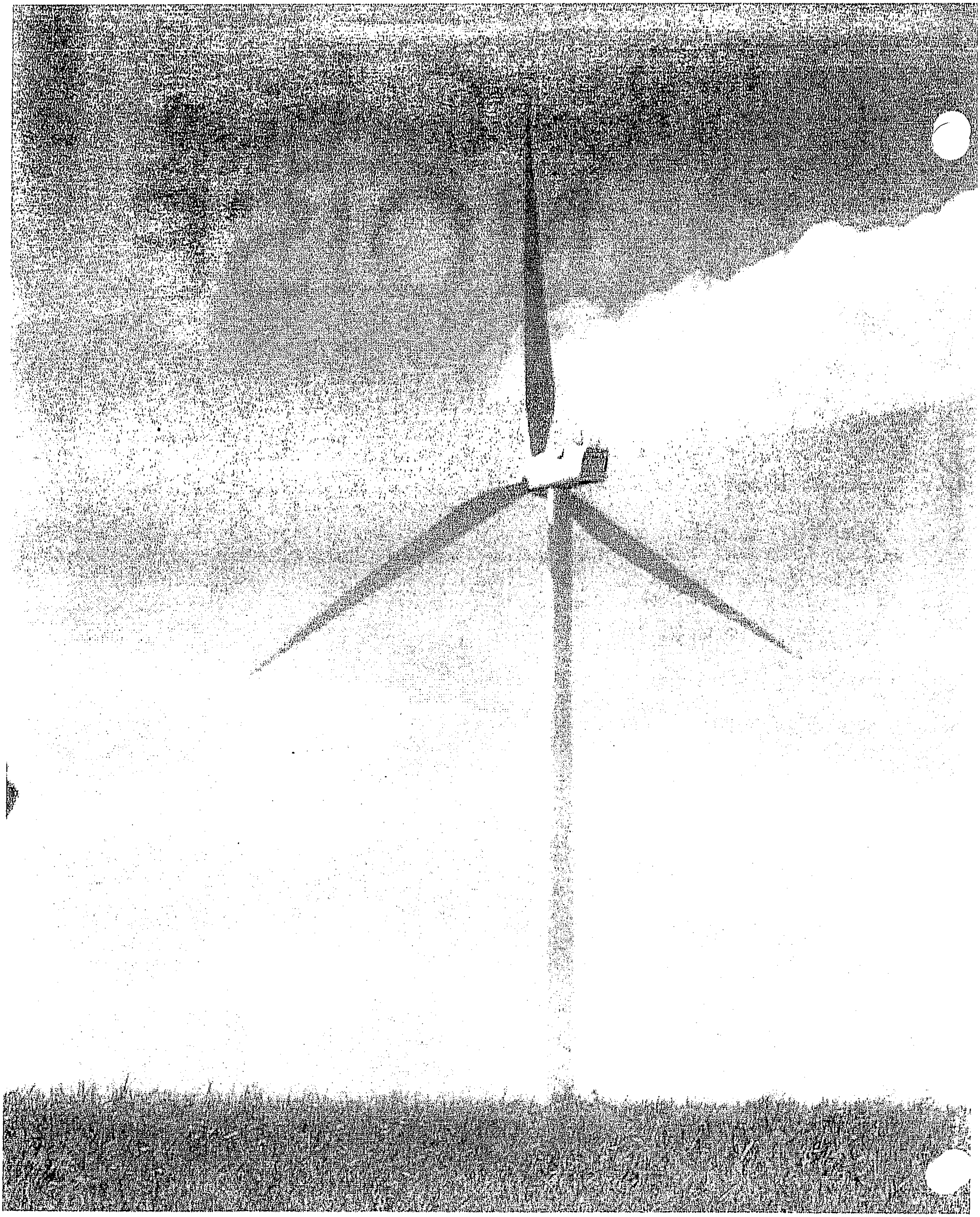

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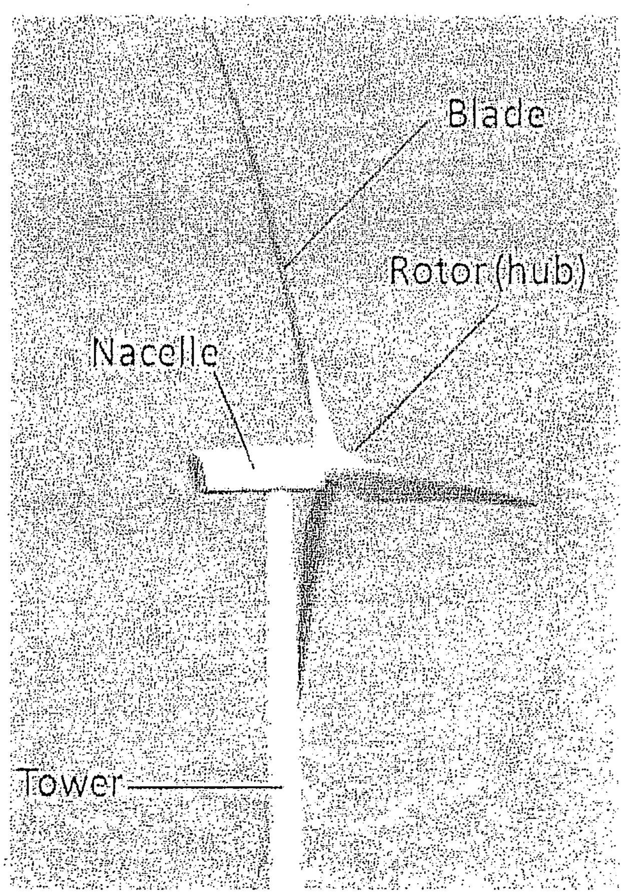
Most of us would agree that the modern wind turbine is a desirable alternative for producing electrical energy. One of the most highly touted ways to meet a federal mandate that 20 percent of all energy must come from renewable sources by 2020 is to install large numbers of utility-scale wind turbines. Evidence has been mounting over the past decade, however, that these utility-scale wind turbines produce significant levels of low-frequency noise and vibration that can be highly disturbing to nearby residents.

None of these unwanted emissions, whether audible or inaudible, are believed to cause hearing loss, but they are widely known to cause sleep disturbances. Inaudible components can induce resonant vibration in solids, liquids, and gases—including the ground, houses, and other building structures, spaces within those structures, and bodily tissues and cavities—that is potentially harmful to humans. The most extreme of these low-frequency (infrasonic) emissions, at frequencies under about 16 Hz, can easily penetrate homes. Some residents perceive the energy as sound, others experience it as vibration, and others are not aware of it at all. Research is beginning to show that, in addition to sleep disturbances, these emissions may have other deleterious consequences on health. It is for these reasons that wind turbines are becoming an important community health issue, especially when hosted in quiet rural communities that have no prior experience with industrial noise or urban hum.



Major components of a modern wind turbine.

The people most susceptible to disturbances caused by wind turbines may be a small percentage of the total exposed population, but for them the introduction of wind turbines in their communities is not something to which they can easily become acclimated. Instead, they become annoyed, uncomfortable, distressed, or ill. This problem is increasing as newer utility-scale wind turbines capable of generating 1.5-5 MWatts of electricity or more replace the older turbines used over the past 30 years, which produced less than 1 MWatt of power. These large wind turbines can have hub heights that span the length of a football field and blade lengths that span half that distance. The increased size of these multi-MWatt turbines, especially the blades, has been associated with complaints of adverse health effects (AHEs) that cannot be explained by auditory responses alone.

For this article, we reviewed the English-language, peer-reviewed literature from around the world on the topic of wind-turbine noise and vibration and their effects on humans. In addition, we used popular search engines to locate relevant online trade journals, books, reference sources, government regulations, and acoustic and vibration standards. We also consulted professional engineers and psychoacousticians regarding their unpublished ideas and research.

## Sources of Wind-Turbine Noise and Vibration

Physically, a modern wind turbine consists of a tower; a rotor (or hub); a set of rotating blades—usually three, located upwind to the tower; and a nacelle, which is an enclosure containing a gearbox, a generator, and



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computerized controls that monitor and regulate operations (FIGURE 1). Wind speed can be much greater at hub level than at ground level, so taller wind towers are used to take advantage of these higher wind speeds. Calculators are available for predicting wind speed at hub height, based on wind speeds at 10 meter weather towers, which can easily be measured directly.

Mechanical equipment inside the nacelle generates some noise, but at quieter levels than older turbines. This mechanical sound is usually considered of secondary importance in discussions of annoyance from today's turbines. The main cause of annoyance is an aerodynamic source created by interaction of the turning blades with the wind. With optimal wind conditions, this aerodynamic noise is steady and commonly described as an airplane overhead that never leaves.

When wind conditions are not optimal, such as during turbulence caused by a storm, the steady sounds are augmented by fluctuating aerodynamic sounds. Under steady wind conditions, this interaction generates a broadband whooshing sound that repeats itself about once a second and is clearly audible. Many people who live near the wind turbine find this condition to be very disturbing.

The whooshing sound comes from variations of air turbulence from hub to blade tip and the inability of the turbine to keep the blades adjusted at an optimal angle as wind direction varies. The audible portion of the whoosh is around 300 Hz, which can easily penetrate walls of homes and other buildings. In addition, the rotating blades create energy at frequencies as low as 1–2 Hz (the blade-passage frequency), with overtones of up to about 20 Hz. Although some of this low-frequency energy is audible to some people with sensitive hearing, the energy is mostly vibratory to people who react negatively to it.

## Adverse Health Effects of Wind-Turbine Noise

Hubbard and Shepherd (1990), in a technical paper written for the National Aeronautics and Space Administration (NASA), were the first to report in depth on the noise and vibration from wind turbines. Most of the relevant research since that time has been conducted by European investigators, as commercial-grade (utility-scale) wind turbines have existed in Europe for many decades. Unfortunately, the research and development done by wind-turbine manufacturers is proprietary and typically has not been shared with the public, but reports of the distressing effects on people living near utility-scale wind turbines in various parts of the world are becoming more common.

Studies carried out in Denmark, The Netherlands, and Germany (Wolsink and Sprengers, 1993; Wolsink et al, 1993), a Danish study (Pedersen and Nielsen, 1994), and two Swedish studies (Pedersen and Persson Waye, 2004, 2007) collectively indicate that wind turbines differ from other sources of community noise in several respects. These investigators confirm the findings of earlier research that amplitude-modulated sound is more easily perceived and more annoying than constant-level sounds (Bradley, 1994; Bengtsson et al, 2004) and that sounds that are unpredictable and uncontrollable are more annoying than other sounds (Geen and McCown, 1984; Hatfield et al, 2002).

Annoyance from wind-turbine noise has been difficult to characterize by the use of such psychoacoustic parameters as sharpness, loudness, roughness, or modulation (Persson Waye and Öhrström, 2002). The extremely low-frequency nature of wind-turbine noise, in combination with the fluctuating blade sounds, also means that the noise is not easily masked by other environmental sounds.

Pedersen et al (2009), in a survey conducted in The Netherlands on 725 respondents, found that noise from wind turbines is more annoying than transportation or industrial noises at comparable levels, measured in dBA. They noted that annoyance from turbine sounds at 35 dBA corresponds to the annoyance reported for other common community-noise sources at 45 dBA. Higher visibility of the turbines was associated with higher levels of annoyance, and annoyance was greater when attitudes toward the visual impact of the turbines on the landscape were negative. However, the height of wind turbines means that they are also most clearly visible to the people closest to them and those who also receive the highest sound levels. Thus, proximity of the receiver to wind turbines makes it difficult to determine whether annoyance to the noise is independent of annoyance to the visual impact. Pedersen et al (2009) also found that annoyance was substantially lower in people who benefitted economically from having wind turbines located on their property.

Among audiologists and acousticians, it has been understood for many decades that sufficiently intense and prolonged exposure to environmental noise can cause hearing impairment, annoyance, or both. In essence, the view has been *what* you can hear can hurt you. In the case of wind turbines, it seems that *what* you can't hear can also hurt you. Again, there is no evidence that noise generated by wind turbines, even the largest utility-scale turbines, causes hearing loss. But there is increasingly clear evidence that audible and low-frequency acoustic energy from these turbines is sufficiently intense to cause extreme annoyance and inability to sleep, or disturbed sleep, in individuals living near them.

Jung and colleagues (2008), in a Korean study, concluded that low-frequency noise in the frequency range above 30 Hz can lead to psychological complaints and that infrasound in the frequency range of 5–8 Hz can cause complaints due to rattling doors and windows in homes.

The energy generated by large wind turbines can be especially disturbing to the vestibular systems of some people, as well as cause other troubling sensations of the head, chest, or other parts of the body. Dr. Nina Pierpont (2009), in her definitive natural experiment on the subject, refers to these effects as Wind-Turbine Syndrome (WTS). TABLE 1 lists the symptoms that, in various combinations, characterize WTS. Although hearing impairment is not one of the symptoms of WTS, audiologists whose patients report these symptoms should ask them if they live near a wind turbine.

It is well known that sleep deprivation has serious consequences, and we know that noncontinuous sounds and nighttime sounds are less tolerable than continuous and daytime sounds. Somewhat related effects, such as cardiac arrhythmias, stress, hypertension, and headaches have also been attributed to noise or vibration from wind turbines, and some researchers are referring to these effects as Vibroacoustic Disease, or VAD (Castelo Branco, 1999; Castelo Branco and Alves-Pereira, 2004). VAD is described as occurring in persons who are exposed to high-level (>90 dB SPL) infra- and low-frequency noise (ILFN), under 500 Hz, for periods of 10 years or more. It is believed to be a systemic pathology characterized by direct tissue damage to a variety of bodily organs and may involve abnormal proliferation of extracellular matrices.

Alves-Pereira and Castelo Branco (2007) reported on a family who lived near wind turbines and showed signs of VAD. The sound levels in the home were less than 60 dB SPL in each 1/3-octave band below 100 Hz. We have measured unweighted sound levels ranging from 60 to 70 dB Leq (averaged over 1 minute) in these low-frequency bands in Ontario homes of people reporting AHEs from wind turbines. A spectral analysis of sounds emitted at a Michigan site revealed that unweighted peak levels at frequencies under 5 Hz exceeded 90 dB SPL (Wade Bray, pers. comm., 2009).

**Table 1. Core Symptoms of Wind-Turbine Syndrome**

| | |
|---|---|
| 1 | Sleep disturbance |
| 2 | Headache |
| 3 | Visceral Vibratory Vestibular Disturbance (VVVD) |
| 4 | Dizziness, vertigo, unsteadiness |
| 5 | Tinnitus |
| 6 | Ear pressure or pain |
| 7 | External auditory canal sensation |
| 8 | Memory and concentration deficits |
| 9 | Irritability, anger |
| 10 | Fatigue, loss of motivation |

Source: Pierpont, 2009

Similar observations have been made in studies of people who live near busy highways and airports, which also expose people to low-frequency sounds, both outdoors and in their homes. Evidence is insufficient to substantiate that typical exposures to wind-turbine noise, even in residents who live nearby, can lead to VAD, but early indications are that there are some more-vulnerable people who may be susceptible. Because ILFN is not yet recognized as a disease agent, it is not covered by legislation, permissible exposure levels have not yet been established, and dose-response relationships are unknown (Alves-Pereira, 2007).

As distinguished from VAD, Pierpont's (2009) use of the term Wind-Turbine Syndrome appears to emphasize a constellation of symptoms due to stimulation, or overstimulation, of the vestibular organs of balance due to ILFN from wind turbines (see TABLE 1). One of the most distinctive symptoms she lists in the constellation of symptoms comprising WTS is Visceral Vibratory Vestibular Disturbance (VVVD), which she defines as "a sensation of internal quivering, vibration, or pulsation accompanied by agitation, anxiety, alarm, irritability, rapid heartbeat, nausea, and sleep disturbance" (p. 270).

Drawing on the recent work of Balaban and colleagues (i.e., Balaban and Yates, 2004), Pierpont describes the close association between the vestibular system and its neural connections to brain nuclei involved with balance processing, autonomic and somatic sensory inflow and outflow, the fear and anxiety associated with vertigo or a sudden feeling of postural instability, and aversive learning. These neurological relationships give credence to Pierpont's linkage of the symptoms of VVVD to the vestibular system.

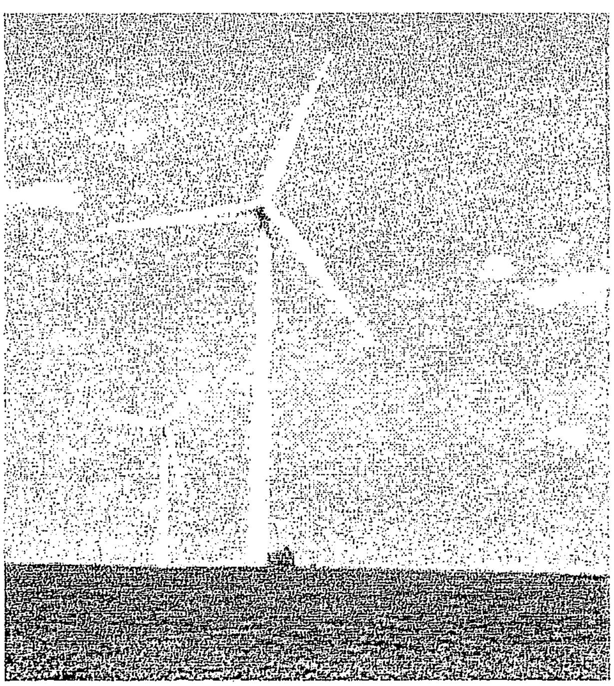
Todd et al (2008) demonstrated that the resonant frequency of the human vestibular system is 100 Hz, concluding that the mechano-receptive hair cells of the vestibular structures of the inner ear are remarkably sensitive to low-frequency vibration and that this sensitivity to vibration exceeds that of the cochlea. Not only is 100 Hz the frequency of the peak response of the vestibular system to vibration, but it is also a frequency at which a substantial amount of acoustic energy is produced by wind turbines. Symptoms of both VAD and VVVD can presumably occur in the presence of ILFN as a result of disruptions of normal paths or structures that mediate the fine coordination between living tissue deformation and activation of signal transducers; these disruptions can lead to aberrant mechano-electrical coupling that can, in turn, lead to conditions such as heart arrhythmias (Ingber, 2008). Ultimately, further research will be needed to sort out the commonalities and differences among the symptoms variously described in the literature as VAD, VVVD, and WTS.

Dr. Geoff Leventhall, a British scientist, and his colleagues (Waye et al, 1997; Leventhall, 2003, 2004) have documented the detrimental effects of low-frequency noise exposure. They consider it to be a special environmental noise, particularly to sensitive people in their homes. Waye et al (1997) found that exposure to dynamically modulated low-frequency ventilation noise (20–200 Hz)—as opposed to midfrequency noise exposure—was more bothersome, less pleasant, impacted work performance more negatively, and led to lower social orientation.

Leventhall (2003), in reviewing the literature on the effects of exposure to low-frequency noise, found no evidence of hearing loss but substantial evidence of vibration of bodily structures (chest vibration), annoyance (especially in homes), perceptions of unpleasantness (pressure on the eardrum, unpleasant perception within the chest area, and a general feeling of vibration), sleep disturbance (reduced wakefulness), stress, reduced performance on demanding verbal tasks, and negative biological effects that included quantitative measurements of EEG activity, blood pressure, respiration, hormone production, and heart rate.

Regarding work performance, reviewed studies indicated that dynamically modulated low-frequency noise, even when inaudible to most individuals, is more difficult to ignore than mid- or high-frequency noise and that its imperviousness to habituation leads to reduced available information-processing resources. Leventhall hypothesized that low-frequency noise, therefore, may impair work performance. More recently, as a consultant on behalf of the British Wind Energy Association (BWEA), the American Wind Energy Association (AWEA), and the Canadian Wind Energy Association (CANWEA), Leventhall (2006) changed his position, stating that although wind turbines do produce significant levels of low-frequency sound, they do not pose a threat to humans—in effect reverting to the notion that *what* you can't hear can't hurt you.

According to the World Health Organization guidelines (WHO, 2007), observable effects of nighttime, outdoor wind-turbine noise do not occur at levels of 30 dBA or lower. Many rural communities have ambient, nighttime sound levels that do not exceed 25 dBA. As outdoor sound levels increase, the risk of AHEs also increases, with the most vulnerable being the first to show its effects. Vulnerable populations include elderly persons; children, especially those younger than age six; and people with pre-existing medical conditions, especially if sleep is affected. For outdoor sound levels of 40 dBA or higher, the WHO states that there is sufficient evidence to link prolonged exposure to AHEs. While the WHO identifies long-term, nighttime audible sounds over 40 dBA outside one's home as a cause of AHEs, the wind industry commonly promotes 50 dBA as a safe limit for nearby homes and properties. Recently, a limit of 45 dBA has been proposed for new wind projects in Canada (Keith et al, 2008).


Utility-scale wind turbines located in Huron County, Michigan.

Much of the answer as to why the wind industry denies that noise is a serious problem with its wind turbines is because holding the noise to 30 dBA at night has serious economic consequences. The following quotation by Upton Sinclair seems relevant here: "It is difficult to get a man to understand something when his salary depends upon his not understanding it" (Sinclair, 1935, reprinted 1994, p. 109).

In recent years, the wind industry has denied the validity of any noise complaints by people who live near its utility-scale wind turbines. Residents who are leasing their properties for the siting of turbines are generally so pleased to receive the lease payments that they seldom complain. In fact, they normally are required to sign a leasing agreement, or gag clause, stating they will not speak or write anything unfavorable about the turbines. Consequently, complaints, and sometimes lawsuits, tend to be initiated by individuals who live near property on which wind turbines are sited, and not by those who are leasing their own property. This situation pits neighbor against neighbor, which leads to antagonistic divisions within communities.

## Measurement of Wind-Turbine Noise

It is important to point out that the continued use of the A-weighting scale in sound-level meters is the basis for misunderstandings that have led to acrimony between advocates and opponents of locating wind turbines in residential areas. The dBA scale grew out of the desire to incorporate a function into the measurement of sound pressure levels of environmental and industrial noise that is the inverse of the minimum audibility curve (Fletcher and Munson, 1933) at the 40-phon level. It is typically used, though, to specify the levels of noises that are more intense, where the audibility curve becomes considerably flattened, obviating the need for A-weighting. It is mandated in various national and international standards for measurements that are compared to damage-risk criteria for hearing loss and other health effects. The A-weighted scale in sound-level meters drastically reduces



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sound-level readings in the lower frequencies, beginning at 1000 Hz, and reduces sounds at 20 Hz by 50 dB.

For wind-turbine noise, the A-weighting scale is especially ill-suited because of its devaluation of the effects of low-frequency noise. This is why it is important to make C-weighted measurements, as well as A-weighted measurements, when considering the impact of sound from wind turbines. Theoretically, linear-scale measurements would seem superior to C-scale measurements in wind-turbine applications, but linear-scale measurements lack standardization due to failure on the part of manufacturers of sound-level meters to agree on such factors as low-frequency cutoff and response tolerance limits. The Z-scale, or zero-frequency weighting, was introduced in 2003 by the International Electro-technical Commission (IEC) in its Standard 61672 to replace the flat, or linear, weighting used by manufacturers in the past.

## State of Michigan Siting Guidelines

Michigan's siting guidelines (State of Michigan, 2008) will be used as an example of guidelines that deal only in a limited way with sound. These guidelines refer to earlier, now outdated, WHO and Environmental Protection Agency (EPA) guidelines to support a noise criterion that SPLs cannot exceed 55 dBA at the adjacent property line. This level is allowed to be exceeded during severe weather or power outages, and when the ambient sound level is greater than 55 dBA, the turbine noise can exceed that higher background sound level by 5 dB. These levels are about 30 dB above the nighttime levels of most rural communities. When utility-scale turbines were installed in Huron County, Michigan, in May 2008, the WHO's 2007 guidelines that call for nighttime, outside levels not to exceed 30 dBA were already in place. Based on measurements made by the authors, these turbines produce 40–45 dBA sound levels at the perimeter of a 1,000 ft radius under typical weather conditions, and the additive effects of multiple turbines produce higher levels. Many of the turbines have been located close enough to homes to produce very noticeable noise and vibration.

Kamperman and James (2009) have offered recommendations for change in the State of Michigan guidelines (2008) for wind turbines. Some of the more pertinent details of the Michigan siting guidelines are shown in the left-hand column of TABLE 2. The state of Michigan permits sound levels that do not exceed 55 dBA or L90 + 5 dBA, whichever is greater, measured at the property line closest to the wind-energy system. These guidelines make no provisions to limit low-frequency sounds from wind-turbine operations.

In consideration of the current WHO guidelines (2007), measurements made by the authors in Huron County, Michigan, indicate that the current Michigan guidelines do not appear adequate to protect the public from the nuisances and known health risks of wind-turbine noise. In fact, these guidelines appear to be especially lenient

**Table 2. Current and Proposed Wind-Turbine Siting Guidelines**

| Current Michigan Guidelines* | Alternative Proposed Guidelines** |
|---|---|
| Sound level cannot exceed 55 dBA or L90 + 5 dBA, whichever is greater. | Operating LAeq is not to exceed the background LA90 +5 dBA, where LA90 is measured during a preconstruction noise study at the quietest time of night. Similar dBC limits should also be applied. |
| Limits apply to sound levels measured at homes (as stated in Huron County Ordinance). | Limits apply to sound levels measured at property lines, except that turbine sounds cannot exceed 35 dBA at any home. |
| No provisions are made for limiting low-frequency sounds from wind-turbine operations. | LCeq-LA90 cannot exceed 20 dB at receiving property, e.g., LCeq (from turbines) minus (LA90 [background] + 5) < 20 dB, and is not to exceed 55 LCeq from wind turbines (60 LCeq for properties within one mile of major heavily trafficked roads). |

*Source: State of Michigan, 2008

**Source: Kamperman and James, 2009

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in terms of tolerable sound levels. Sound levels that approach 20 dBA higher than natural ambient levels are considered unacceptable in most countries; Michigan permits 30 dBA increases.

In considering the health and well-being of people living near wind-turbine projects, the changes recommended by Kamperman and James (2009) would abandon the 55 dBA limit in favor of the commonly accepted criteria of L90 + 5 dBA, for both A- and C-scale readings, where L90 is the preconstruction ambient level. These recommendations also include a prohibition against any wind-turbine-related sound levels exceeding 35 dBA on receiving properties that include homes or other structures in which people sleep. Additional protections against low-frequency sound are given in the right-hand column of TABLE 2. These recommended provisions would protect residents by limiting the difference between C-weighted

**People living near wind turbines may experience sleep disturbance.**

Leq during turbine operation and the quietest A-weighted pre-operation background sound levels, plus 5 dB, to no more than 20 dB at the property line. This level should not exceed 55 dB Leq on the C scale, or 60 dB Leq for properties within one mile of major heavily trafficked roads, which sets a higher tolerance for communities that tend to experience slightly noisier conditions.

Implementation of the recommendations of Kamperman and James would result in siting wind turbines differently than what is currently planned for future wind-turbine projects in Michigan. This change would result in sound levels at nearby properties that are much less noticeable, and much less likely to cause sleep deprivation, annoyance, and related health risks. These sound-level measurements should be made by independent acoustical engineers or knowledgeable audiologists who follow ANSI guidelines (1993, 1994) to ensure fair and accurate readings, and not by representatives of the wind industry.

People living within a mile of one or more wind turbines, and especially those living within a half mile, have frequent sleep disturbance leading to sleep deprivation, and sleep disturbances are common in people who live up to about 1.25 miles away. This is the setback distance at which a group of turbines would need to be in order not to be a nighttime noise disturbance (Kamperman and James, 2009). It is also the setback distance used in several other countries that have substantial experience with wind turbines, and is the distance at which Pierpont (2009) found very few people reporting AHEs.

A study conducted by van den Berg (2003) in The Netherlands demonstrated that daytime levels cannot be used to predict nighttime levels and that residents within 1.9 km 1900 mile (1.18 mile) of a wind-turbine project expressed error annoyance from the noise. Pierpont (2009) recommends baseline minimum setbacks of 2 kilometers (1.24 mile) from residences and other buildings such as hospitals, schools, and nursing homes, and longer setbacks in mountainous terrain and when necessary to meet the noise criteria developed by Kamperman and James (2009).

In a panel review report, the American Wind Energy Association (AWEA) and Canadian Wind Energy Association (CANWEA) have objected to setbacks that exceed 1 mile (Colby et al, 2009). A coalition of independent medical and acoustical experts, the Society for Wind Vigilance (2010), has provided a recent rebuttal to that report. The society has described the panel review as a typical product of industry-funded white papers, being neither authoritative nor convincing. The society accepts as a medical fact that sleep disturbance, physiological stress, and psychological distress can result from exposure to wind-turbine noise.

Wind turbines have different effects on different people. Some of these effects are somewhat predictable based on financial compensation, legal restrictions on free speech included in the lease contracts with hosting landowners, and distance of the residence from wind projects, but they are sometimes totally unpredictable. Planning for wind projects needs to be directed not only toward benefitting society at large but also toward protecting the individuals living near them. We believe that the state of Michigan, and other states that have adopted similar siting guidelines for wind turbines, are not acting in the best interest of all their citizens and need to revise their siting guidelines to protect the public from possible health risks and loss of property values, as well as reduce complaints about noise annoyance.

Wind-utility developers proposing new projects to a potential host community are often asked if their projects will cause the same negative community responses that are heard from people living in the footprint of operating projects. They often respond that they will use a different

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type of wind turbine or that reports of complaints refer to older-style turbines that they do not use. In our opinion, these statements should usually be viewed as diversionary.

Finally, it is important to note that there is little difference in noise generated across makes and models of modern utility-scale, upwind wind turbines once their power outputs are normalized. Kamperman (pers. comm., 2009), after analyzing data from a project funded by the Danish Energy Authority (Søndergaard and Madsen, 2008), has indicated that when the A-weighted sound levels are converted to unweighted levels, the low-frequency energy from industrial wind turbines increases inversely with frequency at a rate of approximately 3 dB per octave to below 10 Hz (the lowest reported frequency). Kamperman has concluded that the amount of noise generated at low frequencies increases by 3–5 dB for every MW of electrical power generated. Because turbines are getting larger, this means that future noise problems are likely to get worse if siting guidelines are not changed.

## Conclusion

Our purpose in this article has been to provide audiologists with a better understanding of the types of noise generated by wind turbines, some basic considerations underlying sound-level measurements of wind-turbine noise, and the adverse health effects on people who live near these turbines. In future years, we expect that audiologists will be called upon to make noise measurements in communities that have acquired wind turbines, or are considering them. Some of us, along with members of the medical profession, will be asked to provide legal testimony regarding our opinions on the effects of such noise on people. Many of us will likely see clinical patients who are experiencing some of the adverse health effects described in this article.

As a professional community, audiologists should become involved not only in making these measurements to corroborate the complaints of residents living near wind-turbine projects but also in developing and shaping siting guidelines that minimize the potentially adverse health effects of the noise and vibration they generate. In these ways, we can promote public health interests without opposing the use of wind turbines as a desirable and viable alternative energy source.

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*Portions of this work were presented at the Annual Convention of the American Speech-Language-Hearing Association (ASHA), November 2009, New Orleans, LA.*

*Acknowledgments. We wish to thank the many families and residents of Huron County, Michigan, with whom we spent many hours discussing a variety of issues related to their concerns about the noise and vibration from nearby wind turbines. Their involvement, and especially their compelling stories, provided information and encouragement that led us to the belief that this work should be shared with members of the audiology profession.*

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00001294

# Wind Turbines, Noise and Health

## February 2007

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## Acknowledgements.

Dr Mariana Alves- Pereira, MSc (Biomechanical Engineering)- for providing information and advice on Vibroacoustic disease.

Dr David Manley PhD, BSc (Hons.) MIEE MIOA, F Ins.P, C.Dip.AF, FICDDS, C.Eng. Who sadly died in 2006. His advice and knowledge in the field of acoustics was invaluable.

Mrs Barbara Frey, BA, MA
For kindly providing all the relevant journal searches and citations.

Mr Peter Hadden, BSc,FRICS
For his ongoing support and advice.

Professor Ralph V Katz, DMD, MPH, PhD – Professor and Chair of The Department of Epidemiology and Health Promotion New York University college of Dentistry-for reading over the report and doing the SPSS programming to collate the data collected and providing the specific graphs with that data.

Professor James Lovelock CH, PhD, DSc– for kindly reading over the report

Mr Alan Nunn- for initially introducing me to the first couple suffering from noise issues as a result of living near turbines.

Mr John Stewart Chair of the UK noise association

**THE EFFECT OF WIND TURBINES ON HEALTH.**

I first realised there might be a problem associated with wind turbines when I was introduced to a couple living near a wind farm in Cornwall. The distance from their home to the nearest turbine is about 400 meters. They told me about poor sleep, headaches stress and anxiety symptoms brought on when the wind was blowing in certain directions. At times, they told me that they have been so disturbed by the noise that after several disturbed nights sleep, they have sought refuge in a nearby bed and breakfast establishment (far enough away not to be similarly affected by the noise).

Since that meeting I have spoken to and / or corresponded with 39 people living between 300meters and 2 km from the nearest turbine of a wind farm all of whom were suffering from the consequences of the noise coming from the turbines. This disturbance is by no means always there and is worse in certain wind directions. The cases mentioned below are from several wind farms in the UK with a variety of turbine sizes from the smaller, older turbines to the taller more modern turbines. However I have had correspondence from people living near wind farms in New Zealand and Australia and have evidence from other sources, (newspapers, journals and papers) of people being similarly affected in France, Germany, Netherlands and the USA.
What this shows is that there is number of people suffering from the consequences of noise from the wind turbines. I'm sure that the cases mentioned here are probably the "tip of the iceberg" and further independent investigation is warranted. The cases are kept anonymous in order to protect the individuals concerned. There is much concern within communities that if one is seen to complain about the noise that if they decide to move away their properties will be difficult to sell and possibly devalued as a result. Therefore they feel that they are in a "Catch 22" situation.

**METHOD**

All people involved in this survey were contacted either by phone or in writing. Questionnaires were completed for all cases. Questionnaires were sent to people already known to be suffering from problems which they felt was due to their proximity to wind turbines.
The identity of the people questioned has been with held in order to maintain confidentiality. The respondents were from a number of sites in the UK- Wales, Cornwall and the north of England

**Example of questionnaire.**

1) Name- (preferred but optional)

2) Age 18-30 30-45
45-60 >60

3) Occupation

4) Address and /or postcode

5) Which wind farm is near your property?

6) How far away from your property is the nearest turbine?

7) How long have you been living at this property?

8) Do you feel that your health has in any way been affected since the erection of these turbines?

9) If yes please answer the following:-
Do you feel that since living near a wind turbine/turbines you have experienced excess of the following symptoms (i.e. more than you did prior to living near these structures)?

| | | |
|---|---|---|
| Headaches | yes | no |
| Palpitations | yes | no |
| Excessive tiredness | yes | no |
| Stress | yes | no |
| Anxiety | yes | no |
| Tinnitus (ringing in ears) | yes | no |
| Hearing problems | yes | no |
| Sleep disturbance | yes | no |
| Migraines | yes | no |
| Depression | yes | no |
| Other- please specify | | |

If you have answered yes to any or the above questions, have you approached your doctor regarding these symptoms? If yes please state any tests and/or treatment initiated.

10) Do you feel that your quality of life has in any way altered since living near the wind turbines? Yes no

If yes could you please explain in what way you feel your life has been altered.

00001258

## RESULTS

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Age | 45-60 | 45-60 | 45-60 | 45-60 |
| Occupation | Cleaner/ housewife | Retired Ill health | Head chef | farmer |
| | | | | |
| | | | | |
| Distance from turbine | 400m | 300m | 350m | 400m |
| Time at property | 36 years | 3 years | 7years | 4years |
| Health altered | Yes | Yes | yes | yes |
| Headaches | Yes | Yes | yes | yes |
| Palpitations | No | no | no | no |
| Excessive tiredness | Yes | No | yes | yes |
| Stress | Yes | Yes | yes | yes |
| Anxiety | Yes | Yes | yes | yes |
| Tinnitus | No | No | no | no |
| Hearing problems | No | No | no | yes |
| Sleep disturbances | Yes | Yes | yes | yes |
| Migraines | Yes | Yes | no | yes |
| | | | | |
| Other | | | | |
| Approached doctor | No | No | no | no |
| Altered quality of life | Yes | Yes | yes | yes |

| | 5 | 6 | 7 | 8 |
|---|---|---|---|---|
| Age | 45-60 | >60 | 18-30 | 18-30 |
| Occupation | Housewife | Retired | Electrician | carer |
| | | | | |
| | | | | |
| Distance from turbine | 300m | 300m | 300-500m | 300-500m |
| Time at property | 2.5 years | 2.5 years | 6 months | 6 months |
| Health altered | Yes | Yes | Yes | yes |
| Headaches | Yes | Yes | Yes | yes |
| Palpitations | No | No | No | no |
| Excessive tiredness | No | Yes | Yes | yes |
| Stress | No | No | No | no |
| Anxiety | No | No | No | no |
| Tinnitus | No | No | No | no |
| Hearing problems | No | No | No | no |
| Sleep disturbance | No | No | Yes | yes |
| Migraines | No | no | No | no |
| Depression | No | no | No | no |
| Other | | Thumping in ears | | |
| Approached doctor | No | Yes-Rx with pain Killers-ongoing assessment | No- didn't associate symptoms with the turbines | |
| Altered quality of life | Yes | yes | Yes | yes |

| | 9 | 10 | 11 | 12 |
|---|---|---|---|---|
| Age | >60 | 30-45 | 30-45 | 30-45 |
| occupation | Retired | candle maker | Retired-nervous Breakdown | Retired-ill health |
| | | | | |
| | | | | |
| Distance from turbine | 300m | ¼ mile | 300m | 300m |
| Time at property | 4years | 10 years | 3 years | 3years |
| Health altered | Yes | no | Yes | yes |
| Headaches | No | no | Yes | yes |
| Palpitations | No | no | No | no |
| Excessive tiredness | No | no | Yes | no |
| Stress | No | no | Yes | yes |
| Anxiety | No | no | Yes | yes |
| Tinnitus | Yes | no | No | no |
| Hearing problems | No | no | No | no |
| Sleep disturbance | No | no | Yes | yes |
| Migraines | Yes | no | Yes | no |
| Depression | No | no | Yes | yes |
| Other | | See comments at end | Stomach upset | |
| Approached doctor | No | no | Yes-seen psychiatrist-Ongoing review | no |
| Quality of life affected | Yes | yes | Yes | yes |
| | | | | |



00001301

| | 13 | 14 |
|---|---|---|
| Age | 30-45 | >60 |
| Occupation | Veterinary nurse and HGV driver | Retired from farming and Teaching |
| Post code | TR8 | SA38 |
| Wind farm | Bears Down | Blean Bowi |
| Distance from turbine | Too close | 1mile |
| Time at property | 19 months | 27years |
| Health altered | Yes | Yes |
| Headaches | Yes | Yes |
| Palpitations | No | Yes |
| Excessive tiredness | Yes | Yes |
| Stress | No | Yes |
| Anxiety | No | Yes |
| Tinnitus | No | Yes |
| Hearing problems | No | No |
| Sleep disturbance | Yes | Yes |
| Migraines | No | No |
| Depression | No | Yes |
| Other | No | Emotional turmoil |
| Approached doctor | Yes- taking sleepers and Headache tablets | Yes-had heart check up |
| Quality of life affected | Yes | Yes |

| | 15 | 16 | 17 | 18 |
|---|---|---|---|---|
| Age | 45-60 | >60 | >60 | 45-60 |
| Occupation | Teacher | Retired | Retired | Charity manager |
| | | | | |
| | | | | |
| Distance from turbine | 700m | 650m | 650 | ½ mile |
| Time at property | 26 years | 30+ | 30+years | Bear Down |
| Health altered | Yes | Yes | No | No |
| Headaches | Yes | No | no | No |
| Palpitations | No | No | No | No |
| Excessive tiredness | Yes | Yes | No | No |
| Stress | No | Yes | No | No |
| Anxiety | Yes | No | No | No |
| Tinnitus | No | No | No | No |
| Hearing problems | No | Yes | No | No |
| Sleep disturbance | Yes | Yes | No | No |
| Migraines | No | No | No | No |
| Depression | No | Yes | No | No |
| Other | No | No | No | No |
| Approached doctor | No | No | No | No |
| Quality of life altered | Yes | Yes | Yes | No |

| | 19 | 20 | 21 | 22 |
|---|---|---|---|---|
| Age | >60 | >60 | >60 | >60 |
| Occupation | Retired | | Retired | Retired |
| | | | | |
| | | | | |
| Distance from turbine | | | 700m | 700m |
| Time at property | 20years | 20 years | 25years | 25 years |
| Adverse health affects | Yes | Yes | Yes | Yes |
| Headaches | | | Yes | Yes |
| Palpitations | | | | |
| Excessive tiredness | Yes | Yes | Yes | Yes |
| Stress | | | Yes | Yes |
| Anxiety | | | Yes | Yes |
| Tinnitus | | | | Yes |
| Hearing problems | | | | Yes |
| Sleep disturbance | | Yes | Yes | Yes |
| Migraines | | | | |
| Depression | Yes | | Yes | Yes |
| Other | | | | |
| Approached doctor | | | Yes | Yes- doctor referred me to the hospital. After tests the consultant could find nothing wrong with my ears. |
| Quality if life affected | Yes | Yes | Yes | Yes |

00001304

| | 23 | 24 | 25 | 26 |
|---|---|---|---|---|
| Age | 45-60 | 45-60 | >60 | 57 |
| Occupation | Farmer | Farmer | Retired | Retired police officer |
| | | | | |
| | | | | |
| Distance from turbines | 430m | 430m | 1000m | 1000m |
| Time at property | 5 ½ years | 5 ½ | 30years | 30years |
| Adverse health affects | No | Yes | Yes | Yes |
| Headaches | | | Yes | Yes |
| Palpitations | | | | |
| Excessive tiredness | | | Yes | Yes |
| Stress | | | Yes | Yes |
| Anxiety | | | | Yes |
| Tinnitus | | Yes | | |
| Hearing problems | | | Yes | |
| Sleep disturbance | | | | Yes |
| Migraines | | | Yes | |
| Depression | | | | Yes |
| Other | | | | |
| Approached doctor | | Yes- been under a specialist in Furness General hospital for 1 ½ years | Yes | No |
| Quality of life affected | Yes | Yes | Yes | Yes |

00001305

| | 27 | 28 | 29 | 30 |
|---|---|---|---|---|
| Age | >60 | >60 | 56 | 79 |
| Occupation | Farmer/ sheep breeder | | Pedigree sheep breeder | War veteran |
| | | | | |
| | | | | |
| Distance from turbine | ½ mile | 700m | 1/3mile | |
| Time at property | 9 years | 33 years | 9 years | 33 years |
| Adverse health affect | Yes | Yes | Yes | Yes |
| Headaches | Yes | | Yes | Yes |
| Palpitations | | | Yes | |
| Excessive tiredness | Yes | | Yes | Yes |
| Stress | Yes | | Yes | Yes |
| Anxiety | | | Yes | Yes |
| Tinnitus | | | | Yes |
| Hearing problems | | | | Yes |
| Sleep disturbance | Yes | Yes | Yes | |
| Migraines | Yes | | Yes | Yes |
| Depression | | | | |
| Other | | | Concentration | |
| Approached doctor | Yes | No | Yes- have had a 24 hour e.c.g. for investigations of palpitations. Brain haemorrhage 2 years ago. | Yes |
| Quality of life affected | Yes | | Yes | Yes |



00001366

| | 31 | 32 | 33 | 34 |
|---|---|---|---|---|
| Age | 81 | 45-60 | >60 | 30-45 |
| Occupation | Retired carpenter | Systems analyst/programmer | Business owner | Retired State registered nurse |
| | | | | |
| | | | | |
| Distance from turbine | | ¾ mile | Less than 1 mile | 300m |
| Time at property | 33 years | 16 years | 16 years | 7 years |
| Health adversely affected | Yes | No | Yes | Yes |
| Headaches | Yes | | No | Yes |
| Palpitations | | | No | |
| Excessive tiredness | Yes | Yes | Yes | Yes |
| Stress | Yes | | Yes | Yes |
| Anxiety | Yes | | No | |
| Tinnitus | Yes | | No | |
| Hearing problems | Yes | | Yes | |
| Sleep disturbance | | | Yes | Yes |
| Migraines | Yes | | no | |
| Depression | | | No | |
| Other | | | | |
| Approached doctor | Yes | Yes | No | No |
| Quality of life affected | Yes | | Yes | Yes |

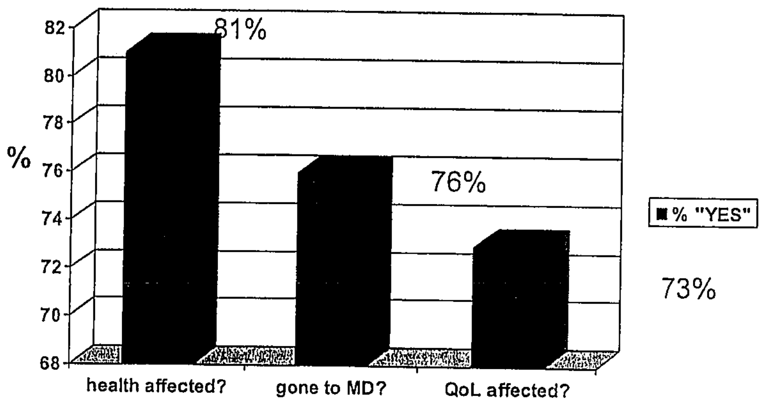
00001307

| | 35 | 36 | 37 | 38 |
|---|---|---|---|---|
| Age | 45-60 | 45-60 | 45-60 | 62 |
| Occupation | Retired due to Nervous breakdown | Semi Retired farmer | Semi retired farmer | Retired |
| | | | | |
| | | | | |
| Distance from turbine | 300m | 800m | 800m | |
| Time at property | 7 years | 11 years | 11 years | 25 years |
| Health adversely affected | yes | Yes definitely | Yes | |
| Headaches | yes | Yes | Yes | |
| Palpitations | | Yes | Yes | |
| Excessive tiredness | | Yes | Yes | Yes |
| Stress | yes | Yes yes | Yes | |
| Anxiety | yes | Yes yes yes | Yes | |
| Tinnitus | | Yes | Yes | |
| Hearing problems | | May be | | |
| Sleep disturbance | yes | Yes yes yes | Yes | Yes |
| Migraines | | No | No | |
| Depression | | No | no | |
| Other | nausea | | | |
| Approached doctor | yes | Yes put on antidepressants and anti-hypertensives | Yes | |
| Quality of life affected | Yes | Absolutely yes | Yes | Yes |

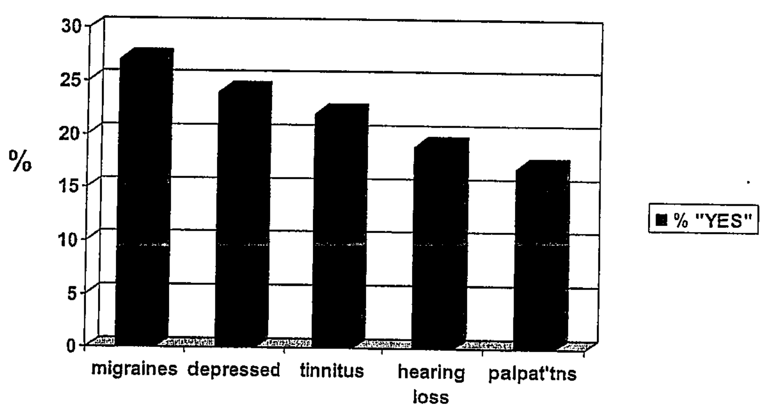
| | 39 | 40 | 41 | 42 |
|---|---|---|---|---|
| Age | | | 45-60 | >60 |
| Occupation | Retired phlebotomist | Running own business | Database administrator | Retired farmer |
| | | | | |
| | | | | |
| Distance from turbine | | 600m | 3/4mile | 1 mile |
| Time at property | 20 years | 24 years | 7 years | 26 years |
| Adverse affect on health | Yes | Yes | Yes | Yes |
| Headaches | | Yes | | Yes |
| Palpitations | | | | Yes |
| Excessive tiredness | Yes | Yes | | Yes |
| Stress | | | | Yes |
| Anxiety | | Yes | Yes | Yes |
| Tinnitus | | | | |
| Hearing problems | | | | |
| Sleep disturbance | Yes | Yes | | Yes |
| Migraines | | | | |
| Depression | | | | Yes |
| Other | Lack of concentration And irritability | | Nausea | |
| Approached doctor | No | No | | Yes |
| Quality of life affected | Yes | Yes | Yes | Yes |

00001309

- *Has your health in any way been affected since the erection of these turbines?*
- *As a result, have you gone to see your doctor?*
- *Do you feel that your Quality of Life has in any way been altered since living near the wind turbines?*

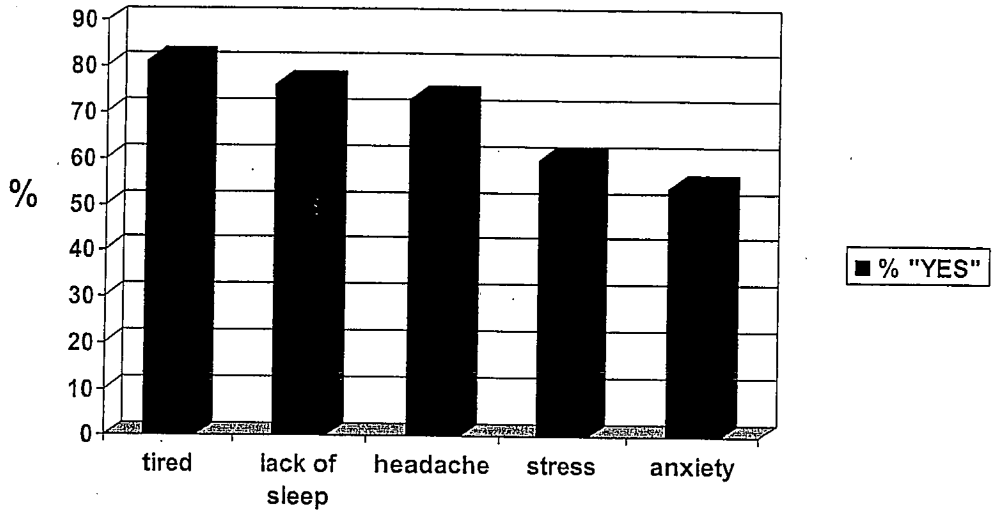



## Top 5 Self-reported Health Symptoms




## Next 5 Self-reported Health Symptoms

00001310




ADDITIONAL COMMENTS MADE BY RESPONDANTS

1) I get little sleep when the noise from the turbines is constant in its low frequency noise. I feel so depressed I want to get away and stay away until I know the wind direction has changed.

2) My symptoms are due to lack of sleep when the wind is in the east or northeast

3) I get headaches frequently especially when the turbines are running at a fast rate towards us.

4) I get headaches and thumping in the ears. I also find its continual noise very distressing.

5) Suffer with headaches more and feel tired more so find daily tasks difficult to do.

6) I also find that the sound we get from the farm affects my metal heart valve.

7) I couldn't say whether or not the storbing effect wakes me up but it is impossible to go back to sleep with it there.

8) Constant worry about noise. I feel sick when the turbines are running fast and towards the property. I came here to a rural area for peace after a busy city life. I feel this has been ruined by the turbines.

9) Stressed and extremely anxious as I am constantly disturbed by them when they are turning fast and facing towards me. We are having to live our lives around them due to the constant noise when they are working causing wind pressure throbbing.

10) The strobing even when curtains are closed is "HELL". The noise is a pain. TV blocks it, night and day. Can't sit and read a book or write letters.

00001311

11) My plan was to stay here- in my newly converted barn (7 years old) (we farmed here) until I died. We have our own private water supply, a good supply of fire wood, my own painting studio- VERY IMPORTANT TO ME! And a good workshop for my husband; friends nearby, brother and sister nearby. I was born 2 miles away- Now WE HAVE TO MOVE. This move has been forced upon us. We planted 7,000 trees here. Etc.etc.etc........

12) We will probably have to move, I can see no future for me here.

13) I dare not sleep at home.

14)
Noise disturbance at night –when wind in certain direction, interferes with sleep patterns, causing restlessness. During the day- makes it difficult to stay out of doors for any length of time through excessive thumping sound. Both can cause headaches, anxiety and irritability.

15) Certain wind directions mean excessive noise, like a thrashing machine constantly pounding, making it unpleasant to be in the garden or to have windows open. With strong wind conditions, double glazed windows vibrate and cause an intrusive, almost sub audible interference in some rooms.

16) Tired, disturbed by noise. Feel it as much as hear it. Developers deny there are any problems unless we can prove, but how can we do that?

17) Irritating noise from wind farm in easterly winds. You can almost feel it as well as hear it. It drives you mad over extended periods because of the nature of the noise, not the level per se. Unable to have front doors/windows open when winds are easterly, or use front bedroom if all 7 turbines are in operation.

18) Our quality of life we had before the wind farm came has gone. We no longer control the way we live our lives e.g. if we can work or sit in the garden, or at times, even where we can sit in our own home or get a full nights sleep.

19) I never suffered from any problems before the turbines. I am convinced that living in a continual state of anxiety over the past four and a half years since the noise nuisance started has contributed to my present problems (hypertension and stress). Prior to 1999 I always enjoyed excellent health and rarely visited the doctor's surgery. As my husband and I have been retired since 1994 and our family grown up and living in different areas of the country we do not have any other problems that are likely to cause stress or anxiety.

20) Not being able to choose when I work or sit in my own garden. Not getting full nights sleep. Waking with headaches when the noise is bad and feeling sick. Ears feel like I experience when travelling by plane- feel as if they are swollen inside. I cannot work more than 2-3 hours in the garden when the wind direction if from the east. We cannot see the wind farm from our property but at times the noise is horrendous.

21) My quality of life has been affected by the shadow flicker and the noise

22) I am bothered by the shadow flicker, and the noise while working behind the building.

23) I feel generally off colour

24) As we leave the house, the turbines are always there, menacing, always drawing your attention, depressing, in a beautiful area. Normally I sleep with the bedroom windows closed, if in summer we have a heat wave and the windows are open, I find I am wheezing in time with the turbine noise, it seems to come inside my body. This is an old stone gatehouse south of the site.

25) Quality of life has almost disappeared. No longer able to relax in the garden (when wind speed/ direction cause noise). Glinting and reflection also cause disturbance. Visual dominance is oppressive- extremely angry.

26) Constant sleep disturbance. Unable to work within certain areas, for noise levels, when wind is in certain directions, very stressful.

27) Disturbed sleeping. View blades whishing in the wind. Drawn to blades going round. Little concentration. Ugly to look at. Dominant. Not able to work in yard for long periods of time.

28) Our lives and home have been trashed and must be seen to be believed. We seem to be short tempered, unable to concentrate. Every thing we have such as mattress, duvets, cushions 4" thick, 3 rolls of sound deadening quilt, 3 sheets of corrugated asbestos, blankets, curtains, pillows even floor carpet stacked against the walls to try and keep out the sound. Not the peace I volunteered to fight for.

29) constant noise

30) Constant noise when turbine is facing us and away from us. Sleepless nights which make me irritable. Stress due to husbands anxiety about the turbines.

31) Noise from turbines effects my sleep patterns, I sleep less. I get nausea when the turbines face our home and causes a drumming at low noise frequency. I worry about the turbine blades coming off and killing me

32) Alienation from mainstream community that have the erroneous impression that wind power is a good alternative. Forced to sell property at a reduced rate- that was meant to be our retirement home. Health improved since moving from the property

33) As soon as the wind farm was operating I experienced horrendous continuous noise when the wind was from the east. This was both inside and outside my home. There were many times I had to leave the garden because of the noise. It was like a Chinese water torture, it was a constant pulsating noise. It was almost a feeling of compression as much as noise. I had to move bedrooms at times in order to escape the noise. It imprints on you, if you have had it all day in the garden, it stays with you,

once it's in your head it's hard to get rid of. It's weird. It's a feeling as much as a noise. It's torture.

34) It's an irritating and tiring noise, especially when you have not had any sleep because of it.

35) Even if you shut the window, the noise is still there, but not as much. The problem is, once you get the noise in your head, it's always there, it does annoy you and it is difficult to disregard.

36) The noise is like a whooshing noise. It is intrusive. It keeps me awake- it doesn't affect my husband as much as me but my being awake keeps him awake.

37) Once the noise gets into your head, it also seems to beat at the same frequency as my heart and I find it annoying and am unable to get any sleep- this can go on for nights on end. It's not always the level of the noise, it's the intermittent nature. You think "Oh it's stopped" then it starts up again.

38) If the wind is from the East or the South the noise is horrendous- you can't get away from it. It's inside and outside the house. It's worse at night- I have to bed hop. It's a whooshing, drumming, constant drumming noise. It's annoying. It's frustrating. It wears you down. You can't sleep at night or concentrate during the day. Once it gets inside your head you can't get rid of it. You get up in the morning, tired, agitated and depressed and it makes you short- tempered.

39) Our lives are hell, they have been ruined and it's all due to those turbines.

40) The noise from the wind farm is different and I can't explain why, it just is. All you ever want to do is to get out of the way of it, by whatever means you can.

## CONCLUSIONS

I think it is clearly evident from these cases that there are people living near turbines who are genuinely suffering from health effects from the noise produced by wind turbines. These neighbours of turbines clearly state that at times the noise from turbines is unbearable. The developers are usually heard to say that noise is not a problem. Clearly this cannot be the case.
A discussion follows which clearly explains why the characteristic noise from these turbines can be producing the symptoms that are being described above. On searching through the current literature I can find no papers written showing that turbines are harmless, only statements from acousticians giving their personal thoughts. In addition to this some of these acoustic experts have made statements categorically saying that the low frequency noise from turbines does not have an effect on health. I feel that these comments are made outside their area of expertise and should be ignored until proper medical, epidemiological studies are carried out by independent medical researchers.

## DISCUSSION

As shown in the case studies, people living near wind farms in the United Kingdom have been complaining of health problems since the construction of the wind farms near their homes. Inquiries reveal that some wind farms located close to peoples residences in Europe, Australia and North America have reported similar problems

The range of symptoms mentioned by complainants includes headaches, sleep disturbance, anxiety, depression, stress, vertigo and tinnitus. People complain of the noise, vibration and shadow flicker (caused by rotation of the blades and the reflection of the sun).

The following seeks to explain why these symptoms and problems could be caused by the wind turbines.

The evidence supplied has been made by a prolonged study of research available worldwide. Some acousticians have expressed the opinion that the level of low frequency noise (in dB (A)) emitted by a wind turbine will not produce health problems. However during my extensive search of the published literature, I have been unable to find any medical evidence to support this opinion.

Although the papers researched are generally not specific to wind turbines they are specific to the type and intensity of noise produced by wind turbines. The noise produced by wind turbines is quite complex therefore our response is likely to be complex also. In addition wind turbines produce a repetitive visual stimulus which goes to reinforce annoyance.

## SOUND AND NOISE

Recently the European Union Noise Committee stated that noise is the biggest pollutant and the fastest growing pollutant in Europe.

Noise can be defined as unwanted sound and is commonly associated with annoyance reactions. It is commonly perceived as an environmental stressor and nuisance. Environmental noise is ubiquitous and annoyance is one of the most widely studied adverse reactions to noise. Noise interferes with task performance; cognitive performance modifies social behaviour and causes stress and irritation.

According to the World Health Organisation (WHO), health should be regarded as "a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity"- WHO 2001. Under this broad definition, noise induced annoyance is an adverse health effect. As with any psychological reaction, annoyance has a wide range of individual variability, which is influenced by multiple personal and situational factors.

WHO also defines noise annoyance as "a feeling of resentment displeasure, discomfort, dissatisfaction or offence which occurs when noise interferes with someone's thoughts, feelings or daily activities- (WHO paper on Environmental noise- Passchier and Verneer 1993.

Noise annoyance is always assessed at the level of populations, using questionnaires. There is consistent evidence for annoyance in populations, exposed for more than one year to sound levels of 37dBA and severe annoyance at 42dBA.

There is no doubt that annoyance from noise adversely affects human wellbeing.

The level of annoyance can only be described by listeners themselves. These descriptions are often fuzzy and not quantified most of the time. In addition to this different people have different subjective responses on the grade of annoyance. There are many theories regarding noise nuisance and many factors are thought to have an influence e.g. the types of noise source, noise energy, frequency, age , previous noise exposure, types of building structures and weather conditions. Subjective annoyance relates not only to the sound level and frequency but also to the physiological and mental factors of the sound recipients.

Field studies performed among people living in the vicinity of wind turbines showed that there is a correlation between sound pressure levels and annoyance but that annoyance is also influenced by other factors such as attitude to wind turbines an the landscape. However noise annoyance from wind turbines was found at lower sound pressure levels than in studies of annoyance from road traffic noise.
This is because the absolute noise level is less important than the character of the noise produced.

Non-auditory effects of noise, can be defined as all those effects on health and well being which are caused by noise exposure with the exclusion of effects on the hearing organ. Non auditory effects include stress, related physiological and behavioural effects and safety concerns. There have been studies showing that aircraft noise can decrease cognitive function resulting in decreased scholastic achievement.

It is obvious that the health issues relating to wind turbines are caused by these non-auditory effects as the sound pressure levels are not high enough to cause an auditory effect ( e.g. hearing impairment resulting from excessive noise exposure).

## How does noise affect health?

It is generally considered that noise can be an intrusion into daily activities and tasks, causing annoyance. In certain circumstances in certain susceptible individuals this annoyance may lead to a stress response which in turn may lead to symptoms and subsequently illness.
The response to noise probably depends upon the characteristics of the sound, including intensity, frequency, and complexity of
sound, duration and meaning of the noise i.e. whether the noise is perceived as threatening or not.

Alternatively, noise may affect health directly and not through annoyance. E.g. studies show elevated cortisol levels in individuals subjected to; vibroacoustic disease caused by excessive exposure to low frequency noise resulting in abnormal proliferation of extra cellular matrices.

Any severe extreme imposed on the sonic environment has a profoundly destabilizing effect on the individual.
This is evident in both the areas of high intensity acoustic energy and also its complete absence.
Anechoic chambers, which create an environment void of sound, have the ability to produce similar feelings of disorientation and disturbance that are evident with high intensity sound. The silence envelops the individual in a suffocating manner causing both psychological trauma and also physiological disturbance in the form of balance problems and other related body functions. It is clearly apparent that the human organism is in an extremely delicate state of equilibrium with the sonic environment and any profound disturbance of this system will have profound ramifications to the individual

The auditory system is an extremely complex system .Because of the complexity of the auditory and cerebral systems it becomes easy to understand why the issues surrounding noise annoyance/ disturbance and associated health effects is not a simple one.

Studies in USA have shown a relationship between anxiety and vestibular disorders such as dizziness and migraines vertigo. Anatomical and electrophysiological evidence suggests that serotonin modulates processing in the vestibular nuclei in the brain. Therefore a disturbance in the serotonin balance which occurs in anxiety and depression syndromes can cause vestibular problems.

Low frequency noise is also produced from wind turbines. Low frequency sound is predominately the result off the displacement of air by a blade and of turbulence at the blade surface. The low frequencies contribute to the overall audible noise but also produce a seismic characteristic which is one of the common complaints from neighbours when they say that not only can they hear the noise but they can also feel it.
The various parts of the body have a specific natural frequency or a resonance frequency. The human body is a strongly damped system, therefore, when a part of it is excited at its natural frequency, it will resonate over a range of frequencies instead of at a single frequency.
(fig. 1).

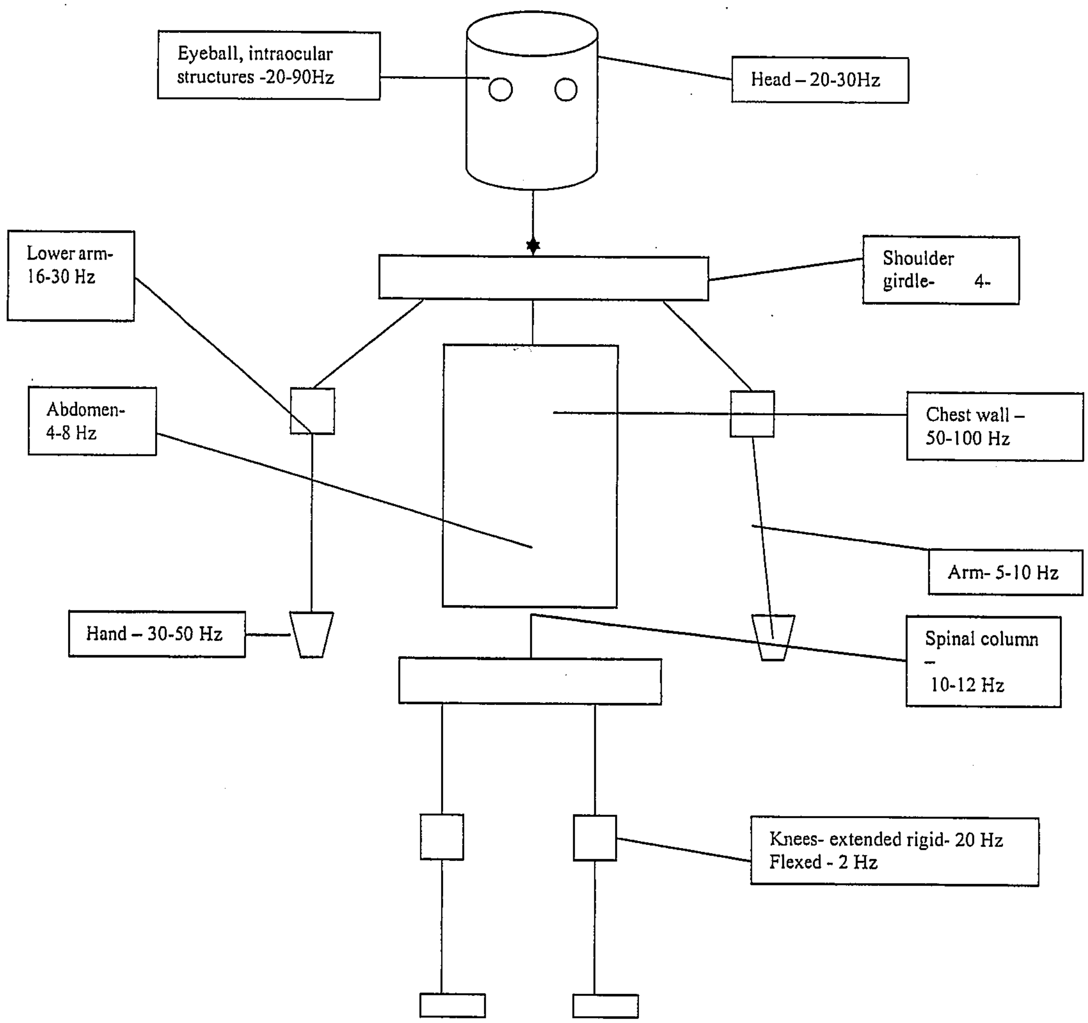
A research paper by G Rasmussen looked at body vibration exposure at frequencies of 1-20 Hz. Part of a table shows:-

| Symptoms | Frequency |
|---|---|
| General feeling of discomfort | 4Hz – 9Hz |
| Head symptoms | 13Hz – 20Hz |
| Influence on speech | 13 Hz – 20 Hz |
| Lump in throat | 12 Hz – 16Hz |
| Chest pains | 5Hz – 7Hz |
| Abdominal pains | 4Hz – 10Hz |
| Urge to urinate | 10Hz – 18Hz |
| Influence on breathing movements | 4Hz – 8Hz |

Also in the region 60-90 Hz disturbances are felt which suggest eyeball resonances, and a resonance effect in the lower jaw/skull system has been found between 100-200 Hz

Fig. 1

The resonance frequency ranges for various parts of the human body- values taken from the International Standards Organisation –ISO standards 2631



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An important contribution to the low frequency part of the sound spectrum may be the result of the sudden variation in air flow the blade encounters when it passes the tower: the angle of attack of the incoming air suddenly deviates from the angle that is optimised for the mean flow. This effect has not been considered important as the blade frequency is of the order of 1Hz where humans' hearing is relatively insensitive. However low frequency modulates well audible, higher frequency sounds and thus creates periodic sound. This effect is stronger at night because in the stable atmosphere there is a greater difference between rotor average and near tower wind speed. In addition to this multiple turbines can interact with each other to further multiply the effect. The effect will be greater for the larger more modern wind turbines.

As wind is variable and not consistent, the nature of the noise produced is also impulsive and unpredictable.

Low frequency noise issues have been researched extensively in Portugal and have been found to cause a complex disease known as vibroacoustic disease. Although this research has been mainly concerned with high levels of low frequency noise, it is felt that over years lower levels of low frequency noise may cause similar problems. It appears that the low frequency noise compromises the mechanotransduction signalling of cells which lead to structural changes of tissues and cells. This damage sustained is dose dependent and it is only in the latter stages that routine medical investigations will become positive. The syndrome can be broken down into various stages:-

Stage 1 - MILD *(1-4 years)* Slight mood swings, indigestion, heartburn, mouth/throat infections, bronchitis
Stage 2 - MODERATE *(4-10 years)* Chest pain, definite mood swings, back pain, fatigue, skin infections (fungal, viral, and parasitic), inflammation of stomach lining, pain and blood in urine, conjunctivitis, allergies.
Stage 3 - SEVERE *(> 10 years)* psychiatric disturbances, haemorrhages (nasal, digestive, conjunctive mucosa) varicose veins, haemorrhoids, duodenal ulcers, spastic colitis, decrease in visual acuity, headaches, severe joint pain, intense muscular pain, neurological disturbances.)

Low frequency noise exposure has also been shown in many studies to interfere with performance and cognitive function in the workplace. The effects are greatest in noise sensitive particularly low frequency noise sensitive individuals. In this group of people salivary cortisol levels are elevated during exposure.

For many years research has been carried out using noise as a non lethal weapon. Recently the Israeli army used such a weapon for crowd dispersal. Witnesses describe d a minute-long blast of sound emanating from a white Israeli military vehicle. Within seconds, protestors began falling to their knees, unable to maintain their balance. The technology is believed to be similar to the LRAD — Long-Range Acoustic Device — used by U.S. forces in Iraq as a means of crowd control.

Professor Pratt a professor of neurobiology specializing in human auditory responses at Israel's Technion Institute explains that by stimulating the inner ear, which houses the auditory and vestibular systems, with high intensity acoustic signals that are below the audible frequencies- below 20 Hz, the vestibular organ can be stimulated and create a discrepancy between inputs from the visual system and somatosensory system and the vestibular organ will erroneously report acceleration ( because of the low- frequency inaudible sound). It doesn't have to be a loud sound This will create a sensation similar to motion sickness. Such cases have been reported in relation to air conditioning systems.

Work by Fritz van den Berg shows why the characteristics of the noise produced by wind turbines increases and alters at night . He showed that the noise at night can be 15-18dBs higher at night time than during the day because of atmospheric changes ( ref. Fritz van den Berg).
Therefore when we are resting in bed at night, the noise from the wind turbines can be at their loudest and most disturbing.

Those people who are disturbed by the noise are often particularly aware of the problems at night. – this statement can be partially explained by lower background noise levels at night, and also the fact that atmospheric stability increases at night giving a greater differential between rotor averaged and near tower wind speed . This explains why the characteristic of the noise emitted from turbines takes on a "beating" character early evening and night-in agreement with the blade passing frequency.

Noise induced sleep disturbance is well known to have adverse health effects and has been studied extensively although not with particular reference to wind turbines. Due to the indisputable restorative function of sleep, noise induced sleep disturbances are regarded as the most deleterious effects of noise.

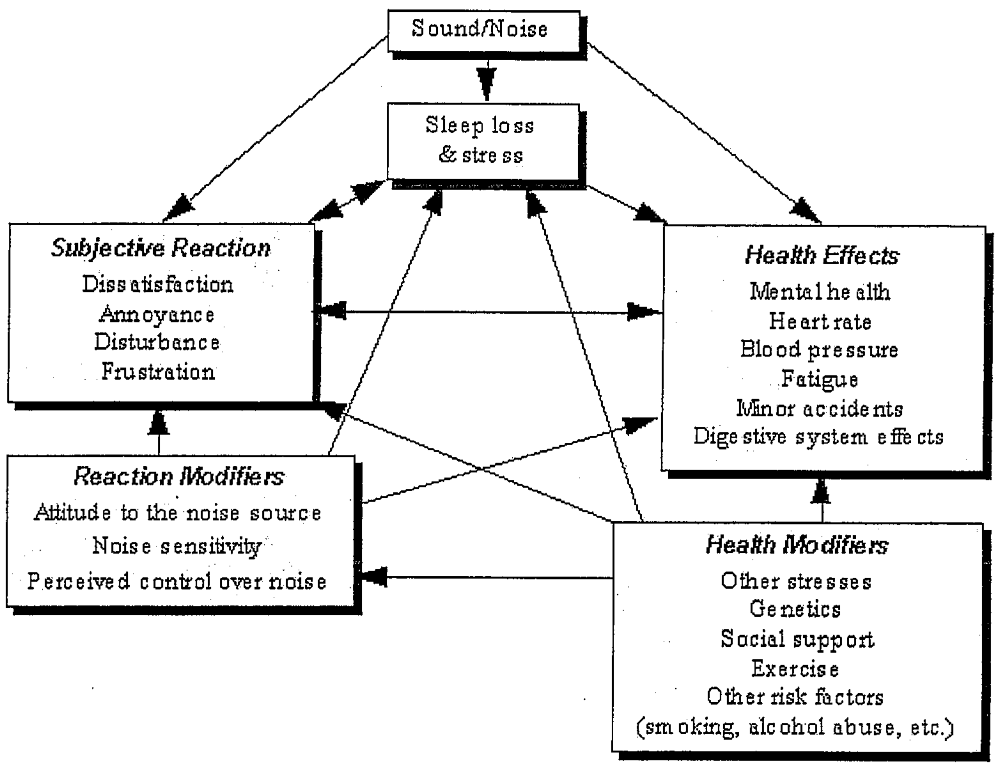
Nocturnal noise disturbance has been shown to disrupt nocturnal cortisol secretion. Nocturnal noise excites areas of the brain such as the amygdyla ( functions as the fear centre) and cortical areas ( arousal, annoyance and awakening). Noise –even levels below awakening threshold – can induce cortisol secretion. Repeated night time disturbance will result in an accumulation of cortisol levels in the blood. In the long term this can result in long term stress activation.

Several epidemiological studies in patients with primary insomnia found to be at a higher risk of developing major depression in the following years.
It has also been shown that women with increased morning cortisol levels show a higher risk of a major depressive episode within the next 12 months.

Psycho physiological reactions such as effects on heart rate and respiration rate have been observed during exposure to noise whilst subjects sleep. These have been found to be induced by road traffic noise with levels exceeding 40 dB LA max ( both in lab and in field studies). Hardly any habituation occurs during or between nights. Children have higher psycho physiological reactivity than adults. In addition for these types of reactions, the difference between the background noise levels and the maximum sound pressure level is of more importance than the absolute sound level. (Vernet 1983).

The potential adverse health effects are usually classified according to the type of noise. Sudden or impulsive noise appears to create more disturbance than non impulsive noise (Job 1996). Intermittent noise has a greater effect than louder more continuous noise ( Westman and Walters 1981). Predictability and controllability are clearly influencing factors in an individual's response to noise and this has been born out by surveys conducted by Eja Pederson in a paper presented in Berlin in Oct 2005.

It has been shown in several studies that depressed people and the elderly have a diminished variability in circadian cortisol levels and a raised morning cortisol in common. ( Kern et al in 1996, Van Cauter et al 1998, Deushle et al 1998). It would therefore be likely that the elderly and patients already suffering depression might be more susceptible to noise induced arousals.




However we as humans experience our environment through multi sensory channels e.g. acoustic, visual, proprioceptive, vibrational and psychological and emotional issues.

Therefore all these factors have to be considered when we try to explain why people might be disturbed by wind turbines. When discussing noise with people who are disturbed by turbines, frequent complaints are of vibration leading to an intrusional and invading noise that they feel they cannot get away from. People say that they can "feel the noise".

I would suggest that several factors are therefore concerned in this annoyance. The "periodic noise" as described previously and the low frequency component. I think that the presence of these two together has an additive effect compounding both. The periodic noise draws the attention to the vibrational component and therefore becomes more annoying than if either were present individually.

In addition to this there is the visual stimulation of the turbine blades rotating- this is particularly disturbing in certain light conditions where strobing occurs, but provide a constant reminder of the presence of the turbines by their movement.

Psychological and social issues must also be considered. E.g. pre-existing psychological problems and also perceptions of having a wind turbine built close to their homes. Most people live in the countryside because they appreciate the quiet and the visual amenity. Therefore reluctance to having a wind farm nearby will exacerbate any problems.

## SUMMARY

There are many people living near wind turbines who are suffering from problems with their health.

The noise produced from wind turbines is an extremely complex one and I feel that it is the complexity of the noise and vibration which causes the disturbance.

From my discussions with people suffering from ill health who live near wind farms, it seems that the symptoms suffered can occur up to a mile from the wind farm. Until further independent medical and epidemiological research has been carried out I would suggest that no wind turbines should be sited closer than 1.5 miles away from the nearest wind turbine.

The current UK guidance for establishing a safe distance between turbines and dwellings is the ETSU-R-97. This document was produced when turbines were approximately 20% the size of the currently proposed turbines. The guidelines pay scant reference to low frequency noise and the complexity of the noise profile produced by the turbines.
The continued use of ETSU-R-97 has been publically condemned by Professor FFowcs- Williams and G.P.Van den Berg.

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Appendix 1

# Something in the Wind

THE SUNDAY TIMES - JANUARY 20, 2002

To some people they are "grotesque"blights on the countryside; to others,graceful machines that offer a welcome alternative to nuclear power and a way of tackling global warming. There are now more than 60 wind farms in Britain – the windiest nation in Europe –with 853 turbines producing enough power to run 500,000 homes a year. The numbers are set to rise as the government cranks up its drive to generate 10% of Britain's electricity from green energy sources by 2010.
Last week Powergen announced that it is considering building one of the biggest wind farms in the world in the Thames Estuary, sinking several hundred turbines into a sand bank in a project worth £500m. It comes in the wake of plans announced in December for a huge onshore wind farm on the Hebridean island of Lewis.
If the project gets planning permission, 300 turbines will be built, eventually meeting 1% of Britain's electricity needs. An increasing number of homeowners therefore have to get used to the prospect of living near the whirling blades. Margaret Gough, for one, cannot stand the sight of the towers that straddle the grassy slopes near her mid-Wales home. When she and her late husband retired to a village outside Aberystwyth 15 years ago, they chose a bungalow which had stunning views – until the Mynydd Gorddu wind farm opened several years later. "The reason we bought this property was for the scenery," says Gough. "It was such a beautiful skyline: if I stood in the garden and looked around all I could see was tree- covered hillsides. Now when I look out I can see about eight or nine wind turbines."

I stand under the turbine in Swaffham in Norfolk [the world's most efficient turbine andat 67m, thought to be Europe's tallest] and you don't know it's turning." Surveys have found that although up to 96% of people say they approve of wind farms, about a quarter would not like to live close to one. Householders' main objections are that wind turbines are "ugly" and they may bring down the value of their properties. Michael Williams, manager of estate agent Shearer & Morris in Aberystwyth, says that unless homes are very close to wind turbines property prices are unaffected. "I've sold quite a few properties within a mile of wind farms without any bother," he says. Nevertheless, some homeowners are fighting back. Martin Wright, Chairman of the Cefn Croes Campaign, is trying to halt the construction of the biggest wind farm in Britain. Under the £35m project – already approved by Brian Wilson, the energy minister – 39 turbines, each 100m high, will be cited at Cefn Croes, near Devil's Bridge in Ceredigion, mid-Wales. Wright says he objects to wind farms because he fears that vast swathes of rural Britain will be lost to the machines. "Mid-Wales is full of them," he laments. "The reason I oppose them isn't because I don't want them in my back yard – there's a wind farm on the mountain above my house and I can't say it disrupts my life – it's to do with the wider issue of the value of our landscape.



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"Wind power is a good idea, but the only way it is going to have any impact on our energy needs is to cover the whole country with turbines. So unless we are going to go down that path, why bother?
"We are going to ruin some of the lovely wildernesses that have been protected since the war: you can't build bungalows, but you can put up a 100m high turbine. That doesn't seem right."

Archaeologist **Dr Stephen Briggs**, also from Wales, claims he moved because infrasound, sound with a frequency below an audible level, from a wind farm made his wife ill. Problems started not long after the Llangwyryfon wind farm, 12 miles from Aberystwyth, opened 10 years ago. The **Briggs**' house was 350m from three of the 20-plus turbines and 650m from six of the machines. "Our initial intention was to stay put, even though we were disturbed by the changes and damage," says **Briggs**. "We had been assured the turbines would make no noise, but we were so close we could hear the wind whistling through them. "We also discovered that not only did they broadcast audible sound, they produced infrasound. It started to make my wife sick." Finally, six years ago, the **Briggs** decided to sell their house and move to a new home five miles away.

**Dr** Peter Musgrove, head of development at National Wind Power, which used to own Llangwyryfon, says; "The issue of the infrasound has been looked into in considerable detail and no evidence has been found that it is emitted by the turbines." Not everybody objects to turbines, however. John Theobald and his wife Sue are more than happy to live in the lee of a wind farm. Their bungalow overlooks Delabole in Cornwall, the oldest commercial wind farm in Britain, which attracts thousands of visitors a year. From their windows, they have a clear view of all 10 turbines.
"My wife and I are inveterate supporters of renewable energy anyway, but I love them," says Theobald, who runs a woodturning business and a bed-and-breakfast. "They change colour depending on the weather: some days they look thunderously grey and broody; other days, when the sun goes down, they turn pink and purple. "Having said that, I don't think anyone would like to live right underneath the tower." "We live about four or five fields away and only occasionally hear the noise from theturbines if the wind is in the East."
In fact, the noise is diminishing all the time as technology advances.
"Noise is no longer an issue," asserts Peter Edwards, owner of Delabole farm.

**Blowing hot and cold: Martin Wright, above, from mid-Wales, fears turbine blight**
**The Theobalds: see no problems with turbines**
Source: *The Sunday Times*, 20 January 2002

# Appendix 2

## Flurry of complaints after wind change

Jul 25, 2005

A wind change at Meridian power company's giant wind farm on the Ruahine Ranges has prompted a flood of complaints from nearby residents.

Residents in the small Manawatu town of Ashurst say that in an easterly there is an intrusive rumble for days on end. They say the windmills emitted a low frequency noise for three days on end, making their lives a living hell.

The Te Apiti windfarm turbines have a steady sound in the prevailing westerly wind but when the wind suddenly, and unusually, turned easterly last weekend Ashurst residents say it bombarded them with noise and vibration.

"On Monday night the rumbling was so bad it sounded like one of those street cleaning machines was driving up and down near the house. In fact it sounded like it was going to come through the house," says Wendy Brock.

Geoff Keall said whether people were inside or outside it had an impact.

The blades on each of the 55 turbines are the size of a Boeing 747 wing and they produce enough electricity to power 45,000 homes.

Tararua District Council says measuring the noise is difficult, but it is concerned for the residents. Spokesman Mike Brown from Tararua District says he believes Meridian is also concerned and they will be talking together to see what can be done to resolve the issue.

But Meridian says it's a small number of people making a big noise about nothing.

Spokesman Alan Seay says they monitor the sound levels at a number of points and the monitoring has shown quite clearly they were well within the guidelines.

There's growing opposition from the public to windfarms.

Previously people have been generally supportive of windpower, but when a power company recently applied to instal a further 40 wind turbines, it attracted objections from more than 250 people.

However, despite the latest complaints windfarms on the Ruahine and Tararua ranges are expected to expand.

# Appendix 3

## FEATURE: And the beat goes on . . .and on and on

18.02.2006
**KATHY WEBB**

They call it the train that never arrives. It's a low, rumbling sound that goes on and on ... and on.

Sometimes, in a stiff easterly, the rumbling develops into a roar, like a stormy ocean.

But worst of all is the beat. An insidious, low-frequency vibration that's more a sensation than a noise. It defeats double-glazing and ear plugs, coming up through the ground, or through the floors of houses, and manifesting itself as a ripple up the spine, a thump on the chest or a throbbing in the ears. Those who feel it say it's particularly bad at night. It wakes them up or stops them getting to sleep.

Wendy Brock says staff from Meridian Energy promised her the wind turbines at Te Apiti, 2.5km from her Ashhurst home in southern Hawke's Bay, would be no noisier than waves swishing on a seashore.

"They stood in my lounge and told me that."

But during a strong easterly, the noise emitted by the triffid-like structures waving their arms along the skyline and down the slopes behind the Brock family's lifestyle block is more like a thundering, stormy ocean. Sometimes it goes on for days. And when the air is still, there's the beat - rhythmic and relentless, "like the boom box in a teenager's car".

"It comes up through the floor of our house. You can't stop it."

Mrs Brock says she can feel it rippling along her spine when she's lying in bed at night. Blocking her ears makes no difference.

"It irritates you, night after night. Imagine you've done your day's work, then you go to bed, and there's this bass beat coming up through the floor and you can't go to sleep. You can't even put headphones on and get away from it.

"My older son sometimes gets woken up by the noise. He gets up and prowls around the house."

She tells of other Ashhurst residents who "feel" the sound hitting their chests in the Ashhurst Domain 3km from the turbines. She says one woman is so distressed by the sensation she has put her home on the market.

Not everyone in the village hears the infrasound - Mrs Brock reels off the names of residents wondering what the fuss is all about - but says those who do feel the sound are distressed by it and have nowhere to turn for redress.

There's little point complaining to the Tararua District Council because all it does is record each complaint and forward it to Meridian, and nothing ever happens.

"What are they (the council) going to do to Meridian - fine them, or shut down the turbines?" asks Mrs Brock.

Meridian is dismissive of complaints about noise from Te Apiti.

"Infrasound is just not an issue with modern turbines," insists spokesman Alan Seay.

"We take it very seriously. We have looked into it seriously, but the advice we are getting from eminently qualified people is that it is just not an issue."

Many people claiming to be putting forward scientific argument about noise from turbines "are not qualified in this area of expertise. I have a problem with some of their statements", Mr Seay said.

He asked Hawke's Bay Today for the names of those complaining about noise from Te Apiti.

Asked why he wanted the names, he replied: "There is a group of people there. They are opposed to wind farms per se".

Asked why he thought they were opposed, Mr Seay said "I don't want to speculate. They just are. Possibly for the visual impact."

Meridian had complied with all legal requirements for sound emissions from Te Apiti, and "the people of Ashhurst are very happy to have those turbines there. They have become an icon," Mr Seay said.

Meridian is currently appealing noise restrictions placed on its proposed 70-turbine wind farm at Makara, near Wellington, where some houses will be about 1km away, and downwind of, the turbines.

J ohn Napier lives on the Woodville side of the Te Apiti turbines, about 2km from the nearest one.

When they first began operating, he couldn't believe the roaring noise they made.

"We can hear it in our bedroom at night."

One night, about 2am, he got out of bed to check whether the bedroom windows were vibrating, and about five times since, he has been woken up and thought "they're making a racket tonight".

He doesn't hear the infrasound beat so much. It's mainly "a roar like a train going through a tunnel or over a bridge, but it never stops".

He complained to Meridian about the noise, and the company put a noise meter on his property for a couple of weeks, but wouldn't tell him the results.

"Wind farm companies say noise from turbines is not an issue, but it is an issue all right. I would be very concerned if I lived in Karori (near Makara, in Wellington)," Mr Napier said.

Harvey Jones, who lives in a valley 3km from Te Apiti, says there is an easterly wind blowing across the wind farm about 10 percent of the time. The wind goes across the top of the hill, but the noise from the turbines rolls down the valley. It sounds like a train constantly passing by, and the stronger the wind, the louder the noise. When there's a westerly blowing, he can even hear the turbines in Woodville, 6-7km away.

"Once you get tuned in to it you can easily pick it up," he says.

Mr Jones says the amount of noise generated by the Te Apiti turbines was unexpected, and landowners prepared to put turbines on their land at Te Pohue should think very carefully about the possibility of a repeat scenario.

He predicts disaster for the residents of Makara and Karori.

"They're going to get hammered, but they don't realise."

Steve Griffin, of Te Pohue, is secretary of the Outstanding Natural Landscape Protection Society, formed to oppose two windfarms proposed for his area on the Napier-Taupo road.

Lines company Unison has resource consent to put up about 50 turbines, and Hawke's Bay Windfarms plans to erect 75 turbines nearby.

The landscape protection society is appealing all the consents in the Environment Court.

Mr Griffin, who is "sick to death of wind farms", says the prospect of 128 giant industrial turbines visually disrupting pristine skyline and covering more than 16km of prominent mountain range near Te Pohue is bad enough. But he and other residents are worried sick about the noise potential - both normal-range and infrasound - from the turbines. Each turbine will have an 80m tower and three 45m blades. They will be 125m high and 90m wide, each taking up the equivalent of 1.5 rugby fields.

They will encircle Te Pohue village and its school, in a valley downwind of the turbines in prevailing winds - and nobody in authority seems to care, he says.

The Government has thrown the doors wide open to wind farm developers, in a bid to meet its Kyoto commitments; there are no national guidelines specific to wind turbines. That stance is unbalanced and unfair, Mr Griffin says.

"Our view is that while wind farms are part of our energy solution, sites must be selected in a socially responsible manner.

"They should not be placed within 5km of schools, hospitals, rest homes, or the private homes of those not involved with a wind farm development."

They should also be kept out of coastal, and recreation areas, and those with high scenic value, he says.

The landscape protection society wants the Government to establish national guidelines for wind farms, and review noise-testing standards to include measurement of low-frequency sound.

Low-frequency sound - sometimes called infrasound - is controversial.

Dr Geoff Leventhall, a noise vibration and acoustics expert from the UK who looked into infrasound at the request of Genesis Power, says "I can state quite categorically that there is no significant infrasound from current designs of wind turbines".

He says "the ear is the most sensitive receptor in the body, so if you cannot hear it you cannot feel it". Engineer Ken Mosley, of Silverstream, has an entirely different view.

The foundations of modern turbines create vibrations in the ground when they are moving, and also sometimes when they are not moving, Dr Mosley says.

"This vibration is transmitted seismically through the ground in a similar manner to earthquake shocks and roughly at similar frequencies.

"Generally, the vibrations cannot be heard until they cause the structure of a house to vibrate in sympathy, and then only inside the house. The effects inside appear as noise and vibrations in certain parts of a room. Outside these areas, little is heard or felt.

"However, the low frequency components of the noise and vibration can cause very unpleasant effects which eventually cause the health of people to deteriorate to an extent where living in the property can become impossible."

Dr Mosley says that wherever wind farms are built close to houses, people complain about noise and vibration.

He quotes a scientist in South West Wales, David Manley, who has been researching noise and vibration phenomena associated with turbines since 1994.

An acoustician and engineer, Dr Manley writes "it is found that people living within 8.2km of a wind farm cluster can be affected and if they are sensitive to low frequencies they may be disturbed".

Two GPs in the UK have researched the health effects of noise and vibrations from turbines. Amanda Harry documented complaints of headaches, migraines, nausea, dizziness, palpitations, sleep disturbance, stress, anxiety and depression. People suffered flow-on effects of being irritable, unable to concentrate during the day, losing the ability to cope.

Bridget Osborne, of Moel Maelogan, a village in North Wales, where three turbines were erected in 2002, is reported as saying "there is a public perception that wind power is 'green' and has no detrimental effect on the environment, but these turbines make low-frequency noises that can be as damaging as high-frequency noises.

"When wind farm developers do surveys to assess the suitability of a site they measure the audible range of noise but never the infrasound measurement - the low-frequency noise that causes vibrations that you can feel through your feet and chest.

"This frequency resonates with the human body, their effect being dependent on body shape. There are those on whom there is virtually no effect, but others for whom it is incredibly disturbing."

Dr Mosley says wind-power generators in New Zealand are aware of such literature on turbine noise and infrasound from all around the world.

"Are they therefore just ignoring what is happening in the rest of the world in the hope that once turbines are up and running, people will quietly endure, or when the noise/vibration situation really starts to damage their health, the community will cut their losses, leave their homes and quietly fade away? Of course, wherever they end up, they must still pay their electricity bills, which is rather like paying the landlord who has evicted you."

The New Zealand Wind Energy Association, which did not return calls from Hawke's Bay Today, acknowledges that turbines produce infrasound, but insists it is so minimal from modern turbines that human beings cannot perceive it. Its website says "there is no evidence to indicate that low frequency sound or infrasound from current models of wind turbine should cause concern."

Infrasound was more of a problem with older turbines, which had their blades downwind of the turbine tower, the association says.

"That caused a low frequency thump each time a blade passed behind the tower."

In contrast, modern turbines "have their blades upwind of the tower, thus reducing the level of this type of noise to below the threshold of human perception, thereby minimising any possible effect on human health or wellbeing".

The association has published excerpts of a report by Dr Leventhall, who suggests that infrasound is a concept that could be classified as pop-science, seized upon by emotionally-overwrought wind farm opponents.

"When a group of residents decides to object to a development, they often support each other with strong emotions, which can sometimes lead them astray. The emphasis on low-frequency noise is an example of this. Over the past 30 years there has been a great deal of confusion and misinformation about low frequency noise, mainly in the popular media. Much of it can best be described as "hot air" but complainants' uncritical acceptance of what they read in unreliable sources has two unfortunate effects:

* It detracts from those people who have genuine low-frequency noise problems, often from industrial exhaust fans, compressors and similar.

* It undermines the credibility of the complainants, who may be harming their own cause in their apparent 'grasping at straws' approach."

Dr Leventhall goes on to say "the rational study of low frequency noise, its effects and criteria for control, has been bedevilled by exaggerations, half-truths and misrepresentations, much of it fomented by media stories over the last 35 years. The result in the UK, and it is probably similar in other countries, is that an incorrect concept - 'low frequency noise is a hazard' - has taken root in the national psyche, where it lies dormant waiting for a trigger to arouse it. The current trigger is wind turbines."

Dr Leventhall says:

* High levels of low-frequency noise are needed before people can perceive it, and the levels must

increase as frequency reduces.

* The ear is the most sensitive receptor in the body, so if you cannot hear it you cannot feel it.

* When there are problems with predominantly low-frequency noise, that is because assessment methods do not cater for it. That leads to the noises being dismissed as not being a nuisance, which in turn leaves unhappy complainants in a distressed state.

Up on the Napier-Taupo road, the printer in Steve Griffin's office is working overtime in preparation for an Environment Court battle. It might be a David and Goliath confrontation, but there's too much at stake to sit back and take it quietly, he says.

Appendix 4

# Guantanamo Serenade

Jon Ronson knew from his investigation into US military intelligence that top brass had adopted some strange practices. Jamal al-Harith, the Briton released from Guantánamo in the spring, confirmed it: here, in our second extract from Ronson's revealing new book, he describes the discordant sounds and apparently random music played to him during all-day interrogation sessions, and four psychological warfare experts give their reaction

**Saturday November 6, 2004**
The Guardian

The more I've delved into the US military's psychological warfare, the more examples of New Age-style, First Earth Battalion tactics I've been noticing in the war on terror. I learned of one fact in particular that struck me as entirely incongruous, something at once banal and extraordinary. It happened to a Mancunian called Jamal al-Harith in a place called the Brown Block. Jamal doesn't know what to make of it either, so he mentioned it to me only as an afterthought when I met him in the coffee bar of the Malmaison Hotel, near Manchester Piccadilly station, one June morning this year.

Jamal is a website designer. He lives with his sisters in south Manchester. He is 37, divorced, with three children. He said he assumed MI5 had followed him here to the hotel, but he's stopped worrying about it. He said that he keeps seeing the same man watching him from across the street, leaning against a car, and that whenever the man thinks he's been spotted, he looks briefly panicked and immediately bends down to fiddle casually with his tyre.

Jamal laughed when he told me this. He was born Ronald Fiddler into a family of second-generation Jamaican immigrants. When he was 23, he learned about Islam and converted, changing his name to Jamal al-Harith: he liked the sound of it. He says al-Harith basically means "seed planter".

In October 2001, Jamal visited Pakistan as a tourist, he says. He was in Quetta on the Afghanistan border, four days into his trip, when the American bombing campaign began. He quickly decided to leave for Turkey and paid a local truck driver to take him there. The driver said the route would take them through Iran, but somehow they ended up in Afghanistan, where they were stopped by a gang of Taliban supporters. They asked to see Jamal's passport, and he was promptly arrested and thrown in jail on suspicion of being a British spy.

Afghanistan fell to the coalition. The Red Cross visited Jamal in prison. They suggested he cross the border into Pakistan and make his own way back home to Manchester, but Jamal had no money, so instead he asked to be put in contact with the British embassy in Kabul.

Nine days later - while he waited in Kandahar for the embassy to transport him home - the Americans picked him up.

"The Americans," Jamal said, "kidnapped me." When he said "kidnapped", he looked surprised at himself for using such a dramatic word.

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The Americans in Kandahar told Jamal he needed to be sent to Cuba for two months for administrative processing, and so on, and the next thing he knew he was on a plane, shackled, his arms chained to his legs and then chained to a hook on the floor, his face covered in earmuffs and goggles and a surgical mask, bound for Guantánamo Bay.

In the weeks after Jamal's release, two years later, he gave a few interviews, during which he spoke of the shackles and the solitary confinement and the beatings - the things the outside world had already imagined about life inside that mysterious compound. He said they beat his feet with batons, pepper-sprayed him and kept him inside a cage that was open to the elements, with no privacy or protection from the rats and scorpions that crawled around the base. But these were not sensational revelations.

He spoke to ITV's Martin Bashir, who asked him (off-camera), "Did you see my Michael Jackson documentary?"

Jamal replied, "I've, uh, been in Guantánamo Bay for two years."

When I met Jamal, he began to tell me about the more bewildering abuses. Prostitutes were flown in from the US - he doesn't know whether they were there to smear their menstrual blood on the faces of the more devout detainees. Or perhaps they were brought in to have sex with the soldiers, and some psychological operations (PsyOps) boffin - a resident cultural analyst - devised this other job for them as an afterthought, exploiting the resources at the army's disposal.

"One or two of the British guys," Jamal told me, "said to the guards, 'Can we have the women?' But the guards said, 'No, no, no. The prostitutes are for the detainees who don't actually want them.' They explained it to us: 'If you want it, it's not going to work on you.' "

"So what were the prostitutes doing to the detainees?" I asked.

"Just messing about with their genitals," said Jamal. "Stripping off in front of them. Rubbing their breasts in their faces. Not all the guys would speak. They'd come back from the Brown Block [the interrogation block] and be quiet for days and cry to themselves, so you know something went on, but you don't know what. But for the guys who did speak, that's what we heard." I asked Jamal if he thought that the Americans at Guantánamo were dipping their toes into the waters of exotic interrogation techniques.

"They were doing a lot more than dipping," he replied. And that's when he told me about what happened to him inside the Brown Block.

Jamal said that, being new to torture, he didn't know whether the techniques tested on him were unique to Guantánamo, or as old as torture itself, but they seemed pretty weird to him. His description of life inside the Brown Block made Guantánamo Bay sound like an experimental interrogation lab, teeming not only with intelligence agents, but also with ideas. It was as if, for the first time in the soldiers' careers, they had prisoners and a ready-made facility at their disposal, and they couldn't resist putting all their concepts - which had until then languished, sometimes for decades, in the unsatisfactory realm of the theoretical - into practice.

First there were the noises.

"I would describe them as industrial noises," said Jamal. "Screeches and bangs. These would be played across the Brown Block into all the interrogation rooms. You can't describe it. Screeches, bangs, compressed gas. All sorts of things. Jumbled noises."

"Like a fax machine cranking up into use?" I asked.

"No," said Jamal. "Not computer-generated. Industrial. Strange noises. And mixed in with it would be something like an electronic piano. Not as in music, because there was no rhythm to it."

"Like a synthesiser?"

"Yes, a synthesiser mixed in with industrial noises. All a jumble and a mishmash."

"Did you ever ask them, 'Why are you blasting these strange noises at us?' " I said.

"In Cuba you learn to accept," said Jamal.

The industrial noises were blasted across the block. But the strangest thing of all happened inside Jamal's own interrogation room. The room was furnished with a CCTV camera and a two-way mirror. Jamal would be brought in for 15-hour sessions, during which time they got nothing out of him because, he said, there was nothing to get. He said his past was so clean - not even a parking ticket - that at one point someone wandered over to him and whispered, "Are you an MI5 asset?"

"An MI5 asset!" said Jamal. He whistled. "Asset!" he repeated. "That was the word he used!"

The interrogators were getting more and more cross with Jamal's apparent steely refusal to crack. Also, Jamal used his time inside the Brown Block to do stretching exercises, keeping himself sane. Jamal's exercise regime made the interrogators more angry, but instead of beating him, or threatening him, they did something very odd.

A military intelligence officer brought a ghetto blaster into his room. He put it on the floor in the corner. He said, "Here's a great girl band doing Fleetwood Mac songs."

He didn't blast the CD at Jamal. This wasn't sleep-deprivation, and it wasn't an attempt to induce the Bucha Effect[1]. Instead, the agent simply put it on at normal volume.

"He put it on," said Jamal, "and he left."

"An all-girl Fleetwood Mac covers band?" I said.

"Yeah," said Jamal.

This sounded to me like the tip of a very strange iceberg.

"And what happened next?" I asked.

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"When the CD was finished, he came back into the room and said, 'You might like this.' And he put on Kris Kristofferson's greatest hits. Normal volume. And he left the room again. And then, when that was finished, he came back and said, 'Here's a Matchbox Twenty CD.' "

"Was he doing it for entertainment purposes?" I asked.

"It's interrogation," said Jamal. "I don't think they were trying to entertain me."

"Matchbox Twenty?" I said.

I didn't know much about Matchbox Twenty. My research reveals them to be a four-piece country rock band from Florida, who do not sound particularly abrasive (like Metallica and Burn Motherfucker Burn!) nor irritatingly repetitive (like Barney The Purple Dinosaur and Ya! Ya! Das Is A Mountain). They sound a bit like REM. The only other occasion when I had heard of Matchbox Twenty was when Adam Piore from Newsweek told me that they, too (like Metallica and Barney), had been blasted into the shipping containers where detainees were held at al-Qa'im in Iraq. I mentioned this to Jamal and he looked astonished.

"Matchbox Twenty?" he said.

"Their album More Than You Think You Are," I said.

There was a silence.

"I thought they were just playing me a CD," said Jamal. "Just playing me a CD. See if I like music or not. Now I've heard this, I'm thinking there must have been something else going on. Now I'm thinking, why did they play that same CD to me as well? They're playing this CD in Iraq and they're playing the same CD in Cuba. It means to me there is a programme. They're not playing music because they think people like or dislike Matchbox Twenty more than other music. Or Kris Kristofferson more than other music. There is a reason. There's something else going on. Obviously I don't know what it is. But there must be some other intent."

"There must be," I said.

Jamal paused for a moment and then he said, "You don't know how deep the rabbit hole goes, do you? But you know it is deep. You know it is deep."

Subsequently, I talked to Joseph Curtis (not his real name), who worked on the night shift at the Abu Ghraib prison, in charge of the computer network. I asked if he knew anything about the music. He said, sure, they blasted loud music at the detainees all the time. "What about quieter music?" I said, and told him Jamal's story about the ghetto blaster and the Fleetwood Mac all-girl covers band and Matchbox Twenty.

Joseph laughed. He shook his head in wonderment. "They were probably fucking with his head," he said.

"You mean they did it just because it seemed so weird?" I asked. "The incongruity was the point of it?"

"Yeah," he said.

"But that doesn't make sense," I said. "I can imagine that might work on a devout Muslim from an Arab country, but Jamal is British. He was raised in Manchester. He knows all about ghetto blasters and Fleetwood Mac and country and western music."

"Hm," said Joseph.

"Do you think ...?" I said.

Joseph finished my sentence for me.

"Subliminal messages?" he said.

"Or something like that," I said. "Something underneath the music."

"You know," said Joseph, "on a surface level that would be ridiculous. But Guantánamo and Abu Ghraib were anything but surface."

Jamal seemed fine when I met him in Manchester. I asked if he felt at all unusual after listening to Matchbox Twenty and he said no. But one shouldn't read too much into this. There is a very strong chance, given the history of the goat staring and the wall walking and so on that US military intelligence honchos went in for, that they blasted Jamal with silent sounds and it just didn't work.

In late June 2004 I sent an email to Jim Channon and everyone else I'd met during my two-and-a-half-year journey who might have some inside knowledge about the current use of the kinds of psychological interrogation techniques that had first been suggested in Jim's First Earth Battalion manual. I wrote:

Dear ---

I hope you are well.

I was talking with one of the British Guantánamo detainees (innocent - he was released) and he told me a very strange story. He said at one point during the interrogations the MI [military intelligence] officers left him in a room - for hours and hours - with a ghetto blaster. They played him a series of CDs - Fleetwood Mac, Kris Kristofferson, etc. They didn't blast them at him. They just played them at normal volume. Now, as this man is western, I'm sure they weren't trying to freak him out by introducing him to western music. Which leads me to think ... Frequencies? Subliminal messages?

What's your view on this? Do you know any time when frequencies or subliminal sounds have been used by the US military for sure?

With best wishes,

Jon Ronson

I received four replies straight away.

Commander Sid Heal (the Los Angeles Sheriff's Department non-lethals expert who told me about the Bucha Effect): "Most interesting, but I haven't a clue. I know that subliminal messages can be incorporated and that they have a powerful influence. There are laws prohibiting it in the US, but I'm not aware of any uses like you describe. I would imagine, however, that it would be classified and no one without a 'need to know' would be aware anyway. If it were frequencies, it would probably need to be in the audible range or they wouldn't need to mask them with other sounds."

Skip Atwater (General Stubblebine's former psychic spying headhunter): "You can bet this activity was purposeful. If you can get anybody to talk to you about this, it would be interesting to know the 'success rate' of this technique."

Jim Channon: "Strikes me the story you tell is just plain kindness (which still exists)."

I couldn't decide if Jim was being delightfully naive, infuriatingly naive, or sophisticatedly evasive.

Then Colonel John Alexander responded to my email. He remains the US army's leading pioneer of non-lethal technologies, a role he created for himself in part inspired by Jim's First Earth Battalion manual.

Colonel Alexander: "Re your assertion he was innocent. If so, how did he get captured in Afghanistan? Don't think there were many British tourists who happened to be travelling there when our forces arrived. Or maybe he was a cultural anthropologist studying the progressive social order of the Taliban as part of his doctoral dissertation and was mistakenly detained from his education. Perhaps if you believe this man's story you'd also be interested in buying a bridge from me? As for the music, I have no idea what that might be about. Guess hard rockers might take that as cruel and unusual punishment and want to report it to Amnesty International as proof of torture."

Jokes about the use of music in interrogation didn't seem that funny any more - not to me, and I doubt they did to him, either. I emailed him back: "Is there anything you can tell me about the use of subliminal sounds and frequencies in the military's arsenal? If anyone alive today is equipped to answer that question, surely you are."

Colonel Alexander's response arrived instantly. He said my assertion that the US army would ever entertain the possibility of using subliminal sounds or frequencies "just doesn't make sense".

Which was strange. I dug out an interview I'd conducted with the colonel the previous summer. I hadn't been that interested in acoustic weapons at that point, but the conversation had, I now remembered, briefly touched on them.

"Has the army ever blasted anyone with subliminal sounds?" I had asked him.

"I have no idea," he said.

"What's a 'psycho-correction' device?" I asked him.

"I have no idea," he said. "It has no basis in reality."

"What are silent sounds?" I asked.



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"I have no idea," he said. "It sounds like an oxymoron to me." The colonel gave me a hard look, which seemed to suggest that I was masquerading as a journalist and was, in fact, a dangerous and irrational conspiracy nut.

"I'm confused," I said. "I don't know much about this subject, but I'm sure I've seen your name linked with something called a 'psycho-correction device'."

Yes, he said, he had sat in on meetings where this sort of thing was discussed, but there was no evidence that machines like this would ever work. "How would you do that [blast someone with silent sounds] without it affecting us? Anybody who's out there would hear it."

How could you blast someone with silent sounds "without it affecting us"? This struck me at the time as an unassailable argument, one that cut through all the paranoid theories circulating on the internet about mind-control machines putting voices into people's heads. Of course it couldn't work.

The thing is, I now realised, if silent sounds had been used against Jamal inside an interrogation room at Guantánamo Bay, there was a clue in Jamal's account, a clue that suggested that military intelligence had craftily solved the vexing problem highlighted by Colonel Alexander.

"He put the CD in," Jamal had said, "and he left the room."

Next, I dug out the recently leaked military report entitled Non-Lethal Weapons: Terms And References. There were a total of 21 acoustic weapons listed, in various stages of development, including the Infrasound ("Very low-frequency sound which can travel long distances and easily penetrate most buildings and vehicles ... biophysical effects: nausea, loss of bowels, disorientation, vomiting, potential internal organ damage or death may occur. Superior to ultrasound ...").

And then, the last entry but one - the Psycho-Correction Device, which "involves influencing subjects visually or aurally with embedded subliminal messages".

I turned to the front page. And there it was. The co-author of this document was Colonel John Alexander.

[1] In the 1950s, helicopters started falling out of the sky, crashing for no apparent reason, and the pilots who survived couldn't explain it. They had been flying as normal and then suddenly they felt nauseous, dizzy and debilitated; they lost control of their helicopters. A Dr Bucha was called in to solve the mystery. What he found was that the rotor blades were strobing the sunlight, and when it reached an approximation of human brainwave frequency, it interfered with the brain's ability to send correct information to the rest of the body.



· This is an edited extract from The Men Who Stare At Goats, by Jon Ronson, published by Picador on November 19 at £16.99. To order a copy for £16.14, with free UK p&p, call 0870 836 0875. Jon Ronson's three-part television series, The Crazy Rulers Of The World, starts on Channel 4 tomorrow. · Jamal al-Harith is one of four Britons released from Guantánamo in March, after more than two years' imprisonment, who claim they were repeatedly tortured at the camp and, it was announced last week, are suing Donald Rumsfeld and other US military leaders for £6m compensation each.

Appendix 5

# Western Morning News

## SHATTERED DREAM OF QUIET LIFE

**09:00 - 06 January 2004**

All they wanted was the good life in Cornwall, and they needed it for the sake of their health - but no sooner had Colin and Kathy Bird fled the city for a modest rural home than their dream was shattered by the noise from wind turbines.

Last year at Christmas the couple booked into B &Bs in Newquay rather than endure sleepless nights in their caravan home at St Eval.

This year they have saved up £1,000 to live in Malta for a month because they cannot bear another winter at home when high winds turn the turbines.

When that noise from the Bears Down wind farm begins, says Kathy,

it's like a "a deep throbbing, or a train that never gets there".

For Colin it's worse. "You never rest your brain, you never get away from them," he says.

What makes it worse for the couple is that they moved to Cornwall to escape the noise of the city.

Colin, 48, had suffered a nervous breakdown when he worked as a car factory worker in Coventry. But he was stirred by warm memories of boyhood holidays in Cornwall. And the couple spent six months each year for three years until 2000 in a rented caravan there, and found it blissfully peaceful.

So they plunged what little money they had into their new life. They bought the neighbouring caravan and moved in one year before the 16-turbine wind farm opened in October 2001.

Their caravan is made mostly of aluminium, which exacerbates the tin can effect.

But they point out that they were there before the wind farm, and they don't have the money to move anywhere else.

Kathy, 43, says: "I did put in a letter of complaint about the plans. I was very concerned about the wildlife - buzzards and peregrine falcons. Then, of course, noise was one of my concerns, but I never realised how bad it would be. At first I thought it was something in the home, but it was the turbines.

"They get to a critical speed, which I believe is 40 knots, and then it disturbs us all the time. It's just as if we're in a box and it's reverberating all the time.

"It's almost like a motion sickness, and it always seems to be worst at Christmas.

"It's the constancy of them that gets to you, it can be for anything like three or four days, it's this deep throbbing."

The couple calculate that they booked into B &Bs four times last year to escape the turbines. But sometimes they just drive around until the wind dies down.

National Wind Power, which owns the Bears Down site, has paid for double-glazing of the caravan to try to curb the noise effect, but this has had little impact.

Kathy and Colin, like their neighbours, complain of headaches, anxiety, sleeplessness and nausea - 97 per cent questioned by Plymouth GP Amanda Harry complained of one symptom or another.

One neighbour, who asked not to be named, describes the effect of the noise as being like "Chinese water torture".

His home is further back from the wind farm, and better insulated against external noise, but he said: "We get a beating sound, it's like a bus engine sitting parked, and we do get headaches. I understand the need for renewable energy, but the problem is that they do not contribute much. To get the things going they have to use electricity anyway."

To add to his sense of injury, he estimates that the wind farm has devalued his property by 25 per cent. Colin's health has got worse since moving to what he dreamed would be the perfect home for the rest of his days. At first he had no opinion of the turbines' appearance, but now he describes them as being "like ogres looking at you".

So what do the couple want, and how do they see a way out of their nightmare?

Kathy wants the turbines stopped at night so that they can sleep, and "some form of compensation" for their misery and troubles.

Colin explains: "We can't afford anywhere else, so what's it going to be like for the rest of our lives? We came here thinking we'd get peace and quiet for the rest of our lives. And it's beautiful - Cornwall has everything.

"But then this happens - you'd need to be in a Chieftain tank with earphones not to hear those things."

Kathy adds: "We came here to live simply, and we both had to retire early because of ill-health. Colin just needed a very quiet environment, and we'd been here before and had three years of peace and quiet and it was gorgeous.

"But this is systematically ruining our lives - and I just feel that people are not aware of the damage these things are doing to health."

The issue is set to come to the fore with a legal test case in Cumbria where people living between 600-800 metres from the 60-metre turbines in the village of Askham complained of headaches and nausea. Barrister John Campbell is representing three couples at Kendal Magistrates Court in a fight to get wind turbines near their homes declared a statutory nuisance under the Environmental Health Act.

He said: "There are a number of complaints of sleep disturbance, headaches, and migraines that are driving people mad. They say it's a pervasive thump, thump noise from the blades."
He said that if they won the test case, which is expected to take several days, the turbines would either have to be stopped or removed.
Meanwhile, one couple living in a residential caravan near the Bears Down site have saved up £1,000 to go to Malta for a month because they say they cannot cope with life next to the turbines in winter when the winds are high.
In desperation last year, they booked into B &Bs in Newquay at Christmas.
Kathy and Colin Bird took early retirement through ill health from their jobs in Coventry as they sought a quiet life in Cornwall. Then they moved into their caravan in 2000, before the wind farm was built. But Mrs Bird now says: "It's just a throb when the wind is up - it's like the sound of a car going by with the stereo blaring, but it doesn't pass."
Matthew Spencer, chief executive of the South West Renewable Energy Agency (Regen) yesterday disputed whether the noise from turbines was the cause of their health complaints.
He said: "People may perceive that is their problem, but the turbines are not very noisy. Nothing has been proved about the health effects, but I would take these initial findings with a pinch of salt. These are arguments that people who are opposed to wind farms use."
He pointed out that travelling at 40mph would create a noise of 55 decibels at 100 metres while a wind turbine produced a noise of 35 decibels at 350 metres.
He said there was no evidence that the new generation of larger turbines planned for the South West would be a problem. "They are becoming less noisy as they are being developed," he said.
He added that the guidelines for the turbines were that they should not be within 400 metres of people's homes, and that noise had not proved a problem in the eyes of planners.
National Wind Power, which owns and operates the Bears Down wind farm, yesterday failed to respond to a series of questions put by the Western Morning News.

Appendix 6

Western Morning News
WIND TURBINES HAVE EATEN INTO MY VERY SOUL
09:00 - 09 January 2004
Mark Taplin has lived in the shadow of wind turbines for more than a decade. As part of our on-going debate on the issue, he describes how the experience has affected his life
Opposed: Mark Taplin says turbines have ruined his way of life MY world has been overshadowed by the spectre of wind turbines for 12 years, and I have lived with the reality for the past eight years of generating machines spinning their blades 75 metres above my house, the closest a mere 440 metres away. They have imposed themselves on my life and eaten into my soul - small wonder that I feel compelled to contribute to the deluge of column inches that this latest debate has generated. I live in a modest cottage which nestles in a small secluded Cornish valley, surrounded by a few acres that I can call my own.
I came here to pursue my ambition of an Arcadian existence, growing my own fruit and vegetables and indulging in a bit of self taught husbandry.
I was eager to leave behind the smug and affluent rural neighbourhood where I had grown up, and endured the tiresome label of leading "the good life".
I was accustomed to a degree of hardship and was prepared for the vicissitudes of the Westcountry climate. I was not expecting a rural idyll "preserved in aspic". I had a grasp of the commercial imperatives that exerted control over the countryside as the end of the century approached. However, what I was not prepared for was the impact on my life of my nearest neighbours - the wind turbines at Four Burrows.
I am not the first, nor will I be the last, to find the terms "windmill" and "windfarm" misplaced. Wind turbines do not mill grain, nor do they harvest the product of their own endeavours.
Arguably they save some forms of pollution, but are responsible in turn for some negative by-products, from the concrete in their foundations to the tips of their blades, offending many by their very sight and sound. I have always considered myself as one who was aware of environmental issues, and I try to live in harmony with the countryside. But, sadly, the intrusive neighbours on my doorstep have introduced a massive note of discord into my peaceful existence.
Why? Because whatever the individual thinks of them aesthetically, I cannot avoid the noise. I hear them nearly all the time. It is not easy to equate it to other noise sources, and I find the attempts at comparisons trite. The dilemma for one such as me is that the industry has always argued that as the wind picks up speed and the

power output and noise level produced increases, the natural background noise created by the wind will mask any turbine noise. Where this argument falls down, however, is when you find yourself in a comparatively sheltered position on lower ground than the turbines and not buffeted by the wind. Then you hear a great deal more than if you stand up close with the wind rushing past your ears. When small but violent changes in wind direction shear past the turbines, the chomp and swoosh of the blades passing the towers creates a noise, albeit mercifully brief, that beggars belief. It is as if a ghostly steam engine were pumping an abandoned mine working.

But this surprising and unacknowledged phenomenon does thankfully pass as the wind abates, whereas the bane of my life - the "tonal" (mechanical whine or resonance) noise - does not. It is ever present when a turbine is generating at more than mere tickover,

despite the manufacturer's claims.

So, how can I hear tonal noise? It has been so distinct at times that I foolishly assumed everyone would own up and do something about it. Sadly, that is where the technicalities come in, and it boils down to mathematics. The wind industry is better supported than local council environmental health departments, and they were well ahead of the game when they formulated the criteria for establishing tones. It is a loaded issue and not what you might call a level playing field. Whatever I hear, they will claim that it does not qualify as a tone - which means that I am stuck with it. Once you hear tonal noise it follows you around, not in your imagination but because the human ear has a natural habit of homing in on an annoying sound.

But, going back to the beginning, what turned me into an "anti" soon after I found myself thrown on to the learning curve in 1992? Was it the way that the whole thrust of renewable energy development was being hijacked by the wind lobby, the cavalier attitude of a new breed of opportunistic developers, the obscenely generous price support structure offered at that time under the Non Fossil Fuel Obligation and the greedy scramble for another subsidy? Was it the arrogance of politicians who jumped on the green bandwagon, the pressure group zealots who adopted the moral high ground in the name of saving the planet and the naive level of argument from the "better than nuclear, nicer than pylons" brigade? Was it the exasperating lesson of having to teach myself all about parliamentary statements, planning procedures and the technicalities of noise attenuation, which only served to disenchant me, when all the while I would much rather have been getting on quietly with my life? Or was it just a selfish determination to defend my precious green and pleasant Shangri La from industrial machines which threatened to invade my privacy?

I resent the same old stale public relations lecture from the vested interest lobby who do not appear to know how or when to apologise.
I do not warm to those who disregard for the sensibilities of others who can be passionate about preserving a particular landscape that is special to them. I cannot accept that wind turbine generators are benign.
I have contributed to the debate with this account not to seek sympathy, but as a reminder to those of a different persuasion that the route down which wind power development has been driven in recent years can cause very real harm. Noise apart, it has turned me, a potential supporter, against my turbine neighbours and what they stand for.

00001317

Appendix 7

# Meridian pays family to move

02 August 2005
By LEE MATTHEWS

**Meridian Energy has paid an undisclosed sum of money to shift a family from their farm where Te Apiti's wind turbines are located, because noise and vibration made it too difficult to live in their house.**

Company spokesman Alan Seay would not say how much the compensation is, as it is a confidential agreement between Meridian and the Bolton family. He understands they will move off their farm and build elsewhere.

He also said the payout is not a surprise, as it had been anticipated in the initial lease agreements with the land owners. It is not part of any of the 20 conditions imposed by the wind farm's resource consent.

"Te Apiti is built on two farm properties. It was recognised right from the start that this family could have issues with noise . . . their house was a only a few hundred metres from the turbines," Mr Seay said.

"The possibility of having to shift was part of the initial lease agreement. These were houses actually in the wind farm, as opposed to neighbouring (houses)."

Meridian has also made a confidential deal with the other farm owners affected. Mr Seay said he understands this has involved building alterations, such as double-glazing windows to reduce noise.

There are no other claims for any kind of compensation for nuisance from Te Apiti, and Mr Seay said he does not anticipate any in future. "This one was made because it was a foreseen situation."

Feedback from the Ashhurst community about Te Apiti has "all" been positive, apart from "one or two vociferous" opponents whom he understands to be working with people objecting to Meridian's proposed Makara wind farm.

"Nimby (not in my back yard) syndrome . . . it's what we've got to expect from some of these groups . . . it's misleading and distorting."

Last November, Ashhurst resident Colin Mahy complained that sun reflection flickering into his house from the Te Apiti turbines was "driving him mad". Meridian had told him to draw his curtains.

Mr Seay said that he had given that advice. "Sun flash is a very momentary thing, it only occurs in certain circumstances and it doesn't last long."

Appendix 8

GWEN's Diary

These wind turbines, they're 76m high, there are three of them, they have a looming presence over the beautiful Teifi Valley, I've been trying hard to come to terms with living within a mile of them ever since they appeared there on Moelfre hill twelve months ago. They don't belong here, they shine in the sunlight, they glow in the moonlight, they stand out stark white against the dark rain clouds, unlike everything else surrounding them they never change. No lichen, no birds encircling them, no ivy creeping up their metallic towers. There is nothing of nature within them ,they don't belong here on Moelfre overlooking the Tivy Valley.

Those living six, ten, fifteen miles and more away from them agree. They can be seen by the inhabitants of many small towns and villages as totally scarring the wondrous outline of the gentle rise from Moelfre to Frenni Fach Frenni Fawr, Foeldrigarn ,Preseli and Caerningly above
Newport. The council planners must have been mad to grant them permission.

I've lived here on my farm now with my husband for twenty six years, I know every nook and cranny of the fifty acres. Our farm is only two miles from the farm where I was born sixty years ago, I grew up looking towards Moelfre and was delighted to be farming within my own community. I've been teaching in local schools, I paint landscapes in a converted shed, I've enjoyed good health, twenty six years of hard but rewarding work, I had planned to spend my remaining days here.

Now I sleep in my outhouse shed, it's not comfortable, I don't want to sleep there, I don't choose to be so far from amenities all night and suffer the sounds of mice within a yard of my head. The trouble is that when I am in the house my heart beat seems to alter, there seems to be a repeated slightly thumping pressure on my lungs. There's a slight throbbing in my head, like a headache without the pain. I feel slightly sick. I know that slightly is a term I've used for all the ailments but it is not a normal state of well being. It makes me feel on edge .When I visit a friend on the other side of the valley that's when I feel normal, and that state of normality suddenly seems the most wonderful feeling on earth. To me this is a tragic turn of events. Compared to the total sum of human misery I admit it might sound trivial. Today we had the fire wood cut up for next winter, here we enjoy our own spring water, my garden, my roses and clematis, and oh the first violets and primroses in the woods. The seven thousand trees we've planted, my studio, this is what our life has been about! Now I feel robbed of all I hold dear, and to complicate the situation my husband is not effected by the turbines, he doesn't like the visual impact but they don't make him ill. The low frequency noise/vibrations from the turbines [not the blades] play havoc with my health.

Where do I go from here? When the company was granted permission for the development the local paper reported that this was a lifeline for the struggling Welsh speaking local farmer who otherwise would have had to leave the land, Hey I'm a Welsh speaking local too, where's my lifeline?
I belong here, those turbines DO NOT.

06/04/03

Diary Tuesday 8th April.

Sat in the gallery yesterday, in Carmarthen, felt well all day. In the evening went to the Teivy Arts meeting, felt well, enjoyed the company and chat. Came home at ten fifteen sat talking to Henning for a while went to bed [ the bed in the house, the wind was fairly light] and the throbbing in my head started. Tried to ignore it, listened to the radio, switched it off, throb throb, feeling of anxiety, tried to sleep, but at twelve thirty I reluctantly took a Nytol tablet. Slept.
This morning I went to see my doctor to have a check up to see if there is some physical cause for my disturbed heart rhythm. She examined my heart, all well, felt my pulse rate, all well, lungs, all well, took my blood pressure, 120/80 that's good. Never felt better, She looked up my records for the hearing test in 1992 but there were no specific detailed figures given for the test only the conclusion that this patient had normal hearing. [had the test because I had been suffering from tinnitus that year]
After lunch I sat down in the living room by the window to read, after five minutes I had to move I couldn't stand the heart rhythm and the churning in my head. I tried to override it I really wanted to get on with my book but I could not stay there any longer. The wind is from the south today and the turbines have their backs turned directly at us.
Went outside to do some gardening and took Tess for a walk, it's always better outside. Thought about buying a wooden garden shed to live in, perhaps in the woods. Back in the house I felt extremely uncomfortable. At five o'clock I baby sat for Lindsay in the old farmhouse until her mother arrived. The noise of the children and telly filled the house so I couldn't compare the two houses for turbine noise.

Wednesday 9th April.

Last night I tried something new, I have a C D of the sound of waves called Ocean Spray, it's called white noise, for relaxation and sound masking. I carried my CD player from the studio up to the bedroom. It's not a portable so it was heavy. The wind was from the south so I knew there would be throbbing in my head. It sounded great,[the sound of waves] I slept quite soon but woke up at five o'clock with a dreadful headache, had to take two soluble aspirins. Wind still from the south and my headache was still with me at ten o'clock. Took more painkillers and kept to our plan of walking on the Preselis.

Three hour walk, beautiful weather, felt great. My mind is going around in circles about what to do in this situation. It's clear that no one else suffers from the same symptoms as me on this farm. There are six adults and three children living here. I really don't want to disrupt everyone else's lives.
Plans: Sell the whole place. Sell only this house; Rent a place and find a tenant for this house; Build a small place for me in some "quiet corner of the farm" if there is such a place; My head is reeling with all the pros and cons. Haven't painted for weeks because of my bed being in the studio. Feel sick again. Trouble is that when I feel ill where can I lie down, in my bedroom? That's where I feel ill.
Later on the wind came from the North, then life gets back to normal again and no way are we going to sell up and move away.

Friday 11th April
North wind, yesterday was no problem to me. What a difference it makes, once the pain has gone there's no need to plan an alternative future for us. Have moved the bed from my studio, I really need to get on with my work. Have moved it to the loft, above another outhouse, I shall sleep there next time the wind is from the south. I'm feeling quite hopeful again that I can live with this once I've learned how to, but in order to make it possible some alterations will have to be made to the loft.
Saturday 12th April
I was far too optimistic yesterday, this is typical of how it goes. Last night was the worst so far. I went to my bed in the house and played the CD of the waves, slept quite soon, CD was on repeat mode. At one forty five am I woke up with the throbbing in my head, really bad, weight on my chest and a distinct pain in my heart. Tried to calm myself, CD was still playing, tried to meditate but was filled with a real sense of panic and felt an urgent need to escape. Too cold to go to the loft so I carried my duvet down to the kitchen which is the furthest room away from the turbines. With the cushions from the settee I made a camp bed but there was no sleep so at six o'clock I dragged it all back upstairs, Got up, had only about three hours sleep.
Shall have to try out the loft tonight, it's the sound of vermin that worries me, and the cold, but nothing could be worse than the way I felt last night.
Sunday 13th April
The loft is as bad as the bedroom. I realized this in the afternoon yesterday when I tried to catch up with some sleep. Spent last night at by brothers' house in the village three miles away. Slept. This is really getting us down, it's taking over our lives. We're now back to selling and moving away, it can't go on like this.
Monday 14th April
Wind from the south again, feel really depressed this morning. Phoned the council about noise pollution, someone will 'phone back today or tomorrow [or never]. I've got to get out of here today, all the symptoms are with me again, Henning is quite sick of hearing about them and I'm sick of suffering them.
Tuesday 14th April,
Wind still from the south, slept in the dining room last night but only after taking a Nytol tablet. Estate agent came out this morning, we'll probably have to move I can see no future for me here. I have to go out today to get some relief from the way I feel.

*Gwen has now moved and does not live near wind turbines- she says that all her symptoms have settled.*



00001351

# Appendix 9

A) **Nick Priest on behalf of 30 families, Chybucca, Allet, Truro, Cornwall, TR4 9DL**

*……the only two families who lived near to the Carland Cross wind farm, Newquay, have now moved out because of unsolvable noise problems. At least one home now lies derelict.*

*Is this positive rural diversification or rural community extinction? The Welsh Affairs Select Committee have recommended that no dwellings should be within 1.5km of a wind farm. There are 30 families within such distance.*

(Extract from noise abatement society, July 1997, 'Windfarms certainly do make a noise').

## Appendix 10

### B) Natalie Gregg, The Courier Mail, Queensland, Australia, 04 Oct 2004

*Rural residents in two states can't sleep at night because of noise from a Queensland Government owned corporation's alternative energy plant. Homeowners in Queensland and Vixctoria have all but resigned themselves to the noise of the Stanwell Corp. wind turbines, which they claim have devalued their properties.*

*Mrs Newman said the throbbing, thumping noise from the generators could be heard at all hours of the day, "It was very frustrating in the beginning and makes us extremely upset, but there is nothing we can do about it." Within 12 months the couple, who are in their fifties, had had enough and they decided to move but they still cannot find a buyer.*

Appendix 11

C) **Times on Line, 10 Jan, 2004 "wind farms ruin peace, says judge"**
*Wind farms can ruin the peace of the countryside and destroy the value of nearby homes, a judge has ruled.*

*District Judge Michael Buckley said that the noise, visual intrusion and flickering of light through the blades of turbines reduced the value of a house by a fifth. He said that the value of a remote house in Marton, in the Lake District, fell significantly because of the construction of a wind farm 40m high turbines, 500 metres away.*

00001354

Appendix 12

**D) Mag. Lotta Nilson, Laholm, Sweden.** (lotta.nilson.fsi@swipnet.se)

*Wind turbines produce nothing but a nightmare for neighbourhoods; conflicts between former friends and within families, stress, ill health…………I left my home because of a wind turbine placed 650m from my house. One day in November 1998 mine and my neighbour's lives changed dramatically. The wind turbine, totally about 90m high started to rotate for the first time. The noise is a torture. After one year I understood we would not get any help and that no one can or will measure the sound level………..Hundreds of families in my small, former beautiful community on the west coast of Sweden are suffering enormously.*

Appendix 13

**E) Murray R. Barber, Bradworthy, Devon. 12 July 2005**

*I understand that Energiekontour A.G. is responsible for operating the Forestmoor wind farm, Bradworthy, Devon. Our home is located 650m from the nearest of three turbines. I wish to complain about noise nuisance created by the wind farm.....*

03001356

National Wind Watch

April 15, 2009
Property values, Safety

# Living with the impact of windmills

**Luxemburger, Chris**

• An overview of how it impacts on aviation safety
• An overview of how land values are established
• An overview of the impact of windmills on land values

*Land Values Argument*

Land value can be expressed in many different ways:

- Reconstruction Value
- Appraised Value
- Liquidity Value
- Market Value
- etc.

When dealing with the OMB hearing I focused on market value since it is defined as the highest price in terms of money, that the property will bring to a willing seller if exposed for sale on the open market; allowing a reasonable time to find a willing buyer, buying with the knowledge of all the uses to which it is adapted and for which it can be legally used, and with neither buyer or seller acting under necessity, compulsion, nor peculiar and special circumstances.

There has never been a comprehensive study that looks at land values and the effect of windmills so there were no criteria to follow. As such I developed the following criteria:
• based on appraisal principals, visible structures have an impact on the value of land
• therefore, divide land where windmills are visible vs not.

Properties inside Windmill Zones – Properties within 3nm of a windmill. 3nm was used as a basis since that is the distance one can see is a straight line due to the earth's curvature when on the same horizontal spectrum of the objects in the distance. Pilots use this as a basis for determining weather minima for the similar reason.

Properties outside Windmill Zones – These are properties a minimum of 3nm from existing windmills. If the object is not readily visible is the same horizontal plane, one can assume that there would be no impact in perceived value of the property due to the windmills.

When this was done (based on a sample of 600 properties that sold in the windmill areas over a period of 3 years) the following was discovered:

- The days on market was more than double for those properties inside the windmill zones
- The sold price was on average $48,000 lower inside the windmill zones than those outside
- The number of homes not absorbed (not sold) was 11% vs 3%

00001357

Download original document: "Living with the impact of windmills" [1]

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URLs in this post:
[1] Download original document: "Living with the impact of windmills": **http://docs.wind-watch.org/luxemburger-living-with-the-impact-of-windmills1.ppt**

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00001358

National Wind Watch

March 8, 2011
Australia, Environment, Health, Noise, Property values, Regulations, Wildlife

# Health effects of living close to the Waubra wind turbines

**Stepnell, Carl and Samantha**

I am writing in regards to the Federal Parliament enquiry. I am a third-generation farmer on our Waubra farm, we farm 4200 acres of high-quality farming land and are currently running 16,000-20,000 sheep, 500 acres of crop and 100 acres or irrigated land included.

From the first day we were asked to have wind turbines on our farm we were very concerned about the impacts of a wind farm in our community. We declined to have 4 wind turbines on our land.

Eventually the Waubra wind farm was under construction, with large amounts of destruction to poor local roads, and destruction of quality farming land. Consisting of new roads through farms, thousands of tons of concrete poured into the ground, massive power grids in paddocks, machinery and administration offices in paddocks and worst of all, hundreds of kilometres of new above ground power lines. Which are a whole new danger in the summer fire season.

It was at this stage when the foundations were laid for the Waubra wind farm. The Lexton wind farm was approved, which is not under construction yet. We were approached by a representative from Wind Power that they needed to run a new above ground power line from the yet to be built but approved Lexton wind farm, straight through our farm to connect to the Waubra wind farm grid. Obviously more cost effective than building another grid at the Lexton site. We declined, therefore weeks later we were approached then by an Acciona representative to put a further 4 wind turbines on our farm, making a total of 8. We declined once again, therefore the proposed new above ground power line has to follow the roads near our farm as we didn't want it through our farm.

The destruction if the power line goes ahead will consist of cutting native trees down and disturbing large amounts of native grasses, then follows the disturbance of bird life, including brolgas and countless other species. This is very concerning and distressing.

Then before long the Waubra wind farm was up and running.

The closest wind turbine is 900 metres from our house and we have 5 wind turbines within 1500 metres from our family home, where I live with my wife
Samantha and three children Jacob, Courtney and Joshua. There is about another 6 wind turbines within 2000 metres of our land at another location on our farm.

We can see nearly all the wind turbines from most areas of our farm. The first day the wind turbines started operating closest to our home, my wife Samantha started feeling ear and head pressure. Similar, she described, as when flying in an aeroplane. About six months after, I started feeling similar affects as Samantha. As the weeks went on it has gotten worse and worse. We now suffer headaches, chest pains, a feeling of heart palpitations, continuous lack of sleep. Every night we can't sleep, we go to sleep then wake and just never settle into a good night sleep.

03001359

National Wind Watch

March 13, 2011
France, Health, Noise

# Infrasound: Wind Energy's Harmful Flaw (in French)

**Renard, Claude**

## Les Infrasons, Nuisances Redhibitoires des Éoliennes

This article is an updated (c. 2006?) summary of a lecture entitled "Infrasound: Hidden and Harmful Pollution", presented by the author in 1997. That lecture was in response, at that time, to concerns arising from the marketing in Sweden of a non-lethal infrasound weapon for riot control, the recognition of "sick building syndrome" due to infrasound emitted by air conditioning systems, and finally, the multiplication of wind turbine projects in Brittany, where the density of the rural population is high and infrasonic harm would be great. …

In the weeks that followed, more information came to light, revealing that the first Airbus 340 planes had pressurization regulators that created infrasound that adversely affected passengers. We also learned that a "Euralille" tower in Lille had been evacuated because of vibrations on the 5th floor. And whistleblowers revealed that 644 employees of the new "Archet" hospital in Nice had suffered from nausea and headaches and that some even had to be hospitalized. In 2005, similar effects occurred at the "Nord" hospital in Marseille.

Today, this article has been revived by good news: The (French) Academy of Medecine has recommended to the government to immediately halt construction of wind turbine [facilities] exceeding 2.5 MW closer than 1500 m [4,921 ft; 0.93 mi] from homes. This is good news, but not very good news. This writer fears that this venerable institution considered only the audible noise (blade swish, gearbox noise) and not the infrasound. Therefore, our aim here is to inform the public about inaudible, but harmful, noise.

(((( ))))

Cet article est un résumé très condensé et remis à jour, d'une conférence intitulée : Les infrasons, pollution discrète et pernicieuse, prononcée par l'auteur en 1997. Cette conférence répondait, à l'époque, à l'inquiétude suscitée par la mise sur le marché suédois d'une arme à infrasons, non létale, pour combattre les émeutes, la reconnaissance du « Syndrome du Mal des Bureaux » (SMB) dû aux infrasons émis par les systèmes de climatisation, et enfin, la multiplication des projets de champs d'éoliennes en Bretagne où la densité de population dans les campagnes est élevée et où les nuisances infrasonores seraient aussi importantes, voire plus, que la pollution visuelle ou les interférences radioélectriques empe?chant toute réception de la télévision ! Dans les semaines qui suivirent, un certain nombre d'informations tombaient, dévoilant que les premiers Airbus 340 avaient une régulation de la pressurisation qui engendrait des infrasons indisposant les passagers. On apprenait aussi qu'une tour d'Euralille à Lille avait été évacuée à cause de vibrations au 5 ème étage. Des indiscrétions révélaient que 644 agents du nouvel hôpital L'Archet à Nice, avaient été l'objet de nausées et de céphalées et que certains avaient même été hospitalisés. En 2005, des malaises semblables se produisaient à l'hôpital Nord de Marseille.

00001360

# SUBMISSION TO THE AUSTRALIAN FEDERAL SENATE INQUIRY ON RURAL WIND FARMS

10th FEBRUARY, 2011

DR SARAH LAURIE
BMBS (Flinders 1995)
Awarded FRACGP 1999
Awarded FACCRM 2000

MEDICAL DIRECTOR
WAUBRA FOUNDATION
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# INDEX

## EXECUTIVE SUMMARY

1. There are reports from around the world of people living adjacent to wind turbine developments becoming unwell with the same range of symptoms

2. The few studies which have been done by concerned medical clinicians have consistently found these problems

3. The medical evidence which exists from Dr Pierpont's landmark peer reviewed case series cross over study clearly links exposure to turbines with the symptoms being described

4. Not all adjacent residents are affected

5. Some developments appear to have more seriously affected residents than others

6. Some residents are affected immediately, others are progressively affected over weeks to months of constant exposure

7. Chronic exposure appears to have a cumulative effect

8. The time taken to achieve full resolution of symptoms is proportional to the time exposed to turbines

9. Not all symptoms are reversible after chronic exposure, when affected residents move away

10. Some extremely ill residents in desperation have signed confidentiality agreements with wind developers, who have purchased their properties, in exchange for <u>agreeing not to talk publicly about their health problems</u>, in order to leave their homes and regain their health.

11. Residents are describing symptoms from a distance of up to 10km away from the nearest turbine

12. Elevations of blood pressure associated with proximity to operating turbines are an emerging issue

13. Some people appear particularly vulnerable to developing wind turbine syndrome symptoms, and they include children and the elderly

14. There a number of possible mechanisms for these symptoms and they include but are not limited to:

- Audible noise causing chronic sleep deprivation (we know from affected residents that wind turbines can be very noisy, both upwind and downwind)
- Wind turbine specific pulsatile infrasound and low frequency noise causing many of the symptoms of wind turbine syndrome (probable, based on current but limited experimental evidence, and recent measurement of wind turbine specific pulsatile infrasound )
- Possible health effects from electromagnetic radiation issues in a few specific cases – in situ measurement required initially in these homes to determine if this is an issue for further investigation

## RECOMMENDATIONS

1. There is an urgent need for further INDEPENDENT medical, acoustic and scientific research, looking specifically at the populations affected by the currently constructed and operating wind developments in Australia

2. An immediate temporary halt in construction of wind turbines closer than 10km to human habitation until adequate research is completed, in order to determine what is a safe setback of turbines from homes and workplaces

3. Current planning and noise guidelines will need to be updated on the basis of this new knowledge

4. There should be an immediate ban on the operation of wind turbines on days of high, extreme and catastrophic fire danger, because of the difficulties in fighting such fires, and the risk to lives should such a fire occur

5. Measurement of wind turbine specific infrasound and low frequency sound needs to be included in post construction noise assessments, and ALL these assessments MUST be performed by experienced Acousticians who are COMPLETELY INDEPENDENT of the wind developers

## BACKGROUND

My name is Dr Sarah Laurie, and I am a legally qualified Medical Practitioner (Bachelor of Medicine, Bachelor of Surgery Flinders University 1995), with subsequent completed post graduate training as a Rural General Practitioner (Fellowship of the Royal Australian College of General Practitioners (FRACGP) 1999, and Fellowship of the Australian College of Remote and Rural Medicine (FACCRM) 2000). I have served as an examiner with the RACGP, and a member on the South Australian AMA State Council. My work as a Rural GP has been exclusively in South Australia, predominantly at Crystal Brook, but also included Balaklava, Port Pirie Aboriginal Community Health Centre, and Nganampa Health Council on the APY lands. I have a particular interest in Mental Health, and was the Mid North Division of General Practice Representative on the local Mental Health Advisory committee.

Since 2002 I have been on leave from my profession, because of personal and family health issues and extended family caring responsibilities. I was preparing to return to my career as a practicing rural General Practitioner in March/April last year when I became aware of a proposed wind turbine development for the hills adjacent to my home, where I live with my husband and seven year old twins. Origin Energy are the proponents, and the initial map one of their employees presented at a community meeting showed that there were to be five turbines at approximately 1km from my home, with a total of approximately 90 turbines spread along a ridge of approximately 15km. There are approximately 90 people who will be within 3km of this development.

I told the Origin Energy PR employee who rang me to tell me of the proposal that I had no objections, and indeed supported the project, because of my longstanding concerns about climate change/global warming, and my concerns about the financial problems faced by farmers (some of whom had previously been my patients) and the issues rural families face because of lack of local employment opportunities for their children.

I did, however, say that my support was on the assumption that there were no adverse health concerns, as I had read an article in an edition of The Australian weekend magazine about a couple from Ballarat who had reported becoming unwell after a turbine development started operating near their home. The Origin employee was very quick to reassure me that "just that week, the Chief Health Officer of Victoria had issued a public statement to the effect that there was no evidence of any adverse health effects from wind turbines".

I was reassured by that, at the time.

However, a month later, a neighbour presented me with Dr Amanda Harry's study, and after reading this I was immediately very concerned that there were indeed some serious health problems emerging. Dr Harry was a rural General Practitioner in the UK, who did a community survey after becoming aware of a new pattern of symptoms and health problems emerging after a turbine development had commenced operation close to where she was practicing medicine.

I also became aware of a Rural Australian GP, Dr David Iser, from Toora in Victoria, who had done his own small study, based on Dr Harry's survey. Dr Iser had found a similar range of problems, some of which were serious. When I contacted Dr Iser to ask him more about his experiences he told me that most of the affected residents had since left the district and were therefore no longer his patients. **Dr Iser mentioned that**

**some former residents whose health had been particularly badly impacted had been bought out by the developer, but only if they signed confidentiality ("gag") agreements, which specifically prevented them from talking publicly about their health problems.** I have since learned from my international colleagues that such practice is widespread in countries with industrial wind developments.

I then decided to devote my time into researching the issue more thoroughly. By the time I spoke at a public meeting at Laura on 18th July, 2010 I was convinced there was a very real problem, that it was global, and that there was a significant lack of primary research into the health effects being described by adjacent affected residents.

For example, nowhere in the world had a population or epidemiological study of the adverse health effects been conducted. Given the existence of "gag" agreements, whose key purpose could be to keep the adverse health effects story out of the public arena and in particular scrutiny by health authorities, this was hardly surprising.

**What research there was, however, done by Medical Practitioners who were actually seeing patients or conducting patient interviews, showed that there were significant and serious problems being reported, including people resorting to walking away from their homes.**

## FORMATION OF THE WAUBRA FOUNDATION

In late July 2010, I was contacted by Mr. Peter Mitchell, from Victoria, who had set up the structure of a not for profit organization he had called the Waubra Foundation, to help further the progress of facilitating and commissioning independent research into the adverse health effects being reported in residents adjacent to wind turbines in Australia. Mr Mitchell was looking for someone to help run the Foundation, and I agreed to help him.

My expenses incurred in working on this issue have been funded by my husband, and some have been reimbursed by farmers and neighbours who have asked me to travel to help educate their communities. I have donated my time in a voluntary capacity, often working 18 hours a day.

The **aims of the Waubra Foundation** are multiple but in summary they are:

1. To act as a catalyst to ensure that the best quality **independent** acoustic, scientific and medical research is urgently done into the adverse health effects of wind turbines being reported

2. To support affected residents

3. To provide information to health professionals treating such affected residents, and facilitate information sharing amongst those health professionals both nationally and internationally

4. To provide information to communities who are being targeted by wind developers, where those proposed developments are closer than 10km to homes and workplaces

5. To lobby government, to ensure that these serious concerns are addressed and considered by health and planning authorities, and other relevant individuals

For further information, please see the Waubra Foundation Objectives on Page 33.

**Importantly, the Waubra Foundation does not take a pro or anti wind position, and our endeavours are to ensure that wind turbines are sited so that they will not adversely impact human health, if they are used as part of a renewable energy strategy.**

**RELEVANT LITERATURE**

I will not go into the details of my personal literature review here, but instead refer everyone to the recent scholarly work on this topic submitted to this inquiry by my Canadian colleague, Dr Robert McMurtry, with which I concur. Dr McMurtry is the cofounder of an organization with similar aims to the Waubra Foundation in Canada, called the Society for Wind Vigilance (windvigilance.com). The Society convened the first International Symposium of the Adverse Health Effects of Wind Turbines in Ontario, in late October last year, which I attended.

Nor will I comment specifically on the Australian National Health and Medical Research Council document entitled the "Rapid Review of the Evidence" relating to the adverse health effects of wind turbines which was released in July 2010. This document has been extensively critiqued by others, including the Society for Wind Vigilance (please see Haste Makes Waste, on windvigilance.com). I will say that after reading that NH&MRC document when it was released in July 2010, I became extremely concerned for a number of reasons:

- its heavy reliance on what were obviously wind industry sponsored "reports/reviews/studies" where there was an **obvious conflict of interest,** without the author(s) appearing to perceive this.

- The way in which the unknown author(s) dismissed Dr Pierpont's work – it was not clear to me that the author(s) had actually read and understood Dr Pierpont's study, or read the detailed case study / raw data section of her book. Their criticisms of her work appeared to mimic wind industry comments, rather than a thorough critical analysis of the one detailed peer reviewed study available, by a qualified medical practitioner.

- there did not seem to be any understanding that there was "**no evidence" because so little research had been done**, rather than that there was "no problem**".**

- The lack of identity of the author(s). I am particularly interested to find out if a medical practitioner or practitioners, experienced in taking clinical histories from patients, were part of this rapid review. To date, the author(s) of this review remain a mystery.

Despite these and other serious inadequacies which have been highlighted by many nationally and internationally, this NH&MRC report in particular has been extensively relied upon publicly by the wind industry, despite employees in the industry clearly being aware of these health problems when they have signed agreements with 'gag' clauses, with affected residents. **Some wind industry employees have privately admitted this to me, and encouraged me with the Waubra Foundation's work, as they also know this current situation is wrong, and should not be allowed to continue.**

This NH&MRC document has also been extensively relied upon by politicians and public servants at all levels of Government in Australia. In particular, the respective health and planning politicians and public servants have kept referring to it, concurrently ignoring the escalating reports of ill health they are directly receiving from affected residents, without making any plans to commission or fund any independent research to investigate these serious health concerns, or any plans to change current planning guidelines which determine appropriate siting of wind turbine developments. In my opinion, this situation cannot be allowed to continue.

## STUDIES BY MEDICAL CLINICIANS, INVOLVING AFFECTED RESIDENTS

There have been an increasing number of reports from around the world particularly in the last 10 years, of people adjacent to wind developments developing a range of symptoms not previously described in the medical literature. At the same time the turbines are getting taller, the blades longer, both factors increasing their power output but also their noise emissions, and they are being built closer to larger rural populations, in order to be close to transmission lines.

The first Medical Practitioner to describe the new illness in a formal study was a UK rural GP (**Dr Amanda Harry**), who carried out a community survey after her patients presented to her with new symptoms and health problems, which they developed after large wind turbines commenced operation near her village in Cornwall.

Subsequently an Australian GP **Dr David Iser** (Toora, Victoria) documented the same range of conditions, using Dr Harry's initial survey form. Follow up work by the Canadian Wind Vigilance Society's WindVOICE, cofounded by Dr Robert McMurtry, used Dr Amanda Harry's survey as a basis for their self reporting survey, and found exactly the same range of symptoms being reported, in rural Ontario (please see windvigilanc.com for the WindVOICE survey reports).

**Dr Nina Pierpont** (an American Rural Paediatrician) progressed the research by performing the landmark study which examined the individual case histories of the members of 10 families from around the world, who had lived adjacent to wind developments, and become so unwell that they needed to leave their homes.

She meticulously recorded details of their health prior to, during, and after exposure to the turbines, after they had left their homes because of severe ill health in one or more family members. What she described was a pattern of symptoms which developed or were exacerbated by the operation of the turbines, and which disappeared when the subjects left their homes, only to return again when they returned back to their homes. She called the constellation of symptoms "Wind Turbine

Syndrome". **Her study, together with the raw data / case histories, has been published in a book with the same name**, available from **windturbinesyndrome.com**, and submitted by her to the Senate Inquiry.

Unfortunately, these practicing clinician's reports and studies to date have been completely ignored by health authorities globally, who continue to prefer to rely particularly on wind industry sponsored reviews or "independent" studies, for example the AWEA/CANWEA funded review by Colby et al (2009), **without seeming to understand there is a major conflict of interest.** Dr Robert McMurtry also highlights this important point, in his submission to the Senate.

Other researchers including acousticians and medical sociologists have completed large studies on noise and annoyance, (particularly in Scandinavia). At times, they have purported to examine "health effects". I refer readers again to Dr McMurtry's report to the Senate for his discussion of this literature.

I note Dr Pierpont's letter to Dr Leventhall on the matter of acousticians commenting on medical diagnoses, submitted as part of her evidence. I can only concur with her words. Acousticians and Medical Sociologists are **not** medical practitioners, they are **not** trained to elicit symptoms or detect new illnesses. **As they do not have the requisite specific training in taking a symptom history from a patient, and assessing the meaning of those symptom descriptions, they are in no position to make any comments on the accuracy or otherwise of the diagnostic and symptom descriptions of Dr Harry, Dr Iser, or Dr Pierpont's work, nor are they in a position to accurately and thoroughly carry out such an assessment themselves.**

Dr Pierpont's detractors claim her study is nothing more than a collection of anecdotes, which is untrue - it is a case series cross over design, which clearly shows the changes which occurred in those subjects with exposure to the turbines, and what happened after they left (almost complete resolution of the symptoms).

Detractors claim it is not peer reviewed, which is also untrue, it has been extensively reviewed and refereed by a number of eminent peers, experts in their particular field (also published in the book, and submitted by Dr Pierpont in her evidence to this Senate Inquiry).

Detractors also denigrate it for being self published. Dr Pierpont's reasons for doing this were multiple; the study itself was too long to be published in a peer reviewed medical journal, and it was impossible to cut it down further without compromising the completeness of the study. PhD papers are in a similar position – they are far too long to be published in a journal, but they are important bodies of work which are also peer reviewed, and contribute to new knowledge about a particular subject.

She was also keen to make it freely available to the many affected people across the world, who were contacting her for information, at the lowest possible price.
After seeking advice from colleagues, Dr Pierpont decided her study was most valuable accompanied with the case histories or raw data, as much of the description of these new symptoms needed to be in the subject's own words to retain maximum accuracy.

Dr Pierpont was also keen for her work to be accessible to lay people with no understanding of medical concepts. This was to help affected residents understand as much as possible about the illness they or their relatives were experiencing; including the symptoms, and the known science at the time which could help to explain the symptoms.

Dr Pierpont did not claim her work was the only work required on the topic, she clearly outlined the need for further research, to determine the exact mechanisms for causation of these symptoms, particularly involving low frequency sound (20 - 200 Hz) and infrasound (0-20 Hz). Her book has now been published in multiple different languages, **testament to both the importance of her clinical research, and the extent of the increasing epidemic of wind turbine syndrome across the world.**

**After listening now to many affected residents in Australia and some in Canada, it is my experience that Dr Pierpont's reports of patient's own descriptions of their symptoms in her study are identical to those being described to me by affected residents in Australia; most of whom had no prior knowledge of her, or her work.**

Other Medical Practitioners who have subsequently become concerned and involved in the international research effort include Dr Robert McMurtry (Canada), Dr Michael Nissenbaum (USA), Dr Christopher Hanning (UK), and Dr Noel Kerin (Canada).

Some of the Acousticians with extensive experience in this field of work who are independent of the wind industry and very concerned about what is going on include Dr Bob Thorne (Australia & NZ), Mr Rick James (USA), Mr George Kamperman(USA), and Dr Daniel Shepherd (New Zealand). There are other Acousticians, similarly independent of the wind industry, who are also very concerned.

The most recent completed clinical research done was done by Dr Michael Nissenbaum, and involved data collected from two wind turbine developments in North America, at Maine and Vinalhaven. Dr Nissenbaum presented some of this research at the conference in Ontario in October. It is now awaiting publication in a peer reviewed journal, and hence is not yet in the public domain.

In it he showed that there is a clear relationship between the distance a turbine is from a home, and various health indicators of residents, which included sleep quality, depression, and quality of life (using internationally validated questionnaires).

## MY FIELD OBSERVATIONS IN AUSTRALIA

The symptoms and health problems well described by the doctors mentioned above, are absolutely identical to the symptoms which have been described to me, in my interviews with over 60 affected residents from wind developments in NSW (Cullerin, Crookwell and Capital), Victoria (Toora, Cape Bridgewater and Waubra) and South Australia (Mt Bryan & Waterloo). **Information from those interviews have been provided to this Senate Inquiry confidentially in a deidentified state, in order to further protect individual privacy.**

Many of these individuals I have interviewed had never heard of Dr Nina Pierpont, or Wind Turbine Syndrome. Indeed, I too had not read her book before I interviewed the first thirty residents, but this was deliberate, so I was able to approach their interviews with a completely open mind. My first question was "Have you noticed any changes since the turbines started operating in your area?". Further clarification was sought as necessary. Some of these interviews have been conducted over the phone, and on multiple occasions. They are an ongoing work in progress, and are being used to determine future research priorities for independent researchers to pursue.

Many people I have interviewed had no idea that these symptoms they had individually noticed were in any way related to the turbines. Their knowledge of their symptoms has been greatly informed by starting to keep personal health journals, which have enabled them to see the connections between turbine operation and their symptoms. This has had the additional benefit of assisting some of their GP's to also see the connections, in particular with blood pressure changes.

I have now spoken directly with Rural Medical Practitioners (General Practitioners and Specialists) from Portland, Ballarat, Clunes, Toora, and Bungendore, who are concerned about the symptoms being experienced and the deteriorating health and sleep patterns of their patients.

The symptoms are characterised by developing after the turbines commence operating in their neighbourhood, and are being noted up to 10km away from the nearest turbines in both South Australia (Mt Bryan & Waterloo) and New South Wales (Cullerin).

Sometimes people develop symptoms straight away, but more commonly nothing is noticed for a few weeks to months apart from the audible noise, and the general pattern is that slowly, symptoms seem to progress in severity.

Sometimes people have described a particular event of exposure where they felt very unwell, and after that they seem to become rapidly worse in terms of symptoms experienced. Often people describe only realizing how unwell they have felt when they go away for over a week, and it is when they return that they suddenly notice the symptoms return, seemingly worse than before.

Some preexisting conditions such as migraines, high blood pressure and tinnitus are noted by affected residents to get worse, with exposure to turbines. It is important to note that not everyone is adversely affected by the turbines. This individual variability is also noted in laboratory experiments which examine the effect of infrasound on blood pressure and heart rate (Qibai & Shi), and work performance (Perrson Waye et al).

The longer people are exposed to the turbines (months – years), the longer it is taking for their symptoms to disappear, if they move away. Disturbingly, some people are reporting that some symptoms appear to be persisting, even after they have not lived at their homes for over a year. These particularly include tinnitus, extreme noise sensitivity (hyperacusis) and impaired memory.

In my experience, residents who are affected and have lived near turbine developments for more than 6 months, are generally able to accurately predict which direction the wind is blowing from by the symptoms they are experiencing, and can also tell without looking whether or not the turbines are operating, on the basis of the symptoms they are experiencing, even when they cannot hear or see the turbines.

Symptoms which have been described to me by Australian affected residents include but are not limited to the following:

**Severe chronic sleep deprivation:**

- from the audible turbine noise,
- from waking up anxious and hyperalert, in a panicked state, for no good reason, and often a number of times a night. They describe being so instantly awake that it takes a long time to get back to sleep again. These residents often tell me that they cannot hear the audible turbine noise at the time
- from markedly increased nocturnal urination – often experienced by many people at the same time in the same household
- for parents, newly disturbed sleep of their children is an additional contributor to their own sleep deprivation, and this can include regular bedwetting (when previously dry at night for some years) and waking up with night terrors
- waking up in the morning not remembering that they had woken up, but nevertheless not feeling at all refreshed
- trying to get to sleep, or back to sleep having been woken up during the night, in a bed which is literally vibrating

**Severe frequent headaches:**

- describing their head feeling as if it was "in a vice", or with a "tight swimming cap on" (some children also badly affected by this, having previously rarely suffered from headaches)
- significant exacerbation of the frequency and severity of their migraines, particularly but not exclusively from shadow flicker. Some people describe their migraines being triggered by just a few seconds of shadow flicker, enough to put them out of action for 24 hours
- frequent severe headaches in children who have never previously complained of them

**tinnitus** (buzzing/ringing in one or both ears, both new onset and exacerbation of a pre existing condition)

**ear pressure sensations** (in one or both ears, uncomfortable and sometimes painful, especially if previous tympanic membrane surgery & scarring)

**hyperacusis** (extreme noise sensitivity to 'normal' sounds)

**nausea** (sometimes severe)

**motion sickness, vertigo symptoms, and balance disturbances,** particularly with residents aged over 60 with chronic exposure

**visual blurring**, which only occurs with turbine operation. Some are also describing sensitivity to flouro lights, particularly in supermarkets, where they are unable to see detail in people's faces

**irritability, extreme anger, and other mood disturbances**

- this is also being described by current and former **workers** on the turbines, or is being observed by their partners. These individuals do not generally have the additional night time exposure to operating turbines, unless they also live adjacent to the turbine development.

**memory and cognitive deficits,**

- increase with prolonged exposure, and do not always completely resolve with relocation away from the turbines
- particularly being noted in relation to school children living and/or attending school close to turbines, by parents and by teachers. Appear to resolve (according to parents) with relocation of home and attending a different school in an area not exposed to turbines

**depression,** sometimes severe, with suicidal ideation

**anxiety**, sometimes acutely severe, with episodes of extreme panic, sometimes waking them up at night (as mentioned previously, children are waking with night terrors, and bed wetting, never previously experienced)

**high blood pressure** (hypertension) which can be a new problem, or an exacerbation of a previous condition, and which is sometimes occurring in conjunction with other symptoms suggestive of an acute hypertensive crisis

**tachycardia,** coinciding with turbine operation

**body vibrations**, which people describe particularly in their chest, their abdomen, their lower limbs whilst in bed, and also their upper lip. Sometimes this upper lip vibration is visible to others

## RECENT DEVELOPMENTS

Most recently in Australia and in Canada I have heard multiple descriptions of angina, chest tightness, and heart attacks occurring when the turbines are operating. These have occurred at a number of different wind developments, in all three states, and require urgent further thorough investigation and analysis. I am hearing from my Canadian colleagues that the same reports are emerging there, in addition to the ones I heard about directly from affected residents in Ontario in October 2010.

Some heart attacks are occurring in patients who do not appear to have any signs of arterial blockage from subsequent angiograms, performed by their treating cardiologists. There is a condition which is now described as Tako Tsubo, in which sudden shock is causing myocardial dysfunction, and recent Japanese research has highlighted the role which stress hormones including adrenaline appear to be playing in this condition. There is also experimental research which has shown an increase in secretion of stress hormones including cortisol and adrenaline, and also evidence of myocardial damage in animals subjected to infrasound exposure. (NIEHS Toxicology of Infrasound review, 2001)

At Waubra particularly, a number of affected residents have started measuring their blood pressures at multiple times during the day and overnight, and some are finding that both their blood pressures and their heart rates are markedly elevated when the turbines are operating, but decrease when either they are away from home, or when the turbines are turned off for any length of time (days). Many of these patients did not have high blood pressure prior to the turbines operating, as measured by their GPs in their surgeries. Some of the blood pressure increases being reported to me include an **increase** in systolic blood pressure of up to 80mm Hg when the turbines are operating.

Below is an extract from an email sent to me recently by an affected resident, who has realized that his blood pressure problems could be connected with the turbines:

"Last night was the first night for a month that we had constant westerlies. Noise was low to average. However the BP readings are of interest. 6 weeks ago at my regular medical, my blood pressure was 120/75. Last night on arriving home from a day out, it was 107/78; and 12 hours later after a night of constant turbine noise, 150/79"

I have also been told of episodes of extremely high blood pressure in conjunction with severe headaches and nausea, a sensation of one's heart leaping out of one's chest, and a "sense of impending doom". This clinical description is identical to that described by patients experiencing acute hypertensive crises.

Such a clinical condition has previously been described in conjunction with the clinical use of excess adrenaline, and with a very rare adrenal tumour called a phaeochromocytoma. In some of the affected residents where this clinical situation has been described, both these explanations for their symptoms have been positively excluded. The cause of these episodes is still unknown. One affected resident has had five episodes of this, only ever occurring when the turbines are turning.

Further independent research is urgently required, as some of these clinical effects are occurring at greater distances than previously described (especially some of the body vibrations). **Specifically, hypertension in conjunction with turbine operation has been reported up to 5km away, and body vibrations and nocturnal wakening in a panicked state up to 10km.**

Acousticians independent of the wind industry have confirmed to me that when these large modern turbines are placed on ridges, and there is a temperature inversion effect or cloudy weather, sound waves (audible and infrasound) they generate could certainly travel that distance, particularly in the weather conditions described.

## Observed Mental Health Issues

Specific mention needs to be made of the extent and severity of psychiatric morbidity being described by affected residents. This is very noticeable, and is evident both in the populations currently exposed to turbines, but also those who are the subject of proposed developments. I believe the social division which is created and amplified by the activities and strategies of the wind developers (including specifically the confidentiality agreements and the secrecy which surrounds the proposals) is directly responsible for much of this morbidity.

I have been told on many occasions by affected residents that it has destroyed the long standing close knit fabric of all the small communities I have been to, and has set family members and old friends against each other, divided church congregations and school communities, and created rifts in important rural social and service networks such as the CWA, the CFA/CFS, to name just a few examples.

Residents of rural communities in Australia already have significant stressors, including the effect of the long term drought which has recently been experienced in much of south eastern Australia, followed by the recent floods. They are significantly disadvantaged with respect to access to health care, particularly mental health care. They do not need the extra burden of serious psychiatric illness which these turbine developments are currently contributing to. There is an urgent need to properly assess, measure and describe what is actually going on in these communities with respect to mental health issues, and to ensure that the appropriate help is made available.

The most positive start would be formal acknowledgement that these are serious psychiatric illnesses, rather than being dismissed as "psychosomatic". For too long, non medical professionals (medical sociologists and acousticians particularly) with no clinical diagnostic expertise or training have dominated the analysis, discussion, and study of these problems.

**CONSEQUENT EFFECT OF THESE SYMPTOMS, ILLNESSES AND SOCIAL DIVISION ON DAILY LIFE – some examples of the hidden costs**

Dr Robert McMurtry, in his submission to this inquiry, has well described the current state of knowledge in the relevant medical literature, particularly with respect to the multiple serious adverse health consequences from sleep deprivation, noise, and stress. Others, such as Professor Arline Bronzaft, have made specific reference to particular situations, such as children, and the effect of noise.

From what I have seen and heard, the overall effect on their day to day lives, for those people and their families affected by the turbines, is profound. Another effect has been the extensive and extraordinarily damaging community division which these developments have directly resulted in, often before they have even been built. I have listed some relevant specific examples I have direct knowledge of below:

- severe sleep deprivation resulting in people describing microsleeps when they are driving, with multiple 'near misses', and reported increased frequency of farming accidents

- office / business workers finding their chronic sleep deprivation is severely affecting their work performance, and unable to do anything about it – apart from take work home to try and keep up, resulting in yet more stress. Some have had to leave paid employment, some are finding it very hard to find subsequent employment and keep it

- viscious circle of sleep deprivation affecting mental health which then affects sleep adversely, which further affects mental health, especially anxiety and depression. There is little GP's can suggest to help, other than sleeping tablets (addictive & risk of falls), or to move

- People can't move if their house is unsaleable, and they have no other financial assets. All too often, I have been told this is the case. One person has had his property on the market for over 10 years, with no buyers when they discover it is near a wind development. Many people affected are close to retirement age, and have no way of generating the resources needed to move. They are literally trapped, in what some describe as a "living hell"

- families are being split, because of adverse health impacts on some members, who cannot stay living in the family home. This has particularly been the case with some families with young children, and is causing extreme financial and emotional hardship for those families

- Marriages are under significant extra pressure, particularly if one person wants the turbines, and the partner does not, and a parent or the children subsequently get sick

- Some people are self medicating their depression and anxiety symptoms with alcohol, with predictable and serious consequences for themselves & their relatives

- longstanding extended family members are no longer talking to each other, directly as a result over conflict concerning turbines. In previously tight knit rural communities, this is having a devastating effect on longstanding community and family relationships

- concern from extended family members **where there are families who are hosting turbines and there is reluctance to get help for vulnerable members of those families who are being severely affected (particularly elderly parents and children)** – I have direct knowledge of a number of these situations, from concerned extended family members, and from concerned teachers

- the secrecy which the wind developers encourage, by way of confidentiality agreements, and the subsequent feelings of betrayal of trust which others in the community have when they realize, often at the last minute, what is going on. This erosion of trust is particularly damaging to the very fabric of close interrelationships which country life relies on, particularly in times of hardship, which are based on good relationships and cooperation between neighbours. I believe from what I have seen and heard that this alone has a very damaging effect on individual and rural community mental health, even before the turbines are built.

## OCCUPATIONAL HEALTH AND SAFETY CONCERNS

I have a number of concerns with respect to occupational health and safety issues.

1. Farmers have workplaces in the vicinity of wind developments, and are themselves employers, as well as employees. Some farmers have said to me that they are very concerned about the health effects of the turbines on their workers, and are concerned about their ability to provide a safe workplace, and their liabilities with respect to this issue. Some have sought advice from the relevant government departments, but with none forthcoming, as officially "there is no health problem".

2. Some farmers have given me instances where their workers have had to leave, because of health problems they developed which included symptoms of motion sickness, headaches, painful ear pressure, and inability to cope with the audible noise of the turbines. One worker from his description may have been having episodes of acute hypertensive crises, and has told me he will never work again near a wind development, as he felt so unwell.

3. I am also concerned about the health of workers employed by the wind

development companies, on site. I am told by current and ex employees of different wind developments that they are not advised of any health issues or monitoring required, as officially "there are no health problems". I am particularly concerned about the need to monitor blood pressures of workers on turbine developments, as elevated blood pressures are generally symptom free.

4. The new national work health and safety laws are to be enacted this year, and will take effect from 1st January, 2012. In those new laws, there is a specific onus on individuals conducting a business to provide a safe workplace, and health is specifically described as including both physical and psychological health. This will further increase the pressure on those farmers to "provide a safe workplace", which it is clearly impossible for them to do if they are surrounded by wind turbines.

**MECHANISMS OF CAUSATION of Illness resulting from Wind turbines, and related regulatory issues**

The exact mechanisms for causation of all the ill health resulting from turbines are not all clear, however I make the following comments

**1. Audible Noise**

Wind Turbines can be noisy, even some elements of the wind industry have admitted this (eg Sloth, 2010, summary page). There is no doubt that some people are particularly affected by the audible noise from turbines, which is uniquely disturbing or annoying for many people at much lower sound pressure levels than for other sources of noise. I am not going to discuss the extensive medical evidence which exists in the published peer reviewed medical literature about the adverse effects of audible noise on health, and on sleep, but again refer readers to Dr Robert McMurtry's submission to the Senate Inquiry on this topic.

In addition, Dr Bob Thorne and Dr Daniel Shepherd's work on individual noise sensitivity is highly relevant here (please refer to their respective Senate Submissions) – what is disturbing to one individual who is noise sensitive, may not disturb another. This is yet another reason to ensure that turbines are sited well away from human habitation, to ensure that those who are noise sensitive are not going to be adversely impacted, with direct health adverse consequences because of chronic sleep deprivation from audible noise.

The issues of increased night time noise from turbines is something which a number of acousticians have written extensively about, particularly Dr Bob Thorne, Dr Frits Van Den Berg, and Mr Rick James. What I hear from affected residents is that their sleep and therefore their health is particularly affected by audible noise on nights where there is ridgetop wind, but the background noise around their home is quiet. On these nights, the audible noise can mean that some affected residents get very little sleep.

This noise has been described to me from residents of houses up to 8km away from the turbines, and I have heard it myself from turbines at a distance of 4km, on such a night, at Waubra. It literally can sound like a loud overhead jet engine, which doesn't ever leave. Other residents describe the noise as being like a washing machine, or a truck or train constantly making a noise, and never going anywhere. I have recently visited a number of houses adjacent to the Capital Wind Development in NSW, and have heard this variation in sound for myself.

I am not an acoustician, but acousticians I work with tell me that current audible noise measurements are based on averages, rather than actual peaks of audible noise intensity. As Professor John Harrison made clear at the Symposium in Ontario, "the ear does not hear 'averages', it hears the peaks (please see his conference paper on the windvigilance.com website).

**If the audible sound "peaks" are what is waking people up, then consideration needs to be given to changing the current guidelines, ensuring that such peaks are measured, and then acted on, if the adverse and serious health consequences of chronically disturbed sleep are to be prevented.**

In addition, many people I spoke to described how their ears / brains seemed to 'tune into' the sound of wind turbine audible noise, so that what was not annoying for the first five minutes became intensely annoying or disturbing after a few hours or days, let alone months.

Mr Erik Sloth, in his frank presentation to the Clean Energy Council in May 2010, referred to some inadequacies of current acoustic modeling in predicting actual wind turbine noise – certainly the perspective of affected residents I have spoken with is that the noise they are living with on a regular basis is very loud, and very disturbing.

There is a major problem with the process, if the noise predictions used by the wind developers in their planning applications bear no reality to the noise actually generated in the field post construction, as is happening currently at multiple wind developments to my knowledge, specifically Waubra, Waterloo, and Mt Bryan. It is simply not good enough for the developers to admit, post construction, that "we didn't realize they would be so noisy".

One of the more damaging and disempowering wind company practices is to refuse to release post construction audible noise monitoring data when requested to do so by the affected residents, giving the excuse that it is "inconclusive", or releasing it in such a form that it is impossible for them to interpret (eg a wad of sheets of paper with noise numbers). According to affected residents I have spoken with, this has happened at Mt Bryan, Waubra, Toora, and Capital wind farms.

## 2. Low Frequency Noise (LFN) and infrasound

Low Frequency noise is generally defined as sound waves with a frequency less than 200 Hz. Infrasound has a frequency of less than 20 Hz, which is generally imperceptible to the human ear, but may be perceived as a vibration. It is important to note that all the current noise regulations specify dBA or audible noise level limits, but there appears to be little or no regulation specifically governing the acceptable or 'safe' sound pressure levels of infrasound.

Dr Alec Salt has shown experimentally how infrasound can adversely affect the mechanisms operating the sensitive inner ear function at much lower sound pressure levels than are perceptible to human hearing. This means that even though you cannot 'hear' the infrasound waves, they are still impacting on your inner ear and brain. (see conference proceedings on windvigilance.com). His work is leading the world in this area, and has been peer reviewed and published.

Dr Nina Pierpont has also referred to the current research literature relating to the brain and the vestibular system in particular, in both her study and in her recent presentation and paper for the International Symposium, (available at windvigilance.com) and submitted to the Senate committee.

There are also published peer reviewed scientific studies which confirm that the effects of exposure to infrasound are cumulative (Perrson & Waye,), can affect cognition & memory (ibid), can affect mood & work performance (ibid), and can result in elevated blood pressure, heart rate, and affect mood (Qibai & Shi).

Whilst these experiments have not been done with wind turbine specific pulsatile infrasound, they are highly suggestive that infrasound may indeed by a causative agent in many of the symptoms of wind turbine syndrome. There is an urgent need for further research into this specific area, because of the finding below.

**Mr Rick James (Acoustician) showed a sound spectogram during his presentation at the International symposium in Ontario on October 29th, 2010, and stated that he had measured the wind turbine specific pulsatile infrasound using a Sound Quality Analysis Instrument, and found infrasound up to a sound pressure level of 90 dB, which was a much higher sound intensity than previously thought possible from modern upwind turbines** (available on windvigilance.com, second last page of his presentation, further details available on request).

There are animal studies which clearly show that infrasound at this sound pressure level of 90dB can cause physiological changes, in particular stimulation of the body's fight / flight response, or sympathetic nervous system. There is also evidence of tissue damage with long term high intensity infrasound exposure. There are multiple relevant papers which are cited in a Review of the toxicology of infrasound, (2001) by the National Institute of Environmental Health Sciences.

A number of the patterns of symptoms which affected residents have described would certainly fit with the experimental evidence of stimulation of the sympathetic nervous system by infrasound; particularly the waking up in the middle of the night panicked, the anxiety symptoms, the elevated blood pressure, the tachycardia, the episodes of acute hypertensive crises, Tako Tsubo induced heart attacks, to name a few.

There is certainly an urgent need for further specific research into the effects of acute and chronic infrasound and LFN exposure on humans and animals, at the measured levels of wind turbine specific pulsatile infrasound in the field being emitted by the turbines. Professor Colin Hansen, Acoustics Professor from Adelaide University, has expressed an interest in being involved in such studies, in conjunction with a Physiologist or Clinician.

This basic infrasound measurement in the field and in the affected people's homes has not ever been done, and urgently needs to be. Both Dr Bob Thorne and Professor Colin Hansen are keen to do this.

**We don't know what a 'safe' level of infrasound emission from a turbine is, particularly with cumulative chronic exposure, and particularly with exposure of particularly vulnerable populations, especially the elderly, children, and unborn babies.**

Some clinicians working in this area are now concerned that the illness called Vibro-Acoustic disease, which results from chronic long term high intensity infrasound exposure, (particularly in the aviation / defence industries) may be relevant in this context of chronic exposure to wind turbine infrasound, given the recent high intensity levels of pulsatile wind turbine specific infrasound, recorded by Mr Rick James, in Ontario, (previously mentioned).

**Given what we do know already about infrasound exposure, it would seem imperative to immediately adopt the precautionary approach, and not site turbines within distances where people are currently experiencing symptoms (10km), until such detailed infrasound studies are done.**

Dr Bob Thorne, Dr Daniel Shepherd and their colleagues from Massey University have submitted a study proposal which would significantly increase current knowledge in this area, which is ready to start immediately, as are the subjects for the study. All that is required is the funding. Dr Thorne has told me that useful results could be available by six months from commencement of the study.

**Other mechanisms**

It may well be that other mechanisms are eventually identified as causative agents for some of the symptoms which are being experienced by affected residents, but these remain unidentified at this time. There is certainly concern on the part of some residents that electromagnetic radiation may be playing a part.

At present there is little evidence to support this, however a preliminary step would be to actually measure the electric and magnetic fields in those locations where people are actually experiencing symptoms or other problems suggestive of electromagnetic interference, such as flouro lights lighting up by themselves, as has been reported by some residents.

## THE NOCEBO ARGUMENT

There is no experimental or study data which support the wind industry assertion that these symptoms are due to the "nocebo" effect.

In my experience, many of the affected residents currently living adjacent to turbine developments actually supported the turbines coming in to their community, and some worked on the turbine construction.

**In my judgement, assertions of the nocebo effect in these circumstances is evidence of a culture of victim blaming which is pervasive within the industry, rather than a valid scientific hypothesis.**

## SOME AREAS REQUIRING FURTHER INDEPENDENT RESEARCH

1. the duration, frequency and intensities of pulsatile infrasound and low frequency noise currently being emitted from turbine developments, under different weather & wind conditions, over weeks to months, and the concurrent measurement with symptoms being experienced by affected residents in their homes (Dr Bob Thorne et al's proposed research)

2. the sleep patterns of affected residents, documented by in situ sleep studies, correlated with turbine operation, and concurrent measurement of audible sound and infrasound

3. the effect on blood pressure of sound and infrasound from turbines, as measured concurrently by sound and infrasound measurement devices and continuous ambulatory blood pressure monitoring

4. the effect of long term chronic infrasound exposure on adults (using a range of health indices), and in particular investigation of any irreversible long term sequelae (possible permanent memory deficits, hyperacusis (noise sensitivity) and permanent tinnitus have been described in residents who have relocated away from turbines some time ago)

5. the effect of chronic infrasound exposure, and exposure to wind turbines on children & unborn babies, (particularly their growth, development, cognitive

development, & learning)

6. ascertain the range and severity of psychiatric illness being observed in populations exposed to turbines, compared with a non-exposed group, with follow up work to determine the causative agent(s) and appropriate and effective therapeutic interventions

**OTHER IMPORTANT HEALTH/PLANNING ISSUES - FIRE**

Finally, particularly in south eastern Australia, there is the issue of increased fire risk which operating wind turbines pose.

1. Turbines can and do catch fire (at least three in South Australia in the last few years - Cathedral Rocks, Lake Bonney and Starfish Hill), and have significant quantities of highly flammable oil in their gearbox.

2. There are significant impediments to fighting wind turbine fires - both the fire authorities and the turbine developers admit there is little that can be done in the event of a fire except just watch it burn, and try and put out any spot fires.

3. CFS staff in South Australia advise me they have been told they cannot approach a burning turbine closer than 300 metres, and the Country Head of Safework SA has confirmed that there are further restrictions if the turbine blades are on fire and spinning, as happened recently at Starfish Hill, requiring the CFS to move back to at least one kilometre from the burning, spinning turbine blades. Preliminary discussions with people interstate have revealed the same issues and restrictions.

4. Finally, there are restrictions on the use of aerial fire fighting apparatus in close proximity to turbines, because of the turbulence the turbines generate. I have been advised that this applies whether the turbines are operating or not.

**There is currently no restriction on the operation of turbines on days of increased fire danger (high, extreme, and catastrophic). In my opinion, this is a major public health disaster, just waiting to happen.**

**RESTRICTIONS TO OPERATION OF TURBINES ON THESE DAYS SHOULD BE**

**IMMEDIATELY IMPLEMENTED.**

## OTHER RELEVANT ISSUES:

### Why has this research not yet been done, anywhere in the world?

I believe the issue of the adverse health effects of wind turbines has not yet been properly examined by my Medical colleagues with the exception of the people already mentioned, **because they have been unaware that there was a problem.**

**I believe there has been an organized effort on the part of the wind industry to keep this issue of adverse health effects out of the public arena, by the combined use of:**

1. **deliberate 'spin' and misinformation**, particularly on the part of the wind industry bodies e.g. the Clean Energy Council in Australia (for example comments such as "after 20 years and 100,000 turbines there have been no problems" despite members of this industry being party to 'gag' agreements

2. **'shooting the messenger'** in the form of attempting to intimidate or discredit the clinicians who have identified problems. I have experienced both, on multiple occasions, from wind industry and government representatives

3. **by the use of confidentiality agreements** with some of the affected residents, who have signed these agreements which prevent them from speaking publicly about their health problems.

I have direct knowledge of these confidentiality agreements occurring in multiple sites with different developers in Australia, and in Canada, and have been advised by my colleagues internationally of this widespread and longstanding industry practice elsewhere.

### FAILURES OF PROCESS AND REGULATION and the consequent effects on mental health of affected residents

In my experiences listening to the stories of affected residents across south eastern Australia, the overwhelming impression I have is one of collective anger and deep despair at being lied to, ignored, or arrogantly dismissed, by both wind developers, their consultants, their lawyers, and politicians and bureaucrats, particularly those in health, environment and planning departments at all layers of government (Federal, State and Local).

There are a few notable exceptions, where individuals have taken affected residents seriously, but they are very few indeed.

**The direct health consequence of this failure has been an escalation of the significant mental health problems which have previously been described**. These are occurring in people already living adjacent to the turbines, but they are also occurring in significant numbers in those populations who are confronted with a proposed development in their "backyard".

Many people I have spoken to in such situations describe it as being "akin to a war", consuming every waking moment, not to mention considerable financial resources, if available. **They also describe feeling utterly abandoned by the authorities such as the health department and the EPA, who are meant to be there to protect the health and well being of all individuals, but particularly those vulnerable individuals such as the elderly, and the children**.

For example, I am told by **all** the affected residents I have spoken with that they have **never** been contacted by any state or federal health bureaucrat, apart from receiving letters telling them "there is no evidence" that they could be suffering from the health problems they describe. Some have also been told this by their doctors. I understand how this situation has arisen, given the lack of research, with the exception of the studies previously mentioned, but such disbelief has only perpetuated the trauma of their experiences.

I have met with such health bureaucrats, or have sometimes received correspondence from them. None of the health officials I have met with to date had actually read the studies I have referred to, particularly Dr Nina Pierpont's study.

I have been told by them they will "monitor developments" and "it is only a few people anyway". Another response has been that it is "for the greater good" of the community – this has also been enshrined in some Australian court judgements, and planning decisions.

Consequently affected rural residents are feeling utterly abandoned, desperate, and very angry, as well as feeling very unwell, mentally and physically. Many have been significantly financially impoverished by their experiences. One couple I know of are effectively homeless, as they become so sick within minutes to hours of returning home, if the turbines are turning. They would be homeless if it wasn't for the kindness of friends and relations.

I sincerely hope that the deliberations of this Senate Committee will result in their voices being heard, and significant and urgent action being taken.

I believe Independent scientifically conducted research is the ONLY way to progress this issue, with the competing and conflicting interests of all the parties involved.

RECOMMENDATIONS

1. There is an urgent need for further INDEPENDENT medical, acoustic and scientific research, looking specifically at the populations affected by the currently constructed and operating wind developments in Australia

2. An immediate temporary halt in construction of wind turbines closer than 10km to human habitation until adequate research is completed, in order to determine what is a safe setback of turbines from homes and workplaces

3. Current planning and noise guidelines will need to be updated on the basis of this new knowledge

4. There should be an immediate ban on the operation of wind turbines on days of high, extreme and catastrophic fire danger, because of the difficulties in fighting such fires, and the risk to lives should such a fire occur

5. Measurement of wind turbine specific infrasound and low frequency sound needs to be included in post construction noise assessments, and ALL these assessments MUST be performed by experienced Acousticians who are COMPLETELY INDEPENDENT of the wind developers

WAUBRA FOUNDATION

# OBJECTIVES

1. Gather, investigate and review complaints of health problems that have been perceived by the complainants as being associated with living or working close to wind turbines or such other industrial sources that may be considered as relevant.

2. Continue to gather additional information from existing and new wind projects or other sources as it becomes available.

3. Build the existing and new data into a high quality data base suitable as a start point for properly constructed studies and review by qualified others.

4. Use the data to engage in co-operative studies with independent researchers both in Australia and internationally.

5. On the basis of data gathered plus local, overseas and co-operative studies, provide relevant and independent advice to communities, the public at large and local, state and federal governments and to the wind turbine industry and other relevant organisations.

6. Promote research into the effects and causes of illnesses that may be associated with living or working close to wind turbines and other relevant sources.

7. Make the results of such research widely available, to members of the public, health professionals, and other interested parties.

8. Facilitate the establishment of individual networks of relevant specialities of medical practitioners and other health practitioners to enable the rapid sharing of information and expertise in the diagnosis, management and treatment of patients with symptoms of wind turbine syndrome

9. Provide such advice and assistance as can be given to individuals and communities who believe that their health is or may be impacted by adjacent wind turbines or other sources.

10. Assemble the necessary resources to carry out the objectives.

11. Raise such funds as may be possible to assist in the work of the Foundation.

12. At all times to establish and maintain complete independence from government, industry and advocacy groups for or against wind turbines.

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**Promoting Research for Authoritative Wind Turbine Guidelines**

## Physiological Health and Wind Turbines

*"...health includes mental, physical and social functioning, which are closely associated and interdependent." - World Health Organization [1]*

Clinicians and other researchers have documented both physiological and psychological symptoms reported by victims experiencing adverse health effects from wind turbines. [2],[3],[4],[5] Many families have abandoned their homes to protect their health. This cannot be denied.

Some of the reported physiological symptoms include headaches, heart palpitations, excessive tiredness, tinnitus, hearing problems, stress, sleep disturbance, and migraines.

The authors of An American and Canadian Wind Energy Association sponsored report (A/CanWEA Panel Review) does not dispute that there are victims experiencing adverse physiological symptoms.[6],[7]

The A/CanWEA Panel Review recognizes wind turbine noise characteristics such as low frequency and fluctuating noise may be annoying to some.[8]

The A/CanWEA Panel Review also acknowledged that In addition to annoyance wind turbine noise may cause stress and sleep disturbance. [9]

One of the authors of the A/CanWEA Panel Review W. David Colby, M.D. reinforced these findings when he stated

> "We're not denying that there are people annoyed and that maybe some of them are getting stressed out enough about being annoyed that they're getting sick."[10]

Wind turbine annoyance, stress and sleep disturbance have been documented in peer reviewed studies[11] and confirmed by The Chief Medical Officer of Health of Ontario and Agency for Health Protection and Promotion.[12],[13]

Wind turbine physiological adverse effects documented by clinicians and researchers are consistent with symptoms commonly associated with annoyance[14], stress[15],[16] and sleep disturbance. [17]

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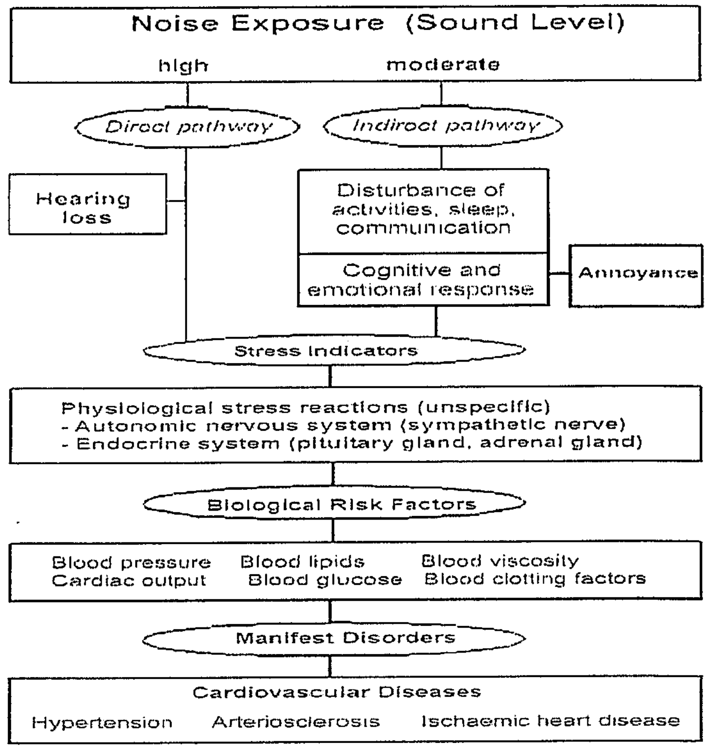


[18]

Currently there is no authoritative international guideline for wind turbine noise designed to protect human health.[19]

The American and Canadian Wind Energy Associations do not appear to support the development of authoritative wind turbine noise guidelines designed to protect human health. On the contrary they are of the opinion that the authoritative noise guidelines of the World Health Organization need not be adhered to.[20]

The Society for Wind Vigilance's mission is to mitigate the risk of both physiological and psychological adverse heath effects through the advancement of independent third party research and its application to the siting of industrial wind turbines.

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The Society for Wind Vigilance





## Promoting Research for Authoritative Wind Turbine Guidelines

### Visual Health Effects and Wind Turbines

> ***"...wind-energy projects create negative impacts on human health and well-being, the impacts are experienced mainly by people living near wind turbines who are affected by noise and shadow flicker."***
>
> *National Research Council (NRC). Environmental Impacts of Wind-Energy Projects, 2007*

World Health Organization acknowledges that in addition to noise pollution wind turbines also have visual burdens. [1]

The health impact of visual burdens cannot be underestimated. An epidemiology study conducted by World Health Organization determined a "bad view out of window" increased the risk for depression by 40%. The same study also demonstrated disturbance by noise and sleep disturbance by noise increased the risk of depression 40%, and 100% respectively. [2] In addition to visual burdens wind turbines create noise pollution [3] which is acknowledged to cause annoyance, stress and sleep disturbance. [4], [5], [6], [7], [8] In light of these statistics it is expected that people may suffer adverse health effects from visual and noise impacts of wind turbines.

Rotating wind turbine blades interrupt the sunlight producing unavoidable flicker bright enough to pass through closed eyelids, and moving shadows cast by the blades on windows can affect illumination inside buildings.

[9] This effect is commonly known as shadow flicker.

Wind turbine shadow flicker has the potential to induce photosensitive epilepsy seizures however the risk is low with large modern models and if proper planning is adhered to. [10], [11] Planning should ensure the flash frequency does not exceed three per second, and the shadows cast by one turbine on another should not have a cumulative flash rate exceeding three per second. [12]

Wind turbine shadow flicker induced adverse human health effects include annoyance and/or stress. [13], [14], [15], [16], [17]

Wind turbine noise including low frequency noise may also contribute to the overall annoyance.

"Wind turbine noise is easily perceived and annoying even at low A-weighted SPLs....Wind turbines are furthermore prominent objects whose rotational movement attracts the eye. Multimodal sensory effects or negative aesthetic response could enhance the risk of annoyance. Adverse reactions could possibly lead to stress-related symptoms due to prolonged physiological arousal and hindrance to psychophysiological restoration." [18]

No generalized dose-response curves have yet been modeled for wind turbine shadow flicker primarily due to the lack of results of published field studies.

Further investigation into the effects of wind turbine stressors including shadow flicker is required to assist in the development authoritative guidelines designed mitigate potential adverse health effects. [19]

Shadow flicker is also a safety concern. For example it can cause vehicle driver distraction. [20]

Most jurisdictions do not have explicit regulations to protect people from the adverse health effects of shadow flicker. [21]

To mitigate risk to human health wind turbines should be sited to ensure people will not be adversely affected. For example in the northern hemisphere people located East-NE or WNW from the turbine must be protected from shadow flicker. [22]

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Recommended shadow flicker setbacks for current wind turbine designs are 10 rotational diameters which would typically translate to approximately 1000 m. [23]

Greater setback distances may be required when wind turbines are sited on elevated ridges as the shadows can be cast over distances of several kilometres.

It is acknowledged that "...shadow flicker can be an issue both indoors and outdoors when the sun is low in the sky. Therefore, shadow flicker may be an issue in locations other than the home." [24] Shadow flicker modelling must consider human exposure to shadow flicker outside a building.

Protection from wind turbine shadow flicker exposure must be engineered into the design of the wind turbine facility during the planning stage. [25], [26]

To ensure protection from adverse human health effects a shadow flicker study must be conducted during the planning stage of a wind turbine facility. The shadow flicker study should:

- Calculate shadow flicker based on the actual location of the wind turbines.
- Calculate shadow flicker exposure on the entire neighbouring properties and not just the "receptor (house)".
- Calculate shadow flicker for both sun and moon induced flicker using conservative assumptions to ensure maximum protection against adverse human health effects and safety risks.
- Protect against photosensitive epilepsy by ensuring the flash frequency does not exceed three per second, and the shadows cast by one turbine on another do not have a cumulative flash rate exceeding three per second.

**Conclusions**

Based on the best available science the following conclusions can be drawn.

- Wind turbines produce noise and visual burdens.
- Scientific research confirms visuals impacts can adversely affect human health.
- Wind turbine shadow flicker has the potential to

induce photosensitive epilepsy seizures however the risk is low with large modern models and if proper planning is adhered to.
- Wind turbine shadow flicker induced adverse human health effects include annoyance and/or stress.
- No generalized dose-response curves have yet been modeled for wind turbine shadow flicker primarily due to the lack of results of published field studies.
- Protection from wind turbine shadow flicker exposure must be engineered into the design of the wind turbine facility during the planning stage.

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Promoting Research for Authoritative Wind Turbine Guidelines

## Low Frequency Noise, Infrasound and Wind Turbines

Wind turbines generate a broad spectrum of noise including low frequency noise and infrasound which may be audible or inaudible. [1], [2], [3] [4]

It is widely affirmed that exposure to audible low frequency noise can cause adverse health effects in humans. [5], [6], [7], [8]

Low frequency noise can cause "...immense suffering to those who are unfortunate to be sensitive to low frequency noise and who plead for recognition of their circumstances." [9]

"Wind turbines are generally located in areas devoid of trees and other large vegetation. Instead, ground cover usually consists of grass, sagebrush, plants, and low shrubs, which are minor impediments to noise propagation except at very high frequencies. At frequencies below ε 1000 Hz, the ground attenuation is essentially zero." [10]

The farther away from the wind turbine the greater is the low frequency content due to a relatively larger atmospheric absorption of high frequencies. Considering the A-weighted sound level outdoors in relevant distances to neighbours, the lower frequencies constitute a substant part of the noise. [11]

There is no doubt that as wind turbines get larger and more densely sited the lower frequency part of the noise spectrum is of importance to th neighbours' perception of noise from large wind turbines. Noise from wind turbines is under certain atmospheric conditions more annoying anc especially the low frequency part - spread much farther than generally accepted. Wind turbines may cause low frequency noise induced annoyance both inside and outside a building. [12]

Annoyance is an acknowledged adverse health effect. [13], [14]

"Regulatory authorities must accept that annoyance by low frequency noise presents a real problem which is not addressed by the commonly assessment methods." [15]

Literature reviews and peer reviewed scientific articles confirm the symptoms associated with low frequency noise exposure include annoyanc stress, sleep disturbance, headaches, difficulty concentrating, irritability, fatigue, dizziness or vertigo, tinnitus, heart ailments anxiety, stitch anc beating palpitation. [16], [17], [18]

International research and media reports document people exposed over time, to too-close wind turbines, are experiencing adverse health eff "These symptoms include sleep disturbance, headaches, difficulty concentrating, irritability and fatigue, but also include a number of otologic symptoms including dizziness or vertigo, tinnitus and the sensation of aural pain or pressure." [19]

The American Wind Energy Association and Canadian Wind Energy Association sponsored literature review entitled "Wind Turbine Sound anc Health Effects" acknowledges wind turbine noise may cause annoyance, stress and sleep disturbance and as a result people may experience adverse physiological and psychological symptoms. The literature review specifically acknowledges that wind turbines may cause low frequen noise induced annoyance. [20]

More specifically Geoff Leventhall, a coauthor of the wind energy association sponsored "Wind Turbine Sound and Health Effects" states

> "The symptoms of... Wind Turbine Syndrome...sleep disturbance, headache, tinnitus, ear pressure, dizziness, vertigo, nausea, visual blurring, tachycardia, irritability, problems with concentration and memory, and panic attack episodes associated with sensations of inte pulsation or quivering when awake or asleep...I am happy to accept these symptoms, as they have been known to me for many years ε the symptoms of extreme psychological stress from environmental noise, particularly low frequency noise." [21]

World Health Organization advises that "Health effects due to low-frequency components in noise are estimated to be more severe than for community noises in general...The evidence on low-frequency noise is sufficiently strong to warrant immediate concern." and consequently "N with low-frequency components require lower guideline values." [22]

The effects of low frequency noise induced annoyance and stress may be serious and it is acknowledged that "The claim that their "lives have been ruined" by the noise is not an exaggeration..." [23]

It is acknowledged that "...LFN *(low frequency noise)* does not need to be considered "loud" for it to cause such forms of annoyance and irritation." [24]

"The effects of infrasound or low frequency noise are of particular concern because of its pervasiveness due to numerous sources, efficient propagation, and reduced efficiency of many structures (dwellings, walls, and hearing protection) in attenuating low frequency noise comparec other noise." [25]

"Unlike higher frequency noise issues, LFN is very difficult to suppress. Closing doors and windows in an attempt to diminish the effects sometimes makes it worse because of the propagation characteristics and the low-pass filtering effect of structures. Individuals often become irrational and anxious as attempts to control LFN fail, serving only to increase the individual's awareness of the noise, accelerating the above symptoms" [26]

"Those exposed may adopt protective strategies, such as sleeping in their garage if the noise is less disturbing there. Or they may sleep elsewhere, returning to their own homes only during the day." [27]

Members of the Society for Wind Vigilance are in contact with victims who have resorted to sleeping in a tent [28], been billeted by the wind energy proponent, [29], [30] or have abandoned their homes [31] [32] to escape the wind turbine noise that has invaded their home. This cann be denied.

Wind turbine produce infrasound which may be inaudible or audible.

A spectral analysis of sounds emitted at a Michigan site revealed that unweighted peak levels at frequencies under 5 Hz exceeded 90 dB SPL (Wade Bray, pers. comm., 2009). [33]

"There is no doubt that some humans exposed to infrasound experience abnormal ear, CNS, and resonance induced symptoms that are real a stressful." [34]

There is no scientific consensus that infrasonic noise below the threshold of hearing will have no effect on health. There is scientific uncertaint regarding the understanding of human response to infrasound.

"There is no consensus whether sensitivity below 20 Hz is by a similar or different mechanism than sensitivity and hearing above 20 Hz..." [35

In a 2009 Environmental Review Report [36] for an Ontario, Canada wind turbine project the consultant acknowledged that regarding wind turl low frequency noise (LFN) and adverse health effects:

"It is acknowledged that LFN may be one area of scientific uncertainty in the wind industry as a whole."

and regarding wind turbine infrasound:

"...it is recognized that this may be an area of scientific uncertainty."

The National Research Council states "Low-frequency vibration and its effects on humans are not well understood. Sensitivity to such vibratio resulting from wind-turbine noise is highly variable among humans.... studies on human sensitivity to very low frequencies are recommended." [37]

The conclusions of a 2010 peer reviewed scientific article states

> "1) Hearing perception, mediated by the inner hair cells of the cochlea, is remarkably insensitive to infrasound.
>
> 2) Other sensory cells or structures in the inner ear, such as the outer hair cells, are more sensitive to infrasound than the inner hair cel and can be stimulated by low frequency sounds at levels below those that are heard. The concept that an infrasonic sound that cannot heard can have no influence on inner ear physiology is incorrect.
>
> 3) Under some clinical conditions, such as Meniere's disease, superior canal dehiscence, or even asymptomatic cases of endolymphati hydrops, individuals may be hypersensitive to infrasound.
>
> 4) A-weighting wind turbine sounds underestimates the likely influence of the sound on the ear. A greater effort should be made to document the infrasound component of wind turbine sounds under different conditions.
>
> 5) Based on our understanding of how low frequency sound is processed in the ear, and on reports indicating that wind turbine noise causes greater annoyance than other sounds of similar level and affects the quality of life in sensitive individuals, there is an urgent nee more research directly addressing the physiologic consequences of long-term, low level infrasound exposures on humans." [38]

It is incorrect to assume that inaudible low frequency noise cannot cause adverse health effects as "...non-aural physiological and psychologic effects may be caused by levels of low frequency noise below the individual hearing threshold." [39]

"Low-frequency noise may also produce vibrations and rattles as secondary effects." [40]

"Although infrasound levels from large turbines at frequencies below 20 Hz are too low to be audible, they may cause structural elements of buildings to vibrate." [41]

"Jung and colleagues (2008), in a Korean study, concluded that low-frequency noise in the frequency range above 30 Hz can lead to psycholo complaints and that infrasound in the frequency range of 5–8 Hz can cause complaints due to rattling doors and windows in homes." [42]

Field studies and "...research has shown that the acoustic energy from wind turbines is capable of resonating houses, effectively turning them three-dimensional loud speakers in which the affected residents are now expected to live. The phenomenon of natural resonance combines to produce a cocktail of annoying sounds which not only disturb the peace and tranquility once-enjoyed by the residents, but also stimulate a nun of disturbing physiological effects which manifest in the physical symptoms..." [43]

A NASA technical paper on wind turbine noise states

"People who are exposed to wind turbine noise inside buildings experience a much different acoustic environment than do those outside....Th may actually be more disturbed by the noise inside their homes than they would be outside....One of the common ways that a person might se the noise-induced excitation of a house is though structural vibrations. This mode of observation is particularly significant at low frequencies, b the threshold of normal hearing." [44]

Living conditions are acknowledged to be a key determinate of health. [45]

A World Health Organization epidemiology study confirms disturbed living conditions caused by noise increases the risk of ill health. [46]

Peer reviewed scientific research confirms "Pollution and degradation of the indoor environment cause illness, increased mortality, loss of productivity, and have major economic and social implications....The health effects of indoor noise include an increase in the rates of diseases disturbances... these illnesses, and the related reduction in human productivity, can result in substantial economic losses." [47]

Wind turbine low frequency noise and infrasound is unique.

Modern upwind industrial wind turbines produce a characteristic audible modulation of aerodynamic noise. [48] This is commonly referred to a amplitude modulation and is acknowledged to contribute to higher levels of wind turbine induced annoyance and/or sleep disturbance in the exposed population. [49], [50], [51]

Wind turbine low frequency noise and infrasound is also modulated.

"Low frequency sound and infrasound are normal characteristics of a wind farm as they are the normal characteristics of wind, as such. The difference is that "normal" wind is laminar or smooth in effect whereas wind farm sound is non-laminar and presents a pulsing nature." [52]

"A limitation of much work on assessment of low frequency noise has been that long term averaged measurements were used and, consequei

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information on fluctuations was lost. Many complaints of low frequency noise refer to its throbbing or pulsing nature." [53]

Research related to low frequency noise "...confirms the importance of fluctuations as a contributor to annoyance and the limitation of those assessment methods, which do not include fluctuations in the assessment." [54]

Adverse health effects associated with low frequency noise and infrasound can be avoided with authoritative regulations that ensure protectio engineered into the design of wind turbine projects.

Low Frequency Noise is an issue that must be resolved quickly and accurately to improve the sound environment and quality of life for the residents. For this reason, it remains the duty of authorities to implement regulations that will account for low frequency noise.[55]

It is widely affirmed that A-weighting underestimates the sound pressure level of noise with low-frequency components. [56], [57], [58], [59], [6 "A-weighted level is very inadequate..." [61] when assessing low frequency noise and infrasound.

C-weighting and Z-weighting are more appropriate to assess noise with low frequency components.

Globally the adoption of low frequency noise and infrasound regulations is hampered by wind energy industry resistance. For example in Cana the Ontario Ministry of the Environment determined that wind turbine developers be required "...to monitor and address any perceptible infrasc (vibration) or low frequency noise. [62] However the Canadian Wind Energy Association (CanWEA) lobbies against having to address the imp of wind turbine low frequency noise and infrasound "...CanWEA submits that the proposed requirement for infrasound or low frequency noise monitoring as a condition of the REA be removed." [63]

**Conclusions**

Based on the best available science the following conclusions can be drawn.

- Wind turbine noise is likely to be audible to receptors in the form of continuous low-level or intermittent swooshing, as well as low frequencies at approximately 50 Hertz.
- Exposure to audible low frequency noise can cause adverse health effects in humans.
- Humans must be protected from the adverse health effects of low frequency noise exposure.
- Wind turbine low frequency noise may induce annoyance, stress and sleep disturbance which may have other health consequences.
- International research and media reports document people exposed to wind turbines reporting adverse health effects. Reported symptc include annoyance, stress, sleep disturbance, headaches, difficulty concentrating, irritability, fatigue, dizziness or vertigo, tinnitus and th sensation of aural pain or pressure.
- Wind turbines emit infrasound which may be audible or inaudible. There is scientific uncertainty regarding infrasound; however, it is plausible wind turbine infrasound could adversely affect human health.
- It is acknowledged infrasound can induce annoyance, stress and sleep disturbance by disturbing people inside their homes through structural vibrations.
- Based on current understanding of how low frequency sound is processed in the ear, and on reports indicating that wind turbine noise causes greater annoyance than other sounds of similar level and affects the quality of life in sensitive individuals, there is an urgent nee more research directly addressing the physiologic consequences of long-term, low level infrasound exposures on humans.
- Adverse health effects associated with low frequency noise and infrasound can be avoided with authoritative regulations that ensure protection is engineered into the design of wind turbine projects.
- Members of the wind energy industry oppose addressing wind turbine low frequency noise and infrasound. For example the Canadian \ Energy Association has lobbied against the introduction of protective guidance designed to address wind turbine low frequency noise a infrasound.

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- Annoyance and Wind Turbines
- Stress and Wind Turbines
- Sleep Disturbance and Wind Turbines
- Physiological Health and Wind Turbines
- Mental Health and Wind Turbines
- Noise and Wind Turbines
- Low Frequency Noise, Infrasound and Wind Turbines
- Visual Health Effects and Wind Turbines
- Wind Turbine Noise Sleep and Health by Dr Hanning
- Proposed Case Definition:Adverse Health Effects And Industrial Wind Turbines
- A Primer on Adverse Health Effects

## Promoting Research for Authoritative Wind Turbine Guidelines

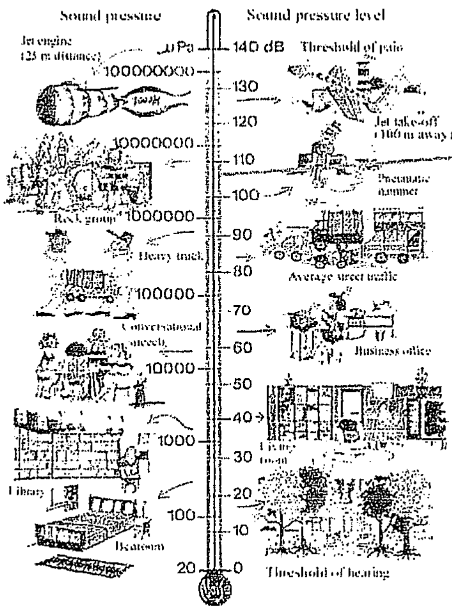
### Noise and Wind Turbines

*"Just like air pollution and toxic chemicals, noise is an environmental hazard to health."*
*- World Health Organization [1]*

The Canadian Wind Energy Association claims that modern wind turbines are not noisy.[2] They also assure the public that "it's possible to carry on a normal conversation at the base" of a wind turbine and at 300 meters the sound is like a "whispering voice."[3]

In light of this information one may ask why are people reporting suffering from adverse health effects and why have families abandoned their homes?

The answer is wind turbines are noisy. A single modern wind turbine emits approximately 105 dBA of industrial noise pollution.[4] To put 105 dBA in perspective, this is between the sound power level of a pneumatic hammer drill and a rock band.[5] Additional wind turbines in the neighbourhood combine to increase the noise level.




Single wind turbine at source
Approximately 105 dBA

Sound Pressure Level (SPL) Examples (Bruel and Kjaer Instruments)

Wind turbine noise propagation is complex. A person standing under a wind turbine may experience much less noise than someone else living in a home hundreds of meters away from the base of the wind turbine.

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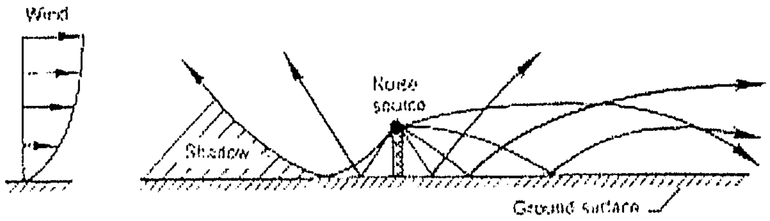


Figure 7-20. Effects of wind-induced refraction on acoustic rays radiating from an elevated point source [Shepherd and Hubbard 1985]

[6]

In their best practices The Canadian Wind Energy Association acknowledges that noise complaints are not uncommon when wind turbines are placed close to homes.[7]

Wind turbine noise is not only loud it is also complex.[8],[9],[10]

> "Sound generated by wind turbines has particular characteristics and it creates a different type of nuisance compared to usual urban, industrial, or commercial noise. The interaction of the blades with air turbulences around the towers creates low frequency and infrasound components, which modulate the broadband noise and create fluctuations of sound level. The lower frequency fluctuation of the noise is described as 'swishing' or 'whooshing' sound, creating an additional disturbance due to the periodic and rhythmic characteristic."[11]

Members of the health care community recognize that of these noise characteristics may have a particularly pronounced effect on people exposed to them.[12],[13]

The American and Canadian Wind Energy Associations appear to disagree and are of the opinion that wind turbine noise is not unique.[14]

In September 2009 the Maine Medical Association passed a resolution that calls for research and development of wind turbine noise guidelines to protect human health.[15]

Many who have studied the issue of wind turbine noise advocate for wind turbine specific noise regulations designed to protect the public from the potential adverse effects. [16],[17],[18] Health based wind turbine noise limits would likely prescribe lower noise limits than those of other sources of noise.

In some jurisdictions such as Ontario the exact opposite has occurred where the wind energy industry has been granted the ability to subject family homes to higher levels of noise pollution than other industries.[19] Higher noise levels benefit the economic interests of the wind industry as noise levels affect the spacing of wind turbines and ultimately the cost of electricity produced.[20]

Currently there is no authoritative international guideline for wind turbine noise designed to protect human health. Wind turbine noise regulations vary by jurisdiction.

A family home in Ontario, Canada could be subjected to 53 dBA while families in British Columbia, Canada or South Australia would be limited to 40dBA and 35 dBA respectively.[21]

These differences are significant as a 10 dBA increase is subjectively heard as an approximate doubling in loudness.[22]

The American and Canadian Wind Energy Associations do not appear to support the development of authoritative wind turbine noise guidelines designed to protect human health. On the contrary they are of the opinion that the authoritative noise guidelines of the World Health Organization need not be adhered to.[23]

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**Promoting Research for Authoritative Wind Turbine Guidelines**

Mental Health and Wind Turbines

*"WHO is making a simple statement: mental health- neglected for far too long - is crucial to the overall well-being of individuals, societies and countries and must be universally regarded in a new light." - World Health Organization* **[1]**

Clinicians and other researchers have documented both physiological and psychological symptoms reported by victims experiencing adverse health effects from wind turbines. [2],[3],[4],[5] Many families have abandoned their homes to protect their health. This cannot be denied.

The reported psychological symptoms include decreased quality of life, stress, anxiety, depression, cognitive dysfunction, anger, grief, and a sense of injustice.

World Health Organization acknowledges individuals suffering adverse psychological symptoms are often victimized from a lack of understanding.[6] Often the stigma, discrimination and human rights violations that affected individuals and families endure are intense and pervasive.[7]

An American and Canadian Wind Energy Association sponsored report (A/CanWEA Panel Review) does not appear to dispute that there are victims experiencing adverse physiological symptoms. Without having studied these victims the A/CanWEA Panel Review speculates that the reported symptoms may be the result of psychological responses to wind turbines.[8]

A presentation attributed to one of the authors of the A/CanWEA Panel Review reinforces this position by stating the reported physiological

> "Symptoms (***are the***) same as those of noise annoyance. Psychological, not physiological"[9]

This simplistic view is not shared by World Health Organization who acknowledges

> "...health includes mental, physical and social functioning, which are closely associated and interdependent."[10]
>
> "In an integrated and evidence-based model of health, mental health (including emotions and thought patterns) emerges as a key determinant of overall health. Anxious and depressed moods, for example, initiate a cascade of adverse changes in endocrine and immune functioning, and create increased susceptibility to a range of physical illnesses."[11]
>
> "Today we know that most illnesses, mental and physical, are influenced by a combination of biological, psychological and social factors."[12]

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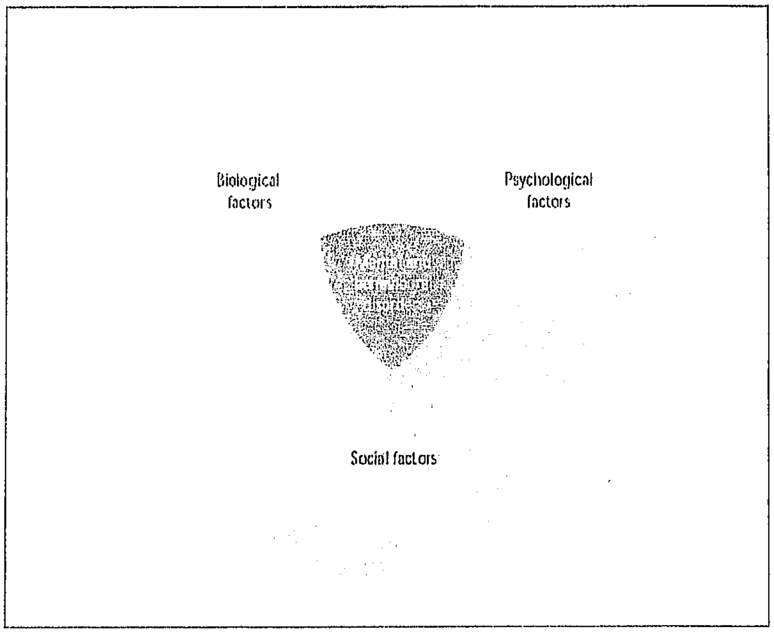
Figure 1.1 Interaction of biological, psychological and social factors in the development of mental disorders




[13]

When people are suffering avoidable adverse health effects the distinction between physiological and psychological is of little consequence. Both are of equal importance.

Health Canada further explains that

> "Mental health is as important as physical health. In fact, the two are intertwined. Our mental health directly affects our physical health and vice versa...mental health factors can increase the risk of developing physical problems such as, diabetes, heart disease, weight gain or loss, gastrointestinal problems, reductions in immune system, efficiency, and blood biochemical imbalances."[14]

The adverse psychological effects being reported by victims do not indicate a sign of weakness and victims should not feel ashamed.

> "All too often, people mistake these disorders for mental weakness or instability. The social stigma attached to mental illness often prevents those with anxiety disorders from asking for help."[15]

Many jurisdictions including Canada have provisions to protect the individual from inflicted psychological harm.[16]

World Health Organization considers prevention and treatment of psychological ill-health a human rights issue.[17],[18],[19]

It appears that The Society for Wind Vigilance and The Canadian and American Wind Energy Associations acknowledge that there are victims experiencing both physiological and psychological symptoms as a result of wind turbines.

In spite of this acknowledgement the A/CanWEA Panel Review does not offer evidence based strategies to protect individuals from these adverse health effects. The report concludes by stating that the authors do not "advocate for funding further studies".[20]

World Health Organization asserts it is possible to prevent the risk of psychological ill-health by employing prevention policies based on systematic assessments of public mental health needs.[21] Suggested prevention strategies include the removal of stressors such as through the "reduction of noise".[22]

The Society for Wind Vigilance's mission is to mitigate the risk of both physiological

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and psychological adverse heath effects through the advancement of independent third party research and its application to the siting of industrial wind turbines.

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[22] Ibid.



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## The Society for Wind Vigilance





## Promoting Research for Authoritative Wind Turbine Guidelines

Stress and Wind Turbines

*"Even seemingly clean sources of energy can have implications on human health. Wind energy will undoubtedly create noise, which increases stress, which in turn increases the risk of cardiovascular disease and cancer."* [1]

In a Canadian Wind Energy Association and American Wind Energy Association sponsored report it is acknowledged that wind turbine noise may cause annoyance, stress and sleep disturbance.[2]

One of the authors of the report W. David Colby, M.D. reinforced this position regarding wind turbines by stating

> "We're not denying that there are people annoyed and that maybe some of them are getting stressed out enough about being annoyed that they're getting sick."[3]

The Chief Medical Officer of Health of Ontario and Agency for Health Protection and Promotion concur in that they acknowledge wind turbines may cause annoyance, stress and sleep disturbance. [4],[5]

Make no mistake stress is a serious risk to human health.

Health Canada states that

> "...stress is considered to be a risk factor in a great many diseases, including: heart disease, some types of bowel disease, herpes, mental illness.
>
> Stress also makes it hard for people with diabetes to control their blood sugar.
>
> Stress is also a risk factor in alcohol and substance abuse, as well as weight loss and gain. Stress has

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> even been identified as a possible risk factor in Alzheimer's Disease.
>
> Severe stress can cause biochemical changes in the body, affecting the immune system, leaving your body vulnerable to disease."[6]

Other health effects associated with stress include becoming increasingly distressed, and irritable, unable to relax or concentrate, have difficulty thinking logically, and making decisions, depression, anxiety, sleep disorders, disorders of the digestive system, increases in blood pressure, headaches and musculo-skeletal disorders.[7],[8]

Prevention includes the ability to resolve one's stress problem. Unfortunately in the case of stress from wind turbine noise and visual impacts (shadow flicker) there is little one can do. The person suffering usually has no control over the level of or the timing of these intrusions.

---

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[2] W. David Colby, M.D. et al.,Wind Turbine Sound and Health Effects, An Expert Panel Review 2009, Prepared for American Wind Energy Association and Canadian Wind Energy Association
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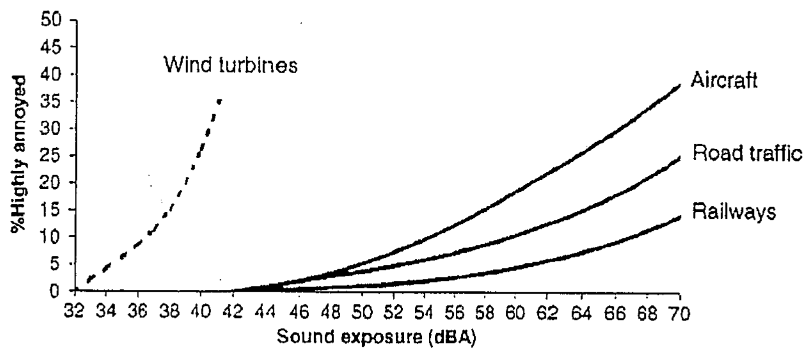
## Promoting Research for Authoritative Wind Turbine Guidelines

### Annoyance and Wind Turbines

> *"Annoyance with wind turbine noise was associated with psychological distress, stress, difficulties to fall asleep and sleep interruption."* [i]

Peer reviewed scientific articles based on studies of European wind turbine facilities have concluded that wind turbine noise is more annoying than equally loud noise sources such as airport and traffic noise. [ii], [iii], [iv], [v] Annoyance is predominately attributed to the unique sound characteristics of wind turbine noise.




Sound exposure is for wind turbines calculated A-weighted $L_{eq}$ for a hypothetical time period and for transportation DNL.

***(Source: Pedersen, E. and K. Persson Waye. 2004. Perception and annoyance due to wind turbine noise: A dose–response relationship, Journal of the Acoustical Society of America 116: 3460–3470.)***

"The sound level associated with wind turbines at common residential setbacks ... may lead to annoyance and sleep disturbance." [vi] and evidence demonstrates "Annoyance and sleep disruption are common when sound levels are 30 to 45 dBA." [vii]

The American Wind Energy Association and Canadian Wind Energy Association sponsored literature review entitled "Wind Turbine Sound and Health Effects" acknowledges wind turbine noise, including low frequency noise, may cause annoyance, stress and sleep disturbance and as a result people may experience adverse physiological and psychological symptoms. [viii]

This wind industry sponsored literature review acknowledges the reported symptoms can be caused by wind turbine noise and states these "...symptoms are not new and have been published previously in the context of "annoyance" to environmental sounds .... The following symptoms are based on the experience of noise sufferers extending over a number of years: distraction, dizziness, eye strain, fatigue, feeling vibration, headache, insomnia, muscle spasm, nausea, nose bleeds, palpitations, pressure in the ears or head, skin burns, stress, and tension...." [ix]

The symptoms listed in the wind industry literature review are consistent with international research and media reports documenting subjects exposed to wind turbines who are reporting adverse health effects. [x], [xi], [xii], [xiii], [xiv]

The health impact of annoyance must not be underestimated.

A coauthor of the wind industry sponsored "Wind Turbine Sound and Health Effects", W. David Colby, M.D., reinforced this position regarding wind turbine induced annoyance by stating

"We're not denying that there are people annoyed and that maybe some of them are getting stressed out enough about being annoyed that they're getting sick." [xv]

Geoff Leventhall, another coauthor of the wind industry sponsored "Wind Turbine Sound and Health Effects", reportedly elaborated:

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"... there was no doubt people living near the turbines suffered a range of symptoms, including abnormal heart beats, sleep disturbance, headaches, tinnitus, nausea, visual blurring, panic attacks and general irritability....it's ruining their lives – and it's genuine..." [xvi]

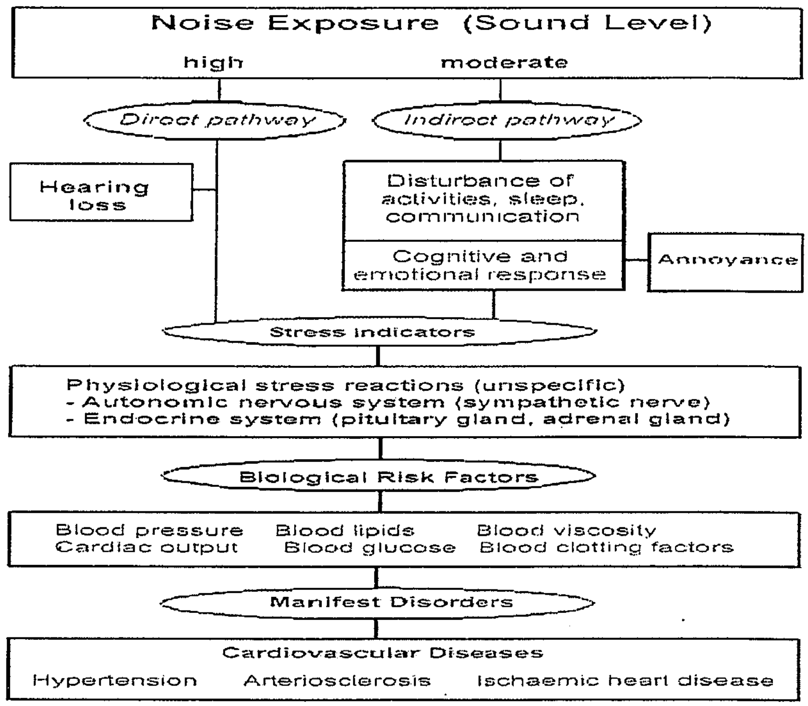
The word annoyance may mean different things to different people however in clinical terms annoyance is acknowledged to be a risk to human health.

The World Health Organization acknowledges noise induced annoyance to be an adverse health effect. [xvii], [xviii]

Regarding noise induced annoyance the US Environmental Protection Agency states "..."annoyance" can have major consequences, primarily to one's overall health." [xix]

A World Health Organization study "...confirmed, on an epidemiological level, an increased health risk from chronic noise annoyance." [xx]

Noise induced annoyance contributes to stress, [xxi] sleep disturbance [xxii] and an increased risk of regulation diseases. [xxiii]




***(Noise effects reaction scheme Source: Babisch, 2002. from World Health Organization, Night Noise Guidelines for Europe, 2009)***

Annoyance may adversely affect physiological health. Research indicates that for "chronically strong annoyance a causal chain exists between the three steps health – strong annoyance – increased morbidity." [xxiv]

The subjective experience of noise stress can, through central nervous processes, lead to an inadequate neuro-endocrine reaction and finally to regulation diseases. [xxv]

"Adults who indicated chronically severe annoyance by neighbourhood noise were found to have an increased health risk for the cardiovascular system and the movement apparatus, as well as an increased risk of depression and migraine...With children the effects of noise-induced annoyance from traffic, as well as neighbourhood noise, are evident in the respiratory system." [xxvi] Peer reviewed studies have consistently concluded that wind turbine noise is more annoying than equally loud traffic. [xxvii], [xxviii], [xxix], [xxx]

To protect against adverse health effects noise level limits "...should be based on annoyance responses to noise." [xxxi]

"Dose-response relations for different types of traffic noise (air, road and railway) clearly demonstrate that these noises can cause different annoyance effects at equal LAeq,24h values." [xxxii] Currently there is no health based generalized dose-response relationship developed to avoid possible adverse health effects from wind turbine noise exposure. [xxxiii]

"The need for guidelines for maximum exposure to wind turbine noise is urgent:" [xxxiv]

Wind turbine visual effects such as shadow flicker may also cause visually induced adverse health effects such as annoyance and/or stress. [xxxv], [xxxvi], [xxxvii], [xxxviii], [xxxix], [xl], [xli], [xlii]

**Conclusions**

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Based on the best available science the following conclusions can be drawn.

- The main conclusion of peer reviewed scientific studies state noise from wind turbines is more annoying than noise from most other sources at comparable sound levels. This annoyance is predominately attributed to the unique sound characteristics of wind turbine noise.

- Noise induced annoyance is an adverse health effect which can result in stress, sleep disturbance and an increased risk of regulation diseases.

- Possible symptoms of wind turbine noise induced annoyance include distraction, dizziness, eye strain, fatigue, feeling vibration, headache, insomnia, muscle spasm, nausea, nose bleeds, palpitations, pressure in the ears or head, skin burns, stress, and tension. These symptoms are consistent with international research and media reports documenting subjects exposed to wind turbines who are reporting adverse health effects.

- The audible sound from wind turbines, at the levels experienced at typical receptor distances is expected to result in an unacceptable percentage of persons being highly annoyed.

- Exposure to wind turbines may also visually induce adverse health effects. It is acknowledged wind turbine shadow flicker may cause annoyance and/or stress.

- Wind turbines must be sited to protect humans from the adverse health effect of visually induced annoyance as well as noise induced annoyance.

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# News

## Recent report ties wind turbine noise to potential health problems

*"There can be no doubt that groups of industrial wind turbines ("wind farms") generate sufficient noise to disturb the sleep and impair the health of those living nearby," states Dr. Christopher Hanning in a recent report titled "Sleep Disturbance and Wind Turbine Noise." Founder of the Leicester Sleep Disorders Service, which is the longest standing and largest service of its kind in Great Britain, Dr. Christopher Hanning's work in the area of sleep disorders has spanned thirty years.*

*July 22, 2009 by Lynda Barry in Betterplan.com*

"There can be no doubt that groups of industrial wind turbines ("wind farms") generate sufficient noise to disturb the sleep and impair the health of those living nearby," states Dr. Christopher Hanning in a recent report titled "Sleep Disturbance and Wind Turbine Noise."

Founder of the Leicester Sleep Disorders Service, which is the longest standing and largest service of its kind in Great Britain, Dr. Christopher Hanning's work in the area of sleep disorders has spanned thirty years. He currently chairs the advisory panel of the SOMNIA study, a major project investigating sleep quality in the elderly.

Dr. Hanning... *[continue via Web link]*

**Web link:** http://betterplan.squarespace.com/todays-special/2...

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# Wind Turbine Syndrome: Living Near Wind Farms May Be Hazardous to Your Health

By Katie Fehrenbacher Aug. 3, 2009, 8:32am PT 19 Comments



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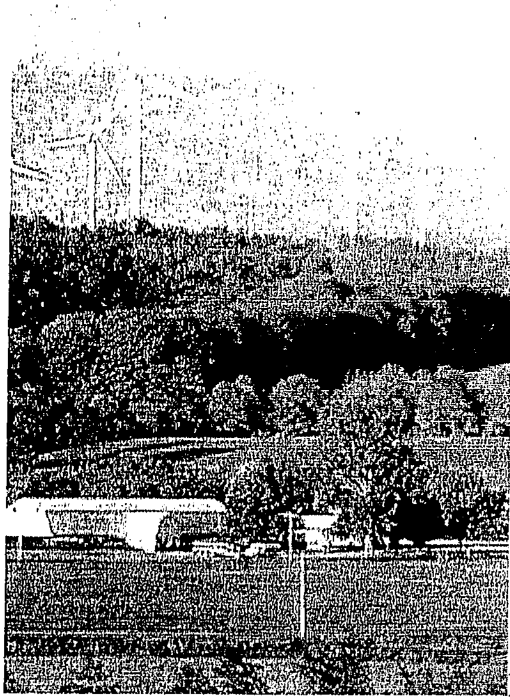Here's some more fodder for the Not in My Backyard (NIMBY) crowd: A doctor says she's conducted research that suggests that people living close to wind turbines are susceptible to what she calls Wind Turbine Syndrome (WTS), an illness with symptoms including sleep disorders, heart disease, panic attacks and headaches, the Independent reports this weekend. So literally, a wind turbine in your backyard could be hazardous to your health.

Nina Pierpont, a pediatrician based in New York, studied 10 families who lived close to wind farms, and says eight out of the 10 ended up moving away from their homes because of WTS-related illnesses. That's a small survey sample, but it's a continuation of research done by other scientists in the field. Pierpont recommends that wind turbines should be built at least 2 kilometers (a little over a mile) away from people's homes, and she tells the Independent that: "It is irresponsible of the wind turbine companies — and governments — to continue building wind turbines so close to where people live until there has been a proper epidemiological investigation of the full impact on human health."

The problem, according to Pierpont, is that the wind farms emit a constant low-frequency vibration and noise, which human beings are sensitive to (not unlike fish's sensitivity to noise in the water) and the wind farm vibrations can disrupt the inner ear's vestibular system (responsible for balance and spatial orientation). Over a sustained period of time, people living too close to the wind farms can develop a disorder related to the inner ear disruption, WTS, which can cause nervousness, heart disorders, nightmares, problems and even cognitive development issues in small children.

Other researchers, from Salford University and UK government agencies, have previously said that noise and vibrations from wind turbines do not cause health problems, says the Independent, so it will be interesting to see how the scientific community responds to Pierpont's latest research. While Pierpont's research sounds plausible, her reactionary comparisons, do her a disservice:

> The wind industry will try to discredit me and disparage me, but I can cope with that. This is not unlike the tobacco industry dismissing health issues from smoking.

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The tobacco industry covering up cancer from smoking, one of the biggest causes of preventable death in the world, is a slightly larger problem (yes, that's sarcastic) than an industry just learning about the possibility of panic attacks caused by wind turbines. But if the research is reproduced and backed up by further studies, it could actually have a big effect on the siting and zoning of wind farms — a 2-kilometer buffer between wind farms and buildings is substantial. It's not like we needed more reasons to slow down the installation of clean power, but if there's merit to the findings, they should be taken seriously.

*Image courtesy of NREL.*

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1. Reply
   *Tyler* Monday, August 3 2009

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A sample of 10 families… hmmm… not very compelling. Also question claims of it being "peer-reviewed." This is published by a group in which Pierpoint is a editorial board member, and it wasn't pear-reviewed in the conventional sense by a panel of experts unknown to the author.

2.  Reply
*Wai Yip Tung* Wednesday, August 5 2009

From what you've reported it sounds like a worthless 'study' to me. Anyone can come up with a 'study' to prove anything they don't like by zeroing in on 10 families who share the same view.

By the way it start to occurs to me that the noise problem of wind turbine is largely a myth. I have gotten close to several small wind turbines and I can hardly hear a thing. In fact, the wind itself is far more noisy. Even heard of the term 'howling' wind? Anyone have experience with large wind farm? Does it really produce any noise over the background noise of wind?

3. Reply
*clayton krenek* Sunday, August 9 2009

Ive worked on wind turbines four the past four years now and ive never experienced any of these symptoms. I dont know of anyone who works on them that has. So how is it that the people who are right next to them and even in them while there running all the time do not feel any of these symptoms?

4. Reply
*waltinseattle* Monday, August 10 2009

Can we say "psychosomatic", children? to paraphrase the well known t.v. personality.

Indeed, we allow folks to live next door to power stations, transformers, cell towers, radio towers, train tracks. Not to mention trains carrying liquid ammonia, propane, natural gass…..

Re above comment "what noise?" I have to agree after visiting the installation run by my power provider. Whisper…oh, and no big pile of dead birds either. I guess all those centuries of living with trees has taught them to be carefull while flying.

I bet the last "research" those scientists "did" was aboyut the horrors of cell phones. Which I'm more inclined to have an ear for, but not the one commonly screamed at me by the likes.

5. Reply
*Greenhome* Monday, August 10 2009

00001427

Before anyone passes judgement maybe they should live within a 1,000 ft. of the large industrial sized wind turbine. Although the study is of less than 100 people Dr. Nina Pierpont would not lack for people that have the same wind turbine syndrome symptoms here in Wisconsin. The noise, flicker and vibrations are causing problems with their health that goes away only when they leave their homes. I admire Dr. Pierpont for financing this at her own expense to help others. Her book is peer-reviewed.

6. Reply
   *Janet* Monday, October 5 2009

   I am looking for information on any legal action that may have been taken on the issue of health damage by wind turbines – especially in the UK. Can anyone help pleaase? Note: I personally have no issue with wind turbines.

7. Reply
   *Mark* Friday, October 9 2009

   It's amazing how succeptible the human mind is to the power of suggestion. I would be inclined to believe that there are many people who live very close to wind towers that suddenly realize that they have WTS only after they listen to the fearmongers. A further, more unbiased, study might show that the symptoms these people are experiencing are no different that those caused by the stresses of everyday life, the current economy, unemployment, looking for a new job,and myriad other things that can cause nausea, dizziness, and migraines. I don't live anywhere near a wind tower, but I get stress-related migraines that cause nausea and dizziness. Nuf sed

8. Reply
   *Flloyd* Thursday, November 5 2009

   In fifty years will people be saying the same things about wind turbines as we are saying about dams today?

   destroying landscapes, relocating people, and threatening species?

   perhaps we should stop looking for new ways to create energy and start using our current methods of energy production more responsibly.

9. Reply
   *Energy Guy* Friday, November 6 2009

   I totally agree with Floyd. We need to focus on reducing our demand for energy instead of just lock step building more and more supply. Then we can build the right size devices that we need.

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In terms of this study. There's no question that there are appropriate places to place turbines and inappropriate ones. Being two miles from these devices isn't unreasonable. Saying that they should be sited in a environmentally friendly manner that doesn't risk hurting either habitats or people isn't NIMBY it's SMART.

10. Reply
*fay stein* Sunday, March 14 2010

I have been sick from day one when they started these wind towers. The blades gave off a chemical and that caused my face, eyes, and throat to swell. I couldn't sleep, still can't. I got a rash, had chest, joint, and heart pains, get headaches, throbbing in my ears, they bled, had blood come out of my mouth and nose, get migraines...never had these problems, have stress, memory loss, and suffer from depression, aniexty, and other sleep deprieved ills. I get nausea, dizzy spells, and had vertigo for two months, with severe feeling of great loss in memory... funny that it would go away once I leave our home. We are surrouned by these huge towers that are 1500-2000 feet away. It is a real problem and we are not rich, so where do we go at our ages and since we loved our home of 27 years, what can we do? Laugh about it and us and call wind power a great thing, but if you had these shoved up your butt, so to speak, you would be singing a different song than, these people are crazy or the findings are wrong...I am a university graduate and a vegan, environmentalist that has seen the dead birds, bats, plant and insect life destroyed, the habitats and migratory routes destroyed and yet, it goes on with the movement of wind energy....let me tell you that wind cost more than it produces and they are breaking the taxpayers backs and making foreigners and billionaires richer...

- Reply
  *Kathy Lowe* Saturday, June 12 2010

  This is comical, not that you are sick, but, that you blame it on wind towers. It sounds more like were a victim in a low budget horror flick If it causes all the problems you have, how would they ever get erected. The construction crew would never make it up the ladder, to get the turbine hooked up. It sounds to me like you have a severe emotional disorder along with heart and respiratory problems. I would maybe even agree with the fact you may be a turbiphobic (extreme fear of wind turbines.)
  I would also suggest you quit allowing large objects to be shoved up your butt, and perhaps eat more meat. Your claims are insane.

11. Reply
*Landlover* Friday, March 26 2010

I live next to three turbines (1,400 feet) and I don't hear a thing nor do I get sick.

12. Reply

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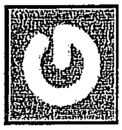
*Damian* Thursday, April 29 2010

"The wind industry will try to discredit me and disparage me, but I can cope with that. This is not unlike the tobacco industry dismissing health issues from smoking."

Whoever the person is that said this is a complete an utter moron and should not be given the opportunity to have his words published about anything, anywhere. That's the most ridiculous statement I've ever seen in print and you should have called him out on it to his response. In which I'm sure he would have further discredited his "expert opinions".

13.  Reply
*mtumba djibouti* Thursday, May 6 2010

A number of comments make light of the possibility (shall I say probability?) that industrial scale wind projects have an impact on human health. Those with open minds might want to check out the site windaction dot org, which simply collects and posts constantly updated articles from newspapers, books, public hearings, etc, worldwide – primarily from Europe, Canada, the UK and the USA, which repeatedly indicate that people around the world are experiencing very significant health and quality of life issues when living within one-two miles of industrial wind projects. The more you read, the more you will find it difficult to deny the possibility that these turbines are not benign – and that siting of land based projects is an important consideration for human as well as animal and bird health.

This doesn't mean we can't build industrial scale wind projects — but it does mean that legitimate setbacks must be developed. In fact, land based wind projects are problematic for many reasons – not the least of which is that most produce only between 8-20% of their "rated capacity" – and so, sadly, conventional power plants must remain on to make up for their tiny, unpredictable power contribution. Germany and Denmark – two huge users of wind power – recently reported that all of their wind projects have NOT reduced national carbon emissions – because coal plants have had to remain constantly on in order to fill in the large gaps of unpredictable wind power.

China is building more wind capacity that any other nation – and it is building brand new COAL power plants to provide backup for the wind power. In China, wind power is actually leading to an increase in carbon emissions.

For a technology that claims to be green and is most often located in pristine rural and wilderness areas, that disturbs animal habitat, kills birds and bats by the thousands – for a miniscule power return on a huge environmental scale disruption – land based wind power is problematic at best.

Anyway, please check it out for yourselves. The more people find themselves living near industrial scale land based wind projects, the more reports are of people having health problems to the point of having to abandon their homes.

In many instances, turbine projects have bought out land owners who complain of health effects, with the legal requirement of binding gag orders not to discuss the circumstances following settlement.

00001430

Why the need for gag orders if the technology is benign?

14. Reply
*Ger* Tuesday, February 22 2011

Its complete nonsense. Any company that is prepared to invest up to €1,000,000/$1,500,000 (yes people take notice of all the zero's!!) per turbine is definitely going to make sure that there is negative vibrations. does anyone know what happens with resonance? The whole project comes crashing to the ground. And, regardless of the frequency, vibrations lead to degredation of the moving parts, which leads to premature wear of the moving parts and hence premature breakdowns. I really do not think anyone with that type of collateral to invest, really wants to be investing in new parts and turbines before the original turbines have paid for themselves?

15. Reply
*Jerry Polverino* Thursday, February 24 2011

This woman is a medical quack trying to sell a $18.00 book full of nonsense.
Her scientific evidence is hearsay, crouched in scientific language. What a joke!

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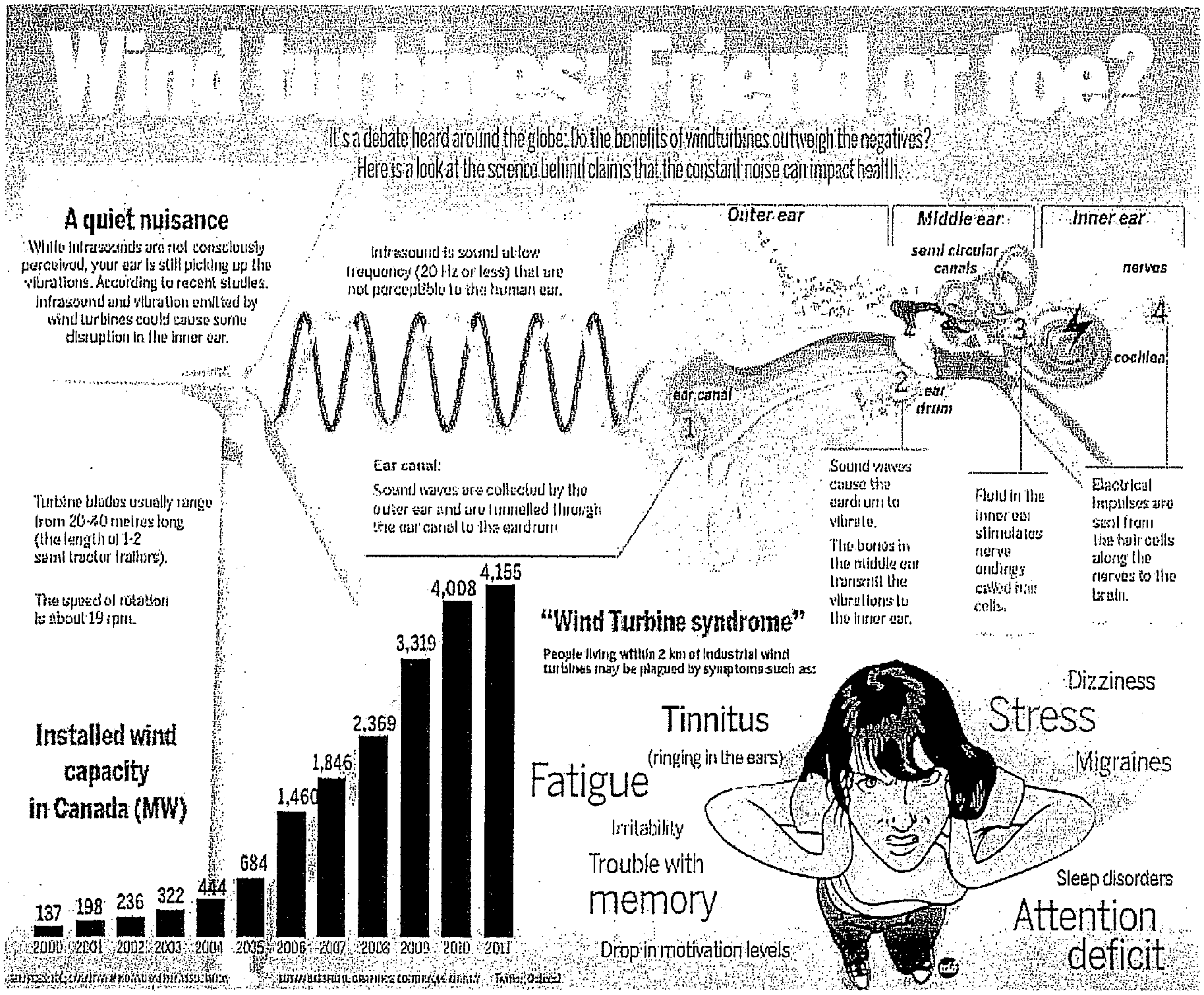
Wind turbines: Friend or foe?
It's a debate heard around the globe: Do the benefits of windturbines outweigh the negatives?
Here is a look at the science behind claims that the constant noise can impact health.
A quiet nuisance
While infrasounds are not consciously perceived, your ear is still picking up the vibrations. According to recent studies, infrasound and vibration emitted by wind turbines could cause some disruption in the inner ear.
Infrasound is sound at low frequency (20 Hz or less) that are not perceptible to the human ear.
Outer ear
Middle ear
Inner ear
semi circular canals
nerves
cochlea
ear canal
ear drum
1
2
3
4
Ear canal:
Sound waves are collected by the outer ear and are funnelled through the ear canal to the eardrum
Sound waves cause the eardrum to vibrate.
The bones in the middle ear transmit the vibrations to the inner ear.
Fluid in the inner ear stimulates nerve endings called hair cells.
Electrical impulses are sent from the hair cells along the nerves to the brain.
Turbine blades usually range from 20-40 metres long (the length of 1-2 semi tractor trailers).
The speed of rotation is about 19 rpm.
Installed wind capacity in Canada (MW)
137
198
236
322
444
684
1,460
1,846
2,369
3,319
4,008
4,155
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
"Wind Turbine syndrome"
People living within 2 km of industrial wind turbines may be plagued by symptoms such as:
Tinnitus
(ringing in the ears)
Fatigue
Irritability
Trouble with memory
Drop in motivation levels
Dizziness
Stress
Migraines
Sleep disorders
Attention deficit

00001432

# The latest news about Wind Turbine Syndrome

Wind Turbine Syndrome
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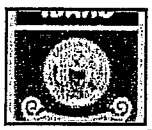
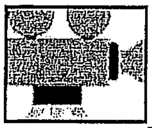
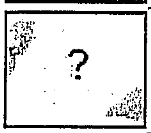
-  Wind Turbine Syndrome prompts state lawmakers to propose 2-year "wind farm" moratorium (Idaho)
-  "Windfall": The movie (Review)
-  Is this Vibro-Acoustic Disease? (Germany)
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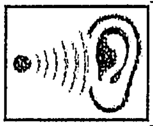
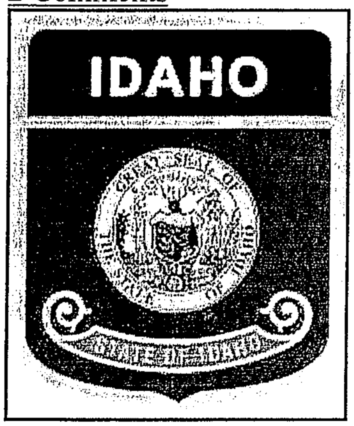
-  "It was emitting a pressured 'whooshing'" (United Kingdom)
-  "It was beyond their Geiger counter's limit" (WTS.com reports on Japan's nuke crisis)

## Wind Turbine Syndrome prompts state lawmakers to propose 2-year "wind farm" moratorium (Idaho)

By admin Sunday March 20, 2011

2 Comments




**"House committee considering moratorium on wind turbine construction"**

—Mitch Coffman, IdahoReporter.com (3/18/11)

.

The [Idaho] House State Affairs Committee got an earful on the issue of wind turbines during a hearing Friday. House Bill 265 proposes a two-year moratorium for those projects not already approved. Rep. Erik Simpson, R-Idaho Falls, introduced the bill. Simpson believes that wind energy isn't a viable resource compared to others and costs more as well.

Testimony on the bill was split fairly evenly with those against the bill falling into two categories: businesses and those with business relationships with them, and farmers/ranchers looking for some supplemental income.

Suzanne Leta Liou, a representative for RES Americas and an opponent of the bill, said this bill would jeopardize her company's wind turbine project in Twin Falls County and others like it. "This bill overrides local authority and local control," adding, "Idaho is a place where we want to do business. To be honest, if this bill was to move forward we would question the decision to be in Idaho."

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Scott Vanevenhoven, a member of Idahoans for Responsible Wind Energy and a proponent for the moratorium, believes proper ordinances and guidelines are not in place for local governments to make tough decisions. "These guidelines we currently have are insufficient. We should take this two-year pause and research everything," he said. Vanevenhoven believes it's a state issue and the state should therefore take a more active role in providing rules and regulations for building wind turbines. "The state has given incentives for people to use, so clearly it's a state issue," adding, "Idaho's wind development is radically higher than other states. Is this really a desirable thing for Idaho?"

Errol Jones, a member of the Bonneville County Planning and Zoning Commission, who is also for the moratorium, said at one time as a member of the board he was in favor of wind farms, but now says people need to really sit back and think about the consequences of building them. He also is in favor of some state oversight, not takeover, of the building process. "There is a definite learning curve. The state should take a good look at this process and what the counties have done." He also had a list of things he thinks the state can help with during this process including statewide guidelines for placing windmills, getting the fish and game department involved early, and having a longer timetable for county boards and commissions to study the issue and make sure it's a good decision.

Dr. Louis Morales, also a proponent of the bill, discussed health concerns with wind turbine farms. He believes wind turbines are a substantial health risk and should be looked at closely. "We need to sit down and look at these ordinances. This moratorium gives us the timetable to do this. These turbines give off a low frequency sound that causes what is known as Wind Turbine Syndrome. It's an inner ear problem resulting in vertigo, headaches, stress, migraines, and sometimes tachycardia."

Rep Lynn Luker, R-Boise, asked Dr. Morales if studies focused on the distance from a turbine and what the harmful distance is. Morales explained that Wind Turbine Syndrome can happen when a person is within about 1.3 miles of a turbine. "To be safe," he said, "it's best to not live much closer than 1.25 miles."

According to testimony, many of the homes in southern Idaho located near wind turbine farms are within ¾ mile to a mile away from wind turbines.

The committee was unable to hear all of the testimony Friday. It will resume testimony Monday morning at 7:45.

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The Problem


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## "Windfall": The movie (Review)

By admin Sunday March 20, 2011

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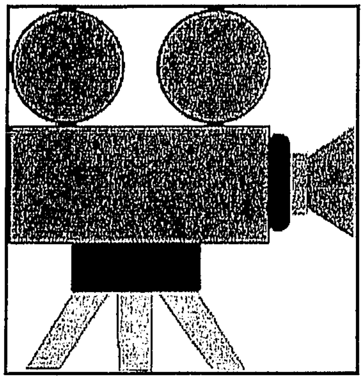

**"Research has suggested that their constant low-frequency noise and the flickering shadows they cast affect public health"**

—Ann Hornaday, The Washington Post (3/18/11)

Faucets don't spit fire in "Windfall," making its local premiere Saturday at the Environmental Film Festival. But incendiary water may be the only side effect not associated with wind power in Laura Israel's absorbing, sobering documentary about the lures and perils of green technology.

With the Oscar-nominated "Gasland" (and its flame-throwing plumbing) enlightening viewers on the environmental and public health implications of natural gas drilling, and with nuclear power's reputation in meltdown as a global community turns an anxious gaze toward Japan, some hardy souls may see hope in wind power. After seeing "Windfall," those optimists will probably emerge with their faith, if not shaken, at least blown strongly off course.


"Windfall" takes place in Meredith, N.Y., a once-thriving dairy-farming community of fewer than 2,000 tucked into a bucolic Catskills valley that is teetering between post-agricultural poverty and hip gentrification. When Irish energy company Airtricity offers leases to build windmills on some residents' properties, the deals initially seem like a win-win. A little extra money in the pockets of

00001436

struggling farmers, an environmentally sound technology, those graceful white wings languorously slicing the afternoon sky — what's not to like?

Plenty, as the concerned residents in "Windfall" find out. Not only do the 400-foot, 600,000-pound turbines look much less benign up close, but research has suggested that their constant low-frequency noise and the flickering shadows they cast affect public health; what's more, they've been known to fall, catch fire and throw off potentially lethal chunks of snow and ice.

Soon Meredith succumbs to drastic divisions between boosters, who see Airtricity's offers as a godsend for the economically strapped community, and skeptics, who see the leases as little more than green-washed carpetbaggery. "Windfall" chronicles the ensuing, agonizing fight, which largely splits lifelong residents and the relatively new "downstaters," who've moved in from Manhattan and want to keep their views and property values pristine.

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## Is this Vibro-Acoustic Disease? (Germany)

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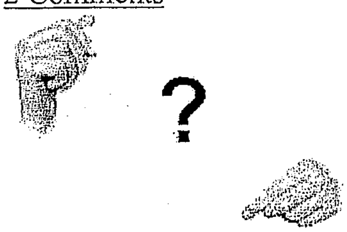

—Calvin Luther Martin, PhD · Is this VAD? We don't know. Read on. Marco Bernardi and his wife Jutta Reichardt have been living next door to wind turbines (Schleswig-Holstein, Germany) since 1994. At first it was 3. Each, 39m (128ft) high and each 200kW, 450-750m (0.28-0.47mi) from their home. Soon, several more went up, with [...]

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## "You can't ignore the fact that people are getting sick," says doc (Australia)

1 Comment

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—Erin Somerville, Central Western Daily (3/18/11) · They may look harmless, but the increasing amount of wind turbines freckling hills and skylines around the central west may be doing more harm than good. Insomnia, nausea and headaches are just some of the health complaints slowly being brought to the surface by people living near wind [...]

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## Do marine wind turbines drive whales to beach themselves? Nobody knows for certain. (UK)

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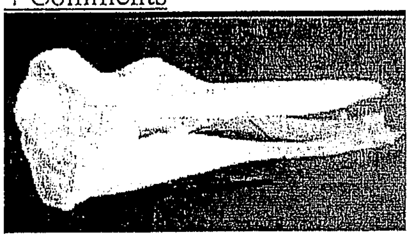

Editor's comment: The other day (March 15th), The Telegraph (UK) flashed the bulletin that "Wind farms blamed for stranding of whales." The article peaked my interest. As is my habit, I began tracking it down—to its source. After several minutes of digging, I discovered the article had not only been pulled from the Telegraph, it [...]

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## Wind Turbine Syndrome diagram: Not accurate, but gettin' there (Ontario)

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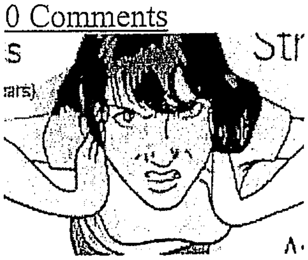

Editor's comment: The following diagram appeared in the London Free Press (Ontario, Canada) earlier this month. We had to crop it to make it fit, below. Click here for the full version. The good news is, the message is finally sinking into media consciousness. The bad news is, the diagram ignores the vestibular organs of [...]

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## [“Cuisinarts” in the sky (Texas)]

By admin Thursday March 17, 2011

## “It was emitting a pressured ‘whooshing’” (United Kingdom)

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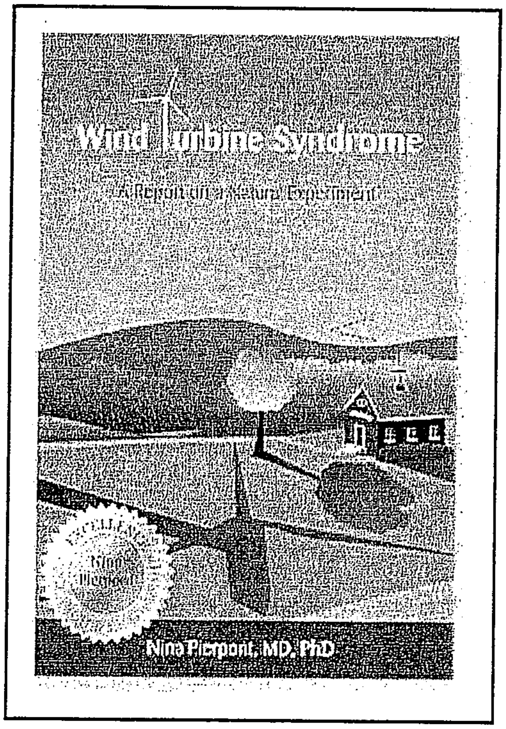


In this engagingly written report by a Johns Hopkins University School of Medicine trained M.D. and Princeton Ph.D., we discover wind energy’s dirty little secret.

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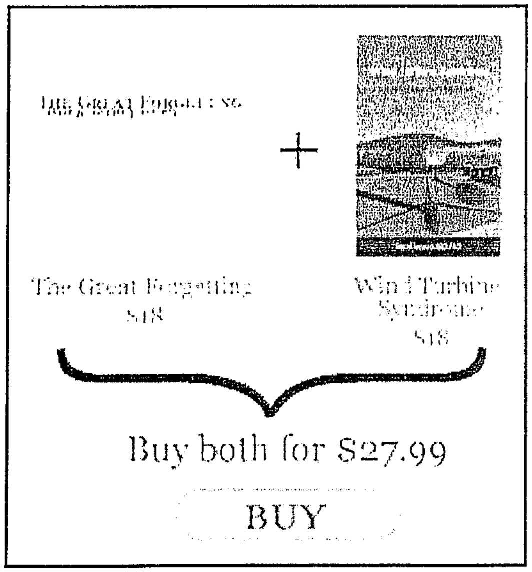


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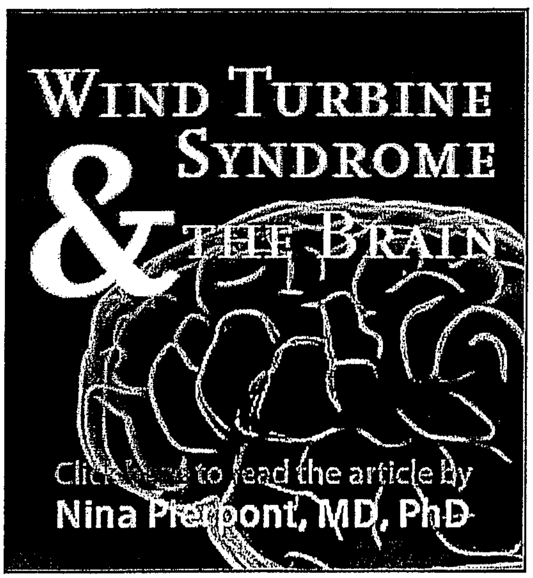


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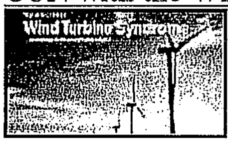
  - 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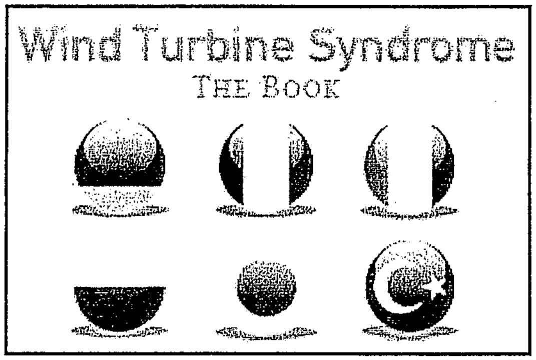


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- Featured
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**Why we do this**

We maintain this site because of a question put to us by a woman named Stephana Johnston (Ontario, Canada), who was forced to abandon her home and with it her life's savings. "What happens to the lab rats, guinea pigs, road kill that are being crushed by the wind developers here in the Clear Creek industrial windplant—those of us who are Big Wind's collateral damage?" This site is our reply to Ms. Johnston—and thousands like her around the world.

J. Acoust. Soc. Am. / Volume 116 / Issue 1 / NOISE: ITS EFFECTS AND CONTROL [50]



# Noise annoyance from stationary sources: Relationships with exposure metric day–evening–night level (DENL) and their confidence intervals



J. ACOUST. SOC. AM. VOLUME 116, ISSUE 1, PP. 334-343 (JULY 2004)

Issue Date: July 2004

ABSTRACT | REFERENCES (18) | CITING ARTICLES

Henk M. E. Miedema and Henk Vos
*TNO Inro, Department Environment and Health, P.O. Box 6041, 2600 JA Delft, The Netherlands*



Relationships between exposure to noise [metric: day–evening–night levels (DENL)] from stationary sources (shunting yards, a seasonal industry, and other industries) and annoyance are presented. Curves are presented for expected annoyance score, the percentage "highly annoyed" (%HA, cutoff at 72 on a scale from 0 to 100), the percentage "annoyed" (%A, cutoff at 50 on a scale from 0 to 100), and the percentage "(at least) a little annoyed" (%LA, cutoff at 28 on a scale from 0 to 100). The estimates of the parameters of the relations are based on the data from a field study ($N$ = 1875) at 11 locations (2 shunting yards, 1 seasonal industry, 8 other industries) in the Netherlands. With the same (yearly) DENL, the seasonal industry causes less annoyance than the other industries, while the other industries cause less annoyance than the shunting yards. It appears that annoyance caused by vibrations from shunting yards and annoyance caused by noise from through trains are (partly) responsible for the relatively high annoyance from shunting yards. The relatively low annoyance from the seasonal industry presumably is related to the presence of a relatively quiet period. Results for the two shunting yards and the seasonal industry are based on fewer data than the other industrial sources, and are indicative. The same patterns of influence of age and noise sensitivity that are generally found are also found in this study. For comparison, results regarding transportation sources are also given, including previously unpublished results for expected annoyance. ©2004 *Acoustical Society of America.*

History: Received 1 July 2003; revised 24 March 2004; accepted 30 March 2004

Permalink: http://dx.doi.org/10.1121/1.1755241

KEYWORDS AND PACS

Keywords

noise pollution, noise (working environment), traffic, transportation

PACS

RELATED DATABASES

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J. Acoust. Soc. Am. / Volume 126 / Issue 2 / NOISE: ITS EFFECTS AND CONTROL [50]



# Response to noise from modern wind farms in The Netherlands



J. ACOUST. SOC. AM. VOLUME 126, ISSUE 2, PP. 634-643 (AUGUST 2009)

Issue Date: August 2009



Eja Pedersen
*Halmstad University and University of Gothenburg, Halmstad University, P.O. Box 823, SE-301 18 Halmstad, Sweden*

Frits van den Berg
*University of Groningen and GGD Amsterdam, GGD Amsterdam, P.O. Box 2200, 1000 CE Amsterdam, The Netherlands*

Roel Bakker
*University Medical Centre Groningen, University of Groningen, A. Deusinglaan 1, 7913 AV Groningen, The Netherlands*



The increasing number and size of wind farms call for more data on human response to wind turbine noise, so that a generalized dose-response relationship can be modeled and possible adverse health effects avoided. This paper reports the results of a 2007 field study in The Netherlands with 725 respondents. A dose-response relationship between calculated *A*-weighted sound pressure levels and reported perception and annoyance was found. Wind turbine noise was more annoying than transportation noise or industrial noise at comparable levels, possibly due to specific sound properties such as a "swishing" quality, temporal variability, and lack of nighttime abatement. High turbine visibility enhances negative response, and having wind turbines visible from the dwelling significantly increased the risk of annoyance. Annoyance was strongly correlated with a negative attitude toward the visual impact of wind turbines on the landscape. The study further demonstrates that people who benefit economically from wind turbines have a significantly decreased risk of annoyance, despite exposure to similar sound levels. Response to wind turbine noise was similar to that found in Sweden so the dose-response relationship should be generalizable.



**History:** Received 3 December 2008; revised 14 April 2009; accepted 8 June 2009

**Permalink:** http://dx.doi.org/10.1121/1.3160293

KEYWORDS AND PACS

Keywords

acoustic intensity, acoustic noise, wind turbines

PACS

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Encyclopedia of Environmental Health
Pages 240-253

doi:10.1016/B978-0-444-52272-6.00245-2 | How to Cite or Link Using DOI


# Effects of Low Frequency Noise and Vibrations: Environmental and Occupational Perspectives

K.P. Waye[a]

[a] Institute of Community Medicine and Public Health, Sahlgrenska Academy, Göteborg University, Göteborg, Sweden



Available online 23 February 2011.

## Abstract

This article provides a current knowledge base of adverse effects due to community and occupational low frequency noise (20–200 Hz). Low frequency noise has a large annoyance potential, and the prevalence of annoyance increases with higher sound pressure levels (SPLs) of low frequencies. Low frequency noise annoyance is related to headaches, unusual tiredness, lack of concentration, irritation, and pressure on the eardrum. Data suggest that sleep may be negatively affected. In occupational environments, low frequency noise may negatively affect performance at moderate noise levels, whereas the health consequences of higher SPLs are less well known. Factors inherent in most low frequency noise such as the throbbing characteristics, the intrusion of low frequencies felt when other frequencies in the sound are attenuated, and the vibration sensations sometimes felt contribute to the response. Measurements need to properly assess the individual exposure and include spectral, temporal, and if present also vibration characteristics. The risks for adverse effects are of particular concern because of its general presence due to numerous sources, an efficient propagation of the noise from the source, and poor attenuation efficiency of building structures. Compared to other noise sources, data on low frequency noise are limited, and further studies are clearly needed.

**Author Keywords:** Acoustic parameters; Adverse health effects; Annoyance; Assessment; Low frequency noise/sound; Perception; Work performance

## Nomenclature

## Abbreviations

Lden
day–evening–night average sound level

LpA
A-weighted sound pressure level

LpC
C-weighted sound pressure level

Lpeq
equivalent sound pressure level

LpG
G-weighted sound pressure level

LpLin
Linear sound pressure level

SPL
sound pressure level

TTS
temporary threshold shift

VAD
vibroacoustic disease

## Article Outline





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# Mental Health Effects of Noise

S. Stansfeld[a] and C. Clark[a]

[a] Centre for Psychiatry, Wolfson Institute of Preventive Medicine, Barts and the London School of Medicine and Dentistry, London, UK



Available online 23 February 2011.

## Abstract

Environmental noise is a pervasive environmental pollutant that leads to annoyance and can be perceived as stressful. Studies have examined whether environmental noise exposure is associated with psychiatric hospital admissions, use of medication, psychological symptoms, and psychiatric disorders measured by questionnaires and structured interviews. There is some evidence, although studies are not consistent, that environmental noise is associated with higher rates of minor psychiatric disorders. The lack of methodologically sound prospective studies means that further research is needed before definite conclusions can be reached on the link between noise and mental health.

**Author Keywords:** Aircraft noise exposure; Child self-reported mental health; Exposure–effect relationships; Hospital admission rates; Medication use; Mental health; Noise annoyance; Noise sensitivity; Psychiatric disorder; Psychiatric morbidity; Psychological health; Quality of life; Road traffic noise exposure

## Nomenclature

## Abbreviations

dB(A)
: decibel is the unit of A-weighted sound pressure level

GHQ
: General Health Questionnaire

KINDL
: questionnaire for measuring health-related quality of life in children and adolescents

OR
: odds ratio

SF-36
: short form 36 General Health Survey

## Article Outline

## Cross References


Built Environment and Mental Health

Combined Noise Exposure at Home

Environmental Noise

Ionizing Radiation Exposure: Psychological and Mental Health Aspects

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OCCUPATIONAL & ENVIRONMENTAL MEDICINE

*Occup Environ Med* 2007;64:480-486 doi:10.1136/oem.2006.031039

Original article

# Wind turbine noise, annoyance and self-reported health and well-being in different living environments

Eja Pedersen, Kerstin Persson Waye

+ Author Affiliations

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**Accepted** 16 February 2007
**Published Online First** 1 March 2007

## Abstract

**Objectives:** To evaluate the prevalence of perception and annoyance due to wind turbine noise among people living near the turbines, and to study relations between noise and perception/annoyance, with focus on differences between living environments.

**Methods:** A cross-sectional study was carried out in seven areas in Sweden across dissimilar terrain and different degrees of urbanisation. A postal questionnaire regarding living conditions including response to wind turbine noise was completed by 754 subjects. Outdoor A-weighted sound pressure levels (SPLs) were calculated for each respondent. Perception and annoyance due to wind turbine noise in relation to SPLs was analysed with regard to dissimilarities between the areas.

**Results:** The odds of perceiving wind turbine noise increased with increasing SPL (OR 1.3; 95% CI 1.25 to 1.40). The odds of being annoyed by wind turbine noise also increased with increasing SPLs (OR 1.1; 95% CI 1.01 to 1.25). Perception and annoyance were associated with terrain and urbanisation: (1) a rural area increased the risk of perception and annoyance in comparison with a suburban area; and (2) in a rural setting, complex ground (hilly or rocky terrain) increased the risk compared with flat ground. Annoyance was associated with both objective and subjective factors of wind turbine visibility, and was further associated with lowered sleep quality and negative emotions.

**Conclusion:** There is a need to take the unique environment into account when planning a new wind farm so that adverse health effects are avoided. The influence of area-related factors should also be considered in future community noise research.

## Articles citing this article

**Local topography affects annoyance over wind farms**
*BMJ* 2007;335:70
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**Work in brief**
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# Project WINDFARMperception

## Visual and acoustic impact of wind turbine farms on residents

Final report, June 3, 2008
FP6-2005-Science-and-Society-20, Specific Support Action project no. 044628
Project partners:
Frits van den Berg, Faculty of Mathematics and Natural Sciences, University of Groningen
Eja Pedersen, Department of Public Health and Community Medicine, Göteborg University
Jelte Bouma, Science Shop for Medicine & Public Health, University Medical Centre Groningen
Roel Bakker, Northern Centre for Health Care Research, University Medical Centre Groningen

A Dutch Study

## SUMMARY

This report gives the results of the EU financed study WINDFARMpertception on how residents perceive a wind farm in their living environment as far as sound and sight are concerned. The study includes a postal survey among Dutch residents (n = 725, response rate: 37%) and an assessment of their aural and visual exposure due to wind farms in their vicinity.

**Respondents in the survey and calculated exposures**
The study group was selected from all residents in the Netherlands within 2.5 km from a wind turbine. As the study aimed to study modern wind farms, wind turbines were selected with an electric capacity of 500 kW or more and one or more turbines within 500 m from the first. Excluded were wind turbines that were erected or replaced in the year preceding the survey. Residents lived in the countryside with or without a busy road close to the turbine(s), or in built-up areas (villages, towns). Excluded were residents in mixed and industrial areas.

The sound level at the residents' dwellings was calculated according to the international ISO standard for sound propagation, the almost identical Dutch legal model and a simple (non spectral) calculation model. The indicative sound level used was the sound level when the wind turbines operate at 8 m/s in daytime -that is: at high, but not maximum power. The size of the turbines was calculated as the viewing angle between the lowest and highest part of the biggest turbine, and also as the fraction of space above the horizon occupied by all wind turbines, both from the perspective of residents' dwellings.

Respondents were exposed to levels of wind turbine sound between 24 and 54 dBA and wind turbines at distances from 17 m to 2.1 km. The (angular) height of the biggest wind turbine ranged from 2 degrees to 79 degrees, with an average value of 10 degrees (the height of a CD box, looking at the front at arm's length). The wind turbines occupied on average 2% of the space above the horizon.

**Attitude and economic involvement of respondents**

Almost all respondents (92%) were satisfied with their living environment, though many reported changes for the better and changes for the worst. One in two respondents were (very) positive towards wind turbines in general, but only one in five were (very) positive towards their impact on the landscape scenery.

Fourteen percent of the repondents had economic benefits from wind turbines by owning them or having shares in wind turbines or otherwise. They usually lived closer to the wind turbines, were higher educated, less old and hence healthier compared to the other respondents, and they relatively often worked at home. Respondents with economical benefits were less negative to wind turbines in general and their influence on the landscape scenery.

**Response to wind turbine sound**

The percentage of respondents noticing the sound of wind turbines increased with increasing sound level, ranging from 25% at low sound levels (less than 30 dBA) to 80% and more at higher sound levels (above 35 dBA). Percentages were the same for those who had benefits and the other respondents.

The percentage of respondents that were annoyed by the sound also increased with sound level up to 40 to 45 dBA and then decreased. Respondents with economic benefits reported almost no annoyance. This in part explains the decrease in annoyance at high sound levels: above 45 dBA, *i.e.* close to wind turbines, the majority of respondents have economical benefits. The percentage of respondents without economic benefits that were rather or very annoyed when outdoors increased from 2% at low levels of wind turbine sound (less than 30 dBA) up to 25% at levels of 40 to 45 dBA.

In general respondents perceived wind turbines as being louder in wind blowing from the turbine to their dwelling (and less loud the other way round), in stronger wind and at night. The majority (75%) of respondents that could hear wind turbines think that swishing or lashing is a correct characterization of the sound. The second most typical characterization was rustling (for 25% of the respondents). Other characterizations were chosen by less than 10% of the respondents.

Respondents were more likely to be annoyed by sound from wind turbines when they noted changes for the worse in their living environment and when they had a more negative view on wind turbines in general or their impact on the landscape scenery.

**Health effects**

There is no indication that the sound from wind turbines had an effect on respondents' health, except for the interruption of sleep. At high levels of wind turbine sound (more than 45 dBA) interruption of sleep was more likely than at low levels. Higher levels of background sound from road traffic also increased the odds for interrupted sleep. Annoyance from wind turbine sound was related to difficulties with falling asleep and to higher stress scores. From this study it cannot be concluded whether these health effects are caused by annoyance or *vice versa* or whether both are related to another factor.

**Response to other aspects of wind turbines**
Respondents were also annoyed by wind turbines in other ways than by sound: between 4% and 13% were rather or very annoyed by vibrations or the movement of rotor blades or their shadows in- or outdoors.

One out of three respondents could not see a wind turbine from their dwelling, especially when living in a built-up area or further away from the turbines. The visibility of wind turbines strongly affected the probability of being annoyed by their sound: when turbines were visible, respondents were far more likely to be annoyed. An unexpected result was that respondents living in a rural area with a main road within 500 m from the wind turbine(s) were less annoyed than respondents living in a built-up area, though the background sound levels from road traffic are on average the same in both area types and one would expect that wind turbines are more readily visible in a rural area.

**Recommendations**
In this survey sound was the most annoying aspect of wind turbines. From this and previous studies it appears that sound from wind turbines is relatively annoying: at the same sound level it causes more annoyance than sound from air or road traffic. A swishing character is observed by three out of four respondents that can hear the sound and could be one of the factors explaining the annoyance. Sound is therefore an important and negative feature of wind farms and we recommend that, in the planning of wind farms, the negative impact of the sound and sound reduction should be given more attention.

Nevertheless, people that have economical benefits from wind turbines are much less or not at all annoyed, even though they often live closer to wind farms and are exposed to higher sound levels. This lack of annoyance may be the result of several factors: *e.g.* the 'benefitters' have a more positive view on wind farms, they have an actual benefit and they have a measure of control on the turbines. These characteristics may show the way to more acceptance and less annoyance with other residents: residents may be given some benefits and a sense of control too. Discussion of the different views on the landscape, instead of opposition to other views, may help in reaching consensus.

Visibility of wind turbines enhances their potential to cause noise annoyance. When wind turbines are invisible, they cause less annoyance. Perhaps less visibility can also be the result of reducing the visual contrast between turbines and landscape. The possibilities to do this will depend on the landscape type.

The capability of busy road traffic to mask the sound of wind turbines is apparently not straightforward: a higher level of background sound from road traffic indeed reduces the probability of noticing the sound of wind turbines, but it does not have an effect on annoyance from the wind turbines. This may be due to differences between both sounds in pitch, in character (swishing) and in diurnal variation. This issue needs further investigation.

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# Letters From Wind Farm Neighbors

**Rodger Hutzell, Jr., Meyersdale, PA**

13 February 2005

Dear Sir:

I am writing to you in regards to living near an industrial wind turbine facility. This facility is located in Somerset County near Meyersdale, Pennsylvania. The facility has been operating since December 2003.

Since this facility has been up and running, my family and I have experienced noise nuisance issues, specifically when trying to go to sleep at night. The noises are greater during the winter months. The noise appears to correlate to a continual droning sound. When awakened at night, there are times that it is impossible to get back to sleep due to the threshing sounds produced by the wind turbines. After the first few weeks of the initial operation; I began to experience difficulty with sleep patterns. My family physician was consulted regarding this issue with difficulties falling alseep. I was prescribed sleeping medication.

The noise nuisance issue continues to exist. February 2003, I was in my yard running my chain saw and the drone of the wind turbines could be heard over the sound produced by the chain saw. I was never made aware of any type of noise nuisances produced by these industrial turbines prior to their construction.

My lifestyle has changed since this operating industrial facility was erected within near vicinity of my residence. I fear that my real estate value has decreased due to the noise nuisance and deterioration of the scenic mountain ridges that surround my residence.

These industrial facilities and landowners should be held accountable and liable for any all nuisances that affect local and adjacent property owners.

Sincerely,

Rodger A. Hutzell Jr.
327 Ridge Road
Meyersdale, PA
15552

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**Karen Ervin, Meyersdale, PA** 00001453

07 March 2006

To Interested Parties:

I would like to share the realities and impacts that are being faced and continue to be faced by living near a wind turbine facility and hope to clear up some of the misconceptions and comparisons of the "so-called" progress regarding this particular industry.

I live within less than a 1-mile range of the Meyersdale Wind Turbine Facility in Somerset County, Pennsylvania. I would like to share, from an up-close and personal experience, I guess one could label it the "Human Experimental Factor", the multiple nuisances and issues that coincide with these particular industrial turbine utilities that affect my neighbors, my family, local adjacent property owners and residents have and continue to experience over the past two years.

Prior to the building of the facility, our neighbors and we were never made aware of the nuisances that occur with a wind turbine facility. The noises emitted from the turbines have definitely changed our style of living. The noises produced from the blades turning on the turbines create a "threshing" sound within and around our home as well as the adjacent properties residing within certain geographical ranges of this facility.

At times it is difficult to fall asleep with the "pounding" of the turbines. One is often awakened by the "droning" noise of the turbines, finding it most difficult to fall back asleep. The noise becomes so disruptive; one can concentrate on nothing else but the constant droning. During the winter months, the noise is quite unbearable at times, sounding like drums beating constantly in the background. Sometimes the sound can be correlated to constant jet aircraft flying overhead. During the summer months, we cannot have our windows open to enjoy the fresh air or listen to the sounds of nature - just the noise created by the turbines. Advocates for these facilities will often compare this "threshing" noise to the "peaceful" sound of waves beating against the rocks at the seashore, but I have been to the seashore and it certainly is in no way comparable to the "calming sound" of waves. (I guess we are now just supposed to close our eyes and pretend we are at the ocean!!) We are no longer able to enjoy peaceful picnics, hikes, and overnight camping upon the hill because of the noise nuisance, flickering and strobing of lights, and ugly view shed of the turbines. How sad it is to know that some of these rural farms and properties that have been intended to be passed down from family generation to family generation have to endure these nuisances.

We should have learned from other countries mistakes regarding extensive turbine erection all over the landscapes. Upon sole opinion and opinion only - I know though, it is a "who knows who" and a "who will benefit from what (amount of money)" mentality. Hey lets face it, if it is not in my back yard and I don't have to put up with it; I could care less about those who are being directly and indirectly affected. If it hurts bats, who cares! How sad it is that one does not fully understand the benefits of our environment and any particular species and/or plant life. There is a particular reason for all, brush up on the facts. One may also want to inquire why particular facilities do not and will not allow any on-going studies of avian species to proceed? Is there something to hide? Remember next it may be who cares about you, your family, your friends, and your neighbors. Let's not worry about whom and how it negatively effects them; let's just make some money! Quite a lot to ponder. Perhaps one may want to CAREFULLY inquire exactly how much these companies do pay in federal, state and local taxes and how much revenue and credits they reap. Who exactly benefits and how much? It is quite astonishing!

Placement of these particular facilities is another issue that should be carefully studied before erecting them for those tax credits. From experience, computer regurgitated data cannot be taken into consideration for these particular projects. Topography is very important and has to be studied carefully in correlation to differential wind speeds, climatic conditions, and noise levels. One size does not fit all. As property owners whom have resided a numerous amount of years - some 50 plus; before this facility was built, and who have chosen to reside within a peaceful environment, we were never given the opportunity or made aware of the nuisances produced by this type of industrial facility. We were never given the chance to look at a waiver to choose if we wanted to live near this nuisance or explained the possible devaluation of property due to view-

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shed, noise, water run off etc.

We have experienced more power outages and surges; as well as excessive water run off from the clear cut ridge top- Glade City was flooded with an enormous amount of water run-off from Hurricane Ivan- photographs and video footage clearly define where the water came from, disruption of portable phones within home and television reception, shadow flicker nuisances while driving on the local roadway and reported at a local Rod and Gun Club, a blinding white strobe light that was malfunctioning on one of the large turbines, and during daytime-close adjacent property owners disrupted by strobes.

One cannot understand that within larger municipalities and cities, noise nuisances and other issues created by those to others are liable for the disruptions. Shouldn't parties involved in this particular industry have to be held responsible and uphole stringent regulations and ordinances like any other industry? Just because we live in the rural countryside and have so for the majority of our lives and want our children to enjoy the peaceful countryside, why should we be the ones to suffer with such nuisances?

Employment by this particular industry is limited. Yes, local individuals may be employed while the facility is under construction, but not in the end - well, look at the numbers - only a few are permanently employed. A slap in the face to a boost in the local economy. Look into the number of local individuals actually employed, the pay scale, and the amount of money the facility actually pays in taxes to the community, local, state and federal governments. Where does the electricity go-is it utilized for local and surrounding areas with no charge? Who in particular is reaping the benefits from your local community? Exactly how much electricity do these particular facilities produce and in comparison to other sources of clean energy what percentage, the cost per kilowatt-hour, and how much maintenance do these structures require? These are just a few of the questions that need to be asked.

Ask the companies to thoroughly explain and to publicly share the clauses that are built into their legal documents between themselves and the landowners. It can be described as a "buyer beware" clause. Can be quite interesting reading, you may want to have your own legal expert with you before signing-the wording is quite creative and meanings quite crafty. I am sure those particular clauses do not want to be shared publicly. Careful, one may be giving up an abundance of rights regarding who is and who is not liable for the very nuisances and issues that these companies insist that the turbines do not create, such as noise, shadow flicker, strobe issues, right of road ways, water issues, and yes, even having the right to determine whether you are entitled to utilize your very own property as you see fit regarding varied farming, building, and recreational useage!

Stringent criteria, federal, state and local laws, regulations and on-going long term pre-post studies should be implemented and enforced prior to and during the operation of these industrial facilities. These industrial facilities and the parties involved who chose to have them erected should be held liable and accountable for any detrimental impacts and nuisances imposed and continue to be imposed upon humans and the environment. The facts should be carefully studied regarding this particular issue.

Remember we must work hand in hand to preserve what God has given us, to be greedy and to want to accomplish the goal of making a quick dollar at the expense of everyone and everything else is selfish. We need to take care of what we have now, not only for our future but also for the future generations that will follow. This industry without stringent regulations can be truly labeled a "Pandora's Box". Be careful for what is opened, and be prepared for the negative impacts that have occurred and continue to occur with this industry.

Sincerely:

Karen Ervin

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Letter to County Commissioners from Robert Larivee,
Professor of Chemistry, Meyersdale, PA

Original letter in full available here.

"My house is located about 3000 feet west from the new 20 wind generators located along Meadow Mountain in the Meyersdale region. I had the noise level measured by Dr. Oguz Soysal of the Department of Physics and Engineering, Frostburg State University...

The preliminary results of the readings showed an average reading of about 75 decibels...These levels are much higher than those predicted by the company...you have not done your job very well for those of us forced to live with this additional noise."

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**Against the wind**

**In Fenner wind farm developers made and broke many promises**
Naples Record

Pastor Kathleen Danley, November 3, 2004

To the Editor:

My husband and I own a home in the township of Fenner, New York, and it is located in the middle of the Madison wind farm. I am not, and never have been, against wind power, but I want people to be well aware of the negative side of these giant windmills before allowing them to be built in your neighborhoods.

We have always believed that our neighbors had the right to use their property as they feel appropriate. In fact, we were even somewhat supportive of the project in our area. Our home also sits well away from the setback distances called for by zoning.

Unfortunately, we were not given all of the facts, or we were given somewhat twisted information. We were told that the windmills had been redesigned so as not to be noisy, but the grinding noise goes on 24 hours a day (when they are operating) and at times is far worse than other times.

From our bedroom window we can see no fewer than five towers and from the living room another two. On a stormy night the wind howls through our bedroom like a freight train -- yes, I know, the blades stop when the wind reaches a certain velocity, but nevertheless, they don't magically disappear. The wind continues to hit them, greatly increasing the sound that travels over them. In the middle of the summer we cannot enjoy our yard or have the windows open because these machines constantly grind and have a negative effect on one's nerves. When at the house I find that my nerves are constantly on edge.

We also have lost our television reception and were forced to purchase a satellite dish. Prior to the towers we always had very good reception of the local stations and generally had two to three more. Now it is impossible to get any of those stations. Incidentally, there is no cable in our area. The wind tower builders/management have more than once promised to look into this situation but have done nothing. They do not answer phone calls or follow up on appointments that they make

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with us.

Out of necessity to aviation there are lights on top of the towers, which now flash directly into our bedroom and living room windows all through the night necessitating the closing of the blinds and robbing us of the view of our own backyard and God's gift of nature -- one of the main reasons we moved to the country in the first place.

Should your area decide to go ahead with the projects, I would suggest that cell phone towers be built into the towers. This was not done in our area and there is terrible cell phone coverage. To increase the coverage more towers now need to be built and I don't see that happening any time soon.

I have also found that the discussion to have or not have wind towers in a neighborhood has pitted neighbor against neighbor in some cases and long friendships have struggled. I find this to be very sad and a huge detriment.

The wind farm in our home area has also brought much traffic to the area that we never had to deal with in the past. Drivers stop and gawk in the middle of the road becoming a hazard to those who simply want to get to work or possibly to a store or doctor appointment, etc.

Promises have been made and broken over and over again, and I find that also to be an extremely sad situation.

I pray that you can find a way to work through many of the issues without having such a huge impact on those living nearby.

Pastor Kathleen Danley, Fenner NY

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**Our Wind Farm Story**

By Pam Foringer

It was almost 23 years ago when we built the home we hope to retire in. While we were looking for land to build on, we searched high and low for a piece of property we could afford. Our funds were limited and so were the parcels of land in our price range. We looked at the 3-acre parcel that seemed so desolate a number of times. We drove by in the early spring and tried to picture what it would be like atop this barren hillside in the cold, snowy months of a "Fenner winter". The one thing that we did know was that in the summer months there was a magnificent view to the west and the sunsets were incredible. We wanted the piece and quiet of the country and this seemed like our best bet. So in April 1981 we started to clear the property and construction began on our new home. During the construction many of the contractors joked about how windy it was up here and told us we ought to put up a windmill. My husband even did a little research on small-scale windmills but never seriously considered erecting one as the cost was high and it would take years to break even.

During the first couple of years we planted over 1500 pines in the 2 acres behind our house. We hoped to be able to cut our own Christmas tree in a few years and eventually we'd have our own little animal sanctuary where deer could have shelter and the birds my husband loves to watch would flourish. And indeed we did cut our 1st Christmas tree about 7 years later. We only cut trees for about 3 more years before they were beginning to tower over us and it was time to let nature take its course. Over the years the Mother Nature has had a hand in changing the landscape.

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Trees have grown and trees have fallen due to several storms that involved high winds or the phenomenal icing, that though beautiful to look at, has done major damage. We have quite a lovely little forest out back now. The pines have grown to somewhere between 20 and 30 feet but they are dwarfed by the giant towers that now dominate the landscape no matter what direction we look. Never in a million years did we expect to be surrounded by these towers that passersby find so mesmerizing in their short 10 or 15 minute visits.

Let me tell you how this all began. It must have been about 5 years ago when we noticed the construction of a test tower directly to our south in the farm field next to our house. Soon rumors of the "Wind farm" began to swirl. Eventually town meeting started to take place and more information was forthcoming. We were never given a chance to vote on whether this project would actually become a reality. Most of our neighbors and I use the word loosely as we live on a road that has only 8 houses, I should probably say, the other residents of the town of Fenner seemed rather excited. They felt this was the best thing to happen to our township in years. My husband and I were concerned about the alteration of the landscape and what affect this project would have on us personally. There were a few other families that like us would be surrounded by towers and they were also concerned. The developer met with a group of 5 families a number of times to explain the plans and to reassure us that there would be very little change to the landscape. We were told they would only remove trees where absolutely necessary and all the cables and wiring would be underground. He reiterated that noise would not be a problem. The placement of the towers was explained to us and he even sent us computer renderings of what they would look like from our homes. We worried about our property values and how this would affect our appraisals. My husband and I never really considered selling our home because of the project; we have too much time invested to just pull up stakes and leave. But in this day and age you never know what circumstances can force you to relocate so we wanted to protect our investment. We were told the developer would extend a contract to us that would protect our property values for a period of 3 years from the time the project became operational. Basically if we decided to sell, and were forced to sell at a lower price due to the impact of the wind farm, the developer would pay us the difference. We received paperwork and sent it off to our lawyer to verify that it was an appropriate means of protecting our property values. He explained that it looked fine, there was certainly no harm in signing it but it really did nothing for us UNLESS we decided to sell and unless we indeed sold at a lower price. Although my husband and I were not planning to sell we signed the contract and waited for the developer to stop by and pick the copies up, as he said he would. Days passed and it seemed like he had dropped off the face of the earth, we were told he was off to work on a new project. I emailed him to let him know the copies were ready. We later found out that the developer had sold the entire project to another company. We still have the signed papers in an envelope but the time period has since passed. We have not pursued the subject any further. I don't know if any of the other families have benefited from their contracts or not. One family has sold and moved away, I do not know the circumstances of their sale. We have had no contact with the other families; I have been told that one of the other families is in arbitration.

As the project began we knew we had been "punked" as the young people say these days. The number of workers and amount of construction equipment was staggering. We saw many hedgerows disappear as they cleared the way for access roads. That summer the dust covered every surface in my home, the only way to avoid it was to keep the windows closed. We have no air conditioning; we've always relied on the breeze to cool our house on hot summer days. How ironic, to find relief from the sweltering heat, we would have to use a air conditioner that uses much more power, just the thing that facilitated all these changes to our peaceful country existence.

The crane used to lift the turbine as it is placed on the tower is something to see, and of course people flocked to the site to watch the progress. Every time the crane had to be moved it was a major undertaking, as it didn't even fit on the roads. The huge tracks it made as it moved slowly across the farm fields like a giant snail could be seen through out that summer. Caravans of trucks came loaded with 100 ft rotor blades. It was a very hectic time as these workers went about their daily duties and the towers inched their way toward the sky. In the autumn of 2001 the project

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went online and most of the workers moved on to their next job.

Not a day went by that I wasn't asked by a friend or coworker what it was like now that the wind farm was up and running. So I'm sure you're wondering how things have been since the project was completed. Well, as I sit in my kitchen and type this on my computer I hear the constant hum of the blades, its early November, a brisk day and of course the windows are closed so that muffles the sound a little. In the summer, with the windows open there is nothing to block out the humming or the grinding sound that the turbine makes when it is being turned. For those that haven't seen a wind tower up close, they are about the height of a 30-story building and the unit on top is the size of a small travel trailer. Because the wind constantly changes direction the blades have to be turned to catch the wind. Now you know, there isn't a little man with a crank that lives in the bottom of each tower who turns the blade at the appropriate time. It is all monitored by computer and done mechanically, imagine turning a 24-ton object perched on top of a 200 ft tower. That takes a bit of force and at times the sounds that are emitted are rather eery. Depending on the weather it can sound like a grinding noise or at times the shrieking sound of a wild animal. In the winter the noise always seems much louder, perhaps because of the starkness of the season and lack of foliage to muffle the noise. Anyway, when people tell you that the wind towers are virtually noiseless, they haven't lived a couple of football fields away from one 24/7. It has been 3 years now, I must say I will never get use to the view that greets me every time I drive home from work or the grocery store or any journey that takes me out of the Town of Fenner. On sunny days the towers are a bright white, a huge contrast to the beautiful blue sky. When it is gray and rainy they take on a gray color that almost, I repeat, ALMOST makes them disappear into the gloom of the day. In the heavy fog that frequently blankets our road they are virtually invisible, not even the red blinking lights can be seen. But regardless of whether you see them or not, you still hear them, even when they are not operating. When the brakes stop the rotors because it's too windy, you hear a clunking and a grinding that sounds like a freight train's cars bumping together. And when it's time to start them again you can at times liken it to the roar of a jet engine.

We have some absolutely gorgeous sunrises and sunsets in Fenner. As the sun slowly rises to the east of our house it usually bathes our bedroom wall with it's rays, unfortunately, we now get a strobe effect that can drive you absolutely crazy. It's commonly called the "flicker factor". As the sun shines through the rotors it creates a shadow pattern that you would liken to a strobe light. Because of the close proximity of 4 of the towers to our house we get this light show at various times of the day as the sun travels from east to west. Most of the time I have to close our shades to prevent this from giving me a migraine. And speaking of light shows, if this one during the day isn't enough, we get the nighttime show as well. Each tower has red blinking lights on top of the turbine so unless the shades are closed in the bedroom at night there is a constant red light blinking in perfect view as we lie in bed. We have always enjoyed watching the night sky but now as we drive toward our road what you notice immediately is a huge cluster of blinking red lights.

In the past we would see thousands of Canadian geese as they made their way to the local swampland for a well-needed rest during their long journey north. The snow geese whose migration pattern brought them directly over us have since found a more convenient route; at least I haven't seen them since. Proponents of the wind farm would say it's not so but after 20+ years I think we can vouch for the fact. Our surrounding cornfields used to be full of geese this time of year, not anymore. It didn't happen overnight but slowly the numbers have dwindled, is that just a coincidence?

That brings me to the next point of contention, traffic. We moved to the country because we liked the seclusion and not having to worry about constant traffic. If you check with our town supervisor he would tell you that the traffic has increased 10 to 20 times from what it used to be. Madison County and the Town of Fenner encourage people to visit the wind farm. Imagine my surprise when a coworker that had been to our county seat in Wampsville, NY brought me a brochure for the Fenner Wind Power Facility and there on the front was my house. My husband and I had no idea that the brochure had our house prominently displayed on it, we were neither asked or notified it would be part of the promoting of the wind farm. Of course we could not stop that anymore than we could stop the traffic. The thing that amazes me is the stupidity of some of

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the drivers. I can't tell you how many times I have crested a knoll on our road to find a STOPPED vehicle just on the other side, sometimes the people remain inside the car but many times they are standing in the road and seem to be oblivious to the fact that this is not only dangerous to themselves but also to people just trying to get to their homes. I've even encountered a tripod set up in the middle of the road while some amateur photographer snaps pictures. One of the biggest shocks I got was the first time I came home to find a tour bus parked across from our house and the entire busload of senior citizens leaving the bus to go look at a rotor that is stored on some town property located across the road from our house. Since then I have seen more than one tour bus and numerous school buses. The increased traffic has not been good for our country roads that are already in need of repair. The town is supposedly receiving some form of compensation from Canastota Windpower, the owner of the project but I have yet to see it go into the upkeep of our roads at least not the one I live on. We've read in the newspapers how good this is for our local economy, I would like to know who locally is benefiting other than the select few who have towers on their property and the individuals who have a weekly ad in our local paper advertising the sale of Wind Farm T-shirts, key chains and bumper stickers.

Some people look at them as modern art; I personally prefer to see my modern art in a gallery. Everyone is shocked to find out we don't get our power for free. It seemed like the right thing to do considering the disruption the project had caused. I understand that those who want to purchase "Green Power" pay a premium price for it. You may have noticed that your electric company has given you a choice of purchasing units of green power. We are already paying outrageous prices for gas now if we want the option of wind power we must pay more for that too. Someone is benefiting from this project, but many of us are paying in ways that have no monetary price. My family and I will continue to live on the property we call "home", we'll watch our trees grow knowing they'll never be tall enough to block the view of the tower that looms just the other side of them. I wonder what these towers will look like in 20 years, lets hope they are not rusting giants!

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**Noise From Windfarm Making Life A Misery**
Original article in full available here.

25th May 2005, Press and Journal

**A settler in Caithness claimed yesterday his life is being blighted by ghostly noises from his new neighbours, the country's first large scale wind farm.**

Frank Bellamy said the steady, pulsing noise emitted by National Wind Power's $ 30 million development at the Causwaymire could force him to sell up and move away. He said if he gets no satisfaction with his complaints, he will consider taking legal action against National Wind Power...

Mr. Bellamy said: 'The problem is particularly bad at night when I try to get to sleep and there's a strong wind coming from the direction of the turbines.

'They just keep on droning on. It's a wooh wooh type of sound, a ghostly sort of noise. It's like torture and would drive anyone mad.'

Mr. Bellamy believes the noise is being transmitted through the ground since it seems to intensify when he lies down.

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He has got nowhere with complaints to the wind company and environmental health officers. I feel I'm just getting fobbed off and can't get anyone to treat me seriously,' he said.

Mr. Bellamy has been asked to take noise readings every 10 minutes during problem times, something he claims is unrealistic to expect him to do.

He said the company's project manager Stuart Quinton-Tulloch said they could not act until it had proof of unacceptable noise levels.

Mr. Bellamy said: 'I'm not the moaning type and I have no problem with the look of the windfarm. It's just the noise which is obviously not going to go away.'

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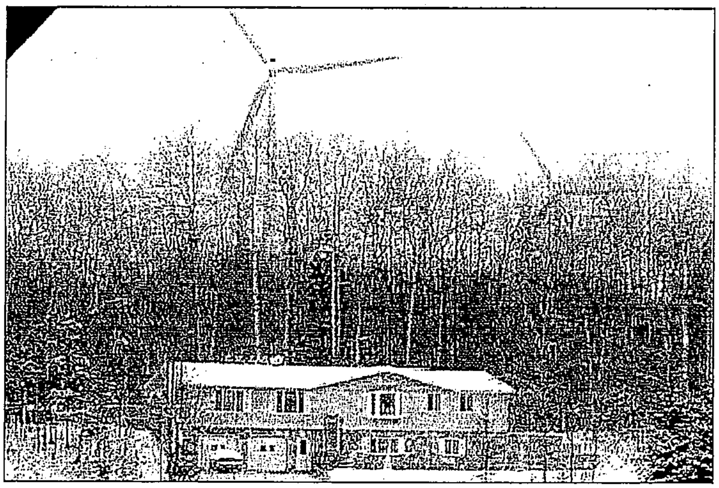

This is Kelly Alexander's Home in Mackinaw City. He believed that wind power would be a good energy source. He did not oppose the wind turbines, because he was told that they were not noisy and that they would not be a problem. To make matters worse, no one told him about the blade flicker that flashes even through closed blinds.

The nearest turbine is 1/4 mile away from his house. These towers are small, only 325 feet. New machines will likely be over 400 feet tall. Decibel readings 280 feet from the turbine are 60-65. A thousand feet further away, the decibel reading at the rear of his house away from the expressway is 50-55 decibels. The noise has only slighlty dissipated over that great distance. Even worse, that noise penetrates his home with doors and windows tightly closed and storm windows installed.

He built this new home near the expressway because his elderly parents lived there and he wanted to live close to them. Kelly's parents live 1500 feet from the turbines. They are hard of hearing, but the noise of the Wind Machines does keep them from sleeping sometimes. Their right to peacefully enjoy their final years has been stolen from them.

Mr. Richard Vander Veen built the first two turbines at Mackinaw City. He knows about the bad noise problem. Why is he preparing to erect three more turbines on the same parcel? The noise impacts will be multiplied.

According to an article published in the Holland Sentinel on December 31, 2002, 'Kelly Alexander, whose home is near the windmills, said he attended all the public meetings and was assured that there would be no problems with noise. Alexander said he can hear a constant

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humming sound inside his home when the turbines are running, whether the windows are open or not. He said the situation was unlivable and all he wants is for things to be the way they were when he moved into the home.'

The article states 'Vander Veen said, Bay Windpower has lived up to ordinance requirements.'

The present owner of the turbines asked Kelly what he could do to help the situation. Kelly's answer was this: 'Stop lying about these turbines. Tell people the truth.'"

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# Documents

## Maine Medical Association adopts resolution on wind energy and public health

*September 12, 2009*

**Summary:**

The Maine Medical Association adopted this important resolution regarding wind energy development and public health at its September 12, 2009 annual meeting.

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**Maine Medical Association**

**Resolution RE: Wind Energy and Public Health**

**WHEREAS**, proposals to locate and build wind energy facilities in the State have at times proven controversial, due to concerns regarding potential effects of such facilities on the public health, and

**WHEREAS**, the trade off between the public good of generating electricity and the adverse health effects warrant appropriate evidence-based scientific research, and

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**WHEREAS**, assessing the potential health impact of wind turbines has been difficult to measure but if present would be of significant concern. This is especially apparent regarding the noise level and other noise characteristics specific to industrial wind turbines, and

**WHEREAS**, there is a need for modification of the State's regulatory process for siting wind energy developments to reduce the potential for controversy regarding siting of grid-scale wind energy development and to address health controversy with regulatory changes to include, but not limited to:

a) Refining certain procedures of the Maine Department of Environmental Protection and the Maine Land Use Regulation Commission to reflect scientific evidence regarding potential health effects, and to further explore such potential health effects;

b) Judging the effects of wind energy development on potential public health by avoiding unreasonable noise and shadow flicker effects, with development setbacks and incorporating upto date noise regulations specific for industrial wind turbines adequate to protect public health and safety.

Therefore be it resolved that the Maine Medical Association work with health organizations and regulatory agencies to provide scientific information of known medical consequences of wind development in order to help safeguard human health and the environment.

**AND BE IT FURTHER RESOLVED** that the Maine Medical Association 1) work with other stakeholders to encourage performance of studies on health effects of wind turbine generation by independent qualified researchers at qualified research institutions; 2) ensure that physicians and patients alike are informed of evidence-based research results.

**Web link:** http://www.mainemed.com/annual/2009/2009_Proposed_...
**Download File(s):**
MMA_2009_Proposed_Resolutions.pdf (153.3 kB)

Filed under : Impact on People : Maine

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Save Western NY

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# Health & Safety

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HEALTH CONCERNS

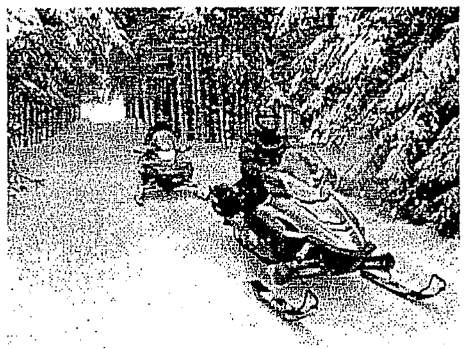
SAFETY ISSUES

Wind Concerns

Economics
Environment
Danger To Wildlife
Health & Safety
Turbine Noise
Landowner Liability
Property Values
Living With Wind
Gallery

Notable Quotes
On Wind

*"Wind companies steadfastly maintain that there is no problem with ice throw. A 2003 study concluded that New York has the iciest conditions in the entire country. But developers in New York State routinely ignore evidence that ice can be thrown over 1600 feet by placing turbines less than 500 feet from roadways."* __ from Remarks Delivered To The Assembly Committee On Energy And The Subcommittee On Renewable Energy, Examining Policy And Implementation Plans For The RPS Program March 7, 2006 by an Ad Hoc Coalition Of Local Community Groups In Upstate New York. Click here for the full transcript.



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## HEALTH CONCERNS

### Clinical Study of "Wind Turbine Noise Syndrome"

**Nina Pierpont, MD, PhD**

Nina Pierpont, MD, PhD, Fellow of the American Academy of Pediatrics and a former clinical professor of pediatrics at the College of Physicians and Surgeons, Columbia University, New York, New York, has begun a clinical study of "wind turbine noise syndrome."

Dr. Pierpont is asking anyone living near wind turbines and suffering ill health effects which he/she suspects are a result of the wind turbines to contact her at either (518) 483-6481 (Malone, New York, USA) or pierpont@westelcom.com (www.ninapierpont.com). She will do a telephone interview (takes about 30 minutes), where your identity will be held strictly confidential. What she is after is evidence and data (as with any medical research project, your identity would remain confidential, always and forever).

Dr. Pierpont's study will be published in a leading clinical medical journal sometime within the next 12 months, she expects. One of the purposes of the study is to influence public policy, around the world, to ensure the proper, medically-responsible siting of wind turbines.

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A summary of Dr. Pierpont's credentials is here.

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• **Industrial Wind Turbines, Infrasound and Vibro-Acoustic Disease (VAD)**: May 31, 2007...Documented in a press release dated May 31, 2007 from the Vibro-Acoustic Disease (VAD) research group in Portugal, people living in the shadow of industrial wind turbines have moved a step closer to understanding the nature of the Wind Turbine Syndrome many of them experience and complain about.

Professor Mariana Alves-Pereira, Dept. of Environmental Sciences & Engineering, New University of Lisbon, Caparica, Portugal, has for many years been part of a team of physicians and scientists studying the pathophysiology of low-frequency noise and infrasound on humans. She is Assistant Coordinator of the Vibroacoustic Disease Project. Alves-Pereira and colleagues have been doing epidemiologic studies of airline pilots and technicians and other people who are chronically exposed to low-frequency noise and infrasound. The effects are grim: cardiovascular, respiratory, neurologic, and renal pathology and symptoms, which they call vibroacoustic disease (VAD).

*VAD is well established in the clinical literature. It has been amply documented and is readily detected by a variety of diagnostic tests.

Alves-Pereira (an acoustical engineer) and Dr. Nuno Castelo Branco (a surgical pathologist) recently took numerous noise/vibration measurements within a Portuguese home surrounded by four (4) industrial wind turbines. The closest turbine is nearly 1000 feet (300 meters), from the affected home. The turbines have been operating since November 2006. The report concludes:

"These results irrefutably demonstrate that windmills in the proximity of residential areas produce acoustical environments that can lead to the development of VAD in the nearby home-dwellers. In order to protect Public Health, ILFN-producing devices must not be placed in locations that will contaminate residential areas with this agent of disease."

The scientific report on this research will be formally presented at Internoise 2007, to be held on 28-31 August in Istanbul, Turkey.

**Noise radiation from wind turbines installed near homes: Effects on health, with an annotated review of the research and related issues"**: Dr. Amanda Harry M.B.Ch.B.P.G.Dip.E.N.T. Barbara J. Frey and Peter J. Hadden, February 2007... Likely the best single source to date within the emerging body of documentation on health issues effected by industrial wind turbines. The review concludes that a safe buffer zone of at least 2km should exist between family dwellings and industrial wind turbines of up to 2MW installed capacity, with greater separation for a wind turbine greater than 2MW installed capacity. Also included is a lengthy annecdotal compilation regarding property devaluations that occur when wind turbines are sited too close to dwellings and residential lands.

Report abstract:

"Wind turbines are large industrial structures that create obtrusive environmental noise pollution when built too close to dwellings. This annotated review of evidence and research by experts considers the impact of industrial-scale wind turbines suffered by those living nearby. First, the paper includes the comments by some of the families affected by wind turbines, as well as coverage in news media internationally. The experiences described put a human face to the science of acoustics.

Second, the paper reviews research articles within the field of acoustics concerning the acoustic properties of wind turbines and noise. The acoustic characteristics of wind turbines are complex and in combination produce acoustic radiation. Next, the paper reviews the health effects that may result from the acoustic radiation caused by wind turbines, as well as the health effects from noise, because the symptoms parallel one

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another. Primarily, the consequent health response includes sleep deprivation and the problems that ensue as a result. In addition, this paper reviews articles that report research about the body's response not only to the audible noise, but also to the inaudible components of noise that can adversely affect the body's physiology. Research points to a causal link between unwanted sound and sleep deprivation and stress, i.e., whole body physiologic responses.

These injuries are considered in the context of Human Rights, where it is contended that the environmental noise pollution destroys a person's effective enjoyment of right to respect for home and private life, a violation of Article 8 of the European Court of Human Rights Act. Furthermore, the paper considers the consequent devaluation of a dwelling as a measure of part of the damage that arises when wind turbines are sited too close to a dwelling, causing acoustic radiation and consequent adverse health responses..."

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### Le retentissement du fonctionnement des éoliennes sur la santé de l'homme

("Repercussions of wind turbine operations on human health")

March 25, 2006

Ventdubocage has posted a report from the National Academy of Medicine in France, warning of wind turbine noise. Click here for the 192 kb .pdf file in French.

Following is a translation of a notice of the report by Dr. Chantal Gueniot in "Panorama du Médecin", 20 March 2006:

### Wind turbines: The Academy Cautious

"The harmful effects of sound related to wind turbines are insufficiently assessed, warns the Academy.

Wind turbines, which are multiplying throughout the French countryside, will have to be considered as industrial installations and to comply, by that fact, to specific regulations that take account of the harmful effects of sound as particularly produced by these structures, determined a working group assembled by the National Academy of Medicine and presided over by professor Claude-Henri Chouard (Paris).

People living near the towers, the heights of which vary from 10 to 100 meters, sometimes complain of functional disturbances similar to those observed in syndromes of chronic sound trauma. Studies conducted in the neighborhoods of airports have clearly demonstrated that chronic invasive sound involves neurobiological reactions associated with an increased frequency of hypertension and cardiovascular illness. Unfortunately, no such study has been done near wind turbines. But, the sounds emitted by the blades being low frequency, which therefore travel easily and vary according to the wind, they constitute a permanent risk for the people exposed to them.

Since 2 July 2003, the law has required a construction permit for wind turbines over 12 meters, including an impact study if their [combined] power is over 2.5 megawatts. An investigation conducted by the Ddass [Direction Départementale des Affaires Sanitaires et Sociales] in Saint-Crépin (Charent-Maritime) revealed that sound levels 1 km from an installation occasionally exceeded allowable limits. While waiting for precise studies of the risks connected with these installations, the Academy recommend halting wind turbine construction closer than 1.5 km from residences."

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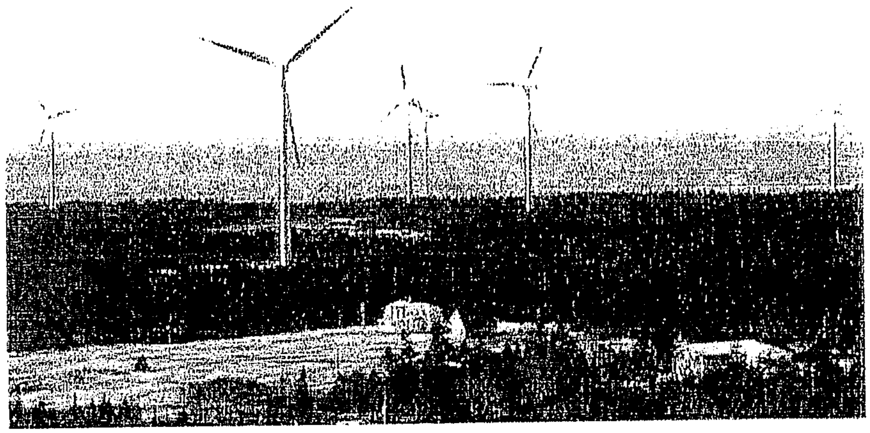
This is a picture of the d'Entremont home in Pubnico, Nova Scotia, where their ancestors have lived since the 1870s. Daniel and Carolyn d'Entremont, with their 6 children, had to abandon it on Feb. 21, 2006, because of "wind turbine syndrome," the cluster of symptoms being found around the world where people live near giant wind turbines.



Dr. Nina Pierpont, of Malone, N.Y., has interviewed them as part of her research into this problem. She testified before the New York State Legislature Energy Committee on March 7. Click here to read her testimony and see the symptoms and risk factors.

Three broadcasts about the d'Entremont family's story have been aired by CBC Radio. You can listen to them in Real Media Stream format (.ram file) here:

March 22: "Running from the wind: A Pubnico man who says a near-by wind farm has driven him from his home. Reporter Lisa Roberts looks into the situation, and speaks with one doctor who says, the family made the right choice." (runs 9:06)

February 28: "Trying to tame the wind:The man in charge of Natural Resources Canada's wind program says he's trying to assess, and relieve, the problems in Pubnico Point." (runs 6:42)

February 27: "Trying to escape the wind: A family in Pubnico Point says the noise and vibration of a nearby wind farm has driven them from their home." (runs 8:12)

(If the links get moved, you can try them here: here, here and here.)

- **Flicker Induced Health Risks**: Chatauqua County Citizens For Responsible Wind..."There are two distinct types of flicker associated with wind turbines. Shadow flicker arises as the shadow of the moving turbine blades moves across the ground. This type of flicker is most common when the sun is at a low angle in the sky, such as mornings and evenings in the summer and just about any time in the winter. These shadows can extend great distances from the base of the turbine, particularly when the shadow is downhill from the turbines... The second type of flicker that can arise from wind turbines is strobing. Strobing occurs when turbine blades catch the sun and reflect it back towards the viewer. Since a turbine blade will be in the position where this reflection takes place up to 60 times per minute (20RPM X 3 blades) the effect is like a strobe light. Strobing can occur at any time of day and can happen anywhere the turbines can be seen - especially from the south, east and west.

The most severe, though by no means the only health risk associated with shadow flicker and strobing is seizure. It is a known fact that flickering or strobing light can cause seizure in susceptible individuals. Other risks due to flicker and strobing include headache, loss of balance, nausea and disorientation. Having a seizure is a severe medical issue but if that seizure, or for that matter disorientation, were to take place while a person was driving a car or operating farm equipment, it could be devastating to that individual and family."

- **Turbines a Health Risk, Warns Foster Doctor**: The Star, March 1, 2005..."Respected South Gippsland doctor, David Iser, has issued a warning about the adverse affects of wind farms on the health of neighboring residents. And he has called

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for further health studies to be carried out by the authorities... 'We are talking about 8 people having health problems as a result of the small Toora Wind Farm. There you have 12 turbines, but it is proposed that there be 48 turbines at Dollar so you could have more than three times the number of health problems... "

- **Health, hazard, and quality of life near wind power installations - How close is too close?**: Nina Pierpont, MD, PhD March 1, 2005..."Dizziness (specifically, vertigo) and anxiety are neurologically linked phenomena. Hence the anxiety and depression seen in association with other symptoms near wind installations are not a neurotic response to symptoms, but rather a neurologically linked response to the balance disturbances people experience from shadow flicker or low-frequency noise... Based on these health effects and hazards, turbines should not be placed within 1700 feet of any road or dwelling. Those living within 1/2 mile (2640 ft) should be apprised that they are likely to experience very bothersome levels of noise and flicker, which continue (though to a lesser degree) to a mile or more from the turbines."

- **Western Morning News and This Is Devon**: 10-14-04...Dr Amanda Harry, who has produced ground-breaking research on the effects of noise from turbines on people living near the Bears Down site explains why she is taking her investigation further.

"I have heard from people all over this country; Cornwall, Wales and Cumbria; from France, Germany, Denmark, Australia, New Zealand and the USA who are experiencing noise problems from nearby wind turbines. So this is not an isolated problem and from the information I have been able to gather, it is not a new problem either... Indeed prolonged exposure to low frequency noise and vibration is known to increase a person's sensitivity to the noise. Much research has been published showing the correlation of health problems and disturbance from noise.

Yet there has been no such research for wind turbines. An initial survey by me indicates that a problem exists and I feel this warrants further in-depth, independent research and investigation. However, the wind industry has taken it upon themselves to state that there isn't a problem without looking into the issues further. It is because of this that I have been working with a physicist and acoustic scientist, Dr David Manley, to try to confirm our observations."

- **HEALTH EFFECTS MUST BE EXPLORED**: Western Morning News, February 2004..."Mounting concerns over the noise effects of wind turbines on the people who live close-by have led to calls for an independent inquiry, as Neil Young reports.

The head of a powerful European committee on the environment has called for an independent inquiry into the health effects of wind turbines. And she is urging Westcountry MPs to put pressure on the Health Secretary, John Reid, and Energy Secretary Stephen Timms, to commission research into the possible impact of turbines on people living close-by.

South West Conservative MEP Dr Caroline Jackson, who is chairman of the European Parliament's Committee on Environment, Public Health and Consumer Policy, says she will also be calling for EU research funding. And she will be writing to the UK's research councils to ask if they would be interested in investigating the reported health effects of headaches, nausea and sleeplessness on people living close to turbines."

- **Wind Farms 'Make people Sick Who Live Up To A Mile Away'**: Catherine Milner, News Telegraph, 25/01/2004... "Onshore wind farms are a health hazard to people living near them because of the low- frequency noise that they emit, according to new medical studies.... Dr Amanda Harry, a local GP who did the research, said: 'People demonstrated a range of symptoms from headaches, migraines, nausea, dizziness, palpitations and tinnitus to sleep disturbance, stress, anxiety and depression. These symptoms had a knock-on effect in their daily lives, causing poor concentration, irritability and an inability to cope'...Similar problems have been found by Dr Bridget Osborne, a doctor in Moel Maelogan, a village in North Wales, where three turbines were erected in 2002. She has presented a paper to the Royal College of General Practitioners detailing a "marked" increase in depression among local people."

**Note: Dr. Osborne's paper was originally, and erroneously, reported as having been "presented to the Royal College of General Practitioners". In May 2004,**

**Dr Osborne confirmed that it was written "for the Royal College of General Practitioners North Wales Faculty Newsletter on the Physiological effects of Wind Turbines".**

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## Safety Issues

- **Warning: don't hug a wind turbine**: May 2006, The Sunday Times, Scotland..."IT HAS been dubbed '21st- century tree-hugging' While Swampy got up close and personal with a Dutch elm, modern eco-enthusiasts are being urged to 'touch a turbine.' ...The trend is backed by the British Wind Energy Association (BWEA), which is calling on the public to visit and touch wind turbines ...But while the trend appears to be growing, the government has warned the public that it could be in for a shock.

  The Department of Trade and Industry (DTI) claims that the turbines carry the risk of electrocution and injury from loose machinery. ...The DTI's engineering inspectorate has issued guidelines discouraging people from touching the turbines following a series of accidents.

  Anti-wind farm campaigners have catalogued hundreds of safety breaches, including turbines collapsing and lumps of ice thrown at high speed. Yesterday it was reported that ScottishPower had ordered a walker to leave the area around a wind farm in Argyll after chunks of ice began falling from the blades."

1,700 feet debris throw

- **Doctor Terry Matilsky On Ice Throw**: Dr. Terry Matilsky, Associate Professor of Physics and Astronomy at Rutgers University, addresses the kinetics of ice throw..."The bottom line is that ice, debris or anything breaking off the wind turbines blades (including the blades themselves) can impact a point almost 1700 feet away from the base of the turbine..."

- **RISK ANALYSIS OF ICE THROW FROM WIND TURBINES**: **Paper presented at BOREAS 6, 9 to 11 April 2003, Pyhä, Finland**, Henry Seifert, Annette Westerhellweg, Jürgen Kröning, et al..."Wind turbines are normally erected far away from houses, industry, etc., as the wind conditions are not favourable in the vicinity of large obstacles... However, the turbines are erected close to roads or agricultural infrastructure in order to avoid long and expensive access roads for erection and maintenance. This induces a risk for persons passing by the wind turbines, cars passing the streets if ice fragments fall down from a turbine. Especially in the mountainous sites or in the northern areas icing may occur frequently and any exposed structure - also wind turbines - will be covered by ice under special meteorological conditions. This is also true if today's Multi Megawatt turbines with heights from ground to the top rotor blade tip of more than 150 m can easily reach lower clouds with supercooled rain in the cold season, causing icing if it hits the leading edge."...

  "...(page 2) If a wind turbine operates in icing conditions which are described in [1], two types of risks may occur if the rotor blades collect ice. The fragments from the rotor are thrown off from the operating turbine due to aerodynamic and centrifugal forces or they fall down from the turbine when it is shut down or idling without power production..."...

  "...(page 5) In principle, a shut down wind turbine does not differ from other structures like towers, antenna masts, masts of power lines, etc. concerning ice accretion. Depending on the rotor position of the braked or idling rotor different fall widths along the prevailing wind will result at the end of the icing event and increasing temperatures. For automatically detecting ice on the rotor blades, several methods can be recommended. However, at present all these methods or instruments have to be improved and further validated... Observation showed that ice fragments which fall from a stopped rotor break into smaller parts on the way down to the ground. In the worst case - large ice fragments reach longer distances from the still standing rotor - two meter long fragments have been investigated."...

"...Conclusion: The experience and the results of many calculations show that during operation small fragments are hitting the ground in a larger distance than those with a big area whereas from stopped turbines the larger pieces can be transported wider than small ones. However, provided that the turbine is operating the area of risk is larger than at standstill. In both cases the wind direction is an important parameter for the assessment of possible risk and an important parameter for the control systems concerning its behaviour during icing events. Ice sensors and also ice detection by using power curve plausibilisation or two anemometers - oneheated, one unheated - is not reliable enough at the moment and needs to be improved. There is still a lot of information required from operators after icing events in their wind farms. Observation of the turbines and especially the blades by web cameras proved to be a suited, but time consuming method in the Tauernwind project. The calculation methods as well as the assumptions made for the ice fragments have to be improved and validated against observation, if available."...

"...As a general recommendation it can be stated that wind farm developers should be very careful at ice endangered sites in the planning phase and take ice throw into account as a safety issue. Each incident or accident caused by ice throw is an unnecessary event and will decrease the public acceptance of wind energy."

- **Man Dies In Wind Tower Fire**: Associated Press, Nov 11, 2005..."A South Dakota man died and two people were injured Friday in a wind tower fire in southwestern Minnesota. Benjamin James Thovson, 26, of Sioux Falls, S.D., died at the scene. He fell about 210 feet, Deputy Randy Donahue said. The other two were able to climb down and escape, but were taken to a local hospital.

  When help arrived, Donahue said, 'the wind generator was engulfed in flames.'"

- **WHITE PAPER: WIND FARMS AND THEIR EFFECTS ON PUBLIC SAFETY RADIO SYSTEMS**: SUMMARY:... "In many parts of the country, wind farms are being installed to alleviate the need to build more electrical generating plants. These wind farms can have a profound effect on your public safety, utility, and governmental microwave systems by chopping and reflecting the microwave beam.

  WHAT YOU SHOULD DO: Notify your city and county zoning authority that any application for a wind farm can profoundly affect your emergency communications system and a design review focused on the wind farm's effects on critical communication systems."

- **Wisconsin Lieutenant Governor Says She Is Stunned At Windfarm-radar Controversy** : May 12, 2006, Radio Plus, INC...The Wisconsin Lieutenant Governor is weighing in on news that state wind energy projects are on hold because of Homeland Security radar concerns. Renew Wisconsin says an open ended stop work order is in place for more than a dozen wind projects...including the Horicon Marsh windfarm. The projects are on hold until a turbine blade-radar impact study is complete and published in the Congressional Report. Lieutenant Governor, Barbara Lawton, tells AM 1170 WFDL's Between the Liens program she is absolutely stunned to hear the news. Lawton says you would think the potential radar concern would have been addressed years ago.

Effect on Radar?

- **Why do wind turbines confuse military radar?**: March 4, 2004, David Adam, The Guardian..."The rotating turbine blades fool techniques used to filter out tall buildings, trees and other stationary objects. And because different blades can be picked out during different radar sweeps, banks of turbines appear as a confusing, twinkling mass on screens that can make genuine targets difficult to pick out... There are even concerns that turbines cast a radar shadow behind them, within

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which enemy planes would be invisible, though recent measurements indicate that it would last for only a few hundred metres and would hide only very small objects."

- **Windfarm plan hits turbulence**: May 2002, The Scotsman..."Plans to build Europe's largest windfarm on a moor south of Glasgow threatens the lives of thousands of airline passengers flying in to the city's airport, according to its owner... A senior air traffic controller at Glasgow Airport said: 'If this windfarm goes ahead we will have a disaster waiting to happen. It is every air traffic controller's nightmare when a snowstorm of blips shows up on the radar screen.'

- **Ministry of Defence and Radar Interference**: Humble Hill, Kielder... "In the Spring 2000 edition of OpenView we featured an article about the need to take account of military and civil radar interference from windfarms. Two projects (07-02Graigenlee Fell in Galloway and 08-07Humble Hill, Kielder Forest, Northumberland ) were mentioned and both have since been rejected or withdrawn after MOD objections."

  "..the Ministry of Defence objected to the original proposal on the grounds that the wind turbines would interfere with primary and secondary radar therefore impairing the effectiveness of the nearby Spadeadam Electronic Tactics Range (EWTR). In an effort to overcome the MOD's objection the Company reduced the number of wind turbines and reconfigured their location on the site. To this effect the Company submitted a variation to the application.........the MOD maintained their original objection, that is, a windfarm operating in the vicinity of the ETWR would be unacceptable as the training facilities of the EWTR are unique and imperative for the front-line training of RAF crews. MOD believe that the proposed windfarm would interfere both with radar and also with low flying, creating an acute safety hazard to both to members of the public and RAF crews.The MOD indicated that current studies have not conclusively proved that the rotating action of wind turbine blades has no effect on ground and airborne radar. Therefore they rely on their own research which concludes that wind turbines cause interference to primary surveillance radar and also that detection and tracking of aircraft flying over a windfarm is extremely difficult since the responses between the aircraft and the turbine cannot be distinguished.

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National Wind Watch

July 3, 2009
Health, Noise, Regulations

# Sleep disturbance and wind turbine noise

**Hanning, Christopher**

Report by Dr Christopher Hanning, BSc, MB, BS, MRCS, LRCP, FRCA, MD, on behalf of Stop Swinford Wind Farm Action Group (SSWFAG [1]) — June 2009

2.2.4. Noise interferes with sleep in several ways. Firstly, it may be sufficiently loud or annoying to prevent the onset of sleep or the return to sleep following an awakening. It is clear also that some types of noise are more annoying than others. Constant noise is less annoying than irregular noise which varies in frequency and loudness, for example, snoring, particularly if accompanied by the snorts of sleep apnoea (breath holding). The swishing or thumping noise associated with wind turbines seems to be particularly annoying as the frequency and loudness varies with changes in wind speed and local atmospheric conditions. While there is no doubt of the occurrence of these noises and their audibility over long distances, up to 3-4km in some reports, the actual cause has not yet been fully elucidated (Bowdler 2008). Despite recommendations by the Government's own Noise Working Group, UK research in this area has been stopped.

1.9 – 2.5 miles

2.2.5. Secondly, noise experienced during sleep may arouse or awaken the sleeper. A sufficiently loud or prolonged noise will result in full awakening which may be long enough to recall. Short awakenings are not recalled as, during the transition from sleep to wakefulness, one of the last functions to recover is memory (strictly, the transfer of information from short term to long term memory). The reverse is true for the transition from wakefulness to sleep. Thus only awakenings of longer than 20-30 seconds are subsequently recalled. Research that relies on recalled awakenings alone may underestimate the effect.

2.2.6. Noise insufficient to cause awakening may cause an arousal. An arousal is brief, often only a few seconds long, with the sleeper moving from a deep level of sleep to a lighter level and back to a deeper level. Because full wakefulness is not reached, the sleeper has no memory of the event but the sleep has been disrupted just as effectively as if wakefulness had occurred. It is possible for several hundred arousals to occur each night without the sufferer being able to recall any of them. The sleep, because it is broken, is unrefreshing resulting in sleepiness, fatigue, headaches and poor memory and concentration (Martin 1997), many of the symptoms of "wind turbine syndrome". Arousals are associated not just with an increase in brain activity but also with physiological changes, an increase in heart rate and blood pressure, which are thought to be responsible for the increase in cardiovascular risk. Arousals occur naturally during sleep and increase with age (Boselli 1998) which may make the elderly more vulnerable to wind turbine noise. Arousals may be caused by sound events as low as 32 dBA and awakenings with events of 42dBA (Muzet and Miedema 2005), well within the measured noise levels of current "wind farms" and the levels permitted by ETSU-R-97 . Arousals in SWS may trigger a parasomnia (sleep walking, night terrors etc.). Pierpont (2009 and personal communication) notes that parasomnias developed in some of the children in her study group when exposed to turbine noise. …

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## Sleep disturbance and wind turbine noise

*May, 2009 by Dr. Christopher Hanning*

**Summary:**

This report centers on the effects of industrial wind turbine noise on sleep as this is the particular area of expertise of the author. It was prepared by Dr. Christopher Hanning who founded, and until retirement, ran the Leicester Sleep Disorders Service, one of the longest standing and largest services in the United Kingdom.

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### Introduction

There can be no doubt that groups of industrial wind turbines ("wind farms") generate sufficient noise to disturb the sleep and impair the health of those living nearby. Section 5.1.1 of the draft New Zealand standard on wind farm noise, 2009, states: "Limits for wind farm noise are required to provide protection against sleep disturbance and maintain reasonable residential amenity." Reports from many different locations and different countries have a common set of symptoms and have been documented by Frey and Hadden (2007). New cases are documented regularly on the Internet. The symptoms include sleep disturbance, fatigue, headaches, dizziness, nausea, changes in mood and inability to concentrate and have been named "wind turbine syndrome" by Dr Nina Pierpont (2006), one of the principal researchers in this field. The experiences of the Davis (2008) and Rashleigh (2008) families from Lincolnshire whose homes were around 900m from wind turbines make salutary reading. The noise, sleep disturbance and ill health eventually

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drove them from their homes. Similar stories have been reported from around the world, in anecdotal form but in large numbers.

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# A Primer on Adverse Health Effects
# and
# Industrial Wind Turbines

March, 2010

Prepared by the Society for Wind Vigilance

www.windvigilance.com


Signed by (Alphabetical order)
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**A Primer on Industrial Wind Turbines**
**and**
**Adverse Health Effects**
**March, 2010**

The American Wind Energy Association and Canadian Wind Energy Association sponsored report entitled "Wind Turbine Sound and Health Effects" (A/CanWEA Panel Review) concludes that "sound from wind turbines does not pose a risk of hearing loss or any other adverse health effect in humans." [1] This denial does not withstand scrutiny.

On January 11, 2010 The Society for Wind Vigilance released a critique of the A/CanWEA Panel Review and concluded that it was "...neither authoritative nor convincing.." and "...independent third party studies must be undertaken to establish the incidence and prevalence of adverse health effects relating to wind turbines. Beyond that a deeper understanding of the potential mechanisms for the impacts must be elucidated in order to define the mechanisms by which the sleep disturbance, stress and psychological distress occur."[2]

On January 19, 2010 The UK National Health Service (NHS) released an independent critique of the A/CanWEA Panel Review and concluded "The link between psychological distress and physical symptoms has not been explored by this report. The acknowledgment that some people exposed to wind turbine noise suffer annoyance suggests that monitoring and maximum permitted levels need to be considered carefully in areas where turbines are planned. Overall, this review will probably not resolve this controversy as there was a lack of high-level evidence on which to base any solid conclusions. What is now needed are studies that compare people exposed to turbine noise with well-matched control subjects who have not had that exposure."[3]

The NHS critique is based on "the best scientific knowledge currently available".

To read the NHS editorial policy visit.
http://www.nhs.uk/aboutNHSChoices/aboutnhschoices/Aboutus/Pages/Editorialpolicy.aspx

Two independent critiques of the same industry sponsored report have come to remarkably similar conclusions.

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[1] W. David Colby, M.D et al., Wind Turbine Sound and Health Effects, An Expert Panel Review 2009, Prepared for American Wind Energy Association and Canadian Wind Energy Association
[2] The Society for Wind Vigilance, Wind Energy Industry Acknowledgement of Adverse Health Effects, An Analysis of the American/Canadian Wind Energy Association sponsored "Wind Turbine Sound and Health Effects An Expert Panel Review, December 2009", 2010 http://windvigilance.com/awea_media.aspx
[3] UK National Health Service, Wind turbine sound 'needs research', Thursday January 28, 2010, http://www.nhs.uk/news/2010/01January/Pages/Wind-turbine-sound-and-health.aspx

Paradoxically the conclusions of the A/CanWEA Panel Review are not supported by its own contents in that it acknowledges wind turbine noise may cause annoyance, stress and sleep disturbance and as a result people may experience adverse physiological and psychological symptoms. [4]

In a radio interview one of the authors of the A/CanWEA Panel Review W. David Colby, M.D. stated:

"We're not denying that there are people annoyed and that maybe some of them are getting stressed out enough about being annoyed that they're getting sick." [5]

The Ontario Ministry of Health and Long Term Care also acknowledge wind turbines may cause annoyance, stress and sleep disturbance.[6]

The A/CanWEA Panel Review acknowledges wind turbine noise induced symptoms may include palpitations, insomnia, nose bleeds, dizziness, nausea, eye strain, feeling vibration and headache. [7]

In 2010 Geoff Leventhall an author of the A/CanWEA Panel Review is quoted as stating "... there was no doubt people living near the turbines suffered a range of symptoms, including abnormal heart beats, sleep disturbance, headaches, tinnitus, nausea, visual blurring, panic attacks and general irritability....it's ruining their lives – and it's genuine...".[8]

"Health Canada advises...that there are peer-reviewed scientific articles indicating that wind turbines may have an adverse impact on human health."[9]

Peer reviewed studies of European industrial wind turbine facilities have documented high annoyance and sleep disturbance in respondents.[10],[11],[12]

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[4] W. David Colby, M.D et al., Wind Turbine Sound and Health Effects, An Expert Panel Review 2009, Prepared for American Wind Energy Association and Canadian Wind Energy Association

[5] W. David Colby, M.D., Sounding Board, 97.9 FM The Beach December 17, 2009

[6] Arlene King M.D., Ontario Ministry of Health and Long Term Care Memorandum, October 21, 2009, http://windvigilance.com/primer_ahe.aspx

[7] W. David Colby, M.D et al., Wind Turbine Sound and Health Effects, An Expert Panel Review 2009, Prepared for American Wind Energy Association and Canadian Wind Energy Association

[8] Countryside News, Wind turbines set to get bigger, January 28 2010 http://www.walesonline.co.uk/countryside-farming-news/countryside-news/2010/01/28/wind-turbines-set-to-get-bigger-91466-25701853/

[9] Safe Environs Program, Health Canada Environmental Assessment Nova Scotia, August 6, 2009, http://windvigilance.com/primer_ahe.aspx

[10] Pedersen, E. and K. Persson Waye. 2004. Perception and annoyance due to wind turbine noise: A dose–response relationship, Journal of the Acoustical Society of America 116: 3460–3470.

[11] Pedersen, E. and K. Persson Waye. 2007. Wind turbine noise, annoyance and self-reported health and well being in different living environments

[12] Pedersen et al., 2008,Project WINDFARMperception Visual and acoustic impact of wind turbine farms on residents

World Health Organization recognizes annoyance and sleep disturbance as adverse health effects. [13]

In 2009 World Health Organization released a 184 page peer reviewed summary of research regarding the risks to human health from noise induced sleep disturbance. Some of the adverse health effect documented in the report include poor performance at work, fatigue, memory difficulties, concentration problems, motor vehicle accidents, mood disorders (depression, anxiety), alcohol and other substance abuse, cardiovascular, respiratory, renal, gastrointestinal, musculoskeletal disorders, obesity, impaired immune system function and a reported increased risk of mortality.[14]

The A/CanWEA Panel Review acknowledges that wind turbine low frequency noise may cause annoyance.[15]

Some of the documented effects of low frequency noise induced annoyance include task performance deterioration, reduced wakefulness, sleep disturbance, headaches, and irritation.[16]

"Unlike higher frequency noise issues, LFN is very difficult to suppress. Closing doors and windows in an attempt to diminish the effects sometimes makes it worse because of the propagation characteristics and the low-pass filtering effect of structures. Individuals often become irrational and anxious as attempts to control LFN fail, serving only to increase the individual's awareness of the noise, accelerating the above symptoms"[17]

The NASA Technical paper "Wind Turbine Acoustics" states "People who are exposed to wind turbine noise inside buildings experience a much different acoustic environment than do those outside....They may actually be more disturbed by the noise inside their homes than they would be outside....One of the common ways that a person might sense the noise-induced excitation of a house is through structural vibrations. This mode of observation is particularly significant at low frequencies, below the threshold of normal hearing."[18]

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[13] World Health Organization, Guidelines for Community Noise,1999
http://www.euro.who.int/mediacentre/PR/2009/20091008_1

[14] World Health Organization, Night Noise Guidelines for Europe, 2009
http://www.euro.who.int/InformationSources/Publications/Catalogue/20090904_12

[15] W. David Colby, M.D et al., Wind Turbine Sound and Health Effects, An Expert Panel Review 2009, Prepared for American Wind Energy Association and Canadian Wind Energy Association

[16] DeGagne et al., Incorporating Low Frequency Noise Legislation for the Energy Industry in Alberta, Canada Source: Journal of Low Frequency Noise, Vibration and Active Control, Volume 27, Number 2, September 2008 , pp. 105-120(16)

[17] DeGagne et al., Incorporating Low Frequency Noise Legislation for the Energy Industry in Alberta, Canada Source: Journal of Low Frequency Noise, Vibration and Active Control, Volume 27, Number 2, September 2008 , pp. 105-120(16)

[18] Harvey Hubbard et al, NASA Technical Document, Wind Turbine Acoustics, 1990

Geoff Leventhall one of the authors of the A/CanWEA Panel Review acknowledges the serious nature of low frequency noise induced annoyance by asserting "The claim that their "lives have been ruined" by the noise is not an exaggeration..."[19]

In a 2009 article the UK National Health Service stated "...it is physically and biologically plausible that low frequency noise generated by wind turbines can affect people..." [20]

The Canadian Wind Energy Association claims that wind turbine "installations meet strict government regulations with respect to sound"[21] but at the same time acknowledges that noise modelling typically used does not purport to consider the worst case and that actual noise levels may exceed that predicted.[22]

According to the Ontario Ministry of Environment "There is currently no scientifically accepted field methodology to measure wind turbine noise to determine compliance or non compliance with a Certificate of Approval limits."[23]

In most jurisdictions there is no requirement for the wind energy industry to monitor or address for wind turbine low frequency noise.

The World Health Organization states:

"The precautionary principle. In all cases noise should be reduced to the lowest level achievable in a particular situation. When there is a reasonable possibility that the public health will be endangered, even though scientific proof may be lacking, action should be take to protect the public health, without awaiting the full scientific proof."[24]

To learn more visit The Society for Wind Vigilance at www.windvigilance.com

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[19] Leventhall HG. Low frequency noise and annoyance. Noise Health [serial online] 2004 [cited 2009 Dec 31];6:59-72. Available from: http://www.noiseandhealth.org/text.asp?2004/6/23/59/31663

[20] UK National Health Service, Are wind farms a health risk? Monday August 3 2009, http://www.nhs.uk/news/2009/08august/Pages/Arewindfarmsahealthrisk.aspx

[21] CanWEA Paper Addressing Concerns With Wind Turbines And Human Health, January 2009

[22] Howe Gastmeier Chapnik Limited, Wind Turbines And Sound: Review And Best Practice Guidelines, Submitted To: CanWEA Canadian Wind Energy Association, February 15, 2007

[23] Correspondence from Ministry of Environment September 30, 2009 ENV1283MC2009-4305, http://windvigilance.com/primer_ahe.aspx

[24] World Health Organization, Guidelines for Community Noise,1999 http://www.euro.who.int/mediacentre/PR/2009/20091008_1

**The Society for Wind Vigilance**





## Promoting Research for Authoritative Wind Turbine Guidelines

### Wind Turbine Noise Sleep and Health by Dr Hanning

Dr. Christopher Hanning concludes in *Wind Turibne Noise, Sleeep and Health*

"...there is compelling evidence that wind turbine noise can and does disturb sleep and impair the health of those living too close and that current guidance is inadequate protection."

"In my expert opinion, from my knowledge of sleep physiology and a review of the available research, I have no doubt that wind turbine noise emissions have been clearly associated with sleep disturbances."

Dr. Hanning has nearly 30 years experience in sleep and its disorders. His expertise in this field has been accepted by the civil, criminal and family courts. Further details about his credentials are cited in the paper.

The paper will be updated from time to time so please check that you have the latest version from the Society for Wind Vigilance website.

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# WIND TURBINE NOISE, SLEEP AND HEALTH

Dr Christopher Hanning. BSc, MB, BS, MRCS, LRCP, FRCA, MD

November 2010

This paper is based on proofs of evidence produced for several UK Planning Inquiries. As such, it concentrates on the regulatory system in the UK. Other jurisdictions will have different systems.

The aim is to inform those seeking to regulate the siting of wind turbines close to human habitation.

The contents may be used freely without acknowledgement.

The paper will be updated from time to time so please check that you have the latest version from the Society for Wind Vigilance website: www.windvigilance.com

# Contents

## Summary

**Section 1** sets out my expertise in sleep medicine and physiology, my brief from CFA, the scope of the report and source material.

**Section 2** reviews the basic physiology of sleep. Noise can disturb sleep by causing awakenings, which are remembered and arousals, which are not recalled but are more likely. Both disrupt sleep making it unrefreshing. Research on the effects of wind turbine noise has concentrated on remembered awakenings and has thus underestimated the effects.

Inadequate or poor quality sleep has many health consequences apart from daytime sleepiness and fatigue. These include obesity, poor memory, increased risk of diabetes, heart disease and high blood pressure. Vulnerable groups such as children and the elderly may be at greater risk.

**Section 3** reviews research on wind turbine noise, sleep disturbance and health. These include the major contributions of van den Berg and Pedersen and the dose-response relationship derived from their data. Also considered are the Salford study and the Hayes McKenzie Partnership study commissioned by the DTI.

Recent major reports by WHO and RIVM are reviewed, both of which mandate lower night time noise levels than are permitted by ETSU-R-97. Predicted external turbine noise should not exceed 35dB to avoid disturbance to sleep and 40dB to avoid risks to health. Experience of existing wind farms mandates a setback of at least 1.5km in order to avoid disturbance to sleep.

It is concluded that there is compelling evidence that wind turbine noise can and does disturb sleep and impair the health of those living too close and that current guidance is inadequate protection.

**Section 4** reviews the means of mitigating wind turbine noise to prevent sleep disturbance. It is concluded that external turbine noise levels of less than 35dB(A) or a setback of at least 1.5km of the turbines is necessary to prevent unacceptable levels of sleep disturbance and potential risk to health.

**Section 5** reviews UK planning guidance and argues that the evidence presented constitute material considerations

**Section 6** presents the conclusions of the report.

**Section 7** lists the documents cited in support of this paper.

# 1. Introduction

## 1.1 The author

1.1.1. My name is Dr Christopher Hanning, Honorary Consultant in Sleep Disorders Medicine to the University Hospitals of Leicester NHS Trust, based at Leicester General Hospital, having retired in September 2007 as Consultant in Sleep Disorders Medicine. In 1969, I obtained a First class Honours BSc in Physiology and, in 1972, qualified in medicine, MB, BS, MRCS, LRCP from St Bartholomew's Hospital Medical School. After initial training in anaesthesia, I became a Fellow of the Royal College of Anaesthetists by examination in 1976 and was awarded a doctorate from the University of Leicester in 1996. I was appointed Senior Lecturer in Anaesthesia and Honorary Consultant Anaesthetist to Leicester General Hospital in 1981. In 1996, I was appointed Consultant Anaesthetist with a special interest in Sleep Medicine to Leicester General Hospital and Honorary Senior Lecturer to the University of Leicester.

1.1.2. My interest in sleep and its disorders began over 30 years ago and has grown ever since. I founded and ran the Leicester Sleep Disorders Service, one of the longest standing and largest services in the country, until retirement. The University Hospitals of Leicester NHS Trust named the Sleep Laboratory after me as a mark of its esteem. I was a founder member and President of the British Sleep Society and its honorary secretary for four years and have written and lectured extensively on sleep and its disorders and continue to be involved in research. My expertise in this field has been accepted by the civil, criminal and family courts. I chaired the Advisory panel of the SOMNIA study, a major project investigating sleep quality in the elderly, and sit on Advisory panels for several companies with interests in sleep medicine. I am an Associate Member of the General Medical Council, chairing Investigation Committee hearings and Registration Panels. In 2010, I was invited to join the Board of the Society for Wind Vigilance.

## 1.2. Scope of report.

1.2.1. This report centres on the effects of industrial wind turbine noise on sleep and consequent effects on health as this is the particular area of expertise of the author.

## 1.3. Source material

1.3.1. A full list of the publications cited and other source material is given in Section 7 and are cited in the text. Material was obtained by searching the Web of Science database using the search terms "Noise", "Sleep" and "Wind turbine", internet searches using the same words and scrutiny of the reference lists of published articles and reviews. Where several articles come to the same conclusion, only the most recent may be cited, in the interests of brevity. As far as possible, articles published in peer reviewed journals are cited. However, it is inevitable that some of the material is available only on the internet reflecting the paucity of government sponsored research, particularly in the UK.

# 2. Background

## 2.1. Introduction

2.1.1. There can be no reasonable doubt that industrial wind turbines whether singly or in groups ("wind farms") generate sufficient noise to disturb the sleep and impair the health of those living nearby and this is now widely accepted. In reviewing potential health impacts of sustainable energy sources, three leading members of the National Institute of Environmental Health Sciences, part of the US National Institutes of Health, state: *"Wind energy will undoubtedly create noise, which increases stress, which in turn increases the risk of cardiovascular disease and cancer."* (Gohlke et al. 2008. Section 5.1.1 of the draft New Zealand standard on wind farm noise, 2009, states: *"Limits for wind farm noise are required to provide protection against sleep disturbance and maintain reasonable residential amenity."* ETSU-R-97, the UK guidance on wind turbine noise, is predicated in part on the WHO guidelines available at the time and so was intended to avoid sleep disturbance. As will be demonstrated, the ETSU-R-97 night time limits were set too high to prevent sleep disturbance. Reports from many different locations and different countries have a common set of symptoms and have been documented by Frey and Hadden (2007). New cases are documented regularly on the Internet. The symptoms include sleep disturbance, fatigue, headaches, dizziness, nausea, changes in mood and inability to concentrate and have been named "wind turbine syndrome" by Dr Nina Pierpont (2006). The experiences of the Davis (2008) and Rashleigh (2008) families from Lincolnshire whose homes were around 900m from wind turbines make salutary reading. The noise, sleep disturbance and ill health eventually drove them from their homes. Similar stories have been reported from around the world, usually in anecdotal form but in considerable numbers.

2.1.2 The WHO Environmental Burden of Disease – European countries project (EBoDE) (WHO, 2009a) selected nine environmental stressors for study, including noise (S6). *"The health effects of environmental noise were selected to cover psychosocial (sleep disturbance), cardiovascular effects* *(elevated blood pressure, IHD including myocardial infarction) and learning performance."* These choices emphasise the importance that WHO place upon the effects of environmental noise on sleep disturbance.

2.1.3. One New York based wind turbine developer is reported as offering future neighbours of wind turbines payments of $5,000 in exchange for a waiver promising not to complain about excessive noise of the turbines once the turbines become operational (Yardley, 2010) which may be interpreted as tacit acceptance by at least one developer that noise complaints are highly likely.

## 2.2. Sleep, sleep physiology and the effects of noise

2.2.1. Sleep is a universal phenomenon. Every living organism contains, within its DNA, genes for a body clock which regulates an activity-inactivity cycle. In mammals, including humans, this is expressed as one or more sleep periods per 24 hours. Sleep was previously thought to be a period of withdrawal from the world designed to allow the body to recuperate and repair itself. However, modern research has shown that sleep is primarily by the brain and for the brain. The major purpose of sleep seems to be the proper laying down and storage of memories, hence the need for adequate sleep in children to facilitate learning and the poor memory and cognitive function in adults with impaired sleep from whatever cause.

2.2.2. Inadequate sleep has been associated not just with fatigue, sleepiness and cognitive impairment but also with an increased risk of obesity, impaired glucose tolerance (risk of diabetes), high blood pressure, heart disease, cancer, depression and impaired immunity as shown by susceptibility to the common cold virus. Sleepy people have an increased risk of road traffic accidents. Sleepiness, as a symptom, has as much impact on health as epilepsy and arthritis. It is not insignificant.

2.2.3 Humans have two types of sleep, slow wave (SWS) and rapid eye movement (REM). SWS is the deep sleep which occurs early in the night while REM or dreaming sleep occurs mostly in the second half of the night. Sleep is arranged in a succession of cycles, each lasting about 90 minutes. We commonly wake between cycles, particularly between the second and third, third and fourth and fourth and fifth cycles. Awakenings are not remembered if they are less than 30 seconds in duration. As we age, awakenings become more likely and longer so we start to remember them.

Even while deeply asleep, the brain is processing sounds and deciding whether they merit awakening either because the sound has meaning or constitutes a threat. For example, at the same noise level, awakening is more likely when one's name is called rather than a non-specific noise. Similarly, a mother will wake when her baby cries but not for a passing car.

2.2.4. Noise interferes with sleep in several ways. Firstly, it may be sufficiently audible and annoying to prevent the onset of sleep or the return to sleep following an awakening. It is clear also that some types of noise are more annoying than others. Constant noise is less annoying than irregular noise which varies in frequency and loudness, for example, snoring, particularly if accompanied by the snorts of sleep apnoea (breath holding). The swishing or thumping impulsive noise associated with wind turbines seems to be particularly annoying as the frequency and loudness varies with changes in wind speed and local atmospheric conditions and the character of the noise may be perceived as threatening. While there is no doubt of the occurrence of these noises and their audibility over long distances, up to 3-4km in some reports, the actual cause has not yet been fully elucidated (Bowdler 2008). Despite recommendations by the Government's own Noise Working Group, government sponsored research in this area has been stopped. Stigwood (2008), an independent noise consultant, has demonstrated that this noise pattern is common with large turbines.

2.2.5. Secondly, noise experienced during sleep may arouse or awaken the sleeper. A sufficiently loud or prolonged noise will result in full awakening which may be long enough to recall. Short awakenings are not recalled as, during the transition from sleep to wakefulness, one of the last functions to recover is memory (strictly, the transfer of information from short term to long term memory). The reverse is true for the transition from wakefulness to sleep. Thus only awakenings of longer than 20-30 seconds are subsequently recalled. Research that relies on recalled awakenings alone will therefore underestimate the effect.

2.2.6. Noise insufficient to cause awakening may cause an arousal. An arousal is brief, often only a few seconds long, with the sleeper moving from a deep level of sleep to a lighter level and back to a deeper level. Because full wakefulness is not reached, the sleeper has no memory of the event but the sleep has been disrupted just as effectively as if wakefulness had occurred. It is possible for several hundred arousals to occur each night without the sufferer being able to recall any of them. The sleep, because it is broken, is unrefreshing resulting in sleepiness, fatigue, headaches and poor memory and concentration (Martin 1997), many of the symptoms of "wind turbine syndrome". Recent research (Dang-Vu, 2010) has shown that some subjects are more easily aroused than others.

Arousals are associated not just with an increase in brain activity but also with physiological changes, an increase in heart rate and blood pressure, which are thought to be responsible for the increase in cardiovascular risk. A clear relationship between high blood pressure and aircraft noise exposure has been shown by the HYENA consortium (Haralabidis 2008, Jarup 2008) and between traffic noise and high blood pressure for adults (Barregard 2009) and, worryingly, for preschool children (Belojevic 2008). The MESA study has suggested a link between exposure to traffic and alterations in heart function (Van Hee 2009) and Selander and colleagues (2009) have suggested a link with myocardial infarction (heart attack) but neither could separate noise effects from pollution. Arousals occur naturally during sleep and increase with age (Boselli 1998), as do awakenings which may make the elderly more vulnerable to wind turbine noise. Arousals may be caused by sound events as low as 32 dB(A) and awakenings with events of 42dB(A) (Muzet and Miedema 2005). The studies of Dang-Vu and colleagues (2010) suggest that arousals may occur at even lower sound levels in susceptible individuals (Fig 4). Arousals in SWS may trigger a parasomnia (sleep walking, night terrors etc.). Pierpont (2009) notes that parasomnias developed in some of the children exposed to turbine noise in her study group.

2.2.7. Arousals are caused by aircraft, railway and traffic noise. In one study of aircraft noise, arousals were four times more likely to result than awakenings (Basner 2008a) and resulted in daytime sleepiness (Basner 2008b). Freight trains are more likely to cause arousals than passenger trains, presumably because they are slower, generating more low frequency noise and taking longer to pass (Saremi 2008). The noise of wind turbines has been likened to a "passing train that never passes" which may explain why wind turbine noise is prone to cause sleep disruption. A recent study of over 18000 subjects has shown a link between exposure to traffic noise and "the risk of getting up tired and not rested in the morning (de Kluizenaar, 2009). This study, together with that of Basner (2008b) confirms that excessive noise disturbs sleep sufficiently to impair its restorative properties and adds credence to the anecdotal reports of those living near wind turbines.

2.2.8. Studies of different alarm signals have shown that arousals and awakenings occur at lower sound levels with low frequency sounds than those of higher frequency (Bruck 2009). Repeated short beeps of 400-520Hz were most intrusive, leading to arousal and awakening. Wind turbine noise often has a considerable low frequency component and has an impulsive nature which may, in part, explain its adverse effect on sleep.

2.2.9. It is often claimed that continual exposure to a noise results in habituation, i.e. one gets used to the noise. There is no research to confirm this assertion although it has been suggested that the absence of noise for those usually subjected to high levels may cause insomnia (HPA 2009 5.29). A recent small study (Pirrera et al. 2009) looking at the effects of traffic noise on sleep efficiency suggests that habituation does not occur. Griefahn and colleagues (2008) have shown that the increases in heart rate with traffic noise induced arousals show no habituation.

2.2.10. Sleep disturbance and impairment of the ability to return to sleep is not trivial as almost all of us can testify. The elderly may be more vulnerable, not just because they have more spontaneous awakenings than the young but because their high frequency hearing loss may remove some of the masking of the lower frequency noise characteristic of wind turbines. In the short term, the resulting deprivation of sleep results in daytime fatigue and sleepiness, poor concentration and memory function. Accident risks increase. In the longer term, sleep deprivation is linked to depression, weight gain, diabetes, high blood pressure and heart disease. There is a very large body of literature but please see Meerlo et al., 2008 for recent work on this subject as well as the 2009 WHO/EU Night Noise Guidelines for Europe (WHO, 2009) and the recent reports of the Health Protection Agency (HPA 2009) and DEFRA (Berry and Flindell, 2009).

2.2.11. Sleep spindles are short bursts of high frequency oscillation seen in the brain's electrical activity (electroencephalogram, EEG) during SWS and are a marker of sleep stability. Recent research has shown that subjects with a higher spindle rate are less likely to show an arousal in response to a transient noise than a subject with a lesser rate and are less likely to report that noise disturbs their sleep (Dang-Vu et al., 2010). The spindle rate decreases with age, explaining the vulnerability of the elderly to noise induced sleep disruption. Insomniacs, when asleep, do not have necessarily have reduced spindle counts, thus suggesting that sensitivity to noise while asleep is not purely psychological but has a physical basis thus confirming the finding that noise sensitivity is, to a large degree, inherited.

A plot of sound level against the probability of stable sleep is presented (Figure 4). This is effectively an inverted dose-response curve of log sound pressure against the likelihood of an arousal. The study only examined noise stimuli of 40-70dB(A). However, it is reasonable to extrapolate backwards to lower noise levels. For subjects with a low spindle rate, even at a stimulus level of 35dB(A) there is an approximate 50% probability of an arousal and a 30% probability at 30dB(A). The subjects were 26.3 (± 7.5) years of age. Older subjects would be expected to have even fewer spindles and to be even more sensitive to noise.

## 2.3. Psychological factors and Noise sensitivity

2.3.1. There is considerable interaction between the psychological response to noise and sleep disturbance, each worsening the other. It is well recognised that psychological factors and personality traits influence the response to noise. Approximately 15% of the population are noise sensitive and have both a lowered annoyance level and an enhanced cortisol response, a physiological marker of stress. Noise sensitivity is considered to be a stable, partly heritable, personality trait; the noise sensitive being at one end of a continuum with the noise tolerant at the other. It is often implied that those who are highly annoyed by noise, including wind turbine noise, are motivated simply by a dislike of the noise source or are psychologically disturbed in some way. This is simply not the case, the response of the noise sensitive being as normal a reaction as that of the noise tolerant.

2.3.2. The noise sensitive are more likely to have stress related disorders, anxiety, headaches etc and poor sleep than the average. They are more likely to be found in the countryside where noise disturbance is less. Pedersen (2004) reported that 50% of her rural subjects were rather or very noise sensitive. Noise sensitivity is more likely in those with brain injury and psychological disorders such as dyslexia and increased community noise may exacerbate depression in susceptible individuals.

Flindell and Stallen (1999) listed factors influencing the degree of annoyance to noise:

- Perceived predictability of the noise level changing
- Perceived control, either by the individual or others
- Trust and recognition of those managing the noise source
- Voice, the extent to which concerns are listened to
- General attitudes, fear of crashes and awareness of benefits

- Personal benefits, how one benefits from the noise source
- Compensation, how one is compensated due to noise exposure
- Sensitivity to noise
- Home ownership, concern about plummeting house values
- Accessibility to information relating to the noise source

to which may be added:

- Perceived value of the noise source
- Expectation of peace and quiet
- Visual impact

Disempowerment and loss of control is a common theme from reports of those subjected to excessive wind turbine noise. The impulsive character of the noise is perceived as threatening and it can not be escaped being audible within the home, the usual source of refuge and quiet to permit restoration (Pedersen 2008). The end result is fear and anger at loss of control over the living environment with increased stress responses including increased difficulty in initiating and maintaining sleep. The increased wakefulness at night and the lower quality sleep increase the impact of nocturnal turbine noise on sleep, increasing the daytime fatigue and stress and so on in a reinforcing cycle.

2.3.3. Petrie, a New Zealand health psychologist, in evidence for the developers to the Wellington Environment Court, claims that reactions to wind turbine noise are akin to the health scares associated with new technologies and draws parallels with previous health scares such as mobile phone masts and electricity (Petrie, 2010). He claims that this explains adverse responses to wind turbine noise at sound levels deemed safe by regulators such as the WHO. In so doing, he makes the unwarranted assumption that the sound levels are indeed safe and overlooks the many observations that turbine noise is often greater than predicted and more intrusive and annoying than other noise sources. Wind turbine noise contains more low frequency sound than other common noises also. Previous health scares he cites have generally been about emanations which are undetectable by the human senses, such as microwave radiation, and where there is no obvious mechanism for the putative harm. This is certainly not true for wind turbine noise which is readily detected and the mechanism for harm clear. There is no dispute that psychological factors play a part in any reaction to turbine noise, to suggest that they are the sole explanation is contrary to the evidence.

2.3.4. The psychological response to noise and noise sensitivity is a complex area and an excellent review is given by Shepherd, a psychoacoustician (Shepherd 2010).

# 3. Wind turbine noise, sleep and health

## 3.1. Introduction

3.1.1. The evidence above demonstrates that it is entirely plausible that wind turbine noise has the potential to cause arousals, sleep fragmentation and sleep deprivation. As noted above, the draft New Zealand standard on wind farm noise (2009) acknowledges that sleep disturbance is the major adverse consequence of wind turbine noise for humans.

3.1.2 Unfortunately **all** government and industry sponsored research in this area has used **reported awakenings** from sleep as an index of the effects of turbine noise and tend to dismiss the subjective symptoms. Because most of the sleep disturbance is not recalled, this approach seriously **underestimates** the effects of wind turbine noise on sleep. It may be argued also that it is not the number of awakenings or arousals that are important but their overall effects on those subjected to the noise. Assessments of sleep quality and daytime functioning (sleepiness, fatigue and cognitive function) would be more appropriate outcome measures.

## 3.2. Early research.

3.2.1. Surveys of residents living in the vicinity of industrial wind turbines show high levels of disturbance to sleep and annoyance. A 2005 survey of 200 residents living within 1km of a 6 turbine, 9MW installation in France showed that 27% found the noise disturbing at night (Butre 2005). A similar US survey in 2001 (Kabes 2001) of a "wind farm" in Kewaunee County, Wisconsin reported that 52% of those living within 400-800 metres found the noise to be a problem, 32% of those living within 800-1600 metres and 4% of those within 1600 and 3200 metres. 67% of those living within 250 to 400 metres and 35% of those within 400-800 metres reported being awoken by the sound in the previous year. The principal health problem reported by the 223 respondents was sleep loss. The landscape of Kewaunee County is described as "undulating to gently rolling". Pedersen and Waye (2004) reported that "16% (*n*=20, 95%CI: 11%–20%) of the 128 respondents living at calculated external turbine noise exposure above 35.0 dB LAeq stated that they were disturbed in their sleep by wind turbine noise." All of these studies use reported awakenings and may therefore underestimate the effects of wind turbine noise on sleep.

3.2.2. Phipps and others (2007) surveyed 1100 New Zealand households sited up to 3.5 km from a wind farm, 604 responded. 75% of all respondents reported being able to hear the noise. Two separate developments have placed over 100 turbines with capacities from 600kW to 1.65MW in a hilly to mountainous area. It has been suggested that mountainous areas may allow low frequency noise to travel further which may explain the long distance over which the turbines were heard. This suggestion tends to be confirmed by a recent study which is detailed below for convenience.

Phipps (2007a) has reported a further analysis of this data. All subjects lived more than 2km from the turbines, 85% living within 3.5km. 13% of 284 respondents heard the turbines at night either frequently or most of the time. 42 households reported occasional sleep disturbance from turbine noise and 26 were disturbed either frequently or most of the time. Phipps concludes that the New Zealand Standard for Wind Turbine Noise should be modified so that "the sound level from the wind farm should not exceed, at any residential site, and at any of the nominated wind speeds, the background sound level ($L_{95}$) by more than 5 dBA, or a level of 30 dBA $L_{95}$, whichever is less."

3.2.3. Bakker and colleagues (Bakker 2009) report their observations on noise problems, including sleep deprivation, associated with wind turbines at least 3km from the affected properties. The Tararua, New Zealand, turbines are sited on a ridge and the affected properties are to the east in a river valley. Noise problems persisted despite the installation of sound reducing glazing. Nocturnal seismic noise monitoring showed noise bursts lasting at least 10 seconds, associated with an easterly wind, which the authors were confident originated from the turbines. The residents confirmed that the noise recorded was identical with that which disturbed their sleep. The authors speculate that the noise was transmitted through the ground. The importance of this report is not the mechanism for sound transmission but scientific confirmation that wind turbines can disturb sleep at distances of 3km. Previous anecdotal reports have often be dismissed as fanciful with assertions that sound transmission over such distances is impossible. While this seems, so far, to be an isolated case, it adds further evidence that much greater setbacks than those currently required are necessary to obviate sleep disturbance.

3.2.4. Van den Berg (2004) found that residents up to 1900 m from a wind farm expressed annoyance with the noise, a finding replicated in his more recent study reported below. Dr Amanda Harry (2007), a UK GP, conducted surveys of a number of residents living near several different turbine sites and reported a similar constellation of symptoms from all sites. A study of 42 respondents showed that 81% felt their health had been affected, in 76% it was sufficiently severe to consult a doctor and 73% felt their life quality had been adversely impacted. This study is open to criticism for its design which invited symptom reporting and was not controlled. While the proportion of those affected may be questioned it nevertheless indicates strongly that some subjects are severely affected by wind turbine noise at distances thought by governments and the industry to be safe.

## 3.3. Project WINDFARMperception

3.3.1. van den Berg and colleagues (2008) from the University of Groningen in the Netherlands have published a major questionnaire study of residents living within 2.5km of wind turbines, Project WINDFARMperception. A random selection of 1948 residents were sent a similar questionnaire to that used by Pedersen in her studies in Sweden (2003, 2004, 2007 and 2008), questions on health, based on the validated General Heath Questionnaire (GHQ), were added. 725 (37%) replied which is good for a survey of this type but, nevertheless, may be a weakness. Non-respondents were asked to complete a shortened questionnaire. Their responses did not differ from full respondents suggesting the latter are representative of the population as a whole.

Questions on wind turbine noise were interspersed with questions on other environmental factors to avoid bias. The sound level at the residents' dwellings was calculated, knowing the turbine type and distance, according to the international ISO standard for sound propagation, the almost identical Dutch legal model and a simple (non spectral) calculation model. The indicative sound level used was the sound level when the wind turbines operate at 8 m/s in daytime -that is: at high, but not maximum power. Ground absorption was set to 1.0, a 100% sound absorbing surface. Typical values are around 0.5 and thus the sound levels may have been under-estimated. Noise exposure ranged between 24 and 54dB LAeq. It is worth noting that the wind industry was approached for assistance in the research but refused. Complaints such as annoyance, waking from sleep, difficulty in returning to sleep and other health complaints were related to the calculated noise levels.

Relevant conclusions include. *"Sound was the most annoying aspect of wind turbines"* and was more of an annoyance at night. Interrupted sleep and difficulty in returning to sleep increased with calculated noise level as did annoyance, both indoors and outdoors. Even at the lowest noise levels, 20% of respondents reported disturbed sleep at least one night per month. At a calculated noise level of 30-35dB LAeq, 10% were rather or very annoyed at wind turbine sound, 20% at 35-40dB LAeq and 25% at 40-43dB LAeq, equivalent to 38-41dB $LA_{90}$, less than the permitted minimum ETSU-R-97 night time level.

3.3.2. Project WINDFARMperception further found that *"Three out of four participants declare that swishing or lashing is a correct description of the sound from wind turbines. Perhaps the character of the sound is the cause of the relatively high degree of annoyance. Another possible cause is that the sound of modern wind turbines on average does not decrease at night, but rather becomes louder, whereas most other sources are less noisy at night. At the highest sound levels in this study (45 decibel or higher) there is also a higher prevalence of sleep disturbance."* The lack of a control group prevents this group from making firmer conclusions about turbine noise and sleep disturbance but it is clear that as ETSU-R-97 permits an exterior night time noise level of 43dB, relying on its calculations will guarantee disturbed sleep for many of those living nearby.

3.3.3. van den Berg concluded also that, contrary to industry belief, road noise does not adequately mask turbine noise and reduce annoyance and disturbance. In addition, the authors compared their results with studies by Miedema on the annoyance from road, rail and air related noise. Wind turbine noise was several times more annoying than the other noise sources for equivalent noise levels (**Fig 1**). Similar data is given by Pedersen (2004) (**Fig 2**) – **see end of text**.

3.3.4 With regard to health it was concluded that: *"There is no indication that the sound from wind turbines had an effect on respondents' health, except for the interruption of sleep. At high levels of wind turbine sound (more than 45 dB(A)) interruption of sleep was more likely than at low levels. Higher levels of background sound from road traffic also increased the odds for* *interrupted sleep. Annoyance from wind turbine sound was related to difficulties with falling asleep and to higher stress scores. From this study it cannot be concluded whether these health effects are caused by annoyance or vice versa or whether both are related to another factor."* The conclusions regarding general health are not justified from the data for the reasons given below and must be disregarded.

3.3.5. Project WINDFARMperception is currently the largest study in this field but the study is not without considerable flaws. The study may be criticised for using calculated noise levels and for not having a control group (residents not living near turbines). While several of the contributors have expertise in the investigation of health matters, none has specific expertise in the physiology and pathophysiology of sleep. The purpose of the study, as its title suggested, was the public perception of wind turbines and their noise. Health questions were added but were of a very general nature. The small number of respondents suggests that any conclusions as to the apparent lack of an effect on health must be regarded as tentative.

3.3.6. The analysis of reported sleep interruption and wind turbine sound levels is flawed by the use of subjects exposed to calculated external turbine sound levels of <30dB(A) (p53) as the "controls". It has been noted by several studies that calculated turbine noise is often less than measured noise and that levels as low as 30dB(A) can cause annoyance (Pedersen 2007). Examination of the odds ratio for different calculated sound levels (Table 7.42) shows that it increases progressively with increasing sound levels starting at 30-35dB(A) and becomes statistically significant for levels >45dB(A). If, as is not impossible, the "control" group had its sleep disturbed by wind turbine noise then the actual effect would be underestimated.

3.3.7. The major objection to the conclusions on health is that the study is grossly under-powered (insufficient subjects were studied for any degree of statistical confidence). Marked ill-health, "Wind turbine syndrome", to the degree reported by Pierpont (2009), does not seem to be common even amongst those exposed to high noise levels. The study tried to detect chronic disease with the GHQ, which is a fairly crude instrument. Assuming that "wind turbine syndrome" affects 1% of those exposed to calculated sound levels >45dB(A) and that 25% of the general population suffer from chronic disease (p47) then at least 30,000 subjects would need to be studied in each group (>45dB(A) v <30dB(A)) to be able to prove a difference with 95% certainty. Even if a prevalence of "wind turbine syndrome" of 5% of those exposed to >45dB(A) is assumed, then there must be at least 1250 subjects in each group. It is possible also that those with a degree of ill health are more vulnerable and more likely to develop symptoms. A general health questionnaire will not detect such people and symptom specific surveys will be required. This study therefore can not conclude that wind turbines do not cause ill health of any degree, it can not even make conclusions about severe ill health.

3.3.8. Pedersen, van den Berg and others (Pedersen 2009a&b) have further analysed the data in an attempt to model a generalised dose-response relationship for wind turbine noise. A noise metric, Lden, was calculated (Miedema 2000). Lden is based on long-term equivalent sound pressure levels adjusted for day (d), evening (e) and night). Penalties of 5 and 10dB are added for evening and night hours respectively to reflect the need for quietness at those times. dB(A) LAeq values for wind turbines may be transformed to Lden values by adding 4.7±1.5 dB (van den Berg 2008). Annoyance is used as the principal human response to wind turbine noise in this analysis. In this context, "annoyance" is more than simply irritation but is a measure of lack of well-being in a wider sense (Pedersen 2009a) and is contrary to the WHO definition of health.

Annoyance increased with increasing sound levels, both indoors and outdoors. The proportion who were rather and very annoyed at different sound levels are shown in Table I. In summary, when outside, 18% were rather or very annoyed at sound levels of 35-40 and 40-45 dB LAeq compared to 7% at 30-35dB LAeq and 2% at <30dB LAeq. When inside, the equivalent figures were 1% at <30dB LAeq, 4% at 30-35dB LAeq, 8% at 35-40dB LAeq and 18% at 40-45dB LAeq. Those respondents who had an economic interest in the turbines had lower levels of annoyance while negative views of the visual impact of turbines increased the likelihood of annoyance.

Although the authors do not seek to recommend minimum sound levels, they do note that turbine noise was more annoying than other sources, with the possible exception of railway shunting yards and was more noticeable at night. They conclude that: *"...night time conditions should be treated as crucial in recommendations for wind turbine noise limits."* Nevertheless, it is clear from this analysis that external predicted turbine sound levels should be less than 35dB LAeq (33dB $LA_{90}$), considerably less than those permitted by ETSU R 97, in order to reduce effects on nearby residents to acceptable levels.

3.3.8. Pedersen (2009a&b) has recently combined the datasets from three studies (Pedersen 2004 (SWE00)) and 2007 (SWE05) and van den Berg 2008 (NL07)) as they used similar questionnaires giving a total of 1764 subjects. A strong correlation was seen in all studies between calculated A weighted sound pressure levels and outdoor annoyance as noted above.

Even at sound pressures of 30-35 dB LAeq, 5-12% of subjects were very annoyed. Correlations were found also between annoyance and symptoms of stress (headache, tiredness, tension and irritability) confirming that "annoyance" is more than irritation and is a marker of impaired health. The sleep disturbance question did not ask causation of the sleep disturbance and a background level would therefore be expected from other causes (traffic noise, weather, etc). Nevertheless, there was a clear increase in levels of sleep disturbance with A-weighted sound pressure in studies SWE00 and NL005. **(Figure 3)**. Pedersen states *"In the first Swedish study (SWE00) the increase of respondents that reported sleep interruption appears to be between the sound level interval 35-40 dB(A) and 40-45 dB(A). The increase came at higher sound levels in the Dutch study (NL07); between the interval 40-45 dB(A) and >45 dB(A)"*. All values are LAeq. There is no true measurement of background levels of sleep disturbance as

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no study had a control group, it is difficult therefore to determine at what sound pressure level turbine noise begins to have an effect. but even the conservative levels suggested above are less than those permitted by ETSU R 97. **Fig 3 see end of text.**

3.3.9. Jabben and colleagues (2009) from RIVM, the Dutch National Institute for Public Health and Environment, were commissioned by the Dutch Government to examine the impact of different values of Lden on the ability to meet targets for onshore wind power generation. They reviewed current evidence and noted that, at present, 440,000 inhabitants (2.5% of the population) were *"receiving significant noise contribution from wind turbine noise of which 1,500 are expected to suffer severe annoyance. It is remarkable that almost half of this number already occurs within the range Lden 30-40db(A)".* Despite this, they recommend an Lden of no more than 40dB(A), which corresponds to a calculated external turbine noise level of about 35dB(A), in order for the Dutch Government to meet its 2011 target for wind turbine installations.

3.3.10. All of the studies cited in this section have used reported sleep disturbance and annoyance in determining maximum sound levels. As noted in Section 2.2, reported sleep disturbances underestimate sleep disturbance and may not reflect actual physiological consequences. The precautionary principle demands that lower sound levels be selected in order to leave a margin of safety.

## 3.4. Pierpont studies

3.4.1. Pierpont (2009) has recently completed a detailed case-series study of 10 families around the world who have been so affected by wind turbine noise that they have had to leave their homes, nine of them permanently. Subjects were selected from respondents to an appeal for those regarding themselves as suffering from ill health as a result of exposure to turbine noise. The turbines ranged from 1.5 to 3MW capacity at distances between 305 to 1500m. The group comprised 21 adults, 7 teenagers and 10 children of whom 23 were interviewed. While this is a highly selected group, the recording of symptoms before, during and after exposure to turbine noise gives it a strength rarely found in similar case-series studies. The subjects described the symptoms of wind turbine syndrome outlined above and confirmed that they were not present before the turbines started operation and resolved once exposure ceased. There was a clear relationship between the symptoms, even in children, and the noise exposure. Pierpont reports also that all adult subjects reported *"feeling jittery inside"* or *"internal quivering"*, often accompanied by anxiety, fearfulness, sleep disturbance and irritability. Pierpont hypothesises that these symptoms are related to low frequency sound and suggests physiological mechanisms to explain the link between turbine exposure and the symptoms.

3.4.2. Of particular concern were the observed effects on children, include toddlers and school and college aged children. Changes in sleep pattern, behaviour and academic performance were noted. 7 of 10 children had a decline in their school performance while exposed to wind turbine noise which recovered after exposure ceased. In total, 20 of 34 study subjects reported problems with concentration or memory.

3.4.3. Pierpont's study mostly addresses the mechanism for the health problems associated with exposure to wind turbine noise rather than the likelihood of an individual developing symptoms. Nevertheless, it convincingly shows that wind turbine noise is strongly associated with the symptoms she describes, including sleep disturbance. She concludes by calling for further research, particularly in children, and a 2km setback distance.

3.4.4. A recent paper (Todd et al, 2008) has shown that the vestibular system in the human ear, the part concerned with detection of movement and balance, is exquisitely sensitive to vibration at frequencies of around 100Hz. Pierpont claims that these findings support her hypotheses although Todd has contradicted these assertions. More recently, Salt (Salt 2010) has suggested that some parts of the inner ear may be sensitive to low frequency noise below the limit of audibility and raises the possibility of influencing function or causing unfamiliar sensations.

3.4.5. Leventhall, formerly Professor and Head of the Institute of Environmental Engineering at South Bank University and an expert on low frequency noise, accepts that the symptoms described by Pierpont's subjects are real but maintains that the low frequency sound energy created by wind turbines is too low to cause direct physiological effects (Pool, 2009 and personal communication 2009). He suggests that the symptoms are a result of psychological stress secondary to noise annoyance, particularly low frequency noise. and sleep disturbance. Similar symptoms were described by Møller and Lydolf (2002).

The NHS Knowledge Service reviewed Dr Pierpont's book (NHS 2009) and concluded: *"No firm conclusions can be drawn from this study as the design was weak and included only 38 people. Participants were asked about their symptoms before they were exposed to wind turbines to provide a control for their symptoms after exposure. This was not a sufficient control as many of the participants were reportedly already convinced that wind turbines caused their symptoms and were actively trying to move out of their homes or had already moved. Further study is needed."*

The call for further research has been heeded in Japan, Yomiuri Shimbun, a leading Japanese newspaper, (November 29th 2009) reports that the Japanese Environment Ministry has commissioned a four year study into the effects of low frequency turbine noise on human health. The question as whether "wind turbine syndrome" is a distinct clinical entity remains unsettled at this time.

A Japanese newspaper, Asahi Shimbun, (Ito and Takeda 2009) in a report of the decision of the Japanese Environment Ministry to investigate the potential health effects of wind turbine noise has reported it's own survey of complaints of wind turbine noise directed at state and local authorities and wind turbine operators in Japan. 30 of 376 locations (8%) had received complaints, 90% of which concerned health problems which included insomnia, headaches, dizziness and buzzing in the ear.

Izumi Ushiyama, president of the Ashikaga Institute of Technology and an expert on wind power generation, is quoted as saying that: "*operators must listen to residents before pushing their projects. Some operators make light of communications with residents in carrying out their projects, which causes friction. This has tarnished the image of wind power generation and blocked its promotion.*"

Ushiyama is quoted also as saying that a third-party "communicator," trusted by both operators and residents, must be called upon to make adjustments because the two sides may become involved in confrontations if left alone to discuss the issue.

This report shows that not only are complaints about wind turbine noise consistent across cultures so also are the symptoms.

## 3.5. DTI report

3.5.1. The UK Department of Trade and Industry (DTI) commissioned a report from the Hayes McKenzie Partnership (HMP) in 2006 which investigated low frequency noise at three UK wind farms. As far as can be determined, no medical or physiological expertise was used in the design of the study. Sound measurements were taken at three of five sites where complaints had been recorded over periods from 1-2 months.

Communication with residents other than those who complained was minimal. However, they did confirm that *"some wind farms clearly result in modulation at night which is greater than that assumed with the ETSU-R-97 guidelines"*. Measured *"internal noise levels were insufficient to wake up residents at these three sites. However, once awoken, this noise can result in difficulties in returning to sleep."*

The lack of physiological expertise in the investigators in not recognising that noise can disturb sleep without actual recalled awakening is a major methodological flaw rendering the conclusions unreliable, as is the short recording period. It is well recognised also that not every resident affected by a nuisance such as noise will actually register a complaint (Health Protection Agency 2009). Many will not be sufficiently literate or confident so to do and others may wish to avoid drawing attention to the problem to protect property prices. They may assume also that protest is futile, which seems to be the experience of many with wind turbine noise. The WHO and other research by DEFRA suggest complaints may represent between 5-20% of sufferers with others seeking alternative coping strategies. Recorded complaints are thus the tip of the iceberg.

3.5.2. It will be claimed also that only 5 of 126 wind energy developments at the time of the study had attracted complaints of noise and thus the matter is trivial. This assertion is, to say the least, disingenuous. Many of the developments at that time were of small turbines set in isolated areas of the countryside, well away from habitation. In addition, as noted above, the proportion of those affected by wind turbine noise who formally complain to their local authority is very small. Research into wind farm noise and health issues in the UK is virtually non-existent and of poor quality. To suggest that there is "no problem" when faced with the large body of evidence presented here is perverse. The conclusion is also contradicted by Moorhouse's study (vide infra) which showed a complaint rate of 20%.

3.5.3. Draft versions of the report (DTI 2006a,b,c) have recently come to light as a result of Freedom of Information requests. They show that HMP had recommended a reduction of the ETSU-R-97 permitted night time limits to 38dB LA90 (40dB LAeq) in the absence of AM with a further penalty of up to 5dB in the presence of modulation. These recommendations were removed from the final version of the report. No scientific explanation for their removal seems to have been offered. An example of removed text follows:

*"The analysis of the external and internal noise levels indicates that it may be appropriate to re-visit the issue of the absolute night-time noise criterion specified within ETSU-R-97. To provide protection to wind farm neighbours, it would seem appropriate to reduce the absolute noise criterion for periods when background noise levels are low. In the absence of high levels of modulation, then a level of 38 dB LA90 (40 dB LAeq) will reduce levels to an internal noise level which lies around or below 30 dB LAeq with windows open for ventilation. In the presence of high levels of aerodynamic modulation of the incident noise, then a correction for the presence of the noise should be considered."*

Similarly, references to WHO guidance for the protection of sleep disturbance which supported HMP's recommendations for a reduction in ETSU-R-97 night time noise limits were removed. The removed text follows:

*"If one takes the guidance within the WHO for the protection against sleep disturbance of 30dB LAEq, and apply a 5 dB correction for the presence of high levels of [aerodynamic] modulation within the incident noise, then this gives rise to an internal noise criterion of 25dB LAeq. Based upon the measured building attenuation performances at Site 1 & 2, then an external level between 35 – 40dB LAEq (33-38 dB LA90) would provide sufficient protection to neighbouring occupants to minimise the risk of disturbance from the modulation of aerodynamic noise."*

It is quite clear that relying on the conclusions of this report, as published, is unwise as they are, at best, misleading.

## 3.6. Salford study

3.6.1. Moorhouse of the University of Salford (2007) were commissioned by DEFRA to conduct a study of Aerodynamic Modulation of Wind Turbine Noise. A survey was made of the local authorities responsible for wind farms in, or adjacent to, their area. 133 wind farms were identified of which 27 (20%) had attracted complaints. An attempt was made to correlate complaint logs with recorded wind speed and direction. Once again the methodology is fundamentally flawed. Complaints were solicited from local authorities and not from residents. The review was entirely theoretical with no communication with residents and relied on the opinions of environmental health officers. The conclusions were that AM was such a minor problem that no further research was warranted.

3.6.2. The Editor of Noise Bulletin greeted the publication of the report thus:

*"'New report eases concerns over wind turbine noise' trumpets the Government press release, then saying aerodynamic modulation is 'not an issue for the UK's wind farm fleet'. This conclusion is not justified based on the report, and by halting further research work without transparently monitoring the wind farms subject to complaints will inflame, not ease concern of objectors ... Only when the public can trust the Government and wind farm developers on noise issues will there be a chance that the public will accept them without a fight ..."*
(Pease J. *Noise Bulletin*, Issue 15, Aug/Sept. 2007 page 5).

3.6.3. On 2 August 2007, Dick Bowdler, an acoustician and member of the Noise Working Group which commissioned the report, resigned from the NWG. This highly unusual step was taken because, as his letter states:

*"I have read the Salford Report and the Government Statement. As a result I feel obliged to resign from the Noise Working Group.*
*The Salford Report says that the aims of this study are to ascertain the prevalence of AM from UK wind farm sites, to try to gain a better understanding of the likely cause, and to establish whether further research into AM is required. This bears little relation to what we asked for which is clearly set out in the minutes of the meeting in August 2006. We all knew then (as was recorded in the original notes of the meeting) that complaints concerning wind farm noise are currently the exception rather than the rule. The whole reason for needing the research was that 'The trend for larger more sophisticated turbines could lead to an increase in noise from AM'.*
*It was not the intended purpose of the study to establish whether more research was required. We all agreed at the August 2006 meeting that such research was needed. That was precisely the outcome of the meeting. The prime purpose of what eventually became the Salford Report was to identify up to 10 potential sites which could be used to carry out objective noise measurements. The brief for the Salford report, which was never circulated to the NWG, completely ignored the NWG views.*
*Additionally, I find it entirely unacceptable that we are not to be told the names of the wind farms listed in the Salford report. So the only part of the*

*report of any value to assist future research is inaccessible to those of us who would like to progress matters further.*
*Looking at the Government Statement it is clear that the views of the NWG (that research is needed into AM to assist the sustainable design of wind farms in the future) have never been transmitted to government and so the Statement is based on misleading information".*
(*Noise Bulletin*, Issue 1.5, Aug/Sept. 2007 page 5)

3.6.4. If both a leading commentator in the field and a leading member of the Government's own working group have no faith in the study then its conclusions may safely be dismissed.

3.6.5. Following a refusal by the Salford research team and the DTI to share the study's full data, the actual questionnaire response forms were finally made available after a Freedom of Information request by the Renewable Energy Foundation. The low quality of this research is evident from the poor responses from many local authorities, many of whom clearly did not understand the concept of AM, compounded by the questionnaire design and the phrasing of the questions. This further serves to demonstrate that current planning guidance, and in particular ETSU R 97, are inadequate at preventing noise annoyance.

## 3.7. Acoustician opinions

3.7.1. George Kamperman, (2008 personal communication) a distinguished US noise engineer, is quoted in Pierpont's book as saying, *"After the first day of digging into the wind turbine noise impact problems in different countries, it became clear the health impact on persons living within about two miles from 'wind farms' all had similar complaints and health problems. I have never seen this type of phenomenon [in] over fifty plus years of consulting on industrial noise problems. The magnitude of the impact is far above anything I have seen before at such relatively low sound levels. I can see the devastating health impact from wind turbine noise but I can only comment on the physical noise exposure. From my viewpoint we desperately need noise exposure level criteria."* Kamperman's recommended setback of at least 1km (Kamperman & James 2008) has changed to at least 2km as a result of Dr Pierpont's evidence (Kamperman

2008 personal communication). He has recently published a more detailed set of recommendations to determine setback distances (Kamperman & James 2008b) which, amongst others, require that turbine noise should not be more than 5dB(A) above background and should not exceed 35dB(A) within 30m of any occupied structure.

3.7.2. Dr Robert Thorne, an Australian acoustician has investigated wind turbine noise at several sites in Australia and New Zealand. His conclusions can be found in several expert reports submitted to Planning Inquiries, most recently Turitea (Thorne 2010a & b) and Yaloak (Thorne 2010c). He states (Thorne 2010c para 6.18):

*"I am of the opinion, based on my own research, that wind farm noise can and does create unreasonable noise within residences and consequential adverse effects in the sense of sleep disturbance, annoyance and potential adverse health effects to residents living within 2000 metres of large wind turbines set in a wind farm. These risks are quantifiable and are of high probability. The effect is significantly more than minor."*

3.7.3. Dr Dan Driscoll, formerly a noise control engineer for the New York Public Service Commission, answered questions at an Environmental Stakeholder Roundtable on Wind Power sponsored by the New York State Energy Research and Development Agency held in New York on the 16th June 2009 (Driscoll 2009). He takes as the basis for his thesis the well established US Environmental Protection Agency's (EPA) paper on Levels of Environmental Noise. The EPA uses a day/night average sound level, $L_{dn}$, similar to the $L_{den}$ recommended in Europe, with a 10dB(A) penalty for night noise. An $L_{dn}$ of 55dB(A) is recommended as adequate to protect from outdoor activity interference and annoyance. Various research studies suggest that a normalised $L_{dn}$ of 55dB(A) would cause little or no community reaction although the noise would be noticeable. The estimated sound output $L_{dn}$ is normalised by adjusting for a range of factors; in this case, 10dB is added for a quiet suburban or rural setting, 5dB if the community has no prior experience with the noise and 5dB if the sound is impulsive. He calculates that a 2.5MW turbine producing an

$L_{eq}$ of 49dB(A) at 500ft would have an uncorrected $L_{dn}$ of 55dB. Adding the adjustments gives a normalised turbine $L_{dn}$ of 75dB which is a level at which the EPA expects that community reaction would include threats of legal action and strong appeals to stop the noise. This certainly corresponds with the current reaction to turbine noise in all parts of the world, including the UK. Using EPA data, Driscoll estimates that a normalised $L_{dn}$ of 59dB would be sufficient to reduce community reaction to sporadic complaints which equates to an external turbine noise of 33dB(A) and a setback of about 1km. It is noteworthy that the conclusions of this noise control approach are in accord with the recommendations of Kamperman and James (Section 3.7.1), Hayes in his recommendations to the DTI (Section 3.5.3) and my own estimations based upon the work of Pedersen and others (Section 3.3.8).

3.7.4 A similar approach has been taken by Ambrose and Rand (Ambrose 2010). They produce a similar graph to Driscoll (Figure 5) but add the annoyance levels determined by Pedersen and Persson Waye (Pedersen 2004). Both studies confirm that an unacceptable level of adverse community response is likely for wind turbine noise levels above 32dBA.

## 3.8. WindVoice

3.8.1 WindVoice (2010) have recently published the initial results of a self-reporting survey of communities affected by wind turbine noise. As of July 2010, 144 responses had been received of which 118 reported one or more health effects. 84 (58%) reported sleep disturbance and 85 (59%). There were no age differences between those that reported sleep disturbance (51.5 yr (19-79)) and those that did not (52.2 yr (26-86)).

Those that reported sleep disturbance lived an average of 897m (360-5000) from turbines compared to 890m (350-3500) for those who did not. The similarity in distance from turbines for the two groups suggests that noise sensitivity may be significant factor in sleep disturbance. A slightly greater proportion of females reported sleep disturbance than males. Caution must be exercised in drawing conclusions from self reporting surveys. Nevertheless, it is evident that significant numbers of individuals are reporting sleep disturbance and health issues at distances considerably greater than those currently deemed safe. All bar five of those reporting sleep disturbance live within 1500m of the turbines adding further support to a minimum setback of at least that distance.

### 3.9. World Health Organisation/European Community recommendations

3.9.1. The WHO Regional Office for Europe in collaboration with the EU established a working party in 2003 to examine the effects of night time noise on sleep disturbance and health. Their brief was to review the current evidence and produce recommendations on permissible night time noise levels. Inevitably, the work concentrates on road traffic and aircraft noise as generating the most complaints and the subjects of most research.

3.9.2. A preliminary report was published in 2007 (WHO 2007). They reported that:

*"The review of available evidence leads to the following conclusions.*

- *Sleep is a biological necessity, and disturbed sleep is associated with a number of adverse impacts on health.*
- *There is sufficient evidence for biological effects of noise during sleep: increase in heart rate, arousals, sleep stage changes, hormone level changes and awakening.*
- *There is sufficient evidence that night noise exposure causes self-reported sleep disturbance, increase in medicine use, increase in body movements and (environmental) insomnia.*
- *While noise-induced sleep disturbance is viewed as a health problem in itself (environmental insomnia) it also leads to further consequences for health and well-being.*
- *There is limited evidence that disturbed sleep causes fatigue, accidents and reduced performance.*
- *There is limited evidence that noise at night causes clinical conditions such as cardiovascular illness, depression and other mental illness. It should be*

*stressed that a plausible biological model is available with sufficient evidence for the elements of the causal chain."*

*"For the primary prevention of subclinical adverse health effects in the population related to night noise, it is recommended that the population should not be exposed to night noise levels greater than 30 dB of $L_{night,outside}$ during the night when most people are in bed. Therefore, $L_{night,outside}$ 30 dB is the ultimate target of Night Noise Guideline (NNGL) to protect the public, including the most vulnerable groups such as children, the chronically ill and the elderly, from the adverse health effects of night noise."*

The report described a new noise metric, $L_{night,outside}$, which is the yearly average of night noise level outside the facade. This seems to have been chosen as more appropriate for health effects that require long term noise exposure, such as high blood pressure, than those related to short term disturbance such as sleep disturbance and insomnia.

3.9.3. A further report was published in 2009 (WHO 2009). A similar approach was taken to that of Pedersen (2009a&b) and the report seeks to establish a No Observed Effect Level (NOEL) and a Lowest Observed Adverse Effect level (LOAEL) for noise and various measures of health. While a useful approach, it must be remembered that the LOAEL will vary with the noise frequency and pattern, the age of the subjects studied and the sensitivity of the measurement of the effect. There will also be a range of LOAEL within the population depending upon noise sensitivity. Allowance should be made for those who are most sensitive. With respect to noise and health, it can not be assumed that all noise is the same; as noted above, several studies have shown that wind turbine noise is more annoying than traffic or aircraft noise. Children and the elderly may be more sensitive than adults who are studied most often. While blood pressure and heart attacks are well defined and easily measured, sleep disturbance, fatigue, mood and similar subjective symptoms are less easily measured and distinguished from the background levels present in the population.

An $L_{night,outside}$ of 40dB was recommended as representing the LOAEL. They state for $L_{night,outside}$ of 30-40dB:

*"A number of effects on sleep are observed from this range: body movements, awakening, self-reported sleep disturbance, arousals. The intensity of the effect depends on the nature of the source and the number of events. Vulnerable groups (for example children, the chronically ill and the elderly) are more susceptible. However, even in the worst cases the effects seem modest. $L_{night,outside}$ of 40 dB is equivalent to the lowest observed adverse effect level (LOAEL) for night noise."*

Body movements, awakenings, self-reported sleep disturbance and arousals will all impact on a subject's sleep and cause impaired daytime functioning. Whether or not this results in long term harm, it remains an effect on the subject which is contrary to the WHO definition of health, i.e. it constitutes ill health.

3.9.4. The recommendation that an $L_{night,outside}$ of 40dB should be the night noise guideline for Europe seems perverse in the light of the conclusions of the effects of sound levels between 30 and 40dB above. A value of 21dB was used for sound attenuation from outside a building to inside. This is greater than the 10-15dB usually cited. Bearing in mind the reservations expressed in Section 3.9.3 and, in particular the nature of wind turbine noise with it's high levels of low frequency noise, an external noise level of 40dB must be regarded as the absolute maximum permissible and must be fully justified, for example by the subject having a financial interest in the turbines. Noise exposure above this level will be associated with a risk of ill health. Kamperman and Pedersen's recommendations of a maximum external limit of 35dB(A) and HMP's recommendations of 33-38 dB(A) would be appropriate for wind turbine noise to prevent annoyance and sleep disturbance and is supported by the WHO/EU findings quoted above.

## 3.10 Nissenbaum

3.10.1. Nissenbaum (2010) has presented the preliminary results of a study of residents living downwind and within 300-1100m (mean 800m) of a wind farm at Mars Hill, Maine, USA. The 28 1.5MW turbines are sited on a 200m high ridge overlooking the homes. 22 of about 35 adult residents have been interviewed so far and compared with a randomly selected control group living a mean 6km away. 18/22 reported new or worsened sleep onset disturbance at least twice a week, for 9 at least 5 times per week (controls 1/28). 8/22 reported new or worsened headaches (controls 1/28) and 18/22 reported new or worsened mental health symptoms (stress 12/22, anger 18/22, anxiety 8/22, hopelessness 12/22, depression 10/22) (controls 0/28).

The 22 subjects received 15 new or increased prescriptions from their physicians in the 18 months between the start of turbine operation and the study, the majority for psychoactive medication (controls 4 prescriptions, none for psychoactive medication). 21/22 reported reduced quality of life and 20/22 considered moving away (controls 0/28 for both).

3.10.2. As a result of the complaints, noise monitoring during turbine operation was undertaken at the community test sites at which background noise monitoring and calculated turbine noise levels had been derived during the planning stage. The residents surveyed generally lived between the 40-45dB contours, two lived within the 45-50dB contours. Noise control regulations in Maine call for test sites to be more than 500ft from "protected properties". Six test sites are relevant to the study group and the results are given below.

| Site No. | Model estimate (dB) | Range of measured sound levels (dB) |
|---|---|---|
| 1 | 51 | 42-52 |
| 5 | 39 | 39-40 |
| 6 | 43 | 39-45 |
| 6A | 42 | 38-44 |
| 7 | 40 | 39-44 |
| 8 | 47.5 | 41-50 |

It can be seen that model estimates generally underestimated the actual noise levels by between 1 and 4dB. Exceedances of ETSU-R-97 night time levels of 43dB are generally small, 1-2dB and only exceed by 7-9dB at the two closest sites. It is clear that the majority of residents were living at distances and sound levels that would be permitted under ETSU-R-97 but nevertheless report high levels of sleep disturbance and health impairment.

3.10.3. The study may be criticised for it's relatively small numbers of subjects but the presence of a control group, well matched for age and gender, adds considerable power. All differences between the groups are statistically highly significant. The turbine noise levels may be enhanced by the high concentration of turbines and the geography but the severe sleep disturbance, psychiatric symptomatology and increased medication requirement in the study group confirms the potential of wind turbine noise to adversely affect health at distances claimed to be safe.

### 3.11 Shepherd

3.11.1. Dr Daniel Shepherd, (2010a) a psychoacoustician from the University of Aukland, New Zealand, has presented a preliminary report of a case-control study of the health status of residents living within 2km of the Makara windfarm. The results were presented at an International Symposium on Sustainability in Acoustics, Sydney, Australia, August 29th-31st 2010. Health related quality of life (HRQoL) was measured using the WHO QOL-BREF which has four subscales, physical, including sleep, psychological, social and environmental. Questions on neighbourhood problems, amenity and noise and air pollution annoyance were added, partly as distractors.

26 of 84 questionnaires were returned by the Makara residents (31%) and 173 of 500 (34%) in a control group from a matched area without wind turbines. Return rates are reasonable for such a study. The groups were evenly matched except the control group had a slightly higher proportion of older people.

The Makara residents reported significantly lower amenity levels than the controls. Overall HRQoL was much lower in the Makara residents and this difference was statistically highly significant (p=0.033) (See Table below). Makara residents scored lower in all subscales except social. The differences were statistically significant (p<0.05) for the physical and environmental subscales.

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| Subscale | Mean Rank | Significance (two-tailed) |
|---|---|---|
| **Physical** | | |
| Makara | 75.25 | *U*=1505.5, *z*=-2.049, *p*=.040 |
| Control | 100.09 | |
| **Psychological** | | |
| Makara | 78.48 | *U*=1883.5, *z*=-1.524, *p*=.088 |
| Control | 99.07 | |
| **Social** | | |
| Makara | 96.49 | *U*=1923.05, *z*=-0.325, *p*=.745 |
| Control | 92.63 | |
| **Environmental** | | |
| Makara | 73.89 | *U*=1423.5, *z*=-1.983, *p*=.047 |
| Control | 97.92 | |
| **Overall QOL** | | |
| Makara | 76.81 | *U*=1543.5, *z*=-2.133, *p*=.033 |
| Control | 99.87 | |

This preliminary report of well designed study adds further weight to the argument that wind turbine noise causes ill health in those living within 2km.

### 3.12. Literature Reviews.

In recent months, a number of "reviews" of the literature relating to wind turbine noise and health have been published. In general, those which are industry or government sponsored tend to suggest that there is no problem while those produced independently confirm that there is a problem.

3.12.1 The American and Canadian Wind Energy Associations (ACANWEA) have recently commissioned a review of the literature on wind turbine noise and health effects (Colby et al., 2009). The panel concluded that:

"• *There is no evidence that the audible or sub-audible sounds emitted by wind turbines have any direct adverse physiological effects.*

• *The ground-borne vibrations from wind turbines are too weak to be detected by, or to affect, humans.*

• *The sounds emitted by wind turbines are not unique. There is no reason to believe, based on the levels and frequencies of the sounds and the panel's experience with sound exposures in occupational settings, that the sounds from wind turbines could plausibly have direct adverse health consequences."*

The quality and authority of this review and its conclusions are open to considerable doubt. The medical members of the panel comprised a microbiologist, an otolaryngologist and an occupational health physician specialising in respiratory disease. From their biographies, none seems to have any expertise in sleep medicine or in psychology. The reference list shows that the literature review was far from complete. The panel admits that wind turbine noise causes annoyance which can lead to sleep disturbance but dismisses these findings. It is clear that they did not understand the significance of "annoyance" in a health context and neither did they comprehend the importance of sleep disturbance in causing ill-health.

The NHS Knowledge Service reviewed the paper (NHS 2010) and concluded: *"This research is unlikely to resolve the controversy over the potential health effects from wind turbines. This is mainly because the research on which the review was based is not sufficient to prove or disprove that there are health effects. The review itself also had some methodological shortcomings, and the reviewing group did not include an epidemiologist, usually a given for assessing potential environmental health hazards. Further research on this issue is needed."*

The Society for Wind Vigilance (Society for Wind Vigilance, 2010a&b) has reviewed the ACANWEA paper, publishing a detailed critique and concluded: *"It is apparent from this analysis that the A/CanWEA Panel Review is neither authoritative nor convincing. The work is characterized by commission of unsupportable statements and confirmation bias in the use of references. Many important references have been omitted and not*



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*considered in the discussion. Furthermore the authors have taken the position that the World Health Organization standards regarding community noise are irrelevant to their deliberation - a remarkable presumption."*

3.12.2. The Chief Medical Officer of Health of Ontario published a review in May 2010 on the Potential Health Impact of Wind Turbines (CMOH, 2010). This document has a number of shortfalls, not least in the selective nature of the literature reviewed, the dismissal of annoyance as a health issue and the ignoring of sleep disturbance as a concern. A comprehensive rebuttal of this paper has been published by the Society for Wind Vigilance (Society for Wind Vigilance 2010c).

3.12.3. The Australian National Health and Medical Research Council published a "Rapid Review of the Evidence" of Wind Turbines and Health in July 2010 (NHMRC, 2010). It starts with the premise that there is no evidence of any health concern and then proceeds, through a very selective use of literature, to prove it. It claims to use peer reviewed literature but only 8 of 29 citations are actually peer reviewed, one of the remainder being an internet blog, "Croakey the Crikey Health Blog". The WHO acceptance of annoyance as an adverse health effect is stated as "not universally accepted" but no references are given to support this extraordinary assertion. A comprehensive rebuttal of this paper has been published by the Society for Wind Vigilance (Society for Wind Vigilance 2010d).

3.12.4. Phillips, an epidemiologist, has prepared an analysis of the epidemiology and related evidence on the health effects of wind turbines on local residents as evidence to the Wisconsin Public Service Commission (Phillips, 2010). He concludes: *"There is ample scientific evidence to conclude that wind turbines cause serious health problems for some people living nearby." "The reports that claim that there is no evidence of health effects are based on a very simplistic understanding of epidemiology and self-serving definitions of what does not count as evidence. Though those reports probably seem convincing prima facie, they do not represent proper* *scientific reasoning, and in some cases the conclusions of those reports do not even match their own analysis."*

He further notes that subjects' revealed preferences, moving out of their bedrooms or houses to avoid the noise is strong evidence in favour of the effects being real rather than a psychologically induced "nocebo" effect.

3.12.5. Horonjeff, an acoustician, has reviewed the siting of wind turbines with respect to noise emissions and the health and welfare effects on humans as evidence to the Public Service Commission of Wisconsin (Horonjeff, 2010). He notes that wind turbine noise is different in character from other noise sources and, after suggesting appropriate noise levels and a setback 1.5-2 miles, concludes: *"Wind turbine noise appears to be eliciting annoyance and physiological responses not experienced from other noise sources of similar sound level."*

3.12.6. Punch and colleagues (Punch, 2010) reviewed wind turbine noise for audiologists and concluded: *"Noise from modern wind turbines is not known to cause hearing loss, but the low-frequency noise and vibration emitted by wind turbines may have adverse health effects on humans and may become an important source of community noise concern."*

3.12.7. The Clean Energy Council of Australia, the trade body representing and advocating on behalf of the wind industry and other "renewable" energy suppliers, commissioned Sonus, an acoustic consulting firm that works extensively with the wind industry, to review environmental noise and wind farms (CEC 2010). No individual authors are listed in the report but none of the staff listed on the company's website has any medical, epidemiological or health expertise. Nevertheless, they confidently conclude: "There is detailed and extensive research and evidence that indicates that the noise from wind farms developed and operated in accordance with the current (Australian) Standards and Guidelines will not have any direct adverse health effects." Review of the cited literature produces no such extensive research nor evidence other than the usual reviews cited in similar wind industry and government sponsored documents. The literature reviewed omits much peer-reviewed and other literature which contradicts the conclusions.

## 3.13. Conclusions

3.13.1. There is no peer-reviewed research showing that industrial wind turbines do not significantly affect sleep at the distances and external noise levels deemed to be safe in most jurisdictions. On the other hand, there is a large body of literature suggesting very strongly that sleep is disturbed to a degree that affects daytime functioning. Many of the studies are surveys using self-completed questionnaires. Response rates have generally been good for this type of enquiry, which may reflect the public interest and concern that wind turbines generate. Nevertheless, it is inevitable that it is more likely that those who feel they have been affected will respond rather than those who have not. The questionnaires themselves have not always have been well drafted. Most do not have a control group, a separate group not exposed to turbine noise with whom to make comparisons. The studies are all post hoc, initiated after the turbines have been operating and generally in response to complaints. The lack of pre-exposure data weakens the studies but does not invalidate them totally. Many of the authors have been criticised for their presumed lack of expertise in this area. Because governments and industry have refused funding and co-operation, individuals have had to rely on their own resources in order to conduct research, which though propelled by a concern for public health, has also enforced limits on their extents. Initial clinical investigations often rely on self-completed questionnaires in order to define, refine, and establish future research projects and this work should not simply be dismissed.

Nevertheless, the number of reports, and in particular the most recent, and the weight of evidence demonstrating the impacts on sleep quality and health of wind turbine noise from existing installations is such that it can be firmly concluded that present guidance to determine setbacks is inadequate.

3.13.2. The UK government, in acknowledging the deleterious effect of noise on human well being, have published two reports through the Health Protection Agency (HPA 2009) and DEFRA (Berry and Flindell, 2009). The former, which is in draft form awaiting comments, reviews the evidence for the effects of noise on health. Traffic, aircraft, railway and industrial noise is considered but, surprisingly, there is no consideration of wind turbines despite the government's plans for a major increase in size and capacity and their proposed placement in generally previously tranquil but well populated areas of countryside. The report calls for more research, including in the areas of sleep disturbance, cardiovascular effects and children's health. They commend the use of dose-response relationships to inform planning policy. The latter report reviews dose-response relationships between noise exposure and human health and concludes that such is a useful approach worthy of further research. They commend the work of RIVM, who were extensively consulted in preparing the report.

3.13.3. The recent analyses of the WINDFARMPerception and earlier Swedish studies by Pedersen and her colleagues gives, for the first time, robust evidence that wind turbines cause sleep disturbance and impair health and that this occurs at set-back distances previously regarded as adequate. However, it must be noted that the measures used in these studies are relatively imprecise. As noted in Section 2.2, arousals due to noise are several times more likely to occur than awakenings but are as destructive to sleep quality. More precise measures such as the Brief Fatigue Inventory, Pittsburgh Sleep Quality Index and Epworth Sleepiness Score or direct assessment of sleep quality are needed to determine a correct dose-response relationship between turbine noise and sleep disturbance. In the meantime, the precautionary principle should prevail and setbacks determined appropriately.

3.13.4. In weighing the evidence, I find that, on the one hand, there are large numbers of reported cases of sleep disturbance and other adverse effects on health, as a result of exposure to noise from wind turbines, supported by an increasing number of research reports that confirm the validity of the anecdotal reports and provide a reasonable basis for the complaints. On the other, we have badly designed, and improperly edited, industry and government reports, which seek to show that there is no problem. I find the latter unconvincing.

3.13.5. The recent RIVM and WHO reports and the draft DTI/HMP reports confirm the potential for noise to adversely effect health through sleep disturbance and set maximum permissible night time noise levels which are less than those permitted by ETSU-R-97.

3.13.6. **In my expert opinion, from my knowledge of sleep physiology and a review of the available research, I have no doubt that wind turbine noise emissions have been clearly associated with sleep disturbances.**

**Further, the evidence now available is quite clear that present noise guidelines are inadequate to protect the sleep of residents living too close to wind turbines.**

# 4. Preventing sleep disturbance from wind turbine noise.

## 4.1 Background

4.1.1. Developers of noisy industrial processes, including wind turbines, seek to mitigate the disturbance by siting them in areas of high ambient noise, such as close to major roads. In the case of wind turbines, it is assumed that rising wind speed will not only increase turbine noise but ambient noise also. The degree to which this occurs depends on the proximity of vegetation and other structures. Motorway noise diminishes at night as the volume of traffic decreases. In addition, it is common for wind speeds to diminish at ground level as night falls while being maintained at turbine hub level, wind shear (Pedersen E and Persson Waye K. 2003, Schneider 2007). In both cases, the turbine noise will be much more audible as ambient noise decreases and explains why complaints of nocturnal noise and disturbed sleep are common. The importance of wind shear has been acknowledged in a recent technical contribution to Acoustics Bulletin (March/April 2009) from some members of the NWG calling for all noise levels to be referenced to wind speed at turbine hub height. Conditions which favour wind shear also favour amplitude modulation (Palmer 2009). Temperature inversion, where ground level air is cooler than higher level air also increases sound propagation by reflection of the noise from the boundary layer (Irvine. 2009). These conditions, which are most likely to occur at night, early morning and in winter have not received as much attention as wind shear but may be a further reason why turbine noise may be heard over greater distances than predicted.

4.1.2. Schneider (Schneider 2007) found that night time turbine noise was between 3 and 7dB(A) greater than predicted during periods of atmospheric stability: "*summer, night-time noise levels exceeded levels predicted for two sites within the Maple Ridge Wind Farm. For winds above generator cut-in speed (e.g., 3.0 m/s @ 80-m), the measured noise was 3-7 dBA above predicted levels. The decoupling of ground level winds from higher level winds, i.e.,* *atmospheric stability, was apparent in the noise data at both sites during evening and night-time periods. At wind speeds below 3.0 m/s, when wind turbines were supposedly inoperative, noise levels were 18.9 and 22.6 dBA above the expected background levels for each of the sites and these conditions occurred a majority of the time."*

In addition, as noted above, the characteristics of wind turbine noise are such that it can be heard despite road noise.

4.1.3. van den Berg, in a paper presented at Euronoise 2003, investigated the relationship between calculated noise generated by wind turbines and that actually measured. He confirmed that the turbines were more audible at night principally due to amplitude modulation. To quote his paper: *"As measured immission levels near the wind park Rhede show, the discrepancy may be very large: sound levels are up to 15 dB (!) higher than expected at 400 m from the wind park. At a distance of 1500 m actual sound levels are 18 dB higher than expected, 15 dB of this because of the higher sound emission and 3 dB because sound attenuation is less than predicted by the sound propagation model."* This study, is further confirmation that calculated measures of wind turbine noise may be woefully inadequate.

4.1.4. In contrast, Bullmore and colleagues (2009) reported, from studies of four established large wind farms, that ISO 9613 predicted turbine noise immissions with reasonable accuracy and, at three of the sites, over estimated the measured sound levels. However, the actual location of the sites was not revealed although some detail was given. No attempt was made to determine the degree of wind shear during the measurement period.

4.1.5. Nelson (2007), in a small laboratory based study examined the ability of background noise to mask turbine noise. When background noise and turbine noise where adjusted to the same loudness, the residual perceived loudness of the turbine noise was approximately half of its unmasked value (1.8sone). Even when the background noise was increased from 41 to

49dB(A) the turbine noise was not fully masked. Hayes (2007) has interpreted this by stating that: *"one would expect the wind turbine (warranted to be free of tonal noise) to be audible even if the turbine noise was 10 - 15 dB below the background noise level".* It can be inferred that if tonal noise is present, the turbine noise will be audible at a greater level below background noise.

4.1.6. Bolin (2009) has reported an experimental study of the masking of wind turbine noise by vegetation noise (leaves rustling etc). Subjects were exposed to vegetation noise in a laboratory and turbine noise introduced at varying sound pressures and vice versa and a threshold for detection determined. The results were compared with the Moore and Glasberg methods for calculating masking. The results suggest that: *"....existing models of partial masking overestimate the ability to conceal wind turbine noise in ambient sounds."* In other words, wind turbine noise is not masked as well as current models predict and is thus more intrusive. This is in accord with the work of Nelson and of van den Berg and Miedema who show that traffic noise does not mask wind turbine noise as well as predicted.

## 4.2. Mitigation of wind turbine noise

4.2.1. Bowdler (2008) has reviewed the causation of the swishing and thumping noises associated with wind turbines. He concludes that, while there are several theories, no definitive mechanism can be established. It follows that industry claims to mitigate turbine noise by changing blade shape, pitch and turbine spacing should be treated with scepticism until definitive evidence of their efficacy are presented.

4.2.2. It follows that attempts to reduce wind turbine noise immissions after a plant becomes operational are unlikely to be successful. Noise mitigation will reduce power output, which will be opposed by the operators. The importance of assuring residents that noise limits are capable of being met before construction was emphasised by Mr Lavender, Inspector at the

Thackson's Well Inquiry (APP/E2530/A/08/2073384) who stated: *"securing compliance with noise limit controls at wind farms, in the event of a breach, is not as straightforward as with most other forms of noise generating development. This is because noise from turbines is affected primarily by external factors such as topography and wind strength, a characteristic that distinguishes them from many other sources of noise, such as internal combustion engines or amplified music, which can be more directly and immediately influenced by silencing equipment, insulation or operator control."* It follows that application of the precautionary principle is essential where there is any possibility of noise disturbance from wind turbines.

4.2.3. Thus, the **only** mitigation for wind turbine noise is to place a sufficient distance between the turbines and places of human habitation. PPS22 advises that ETSU-R-97 *should* (author's italics) be used to estimate noise levels around turbines which, taken with measurements of ambient noise, can, in theory, predict noise disturbance in adjacent properties. Many expert acousticians have severely criticised ETSU-R-97, not least Mr Dick Bowdler (2007), a former member of the Government's Noise Working Group considering ETSU-R-97. A number of Her Majesty's Inspectors have been equally critical, not least Mr Andrew Pykett (Appeal Ref: APP/Q1153/A/06/2017162) and Ms Elizabeth Ord (Appeal Ref: APP/W4705/A/09/2114165). As noted above, the recent recommendation by some members of the Noise Working Group to provide more allowance for wind shear in predicting turbine noise levels is a tacit admission of the unsuitability of ETSU-R-97 methodology for large turbines. In addition the suppressed recommendations by HMP, at least one of whose employees sat on the NWG, for a reduction in the ETSU-R-97 night time noise limits to 33-38dB(A) suggests very strongly that it is inappropriate to continue to rely on ETSU-R-97 as presently formulated.

4.2.4. Stigwood (2008) has shown that large turbines (hub heights 50-100m) are more likely than smaller turbines (hub height 30m) to cause excessive amplitude modulation, increased likelihood of low frequency noise and greater disturbance inside buildings. Internal noise can modulate over 15-

20dB, changes which is easily perceived. This is probably due to different wind speeds and atmospheric conditions at these heights. He concludes that ETSU-R-97, which was developed for smaller turbines, is inappropriate for large turbines.

4.2.5. Despite, or because of, ETSU-R-97, complaints of noise disturbance from industrial wind turbines continue and it is clear that ETSU-R-97 can not be relied upon to prevent sleep disturbance in those living near wind turbines. To quote Mr Peter Hadden in evidence to the House of Lords Economic Affairs Committee, printed 12th November 2008 para 6:

*"There is material evidence available to show that ETSU R 97 has failed to provide a reasonable level of protection to family homes from unbearable noise pollution where wind turbines are located too close to homes. Symptoms include sleep disturbances and deprivation, sometimes so severe that families are forced to evacuate their homes in order to stabilise well-being and to resume normal family life. This is a worldwide phenomenon where wind turbines are located too close to homes."*

4.2.6. It should be noted also that the application of ETSU-R-97 is advisory in PPS22, not mandatory (*should* not *must*). It is subordinate also to the precautionary principle set out in PPS 22. Rather than rely on a provably inadequate set of theoretical calculations to determine setback distance, it is logical to look at the real world and the relationship between setback and noise complaints from existing sites. Human senses and opinion are used to judge visual impact. It is therefore consistent and logical to rely on human senses and opinion in respect of noise impact. Many of these sites causing problems have been in place for several years. Current applications are generally for large 2.0-3MW turbines and thus allowance must be made for their additional noise in determining setback.

4.2.7. While it may be possible to produce a reasonable acoustically based theoretical approach to calculating set-back distances (Kamperman and James 2008b), it makes more sense to rely on recommendations from observations of the effects on real people at established wind farms and the dose-response relationship described by Pedersen (2009a&b) is relevant.

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## 4.3. Conclusions

4.3.1. There are two possible approaches to judging an appropriate setback distance. The first is to determine a dose-response relationship between turbine noise and a health concern, for example, sleep disturbance. The next step is to determine an acceptable level of sleep disturbance. For example, should it be 0%, 1% or 5% of the population for 1 night per year, per month or per week? Consideration should be given to whether the measured concern, in this case reported sleep disturbance, is sufficiently sensitive. I have shown that reported sleep disturbance is the tip of an iceberg and that arousals with sleep fragmentation are likely to be more common and insidious with consequences including fatigue and elevated blood pressure In this situation, it would be appropriate to invoke the precautionary principle and select a conservative dose level (turbine noise) that minimises the measured response (sleep disturbance). Examination of data from the Swedish and Dutch studies suggests that an external predicted noise level of no more than 35dB(A) $LA_{90}$ would be appropriate. This view is supported by a presentation by members of RIVM, the widely respected Dutch National Institute for Public Health and Environment, (Jabben et al 2009) which recommends an outdoor $L_{den}$ limit of 40dB(A) which corresponds to an external noise level of about 35dB(A). The data is now available as a RIVM report (Verheijen et al., 2009) which recommends that wind turbine parks be designed so as to stay below $L_{den}$ 40 dB at nearby dwellings which is regarded as the "no effect" level. $L_{den}$ 45 dB(A) is recommended as a maximum allowable limit which should avoid severe effects and minimise health effects.

Hayes (2007), of the Hayes McKenzie Partnership. notes that "the intent of New Zealand Standard 6808 is not inaudibility but the prevention of severe annoyance". The relevant section of that Standard states:

"***4.4.2 Acceptable limit***

*As a guide to the limits of acceptability, the sound level from the WTG (or windfarm) should not exceed, at any residential site, and at any of the* *nominated wind speeds, the background sound level ($L_{95}$) by more than 5dB(A), or a level of 40 dB(A) $L_{95}$, whichever is the greater.*

Hayes therefore concedes that the noise level above which **severe annoyance** occurs is 40dB(A) $L_{95}$. Thorne (2010c), from an analysis of noise complaints concludes that **unreasonable** noise occurs at noise levels above 30dB(A)$_{LA90}$ in the presence of excess amplitude modulation. Together with van den Berg he states: "*We believe annoyance and loss of amenity will be protected when the wind turbine noise limit would be 30 dBA $L_{95}$ in conditions of low wind speed at the dwellings and modulation restricted to 3dB".*

**Overall, it is apparent that the present ETSU-R-97 night time noise limits are too high to protect receptors from severe annoyance and sleep disturbance and that a level of 35dB(A) $LA_{90}$ is appropriate, in the absence of excessive modulation.**

4.3.2. The second approach is to correlate reports from those living in proximity to wind turbines to their distance to the turbines, the approach taken by, amongst others, WindVoice. This has the disadvantage that symptoms are generally self-reported and subjective. Nevertheless, it can be argued that it is logical to rely on the actual reports of human receptors in the same way that human opinions are used to judge visual amenity. It has the advantage also that it may better detect those subjects that are most sensitive to turbine noise than surveys. It has the merit also of simplicity. The New South Wales Legislative Council General Purpose Standing Committee No 5, under the Chairmanship of Mr Ian Cohen, a member of the Green Party, has recently published the report of an inquiry into rural wind farms (NSW 2009). Recommendation 7 to the NSW Planning Minister is for a minimum setback of 2 km. In the UK, Mr Peter Luff, MP for Mid-Worcestershire, was given leave to introduce a Bill to Parliament to establish a legal minimum setback distance. This Bill was lost with the recent dissolution of Parliament and election but Lord Reay has recently introduced a similar Bill in the House of Lords.

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4.3.3. **Table II** (see end of text) shows recommendations for setback distance by a number of authorities. References can be found in the Bibliography. In general, noise engineers recommend lesser setback distances than physicians. The former rely more on measured and/or calculated sound pressures and the latter on clinical reports. It is logical to prefer the actual reports of the humans subjected to the noise rather than abstract calculations, even if the latter accurately measure ambient noise and allow for the low frequency components of wind turbine noise. Calculations can not measure annoyance and sleep disturbance, only humans can do so. **In my opinion, based on the reports cited in the table and the data from WindVoice, a minimum setback of 1.5km is appropriate.**

# 5. Planning considerations

## 5.1 ETSU-R-97

5.1.1. UK Government policy is that ETSU-R-97 should be used for the assessment of the likely impact of wind turbine noise and this was restated in a 2007 policy statement. Developers will often assert that, as it is government policy, ETSU-R-97 may not be questioned. However, as Mr Justice Mitting stated in a judicial review brought by the Renewable Energy Foundation (CO/9686/2007): "It will always be open to any objector to an application for permission to develop a site as a windfarm, to contend that the Statement is technically inadequate or erroneous." David Forsdick, of Landmark Chambers, a leading barrister with particular expertise in planning matters, stated, at a seminar on renewable energy on the 1st October 2008 (Forsdick 2008):

*"...., general policy and guidance cannot prevent consideration of:*

*a. the specific facts of an individual case;*

*b. scientific information which suggests that the general methodology may need to be adjusted on the facts of an individual case; or*

*c. actual experience elsewhere on the ground which shows that the government approved methodology does not always accurately predict the impacts.*

*Thus, whilst it is undoubtedly true that it is not for parties to an inquiry to question the merits of government policy, their evidence on the matters in the previous paragraph is plainly capable of constituting "other material considerations" which the decision maker has to take into account and, in an appropriate case, reach a conclusion on.*

5.1.2 It would seem logical that the specific facts of an individual case would include the presence of particularly sensitive or vulnerable receptors, such as the elderly and children, and the likelihood of excessive wind shear or amplitude modulation.

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5.1.3. There is now a large body of scientific information showing that the ETSU-R-97 methodology is in need of adjustment for wind shear and amplitude modulation. Many developers have acknowledged this by making an allowance for wind shear. The evidence that adjustments are necessary for amplitude modulation is equally strong.

5.1.4. There is a large body of evidence also showing that ETSU-R-97 noise levels are too high for human health and well being. These include the 2009 WHO Night Noise Guidelines and the 2006 draft reports by HMP to DTI.

5.1.5. It follows that it is appropriate and reasonable for planners and decision makers not to rely exclusively on ETSU-R-97 methodology and to take account of the other material considerations set out in this paper.

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## 6. Overall Conclusions

6.1. The appropriate mitigation of sleep disturbance and annoyance from industrial wind turbine noise is a maximum external turbine noise level of 35dB(A) or a setback of at least 1.5km.

**CD Hanning**

**16th November 2010**

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**Figure 1. Sound level and annoyance for different noise sources** (van den Berg 2008)

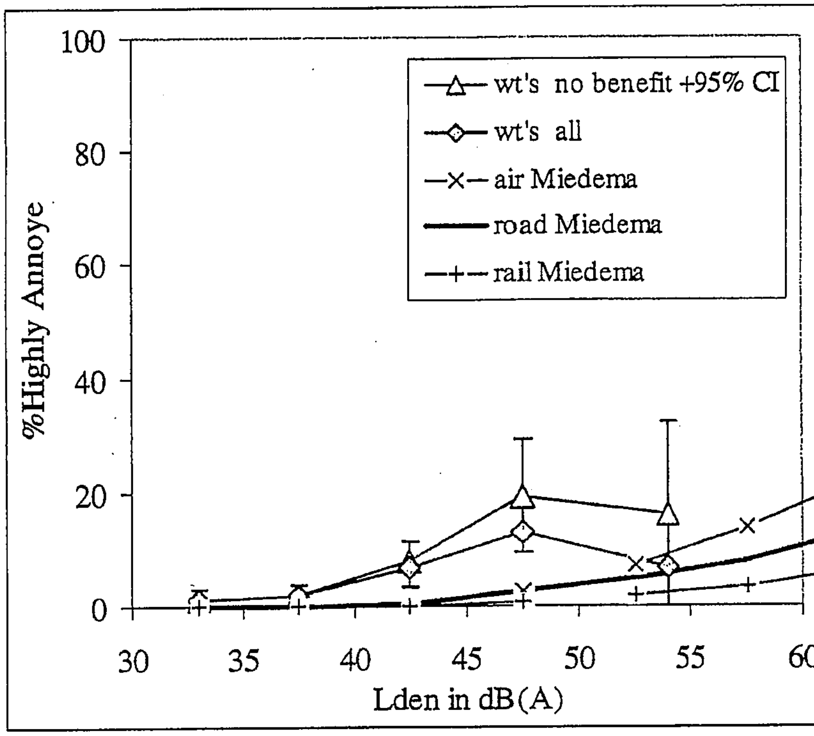
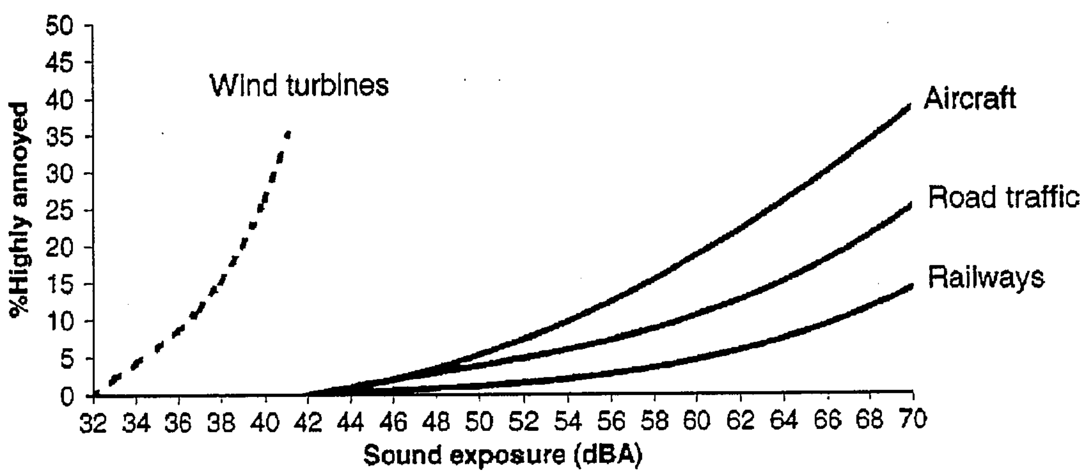



*Figure 8.1: relation between sound level Lden and percentage highly annoyed residents exposed to that sound, for three transportation noise sources and for wind turbines; the relation is given for all respondents and for those that have no economical benefit from a wind turbine.*

*Bars denote 95% confidence interval for non-benefitters.*

**Figure 2. Sound level and annoyance for different noise sources** (Pedersen E and Persson Waye, 2004)




Sound exposure is for wind turbines calculated A-weighted $L_{eq}$ for a hypothetical time period and for transportation DNL.

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**Figure 3.** Relationship between A-weighted sound pressure levels (equivalent levels at wind speed 8 m/s, 10 m over the ground) and proportion of respondents disturbed in the sleep by noise in three studies: SWE00 ($n$ = 341), SWE05 ($n$ = 746) and NL07 (only respondents that did not benefit economically from wind turbines; $n$ = 593). (Pedersen 2009)

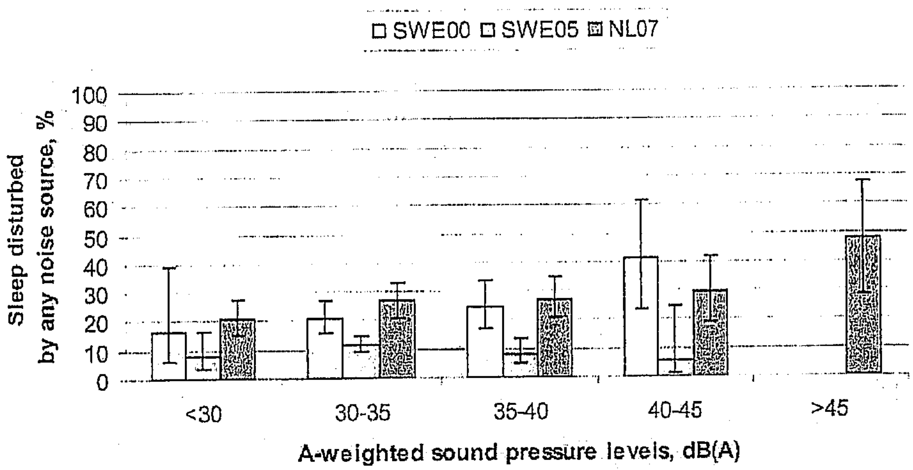




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**Figure 4.** Spindle rate and sleep stability. Observations were pooled among subjects in the lower and upper halves of the spindle rate distribution (ranges 4.57-5.44 and 5.58-6.14 spindles/min respectively) based on EEG lead C3 during stage N2. Corresponding sleep survival curves were derived from each pool in stage N2 using the Kaplan-Meier (product-limit) method.

Backward extrapolation of the response curve for low spindle rate subjects shows only a 50% likelihood of stable sleep at noise levels of 35 dB(A) and 75% likelihood for those with high spindle rates. From Dang-Vu et al., 2010

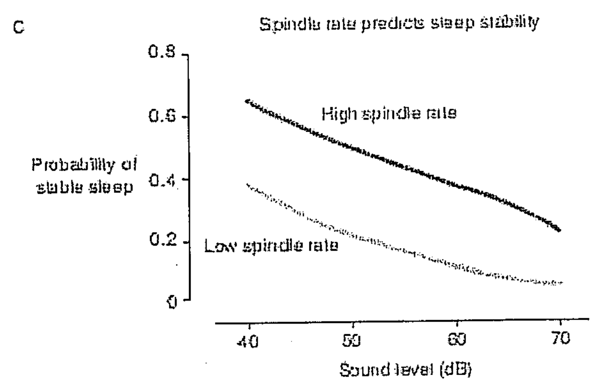

**Figure 5.** Percent of community highly annoyed by wind turbine noise correlated to normalized EPA community reactions to intrusive noise. From Ambrose 2010

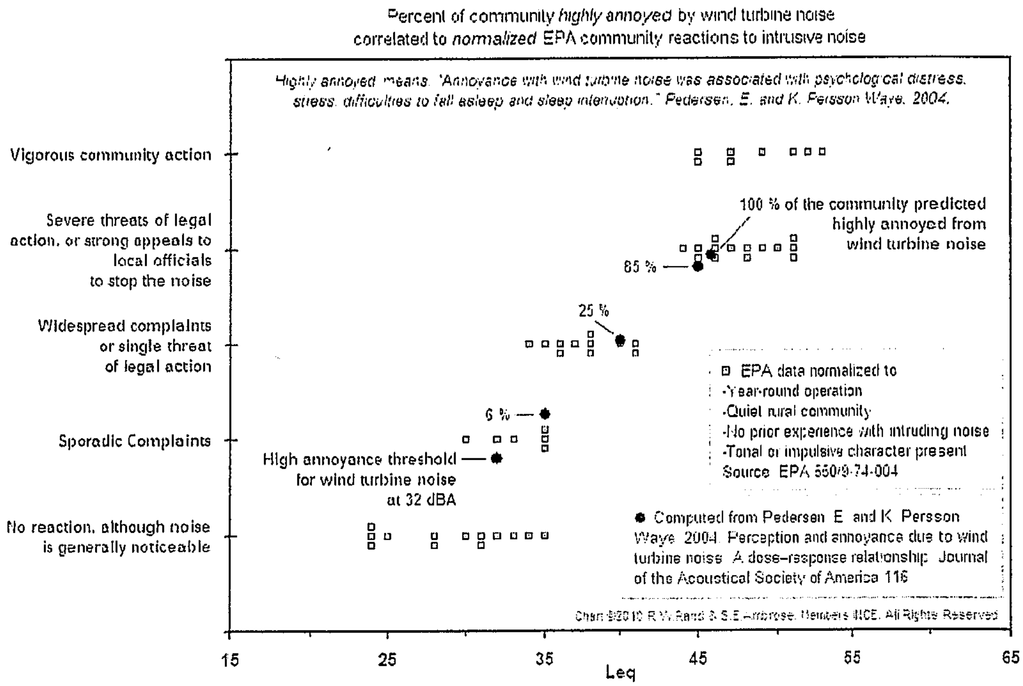

**Table I. Response to wind turbine noise outdoors or indoors, proportion of respondents (*n*=708) according to 5-dB(A) sound level intervals, and 95% confidence intervals (95%CI). (From Pedersen 2009a)**

| | Predicted *A*-weighted sound pressure levels dB(A) | | | | |
|---|---|---|---|---|---|
| | <30 | 30–35 | 35–40 | 40–45 | >45 |
| Outdoors *n* | 178 | 213 | 159 | 93 | 65 |
| Do not notice (%) (95%CI) | 75 (68–81) | 46(40–53) | 21(16–28) | 13 (8–21) | 8(3–17) |
| Notice, but not annoyed (%) (95%CI) | 20 (15–27) | 36(30–43) | 41(34–49) | 46 (36–56) | 58(46–70) |
| Slightly annoyed (%) (95%CI) | 2 (1–6) | 10(7–15) | 20 (15–27) | 23 (15–32) | 22(13–33) |
| Rather annoyed (%) (95%CI) | 1 (0–4) | 6(4–10) | 12 (8–18) | 6 (3–13) | 6(2–15) |
| Very annoyed (%) (95%CI) | 1 (0–4) | 1(0–4) | 6 (3–10) | 12 (7–20) | 6(2–15) |
| Indoors, *n* | 178 | 203 | 159 | 94 | 65 |
| Do not notice (%) (95%CI) | 87 (81–91) | 73(67–79) | 61(53–68) | 37 (28–47) | 46(35–58) |
| Notice, but not annoyed (%) (95%CI) | 11(7–17) | 15(11–20) | 22 (16–29) | 31(22–31) | 38(28–51) |
| Slightly annoyed (%) (95%CI) | 1 (0–4) | 8(5–12) | 9 (6–15) | 16 (10–25) | 9(4–19) |
| Rather annoyed (%) (95%CI) | 0 (0–2) | 3(1–6) | 4 (2–8) | 6 (3–13) | 5(2–13) |
| Very annoyed (%) (95%CI) | 1 (0–4) | 1(0–4) | 4 (2–8) | 10 (5–17) | 2(0–8) |

## Table II. Recommendations for setback of residential properties from industrial wind turbines

Note 1. The 2km limit from edges of towns and villages seems to have been set more for visual than noise reasons
Note 2. Dixsaut and colleagues (2009) report a review of this recommendation by AFSSET. They concluded that the 1.5km setback was "not relevant" and would compromise wind park development.

| Authority | Year | Notes | Recommendation | |
|---|---|---|---|---|
| | | | Miles | Kilometres |
| Frey & Hadden | 2007 | Scientists. Turbines >2MW | >1.24 | >2 |
| Frey & Hadden | 2007 | Scientists. Turbines <2MW | 1.24 | 2 |
| Harry | 2007 | UK Physician | 1.5 | 2.4 |
| Pierpont | 2008 | US Physician | 1.5 | 2.4 |
| Welsh Affairs Select Committee | 1994 | Recommendation for smaller turbines | 0.93 | 1.5 |
| Scottish Executive | 2007 | See note 1. | 1.24 | 2 |
| Adams | 2008 | US Lawyer | 1.55 | 2.5 |
| Bowdler | 2007 | UK Noise engineer | 1.24 | 2 |
| French National Academy of Medicine | 2006 | French physicians See note 2 | 0.93 | 1.5 |
| The Noise Association | 2006 | UK scientists | 1 | 1.6 |
| Kamperman & James | 2008 | US Noise engineers | >.62 | >1 |
| Kamperman | 2008 | US Noise engineer | >1.24 | >2 |
| Bennett | 2008 | NZ Scientist | >0.93 | >1.5 |
| Acoustic Ecology Institute | 2009 | US Noise engineers | 0.93 | 1.5 |
| NSW General Purpose Standing Committee | 2009 | Legislators | 1.24 | 2 |
| Thorne | 2010 | Aus/NZ acoustician | 1.24 | 2 |
| Horonjeff | 2010 | US acoustician | 1.5-2 | 2.4-3.2 |

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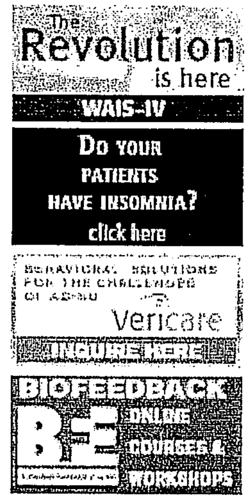


# Sleep deprivation may be undermining teen health

**Lack of sufficient sleep--a rampant problem among teens--appears to put adolescents at risk for cognitive and emotional difficulties, poor school performance, accidents and psychopathology, research suggests.**

**BY SIRI CARPENTER**
***Monitor* staff**

On any given school day, teen-agers across the nation stumble out of bed and prepare for the day. For most, the alarm clock buzzes by 6:30 a.m., a scant seven hours after they went to bed. Many students board the school bus before 7 a.m. and are in class by 7:30.

In adults, such meager sleep allowances are known to affect day-to-day functioning in myriad ways. In adolescents, who are biologically driven to sleep longer and later than adults do, the effects of insufficient sleep are likely to be even more dramatic--so much so that some sleep experts contend that the nation's early high-school start times, increasingly common, are tantamount to abuse.

"Almost all teen-agers, as they reach puberty, become walking zombies because they are getting far too little sleep," comments Cornell University psychologist James B. Maas, PhD, one of the nation's leading sleep experts.

There can be little question that sleep deprivation has negative effects on adolescents. According to the National Highway Traffic Safety Administration, for example, drowsiness and fatigue cause more than 100,000 traffic accidents each year--and young drivers are at the wheel in more than half of these crashes.

Insufficient sleep has also been shown to cause difficulties in school, including disciplinary problems, sleepiness in class and poor concentration.

"What good does it do to try to educate teen-agers so early in the morning?" asks Maas. "You can be giving the most stimulating, interesting lectures to sleep-deprived kids early in the morning or right after lunch, when they're at their sleepiest, and the overwhelming drive to sleep replaces any chance of alertness, cognition, memory or understanding."

Recent research has also revealed an association between sleep deprivation and poorer grades. In a 1998 survey of more than 3,000 high-school students, for example, psychologists Amy R. Wolfson, PhD, of the College of the Holy Cross, and Mary A. Carskadon, PhD, of Brown University Medical School, found that students who reported that they were getting C's, D's and F's in school obtained about 25 minutes less sleep and went to bed about 40 minutes later than students who reported they were getting A's and B's.

In August, researchers at the University of Minnesota reported the results of a study of more than 7,000 high-school students whose school district had switched in 1997 from a 7:15 a.m. start time to an 8:40 a.m. start time. Compared with students whose schools maintained earlier start times, students with later starts reported getting more sleep on school nights, being less sleepy during the day, getting slightly higher grades and experiencing fewer depressive feelings and behaviors.

Also troubling are findings that adolescent sleep difficulties are often associated with psychopathologies such as depression and attention deficit hyperactivity disorder (ADHD).

This research, combined with studies showing widespread sleep deprivation among teens, has propelled efforts to educate children and adults about the importance of a good night's sleep and to persuade schools to push back high-school starting times.

"There is substantial evidence that the lack of sleep can cause accidents, imperil students' grades and lead to or exacerbate emotional problems," says U.S. Rep. Zoe Lofgren (D-Calif.), who has introduced a bill that would provide federal grants to help school districts defray the cost of pushing back school starting times. Adjusting school schedules, Lofgren says, "could do more to improve education and reduce teen accidents and crime than many more expensive initiatives."

The research has also spurred further investigations into why teens need extra sleep, the effects of sleep deprivation on cognition, emotion regulation and psychopathology, and the long-term consequences of chronic sleep deprivation.

**Dogma reversed**

For decades, experts believed that people require less sleep as they move from infancy through adulthood.

It's easy to see why this belief persisted: Adolescents sleep less than they did as children, declining from an average of 10 hours a night during middle childhood to fewer than 7.5 hours by age 16. According to Wolfson and Carskadon's 1998 study, 26 percent of high school students routinely sleep less than 6.5 hours on school nights, and only 15 percent sleep 8.5 hours or more. The same study indicated that to make up for lost sleep, most teens snooze an extra couple of hours on weekend mornings--a habit that can lead to poorer-quality sleep.

But to researchers' surprise, in the past two decades studies have shown that teen-agers require considerably more sleep to perform optimally than do younger children or adults. Starting around the beginning of puberty and continuing into their early 20s, Carskadon and colleagues have shown, adolescents need about 9.2 hours of sleep each night, compared with the 7.5 to 8 hours that adults need.

In addition to needing more sleep, adolescents experience a "phase shift" during puberty, falling asleep later at night than do younger children. Researchers long assumed that this shift was driven by psychosocial factors such as social activities, academic pressures, evening jobs and television and Internet use. In the past several years, however, sleep experts have learned that biology also plays a starring role in adolescents' changing sleep patterns, says Carskadon.

Indeed, Carskadon's research is greatly responsible for that new understanding. In a pair of groundbreaking studies published in 1993 and 1997, she and colleagues found that more physically mature girls preferred activities later in

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the day than did less mature girls, and that in more physically mature teens, melatonin production tapered off later than it did in less mature teens. Those findings, Carskadon says, suggest that the brain's circadian timing system--controlled mainly by melatonin--switches on later at night as pubertal development progresses.

Changes in adolescents' circadian timing system, combined with external pressures such as the need to awaken early in the morning for school, produce a potentially destructive pattern of early-morning sleepiness in teen-agers, Carskadon argues. In a laboratory study of 40 high-school students published in the journal Sleep (Vol. 21, No. 8) in 1998, she, Wolfson and colleagues examined the effect of changing school starting times from 8:25 a.m. to 7:20 a.m.

Their results were disturbing: Almost half of the students who began school at 7:20 were "pathologically sleepy" at 8:30, falling directly into REM sleep in an average of only 3.4 minutes--a pattern similar to what is seen in patients with narcolepsy.

Those findings, says Carskadon, persuaded her that "these early school start times are just abusive. These kids may be up and at school at 8:30, but I'm convinced their brains are back on the pillow at home."

**Elusive questions**

The evidence of adolescents' increased need for sleep and that many--if not most--teen-agers are chronically sleep deprived has raised further questions. Particularly elusive, says Carskadon, has been the question of why adolescents' circadian clocks shift to a later phase around the beginning of puberty.

One possibility, she believes, is that the brain's sensitivity to light changes during adolescence. At the annual meeting of the Associated Professional Sleep Societies in June, she and colleagues presented research showing that in the evening, exposure to even very dim lighting delayed melatonin secretion for participants who were in middle or late puberty, but not for prepubertal participants.

Carskadon is also interested in how teen-age

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alcohol use might affect the brain's sleep system. Following up on studies in adults that have established a link between drinking problems and changes in sleep patterns, for example, she and her colleagues plan to examine whether during early development, young people with a family history of problem drinking might have abnormalities in the brain mechanisms that govern sleep.

Just as important as the question of why sleep patterns change during adolescence is the issue of how sleep deprivation influences adolescents' emotion regulation and behavior. Many researchers have noted that sleep-deprived teen-agers appear to be especially vulnerable to psychopathologies such as depression and ADHD, and to have difficulty controlling their emotions and impulses.

Although it's difficult to untangle cause and effect, it's likely that sleep deprivation and problems controlling impulses and emotions exacerbate one another, leading to a "negative spiral" of fatigue and sleepiness, labile emotions, poor decision-making and risky behavior, says Ronald E. Dahl, MD, a professor of psychiatry and pediatrics at the University of Pittsburgh.

Despite the evidence that insufficient sleep affects young people's thinking, emotional balance and behavior, the long-term effects of chronic sleep deprivation on learning, emotion, social relationships and health remain uncertain.

"There's a real need for longitudinal studies to follow through later childhood and adulthood," says psychologist Avi Sadeh, PhD, a sleep researcher at Tel Aviv University. Although research has amply demonstrated that sleep problems affect young people's cognitive skills, behavior and temperament in the short term, he says, "It's not at all clear to what extent these effects are long-lasting."

**Researchers push for school changes, public outreach**

With such a wealth of evidence about the prevalence of adolescent sleep deprivation and the risks it poses, many sleep researchers have become involved in efforts to persuade school districts to push back high-school starting times so that teens can get their needed rest.

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Some schools argue that adjusting school schedules is too expensive and complicated. But others have responded positively to sleep experts' pleas. The Connecticut legislature is considering a bill that would prohibit public schools from starting before 8:30 a.m., and Massachusetts lawmakers are also weighing the issue. And Lofgren's "Zzzzz's to A's" bill, first introduced in the U.S. House of Representatives in 1998, would provide federal grants of up to $25,000 to school districts to help cover the administrative costs of adjusting school start times.

These efforts are a move in the right direction, says Wolfson. But, she says, changing school start times isn't the entire answer. "I think we have to be educating children, parents and teachers about the importance of sleep, just as we educate them about exercise, nutrition and drug and alcohol use."

Toward that end, several public-education efforts are now under way:

* With a grant from the Simmons mattress company, Cornell's Maas recently produced a film on teen-age sleep deprivation, its consequences and the "golden rules" for healthy sleep. The film is scheduled for distribution through parent-teacher associations and school principals this fall. In August, Maas also published a children's book, "Remmy and the Brain Train," which discusses why the brain requires a good night's sleep.

* Next year, the National Center for Sleep Disorders Research at the National Institutes of Health plans to release a supplemental sleep curriculum for 10th-grade biology classes, addressing the biology of sleep, the consequences of insufficient sleep and the major sleep disorders. In a related effort, the center is coordinating a sleep-education campaign aimed at 7- to 11-year-olds.

* Wolfson and colleague Christine A. Marco, PhD, a psychologist at Worcester State College, are pilot-testing an eight-week sleep curriculum for middle-school students. As part of the curriculum, students keep sleep diaries, play creative games and participate in role-playing about sleep, and set goals--for example, for the amount of sleep they want to get or for regulating their caffeine intake. Preliminary results indicate that the curriculum

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helps students improve their sleep habits.

"Changing school start times is one critical measure we can take to protect young people's sleep," says Wolfson. "And then, if we can only understand what's going on with sleep in these sixth-, seventh- and eighth-graders, we can intervene to change their sleep behavior before it gets out of hand."

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Life Sciences
Volume 20, Issue 9, 1 May 1977, Pages 1501-1508

doi:10.1016/0024-3205(77)90441-6 | How to Cite or Link Using DOI


# Urinary melatonin rhythms during sleep deprivation in depressed patients and normals[☆]



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Received 14 March 1977. Available online 25 November 2002.

## Abstract

Melatonin excretion was measured in 8 hour urine aliquots for eight healthy controls and six depressed patients. Both groups had similar diurnal rhythms, with increased melatonin excretion during the night. When subjects were sleep deprived, remaining awake and active in continuous light from 7 a.m. one morning until 11 p.m. the following day, the diurnal rhythm in melatonin excretion remained unchanged. These data in man appear to be inconsistent with previous studies in rats showing rapid light-induced suppression of the nocturnal rise in pineal melatonin synthesis.

[☆] Supported by Grant NGR-22-009-627 from the National Aeronautics and Space Administration.



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# Clinical effects of sleep fragmentation versus sleep deprivation☆

Michael H. Bonnet[f1], Donna L. Arand

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## Abstract

Common symptoms associated with sleep fragmentation and sleep deprivation include increased objective sleepiness (as measured by the Multiple Sleep Latency Test); decreased psychomotor performance on a number of tasks including tasks involving short term memory, reaction time, or vigilance; and degraded mood. Differences in degree of sleepiness are more related to the degree of sleep loss or fragmentation rather than to the type of sleep disturbance. Both sleep fragmentation and sleep deprivation can exacerbate sleep pathology by increasing the length and pathophysiology of sleep apnea. The incidence of both fragmenting sleep disorders and chronic partial sleep deprivation is very high in our society, and clinicians must be able to recognize and treat Insufficient Sleep Syndrome even when present with other sleep disorders.

**Keywords:** sleep deprivation, sleep fragmentation, partial sleep deprivation, sleep apnea, sleepiness, insomnia

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Dayton Department of Veterans Affairs Medical Center, Wright State University, Kettering Medical Center, and the Wallace Kettering Neuroscience Institute

☆ Supported by the Dayton Department of Veterans Affairs Medical Center, Wright State University School of Medicine, and the Sleep–Wake Disorders Research Institute.

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PII: S1087-0792(01)90245-X

doi:10.1053/smrv.2001.0245



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Electroencephalography and Clinical Neurophysiology
Volume 51, Issue 5, May 1981, Pages 483-493

doi:10.1016/0013-4694(81)90225-X | How to Cite or Link Using DOI


# Sleep deprivation: Effect on sleep stages and EEG power density in man☆
# Privation de sommeil: effets sur les stades de sommeil et la densité de puissance électroencéphalographique chez l'Homme

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Accepted 19 January 1981. Available online 7 March 2003.

## Abstract

Sleep was analysed in 8 young adult subjects during two baseline nights and two recovery nights following 40.5 h sleep deprivation. Sleep stages were scored from the polygraph records according to conventional criteria. In addition, the EEG records of the entire nights were subjected to spectral analysis to compute the frequency distribution of the power density in the 0.25–25 Hz range for 0.5 Hz or 1.0 Hz bins. In the first recovery night, the power density in the delta band was significantly higher than baseline for total sleep time as well as for sleep stages 2, 3 and 4, 4 and REM. These changes were not restricted to the delta band, but extended to higher frequency bands. Minor, but significant, effects of sleep deprivation were seen in the power density distribution of the second recovery night. In the baseline nights, a progressive reduction of power density in the delta/theta range was present for successive non-REM-REM sleep cycles for total sleep time and stages 2, 3 and 4, and 4. The results show that effects of sleep deprivation as well as trends within the sleep periods are readily apparent from spectral analysis, but are inadequately reflected by conventional sleep scoring. When the power density values were integrated over the entire frequency range (0.75–25 Hz) for each non-REM-REM sleep cycle, an exponential decline from cycle 1 to cycle 3 was suggested. The present findings support the hypothesis that the EEG power density in the low frequency range is an indicator of a progressively declining process during sleep whose initial value is determined by the duration of prior waking.

## Résumé

Le sommeil de 8 jeunes adultes a été enregistré pendant 2 nuits de base et 2 nuits de b récupération après une privation de sommeil de 40,5 h. Les stades de sommeil furent identifiés selon des critères conventionnels sur la base d'enregistrements polygraphiques. En plus, l'EEG fut soumis à l'analyse spectrale pour obtenir la distribution de fréquence (0.25–25 Hz en bins de 0.5 Hz ou 1.0 Hz) de la densité de puissance. Pendant la première nuit de récuperation la densité de puissance de la bande delta était significativement supérieure à celle des nuits de base pour le temps de sommeil total ainsi que pour les stades 2, 3 et 4, 4 et REM. Ces effets ne s'obervaient pas seulement

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pour la bande delta, mais étaient également présents dans des bandes de fréquences plus élevées. La distribution de la densité de puissance montrait des changements mineurs, mais significatifs, dans la deuxième nuit de récupération. Pendant les nuits de base, une réduction progressive de la densité de puissance dans la bande delta/thêta s'observait pour les cycles non-REM-REM successifs pour le temps de sommeil total ainsi que pour les stades 2, 3 et 4, et 4. Ces résultats montrent que les effets de la privation de sommeil ainsi que des tendances dans les périodes de sommeil sont mis en évidences par l'analyse spectrale, mais ne sont apparents qu'en partie dans la distribution des stades de sommeil. Après l'intégration des valeurs de densité de puissance sur la gamme de fréquence entière (0.75–25.0 Hz) pour chaque cycle non-REM-REM une décroissance exponentielle s'observait entre cycle 1 et cycle 3. Les résultats sont compatibles avec l'hypothèse que la densité de puissance de l'EEG dans les bandes de fréquences basses est un indicateur d'un processus de sommeil qui décroit progressivement et dont la valeur initiale est déterminée par la durée de l'éveil précédent.

☆ Supported by the Swiss National Science Foundation, Grants No. 3.254-0.77, 3.561-0.79 and 3.522-0.79 and Stiftung für wissenschaftliche Forschung an der Universität Zürich.

[1] The help of the following persons is gratefully acknowledged: Ms M. Leopfe (data analysis and supervision of experiments), Ms M. Eglin and Mr. A. Wöhrle (supervision of experiments), Dr. I. Tobler (comments on the manuscript), Ms K. Schwarz (illustrations) and Ms R. Steiger (typing).



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## Sleep as a Mediator of the Relationship between Socioeconomic Status and Health: A Hypothesis

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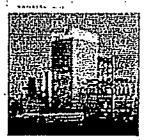
Article first published online: 6 FEB 2006

DOI: 10.1111/j.1749-6632.1999.tb08120.x

Issue



Annals of the New York Academy of Sciences

Volume 896, SOCIOECONOMIC STATUS AND HEALTH IN INDUSTRIAL NATIONS: SOCIAL, PSYCHOLOGICAL, AND BIOLOGICAL PATHWAYS

pages 254–261, December 1999



ABSTRACT: This article discusses the hypothesis that the adverse impact of low socioeconomic status (SES) on health may be partly mediated by decrements in sleep duration and quality. Low SES is frequently associated with a diminished opportunity to obtain sufficient sleep or with environmental conditions that compromise sleep quality. In a recent study, we examined carbohydrate metabolism, endocrine function, and sympatho-vagal balance in young, healthy adults studied after restricting sleep to four hours per night for six nights as compared to a fully rested condition obtained by extending the bedtime period to 12 hours per night for six nights. The state of sleep debt was associated with decreased glucose tolerance, elevated evening cortisol levels, and increased sympathetic activity. The alterations in glucose tolerance and hypothalamo-pituitary-adrenal function were qualitatively and quantitatively similar to those observed in normal aging. These results indicate that sleep loss can increase the "allostatic load" and facilitate the development of chronic conditions, such as obesity, diabetes, and hypertension, which have an increased prevalence in low SES groups.



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# Neural basis of alertness and cognitive performance impairments during sleepiness. I. Effects of 24 h of sleep deprivation on waking human regional brain activity

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Issue

Journal of Sleep Research
Volume 9, Issue 4, pages 335–352, December 2000

Article first published online: 7 JUL 2008
DOI: 10.1046/j.1365-2869.2000.00225.x



Keywords: alertness; cognitive performance; prefrontal cortex; regional brain activity; sleep deprivation; thalamus

## Abstract



The negative effects of sleep deprivation on alertness and cognitive performance suggest decreases in brain activity and function, primarily in the thalamus, a subcortical structure involved in alertness and attention, and in the prefrontal cortex, a region subserving alertness, attention, and higher-order cognitive processes. To test this hypothesis, 17 normal subjects were scanned for quantifiable brain activity changes during 85 h of sleep deprivation using positron emission tomography (PET) and $^{18}$Fluorine-2-deoxyglucose ($^{18}$FDG), a marker for regional cerebral metabolic rate for glucose (CMRglu) and neuronal synaptic activity. Subjects were scanned prior to and at 24-h intervals during the sleep deprivation period, for a total of four scans per subject. During each 30 min $^{18}$FDG uptake, subjects performed a sleep deprivation-sensitive Serial Addition/Subtraction task. Polysomnographic monitoring confirmed that subjects were awake. Twenty-four hours of sleep deprivation, reported here, resulted in a significant decrease in global CMRglu, and significant decreases in absolute regional CMRglu in several cortical and subcortical structures. No areas of the brain evidenced a significant increase in absolute regional CMRglu. Significant decreases in relative regional CMRglu, reflecting regional brain reductions greater than the global decrease, occurred predominantly in the thalamus and prefrontal and posterior parietal cortices. Alertness and cognitive performance declined in association with these brain deactivations. This study provides evidence that short-term sleep deprivation produces global decreases in brain activity, with larger reductions in activity in the distributed cortico-thalamic network mediating attention and higher-order cognitive processes, and is complementary to studies demonstrating deactivation of these cortical regions during NREM and REM sleep.

## INTRODUCTION



Lack of adequate sleep, or sleep deprivation, reduces workplace productivity, public safety, and personal well being (Dement and Vaughan 1999). Sleep deprivation is one cause of accidents and catastrophic failures in real-world situations (Mitler *et al.* 1988), including military friendly fire incidents (Belenky *et al.* 1994) and vehicular accidents (Horne and Reyner 1995). Short periods of total sleep deprivation (i.e. 24 h) typically occur in instances where individuals or groups undergo extended wakefulness to meet deadlines. Longer periods of sleep deprivation (i.e. greater than 40 h) can occur during atypical sustained work conditions (Kroemer *et al.* 1990), such as in some military training exercises and combat operation missions (Haslam 1982; Krueger 1991; Belenky *et al.* 1994) and civilian emergency work situations (Krueger 1989). Substantial sleep deprivation can also occur in individuals suffering from sleep disorders (Kelly 1991), in those with suspected neurologic dysfunction (Williams *et al* 1996), and in the elderly (Reynolds *et al.* 1987).

Two cardinal features of sleep deprivation are diminished alertness and cognitive performance. These neurobehavioral deficits are well established, beginning with the first published study of long-term human sleep deprivation over 100 years ago (Patrick and Gilbert 1896). Reduced alertness has been shown in short- as well as long-term sleep deprivation studies using objective and/or subjective measures of sleepiness (e.g. Carskadon and Dement 1979; Mikulincer *et al.* 1989; Newhouse *et al.* 1989; Penetar *et al.* 1993; Harma *et al.* 1998). Decrements in cognitive performance, often independent of loss of alertness or lapses in attention, are also produced by both short- and long-term sleep deprivation. Simple task performance is impaired, as reflected by tests of reaction time, vigilance, and attention (e.g. Horne 1988a; Dinges and Kribbs 1991; Koslowsky and Babkoff 1992; Gillberg and Akerstedt 1998). Similarly, complex task performance is impaired, as reflected by tests of working memory, verbal fluency and speech articulation, language, logical reasoning, creative and flexible thinking and planning, decision making, and judgment (e.g. Banderet *et al.* 1981; Horne 1988a; Newhouse *et al.* 1989; Harrison and Horne 1997, 1998, 1999). Performance deficits can occur as early as during the first night without sleep (Angus and Heslegrave 1985; Monk and Carrier 1997) and are amplified after two-to-three nights without sleep (e.g. Horne and Pettit 1985; Koslowsky and Babkoff 1992; How *et al.* 1994).

The degrading effects of sleep deprivation on alertness and cognitive performance suggest alterations in underlying brain physiology and function. To date, however, only a few studies have investigated *in vivo* brain activity changes mediating sleep deprivation-induced neurobehavioral impairment in normal volunteers. In the first study, Wu *et al.* (1991) quantified absolute changes in regional cerebral glucose metabolic rate (CMRglu), a marker for neuronal activity, using $^{18}$Fluorine-2-deoxyglucose ($^{18}$FDG) (Reivich *et al.* 1979) and positron emission tomography (PET) (Cherry and Phelps 1996) during a Continuous Performance Test, a visual vigilance task. At 32 h of sleep deprivation, significant decreases in absolute regional CMRglu were found in thalamus and cerebellum along with significant decreases in relative regional CMRglu (absolute regional CMRglu normalized to the whole brain) in these same regions and temporal cortex. These brain deactivations were accompanied by a concomitant decrease in task performance. In another study, Drummond *et al.* (1999a, 2000) evaluated alterations in the cerebral hemodynamic response using blood-oxygen-level-dependent functional magnetic resonance imaging (BOLD-fMRI) during both a Serial Subtraction task and a Verbal Learning task. The Serial Subtraction task, a variant of the Serial Addition/Subtraction task (Thorne *et al.* 1985), involved attention, working memory, and arithmetic subtraction, while the Verbal Learning task involved recognition and recall. Statistical comparisons between normal wakefulness and 35 h of sleep deprivation revealed decreased BOLD responses, associated with impaired arithmetic performance, in the prefrontal anterior cingulate gyrus, lateral posterior parietal lobules, pulvinar thalamus, and visual cortices (Drummond *et al.* 1999a). With impaired verbal recall performance (Drummond *et al.* 2000), decreased BOLD responses were found in the prefrontal anterior cingulate and temporal lobes, and increased BOLD responses were noted in both the prefrontal and lateral posterior parietal regions.

Although the Wu *et al.* (1991) study provided the first quantitative assessment of absolute human brain activity changes and cognitive function during extended wakefulness, longer periods of sleep deprivation beyond 32 h, i.e. the effects of more than one night of sleep deprivation, were not evaluated. Moreover, the regions of interest analysis used (e.g. single activity measure over an entire cortical lobe) was not as sensitive as the more recent voxel-based method of analysis (e.g. statistical parametric mapping [SPM]; Friston *et al.* 1995a,b). This latter analysis allows assessment of multiple, smaller functional areas of cortex. Either of these factors may have minimized other significant regional effects of sleep deprivation.

The Drummond *et al.* (1999a, 2000) sleep deprivation findings were based on the BOLD-fMRI technique that evaluates the hemodynamic response to neuronal activation using high spatial resolution scanning. Because the technique does not utilize radiotracers and long scanning periods, several tasks can be evaluated in an experimental session. While a sensitive indicator of relative cerebral activation, the BOLD signal as currently applied is not a quantifiable measure of neural activity (Howseman and Bowtell 1999). Relative changes in the regional hemodynamic response are obtained by comparing the BOLD signal during the task of interest to the BOLD signal during a baseline or control task (Ogawa *et al.* 1998). The ability to quantify absolute brain activity in investigations of sleep deprivation may be important, however, when global activity is affected, as changes based on

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relative brain activity alone cannot characterize with certainty the magnitude or the direction of changes in regional brain activity response. On the other hand, when absolute quantification of brain activity has been accomplished and a whole brain or global change has occurred, the normalization procedure (e.g. transforming the data to *z* scores or ratios, or removing the global effect with analysis of covariance [ANCOVA]), can exclude some regions in terms of statistical significance. Also, other regions may appear activated or deactivated, depending on the direction of the global change, when in fact a real change has not occurred (see Braun *et al.* 1997 and Kajimura *et al.* 1999 for related discussions). These aspects of brain imaging data acquisition and analysis – lack of absolute quantification and the statistical analysis of normalized (i.e. relative) values without concomitant analysis of absolute values – may obscure the extent and/or interpretation of regional brain activity changes.

In the present study, we quantified absolute regional CMRglu with $^{18}$FDG and PET four times each in 17 normal volunteers during 85 h of sleep deprivation and utilized the SPM method for analysis of the absolute and relative neuroimaging data. During the four-day experimental phase, subjects were scanned after a night of normal sleep and then serially after 24, 48, and 72 h without sleep. During each $^{18}$FDG uptake, and at 2-h intervals between PET scans (Fig. 1), subjects performed a computer-based Serial Addition/Subtraction task (Thorne *et al.* 1985). As shown in Fig. 1 and by other sleep deprivation studies (e.g. Thorne *et al.* 1983; Newhouse *et al.* 1989; Penetar *et al.* 1994; Drummond *et al.* 1999a), Serial Addition/Subtraction is sensitive to the effects of sleep deprivation, even when performed for short durations. This task is more complex than tests of simple reaction time or vigilance and involves not only sustained attention, but also working memory and arithmetic processing. All of these mental processes have been attributed, in large part, to the prefrontal cortex (e.g. Cohen *et al.* 1988; Coull *et al.* 1996, 1998; Dolan *et al.* 1997; Roland and Friberg 1985; Dehaene *et al.* 1996; Dehaene *et al.* 1999).

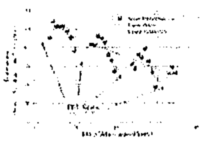

**Figure 1.** Graph of the cognitive performance decline, modulated by the circadian rhythm, for the Serial Addition/Subtraction task during the 85 h of sleep deprivation. Data points are associated with performance measurements collected approximately every 2 h between PET scans, where Serial Addition/Subtraction task duration was 2–3 min. Hatched arrows indicate temporal occurrence of long-term sleep deprivation $^{18}$FDG-PET scans, which will be reported separately.

The main purpose of our experiment was to quantify and characterize global and regional brain activity changes implicated in sleep deprivation-induced neurobehavioral impairment during cumulative, extended sleep loss. We endeavored to model real-world sustained operations requiring wakefulness and near continuous task performance across four consecutive days. Based on previous behavioral research, we expected 'dose-dependent' decreases in alertness and cognitive performance with cumulative sleep deprivation. We hypothesized that sleep deprivation would result in dose-dependent deactivation of the thalamus, a subcortical structure involved in alertness and attention (Mesulam 1985). Additionally, we hypothesized that sleep deprivation would produce dose-dependent deactivation of the prefrontal cortex, a region that subserves higher order cognitive processes (Fuster 1989; Frith and Dolan 1996) along with alertness and attention (Posner and Tudela 1997). Prefrontal cortical vulnerability to sleep deprivation has been suggested previously by Horne (1988b, 1993). We extended our prefrontal cortical deactivation hypothesis during sleep deprivation to include the anterior cingulate gyrus because of its participation in attentional processes (Vogt *et al.* 1992).

This is the first of a series of reports examining progressive changes in regional CMRglu with increasing sleep deprivation. We describe here the results of 24 h of sleep deprivation compared to rested baseline. These results have been published previously in preliminary form (Thomas *et al.* 1998a,b).

## METHOD

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### Subjects

The 17 volunteers participating in the study were right-handed civilian males, between the ages of 21–29 years (mean 24.7 ± 2.8 years), with no history of medical, neurological, psychiatric, or sleep disorder conditions. Their histories also included 7–8 h of nightly sleep on a regular basis, no nicotine use, and low caffeine use (less than 100 mg/day). Subjects passed a physical examination, including CBC and electrocardiography (EKG) tests and a narcotics screening test. Subjects were within normal range on mental states exams (Beck Depression Inventory, Beck *et al.* 1961; and Leeds Anxiety-Depression Scales, Snaith *et al.* 1976) and a cognitive test (Wonderlic® Personnel Test, Wonderlic, Inc., Libertyville, Illinois, USA).

Informed, written consent was obtained from all subjects. Subjects were paid for their participation in the study.

### Experimental design and methodological considerations

A time series design was used, with progressive sleep deprivation as the independent variable. Repeated measures of absolute regional CMRglu, cognitive performance, alertness, mood, and subjective experiences were collected after 0, 24, 48, and 72 h of sleep deprivation. Additional measures of alertness, cognitive performance, and mood were collected at fixed intervals throughout the sleep deprivation period. These measures were included to place the performance results associated with the PET scans in the context of the circadian rhythm of cognitive performance, as well as to impose a moderate-to-heavy near continuous workload on the subjects as might be anticipated in a real-world sustained operation.

Ideally, the evaluation of a rested control group of subjects, for whom nightly sleep occurred for three days in place of sleep deprivation, would have been helpful to account for potential nonspecific effects on brain activity (e.g. regional CMRglu effects that may be produced by task habituation, by day-to-day variability in regional brain activity, by unbalanced order of scans, or by learning and/or task tedium effects). Additionally, a sleep deprived control group, in which a performance deficit did not occur, may have been useful to possibly delineate primary or first-order effects of sleepiness on regional brain activity; e.g. perhaps indicating just one or two brain areas directly affected by sleepiness and therefore responsible, via their connectivity, for remote areas of deactivation. Also of interest would have been the addition of a fifth PET scan at the end of the study to assess recovery sleep effects on brain activity and task performance as well as to have compared several tasks within the same study to address the issue of task specificity and regional brain activity response to sleep deprivation.

In our four-consecutive day $^{18}$FDG-PET scanning study, which included a pre-experiment day where subjects underwent a simulation PET scan, the addition of an extra PET scan to assess recovery sleep effects on subsequent wakefulness and the addition of a rested control group were precluded because of cost and logistical constraints. Given this circumstance, the comparison of the sleep deprivation scans to the baseline rested scans was a reasonable alternative to using a rested control group. For similar reasons, we were not able to include a sleep deprived-control group where performance did not vary. Even so, stable performance levels, in terms of both accuracy and reaction times, would have been impractical to accomplish out to 72 h of sleep deprivation, without either changing the task itself (i.e. making it considerably easier) or adding further financial incentives. Implementing these manipulations may not have proven successful, though, as in a previous study where substantial monetary rewards were given for maintaining performance at rested baseline values, intact performance could not be achieved on a simple vigilance test at 48–72 h of sleep deprivation (Horne and Pettitt 1985). Consequently, we focused our investigation on the underlying brain physiology of performance deficit, rather than intact performance, because we were most interested in delineating the regional brain pattern associated with the behavioral impairments. The use in our study of two additional days of sleep deprivation was a viable approach to discerning brain areas that might be more sensitive (i.e. show greater deactivation than other regions) to sleep deprivation. With respect to the effect of the specific task and brain activity response to sleep deprivation, a radiotracer with quantification capability, a very short half life, and low radiation exposure would have been required to allow evaluation of absolute brain activity responses during multiple task performances within a brief time window. The tracer $H_2{}^{15}O$, which measures cerebral blood flow (a correlate of cerebral glucose metabolism) and allows up to 12 PET scans per subject, meets these criteria. However, because of its short half life, quantifying absolute blood flow by the $H_2{}^{15}O$–PET method necessitates automatic arterial sampling. Inserting an arterial line in the same subject in his one available wrist on four contiguous days would have been technically unfeasible in our study.

We did attempt within our experimental design to minimize scan order and other nonspecific effects. Firstly, we included a realistic simulation (except for injection of actual radioisotope) of the $^{18}$FDG uptake and PET scan procedure prior to the first experimental PET scan. This was done to avoid possible novelty, anxiety, or excitement effects due to the introduction of the imaging procedure (Roland 1993) during the rested baseline scan. Subjective measures of tension and calmness showed that anxiety and excitement levels were not significantly different between the rested baseline and 24 h sleep deprivation scans (see RESULTS). Secondly, we tested our subjects during performance of the same complex cognitive task in the four $^{18}$FDG uptake periods. It has been shown in test-retest neuroimaging studies that the use of a standard task (vs. a 'rest' task) reduces inherent

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between-subject and day-to-day regional CMRglu variability (Duara et al. 1987; Holcomb et al. 1993). Thirdly, we included training and practice on the Serial Addition/Subtraction task prior to the baseline PET scan to preclude the situation of comparing learning and novelty effects of the task at the baseline scan vs. practice effects at the 24 h, and subsequent, sleep deprivation scans. Finally, we gave feedback of performance to subjects at 5-min intervals throughout the 30 min Serial Addition/Subtraction task and $^{18}$FDG uptake to assist in sustaining effort and motivation levels (Wilkinson 1961). With sleep deprivation, we observed a significant increase in subjectively rated effort and a trend for increased motivation to perform the task (see RESULTS) indicating that the cognitive performance deficits were most likely due to a direct effect of sleep deprivation on attention and cognition and not to an indirect effect of decreased effort and motivation produced by task repetition- or task duration-induced tedium.

## Procedures

### Pre-study phase

Each volunteer wore a Precision Control Design (PCD Inc., Fort Walton Beach, Florida, USA) BMA-32 wrist-worn movement activity device or actigraph (Redmond and Hegge 1985), 7–10 days prior to entering the study to document his adherence to a 22.00 to 05.45 h nightly sleep schedule, the sleep schedule prescribed in the nighttime sleep portion of the study. Subjects were advised to refrain from caffeine intake for the three days before the start of the study.

### Acclimation and training phase

Each in-residence session lasted eight days. Subjects arrived on Day 1 in groups of three or four at the Division of Neuropsychiatry, WRAIR. Their pre-study actigraph data were assessed, and they were briefed on all study procedures. Afterwards, subjects were instrumented for continuous recording of electroencephalography (EEG), electrooculography (EOG), and electromyography (EMG) and were trained on two different cognitive test batteries, each of which took approximately 25 min to complete. The first test battery consisted of the Wisconsin Card Sort Test, Thurstone's Word Fluency Test, and the Benton's Verbal Fluency Test, while the second test battery consisted of several cognitive and reaction time tasks, including a 2–3 min Serial Addition/Subtraction task, from the Walter Reed Performance Assessment Battery. Subjects were then transported to the General Clinical Research Center (GCRC), Johns Hopkins Bayview Medical Center, Baltimore, Maryland, where they began the residential portion of the study and continued to practice the cognitive tests. Subjects retired for sleep at 22.00 h and were awakened at 05.45 h on Day 2, and the same sleep schedule was followed for Days 2 and 3. Throughout Days 2 and 3, subjects practiced the cognitive performance tests, including the 2–3 min Serial Addition/Subtraction test (12 sessions total prior to the baseline PET scan). They were pretrained on the Serial Addition/Subtraction task and the other performance tests prior to the experimental sleep deprivation phase to hold learning constant. Also during Days 2 and 3, subjects took modified Multiple Sleep Latency Tests (MSLTs) and other physiological tests (e.g. oculomotor and vital signs monitoring). On the afternoon of Day 3, subjects attended the Johns Hopkins Radiochemistry and PET Scanning Facility at the Johns Hopkins Medical Institutions (JHMI) where they underwent a simulation PET scan procedure. This procedure included insertion of an antecubal IV catheter (which remained in-place and patent for the next four days), individual plastic face mask fitting, rehearsal of radiotracer injection, practice of the Serial Addition/Subtraction task for 30 min and subjective scales, and simulated PET scanning.

### Experimental phase

On the morning of Day 4, after a night of normal sleep, subjects donned thermal underwear tops and bottoms, which were worn beneath their clothing, to keep them warm in order to facilitate the arterialization of venous blood flow through their hands for later venous blood draws (thermal clothing was then doffed after PET scanning and donned again the morning of the next PET scan). They took one modified MSLT between 07.00 and 08.00 h and ate a light breakfast, timed to maintain a 3-h fast prior to their designated $^{18}$FDG injection. Subjects were next transported to the JHMI Radiochemistry and PET Facility for their baseline $^{18}$FDG-PET scans.

Each 30-min $^{18}$FDG injection and uptake occurred in the same room and in an enclosed tent-like structure that was erected to shield personnel associated with blood drawing and monitoring from the subjects' view. Prior to the $^{18}$FDG uptake, subjects had a butterfly IV catheter inserted in the volar side of the left hand for blood drawing pre, during, and post $^{18}$FDG injection and uptake. Their left hands were warmed with a heating pad to enhance blood flow and arterialize the venous blood. Thereafter, subjects took the Stanford Sleepiness Scale (SSS) and the Global Vigor and Affect (GVA) scales (the latter included mood scales). Headphones were worn to attenuate transient background noise while they performed 5 min of the Serial Addition/Subtraction task as a 'warm up' to the uptake. Immediately prior to each $^{18}$FDG injection, subjects were instructed to maintain wakefulness and to perform the task as quickly and accurately as possible. During and post $^{18}$FDG injection, performance on the cognitive task continued for the 30 min of the uptake period. Task performance compliance was ascertained by monitoring subjects via video camera and wakefulness by monitoring their EEG via computer-based polygraph. Upon concluding the $^{18}$FDG uptake, subjects completed another set of GVA scales and other visual analogue scales relating to sleep deprivation experiences. Afterwards, they relieved their bladders (to reduce radiation exposure to this target organ) and were carefully positioned in the PET scanner with their heads immobilized by an individually molded plastic face mask. Scanning then commenced for 30 min. Subjects began the 85 h of sleep deprivation following the baseline PET scans. They were scanned the following three days at the same time as their baseline scan (either 09.30, 10.30, 11.30, or 12.30 h).

During the time when subjects were not at the PET facility, they performed two cognitive test batteries (previously described) at alternate hours during the 85-h sleep deprivation period. As part of one of these cognitive test batteries, subjects performed a total of 8 sessions of the short-duration Serial/Subtraction task after the baseline PET scan and prior to the 24-h PET scan. Subjects continued to perform the cognitive test batteries after the fourth PET scan to preclude potential end spurt effects during the last $^{18}$FDG uptake. Throughout the entire study, subjects were closely monitored by staff members, who administered test procedures and assisted in keeping them awake. Caffeine and other stimulants were not available to subjects during the study.

### Recovery phase

Subjects received approximately 12 h of recovery sleep at the end of the 85-h sleep deprivation phase (19.00 to 06.45 h). On the morning of the last day, subjects took a modified MSLT, performed a set of the two cognitive test batteries, and completed the other physiological tests. At 10.00 h they were tested for 30 min on the Serial Addition/Subtraction task to assess recovery sleep effects on this performance measure. Following this, the subjects' electrodes were removed, and they were allowed to shower. They were then clinically assessed and de-briefed prior to departure from the study.

## Measures

### Polysomnography (PSG)

Scalp and facial electrodes were applied to: C3, C4, F3, F4, P3, P4, O1, O2, T3, and T4 for EEG; outer canthus of each eye for EOG; and submental for EMG. These signals were recorded continuously on Oxford Medilog 9000-II ambulatory recorders (Oxford Medical Instruments, Hawthorne, New York, USA). Oxford Mentor laptop computers provided on-line, real-time output of PSG signals for monitoring sleep latency tests and verifying wakefulness during the $^{18}$FDG uptake periods. Sleep periods during the study were scored in 30-sec epochs according to standard PSG criteria (Rechtschaffen and Kales 1968). Microsleep during the $^{18}$FDG uptake was scored as theta, or stage 1 sleep, in the absence of artifact, with a duration of 1 to 15 sec. EEG from C3 was used for scoring theta events, and left and right EOG and EMG were used for assessing the presence of artifacts.

### Neuroimage acquisition

Measurement of CMRglu was implemented according to standard practice and procedure (Reivich et al. 1979). Subjects were infused with a slow bolus, intravenous injection of $^{18}$FDG (5 mCi per injection) in a right forearm vein. During the infusion and 30-min $^{18}$FDG uptake period, subjects performed the Serial Addition/Subtraction task (see below). PET scanning then commenced (45 min post $^{18}$FDG injection) and continued for a duration of 30 min. A GE 4096+ PET scanner (General Electric Medical Systems, Milwaukee, Wisconsin, USA) with an axial and in-plane resolution of 6.5 mm at full-width-half-maximum (FWHM) and a 15-cm field of view was used to acquire the distribution of radioactivity in the brain. Emission data were corrected for attenuation using a transmission scan obtained at the same levels. Attenuation-corrected data were reconstructed into 15 image planes. As indicated above, a heating pad was used to warm the subject's left hand to 44 °C to transform the pH, $P_{O2}$, $P_{CO2}$, and glucose levels in the venous blood to values more nearly resembling those of arterial blood. Samples of arterialized-venous blood were drawn at fixed intervals throughout each uptake and imaging procedure and were used to transform radioactivity counts to CMRglu (Phelps et al. 1979). Repositioning of the subjects on the PET scanner between the experimental days was accurate to within 2 mm.

### Alertness test

Objective alertness was assessed using a modified version of the MSLT (Carskadon et al. 1986). Subjects were allowed to sleep in a quiet, darkened bedroom until they reached stage 2 sleep or after 20 min had elapsed. Sleep latency was defined as the elapsed time to the first 30 sec of stage 2 sleep.

### Self-reports

Subjects' self-ratings of sleepiness were assessed with a computerized version of the Stanford Sleepiness Scale (SSS) (Hoddes et al. 1973). The SSS is a one-item choice scale consisting of seven numbered statements that describe alertness states ranging from 1 ('feeling active and vital; alert; wide awake') to 7 ('almost in reverie; sleep onset soon; losing struggle to remain awake'). Self-rated levels of effort and motivation in Serial Addition/Subtraction performance were assessed using visual analogue scales (single straight 10 cm horizontal lines scored between 0 and 100). Visual analogue scales relating to vigor and affect (Monk 1989), and sleep deprivation experiences (data not reported) were also acquired near the $^{18}$FDG uptake periods.

### Cognitive task

The Serial Addition/Subtraction task (Thorne et al. 1985) consists of two randomly selected single digits (0–9) and an operator (either + or − sign) displayed sequentially in the same center-screen location, followed by a '?' prompt. The subject performs the indicated addition or subtraction and, if the result is positive, enters the least significant digit of the result. If the result is negative, the subject adds 10 and enters the positive single digit result. The digits and operator are each presented for 250 msec, with a 200 msec interdigit/operator interval. The next trial begins 300 msec after a key entry, or response, is made by the subject. Consequently, there is no opportunity for an omission, or lack of response. The 200 possible combinations of two digits with two operators were randomly sampled several times during each $^{18}$FDG uptake, and hence, were essentially of equal difficulty. Consistent for each uptake period, the task was divided into six, 5-min segments, to document time-on-task effects as well as to provide periodic feedback of performance results to the subjects (visually on the computer monitor).

## Data analysis

### PET data

Statistical parametric mapping (SPM) software (SPM95, Wellcome Department of Cognitive Neurology, London, UK) was used for registering and statistically analysing the PET data (Friston et al 1995, 1996). The 15 original axial PET planes were trilinearly interpolated to yield 43 planes in which voxels (3-D picture elements [pixels] in neuroanatomical space) were approximately cubic. To minimize the effects of head displacement, the scans of each subject were realigned to the first PET scan on a voxel-by-voxel basis using the SPM routine employing a rigid body spatial transformation. Next, the PET scans of all of the subjects were transformed into standard stereotaxic space using both linear and nonlinear three-dimensional transformation methods to allow for voxel-by-voxel averaging across subjects. The stereotaxically normalized scans consisted of 26 planes (voxel size 2 × 2 × 4 mm) corresponding to the brain atlas of Talairach and Tournoux (1988). Images were smoothed using a 12 mm Gaussian filter to accommodate intersubject differences in gyral and functional anatomy and to increase the signal-to-noise in the images. This produced a final image resolution of 19 × 20 × 17 mm.

To evaluate quantifiable changes in regional CMRglu that occurred during the progression of sleep deprivation, the absolute rates of regional CMRglu during sleep deprivation and the rested baseline were analysed and compared. The global normalization parameter was not used in the absolute regional CMRglu analysis. Global CMRglu values (i.e. means) were obtained for each subject's PET scans from the absolute regional CMRglu analysis. The difference between days was analysed using a one-tailed paired $t$-test, with a Bonferonni adjustment applied based on the number of comparisons across the entire experimental sleep deprivation phase. Absolute regional CMRglu effects were obtained from the transformation of one-tailed $t$-tests to the $Z$ probability distribution. Also, relative regional CMRglu effects were analysed in the same way after covarying out the effect of global CMRglu using ANCOVA and normalization of the values relative to 5.4 mg/100 g · min. The resulting $Z$-values comprised a statistical parametric map SPM(Z). For both absolute and relative regional CMRglu comparisons, the SPM was thresholded for statistical significance at $P \leq 0.001$, uncorrected for multiple comparisons ($Z \geq 3.09$), for regions predicted to change a priori (thalamus and prefrontal cortex) or which had been shown to significantly change in the Wu et al. (1991) sleep deprivation study of CMRglu (temporal cortex, thalamus, and cerebellum). A threshold of $P \leq 0.05$ corrected for multiple comparisons ($Z \geq 4.16$) was used for nonhypothesized regions. Individually acquired MRI scans showed that each subject's neuroanatomy was normal (i.e. without signs of disease or atrophy). The high resolution MRI scan of a normal male brain provided in the SPM program was subsequently used to identify neuroanatomical locations of functional change for the group.

### Behavioral data

Sleep latency, self-report, and cognitive performance data were analysed using one-tailed paired $t$-tests, with the exception that subjectively rated mood data were analysed using two-tailed paired $t$-tests. Bonferonni adjustments were applied to the behavioral data. Self-report data were log transformed prior to statistical analysis. Correlation analyses between behavioral measures and regional CMRglu are planned for a future report.

# RESULTS

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## Polysomnography

### Scheduled sleep

Subjects obtained an average of 396 min (6 h and 36 min) of sleep the night before the baseline PET scan. This amount is equivalent to that obtained for each adaptation night. Sleep stage distribution was consistent for all nights prior to the sleep deprivation period. The sleep parameters for all nights were within the range for normal sleep (sleep onset ≤ 30 min, sleep efficiency ≥ 90%, and number of arousals ≤ 30).

### Unscheduled sleep on PET scanner

Subjects obtained an average of 14 min of unscheduled sleep during the baseline rested PET scan. The sleep occurred when subjects were required to remain motionless on the scanner for 30 min to ensure successful image acquisition. The regional CMRglu activity imaged by the scanner reflects brain activity during the $^{18}$FDG uptake and not brain activity during image acquisition. The amount of sleep acquired on the scanner represents 1% of the total 24 h sleep deprivation period. The resultant sleep consisted primarily of stage 1 and occurred approximately 24 h prior to the 24-h sleep deprivation $^{18}$FDG uptake.

### Wakefulness during $^{18}$FDG uptakes

Post hoc analysis of the recorded polysomnographic signals showed that all subjects were awake during the 30-min $^{18}$FDG uptake period by polysomnographic criteria. The amount of microsleep was negligible and occurred during both the rested (mean=2 sec) and 24-h sleep deprivation (mean=5 sec) $^{18}$FDG measurements.

## Brain Activity

### Global CMRglu

Global CMRglu, expressed as the average of all voxels (excluding white matter), decreased by approximately 8% (actual 7.76%) after 24 h of sleep deprivation [5.67 milligrams/100 g · min (31.4 µmol/100 g · min), rested PET scans vs. 5.23 milligrams/100 g · min (29.0 µmol/100 g · min), 24-h sleep deprived PET scans; $t$=3.78, $P \leq 0.001$].

### Decreases in regional CMRglu

Following 24 h of sleep deprivation, significant decreases in absolute regional CMRglu were observed for numerous brain regions (Fig. 2). As revealed by significant decreases in relative regional CMRglu (Fig. 3), there was heterogeneity in regional brain activity response during sleep deprivation. Table 1 shows that at the same voxel location for relative regional CMRglu, the decreases in absolute regional CMRglu were approximately 3–7% greater than the 8% decrease in global CMRglu. This indicates that regions that significantly decreased in relative regional CMRglu were more affected than those which decreased at the global or whole brain level. Hemispheric analyses revealed no statistically significant laterality differences in either absolute or relative regional CMRglu with 24 h of sleep deprivation.

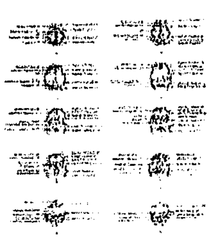

Figure 2. Significant decreases from baseline in absolute regional CMRglu during wakefulness and cognitive task performance after 24 h of sleep deprivation across 17 subjects. Deactivations are superimposed on a single subject's magnetic resonance imaging (MRI) template. Axial images are oriented in millimeters relative to the anterior commissure-posterior commissure (AC-PC) plane. The left/right hemispheres appear as the left/right sides of each image. Significant regions are color coded to reflect thresholds for statistical probability levels: 5.02 =0.001 corrected, 4.57=0.01 corrected, 4.16=0.05 corrected, 3.09=0.001 uncorrected. Thresholds for statistical significance are $Z \geq 3.09$ for regions predicted to decrease *a priori* (thalamus and prefrontal cortex) and/or previously published for short-term sleep deprivation effects on regional CMRglu (temporal cortex, thalamus, and cerebellum [Wu et al. 1991]), and $Z \geq 4.16$ for nonhypothesized regions. Statistically significant regions are neuroanatomically labeled and approximate Brodmann areas (BAs) are noted in parenthesis ().

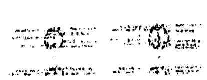

Figure 3. Significant decreases from baseline in relative regional CMRglu during wakefulness and cognitive task performance after 24 h of sleep deprivation across 17 subjects. Details are the same

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as for Fig. 2. Decreases in relative regional CMRglu resulting from sleepiness, while spatially smaller, actually represent the areas with the largest reductions in absolute regional CMRglu (i.e. 3 – 7% greater decreases in absolute regional CMRglu than the global CMRglu decrease of approximately 8%; see Table 1 for direct comparison of voxel locations and percent decreases between relative and absolute regional CMRglu).

**Table 1. Significant decreases from baseline in regional CMRglu during wakefulness and cognitive task performance after 24 h of sleep deprivation ($n$ = 17*)**

| | | Left Hemisphere | | | | | Right Hemisphere | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Relative Regional CMRglu | | Absolute Regional CMRglu | | | Relative Regional CMRglu | | Absolute Regional CMRglu | |
| Region† | BA‡ | x, y, z coordinates§ | Z¶ | % Δ | Z | % Δ | x, y, z coordinates | Z | % Δ | Z | % Δ |
| Frontal Cortex – Lateral | | | | | | | | | | | |
| Middle Frontal Gyrus | 6 | −36, 10, 44 | 4.90 | 5.67 | 5.55 | 12.83 | 36, 10, 44 | 6.23 | 5.38 | 5.67 | 12.91 |
| Superior Frontal Gyrus | 8 | −16, 32, 44 | 6.03 | 5.05 | 5.47 | 12.61 | | | | | |
| Middle Frontal Gyrus | 8 | | | | | | 34, 16, 44 | 7.26 | 5.02 | 5.46 | 13.03 |
| Superior Frontal Gyrus | 9 | −16, 46, 36 | 5.72 | 3.85 | 5.14 | 11.31 | | | | | |
| Middle Frontal Gyrus | 9 | | | | | | 32, 14, 40 | 5.52 | 4.46 | 5.12 | 12.09 |
| Inferior Frontal Gyrus | 44 | −50, 8, 28 | 4.18 | 2.90 | 4.79 | 10.16 | 46, 16, 24 | 5.00 | 3.73 | 5.08 | 11.47 |
| Inferior Frontal Gyrus | 45 | −46, 34, 0 | 2.99‡‡ | 2.14 | 4.44 | 9.89 | 56, 16, 24 | 5.57 | 4.38 | 5.35 | 12.41 |
| Middle Frontal Gyrus | 46 | −34, 42, 4 | 4.96 | 3.18 | 4.65 | 10.56 | 46, 42, 0 | 6.58 | 5.06 | 5.78 | 13.31 |
| Middle Frontal Gyrus | 10 | −34, 48, 8 | 4.89 | 3.03 | 4.55 | 10.25 | 34, 46, −4 | 6.84 | 6.92 | 6.07 | 14.14 |
| Middle Frontal Gyrus | 47 | −40, 38, −8 | 5.15 | 4.71 | 5.32 | 11.82 | 38, 44, −4 | 5.14 | 5.27 | 6.13 | 14.61 |
| Orbitofrontal Gyrus | 11 | −34, 38, −12 | 5.16 | 6.36 | 5.74 | 13.25 | 36, 42, −12 | 5.56 | 7.36 | 5.76 | 15.52 |
| Frontal Cortex – Medial | | | | | | | | | | | |
| Medial Frontal Gyrus | 8 | −12, 38, 40 | 4.76 | 3.11 | 4.84 | 10.86 | 10, 38, 40 | 6.19 | 4.17 | 5.29 | 12.30 |
| | 9 | −16, 42, 32 | 4.87 | 3.14 | 4.68 | 10.71 | 14, 44, 32 | 4.54 | 3.13 | 4.78 | 11.33 |
| | 10 | −14, 58, 12 | 4.53 | 3.88 | 4.99 | 11.91 | 16, 56, 0 | 4.31 | 3.77 | 4.81 | 11.28 |
| Rectus Gyrus | 11 | −12, 24, −20 | 4.36 | 6.26 | 5.42 | 13.77 | 12, 36, −20 | 4.03 | 5.01 | 5.12 | 13.11 |
| Parietal Cortex – Lateral | | | | | | | | | | | |
| Superior Parietal Lobule | 7 | −36, −74, 32 | 6.02 | 5.06 | 5.61 | 12.57 | 36, −62, 40 | 5.49 | 5.72 | 5.56 | 13.33 |
| Inferior Parietal Lobule | | | | | | | | | | | |
| Supramarginal Gyrus | 40 | −50, −50, 40 | 6.11 | 6.88 | 5.87 | 14.57 | 44, −58, 32 | 5.35 | 4.72 | 5.26 | 12.66 |
| Angular Gyrus | 39 | −42, −68, 32 | 6.14 | 5.07 | 5.46 | 12.78 | 42, −28, 36 | 6.05 | 5.94 | 5.61 | 13.51 |
| Parietal Cortex – Medial | | | | | | | | | | | |
| Precuneus | 7 | −10, −56, 32 | 5.97 | 4.17 | 5.49 | 12.61 | 2, −44, 32 | 5.73 | 4.35 | 5.28 | 11.41 |
| | 31 | −4, −34, 24 | 5.41 | 4.61 | 5.35 | 11.85 | 6, −31, 24 | 5.41 | 4.23 | 5.24 | 11.61 |
| Temporal Cortex – Lateral | | | | | | | | | | | |
| Transverse Temporal Gyrus | 42 | −36, −26, 12 | §§ | §§ | 4.05 | 8.78 | 36, −26, 12 | §§ | §§ | 4.20 | 9.43 |
| Superior Temporal Gyrus | 22 | −58, −48, 20 | 2.70‡‡ | 2.52 | 4.45 | 10.21 | 56, −50, 20 | 2.94‡‡ | 2.29 | 4.43 | 10.81 |
| | 38 | −22, 4, −24 | §§ | §§ | 3.98 | 11.12 | 22, 4, −24 | §§ | §§ | 4.41 | 10.54 |
| Middle Temporal Gyrus | 39 | −44, −70, 24 | 5.53 | 3.56 | 5.01 | 11.40 | 46, −70, 24 | 4.86 | 3.16 | 4.89 | 10.71 |
| | 21 | −58, −44, −16 | 3.74 | 4.76 | 4.95 | 13.62 | 54, −48, −16 | 4.29 | 5.32 | 5.24 | 12.76 |
| Inferior Temporal Gyrus | 37 | −58, −46, −16 | 3.79 | 4.97 | 5.00 | 13.69 | 52, −46, −20 | 4.44 | 5.53 | 5.32 | 13.29 |
| | 20 | −36, −24, −28 | 4.06 | 3.51 | 4.81 | 11.36 | 51, −26, −28 | 4.65 | 6.02 | 5.38 | 14.26 |
| Temporal Cortex – Medial | | | | | | | | | | | |
| Fusiform Gyrus | 37 | −52, −44, −24 | 2.62‡‡ | 3.53 | 4.52 | 12.53 | 48, −44, −24 | 3.76 | 5.56 | 5.10 | 13.32 |
| | 20 | −42, −32, −28 | 3.28 | 5.26 | 4.92 | 13.41 | 42, −40, −28 | 3.79 | 5.21 | 5.07 | 12.51 |
| Parahippocampal Gyrus | 36 | −34, −32, −4 | 2.92‡‡ | 3.51 | 4.62 | 11.93 | 26, −30, −28 | 4.61 | 6.46 | 5.59 | 13.41 |
| Cingulate Cortex | | | | | | | | | | | |
| Anterior Cingulate Gyrus | 32 | −4, 20, 40 | 3.48 | 2.89 | 4.67 | 10.30 | 6, 22, 28 | 3.11 | 3.13 | 4.86 | 10.90 |
| | 24 | −2, −24, 36 | 4.71 | 3.93 | 5.12 | 11.31 | 2, −24, 36 | 4.60 | 3.94 | 5.16 | 11.28 |
| Posterior Cingulate Gyrus | 31 | −12, −54, 28 | 5.85 | 3.96 | 5.12 | 11.87 | 6, −54, 28 | 5.52 | 4.12 | 5.20 | 11.62 |
| | 23 | −2, −52, 20 | 5.36 | 4.91 | 5.43 | 12.03 | 2, −46, 24 | 5.42 | 5.36 | 5.54 | 12.54 |
| | 30 | −2, −50, 26 | 5.29 | 5.09 | 5.45 | 12.32 | 2, −46, 20 | 5.11 | 5.63 | 5.53 | 12.86 |
| Insular Cortex | | | | | | | | | | | |
| Anterior Insula | | −38, 10, 0 | 2.40‡‡ | 1.51 | 4.22 | 9.76 | 38, 10, 0 | 3.35‡‡ | 1.98 | 4.39 | 10.57 |
| Posterior Insula | | −34, −18, 12 | 2.44‡‡ | 2.15 | 4.58 | 9.45 | NS** | | | | |
| Subcortical Structures†† | | | | | | | | | | | |
| Caudate | | −16, 4, 12 | 4.68 | 3.65 | 5.12 | 10.32 | 18, 2, 12 | 3.30‡‡ | 3.43 | 4.78 | 10.61 |
| Putamen | | −28, −6, 0 | 2.40‡‡ | 1.42 | 4.23 | 9.12 | 28, −4, 0 | 2.42‡‡ | 1.80 | 4.29 | 9.09 |
| Globus Pallidus | | −20, −6, 0 | 3.41‡‡ | 2.54 | 4.50 | 10.16 | 22, −8, 0 | 2.56‡‡ | 2.53 | 4.45 | 10.13 |
| Thalamus (Dorsal) | | −8, −16, 8 | 6.65 | 7.21 | 5.98 | 15.07 | 16, −18, 8 | 6.06 | 5.80 | 5.61 | 13.64 |
| Thalamus (Ventral) | | −2, −26, −4 | 1.42‡‡ | 1.19 | 4.03 | 7.84 | 10, −26, −4 | 3.62 | 2.89 | 4.76 | 9.62 |
| Basal Forebrain (Hypothalamus) | | −2, −12, −4 | 2.61‡‡ | 2.60 | 4.48 | 10.26 | 2, −12, −4 | 2.54‡‡ | 2.25 | 4.46 | 10.03 |
| Midbrain Tegmentum | | −2, −30, −12 | 3.80‡‡ | 2.66 | 4.83 | 8.60 | 2, −28, −12 | 2.87‡‡ | 2.58 | 4.83 | 8.97 |
| Mesopontine Tegmentum | | −2, −32, −16 | 3.39‡‡ | 2.61 | 4.54 | 8.70 | 2, −32, −16 | 2.18‡‡ | 2.20 | 4.59 | 8.50 |
| Pontine Tegmentum | | −2, −40, −20 | 2.58‡‡ | 3.03 | 4.54 | 9.16 | 2, −40, −20 | 2.48‡‡ | 2.58 | 4.49 | 9.30 |
| Cerebellar Vermis | | | | | | | | | | | |
| Anterior Lobe | | −6, −50, −16 | 3.63 | 4.27 | 4.99 | 11.31 | 2, −46, −16 | 2.99‡‡ | 3.43 | 4.69 | 10.45 |
| Posterior Lobe | | −2, −56, −24 | 4.60 | 4.73 | 5.20 | 11.09 | 2, −50, −20 | 3.94 | 3.76 | 4.96 | 11.02 |
| Cerebellar Hemispheres | | | | | | | | | | | |
| Anterior Lobe | | −8, −48, −16 | 3.57 | 4.22 | 5.00 | 11.04 | 12, −44, −16 | 1.64‡‡ | 1.33 | 4.00 | 8.99 |
| Posterior Lobe | | −26, −74, −24 | 1.13‡‡ | 0.91 | 3.93 | 9.26 | 26, −68, −28 | 3.54 | 3.62 | 4.84 | 11.79 |

*Z-score statistic, voxel location in Talairach space, and percent decrease in relative and absolute regional CMRglu for each region/Brodmann area by hemisphere. For relative regional CMRglu, Z-score maxima are given. For absolute regional CMRglu, Z scores (and percent decreases) are shown at the same voxel location as shown for relative regional CMRglu as a direct comparison, and consequently may not reflect the Z-score maxima for absolute regional CMRglu for that region. †Regional CMRglu decreases in frontal cortex were extensive; therefore, only frontal regions associated with the Z-score maxima for significant Brodmann areas are listed. ‡Approximate locations. §Talairach coordinates: x is the lateral distance from the midline (positive = right), y is the anteroposterior distance from the anterior commissure (positive = anterior), z is the rostrocaudal distance from the intercommissural plane (positive = rostral). ¶Thresholds for statistical significance are Z ≥ 3.09 (P ≤ 0.001 uncorrected) for regions predicted to decrease a priori (thalamus and prefrontal cortex) and as previously published for regional CMRglu (temporal cortex, thalamus, and cerebellum [Wu et al. 1991]), and Z ≥ 4.16 (P ≤ 0.05 corrected) for all others. **NS = not significant for both relative and absolute regional CMRglu. ††Some subcortical regions listed are small relative to the spatial resolution of the PET scanner used in this study (i.e. basal forebrain-hypothalamus, midbrain, pontine tegmentums). They are important to cerebral activation but must await confirmation of involvement in sleepiness by future studies using higher spatial resolution scanners. ‡‡Not significant by Z-score threshold criteria. §§Data not available. A voxel was not retained for further analysis if the F ratio for that voxel did not reach significance (P < 0.05 uncorrected) or if the activity of the voxel was not of a reasonably high activity, e.g. in the range of grey matter activity.

For hypothesized regions, decreases in absolute regional CMRglu occurred bilaterally throughout the prefrontal cortex (including dorsal and ventral anterior cingulate gyri), and in the dorsal and ventral thalami after 24 h of sleep deprivation. Additionally, absolute decreases occurred bilaterally in the temporal lobes and parahippocampal gyri, as well as the cerebellar hemispheres and vermis. Decreases in relative regional CMRglu occurred bilaterally in the prefrontal cortex (including dorsal anterior cingulate gyrus) and in the thalamus. Also, decreased regional CMRglu was observed in the middle and inferior temporal gyri, in medial temporal cortex consisting of the right fusiform and parahippocampal gyri, in the cerebellar vermis, and in a small area in the right ventral cerebellar hemisphere.

Several nonhypothesized regions also evidenced decreases in absolute regional CMRglu, such as the lateral posterior parietal (both inferior and superior lobules) and the medial parietal cortices (including posterior cingulate gyrus and precuneus), the right anterior and left posterior insula, caudate, putamen, globus pallidus, basal forebrain-hypothalamus, midbrain tegmentum, and mesopontine and pontine tegmentums. Significant decreases in relative regional CMRglu were also apparent throughout the posterior parietal lobes.

## Increases in regional CMRglu

No significant increases in absolute regional CMRglu, nor trends for significant increases, were noted with 24 h of sleep deprivation. Therefore, increases in relative regional CMRglu (data not shown), which were evident after covarying out the global CMRglu decrease, reflected either a lack of statistically significant decrease in absolute regional CMRglu or invariance in regional CMRglu: left postcentral gyrus (BAs 3, 4); left/right lateral occipital cortices (BAs 18, 19); left superior temporal cortex (BA 22); left/right lingual and fusiform gyri (BAs 18, 19); right mesial temporal lobe (amygdala area, BA 28); and right dorsal cerebellar lobe.

## Behavior

After 24 h of sleep deprivation, objective and subjective alertness declined but mood remained constant (Table 2): latency to stage 2 sleep significantly decreased on the modified

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MSLT, sleepiness ratings on the SSS significantly increased, and significant changes were found for all vigor-related scales of the GVA instrument indicating increased sleepiness and effort to remain awake and perform. Significant changes, however, were not found for any of the mood-related scales of the GVA instrument after sleep deprivation. Analysis of other visual analogue scales revealed that after sleep deprivation, subject-perceived effort to perform the Serial Addition/Subtraction task during the $^{18}$FDG uptake increased significantly, while subjective ratings of motivation to perform the task remained consistently high (Table 2).

**Table 2. Alertness, self-assessments, and cognitive performance during wakefulness after a night of normal sleep (rested baseline) and 24 h of sleep deprivation (*n*=17)**

| *Test* | *Rested Baseline* | *24 h of Sleep Deprivation* | *t* | *P* |
|---|---|---|---|---|
| Modified Multiple Sleep Latency Test | | | | |
| Elapsed time to stage 2 (min:sec) | 18:12 (04:46) | 03:26 (01:39) | 11.41 | 0.000 |
| Stanford Sleepiness Scale (1–7) | 1.8 (1.0) | 2.9 (1.2) | − 3.04 | 0.004 |
| Global Vigor and Affect Scales (0–100) | | | | |
| Pre-$^{18}$FDG Uptake | | | | |
| Vigor – Alert | 88.7 (17.8) | 62.9 (24.7) | 4.27 | 0.000 |
| Vigor – Effort | 11.5 (13.8) | 33.5 (24.3) | − 4.22 | 0.000 |
| Vigor – Weary | 13.3 (18.0) | 40.1 (25.2) | − 4.54 | 0.000 |
| Vigor – Sleepy | 10.9 (15.9) | 46.1 (26.6) | − 5.50 | 0.000 |
| Affect – Sad | 12.8 (24.8) | 5.7 (10.7) | 0.83 | 0.42 |
| Affect – Tense | 38.4 (36.8) | 41.3 (36.4) | − 0.19 | 0.85 |
| Affect – Happy | 63.5 (27.3) | 62.1 (19.6) | 0.20 | 0.85 |
| Affect – Calm | 60.7 (28.1) | 60.8 (31.0) | 0.45 | 0.66 |
| Post-$^{18}$FDG Uptake | | | | |
| Vigor – Alert | 71.8 (21.9) | 44.1 (23.3) | 3.71 | 0.001 |
| Vigor – Effort | 23.4 (24.9) | 53.7 (29.3) | − 1.86 | 0.000 |
| Vigor – Weary | 22.6 (27.0) | 50.6 (35.6) | − 3.30 | 0.002 |
| Vigor – Sleepy | 22.0 (23.4) | 68.1 (23.3) | − 6.03 | 0.000 |
| Affect – Sad | 2.2 (4.6) | 5.2 (8.6) | − 1.66 | 0.12 |
| Affect – Tense | 23.5 (34.0) | 27.3 (32.1) | 1.65 | 0.12 |
| Affect – Happy | 64.0 (28.9) | 54.8 (28.6) | 0.95 | 0.36 |
| Affect – Calm | 60.5 (33.4) | 61.7 (27.1) | 0.70 | 0.50 |
| Post-$^{18}$FDG Cognitive Performance Scales (0–100) | | | | |
| Effort | 54.7 (32.0) | 74.7 (26.6) | − 3.06 | 0.004 |
| Motivation | 78.7 (30.5) | 82.0 (28.4) | − 1.04 | 0.16 |
| Serial Addition/Subtraction Task during $^{18}$FDG Uptake (30 min total) | | | | |
| Accuracy (% correct) | 95.5 (5.2) | 92.3 (6.4) | 2.97 | 0.005 |
| Speed (responses/min) | 71.0 (27.2) | 61.4 (24.6) | 3.48 | 0.002 |
| Throughput (correct responses/min) | 68.3 (27.3) | 57.5 (25.2) | 3.54 | 0.001 |

Values are mean ± standard deviation

A significant reduction was observed after sleep deprivation in cognitive performance on the Serial Addition/Subtraction task during the $^{18}$FDG uptake with respect to accuracy, speed, and throughput (Table 2): accuracy decreased by 3%, speed by 13%, and throughput, a speed-accuracy product and index of overall productivity (Thorne *et al.* 1983), by 16%. Table 3 shows that within the 30-min Serial Addition/Subtraction task during the rested baseline $^{18}$FDG uptake, there was no significant time-on-task decrease in performance when each subsequent 5 min segment was compared with the first segment. In the 24-h sleep deprivation session, each subsequent segment was significantly different than the first segment for all three performance measures. This time-on-task effect was linear over the first 15 min and then remained stable for the remaining 15 min.

**Table 3. Time-on-task 30 min performance during $^{18}$FDG uptake periods (5 min segments) after a night of normal sleep (rested baseline) and 24 h of sleep deprivation (*n*=17)***

| *Serial Addition/ Subtraction Task* | *Rested Baseline* | *t* | *P* | *24 h of Sleep Deprivation* | *t* | *P* |
|---|---|---|---|---|---|---|
| Accuracy (% correct) | | | | | | |
| 1st 5 min | 95.5 (4.7) | | | 96.1 (3.0) | | |
| 2nd 5 min | 96.5 (3.4) | − 1.50 | 0.08 | 93.9 (5.4) | 2.41 | 0.01 |
| 3rd 5 min | 95.4 (4.2) | 0.13 | 0.45 | 92.2 (7.4) | 2.98 | 0.004 |
| 4th 5 min | 94.3 (9.7) | 0.67 | 0.26 | 90.9 (8.7) | 3.31 | 0.002 |
| 5th 5 min | 95.6 (7.4) | − 0.08 | 0.47 | 90.5 (8.7) | 3.30 | 0.002 |
| 6th 5 min | 95.9 (5.6) | − 0.31 | 0.38 | 90.1 (8.9) | 3.27 | 0.002 |
| Speed (response/min) | | | | | | |
| 1st 5 min | 72.2 (28.4) | | | 71.6 (29.2) | | |
| 2nd 5 min | 69.3 (25.3) | 1.29 | 0.11 | 63.3 (27.9) | 2.95 | 0.005 |
| 3rd 5 min | 72.4 (32.3) | − 0.07 | 0.47 | 59.5 (28.5) | 3.10 | 0.003 |
| 4th 5 min | 68.9 (28.2) | 1.45 | 0.08 | 57.9 (26.4) | 3.30 | 0.002 |
| 5th 5 min | 70.7 (25.2) | 0.58 | 0.28 | 57.6 (20.3) | 3.05 | 0.004 |
| 6th 5 min | 72.7 (28.4) | − 0.25 | 0.41 | 58.7 (23.9) | 3.41 | 0.002 |
| Throughput (correct responses/min) | | | | | | |
| 1st 5 min | 69.3 (28.5) | | | 69.3 (29.3) | | |
| 2nd 5 min | 67.2 (25.9) | 0.94 | 0.18 | 60.1 (28.0) | 3.20 | 0.003 |
| 3rd 5 min | 69.7 (32.3) | − 0.14 | 0.46 | 55.7 (29.0) | 3.42 | 0.002 |
| 4th 5 min | 65.7 (28.7) | 1.69 | 0.05 | 53.6 (27.4) | 3.69 | 0.001 |
| 5th 5 min | 67.9 (25.1) | 0.54 | 0.30 | 52.5 (20.7) | 3.83 | 0.001 |
| 6th 5 min | 70.0 (28.4) | − 0.35 | 0.37 | 53.8 (25.2) | 3.99 | 0.001 |

* Statistical comparisons are between the first 5-min segment and each of the last five 5-min segments within each day.
Values are mean ± standard deviation.

## DISCUSSION

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### Implications for sleep deprivation-induced alertness and cognitive performance decrements

Concurrent with impaired alertness and cognitive performance, 24 h of sleep deprivation produced a decrease in global CMRglu during polysomnographically defined wakefulness, and decreased absolute regional CMRglu in several cortical and subcortical regions. Increases in absolute regional CMRglu were not observed in any region. Decreases in relative regional CMRglu – indicating areas more deactivated than the global decrease – were found throughout the thalamus and prefrontal cortex. These brain regions subserve alertness and attention, while the prefrontal cortex also mediates the highest-order cognitive processes, the mental abilities most impaired by sleep deprivation. Extensive decreases in absolute and relative regional CMRglu were found throughout another cortical region, the posterior parietal lobes, following sleep deprivation. The vast deactivations in the prefrontal and posterior parietal cortices included the heteromodal association areas (BAs 8, 32, 45, 46, 9, 10, 11 in the prefrontal cortex and BAs 7, 40, 39 in the posterior parietal cortex), which are involved in the higher-order analysis and integration of sensory-motor information and cognition (Mesulam 1985).

The finding of thalamic deactivation after 24 h of sleep deprivation in the present study is highly consistent with this structure's role in cerebral activation and alertness (Roland 1993) and with the measured decrease in sleep latency and increase in subjective sleepiness. Decreased regional CMRglu in the thalamus has also been observed following extreme sleepiness in rats (Everson *et al.* 1994) and has been found to negatively correlate with benzodiazepine-induced sleepiness during wakefulness (Volkow *et al.* 1995). Moreover, the thalamus is important to task performance requiring attention and alertness (Kinomura *et al.* 1996; Shulman *et al.* 1997), and reduced activity of this region following sleep deprivation may have contributed to deficits in attention during Serial Addition/Subtraction performance. Other evidence supporting this view is that thalamic deactivation has been found in previous studies of sleep deprivation and impaired attentional performance (Wu *et al.* 1991; Drummond *et al.* 1999a) and has been shown to coincide with attention and vigilance deficits in patients with fatal familial insomnia, a disease characterized by thalamic lesions and intractable insomnia (Perani *et al.* 1993).

Anatomically, the thalamus has known bi-directional connections with the prefrontal-posterior parietal cortical association areas, which were also substantially deactivated by sleep deprivation. The thalamus and these cortical regions are considered to be part of a distributed neural network for directed attention (Mesulam 1990), and studies have demonstrated coactivation of these three areas during tasks requiring sustained attention (Coull *et al.* 1996, 1998) and intrinsic alertness (Sturm *et al.* 1999). Of particular relevance is that decreased activity in these structures has been found for degraded time-on-task vigilance performance during normal alertness (Paus *et al.* 1997). Time-on-task impairments in performance are well-documented in sleep deprivation studies (Johnson 1982) and were found with sleep deprivation in the current study.

In addition to contributing to attentional processes, cerebral activation studies show that under normal alertness conditions the prefrontal and posterior parietal cortices are recruited during tasks requiring visual verbal working memory (Coull *et al.* 1996; Dolan *et al.* 1997) and arithmetic calculations (Roland and Friberg 1985; Dahaene *et al.* 1996, 1999). Behaviorally, these cognitive functions are also necessary for Serial Addition/Subtraction performance, which decreased in conjunction with deactivation of these cortical areas after 24 h of sleep deprivation. Due to the long half life (110 min) of $^{18}$FDG, a control task was not evaluated to directly discern the functional brain components of the Serial Addition/Subtraction task. A control task was evaluated in the Drummond *et al.* (1999a) sleep deprivation study using a similar arithmetic task, which revealed task-related relative activations in localized areas of the prefrontal and posterior parietal regions during rested arithmetic performance. The deactivations in the prefrontal cortex in the present study were more extensive than those observed in that sleep deprivation study, however, and therefore may have functional implications beyond simply reflecting the cognitive task used. The prefrontal cortex mediates other higher-order mental abilities impaired by sleep deprivation (see INTRODUCTION), such as verbal fluency, speech, flexible and innovative thinking, and planning, judgment, and decision making based on new or updated information (Fuster 1989; Roland 1993; Damasio 1994; Frith and Dolan 1996). The magnitude and amount of reduced activity found in this region suggest that other higher-order cognitive impairments proposed by Horne (1988b, 1993) and noted in various sleep deprivation experiments could be a consequence of, and explained by, declines in prefrontal cortical functioning.

## Reconciliation with other brain activity findings of human sleep deprivation

Our brain activity results for sleep deprivation confirm several findings from a previous study of absolute and relative regional CMRglu changes of short-term sleep deprivation and visual attention deficits (Wu *et al.* 1991). We found a decrease in global CMRglu of approximately 8% compared with a 7% decrease observed by Wu *et al.* (1991), albeit theirs did not reach statistical significance. We also found deactivation of the temporal lobes, thalamus, and cerebellum. Likewise, we noted increases in relative regional CMRglu in occipital cortex, which reflected nonsignificant decreases in absolute regional CMRglu. In contrast, we found significant decreases in absolute and relative regional CMRglu throughout the prefrontal cortices, including anterior cingulate gyrus, and the posterior parietal cortices, including posterior cingulate gyrus and precuneus. Decreases in absolute regional CMRglu in basal ganglia, basal forebrain, and midbrain and pontine tegmentum brainstem areas were also apparent. Incongruity in findings between the two investigations may be explained in part by differences in the image analysis procedures used as already described. Evidence of this is given by a recent report (Wu *et al.* 1999), where the authors applied a more sensitive analysis to their data and showed decreases in regional CMRglu in right dorsolateral prefrontal cortex (BA 46).

Apart from the analysis procedure, the differences in regional brain activity results between the studies might be explained by apparent differences in task demands (i.e. level of difficulty related to rate of stimulus presentation and cognitive processing) and complexity (i.e. type of mental processing, such as memory and arithmetic processing) necessitated by the two different tasks used to probe brain function during sleep deprivation. In the present study, Serial Addition/Subtraction performance involved sustained attention, working memory and arithmetic calculations of all fast-paced stimulus presentations, whereas in the Wu *et al.* (1991) study, Continuous Performance Test performance required sustained attention and a vigilance component, necessitating identification responses when an infrequently occurring target stimulus appeared (Mesulam 1985). While both sleep deprivation studies produced performance impairments, the rate and nature of task requirements imposed by the Serial Addition/Subtraction task is arguably more difficult and complex than those imposed by the Continuous Performance Test. Subjects in our study reported not only a moderate amount of effort to perform this task when well-rested but also significant increases in effort over baseline with sleep deprivation, substantiating that the task became more difficult to perform when sleepy.

The idea that brain activity response to sleep deprivation could be task and/or task outcome specific has been noted previously (Thomas 1997; Drummond *et al.* 2000). In fact, our findings of decreased activity in prefrontal anterior cingulate cortex, lateral posterior parietal cortices, and thalamus during sleep deprivation and decreased Serial Addition/Subtraction task performance are in agreement with findings on a similar, but of shorter-duration, complex cognitive task resulting in performance impairment (Drummond *et al.* 1999a). Support for task-specific neural responses, with and without performance impairment, has been demonstrated in other short-term sleep deprivation studies (Portas *et al.* 1998; Smith *et al.* 1999; Drummond *et al.* 1999b; 2000). The results of studies where performance was held constant revealed either no change or primarily increases in regional brain activity. However, the tasks used may not have been of sufficient cognitive load or challenge to evoke diminished neural responses. This concept was evaluated in a study where differences in dorsolateral prefrontal cortical activation between schizophrenic patients and controls became apparent only after difficulty on a memory task increased and performance impairment occurred (Fletcher *et al.* 1998). Nonetheless, in addition to task difficulty and task complexity characteristics, task duration characteristics may play an important role in delineating brain activity responses during sleep deprivation. Differences in time-on-task performance are likely to occur between studies using different designs and scanning methods (and hence different task durations) to assess sleep deprivation brain activity effects; for example, temporal differences between a 30-min $^{18}$FDG uptake acquisition, in which the first 10 min accounts for a majority of the regional brain activity response, vs. multiple, 40-sec scans for a BOLD-fMRI response acquisition.

Based on the results of the above studies of sleep deprivation, these brain imaging data suggest that following one night of sleep deprivation, neurons have the capacity to respond normally when the brain is presented with a nonchallenging task, or may be able to temporarily increase their response in specific regions in an attempt to meet the demands of simple short-term task performance. In the case of complex task performance and/or sustained task performance during sleep deprivation, the findings of decreased regional brain activity suggest that neurons cannot keep pace with high task load requirements and/or neuronal responsivity is diminished or fatigued after a certain period of performance (i.e. a time-on-task effect) thereby resulting in a decrement in task outcome.

## Comparisons with regional brain activity alterations observed during human sleep

An intriguing implication of the results from the current functional neuroimaging study of sleep deprivation, when compared with results for sleep, is that the larger decreases in activity in the prefrontal and posterior parietal heteromodal association cortices may indicate a greater biological vulnerability of these areas to extended wakefulness. Other work from our laboratory (Balkin *et al.* 1992; Braun *et al.* 1997) has shown absolute and relative decreases in dorsolateral prefrontal and inferior parietal cortical activity (as measured by cerebral blood flow) during light sleep, slow wave sleep and REM sleep, which has also been reported by others (e.g. Buchsbaum *et al.* 1989; Andersson *et al.* 1998; Maquet *et al.* 1996; Kajimura *et al.* 1999). Thus, the same higher-order cognitive areas differentially affected by sleep deprivation are also differentially affected by sleep indicating that these areas may be more susceptible to sleep deprivation and consequently have a greater need for the recuperative processes underlying sleep. Such homeostatic processes may include brain energy substrate and neuromodulator replenishment (Benington and Heller 1995; Newhouse *et al.* 1989; McCann *et al.* 1992, 1993, 1995) and/or adjustment of ionic

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currents and reorganization of network patterns of synaptic activity as a consequence of learning (Steriade et al. 1993).

Neuroimaging studies of sleep have also uniformly revealed decreased activity in the thalamus when measured during light and/or deep NREM sleep (e.g. Buchsbaum et al 1989; Balkin et al. 1992; Maquet et al. 1990, 1992, 1997; Braun et al. 1997; Hofle et al. 1997; Andersson et al. 1998; Kajimura et al 1999). Complementary to this, we showed that the largest subcortical deactivation in waking regional CMRglu after one night of sleep deprivation occurred in the thalamus, and this has been a relatively consistent result in other neuroimaging studies of sleep deprivation (Wu et al 1991; Everson et al. 1994; Drummond et al. 1999a). Taken together, these findings suggest that a progressively deactivated thalamus may be necessary for the transition from waking to sleep and for the occurrence of deeper stages of sleep.

### Temporal occurrence of sleep deprivation-induced deactivations

Given the limited temporal resolution of PET-based brain imaging, we cannot determine the source of our sleep deprivation-induced brain deactivation. Deactivation could have originated in the thalamus, in the cortex, or in other more caudal brain regions known to be involved in thalamic and cortical activation (McCormick and Bal 1997). Thus far, decreased corticothalamic activity is the most marked brain alteration seen with human sleep deprivation, whereas activity in the areas of the basal forebrain and mesencephalon and pontine tegmentums is either less affected as in the current study or observed not to change significantly (Wu et al. 1991; Drummond et al. 1999a,b; 2000). These latter areas, specifically the small nuclei associated with promoting thalamic and cortical activation and those associated with promoting sleep in animals (Steriade and McCarley 1990; Szymusiak 1995), will require higher spatial, as well as temporal, resolution scanners to accurately identify their involvement in human sleepiness.

Further data analyses of the present study, to include correlation analysis of alertness and cognitive performance alterations with the changes in regional brain activity, as well as the neuroimaging measures associated with the 48 and 72 h sleep deprivation time points, may shed light on regions which may be affected directly or might be most sensitive to sleep deprivation.

## CONCLUSIONS

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One night of sleep deprivation in humans diminishes waking regional brain activity predominantly in a bilateral prefrontal-posterior parietal-thalamic network mediating alertness attention and higher-order cognitive processes. The cortical association findings are complementary to studies of slow wave and REM sleep demonstrating deactivation of these same cortical regions, with the implication that the need for recuperation during sleep may be greater in these areas relative to other brain regions. Our results of brain activity, alertness, and cognitive performance impairments following one night of sleep deprivation suggests that the neurobehavioral function of sleep in humans is to restore and sustain normal waking brain activity and behavior. These findings substantiate the biological necessity of sleep to normal brain functioning and are particularly powerful in underscoring the importance of adequate sleep for workplace productivity, public safety, and personal well being.

## ACKNOWLEDGEMENTS

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Funding was provided by the Military Operational Medicine Program, Project #S15 Q, U.S. Army Medical Research and Materiel Command, Ft. Detrick, Maryland, and by the GCRC/Johns Hopkins Bayview Medical Center, Grant #M01RR02719, Baltimore, Maryland. Technical support was also provided by Science Applications International, Inc. (SAIC) through Contract #MDA903–92–0068 with the Human Research and Engineering Directorate, US Army Research Laboratory, Aberdeen Proving Ground, Maryland.

We thank our anonymous reviewers for their thoughtful comments and suggestions. We also thank our volunteers for their participation. For technical assistance, we thank the following: Johns Hopkins Radiochemistry and PET staff, Walter Reed enlisted military and student contract staff, GCRC/Johns Hopkins Bayview research nursing staff (J. Wright, Nursing Supervisor; P. Knighton, Study Manager), and staff at Henry M. Jackson Foundation (J. Williams), SAIC (J. Zurer), Walter Reed Army Medical Center (P. Peller), Johns Hopkins Medical Institutions (M. Murrell and J. Leal), and Maryland Psychiatric Research Center (M. Zhao). Additionally, we thank Dr Karl Friston (Wellcome Department of Cognitive Neurology, London) for Statistical Parametric Mapping software.

This study was done in partial fulfillment of the first author's doctoral degree in Applied-Experimental Psychology at George Mason University, Fairfax, Virginia (Advisor: R. Smith. Committee Members: R. Holt and D. Boehm-Davis, Department of Psychology; and H. Morowitz, Krasnow Institute for Advanced Study).

## DEPARTMENT OF DEFENSE DISCLAIMER

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Human volunteers participated in this study after giving their free and informed consent. Investigators adhered to AR 70–25 and USAMRDC Reg 70–50 on the use of volunteers in research. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.

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00001584

# Systemic bacterial invasion induced by sleep deprivation

Expand

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+ Author Affiliations

Submitted 20 August 1999. Accepted in final form 27 October 1999.

## Abstract

Profound sleep disruption in humans is generally believed to cause health impairments. Through comparative research, specific physical effects and underlying mechanisms altered by sleep deprivation are being elucidated. Studies of sleep-deprived animals previously have shown a progressive, chronic negative energy balance and gradual deterioration of health, which culminate in fatal bloodstream infection without an infectious focus. The present study investigated the conditions antecedent to advanced morbidity in sleep-deprived rats by determining the time course and distribution of live microorganisms in body tissues that are normally sterile. The tissues cultured for microbial growth included the blood, four major organs, six regional lymph nodes, the intestine, and the skin. The principal finding was early infection of the mesenteric lymph nodes by bacteria presumably translocated from the intestine and bacterial migration to and transient infection of extraintestinal sites. Presence of pathogenic microorganisms and their toxins in tissues constitutes a septic burden and chronic antigenic challenge for the host. Bacterial translocation and pathogenic sequelae provide mechanisms by which sleep deprivation appears to adversely affect health.

bacterial translocation bacterial infections immunity immunocompetence neuroimmunology

## Footnotes

Portions of this work were presented at the 11th Annual Meeting of the Association of Professional Sleep Societies and the 14th Congress of the European Sleep Research Society.

The principal research support was provided by the National Heart, Lung, and Blood Institute Grant HL-59271. Additional support was provided by National Institutes of Health Grants NS-26429, NS-25378, and CA-21765, and the American Lebanese Syrian Associated Charities.

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## Article



Journal of American College Health
Issue: Volume 46, Number 3 / November 1997
Pages: 121 - 126
URL: Linking Options
DOI: 10.1080/07448489709595597

### How Sleep Deprivation Affects Psychological Variables Related to College Students' Cognitive Performance

June J. Pilcher and Amy S. Walters

**Abstract:**

The effects of sleep deprivation on cognitive performance and on psychological variables related to cognitive performance were studied in 44 college students. Participants completed the Watson-Glaser Critical Thinking Appraisal after either 24 hours of sleep deprivation or approximately 8 hours of sleep. After completing the cognitive task, the participants completed 2 questionnaires, one assessing self-reported effort, concentration, and estimated performance, the other assessing off-task cognitions. As expected, sleep-deprived participants performed significantly worse than the nondeprived participants on the cognitive task. However, the sleep-deprived participants rated their concentration and effort higher than the nondeprived participants did. In addition, the sleep-deprived participants rated their estimated performance significantly higher than the nondeprived participants did. The findings indicate that college students are not aware of the extent to which sleep deprivation negatively affects their ability to complete cognitive tasks.

**Keywords:**

cognitive performance, psychological variables, self-reports, sleep deprivation

*The references of this article are secured to subscribers.*

OCCUPATIONAL & ENVIRONMENTAL MEDICINE

*Occup Environ Med* 2000;57:649-655 doi:10.1136/oem.57.10.649

Paper

# Moderate sleep deprivation produces impairments in cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication

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Accepted 15 June 2000

## Abstract

OBJECTIVES To compare the relative effects on performance of sleep deprivation and alcohol.

METHODS Performance effects were studied in the same subjects over a period of 28 hours of sleep deprivation and after measured doses of alcohol up to about 0.1% blood alcohol concentration (BAC). There were 39 subjects, 30 employees from the transport industry and nine from the army.

RESULTS After 17–19 hours without sleep, corresponding to 2230 and 0100, performance on some tests was equivalent or worse than that at a BAC of 0.05%. Response speeds were up to 50% slower for some tests and accuracy measures were significantly poorer than at this level of alcohol. After longer periods without sleep, performance reached levels equivalent to the maximum alcohol dose given to subjects (BAC of 0.1%).

CONCLUSIONS These findings reinforce the evidence that the fatigue of sleep deprivation is an important factor likely to compromise performance of speed and accuracy of the kind needed for safety on the road and in other industrial settings.

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DOI: 10.1055/s-2005-867080



## Neurocognitive Consequences of Sleep Deprivation

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## ABSTRACT

Deficits in daytime performance due to sleep loss are experienced universally and associated with a significant social, financial, and human cost. Microsleeps, sleep attacks, and lapses in cognition increase with sleep loss as a function of state instability. Sleep deprivation studies repeatedly show a variable (negative) impact on mood, cognitive performance, and motor function due to an increasing sleep propensity and destabilization of the wake state. Specific neurocognitive domains including executive attention, working memory, and divergent higher cognitive functions are particularly vulnerable to sleep loss. In humans, functional metabolic and neurophysiological studies demonstrate that neural systems involved in executive function (i.e., prefrontal cortex) are more susceptible to sleep deprivation in some individuals than others. Recent chronic partial sleep deprivation experiments, which more closely replicate sleep loss in society, demonstrate that profound neurocognitive deficits accumulate over time in the face of subjective adaptation to the sensation of sleepiness. Sleep deprivation associated with disease-related sleep fragmentation (i.e., sleep apnea and restless legs syndrome) also results in neurocognitive performance decrements similar to those seen in sleep restriction studies. Performance deficits associated with sleep disorders are often viewed as a simple function of disease severity; however, recent experiments suggest that individual vulnerability to sleep loss may play a more critical role than previously thought.

## KEYWORDS

Sleep deprivation - neurocognitive - performance - neurobehavioral - sleep restriction - sleepiness - microsleeps - executive function - working memory - attention

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# Association of Usual Sleep Duration With Hypertension: The Sleep Heart Health Study

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[1]*Boston University School of Medicine and VA Boston Healthcare System, Boston, MA;* [2]*Case Western Reserve University, Cleveland, OH;* [3]*University of Wisconsin-Madison, Madison, WI;* [4]*Arizona State University College of Nursing (Southwest Borderlands), Tempe, AZ;* [5]*University of Pittsburgh, Pittsburgh, PA* [6]*MedStar Research Institute, Hyattsville, MD;* [7]*Johns Hopkins University, Baltimore, MD*

**Study Objectives:** Limited experimental data suggest that sleep restriction acutely elevates blood pressure; however, little is known about the relationship between usual sleep duration and hypertension. This study assesses the relationship between usual sleep duration and hypertension in a community-based cohort.

**Design:** Cross-sectional observational study.

**Setting:** The Sleep Heart Health Study, a community-based prospective study of the cardiovascular consequences of sleep-disordered breathing.

**Participants:** Two thousand eight hundred thirteen men and 3097 women, aged 40 to 100 years.

**Interventions:** None.

**Measurements and Results:** Usual weekday and weekend sleep durations were obtained by questionnaire, and their weighted average were categorized as less than 6, 6 to less than 7, 7 to less than 8, 8 to less than 9, and 9 or more hours per night. Hypertension was defined as a systolic blood pressure of 140 mm Hg or greater, a diastolic blood pressure of 90 mm Hg or greater, or use of medication to treat hypertension. The relationship between sleep duration and hypertension was examined using categorical logistic regression with adjustment for age, sex, race, apnea-hypopnea index, and body mass index. Compared to subjects sleeping 7 to less than 8 hours per night, those sleeping less than 6 and between 6 and 7 hours per night had adjusted odds ratios for hypertension of 1.66 (95% confidence interval 1.35-2.04) and 1.19 (1.02-1.39), respectively, whereas those sleeping between 8 and 9 and 9 or more hours per night had adjusted odds ratios for hypertension of 1.19 (1.04-1.37) and 1.30 (1.04-1.62), respectively ($p < .0001$ for association of sleep duration with hypertension). These associations persisted when analyses were further adjusted for caffeine and alcohol consumption, current smoking, insomnia symptoms, depression symptoms, sleep efficiency, and prevalent diabetes mellitus or cardiovascular disease.

**Conclusions:** Usual sleep duration above or below the median of 7 to less than 8 hours per night is associated with an increased prevalence of hypertension, particularly at the extreme of less than 6 hours per night.

**Keywords:** Hypertension, sleep deprivation, epidemiology

**Citation:** Gottlieb DJ; Redline S; Nieto FJ et al. Association of usual sleep duration with hypertension: the sleep heart health study. SLEEP 2006;29(8):1009-1014.

## INTRODUCTION

TYPICAL DAILY SLEEP DURATION HAS BEEN DECLINING AMONG ADULTS IN THE UNITED STATES FOR MORE THAN A GENERATION, WITH MEDIAN SLEEP duration falling from 8 hours per night in the 1950s to 7 hours per night in recent years, with more than one-third now sleeping fewer than 7 hours per night.[1,2] Much of this reduction in sleep duration reflects voluntary sleep restriction, with nearly half of individuals reporting that they restrict sleep in order to watch television, use the Internet, or work.[3] Several studies have found higher rates of mortality or coronary heart disease with both long (>8 hours/night) and short (<7 hours/night) usual sleep durations.[4-9] Short-term experimental sleep restriction for as little as 1 night has been reported to increase blood pressure in both healthy[10-12] and hypertensive[13] subjects. Because hypertension carries a high risk for cardiovascular disease, an effect of short sleep duration on hypertension might increase the risk of cardiovascular disease and mortality. In the present study, we examined the relationship between self-reported usual sleep duration and prevalent hypertension in a large, community-based sample of middle-aged and older adults.

**Disclosure Statement**

This was not an industry supported study. Dr. Redline was a scientific advisor for Organon and Cypress Pharmaceuticals. Drs. Gottlieb, Nieto, Baldwin, Newman, Resnick, and Punjabi have indicated no financial conflicts of interest.

**Submitted for publication November 25, 2005**

**Accepted for publication March 21, 2006**

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## METHODS

### Study Sample

Subjects were participants in the Sleep Heart Health Study (SHHS), a community-based, prospective cohort study of the cardiovascular consequences of obstructive sleep apnea/hypopnea (OSAH).[14] Although not the primary aim of the SHHS, the present analysis takes advantage of data on sleep duration, hypertension, and relevant covariates collected as part of the baseline SHHS examination. All SHHS participants completed a Sleep Habits Questionnaire (SHQ) and underwent overnight polysomnography between 1995 and 1998. Medication use was ascertained at the time of polysomnography, and blood pressure was measured at the time of polysomnography or, in fewer than 5% of subjects, at a recently preceding clinic visit. Subjects in the present analysis are SHHS participants for whom hypertension status was determined within 1 year of ascertainment of usual sleep duration, who also had complete data for age, sex, race, body mass index (BMI), and apnea-hypopnea index (AHI). Of the 6441 SHHS participants, 531 (8.2%) were excluded for missing data (listed hierarchically: 124 missing sleep duration, 21 missing hypertension



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status, 284 with the timing of hypertension assessment unknown or more than 1 year before or after the assessment of sleep duration, and 102 missing BMI). Excluded subjects were somewhat older (66.5 ± SD 13.4 vs 63.1 ± 10.7 years), had lower mean BMI (27.8 ± 5.1 vs 28.6 ± 5.4 kg/m$^2$), were more likely to be women (57% vs 52%), and were more likely to identify themselves as a member of a minority race or ethnicity (34% vs 22%). Inclusion of the 284 subjects excluded on the basis of the interval between assessments of sleep duration and hypertension had no meaningful impact on the main analysis. The protocol was approved by the Institutional Review Board of each participating center, and signed informed consent was provided by each subject.

### Sleep Habits Questionnaire

Usual sleep duration on weekdays was defined as the response to the question, "How many hours of sleep do you usually get at night (or your main sleep period) on weekdays or workdays?" Responses were integer values. A similar question was used to define usual weekend sleep duration. The stability of these measures over time in SHHS participants has been reported.[15] Usual daily sleep duration was calculated as a weighted average of weekday and weekend sleep durations, using the formula: ([{usual weekday sleep duration}×5]+[{usual weekend sleep duration}×2])/7. In the 4117 subjects whose entire sleep period was recorded during home polysomnography, mean polysomnographic total sleep time was shorter than self-reported usual sleep duration (5.9 vs 7.1 hours). The 2 measures were weakly, although significantly, correlated ($r = 0.17$, $p < .0001$).

Symptoms of insomnia were obtained from responses on a 5-point Likert scale to the items "Have trouble falling asleep," "Wake up during the night and have difficulty getting back to sleep," "Wake up too early in the morning and be unable to get back to sleep," and "Take sleeping pills or other medication to help you sleep." Response options were Never, Rarely (1/month or less), Sometimes (2-4/month), Often (5-15/month), and Almost Always (16-30/month). For analysis, these variables were collapsed into 2 categories: Infrequent, comprising the responses Never, Rarely, and Sometimes; and Frequent, comprising the responses Often and Almost Always. Insomnia was operationally defined as a "frequent" response to any of these 4 questions.

### Hypertension

Blood pressure was measured at an evening visit to the participant's home. After at least 5 minutes of rest, 3 seated blood-pressure measurements were made at 5-minute intervals with the subject seated, using a mercury gauge sphygmomanometer and recording systolic (SBP) and diastolic (DBP) blood pressure to the nearest 2 mm Hg, according to a standardized protocol that has been previously reported.[16] For this analysis, SBP and DBP were obtained by taking the mean of the second and third blood-pressure measurements. Use of antihypertensive medications was obtained via a standardized health interview administered on the evening of the home visit. Hypertension was defined as SBP ≥ 140 or DBP ≥ 90 mm Hg or current use of antihypertensive medication.[17]

### Other Measures

Waist girth (measured at the level of the umbilicus) and height were ascertained by each parent cohort at a regularly scheduled clinic examination. BMI was calculated using height measured in the clinic and weight measured at the time of the home visit or, in some cases, at a clinic visit if scheduled within 1 month of the home visit (n=334). Usual daily alcohol consumption was also ascertained by each parent cohort. Unattended, in-home polysomnography was performed on the night of the home visit, and records were centrally scored. The AHI was defined as the number of apneas plus hypopneas, each associated with at least a 4% decrease in oxyhemoglobin saturation, per hour of sleep.[18] A standardized health interview administered prior to polysomnography was used to obtain data on smoking habits; daily caffeine consumption; physician-diagnosed angina, myocardial infarction, stroke, or heart failure; and history of coronary revascularization procedures. Resting heart rate was recorded at the time of polysomnography set-up. Symptoms of depression were obtained from 2 questions on the Medical Outcomes Study 36-item short-form health survey[19]: "During the past 4 weeks, how much of the time..." (1) "Have you felt so down in the dumps that nothing could cheer you up?" and (2) "Have you felt downhearted and blue?" Responses from the 6-point Likert scale were collapsed into 2 categories: "none," "a little," or "some" of the time versus "all," "most," or "a good bit" of the time. Current medication use and blood pressure were ascertained by reviewing actual medication containers and coding each medication into standardized classes, as previously described.[20]

### Statistical Analysis

Unadjusted differences in continuous and categorical variables across sleep-duration categories were assessed for significance using single-factor analysis of variance or contingency table analysis, as appropriate. General categorical logistic regression analysis was implemented using PROC CATMOD in SAS (SAS version 8.1, SAS Institute, Cary, NC) to assess the relation of usual sleep duration to hypertension, adjusting for relevant covariates. Covariates included in the main model were age, BMI, and AHI as continuous measures and sex and race as categorical variables. Waist girth was also considered but was not included in the main model because it was not a significant predictor when BMI was included and had no meaningful impact on the outcome of interest. Additional analyses assessed the impact of caffeine and alcohol consumption, smoking status, depressive symptoms, insomnia symptoms, and prevalent cardiovascular disease on the association of sleep duration with hypertension. Secondary analyses stratified on sex, age, AHI, and presence of insomnia symptoms were performed to assess the consistency of results across the study sample and to assess the contribution of insomnia to the observed effects.

## RESULTS

Among the 5910 subjects (2813 men, 3097 women), the mean age was 63.1 years (SD 10.7, range 40-100), BMI was 28.6 kg/m$^2$ (SD 5.4), and AHI was 8.8 (SD 12.4; median 4.4). Blood pressure was measured a median of 43 days after the assessment of usual sleep duration (interquartile range 1 to 88 days). Hypertension was identified on the basis of measured blood pressure or use of antihypertensive medication in 52.2% of subjects, 75.2% of whom were on antihypertensive medication. Median reported sleep duration was 7.0 hours per night. A usual sleep duration of less than

Table 1—Characteristics of the Study Sample[a]

| | Reported Usual Sleep Duration, h/night | | | | | p Value |
|---|---|---|---|---|---|---|
| | < 6 | 6 to < 7 | 7 to < 8 | 8 to < 9 | ≥ 9 | |
| Number of subjects[b] | 545 | 1204 | 2022 | 1689 | 450 | |
| Age, y | 63.8 (11.0) | 62.4 (10.8) | 61.9 (10.4) | 63.8 (10.4) | 67.2 (11.0) | < .001 |
| BMI, kg/m² | 29.1 (6.5) | 28.8 (5.5) | 28.4 (5.1) | 28.4 (5.3) | 28.6 (5.6) | .02 |
| AHI, events/hour | 10.1 (14.5) | 8.7 (12.2) | 8.3 (11.6) | 8.8 (12.4) | 9.6 (13.3) | .02 |
| Women, % | 54.7 | 51.2 | 51.4 | 53.3 | 54.2 | .43 |
| Minority race, % | 30.1 | 27.1 | 19.6 | 19.7 | 22.9 | < .001 |
| Alcohol consumption ≥ 2 drinks/day, % | 4.5 | 5.4 | 6.0 | 7.2 | 9.3 | .02 |
| Caffeine consumption, cups/day | 3.1 (3.3) | 3.1 (3.3) | 3.0 (3.2) | 2.9 (2.9) | 3.1 (3.1) | .24 |
| Current smoking, % | 12.2 | 12.2 | 10.4 | 11.4 | 12.0 | .53 |
| Any cardiovascular disease, % | 23.3 | 17.4 | 14.7 | 17.7 | 21.4 | <.001 |
| Often or always..., % | | | | | | |
| Have trouble falling asleep | 42.9 | 20.7 | 11.1 | 8.7 | 7.2 | <.001 |
| Wake up too early in the morning | 52.4 | 26.9 | 13.5 | 8.1 | 6.1 | <.001 |
| Wake up and cannot return to sleep | 55.4 | 27.0 | 15.5 | 12.3 | 10.9 | <.001 |
| Take a pill to help sleep | 11.0 | 8.0 | 6.8 | 6.6 | 7.0 | .01 |
| Any insomnia symptom | 68.8 | 43.6 | 28.3 | 21.9 | 20.1 | <.001 |
| Often feel "down" | 6.2 | 3.2 | 1.9 | 2.6 | 3.3 | <.001 |
| Often feel "blue" | 8.5 | 5.7 | 3.6 | 3.1 | 4.9 | <.001 |
| Resting heart rate, beats/min | 73.5 (11.6) | 73.7 (11.4) | 73.6 (11.4) | 73.7 (11.0) | 74.7 (11.3) | .37 |
| Systolic blood pressure, mm Hg | 132.2 (18.7) | 130.5 (18.5) | 128.4 (18.0) | 130.5 (19.1) | 133.0 (20.2) | <.001 |
| Diastolic blood pressure, mm Hg | 75.2 (11.3) | 75.0 (10.3) | 74.3 (10.6) | 73.9 (11.4) | 73.0 (10.4) | .002 |
| Use of antihypertensive medication, % | 48.3 | 39.5 | 34.5 | 39.9 | 46.2 | <.001 |

[a]Data are presented as mean (SD) or percentages. Significance tests for the unadjusted difference across categories of sleep duration are based on the $\chi^2$ for contingency table analysis of categorical variables and analysis of variance for continuous variables. Due to the highly skewed distribution of apnea-hypopnea index (AHI), the difference in ln(AHI +1) was tested.
[b]Due to missing data, the number of subjects with data for alcohol consumption is 5197, caffeine 5848, smoking 5888, cardiovascular disease 5643, insomnia symptom 5850, and depressive symptoms 4367.

7 hours per night was reported by 29.6% of subjects, including 9.2% sleeping less than 6 hours per night. A usual sleep duration of 8 or more hours was reported by 36.2% of subjects, including 7.6% sleeping 9 or more hours per night. Subjects at the extremes of sleep duration were slightly older and heavier, more likely to be minorities, and had a higher mean AHI than subjects sleeping 7 to < 8 hours per night (Table 1). They were also more likely to have depressive symptoms or prevalent cardiovascular disease. Daily consumption of 2 or more alcoholic beverages per day was reported more commonly among individuals who also reported longer sleep durations, whereas the prevalence of insomnia symptoms was higher in subjects with shorter usual sleep duration. There was no significant difference in sex, caffeine consumption, or current smoking status across sleep-duration categories. Among subjects with hypertension, the percentage using antihypertensive medications was similar in all sleep-duration categories (range 74% to 78%, p = .66 for difference across categories).

Compared with sleep durations of 7 to < 8 hours per night, self-reported usual sleep durations of less than 7 hours per night or 8 or more hours per night were associated with higher adjusted odds ratio (OR) for hypertension (Table 2). As expected, older age, higher AHI, and minority race/ethnicity were associated with higher adjusted OR for hypertension. After considering these covariates, sex was not significantly associated with hypertension. Adjustment for these variables modestly attenuated the observed association of sleep duration with hypertension (Table 2). Although higher BMI was a strong predictor of the presence of hypertension, adjustment for BMI had no impact on the observed association of sleep duration with hypertension (Table 2). There was also little change in the magnitude of the association of sleep duration with hypertension when the models were additionally adjusted for waist girth; prevalent diabetes mellitus, coronary artery disease, heart failure, stroke, or any cardiovascular disease; current cigarette smoking; usual daily alcohol consumption; presence of insomnia symptoms; or presence of depressive symptoms. When caffeine consumption was included in the models, there was a significant inverse correlation of usual daily caffeine consumption with hypertension (adjusted OR 0.95 [95% CI 0.93 – 0.97] for each additional cup of coffee), although adjustment for caffeine consumption did not diminish the magnitude of the association of sleep duration with hypertension. Sleep efficiency was available from polysomnography for 3368 subjects in whom the entire period from lights out to final awakening was recorded. Mean sleep efficiency was highest in subjects with a reported usual sleep duration of 7 to less than 8 hours (83.1%), falling to 80.2% in those reporting a usual sleep duration less than 6 hours and to 78.1% in those reporting a usual sleep duration of 9 or more hours. When this variable was included in the models, sleep efficiency was inversely associated with the risk of hypertension (adjusted OR 0.80 [95% CI 0.74-0.87] for a 10% increase in sleep efficiency) but had little impact on the association of reported sleep duration with hypertension. Additional analyses demonstrated that the association of sleep duration with hypertension was not significantly different between men and women, younger (age <63) and older subjects, those with an AHI less than 5 and those with an AHI of 5 or higher, and those with or without insomnia symptoms.

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Table 2—Odds ratios (95% Confidence Intervals)* for Hypertension by Reported Usual Sleep Duration

| Usual sleep duration, h/night | Model 1 Unadjusted | p | Model 2 Adjusted for age, sex, race, and AHI | p | Model 3 Adjusted for all covariates in Model 2 plus BMI | p |
|---|---|---|---|---|---|---|
| | | < .0001 | | < .0001 | | < .0001 |
| < 6 | 1.86 (1.54 – 2.26) | | 1.67 (1.36 – 2.05) | | 1.66 (1.35 – 2.04) | |
| 6 to < 7 | 1.25 (1.08 – 1.44) | | 1.20 (1.03 – 1.39) | | 1.19 (1.02 – 1.39) | |
| 7 to < 8 | 1.0 (referent) | | 1.0 (referent) | | 1.0 (referent) | |
| 8 to < 9 | 1.31 (1.15 – 1.49) | | 1.19 (1.04 – 1.36) | | 1.19 (1.04 – 1.37) | |
| ≥9 | 1.75 (1.42 – 2.15) | | 1.31 (1.05 – 1.63) | | 1.30 (1.04 – 1.62) | |

*Odds ratios are for the presence of hypertension, from categorical logistic regression models using 7 to < 8 hours of sleep per night as the referent category. P values reflect the overall significance level of the effect of sleep duration on hypertension, based on the likelihood ratio chi$^2$ with 4 degrees of freedom. AHI refers to apnea-hypopnea index.

## DISCUSSION

The present study provides epidemiologic evidence that both short and long habitual sleep durations are associated with prevalent hypertension in community-dwelling middle-aged and older adults. The association of sleep duration with hypertension persisted after adjustment for factors believed a priori to be potential confounders of the association between sleep duration and hypertension, including age, sex, race, obesity, and AHI. Although BMI is an imperfect measure of adiposity, adjustment for BMI caused no attenuation of the association of sleep duration with hypertension, implying that residual confounding by adiposity is unlikely. Secondary analyses also indicate that the association of sleep duration with hypertension was not confounded by caffeine or alcohol consumption or cigarette smoking, which might influence sleep habits. Almost three fourths of subjects with hypertension were being treated with antihypertensive medication, raising the concern that an effect of medication on sleep duration might underlie the association of sleep duration with hypertension; however, because the likelihood that a subject with hypertension was taking antihypertensive medications did not differ by sleep duration, confounding by medication use is unlikely. These findings extend to a community-based sample the observation from experimental studies that acute sleep restriction is associated with an increase in blood pressure. They suggest that levels of habitual sleep restriction that are common in the adult population may contribute to the high population prevalence of hypertension.

There have been several studies of the effect of acute sleep restriction on blood pressure. In a group of Japanese technical workers, a night of sleep restriction to a mean of 3.6 hours due to working overtime was associated with a 6-mm Hg increase in mean SBP and a 3-mm Hg increase in mean DBP, compared with a night of 8 hours sleep, although the possible effects of work stress per se must be considered.[21] Lusardi and colleagues found that a single night of experimental sleep restriction to 4 hours of sleep in the home setting resulted in a 4- to 7-mm Hg increase in mean morning SBP in normotensive and hypertensive subjects, respectively, with smaller increases in mean morning DBP.[10,13] Others have found a similar increase in blood pressure in healthy subjects following a single night of total sleep deprivation.[11] A progressive increase in blood pressure across 88 hours of total sleep deprivation has also been reported[12] but should be interpreted with caution because there was no control group and blood pressure continued to increase during the recovery day. The same group reported increases of 22 mm Hg in mean SBP and 17 mm Hg in mean DBP across 10 days of partial sleep deprivation to 4 hours per night in 4 healthy subjects, but this was not significantly different from the 10-mm Hg increase in mean SBP and 13-mm Hg increase in mean DBP observed in the 5 control subjects.[12] The study had little statistical power to exclude even such large effects of sleep deprivation, although it is possible that other aspects of the protocol were responsible for the observed increase in blood pressure. Another group reported considerably smaller and statistically nonsignificant increases in morning mean SBP and DBP after 4 nights of sleep restriction to 4 hours per night.[22]

The biologic mechanisms underlying an association of short sleep duration and hypertension are uncertain. Sleep deprivation has been reported to cause an increase in sympathetic nervous system activity,[13, 21, 23] which may cause sustained hypertension, although the importance of this mechanism in the apparent hypertensive response to sleep deprivation has been questioned.[11] Sleep deprivation also alters activity of the hypothalamic-pituitary-adrenal axis, with short-term partial sleep deprivation causing a shorter quiescent period of cortisol secretion and slower clearance of free cortisol,[23,24] and the resultant elevated cortisol levels may increase blood pressure. Primary insomnia is associated with increased activity of the hypothalamic-pituitary-adrenal axis,[25,26] and patients suffering from insomnia often underestimate their actual sleep duration.[27] However, the observed association of short sleep duration with hypertension in the current study remained significant after adjustment for insomnia or excluding subjects with insomnia, implying that voluntary sleep restriction at levels common in the population may lead to hypertension. Exercise has been reported both to improve sleep quality and to reduce blood pressure and might explain, in part, the observed association of short sleep with hypertension. Although data on activity level were not available for all SHHS parent cohorts, a prior report from the Nurses Health Study suggests that short sleep duration is not associated with lower levels of voluntary activity.[28]

The mechanisms mediating the association of long sleep duration with hypertension are even less certain, although the consistency of epidemiologic data showing increased morbidity and mortality in individuals who are long sleepers suggests the need to consider a causal basis for such associations. Women in the Nurses Health Study who reported sleeping 9 or more hours per night reported 15% less physical activity per week than those sleeping 7 to 8 hours per night,[28] and inactivity may place these long sleepers at increased risk of hypertension. Depression is often associated with altered sleep duration and also may be associated with an increased cortisol level, a neurohumoral response that may increase blood pressure. Although depression was not formally assessed in our subjects, both short and long sleep durations were significantly associated with depressive symptoms obtained from the SF-36. Adjustment for depressive symptoms did not, however, meaningfully alter the observed association of sleep duration to hypertension. Although adjustment for usual alcohol consumption did not meaningfully alter the association of sleep duration with hypertension, long sleep duration was significantly associated with higher alcohol consumption. Because heavy alcohol users may underreport their actual consumption, it is possible that alcohol use contributes to the higher prevalence of hypertension in those sleeping 8 or more hours per night. It is possible that long sleep duration reflects poor sleep quality. Subjects reporting a usual sleep duration of 9 or more hours per night did have slightly higher AHIs and lower sleep efficiencies than subjects sleeping 7 to less than 8 hours per night, but the association of sleep duration with hypertension was not meaningfully affected by adjustment for these variables.

Several limitations of this study merit discussion. Usual sleep duration was obtained by self-report. In the Nurses Health Study, self-reported usual sleep time determined using a similar question has been validated against 1 week of sleep diaries (r=0.79),[9] and the stability of self-reported usual sleep time over a mean interval of 2.4 years in SHHS participants has been reported (r=0.57).[15] Although the correlation of self-reported sleep duration with total sleep time measured on a single night of unattended polysomnography was weak, a night of sleep while wearing instrumentation for polysomnography is sufficiently different from a typical night of sleep that it is unlikely to be a valid measure of usual sleep duration. Whereas some misclassification on sleep duration is likely, this is likely to be nondirectional and thus should bias the study toward a null result. The results of this study add to a growing literature relating self-reported sleep duration with adverse health outcomes,[4-9,15,28] which indicates the importance of this self-report measure. Because it is likely that the sleep need of individuals varies due to genetic, behavioral, and environmental factors, usual sleep duration is likely to be an imperfect measure of sleep sufficiency. To the extent that short sleep duration does not reflect insufficient sleep in some individuals, this will again bias the study toward a null result. Thus, the true effect of sleep deprivation may be greater than that observed in this study. The development of simple valid methods for assessment of individual sleep need or sleep deprivation per se would facilitate future epidemiologic studies of the effects of sleep duration. The present study utilized evening blood-pressure measurements. While circadian variation in the effect of sleep deprivation on blood pressure is possible and merits further study, circadian effects would likely have little effect on the results of this analysis, as 75% of hypertensive subjects were identified on the basis of antihypertensive medication use rather than on the evening blood-pressure measurement. Because this was a cross-sectional observational study, the possibility of confounding by unmeasured variables, such as sedentary lifestyle and diet, cannot be excluded, and the temporal relationship between sleep duration and hypertension is unknown. Finally, this was a study of middle-aged and older adults and may not be relevant to younger subjects; however, the relationship between sleep duration and hypertension was similar in those older and younger than 63 years, the median age of the study sample. Notwithstanding these limitations, the present study provides epidemiologic evidence that the increase in blood pressure reported from experimental studies of severe sleep restriction is also present at levels of chronic sleep restriction that are common in the adult population. The association of sleep duration with hypertension may explain, in part, the association between sleep duration and both myocardial infarction[16] and mortality[4-7] and lends empiric support to the common recommendation to obtain 7 to 8 hours of sleep per night. Moreover, it suggests that obtaining adequate total sleep duration should be tested as a nonpharmacologic treatment modality in the management of patients with hypertension.

## ACKNOWLEDGMENTS

This work was supported by National Heart, Lung and Blood Institute cooperative agreements U01HL53940 (University of Washington), U01HL53941 (Boston University), U01HL53938 and Cooperative Agreement Supplement HL53938-07S1 (University of Arizona), U01HL53916 (University of California, Davis), U01HL53934 (University of Minnesota), U01HL53931 (New York University), U01HL53937 and U01HL64360 (Johns Hopkins University), U01HL63463 (Case Western Reserve University), and U01HL63429 (Missouri Breaks Research).

Sleep Heart Health Study (SHHS) acknowledges the Atherosclerosis Risk in Communities Study (ARIC), the Cardiovascular Health Study (CHS), the Framingham Heart Study (FHS), the Cornell/Mt. Sinai Worksite and Hypertension Studies, the Strong Heart Study (SHS), the Tucson Epidemiologic Study of Airways Obstructive Diseases (TES) and the Tucson Health and Environment Study (H&E) for allowing their cohort members to be part of the SHHS and for permitting data acquired by them to be used in the study. SHHS is particularly grateful to the members of these cohorts who agreed to participate in SHHS as well. SHHS further recognizes all of the investigators and staff who have contributed to its success. A list of SHHS investigators, staff and their participating institutions is available on the SHHS website, www.jhucct.com/shhs.

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Hypertension



Hypertension. 2006;47:833-839
Published online before print April 3, 2006, doi: 10.1161/01.HYP.0000217362.34748.e0

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(*Hypertension.* 2006;47:833.)


## Original Articles

# Short Sleep Duration as a Risk Factor for Hypertension

## Analyses of the First National Health and Nutrition Examination Survey

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Depriving healthy subjects of sleep has been shown to acutely increase blood pressure and sympathetic nervous system activity. Prolonged short sleep durations could lead to hypertension through extended exposure to raised 24-hour blood pressure and heart rate, elevated sympathetic nervous system activity, and increased salt retention. Such forces could lead to structural adaptations and the entrainment of the cardiovascular system to operate at an elevated pressure equilibrium. Sleep disorders are associated with cardiovascular disease, but we are not aware of any published prospective population studies that have shown a link between short sleep duration and the incidence of hypertension in subjects without apparent sleep disorders. We assessed whether short sleep duration would increase the risk for hypertension incidence by conducting longitudinal analyses of the first National Health and Nutrition Examination Survey (*n*=4810) using Cox proportional hazards models and controlling for covariates. Hypertension incidence (*n*=647) was determined by physician diagnosis, hospital record, or cause of death over the 8- to 10-year follow-up period between 1982 and 1992. Sleep durations of ≤5 hours per night were associated with a significantly increased risk of hypertension (hazard ratio, 2.10; 95% CI, 1.58 to 2.79) in subjects between the ages of 32 and 59 years, and controlling for the potential confounding variables only partially attenuated this relationship. The increased risk continued to be significant after controlling for obesity and diabetes, which was consistent with the hypothesis that these variables would act as partial mediators. Short sleep duration could, therefore, be a significant risk factor for hypertension.

• High Blood Pressure

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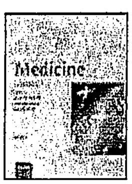

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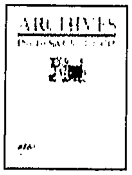

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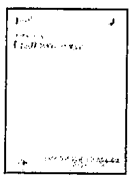

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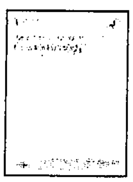

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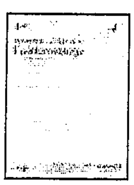

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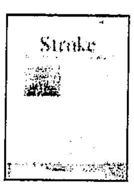

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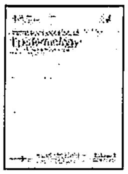

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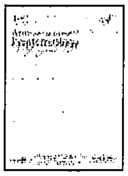

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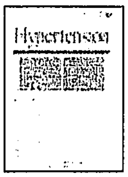

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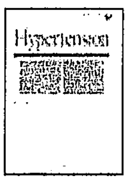

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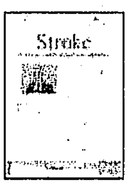

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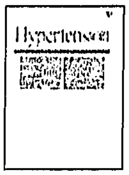

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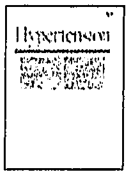

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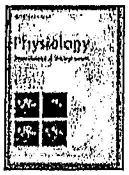

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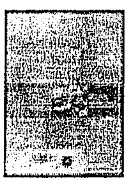

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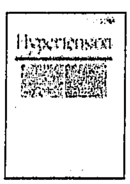

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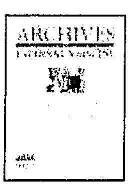

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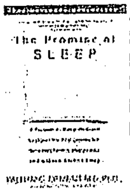


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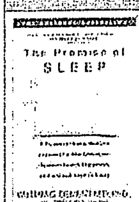

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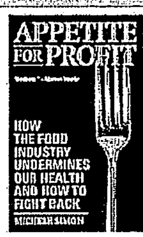

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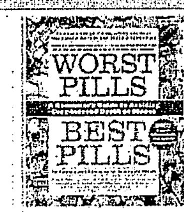

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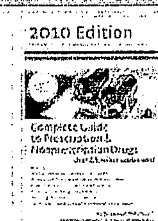

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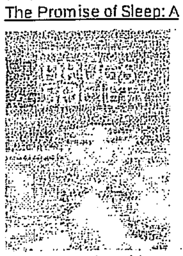
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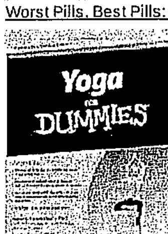

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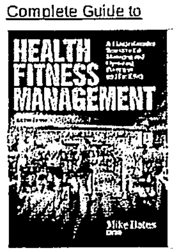

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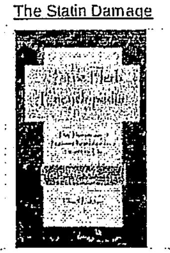
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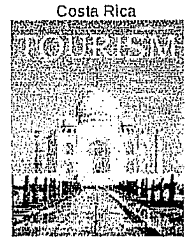

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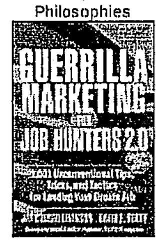

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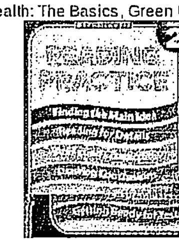

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**Accession Number :** ADA249653



**Title :** Health Effects of Sleep Deprivation,

**Corporate Author :** NAVAL HEALTH RESEARCH CENTER SAN DIEGO CA

**Personal Author(s) :** Naitoh, Paul ; Kelly, Tamsin L. ; Englund, Carl

**Handle / proxy Url :** http://handle.dtic.mil/100.2/ADA249653

**Report Date :** JUN 1990

**Pagination or Media Count :** 32

**Abstract :** Biomedical and health consequences of total, selective, and partial sleep loss were documented in this paper by examining adrenomedullary activity, adrenocortical activity, metabolism, hematological and immunological changes, autonomic nervous system activity, epileptiform discharges, physical work capacity, antidepressant effects, and mental health.

**Descriptors :** *PERFORMANCE(HUMAN), *HEALTH, *SLEEP DEPRIVATION, REPRINTS, STRESS(PHYSIOLOGY), AUTONOMIC NERVOUS SYSTEM, BIOMEDICINE, METABOLISM, NERVOUS SYSTEM, MENTAL HEALTH

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# Stress and Infectious Disease in Humans

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This article reviews research on the role of stress in infectious disease as measured either by illness behaviors (symptoms and use of health services) or by verified pathology. Substantial evidence was found for an association between stress and increased illness behavior, and less convincing but provocative evidence was found for a similar association between stress and infectious pathology. Introverts, isolates, and persons lacking social skills may also be at increased risk for both illness behaviors and pathology. Psychobiological models of how stress could influence the onset and progression of infectious disease and a psychological model of how stress could influence illness behaviors are proposed.

Psychologists interested in the role of psychological factors in human diseases have focused primarily on coronary heart disease and cancer to the relative neglect of infectious diseases. For example, the role of stress and other psychological factors in infectious disease is not a topic in *Behavioral Health*, Matarazzo, Weiss, Herd, Miller, and Weiss' (1984) compendium of the field nor in either of the *Annual Review of Psychology* chapters on Health Psychology (Krantz, Grunberg, & Baum, 1985; Rodin & Salovey, 1989). However, interest in this area has been recently stimulated both by evidence that psychological factors influence immune function (e.g., Ader, 1981; Coe & Levine, in press; Jemmott & Locke, 1984) and by increasing recognition of the importance of understanding the role of stress and other psychological factors in the onset and progression of acquired immunodeficiency syndrome (AIDS; Baum & Nesselhof, 1988; Kiecolt-Glaser & Glaser, 1988b).

When exposed to an infectious agent, only a proportion of people develop clinical disease (Cornfeld & Hubbard, 1964; Fernald, Collier, & Clyde, 1975). Moreover, severity and duration of symptomatology vary widely among those who do become ill. Reasons for variability in response are not well understood and the possibility that psychological factors play a role has received increased attention (e.g., Bierman, 1983; Stein, 1981). The purpose of this article is to address the possible role of psychological factors in the etiology and progression of infectious diseases. Because the majority of studies in this literature examine the influence of *stress* on susceptibility, our review and theoretical discussion focus on stress. However, in reviewing the literature, we also touch on other psychological factors that have been investigated as risk factors for infection.

We begin by providing background information on psychological and biological issues involved in studying the relation between stress and infectious disease. We then propose models of how stress could influence infectious pathology and how stress could influence illness behaviors; address methodological and conceptual problems relevant to designing and conducting studies in this area; and review and interpret the literature on psychological influences on the onset, duration, and recurrence of infections in humans.

## Definitions

### *What Do We Mean By Stress?*

The focus of this article (and of the work we review) is on negative stressful life events and negative affective states as possible contributors to the development of infectious pathology. The theoretical models we propose assume that negative events (major or daily) and psychological distress measures tap different stages of the same underlying process: stressful events, causing negative affective states that (for reasons described later) put people at higher risk for infectious disease. We recognize that negative events do not always trigger psychological distress. Distress arises only when imposed demands are perceived to exceed ability to cope (Lazarus & Folkman, 1984). However, the work we review does not address conditions under which environmental stressors produce distress. Moreover, categorizing studies according to whether they use stressor or distress measures does not predict study results. As a consequence, our theoretical discussions begin with stressor-elicited distress. We caution the reader, however, that there are important psychological moderators of the stressor–distress relation (see reviews by Cohen & Edwards, 1989; Cohen & Wills, 1985; Gentry & Kobasa, 1984; Kessler & McLeod, 1985).

For the most part, the stressor and distress measures used in

Sheldon Cohen's participation in the preparation of this article was supported by a Research Scientist Development Award from the National Institute of Mental Health (K02 MH00721) and grants from the National Institute of Allergies and Infectious Diseases (AI23072) and the Office of Naval Research (N00014-87-K-0369). Gail M. Williamson's participation was supported by a postdoctoral fellowship in Clinical Services Research from the National Institute of Mental Health (MH17184) and by a grant from the National Institute on Aging (R. Schulz, principal investigator, AG0-5444). We thank Joan Cunnick, Robyn Dawes, Bruce Rabin, Richard Schulz, and David Tyrrell for their comments on an earlier draft.

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this literature are cumulative; that is, they combine events or assess general (source unspecified) distress. Many of the studies use major stressful life event or daily event checklists. Examples of events included in major life event checklists are moving, divorce, and death of a loved one. Major stressful life event measures used in the reviewed literature include versions of Holmes and Rahe's (1967; Holmes & Masuda, 1974) original scale (e.g., Schedule of Recent Life Experience [SRE], Social Readjustment Rating Scale [SRRS], and Life Change Inventory [LCI]) as well as several second generation scales (e.g., Life Events Survey [LES], Sarason, Johnson, & Siegel, 1978; College Student Life Events Scale [CSLES], Levine & Perkins, 1980; Life Events Inventory [LEI], Tennant & Andrews, 1976; and Psychiatric Epidemiology Research Interview [PERI], Dohrenwend, Krasnoff, Askenasy, & Dohrenwend, 1978). Examples of events in daily event checklist include misplacing or losing things, social obligations, and problems and arguments with friends. Daily event measures used in the reviewed literature include the Daily Hassle Scale (DHS; Kanner, Coyne, Schaeffer, & Lazarus, 1981) and the Assessment of Daily Experience (ADE; Stone & Neale, 1982). Finally, psychological distress measures include items (and subscales) assessing anxiety, depression, dysphoria, and other negative affective states—all highly intercorrelated components of distress (Dohrenwend, Shrout, Egri, & Mendelsohn, 1980). Distress measures used in the reviewed literature include the Beck Depression Inventory (BDI; Beck, Ward, Mendelson, Mock, & Erlbaugh, 1961), Cornell Medical Index (CMI; Brodman, Erdman, & Wolff, 1956), General Health Questionnaire (GHQ; Goldberg, 1972), Manifest Affect Rating Scale (MARS; Spilken & Jacobs, 1971), Middlesex Hospital Questionnaire (MHQ; Crown & Crisp, 1966), Minnesota Multiphasic Personality Inventory (MMPI; Hathaway & McKinley, 1951), Mood Adjective Checklist (MACL; Nowlis, 1965), and Profile of Mood States (POMS; McNair, Lorr, & Droppleman, 1971). (Abbreviations used in the text for each of the stressor and distress scales are provided in Table 1.) We recognize that scores on cumulative events and psychological distress measures may be partly or wholly attributable to trait (as opposed to state) distress and address this issue in the Discussion section.

Table 1
*Abbreviations for Stressor and Distress Measures*

| Abbreviation | Measure |
|---|---|
| | Major life events scales |
| CSLES | College Student Life Events Scale |
| SRE | Schedule for Recent Life Experience |
| SRRS | Social Readjustment Rating Scale |
| LCI | Life Change Inventory |
| LES | Life Events Survey |
| LEI | Life Events Inventory |
| PERI | Psychiatric Epidemiology Research Interview |
| | Daily life event scales |
| ADE | Assessment of Daily Experience |
| DHS | Daily Hassle Scale |
| | Psychological distress scales |
| BPI | Boston University Personality Inventory |
| BDI | Beck Depression Inventory |
| CMI | Cornell Medical Index |
| GHQ | General Health Questionnaire |
| MACL | Mood Adjective Checklist |
| MARS | Manifest Affect Rating Scale |
| MHQ | Middlesex Hospital Questionnaire |
| MMPI | Minnesota Multiphasic Personality Inventory |
| POMS | Profile of Mood States |

### *What Do We Mean By Infectious Disease?*

Infectious diseases result from the growth and action of microorganisms or parasites in the body and may or may not be contagious. The diseases studied in the literature we review include those believed to be caused by viruses, bacteria, and mycoplasma. Standard research criteria for diagnosis of *clinical* infectious disease require *both* biologic evidence of infection and manifestation of related symptomatology (Beare & Reed, 1977; Kasl, Evans, & Neiderman, 1979). Below, we discuss measures of infection and symptomatology, as well as indirect measures sometimes used as disease markers.

#### *Infection*

Biological verification of infection can be accomplished by establishing that an infectious agent is present or replicating in tissue, fluid, or both. Studies of diseases with unknown etiologies, for example, community studies of upper respiratory infections (URI), often use generic methods for detecting the presence of *unspecified* pathogens. A common procedure is to culture the sample (put it in a medium that stimulates pathogen reproduction). If pathogens are present they will reproduce in the medium and can be detected with the naked eye or under magnification. This procedure works well for detecting unspecified bacteria but not for viruses.

Studies of diseases with known etiologies, for example, viral inoculation studies, use methods designed to detect the presence of a particular pathogen. This can be done by (a) culturing samples in mediums that stimulate growth of only certain pathogens or (b) demonstrating that the immune system is responding to an agent by producing antibodies. Antibodies are protein molecules that attach themselves to invading microorganisms and mark them for destruction or prevent them from infecting cells. Because each antibody recognizes only a single type of microorganism, the production of antibodies to a specific infectious agent is evidence for the presence and activity of *that* agent. Antibody levels are generally assessed by determining the extent to which the serum from an infected person binds to a sample of an infectious agent. A significant increase (within subject) in the level of antibodies to a specific agent is considered evidence for infection by that agent (see techniques for determining significant within-individual increases described in Ershler, Moore, & Socinski, 1984).

We have suggested that the presence of an infectious agent can be established either directly through the use of culturing techniques or indirectly through detection of significant increases in antibodies to that agent. These two techniques, however, are often only moderately correlated and optimally, both procedures should be included to verify infection (Beare & Reed, 1977). Either antibody increase *or* detection of the pathogen is considered sufficient evidence of infection.

Procedures for detecting pathogens and their antibodies are invasive, time consuming, and expensive. Moreover, in naturalistic studies, techniques for screening symptomatic patients to verify diseases caused by unknown pathogens are not especially successful in finding responsible agents (e.g., 28% verification in Boyce et al., 1977; 15% verification in Graham, Douglas, & Ryan, 1986).

### *Signs and Symptoms*

Measures of disease symptomatology in this literature can be separated into two categories: signs and symptoms. *Signs* are observable (sometimes with the aid of x-rays or other technology), for example, lesions, rashes, and swelling. Trained clinicians are often used to identify observable signs such as the occurrence of oral lesions in herpes simplex. *Symptoms* are *not* observable but are reported by a patient, for example, headaches and stomachaches. Although it is theoretically possible to validate symptom protocols by establishing that they are strongly associated with verified disease outcomes, there is only one study in this literature (Friedmann, Katcher, & Brightman, 1977) that reports such a validation.

Many of the studies use unverified self-reported symptom protocols as their only criterion for disease. Although these reports may reflect underlying infectious pathology, they may also reflect influences of stress on cognitive processes and self-perceptions that are *not* associated with infectious disease. In other words, people may report symptoms or illness episodes without actually experiencing clinical illness or may not report symptoms or illness episodes when they do have clinical disease. Nonpathogenic pathways that might link stress to symptom reporting are discussed later.

### *Seeking Medical Care*

A final measure of illness used in this literature is use of health-care services. Seeking medical care involves both defining a constellation of symptoms as an illness and deciding to seek care. As with self-reported symptoms, multiple psychological processes are involved. Such behavior may be driven by underlying infectious pathology but may often occur independent of pathology. Moreover, those seeking care who actually have verifiable pathology are not necessarily representative of persons with that disease. In short, those who do not seek care may be as ill as those who do, and these groups may differ psychologically.

## *How Could Stressors Influence Infection and Illness?*

Stressors are generally thought to influence the pathogenesis of physical disease by causing negative affective states (such as anxiety and depression), which in turn exert direct effects on biological processes or behavioral patterns that increase disease risk (see Cohen, Evans, Stokols, & Krantz, 1986; Krantz, Glass, Contrada, & Miller, 1981). We recognize that stressors may also elicit behavioral or biological changes that *decrease* disease risk. Although our models primarily address the former hypotheses, we discuss stressor-induced health promoting pathways as well. The focus of this article is on negative stressful life events and negative affective states as possible contributors to pathology. Our models start with negative affective states and do not address the conditions under which environmental stressors produce negative affect (see Lazarus & Folkman, 1984, for discussions of these issues). In our theoretical discussion, we use the term *stress* because we are discussing the state of psychological distress and not environmental characteristics (*stressors*) that may contribute to that state.

Even the most severe stress cannot result in infection without the presence of an infectious agent. Plausible routes through which stress might influence susceptibility to infectious disease include (a) altering biologic susceptibility and hence *predisposing* persons exposed to a pathogen to infection, (b) *initiating* or triggering a process that allows a pathogen that is already in the body (e.g., a latent virus) to reproduce, or (c) contributing to *maintenance* of an ongoing pathogenic process.

We propose two models representing plausible pathways linking stress to infectious pathology. The first addresses the role of stress in predisposing persons to the onset of a new infection. The second model addresses pathways through which stress may influence duration and severity of an existing infection either by maintaining ongoing pathogenic processes or by initiating (reactivating) latent infections. Pathways in each of these models are depicted in Figures 1 and 2, respectively, and are described later.

We also propose a third model addressing how stress may influence labeling of physical sensations as symptoms, labeling of symptoms as disease, and use of health care facilities. Our intent is to provide explanations for stress-induced illness behaviors that do not assume underlying pathology. This model is depicted in Figure 3. All three models indicate paths moving in only one causal direction, from stress to disease or from stress to illness behaviors. Alternative paths are excluded for the sake of brevity. Their exclusion is not intended to reflect hypotheses about their existence.

### *Stress and the Onset of Infectious Disease*

Susceptibility to infection is presumed to be primarily mediated by immune function. As indicated in Figure 1, stress may influence immunity either through direct innervation of the central nervous system (CNS) and immune system (nerves terminating in lymphoid organs), or through neuroendocrine-immune pathways (release of hormones). A number of direct neural pathways linking the CNS to the immune system have been identified (e.g., Felten, Felten, Carlson, Olschowka, & Livnat, 1985; Felten & Olschowka, 1987). In the case of hormonal pathways, a wide range of hormones released under stress have been implicated in immune modulation. Examples include the catecholamines epinephrine and norepinephrine secreted by the adrenal medulla, cortisol secreted by the adrenal cortex, growth hormone and prolactin secreted by pituitary gland, and the natural opiates beta endorphin and enkephalin released in the brain (see Baum, Grunberg, & Singer, 1982, for discussion of hormones released under stress; see Hall & Goldstein, 1981; Laudenslager, 1988; Rabin, Cohen, Ganguli, Lysle, & Cunnick,

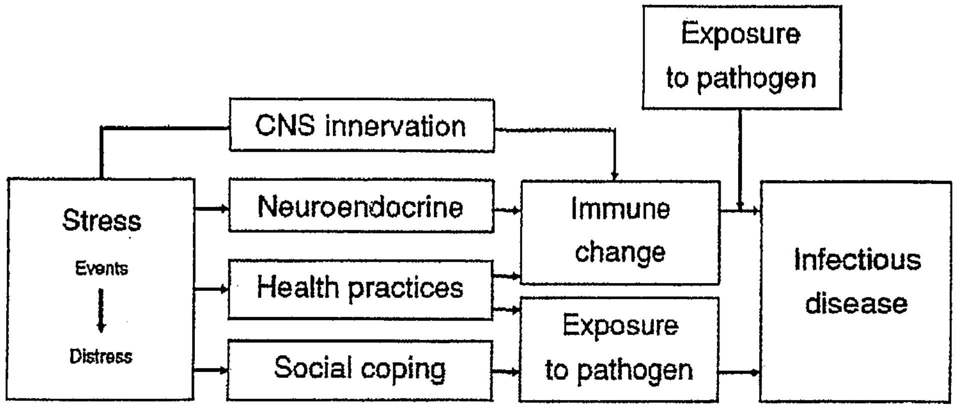


*Figure 1.* Behavioral and biological pathways linking stress to the onset of infectious diseases. (CNS = central nervous system. For brevity, the model indicates paths moving in only one causal direction, from stress to disease.)

1989, for discussions of the influence of these hormones on immune function).

Behavioral changes occurring as adaptations or coping responses to stress may also influence immunity. For example, persons under stress tend to engage in poor health practices. They may smoke more, drink more alcohol, eat poorly, and sleep less (Cohen & Williamson, 1988; Conway, Vickers, Ward, & Rahe, 1981). Increased smoking, drinking, and changes in diet may all influence immune response (see Kiecolt-Glaser & Glaser, 1988a).

Although effects of stress on immune response are often described as immunosuppressive, implications of stress-induced immune changes for disease susceptibility are not as yet clear. First, in studies of stress effects on immunity, immune responses of stressed persons generally fall within *normal* ranges (Laudenslager, 1987; Rabin et al., 1989). Second, there are few data on immune status in healthy persons as a predictor of disease susceptibility. There is sufficient evidence to convince us that stress influences the immune system. However, it is not clear that either the nature or magnitude of change found in these studies alters disease susceptibility (Calabrese, Kling, & Gold, 1987; Jemmott & Locke, 1984; Palmblad, 1981). Finally, the immune system is complex: One or even several measures of immune function may not provide an adequate representation of host resistance (Palmblad, 1981; Plaut & Friedman, 1981; Rogers, Dubey, & Reich, 1979).

Behavioral changes under stress may also influence susceptibility to infection by influencing whether and for how long persons are exposed to pathogenic agents. For example, stressed persons often engage in *social coping*—drawing on the resources of their social networks (Cohen & Wills, 1985). Increased interaction with others results in greater probability of exposure to infectious agents and consequent infection. However, social interaction under stress is, to some degree, influenced by both the nature of the stressor (Cohen & McKay, 1984) and individual differences in social skills and affiliative

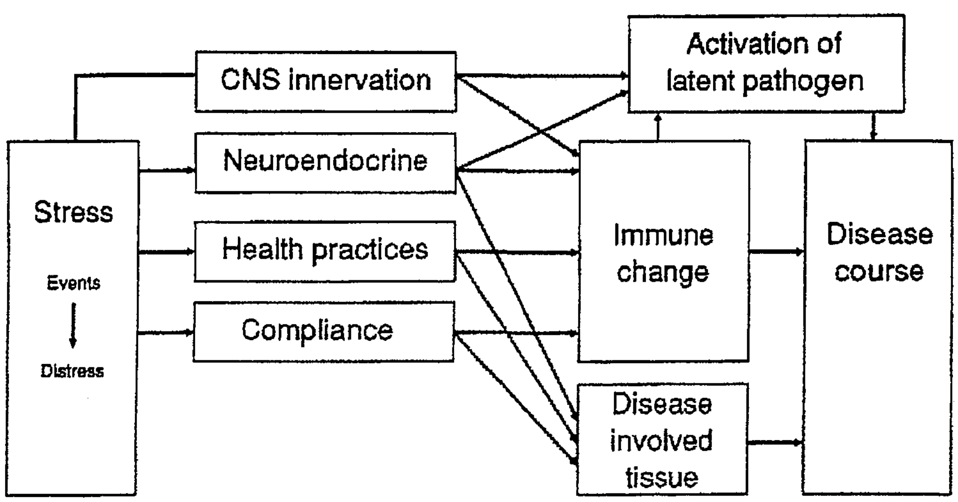


*Figure 2.* Behavioral and biological pathways linking stress to reactivation of latent pathogens and to the severity of infectious disease. (CNS = central nervous system. For brevity, the model indicates paths moving in only one causal direction, from stress to disease.)

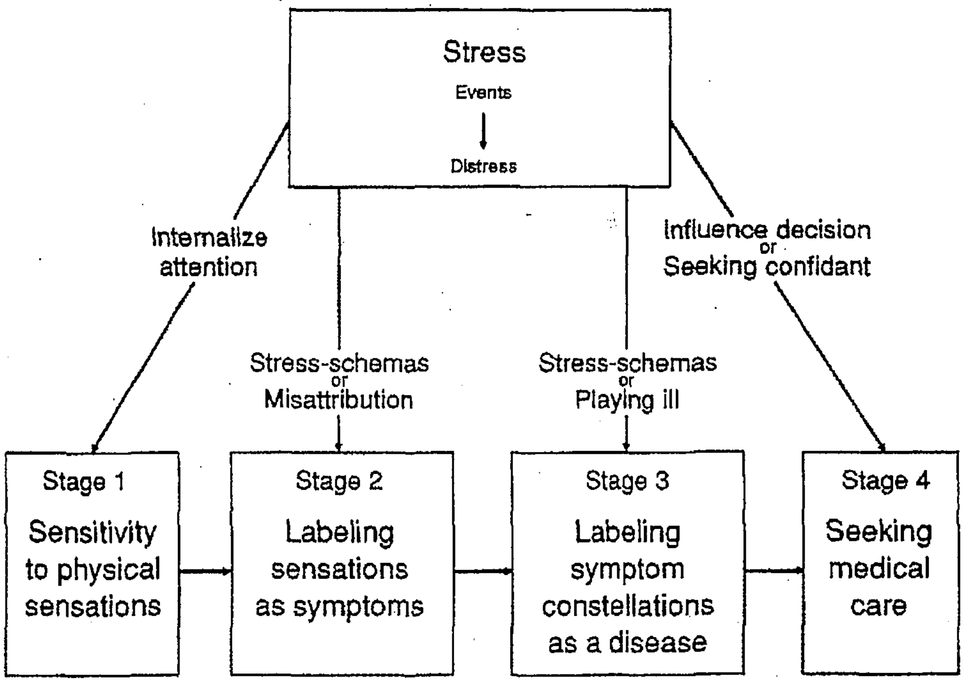


*Figure 3.* Psychological pathways linking stress to illness behaviors. (For brevity, the model indicates paths moving in only one causal direction from stress to illness behavior.)

tendencies (Heller, 1979). Hence, under some conditions stress may lead to social withdrawal and decreased risk of exposure. Other stress elicited behaviors, for example, unsafe sexual practices or poor hygienic practices, could also increase exposure to infectious agents.

### *Stress and the Severity and Course of Infectious Disease*

Pathways proposed as responsible for changing immune function and hence predisposing persons to disease onset (Figure 1) are also involved in modeling stress effects on duration and severity of disease (Figure 2). However, the course of illness may be influenced by direct effects (not involving the immune system) on *disease-involved tissues* as well. For example, stress-triggered hormones such as cortisol and epinephrine may increase mucous secretion and vasodialation (Laudenslager, 1987) or modulate reflex responses enhancing symptoms such as irritation or sneezing. Stress may also influence disease-involved tissue through changes in *health practices.* For example, increased smoking under stress could irritate nasal and lung tissues. Finally, failure to *comply* with medical regimens under stress could result in more severe and longer-lasting illness, either because undesirable behaviors aggravate existing problems or because failure to perform desirable behaviors (e.g., following medication regimens) results in disease progression. These actions may occur through influences on immune function or through influences of disease-involved tissue.

As indicated in Figure 2, stress may also play a role in reactivating latent pathogens (agents already in the body but not currently multiplying). Diseases with latent viral states include oral and genital herpes as well as AIDS. Reactivation could occur through hormonal or neural stimulation of pathogen reproduction or through suppression of aspects of the immune system that might otherwise hold the pathogen in check (Glaser & Gotlieb-Stematsky, 1982; Kiecolt-Glaser & Glaser, 1987a).

### *Stress and Illness Behaviors*

Our final model addresses how stress may influence the various stages of recognizing and acting on symptoms. Illness behaviors are often accurate indicators of underlying pathology. However, stress and other psychological factors can independently influence these behaviors. This model presents explanations for how stress may influence symptom reporting and medical care seeking without influencing pathology. These mechanisms may operate alone or in conjunction with stress-induced pathology to influence illness behaviors.

Figure 3 depicts the potential sequence of processes that might lead from physical sensation to seeking medical care: sensitivity to physical sensations, labeling sensations as symptoms, labeling symptom constellations as disease, and seeking medical care. These processes are discussed in detail by others (see Cacioppo, Andersen, Turnquist, & Tassinary, 1989; Leventhal, Meyer, & Nerenz, 1980; Mechanic, 1972; Pennebaker, 1982). Although we recognize that there are multiple cultural, social, and individual determinants of illness behaviors, our model only addresses how each behavior may be influenced by stress.

Because psychological stress often triggers physiologic arousal, people under stress may be more attentive to their internal physical states (Stage 1). Stress may also facilitate the labeling of sensations as symptoms (Stage 2) because people are reminded (in cognitive parlance, a schema is triggered) of previous times when stress was associated with symptoms or simply because they believe that stress triggers symptoms. Alternatively, stress may result in physical sensations whose causes are mistakenly attributed to disease symptoms rather than the stress (Mechanic, 1972; Schachter & Singer, 1962). Labeling symptom constellations as disease may similarly be activated by stress–disease schemas (Stage 3). For example, it is widely believed that stress causes the recurrence of oral herpes. Under stress, a minor oral lesion that would be ignored under nonstressful conditions may be defined as disease recurrence. Reports of symptoms and illness are also ways to avoid stressful situations (Mechanic, 1977). The prototypic example is the child who reports symptoms to avoid attending school on an especially stressful day (playing ill). Finally, stress may influence the decision to seek medical care when persons label themselves as ill (Stage 4). Stress could interfere with deciding whether it is necessary to seek care, increasing care seeking for minor symptoms or decreasing care seeking for serious ones. Persons under stress may also seek medical care unnecessarily because medical providers are viewed as persons to whom one can confide problems. Stress could also *decrease* care seeking because the time demands of many stressors make such visits inconvenient (Schulz, Visintainer, & Williamson, 1990).

Stress-triggered illness behaviors are thought to be general in nature, that is, they do not fall within the domain of a single disease (Pennebaker, 1982; Rabkin & Struening, 1976; Spilken & Jacobs, 1971). Therefore, to the extent that stress effects on illness behaviors are *not* disease specific, there is reason to assume that they are caused by psychological processes influencing symptom reporting and care seeking rather than by underlying pathology.

We have proposed plausible psychological and biological pathways that could link stress to disease. Unfortunately, existing research has focused on establishing a relation between stress and infectious disease with only a handful of studies assessing possible pathways through which such an association might occur. These models provide psychological and biological reasons for expecting stress to increase risk for infectious disease and theoretical frameworks for future work.

## Methodological Approaches

Of the many published papers addressing the role of psychological factors in infectious disease in humans, relatively few meet contemporary scientific criteria. Our review is limited to published studies (as of August, 1989) that use standardized measurement, include control groups, and use procedures allowing statistical inference. We have excluded anecdotal accounts of patients' experiences, descriptions of clinical cases, and speculative pieces by physicians who notice similarities among their patients. We have also excluded work not published in peer review journals and secondary descriptions of unpublished work.

### *Causal Inference*

The human literature relating stress to infectious disease is limited to *correlations* between stress and disease. In a typical study, persons reporting high stress are compared to those reporting relatively lower levels of stress in terms of their risk for developing disease. Although a correlation between stress and disease suggests that stress makes people vulnerable to infectious agents, it may also be that disease (or premorbid pathology) causes greater stress, or that a third factor (e.g., age or social class) puts people at higher risk for both stress and disease. We review relevant retrospective studies. However, we place special emphasis on prospective studies where subsequent disease is predicted from stress levels in *initially healthy* persons. In prospective studies, the possibility that disease-caused stress can be eliminated (see discussions in Cohen et al., 1986, chap. 2; Kessler, 1983; Monroe, 1983). Several prospective studies are infectious-challenge trials in which healthy volunteers were experimentally exposed to a specific infectious agent after psychological measures were taken. Infection and (in most cases) symptoms were then assessed over a period of several days. This design eliminates stress influences on exposure to an infectious agent as an explanation for relations between stress and infectious outcomes.

### *Rates of Infectious Disease*

To predict the occurrence of a disease in a sample, a reasonable percentage of the sample must develop the disease over the course of a study. Although the minimum percentage infected depends on sample size, in the relatively small samples (less than 300) typically used in the verified disease studies in this literature, an infection rate of at least 25% is usually required. This is one reason why the infectious diseases studied most often in this literature are colds, influenza, and herpes—diseases with very high base rates of occurrence.

### *Other Factors Influencing Susceptibility to Infection*

Stress is not the primary etiologic agent in infectious disease, but rather, may be one of many contributors. The primary factor in susceptibility is prior exposure and consequent development of immunity. This immunity is partly attributable to the production of antibodies that occurs when persons are exposed to an infectious agent. Some antibodies remain in circulation and help fight the same infectious agent upon later exposure. Presence of antibodies also provides evidence of prior exposure. Exposure to an infectious agent also sensitizes a population of white blood cells (lymphocytes) to recognize and aid in destroying that agent upon subsequent exposure.

Other factors influence risk for infectious disease (see Jackson et al., 1960; Jemmott & Locke, 1984; Kiecolt-Glaser & Glaser, 1988a; Plaut & Friedman, 1981). These include nutritional status of the host, previous history of illness, presence of other disease, genetic–immune factors, age, race, gender, pregnancy, rhythms (e.g., circadian, menstrual phase, annual), and seasons of the year (e.g., temperature, light exposure). Some of these factors (e.g., race and gender) may be correlated with both stress and infection and consequently provide alternative (spurious) explanations for correlations between stress and infectious disease. Each factor may also make significant independent contributions to unexplained error variance. The more of these factors controlled for in any study, the greater the probability of isolating effects of stress in the context of multiple environmental, social, and biological predictors (see Plaut & Friedman, 1981; Schleifer, Scott, Stein, & Keller, 1986).

## Review

As discussed earlier, a conservative research criterion for diagnosis of clinical infectious disease requires both biologic evidence of infection and manifestation of related symptomatology. Because of the relatively small number of studies using this criterion, we take a somewhat less conservative approach. We treat studies using symptoms *in addition to* biologically verified infection as well as those using physician diagnosis as studies of verified disease.

A number of the investigations, especially those of unidentified URI, include *only* illness behavior measures. In our review, we include only those illness behavior studies intended to identify behaviors specifically associated with an infectious disease, in most cases URI.

Also of concern is the differentiation between subclinical and clinical infection. In short, persons can be biologically infected without manifesting symptoms. It is not known whether this occurs because the biologic response is not sufficient to result in symptoms or because the immune pathways involved in subclinical and clinical responses are different. For the most part (an exception is made in *Herpesvirus Infections*), we review studies with biologic verification but without symptom measures in the verified disease section. However, we caution that there are great practical and theoretical differences between subclinical and clinical disease. Biologic response alone (e.g., increased antibody response) is *not* sufficient evidence for clinical disease.

Our review is organized into separate sections on human studies of (a) upper respiratory infections, (b) herpes infections, and (c) miscellaneous bacterial infections. This categorization has no inherent biologic basis, but rather reflects areas in which work has been done. Most URI studies either combine viral and bacterial infections or address unidentified infections. Hence, we review all URI studies in one section rather than separate the few that were specifically viral or bacterial. We do not review infrahuman studies (see reviews by Monjan, 1981; Plaut & Friedman, 1981; Rogers et al., 1979), although we do draw on the animal literature to both clarify and raise issues.

In each section, we distinguish between retrospective and prospective studies. When relevant, prospective infectious-challenge studies—in which volunteers are experimentally exposed to an infectious agent—are also treated separately. Evidence relevant to neuroendocrine, immune, and behavioral pathways (as proposed in our models) is addressed in *Testing Pathways*, at the end of the review.

### *Upper Respiratory Infection*

The respiratory system is vulnerable to a wide range of viral and bacterial infections. Most familiar are common colds and influenza. Colds and flu are both viral infections. Colds can be caused by more than 100 viruses. Influenza is primarily caused by two types of viruses (A and B), each with many subtypes and strains, but influenza-type diseases can also be caused by many other viruses, for example, adenoviruses, parainfluenza, and respiratory syncytial virus. Both colds and flu are characterized by sore throat, congestion, and mucus secretion. Unlike most colds, however, flu can be accompanied by elevated temperature, gastrointestinal discomfort, and joint pain. Viral infections of the upper respiratory tract are sometimes complicated by secondary bacterial infections caused by inflammation of mucous membranes reducing ability to protect against pathogenic bacteria.

### *Illness Behaviors*

We begin by discussing work on associations between psychological factors and illness behaviors. In these studies, outcomes include URI symptoms, health care utilization, or both, without medical or biologic verification of disease.

*Retrospective studies.* Several retrospective studies report relations between psychological distress measures and URI-related illness behaviors. Self-reported incidence of URI has been associated with high self-rated negative impact of life events (LES) and high scores on the Taylor Manifest Anxiety Scale, a measure of trait anxiety (Belfer, Shader, Mascio, Harmatz, & Nahum, 1968). High numbers of stresses (upsets, worries, sources of tension, etc.) have also been associated with retrospective reports of URI severity as well as severity of all illnesses (McClelland, Alexander, & Marks, 1982). In one study, use of health services was similarly higher among those reporting more life changes (LCI)—especially personal failures (Jacobs, Spilken, Norman, & Anderson, 1970).

These studies also include failures to find associations between measures of both trait anxiety (Scheier Cattell Anxiety Battery) and depression (Depression scale of the MMPI) and retrospective reports of URI episodes (Belfer et al., 1968) and between life event impact (LES) and use of health services (Sarason, Sarason, Potter, & Antoni, 1985). Other psychological measures not associated with illness behaviors include power motivation (McClelland et al., 1982; McClelland, Floor, Davidson, & Saron, 1980) and perceived social support (Sarason et al., 1985).

Stress may also interact with other psychological variables in predicting URI symptomatology. For example, Sarason et al. (1985) found that those with many negative life events *and* few social supports were more likely to report chronic (mostly URI) illness than all other groups. McClelland et al. (1982) found that people that were *both* high in number of stresses and in need for power reported more severe illness than all other groups combined. In a similar study, McClelland et al. (1980) found that persons with high numbers of stressful life events (SRRS), need for power, *and* action inhibition reported more illnesses, more severe URIs, and more severe non-URI illnesses.

*Prospective studies.* Parens, McConville, and Kaplan (1966) tracked the use of health services of two samples of first year nursing students (*N*s = 75 and 61) for 8 months after administering a series of psychological measures. In both studies, those reporting poor adjustment to their new environment (on a measure devised by the authors) and those reporting very high depressive affect (BDI) used health services (mostly for URI) more frequently. In the second study only, a positive relation was found between life events (object losses over the entire life) and illness frequency. Number of health service visits was also higher among those with the highest scores on a helplessness ("giving up") measure devised by the authors.

Spilken and Jacobs (1971) administered a series of psychological scales—LCI, MARS, and BPI (Boston University Personality Inventory)—to 92 healthy college students and then monitored them for a year. Those seeking medical care for URI during the year had reported more life events and negative affect and had higher scores on trait measures of defiance and neurotic emotionality. Those reporting having sought care for non-URI problems similarly reported more life events, as well as more negative affect and neurotic emotionality.

In a study reported by Linville (1987), 106 undergraduates completed a life events measure (CSLES) and self-reported measure of illness and then reported illness data again 2 weeks later. With initial illness ratings controlled for statistically, those with more negative events were more likely to report having had the flu in the intervening period than those with fewer events. They were also more likely to report having other illnesses—illness in general as well as aches (could be flu related) and cramps. Negative events were not, however, associated with abdominal problems or with injuries.

Glaser et al. (1987) followed 40 first year medical students throughout the academic year. Students reported the number of days that their activities were restricted because of acute infectious illness during three high-stress (exam) and low-stress (1 month prior to exam) periods. More infectious (mostly URI) illnesses were reported during examination periods than during the preexam baseline periods.

Stone, Reed, and Neale (1987) studied 79 married couples who completed checklists of 80 life events (ADE) daily for 3 months. Daily life events rated as undesirable increased 3 to 4 days prior to onset of an URI episode (defined as 2 or more days of self-reported symptoms). Events rated as desirable decreased 4 to 5 days prior to onset. Finally, Imboden, Canter, and Cluff (1961) report data on *speed of recovery* from influenza. Psychological questionnaires (MMPI and CMI) were administered to 600 military employees. The study focused on the 26 members of this group who reported to the dispensary with flu during the following winter. Of the 26, those still reporting flu symptoms 3 to 6 weeks later had reported more symptoms of depression and emotional disturbance.

Overall, there is fairly consistent evidence for a positive relation between measures of both stressors (e.g., Glaser et al., 1987; Linville, 1987; Parens et al., 1966; Spilken & Jacobs, 1971; Stone Reed, & Neale, 1987) and distress (Imboden et al., 1961; Parens et al., 1966; Spilken & Jacobs, 1971) and URI-related illness behaviors. There is good reason, however, to question the extent to which these studies reflect stress-induced pathology as opposed to other (nonpathogenic) stress-induced processes that drive illness behaviors (see Figure 3). Of special concern is the fact that studies examining non-URI behaviors have found similar increases with stress for both URI and non-URI illness behaviors (Linville, 1987; McClelland et al., 1980; Spilken & Jacobs, 1971). This suggests that stress affects all illness behaviors rather than just behaviors specific to URI (see Pennebaker, 1982; Rabkin & Struening, 1976). However, there are also data indicating that stress associations with self-reported illness may be partly or wholly attributable to underlying pathology. Stone et al. (1987) found that stress may precede URI symptomatology by 3 to 4 days—close in time to the incubation period of many common cold viruses (24 to 72 h) and other studies indicate stress-induced changes in immunity as well as illness behavior (see work discussed later in the section on testing pathways; e.g., Glaser et al., 1987; McClelland et al., 1980).

### *Verified Upper Respiratory Infections*

We turn now to studies in which URI was verified either by physician diagnosis or biological methods.

*Retrospective studies.* In a study by Jacobs, Spilken, and Norman (1969) undergraduates completed the LCI, BPI, and MARS. More physician diagnosed cases of URI were found among those with relatively numerous life changes. The effect occurred only for "personal failure and role crisis" events. URI incidence was also associated with greater defiance, danger-seeking behavior, and unpleasant affect. In another student sample, Alexander and Summerskill (1956) found no differences between stressful (e.g., exam and preexam) and nonstressful periods on campus and diagnosed incidence of URI. Nor were academic probation, university disciplinary action, or university activities related to URI incidence. However, persons seeking help at the mental health clinic had a higher incidence of URI than the sample as a whole. Finally, in a community study of children (mean age 4.3 years), Boyce et al. (1977) found that increased life events (as retrospectively reported by parents on a pediatric modification of the SRE) were associated with increased duration of illness and illness severity (as evaluated by health professionals) but not with number of illnesses. Moreover, contrary to prediction, children in families with unchanging daily routines were predisposed to greater stressor-elicited illness severity instead of protected from it.

*Prospective studies.* In an early study, Meyer and Haggerty (1962) followed 100 members of 16 families for a 12-month period. Family diaries were used to record stressful life events. Throat cultures (screened for streptococcal infections) were made every 3 weeks and at times of acute illness. Blood (for antibody levels) was drawn every 4 months. Daily life events that disrupted family and personal life were 4 times more likely to precede than to follow new streptococcal and nonstreptococcal infections and associated symptomatology. In addition, chronic family stress (as judged by observers) was related to greater numbers of new infections, prolonged production of the bacterium without symptoms, higher streptococcal illness rates, and elevated antibodies to a streptococcal-produced toxin (antistreptolysin O). Separate analyses indicated that a large group of control variables including sex, family history of respiratory infections, family size, and allergic history were unrelated to infectious outcomes.

Similar results were reported in a study of viral URIs in 235 members of 94 families (Graham et al., 1986). Diary data on respiratory symptoms were collected daily for 6 months. Major stressful life events (LEI) were assessed before and after the study period, and daily events (DHS) and psychological distress (GHQ) were assessed at study onset and twice during the study. Illness episodes were validated by viral cultures of nose and throat swabs, and analyses included controls for a wide range of other factors such as sex, age, family size, and proneness to infection. High stress was defined as above median scores on *all three* stress measures: life events, daily events, and psychological distress. Those reporting higher levels of stress over the course of the study (retrospective analysis) experienced more verified episodes and more symptom days of respiratory illness. Those with higher levels of stress at the beginning of the study (prospective analysis) demonstrated similar but somewhat attenuated effects of stress on number of episodes and days with symptoms. In analyses designed to determine independent effects of the three stress measures, prestudy daily event frequency was positively associated with verified episodes, and prestudy life events were positively associated with the number of symptom days in verified episodes.

Two prospective studies have addressed psychological susceptibility to influenza. In the first (Cluff, Canter, & Imboden, 1966), 480 male employees of a military research installation completed the CMI and the hypochondriasis, morale loss, and ego strength scales of the MMPI 6 months before an epidemic of Asian influenza. On the basis of test scores, they were classified as either psychologically vulnerable or nonvulnerable. During the subsequent epidemic period, all persons presenting an influenzalike illness were followed over a 3-week period to evaluate acute disease. Infection was verified both through antibody increase and virus isolation. Illness reports in the psychologically vulnerable group were about three times higher than in the nonvulnerable group. However, there were no differences in infection rates or illness severity.

In the second flu study (Clover, Abell, Becker, Crawford, & Ramsey, 1989), 246 individuals in 58 families completed instruments assessing family relationships (Family Adaptability and Cohesion Evaluation Scales and Family APGAR) and individual stressful life events (SRRS) prior to the start of flu season. Antibodies to two strains of influenza B were measured before and after flu season. Incidence of illness was defined as a fever greater than 100°F, a criterion number of flu symptoms, *and* "influenza infection" (isolation of flu virus in throat culture or a four-fold increase in antibodies to Influenza B). They found that incidence of disease was greater in stressed ("rigid" and "chaotic") families than in nonstressed ("balanced") families. Incidence also increased as family cohesiveness increased, possibly because increased social contacts among family members result in increased exposure (Cohen, 1988). Illness incidence was not related to life events or family satisfaction.

In sum, evidence from studies verifying infectious episodes suggests that stress increases risk for upper respiratory disease. The retrospective work is fairly consistent in this regard, but the prospective studies are mixed. Two community based studies of families (Graham et al., 1986; Meyer & Haggerty, 1962) found support for reliable increases in verified disease with increased life events, although a third (Clover et al., 1989) did not. Two of these studies (Clover et al.; Meyer & Haggerty) similarly indicated evidence for greater incidence of disease among those with relatively high levels of family distress. Finally, Cluff et al. (1966) found that psychological distress was related to illness reporting, but not to verified illness.

*Viral-challenge studies.* Several studies have exposed healthy volunteers to specific viruses in attempts to determine whether psychological factors (measured prior to the viral challenge) influence susceptibility to URI. Advantages of this paradigm include eliminating the possible role of psychological effects on exposure (see Figure 1), controlling dosage of the infectious agent, and allowing biologic verification through tests for the specific virus used. For these studies to work, the *dose* of virus must be carefully chosen to result in a reasonable distribution of infected and uninfected persons. Although the optimal distribution depends on sample size and whether a dichotomized (infected or not) or trichotomized (not infected, infected without symptoms, infected with symptoms) outcome is used, a minimum of 20% in each group is usually required.

Four of the viral-challenge studies examined the role of stress in susceptibility to infection. In the first study (Totman, Kiff, Reed, & Craig, 1980), 52 healthy volunteers completed a stressful life events interview (modified procedure proposed by Brown, 1974) and the SRE. Subsequently, they were inoculated with two rhinoviruses (RV2 & RV31) and followed daily (in isolation) for 1 week. After controlling for prechallenge antibodies to the two rhinoviruses, total amount of virus shedding (extent of infection) was predicted by only one of five life event scores: Increased shedding (but not a combined measure of signs and URI symptoms) was associated with increases in total level of purposeful activity and social contact. None of the other stressor measures (including the standard SRE) were related to viral shedding or symptom scores. They also found that introverts (as assessed by the Eysenck Personality Questionnaire [EPQ]) had greater infection and symptomatology than extroverts.

In the second study, Broadbent, Broadbent, Phillpotts, and Wallace (1984) report data from 39 people receiving rhinoviruses (RV9 or RV9 + RV14) and 51 receiving influenza viruses (A Munich or A California). In the rhinovirus trials, people higher in introversion as assessed by the EPQ were more likely to demonstrate verified infection through viral isolation. Total clinical symptom score (combining both signs and symptoms) was predicted by obsessionality and by total psychological distress (MHQ). In the influenza trials, the total clinical symptom score was similarly predicted by greater obsessionality. However, infection (viral isolation) was not predicted by any of the psychological measures.

In the third study, Greene, Betts, Ochitill, Iker, and Douglas (1978) examined effects of self-reported life events (College SRE) and moods (POMS) in 33 subjects receiving nasal inoculations of an influenza virus (A Victoria) and the drug isoprinosine. Life events and mood states were assessed on Day 1; symptoms were rated on Day 1 and twice daily for the remainder of the week. On the second day, subjects received nasal inoculation of the virus. Neither life events nor moods were related to antibody production, viral isolation, or symptomatology. Similar results were found in a study with a larger sample. Locke and Heisel (1977) gave 124 volunteers a "swine" (A/NJ/76) flu vaccine and had them complete life events (SRE) and mood (POMS) scales. Again, no relations were found between the psychological measures and production of specific antibodies.

In another viral-challenge study, Totman, Reed, and Craig (1977) attempted to manipulate cognitive dissonance and assess its effects on susceptibility in 52 volunteers. Half the subjects were given a choice (dissonance) of receiving a "trial antiviral drug" and half were not asked (or given the drug). The design called for all those in the choice condition to accept. Unfortunately, over half (56%) declined. Contrary to predictions, all persons offered the drug (whether or not they agreed to take it) had higher clinical symptom scores (combined signs and symptoms) than those not offered the drug. No differences were found for virus isolation. The interpretation of these results was that being presented with the decision of whether or not to take the drug was stressful, resulting in greater symptomatology.

In sum, viral-challenge studies provide mixed evidence for a relation between stress and susceptibility to rhinovirus infections and no evidence for a relation between stress and influenza. In light of support for a relation between stress and URI in prospective epidemiologic field data, the relative failure of viral-challenge studies to find consistent relations between stress and susceptibility to URI is difficult to interpret. It may be that field results are attributable to stress-induced social contacts resulting in increased exposure to infectious agents (see Figure 1), and hence, because viral-challenge studies control for exposure they do not find such results. However, methodological limitations of the challenge studies may also account for their failure in this regard. Individual studies suffer from insufficient sample sizes, concurrent administration of drugs, lack of information on overall rates of infection in response to the dose of virus administered, and controls for important predictors of susceptibility such as preexisting antibodies to the infectious agent, gender, and age (see Jackson et al., 1960).

It is interesting that two viral-challenge studies found relations between introversion and infectious outcomes. Introverts demonstrated a greater extent of both infection and symptomatology in the first study (Totman et al., 1980) and infection (but not symptomatology) in the second (Broadbent et al., 1984).

*Summary.* Overall, there is enough evidence supporting a relation between stress and onset of URI to suggest that further work is worthwhile, but not enough to draw definitive conclusions. There is strong evidence for an association between stress and illness behaviors and a reasonable amount of provocative field data suggesting similar effects for verified infectious disease. At this time, however, it is impossible to tell whether these latter results are attributable to stress-induced increases in exposure to URI pathogens or to stress-induced influences on immunity.

### *Herpesvirus Infections*

A number of studies have addressed the role of psychological factors in human herpesvirus infection and recurrence of lesions. Included are studies of herpes simplex type 1 (HSV-1), herpes simplex type 2 (HSV-2), Epstein-Barr virus (EBV), and Cytomegalovirus (CMV). HSV-1 is most frequently associated with cold sores, HSV-2 with genital lesions, EBV with infectious mononucleosis, and CMV with mononucleosis syndrome and deafness in neonates (Kiecolt-Glaser & Glaser, 1987a). However, herpesviruses can cause a range of illnesses. For example, HSV-1 can also produce generalized infections and encephalitis (Kiecolt-Glaser & Glaser, 1987a). Herpesviruses differ from most other known viruses in that after exposure, they are present all of the time, although often in latent states. Competency of cellular immune response is thought to be a critical factor in limiting primary herpes virus infection and in subsequent latent virus control (Glaser & Gotlieb-Stematsky, 1982).

Many of the studies in this literature address *reactivation* of herpes. Disease recurrence may be frequent, relatively rare, or never occur and is thought to be influenced by fever, exposure to the sun, hormones, and psychological factors such as stress (Laudenslager, 1987; VanderPlate & Aral, 1987). As discussed earlier (see the activation of latent pathogen box in Figure 2), stress influences on latent pathogens could be mediated by direct stimulation of pathogen reproduction (herpesvirus, in this case) or through suppression of immune defenses that hold the pathogen in check. Either of these processes could cause the immune system to produce antibodies to the virus. Research on susceptibility to herpes recurrence is particularly interesting because of the possibility that models of herpes activation may be relevant to understanding relations between stress and another latent virus, human immunodeficiency virus (HIV), the virus responsible for AIDS (Glaser & Kiecolt-Glaser, 1987).

*Antibody increases with stress.* A series of studies have examined reactivation of herpesviruses under stress (as measured by increased antibody response) in latently infected persons. These studies were *not* designed to investigate clinical herpes outcomes, and they do not include measures of herpes symptomatology. Moreover, because analyses examine differences between mean group changes in antibody levels, as opposed to comparing the number of individuals who show clinically significant changes, they are not entirely comparable to studies using antibody increase as an indicator of infection. They do, however, provide a consistent literature demonstrating sensitivity of latent herpesviruses to stressful situations.

Recall that activation of a latent pathogen can be detected by an increase in the production of antibodies in response to the activated virus. Studies of first year medical students indicate elevations of HSV-1, EBV, and CMV antibodies during and just prior to exam periods (Glaser, Kiecolt-Glaser, Speicher, & Holliday, 1985; Glaser et al., 1987). When compared with nonstressed control groups, higher levels of herpesvirus antibodies have also been found among those exposed to other psychological stressors including elevated antibody levels to EBV among recently separated women (Kiecolt-Glaser, Fisher, et al., 1987), EBV and HSV-1 among separated and divorced men (Kiecolt-Glaser et al., 1988), EBV among caregivers of Alzheimers victims (Kiecolt-Glaser, Glaser et al., 1987), and HSV-1 among persons living near the Three Mile Island nuclear plant (McKinnon, Weisse, Reynolds, Bowles, & Baum, 1989) and depressed patients (Cappel, Gregoire, Thiry, & Sprecher, 1978; Halonen, Rimon, Arohonka, & Jantti, 1974; Rimon & Halonen, 1969; Rimon, Halonen, Anttinen, & Evola, 1971). Because herpesvirus activation is a necessary condition for disease recurrence, these data suggest that stress may play an important role in the progression of diseases caused by herpesviruses.

One could argue that increased antibody levels to latent herpesviruses are not a reflection of stress-induced herpes activation but instead merely reflect a nonspecific increase in serum antibody levels in response to stress. However, those studies that also assessed stress-related changes in common (i.e., to which almost everyone has been exposed) nonlatent viruses such as poliovirus and rubella found no association between antibody levels of the nonlatent viruses and stressor exposure (Cappel et al., 1978; Glaser et al., 1985; Halonen et al., 1974; Kiecolt-Glaser et al., 1987; McKinnon et al., 1989). Hence, the data described earlier appear to indicate stress-induced antibody changes in response to latent but not nonlatent viruses.

*HSV-1: oral herpes.* Retrospective studies are mixed in their support for a relation between psychological distress and herpes recurrence. There was no relation found between distress (CMI) and verified ulcers in 343 students and 242 hospital patients (Ship, Brightman, & Laster, 1967). In contrast, positive relations were found between questions about depression and nervous troubles and self-reported recurrence in 1,133 medical and nursing students (Ship, Morris, Durocher, & Burket, 1960). Verified ulceration was also found to increase with distress in a study of only 10 patients (Schmidt, Zyzanski, Ellner, Kumar, & Arno, 1985). Greater retrospective reports of anxiety (POMS), daily hassles (DHS), and stressful life events (modified PERI) were reported for the weeks leading up to the recurrence of lesions than for weeks prior to dormant periods. There were no differences between dormant and active phases for coping, uplifts, Type A behavior pattern, and depression.

Early prospective support for stress-induced lesions was reported by Katcher, Brightman, Luborsky, and Ship (1973). These investigators administered the CMI, the Clyde Mood Scale, and a social assets scale to 38 young women entering nurse's training and then monitored them for 1 year. On entering the study, 37% had detectable HSV-1 antibody and 71% reported a history of cold sores. (It is probable that most if not all subjects in this study had latent HSV-1 infections that were not detected with a relatively insensitive technique [e.g., Glaser & Gotlieb-Stematsky, 1982]). The women were asked to report the onset of cold sores, and a subset of their reports were then verified by oral examination and HSV-1 viral isolation. Those reporting chronically unhappy moods had more verified episodes of herpes during the following year. Those with stronger social assests (social competence) had fewer episodes. Major stressful life events (LCI) were not related to reports of lesions.

An attempt at replication by this same research group was unsuccessful (Luborsky, Mintz, Brightman, & Katcher, 1976). In this case, the sample consisted of 43 young student nurses who were latently infected with (i.e., seropositive for) HSV-1. Subjects filled out the Clyde Mood Scale daily for 3 weeks and were checked daily for herpes sores on lips and herpesvirus in mouth secretions. A daily calendar was kept by each woman containing a notation of cold sores and other illnesses. Mood scores prior (and subsequent) to illness episodes were unrelated to the onset of herpes, upper respiratory infection, or aphthous ulcers. Moreover, neither mean mood scores (collapsing over all days of the study) nor variance in mood scores were related to illness incidence.

A final 3-year study of 149 student nurses by members of the same research group again found evidence for stress-induced virus reactivation (Friedmann, Katcher, & Brightman, 1977). At the onset of the study, antibodies to HSV-1 and history of primary and recurrent herpes infections were assessed. Participants also completed measures of enduring mood trait characteristics (Clyde Mood Scale). Incidence of herpes recurrence was reported on daily calendar forms (previous data had indicated that calendar reports of recurrence were consistent with documented lesions). Although the best predictors of recurrence were greater past incidence and HSV antibody levels, those reporting more unpleasant moods at study onset also had higher rates of recurrence. When rate of recurrence was predicted among only those with at least one episode, those with higher social assets scores had fewer episodes.

Overall, the oral herpes literature is inconsistent but suggestive. Disease episodes were preceded by measures of unpleasant moods in two prospective studies (Friedmann et al., 1977; Katcher et al., 1973). Both studies also found fewer episodes of disease among those with greater social competence.

*HSV-2: genital herpes.* In a retrospective study, Manne and Sandler (1984) found that persons reporting more symptoms of genital herpes also reported more stressful (negative) thoughts about having herpes, more depression (BDI), and lower self-esteem (Rosenberg Scale). Higher symptom reporting was also related to lower levels of social support, more characterological self-blame, more blaming the person who gave them herpes, and more wishful thinking as a coping strategy (Ways of Coping Scale).

Similarly, VanderPlate, Aral, and Magder (1988) studied 59 patients who reported that they had culture verified genital herpes. In this study life events (SRE) were found to be associated with increased self-reports of recurrence for those with low levels of herpes related social support and for those who had had the disease for less than 4 years. Recurrence for those with high levels of herpes related support and for those with the disease for more than 4 years was not associated with life events. A global measure of perceived stress designed by the authors was also associated with increased recurrence.

A study of 36 patients with chronic recurrent genital herpes was reported by Kemeny, Cohen, Zegans, and Conant (1989). They found that depressive symptoms (POMS subscale) were related to herpes recurrence only for persons without multiple recurrent infections, with greater symptoms associated with greater recurrence. Stress (linear combination of five stressor and distress scales) and the hostility and anger subscales of the POMS did not predict recurrence. Although longitudinal data were collected monthly for 6 months, data analysis was based on average of monthly outcome values across the study and hence is retrospective.

Two prospective studies provide evidence for stress-induced genital herpes recurrence, although both studies are methodologically flawed. Goldmeier and Johnson (1982) followed 58 patients for 28 weeks after diagnosis (virus isolation) of the first occurrence of genital herpes. Patients with higher psychological distress (GHQ) at the onset of the study had higher verified rates of recurrence. Unfortunately 13 of the 29 persons without recurrences were lost to attrition, leaving the possibility that distressed persons without recurrence may have dropped out of the study.

McLarnon and Kaloupek (1988) studied 16 genital herpes patient volunteers prior to beginning 5 weeks of psychologic therapy (T1), 1 week after therapy (T2), and again 12 weeks after therapy (T3). Anxiety (but not dysphoria) rates as assessed by the Hopkins Symptom Checklist were higher during the 4 days prior to a self-reported recurrence than during the 4 days after healing. Higher recurrence rates (daily reports during therapy) were associated with higher loneliness (UCLA Loneliness Scale), less endorsement of denial and behavioral action as coping strategies (Ways of Coping Scale), and more positive attitudes about herpes at T1. There were, however, a large number of analyses in this study with no correction for Type I error.

In sum, genital herpes studies generally support a relation between stress and recurrence. However, the evidence is not entirely consistent, and methodological limitations of the two existing prospective studies lead to cautious interpretation of these results. There is some indication that the influence of stress may vary between samples whose subjects have many or few recurrences (Kemeny et al., 1989).

*EBV: mononucleosis.* As discussed earlier, most of the work with HSV-1 and HSV-2 has focused on recurrence in latently infected persons. In contrast, EBV studies have focused on the relation between psychological factors and having (retrospective) or developing (prospective) mononucleosis.

Two retrospective studies compared students diagnosed with mononucleosis with control groups diagnosed with other illnesses. Roark (1971) found few differences in emotional distress, personality (California Personality Inventory), and anxiety (Spielberger State Anxiety) between groups, whereas Wilder, Hubble, and Kennedy (1971) found that the mononucleosis group reported *fewer* life changes (college student SRE) than did both healthy and ill control groups. In a study of time to recover from mononucleosis, Greenfield, Roessler, and Crosley (1959) found that students with *longer* recovery periods reported higher levels of general psychological health (MMPI) when tested 6 months later than those with shorter recovery periods.

In the only prospective study of mononucleosis, a class of 1,400 West Point cadets was followed for 4 years (Kasl, Evans, & Niederman, 1979). Presence or absence of EBV antibody was used to identify those susceptible or immune to mononucleosis. New infections were identified by appearance of the antibody (seroconversion) in previously uninfected cadets. Cadets viewed as under stress because of a combination of high motivation and poor academic performance were more likely to seroconvert, to develop clinical mononucleosis if they seroconverted, and to spend more time in the hospital if they developed clinical infection.

*Summary.* Overall, evidence that reactivation of latent herpesviruses can be triggered by emotional distress is suggestive but not conclusive. Although the retrospective evidence is quite mixed, prospective support for stress-triggered reactivation comes from studies of oral (Friedmann et al., 1977; Katcher et al., 1973) and genital herpes (Goldmeier & Johnson, 1982; McLarnon & Kaloupek, 1988). Moreover, studies of changes in herpes antibody levels indicate HSV-1, EBV, and CMV antibody increases under stress. A single prospective study (Kasl et al., 1979) also indicates the possibility of stress-triggered primary infection. Evidence from four studies (Friedmann et al., 1977; Katcher et al., 1973; Manne & Sandler, 1984; McClarnon & Kaloupek, 1988) also suggests that social skills or social support is associated with fewer episodes of disease. Moreover, VanderPlate et al. (1988) found that persons with support for herpes did not demonstrate the increase in recurrence under stress found for those without support. Some of these studies suffer from methodological problems, and further prospective work with larger, more representative samples would be a welcome addition.

### *Bacterial Infections*

Common respiratory bacterial infections were addressed in the section on URI (e.g., Meyer & Haggerty, 1962). Although there are hundreds of other infectious diseases caused by pathogenic bacteria, research on psychological influences on these diseases is relatively sparse and scattered. Retrospective studies have found relations between stressful life events and a variety of diseases caused by bacterial infections. Frequency of stressful life events has been associated with tuberculosis (Hawkins, Davies, & Holmes, 1957; Rahe, Meyer, Smith, Kjaer, & Holmes, 1964) and verified cases of trenchmouth (Cohen-Cole et al., 1981). Similarly, persons reporting a recent stressful life event had more frequent cavities (Sutton, 1962), and those reporting longer lasting events had more severe cavities (Sutton, 1965). Greater psychological distress has been reported by persons still experiencing "general symptomatology" 4 to 8 years after a diagnosis of acute brucellosis (undulent or Mediterranian fever) (Imboden, Canter, Cluff, & Trever, 1959) and by verified trenchmouth patients both during and after infection (Cohen-Cole et al., 1981).

A range of personality variables have been retrospectively correlated with severity of periodontal disease. Manhold (1953) found that those with more severe periodontal pathology were higher in neurotic tendency and introversion, and Formicola, Witte, and Curran (1970) found that dominance was positively correlated and succorance negatively correlated with disease severity. However, both studies used a large number of statistical tests and many other traits were unrelated to infection (Type I error).

In a single prospective (bacterial-challenge) study, 37 healthy male volunteers were exposed to typhoidal type tularemia (Canter, 1972). Tularemia is a plaguelike disease characterized by inflammation of lymph nodes, headaches, chills, fever, and vomiting. Subjects were defined as "psychologically vulnerable" if they scored above the median on at least three of four psychological distress scales (MMPI hypochondriasis, morale loss, and ego strength and the CMI) administered 2 days prior to exposure. Those scoring below the median on at least three scales were defined as "psychologically nonvulnerable". Prospective analysis indicated that severity of illness (defined as number of hours with fever over 100°F plus highest self-reported symptom scores) was higher for vulnerable than nonvulnerable and other subjects. They also report that 34 of the 37 subjects showed significant declines in positive mood (MACL) and increases in negative mood (MACL) at least 6 hours before onset of fever.

*Summary.* There are few studies of the role of stress (or other psychological factors) and bacterial infection, and existing data are spread across diseases. Although the retrospective studies vary in focus and quality, they are generally consistent with a relation between susceptibility to bacterial infection and stress. It is also promising that the two prospective studies on bacterial infections—the Meyer and Haggerty (1962) study discussed in the URI section and the Canter (1972) bacterial-challenge study on tularemia—both find evidence for relations between stress and disease incidence.

### *Testing Pathways*

Earlier, we proposed that stress (and other psychological factors) could be linked to infectious disease through behavioral, hormonal, and immune pathways, as well as through direct CNS-immune innervation. Only a handful of studies assess a proposed pathway *in addition to* stress and infectious disease measures. (As discussed earlier, some of the individual paths, for example, the relation between stress and immunity, have been studied separately but have not been shown to mediate stress influences on disease.) Only one study (Kemeny et al., 1989) provides direct tests (e.g., path analysis or structural equation models) of whether covarying effects actually mediated reported relations. Hence, at best, these few studies can be considered consistent with the possibility that examined pathways are involved in linking stress to disease.

#### *Endocrine Pathways*

Two retrospective studies examined endocrine pathways. Both assessed hormones known to be released under stressful conditions. These hormones have also been implicated in immune modulation. Recall that McClelland, Floor, Davidson, and Saron (1980) found that persons high in stress, need for power, *and* action inhibition reported more illnesses and more severe URIs. This group also showed marginally less epinephrine (but not norepinephrine). Cohen-Cole et al. (1981), who found relations between trenchmouth and more life events and psychological distress, also found that levels of overnight urine cortisol were higher for those with more life events and for those diagnosed with trenchmouth. Serum cortisol, prolactin, growth hormone, and urine catecholamines were not correlated with either psychological distress or trenchmouth.

#### *Health Behavior Pathways*

Three studies measured health practices. Recall that Graham et al. (1986) found that stress predicted URI. The high-stress group also contained more smokers than the low-stress group; however, there were no direct tests of the relation between smoking and URI in this study. Kemeny et al. (1989) found a relation between depression and genital herpes recurrence, but failed to find any relations between recurrence and number of hours sleep and average hours of exercise. Although alcohol consumption was positively correlated with recurrence rate, a regression analysis indicated that it did not mediate the effect of depression on recurrence. Finally, Glaser et al. (1987) found less sleep and less exercise preceded exam periods. However, the differences were small, and there were no direct tests of the relations between these behavioral changes and reports of illness.

#### *Immune Pathways*

Several investigators have examined possible immune pathways. McClelland et al. (1980) found that persons high in stress, need for power, and action inhibition reported more illnesses and also had lower concentrations of total (to all antigens) salivary immunoglobulin A (IgA). IgA is a secretory antibody that, when specific to the infectious agent one is exposed to (as opposed to total IgA as assessed in this study), would theoretically help protect against infection (see Jemmott & McClelland, 1989; Stone, Cox, Valdimarsdottir, & Neale, 1987). In McClelland et al. (1980) those excreting more epinephrine also had lower concentrations of IgA. Correlations between IgA and illness frequency and illness severity were not, however, significant. In another study, McClelland et al. (1982) found that people with both high need power and high stress reported more severe illnesses, had lower concentrations of total secretory IgA, and that those with more severe URIs also had lower IgA concentrations.

Recall that Glaser et al. (1987) found more reports of infectious illnesses during medical student exams than during baseline periods. Exam periods were also characterized by poorer cellular immune control of a latent herpesvirus and a decline in the ability of white blood cells to kill EBV infected cells indicating a general suppression of cellular immune function. Exam stress was also associated with an increase in intercellular levels of cyclic adenosine monophosphate, a chemical released within cells in response to hormones and associated with suppression of immune function in lymphocytes (white blood cells central to immune response). Associations between immune measures and illness were not reported.

Kemeny et al. (1989) found a relation between depressive symptoms and genital herpes. Depression was also related to decreases in the CD8 population of T-lymphocytes and decreases in the CD8 population tended to precede herpes recurrence. The CD8 population consists of T-cytotoxic cells that can kill virally infected cells and T-suppressor cells involved in down-regulation (suppression) of immune response. However, further analyses indicated that changes in the CD8 population did not mediate the relation between depression and herpes recurrence. Finally, Cohen-Cole et al. (1981) found that those with trenchmouth demonstrated deficits in function of several types of white blood cells including lymphocytes, polymorphonuclear cells, and phagocytes. Relations between stress and immune measures were not reported.

#### *Summary*

It would be premature to suggest that any of this evidence is more than suggestive of the role of behavioral, endocrine, and immune mechanisms in linking stress to infectious disease. However, we applaud these investigators' interest in specifying and measuring pathways linking stress to infectious disease and hope that future research will examine alternative pathways in more detail and with greater sophistication in analysis.

## Discussion

The literature reviewed in this article suggests that stress may play a role in the onset of infectious diseases and reactivation of latent viruses. First, there is consistent evidence that persons under stress report greater levels of URI symptoms and that stress results in greater health care utilization for URI. As discussed earlier, the illness behaviors used as criteria in these studies may tap underlying pathology but in some cases may be driven by purely psychological mechanisms (see Figure 3). The latter interpretation is reinforced by studies in which effects of stress on symptoms but not verified disease were observed (Broadbent et al., 1984; Cluff et al., 1966; Imboden et al., 1959) and by evidence that stress is associated with increased illness behavior in general, not only behaviors directly associated with infectious pathology (e.g., Linville, 1987; McClelland et al., 1980; Spilken & Jacobs, 1971; also see review by Andrew & Tennant, 1978). Even if stress links to illness behavior do not have pathogenic origins they are theoretically and practically important. From a theoretical perspective there are implications for understanding how people perceive and understand their physical states as well as indicating a specific role of stress in life satisfaction. From a practical perspective, there are implications for health-care policy such as the advantages of employing triage procedures to separate those with underlying pathogenesis from those without so that medical personnel can be used most efficiently.

Second, there is evidence suggesting that stress increases risk for verified upper respiratory infections. The most impressive data are from two prospective community-based studies (Meyer & Haggerty, 1962; Graham et al., 1986). On the other hand, prospective URI viral challenge studies do not generally support a relation between stress and URI. The cause of this relative failure may be that by controlling for *exposure* to the pathogen (an important operative pathway in the stress–infection link to URI) was eliminated. However, the methodological limitations of these studies (outlined earlier) may also account for their failure in this regard.

Third, there are only scattered studies of the role of stress in bacterial infections. Retrospective studies of tuberculosis, brucellosis, periodontal disease, and acute caries all suggest associations between stress and disease. Moreover, the only bacterial (tularemia) challenge study (Canter, 1972) and the only prospective study focusing on bacterial (streptoccocal) infections (Meyer & Haggerty, 1962) both indicate increased risk for disease among high-stress persons.

Finally, there is growing evidence that stress may trigger *reactivation* of herpesviruses, hence recurrence of disease among those with previous exposure to herpes. Support for stress-triggered reactivation comes from a series of studies indicating increased antibodies to three herpesviruses under stress (e.g., Glaser et al., 1985; Glaser et al., 1987) and from prospective studies of oral (Friedmann et al., 1977; Katcher et al., 1973) and genital herpes (Goldmeier & Johnson, 1982; McLarnon & Kaloupek, 1988). A single prospective study (Kasl et al., 1979) also indicates the possibility of stress-triggered primary infection. The methodological sophistication of these studies is inconsistent, and further prospective work with larger, more representative samples is needed.

### *Are These Studies Measuring Stress?*

Studies in this literature are primarily based on self-reported events and psychologic distress. Consistent with our conceptualization of events and distress as reflecting different stages of a single process, these measures seem to be roughly equal in their reliability as predictors of infectious outcomes. Prospective studies of daily or weekly events (Meyer & Haggerty, 1962), family stress (Clover et al., 1989; Meyer & Haggerty, 1962), and psychological distress (Canter, 1972; Friedmann et al., 1977; Goldmeier & Johnson, 1982; Graham et al., 1986; Katcher et al., 1973; McLarnon & Kaloupek, 1988) have all predicted verified disease outcomes. This may be because stressful events (as assessed in these studies) generally result in distress, or because self-reports of events are inherently confounded with existing distress (Costa & McCrae, 1980).

These results must, however, be viewed in the context of the limitations of self-reported cumulative measures of stressors and distress. First, it is difficult to know whether these measures assess state or trait distress. It is possible that in many of the studies, life events and psychological distress measures reflect *stable personality styles* (negative affective or neurotic) more than impact of environmental stressors (e.g., Costa & McCrae, 1980, 1985; Watson & Pennebaker, 1989). Studies using between-subject designs—retrospective studies and prospective studies assessing stress only at study onset—are most susceptible to such an interpretation. Within-subject designs—comparing the same person under stress and nonstress conditions—are not susceptible. Because our models of the relation between stress and infectious disease are driven by negative affective state rather than the stressor itself, they also apply to a personality interpretation. However, there are enough within-subject studies in the literature to suggest that neurotic personalities are not the only things operating here (e.g., in nonverified disease studies by Glaser et al., 1987; Stone et al., 1987; in verified studies by McLarnon & Kaloupek, 1988; Meyer & Haggerty, 1962; and in all of the herpes antibody studies, e.g., Kiecolt-Glaser, Fisher, et al., 1987; Kiecolt-Glaser, Glaser, et al., 1987).

Second, the existing literature does not provide the strongest possible test of the hypothesis that stress influences pathogenesis of infectious disease. Cumulative stress scales used widely in this literature, for the most part, tap levels of stress within the normal range of variations that people experience in day-to-day life. Impact of severe events would provide the fairest test of a stress–disease relation. Restriction of stress variance is a particular problem in student samples that represent a cohort experiencing few traumatic events (Schulz & Rau, 1985). Given this, it is impressive that cumulative event and distress scales are related to disease outcomes. Further work using more sophisticated techniques for measuring life events in the context of their meaning for the individual (see techniques developed by Brown & Harris, 1989) and examining effects of single stressful events (e.g., Alexander & Summerskill, 1956; Glaser et al., 1987), especially more serious and even traumatic events (e.g., divorce, bereavement, and job loss) would significantly strengthen this literature (see Kasl, 1984).

### *Other Psychological Variables and Infectious Disease*

Although a number of factors were associated with disease in one study or another, two variables—introversion–extroversion and social support—were related to infection across a number of studies. Introverts were more susceptible to infection or more severe illness (Broadbent et al., 1984; Manhold, 1953; Totman et al., 1980). Persons with social skills or social support had fewer episodes of disease (Friedmann et al., 1977; Katcher et al., 1973; Manne & Sandler, 1984; McClarnon & Kaloupek, 1988), and those with social support did not demonstrate the positive relation between life events and a chronic URI episode (Sarason et al., 1985) and life events and herpes recurrence (VanderPlate et al., 1988) found among those without support. A single study (Clover et al., 1989) found *more* disease episodes in cohesive families; a finding we interpreted as attributable to increased social contacts resulting in increased exposure to infectious agents. It is possible that introversion–extroversion and social support reflect a single underlying construct—an outgoing (extroverted) personality that results in less susceptibility to infection, either because such persons are good at drawing resources from their social networks (Cohen, 1988) or because of some other biological or social correlate of introversion–extroversion.

### *Stress–Immune-Disease Specificity*

Stress influence on immunity is considered by many to be the primary pathway through which stress influences infectious disease susceptibility. Specific stress-induced changes in immune function that lend persons susceptible to infection have not been delineated. However, it is commonly believed that different stressors have the same influence on immune function (Mason, 1975, assumes nonspecificity is mediated by psychological distress; Selye, 1956, does not) and that stress induced changes in the immune system result in susceptibility, to most if not all infectious agents (e.g., Cassell, 1975). One test of these nonspecificity assumptions is equivalent influences of stress across diseases. The current literature is very roughly supportive of equivalency—distress and stressful life events influencing susceptibility to different pathogens—but there are too few studies and too few infectious diseases examined to provide an answer to the specificity question at this time. Moreover, there are data in the animal literature indicating that nonspecificity assumptions may be incorrect. Work with rodents suggest that immune responses may differ across stressors and that the same stressors influence susceptibility to some but not other pathogens (Friedman et al., 1965; Friedman, Glasgow, & Ader, 1969; Rasmussen, Marsh, & Brill, 1957). A single study comparing different specified pathogens in humans (Broadbent et al., 1984) reported some similarities and some differences in the effects of psychological measures on rhinoviruses and influenza viruses. Future work comparing the influence of various pathogens in humans, in the same stress paradigm, and examining the effects of different stressful events on the same disease would provide welcome evidence in relation to this important question.

## *Where Do We Go From Here?*

The work reviewed in this article suggests that stress may influence both infectious illness behaviors and infectious pathology. However, it tells us little about how stress influences pathology, the nature of stressors that put persons at risk for disease, timing of the stressor relative to exposure and disease onset, and psychological and biological characteristics that may moderate these effects.

### *Behavioral and Biological Pathways*

Existing work reveals little about the pathways outlined in Figures 1 and 2. Further epidemiologic-style studies assessing pathways *and* using appropriate statistical tests for mediation could make a major contribution to this area. Moreover, experimental studies in which individual pathways are eliminated, for example, exposing all volunteers to an infectious agent or blocking hormonal or immune pathways through the use of drugs (e.g., Bandura, Cioffi, Taylor, & Brouillard, 1988), could also help identify operative mechanisms.

### *Temporal Courses of Stressor, Mediators, and Disease Pathology*

If there is a major barrier preventing a general understanding of relations between stress and infectious disease, it has to do with time. We know little about time courses of many processes central to stress–disease models. Relative to exposure to an infectious agent, when (e.g., before, during, or after) is stress most likely to influence susceptibility? How long an exposure to stress is required to alter biologic or behavioral pathways to disease? How long must these pathways be altered to influence subsequent pathways, for example, hormone levels altering immunity? How long must the most proximal pathways be altered to influence disease susceptibility? How long after a stressor is terminated do these changes last?

Evidence from experimental studies in which mice are randomly assigned to stress or control conditions and exposed to an infectious agent indicate that timing issues are complex (Friedman et al., 1965; Plaut & Friedman, 1981; Rogers, Dubey, & Reich, 1979). For example, stress *prior* to exposure may either increase resistance (e.g., Friedman et al., 1969; Jensen & Rasmussen, 1963a; 1963b) or susceptibility to infection (e.g., Friedman et al., 1969; Plaut, Ader, Friedman, & Ritterson, 1969). However, stress experienced *after* exposure to a pathogen generally increases susceptibility (e.g., Chang & Rasmussen, 1965; Davis & Read, 1958; Friedman et al., 1969; but see Friedman, Ader, & Grota, 1973; Rasmussen, Hildemann, & Sellers, 1963 for exceptions). As we discuss later, the issue of timing makes manipulating stress in studies of humans difficult at this time. It also suggests that correlational studies should be carefully planned to assess different temporal relations between stress and infectious outcomes (e.g., Stone, Reed, & Neale, 1987) or to focus on chronic or cumulative stressors resulting in relatively long-lasting psychological distress and maximizing length of exposure (Cohen & Matthews, 1987).

### *Chronicity of Stressors and Disease Risk*

The effects of stressors presumably depend on their chronicity: acute, chronic, or repetitive. Because scales used in this literature often combine these different categories and focus on cumulative effects, little information on how single stressors influence disease is available. Effects of an acute stressor presumably would depend on its concordance with the pathogenic process (Cohen & Matthews, 1987; Cohen & Syme, 1985). For example, if stressors operate by increasing exposure to pathogens, an acute stressor occurring after exposure would not influence pathogenesis. It may be that questions of timing are not of major importance in the existing human literature because most studies assess chronic distress. Because persons are under stress for a prolonged period, the minimum exposure necessary to affect a pathway is exceeded. Studies more carefully characterizing stressor chronicity and timing could help clarify conditions under which stress influences disease susceptibility.

### *Prospective Infectious-Challenge Studies*

Although the challenge studies reviewed in this article have not been particularly successful, we still feel this paradigm provides the best current strategy for pursuing the role of stress in infectious disease susceptibility. As noted earlier, it allows for control of previous exposure (through antibody measurement), control of current exposure (through experimental challenge), and careful assessment of both infection and symptomatology. Future work can capitalize on past mistakes by examining each pathogen separately, controlling for extraneous factors that may influence disease susceptibility (e.g., age, gender, season, history of infection), using large numbers of subjects, and carefully selecting psychosocial instrumentation to reflect plausible effects.

### *Manipulating Stress*

A powerful test of the hypothesis that stress influences infectious pathology is to randomly assign persons to stress or nonstress conditions and assess subsequent susceptibility to infection. Such a technique, in the context of an infectious-challenge trial where exposure to the agent (and amount of infectious agent) is controlled, would provide a strong test of the role of stress in susceptibility. This design is not, however, without problems. Some guessing and piloting would be required to determine type of stressor to use, duration and intensity of exposure, and timing of exposure in relation to infectious challenge. Moreover, both ethical and practical limitations on type and intensity of experimental stressors may limit the probability of finding an effect.

One approach to addressing the problems involved in conducting experimental research in humans is to move to a nonhuman primate model. Unlike rodents, these animals can be exposed to chronic social stressors that are analogous to those encountered by humans (e.g., Coe, Rosenberg, & Levine, 1988; Laudenslager, 1988; Manuck, Muldoon, Kaplan, Adams, & Polefrone, 1989). Moreover, their behavioral responses to social stressors (e.g., affiliation and aggression) also are similar to human response patterns. Studies in which monkeys are randomly assigned to social stressor or nonstressor groups, are assessed for hormonal and immunologic change, and then exposed to an infectious pathogen (e.g., a cold virus) could provide important evidence to substantiate the human correlational research.

### *Moderators of Stressor–Disease Relations*

Effects of stressors on disease may be moderated by social (Cohen & Wills, 1985), personal (Cohen & Edwards, 1989), and biological (Schleifer et al., 1986) factors. Social and personal characteristics are thought to influence whether stressful events result in psychological distress, although they may influence manifestations of distress such as behavioral and neuroendocrine response (Cohen & Wills, 1985). Biologic characteristics may influence susceptibility of immune and other disease-relevant biologic systems to CNS, hormonal, and behavioral changes triggered by stress. It is of particular interest that stress may have its greatest effect among those whose immune systems are already compromised (e.g., the elderly), individuals whose health is already impaired, and patients with immunosuppressive diseases (e.g., AIDS; Kiecolt-Glaser & Glaser, 1987b).

### *Summary*

The relation between stress and infectious disease is extraordinarily complex. Assumptions about parametrics of the relation are premature and potentially damaging to our long-term understanding of the role of stress in human disease susceptibility. A slow and cautious approach in which each relation between a stressor, a specific pathway, immunity, and disease is systematically examined would be most likely to yield valid answers. This strategy could be complemented by experimental work with nonhuman primates.

## Conclusion

The literature reviewed in this article is provocative. It suggests that stress is associated with increases in illness behaviors and may be similarly associated with increased onset and reactivation of verified infectious disease. Weaknesses in the existing work include designs limiting causal inference, unrepresentative samples, and lack of adequate examination of potential pathways linking stress to disease. This work indicates that studying this issue is a complex endeavor and that interdisciplinary collaboration is required to design adequate tests of the hypothesis that persons under stress are at higher risk for infection. Further pursuit of this question is justified—especially work using designs that allow us to address numerous remaining ambiguities and unanswered questions.

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Received September 18, 1989
Revision received May 9, 1990
Accepted June 15, 1990 ■

# PSYCHOLOGICAL STRESS AND SUSCEPTIBILITY TO THE COMMON COLD

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**Abstract** *Background.* It is not known whether psychological stress suppresses host resistance to infection. To investigate this issue, we prospectively studied the relation between psychological stress and the frequency of documented clinical colds among subjects intentionally exposed to respiratory viruses.

*Methods.* After completing questionnaires assessing degrees of psychological stress, 394 healthy subjects were given nasal drops containing one of five respiratory viruses (rhinovirus type 2, 9, or 14, respiratory syncytial virus, or coronavirus type 229E), and an additional 26 were given saline nasal drops. The subjects were then quarantined and monitored for the development of evidence of infection and symptoms. Clinical colds were defined as clinical symptoms in the presence of an infection verified by the isolation of virus or by an increase in the virus-specific antibody titer.

*Results.* The rates of both respiratory infection ($P<0.005$) and clinical colds ($P<0.02$) increased in a dose–response manner with increases in the degree of psychological stress. Infection rates ranged from approximately 74 percent to approximately 90 percent, according to levels of psychological stress, and the incidence of clinical colds ranged from approximately 27 percent to 47 percent. These effects were not altered when we controlled for age, sex, education, allergic status, weight, the season, the number of subjects housed together, the infectious status of subjects sharing the same housing, and virus-specific antibody status at base line (before challenge). Moreover, the associations observed were similar for all five challenge viruses. Several potential stress–illness mediators, including smoking, alcohol consumption, exercise, diet, quality of sleep, white-cell counts, and total immunoglobulin levels, did not explain the association between stress and illness. Similarly, controls for personality variables (self-esteem, personal control, and introversion–extraversion) failed to alter our findings.

*Conclusions.* Psychological stress was associated in a dose–response manner with an increased risk of acute infectious respiratory illness, and this risk was attributable to increased rates of infection rather than to an increased frequency of symptoms after infection. (N Engl J Med 1991; 325:606-12.)

Stressful life events are commonly believed to suppress host resistance to infection. When demands imposed by events exceed a person's ability to cope, a psychological stress response composed of negative cognitive and emotional states is elicited.[1] Psychological stress, in turn, is thought to influence immune function through autonomic nerves innervating lymphoid tissue[2,3] or hormone-mediated alteration of immune cells.[4,5] Stress may also alter immune responses through the adoption of coping behaviors such as increased smoking and alcohol consumption.[6]

There is substantial evidence that stressful life events and perceived stress are associated with changes in immune function.[7-9] Although psychological stress is often described as suppressing immune response, the implications of stress-induced immune changes for susceptibility to disease have not been elucidated.[10,11]

There is some direct evidence from previous studies that psychological stress increases the risk of verified acute infectious respiratory illness.[12-14] These studies, however, did not control for the possible effects of stressful events on exposure to infectious agents (as opposed to their effects on resistance) or provide evidence about other behavioral and biologic mechanisms through which stress might influence a person's susceptibility to infection. Moreover, the literature on this topic is not entirely consistent; several studies have failed to find a relation between stress and respiratory disease.[15,16]

We present data from a prospective study of the association between psychological stress and susceptibility to the common cold. Healthy persons were assessed for degree of stress and then experimentally exposed to one of five cold viruses (394 subjects) or placebo (26 subjects). The association between stress and the development of biologically verified clinical disease was examined with use of control for base-line (prechallenge) serologic status, the identity of the challenge virus, allergic status, weight, the season, the number of subjects housed together, the infectious status of any subjects sharing housing, and various demographic factors. In further analyses we tested the possibility that a relation between stress and susceptibility to illness could be attributed to differences in health practices or differences in base-line white-cell counts or total antibody levels. A final analysis investigated the possibility that differences in personality rather than environmental factors causing stress might account for the association between stress and clinical colds.

## Methods

The subjects were 154 men and 266 women who were residents of Britain and who volunteered to participate in trials at the Medical Research Council's Common Cold Unit (CCU) in Salisbury. All reported on their applications that they had no chronic or acute illness and were taking no regular medication; all were judged to be in good health after clinical and laboratory examination on their arrival at the unit. Pregnant women were excluded. The subjects' ages ranged from 18 to 54 years (mean [±SD], 33.6±10.6). Sixty-three percent of the subjects were women. Twenty-two percent had not completed their secondary education, 51 percent had completed secondary school but did not attend a university, and 27 percent

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Supported by grants from the National Institute of Allergy and Infectious Diseases (AI23072) and the Office of Naval Research (N00014-88-K0063), by a Research Scientist Development Award to Dr. Cohen from the National Institute of Mental Health (MH00721), and by the Medical Research Council's Common Cold Unit, Salisbury, United Kingdom.

had spent at least one year at a university. The subjects were reimbursed for their travel expenses and received free meals and accommodations during the study. The trial was approved by the Harrow District Ethical Committee, and informed consent was obtained from each subject after the nature and possible consequences of the study were fully explained.

### Procedures

During their first two days at the CCU, the subjects underwent a thorough medical examination, completed a series of questionnaires related to behavior, psychological stress, personality, and health practices and had blood drawn for immune assessments and measurement of cotinine (a biochemical indicator of smoking) in serum. Subsequently, the subjects were given nasal drops containing a low infectious dose of one of five respiratory viruses — rhinovirus type 2 (n = 86), type 9 (n = 122), or type 14 (n = 92), respiratory syncytial virus (n = 40), or coronavirus type 229E (n = 54) — or saline drops (n = 26). The viral doses were intended to resemble those common in person-to-person transmission and to result in illness rates between 20 and 60 percent. For two days before and seven days after the viral challenge, the subjects were quarantined in large apartments (alone or with one or two others). Starting two days before the viral challenge and continuing through six days after the challenge, each subject was examined daily by a clinician who used a standard checklist of respiratory signs and symptoms.[17] Examples of items on the checklist are sneezing, watering of the eyes, nasal stuffiness, nasal obstruction, postnasal discharge, sinus pain, sore throat, hoarseness, cough, and sputum. The number of facial tissues used daily by each subject was also counted. Approximately 28 days after the challenge, a second serum sample was collected by the subjects' own physicians and shipped to the CCU for serologic testing. All the investigators were blinded to the subjects' psychological status and to whether they had received virus or saline drops.

### Psychological-Stress Index

Three measures of psychological stress were used: the number of major stressful life events judged by the subject as having had a negative impact on his or her psychological state in the past year, the degree to which the subject perceived that current demands exceeded his or her ability to cope, and an index of current negative affect. The list of major stressful life events contained events that might have occurred in the life of the subject (41 items) or those of others close to the subject (26 items). The events were taken from the List of Recent Experiences compiled by Henderson et al.[18] and were chosen because of their potential negative impact and their relatively high frequency in population studies. The score on this life-events scale was the number of events during the previous 12 months that the subject reported as having had a negative impact on his or her life. The 10-item Perceived Stress Scale[19] was used to assess the degree to which situations in life were perceived as stressful (reliability, $\alpha = 0.85$).[20] Items on the Perceived Stress Scale were designed to measure the degree to which the subjects felt their lives were unpredictable, uncontrollable, and overwhelming. Finally, the negative-affect scale included 15 items from Zevon and Tellegen's list of negative emotions[21]: "distressed," "nervous," "sad," "angry," "dissatisfied with self," "calm" (scored negatively), "guilty," "scared," "angry at yourself," "upset," "irritated," "depressed," "hostile," "shaky," and "content" (scored negatively). Each subject was asked to indicate the intensity of each feeling during the past week on a five-point scale ranging from 0 to 4 (reliability, $\alpha = 0.84$).

All three stress scales formed a single principal component with loadings of 0.66, 0.86, and 0.86, providing evidence that the scales measured a common underlying concept.[22] An index combining the three measures was therefore used as an indicator of the degree of psychological stress experienced by the subjects (stress index). Because life events were not distributed normally, an index based on normalized scores was not appropriate. Instead, the index was created by calculating the quartiles for each scale and summing the quartile ranks for each subject (assigning a value of 1 for the lowest quartile and 4 for the highest); the resulting stress index ranged from 3 to 12. The quartiles divided the subjects into groups with the values 0, 1 through 2, 3 through 4, and 5 through 14 for the life-events scale; 0 through 10, 11 through 14, 15 through 18, and 19 through 33 for the Perceived Stress Scale; and 0 through 7, 8 through 13, 14 through 20, and 21 through 49 for the negative-affect scale. The index scores were approximately normally distributed. In all cases, a higher score indicated a greater degree of stress.

### Viral Isolates and Virus-Specific Antibody Levels

Nasal-wash samples were collected for viral isolation before inoculation and on days 2 through 6 after inoculation. They were mixed with broth and stored in aliquots at −70°C. Rhinoviruses were detected in O-HeLa cells, respiratory syncytial virus in HEp-2 cells, and coronavirus in the C-16 strain of continuous human fibroblast cells. When a characteristic cytopathic effect was observed in the tissue culture, fluids were transferred to further cultures and tests were performed to identify the virus. The identity of rhinoviruses and coronaviruses was confirmed by neutralization tests with specific rabbit immune serum, and that of respiratory syncytial virus by immunofluorescent staining of culture cells.

Levels of neutralizing antibodies and of specific antiviral IgA and IgG were determined before and 28 days after the challenge. Neutralizing antibodies (for rhinoviruses only) were determined by neutralizing tests with homologous virus.[23] The results were recorded as the highest dilution showing neutralization, and a fourfold increase was regarded as significant. Suitable neutralizing tests were not available for respiratory syncytial virus and coronavirus.

Specific IgA and IgG levels for rhinoviruses,[24] coronavirus,[25] and respiratory syncytial virus[25] were determined by enzyme-linked immunosorbent assay. This test detects antibody that correlates with neutralization titers, is associated with resistance to infection, and increases in response to infection.[23]

### Infections and Clinical Colds

A subject was deemed infected if virus was isolated after the challenge or if there was a significant increase over base-line levels in the virus-specific serum antibody titer (i.e., a fourfold increase in neutralizing antibody [rhinoviruses]) or an increase in the IgG or IgA level of more than 2 SD above the mean for the unchallenged subjects (all viruses). Eighty-two percent of the subjects who received virus (325 subjects) were infected. Five subjects who received saline (19 percent) were also infected. We attributed infections in the saline (placebo) group to transmission of virus from infected subjects to others housed in the same apartments. Control for person-to-person transmission was included in the data analysis.

At the end of the trial, a physician judged the severity of each subject's cold on a scale ranging from none (0) to severe (4). Ratings of mild cold (2) or more were considered positive clinical diagnoses. The subjects also rated the severity of their colds on the same scale. The clinical diagnosis was in agreement with the subject's rating in 94 percent of the cases. The subjects were classified as having clinical colds if they both had evidence of infection and were given the diagnosis of a clinical cold. Of the 394 subjects who received virus, 38 percent (148) had clinical colds. None of the 26 subjects who received saline had a cold.

Seven subjects with positive clinical diagnoses but no indication of infection were excluded from the sample because we assumed the illness was caused by exposure to another virus before the trial. Analyses including these seven subjects resulted in conclusions identical to those reported here.

### Standard Control Variables

We used a series of control variables that might provide alternative explanations for the relation between stress and illness. These include serologic status for the experimental virus before the challenge, age, sex, education, allergic status, weight, the season, the number of subjects housed together, whether a subject housed in the same apartment was infected, and the identity of the challenge virus.

Serologic status was defined as positive when a subject had a base-line neutralizing antibody titer above 2 for rhinoviruses and a base-line antibody level greater than the sample median for coronavirus or respiratory syncytial virus. Forty-three percent of the subjects were seropositive before the challenge: 55 percent for rhino-

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virus type 2, 48 percent for rhinovirus type 9, 20 percent for rhinovirus type 14, 50 percent for respiratory syncytial virus, and 50 percent for coronavirus.

Because age was not normally distributed, it was scored categorically as above or below the median: 18 through 33 years or 34 through 54 years. Education levels were classified on an 8-point scale ranging from no schooling (0) to a doctoral degree (8), as reported by the subjects. Allergic status was determined on the basis of the subjects' answers to questions about allergies to food, drugs, or other allergens. Subjects who reported any allergy were defined as allergic. A ponderal index (the weight divided by the cube of the height) was used to control for subjects' weight. We used the number of hours of daylight on the first day of the trial as a continuous measure of the season. The number of daylight hours is correlated ($r = 0.80$, $P<0.001$) with the average temperature on the same day. Control for the possibility that person-to-person transmission rather than viral challenge might be responsible for infections or clinical colds was also included. Because person-to-person transmission would have been possible only if a subject sharing the same housing had been infected by the viral challenge, a control variable indicated whether or not any subject sharing the same housing was infected. Finally, the challenge virus was a categorical variable indicating the experimental virus to which a subject was exposed.

### Measures of Health Practice

Health practices — including smoking, alcohol consumption, exercise, quality of sleep, and dietary practices — were assessed as possible factors linking stress and susceptibility. Cotinine measured in serum by gas chromatography was used as a biochemical indicator of the smoking level because it provided an objective measure of nicotine intake that was not subject to reporting bias.[26,27] We used the base-10 logarithm of the average of the two cotinine measures (before and 28 days after challenge) as an indicator of the level of smoking. (The correlation between the two measures was 0.95 [$P<0.001$, $n = 348$].) The correlation between $\log_{10}$ average cotinine level and the $\log_{10}$ number of cigarettes reported as smoked per day was 0.96 ($P<0.001$, $n = 372$).

The remaining health practices were assessed by questionnaire before the viral challenge. The average number of alcoholic drinks per day was calculated on the basis of separate estimates of weekday and weekend drinking. A half-pint, bottle, or can of beer, a glass of wine, and a shot of whiskey contain approximately equal amounts of alcohol, and each was treated as a single drink. The exercise index included items on the frequency of walking, running, jogging, swimming, aerobic exercise, and work around the house. The quality-of-sleep index included items on feeling rested, difficulty falling asleep, and awakening early; and the dietary-habit index was made up of items designed to assess concern with a healthful diet and included the frequency of eating breakfast, fruits, and vegetables.

### White-Cell Counts and Total Immunoglobulin Levels

White-cell counts and total immunoglobulin levels were assessed as possible factors linking psychological stress and susceptibility to illness. Assays were performed in blood samples collected before the viral challenge. White cells were counted with an automatic cell counter, and differential counts (lymphocytes, monocytes, and neutrophils) were calculated from 200 cells in a stained film. Total serum and nasal-wash IgA and IgE levels and total nasal-wash protein levels were assessed by enzyme-linked immunosorbent assay.[25] We used the base-10 logarithm of each differential count and immunoglobulin measurement.

### Measures of Personality

Because the degree of psychological stress might reflect stable personality styles rather than responses to environmental factors causing stress, two personality characteristics closely associated with stress — self-esteem and personal control (the expectation that one can control events) — were assessed before the viral challenge. Self-esteem was measured with the self-regard and social-confidence subscales of the Feelings of Inadequacy Scale[28] (reliability, $\alpha = 0.89$) and personal control with the personal-efficacy and interpersonal-control subscales of the Spheres of Control Scale[29] (reliability, $\alpha = 0.76$). A third personality characteristic, the degree of relative introversion or extraversion, was also assessed because some evidence had suggested that introverts were at higher risk for infection.[30,31] This characteristic was assessed with the Eysenck Personality Inventory[32] (reliability, $\alpha = 0.80$).

### Statistical Analysis

The primary analysis tested whether psychological stress was associated with a higher incidence of clinical colds. Secondary analyses assessed the importance of the two components of the definition of a clinical cold, documented infection and symptoms, in accounting for the association between stress and clinical colds. Specifically, we determined whether the relation between stress and colds was attributable to an increase in infection or to an increase in diagnosed colds among infected persons. The subjects who received saline were not included in these analyses.

Logistic regression was used to predict categorical outcomes.[33] We conducted a series of analyses. In the first stage, only the psychological-stress index was entered as a predictor. In the second, we entered the standard control variables in the initial step of the regression analysis and then tested whether there was a significant change in the log likelihood of a clinical cold when the stress index was added to the equation. Education, weight, the season, and the number of subjects sharing an apartment were entered as continuous variables, and the remainder of the standard controls as dummy (categorical) variables.[33] Because the predictor (the stress-index score) was a continuous variable, we have reported raw regression coefficients (b) and their standard errors.[33] To estimate the sizes of effects, we have also reported odds ratios and their 95 percent confidence intervals, derived from modified regression models in which the continuous stress-index score was replaced with a contrast between the subjects in the bottom and the top quartiles of the stress index. The odds ratio approximates how much more likely it was that the outcome (infection or clinical cold) would be present among those with the highest stress-index scores (top quartile group) than among those with the lowest scores (bottom quartile group).[33]

Additional analyses tested possible roles for immunity, health practices, and personality variables in mediating the relation between stress and clinical colds. In the first analysis, the possibility that white-cell counts, total antibody levels, or five different health practices operated as pathways through which psychological stress influenced the risk of having a clinical cold was assessed by entering these variables along with the standard control variables in the first step of the regression equation and then testing whether adding stress to the equation accounted for a significant change in the log likelihood of illness. In the second analysis, the possibility that the effects of stress might reflect differences in personality rather than reactions to environmental stress factors was assessed by adding first two personality variables associated with stress (self-esteem and personal control) and then another previously associated with susceptibility to infection (introversion–extraversion) to the set of control variables and testing for any additional contribution of stress. All the immune measures, health practices, and personality variables were entered as continuous variables.

## Results

Preliminary analysis indicated that there were no statistically reliable interactions between the standard control variables and the stress index in predicting clinical colds (highest $t = 1.62$, $P = 0.11$).[33] The relations we report between the stress index and colds were thus similar for the five viruses and for groups defined by serologic status, age, sex, allergic status, education, weight, the number of subjects sharing an apartment, whether another subject in the same housing was infected, and the season.

There were, however, main effects of three standard

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control variables — serologic status (P<0.001), the virus (P<0.001), and whether another subject in the same apartment was infected (P<0.02). The P value for the remaining variables was >0.20. Subjects who were seronegative at base line had more colds (49.3 percent) than those who were seropositive (22.2 percent). The incidence of colds was 61.1 percent for coronavirus, 42.4 percent for rhinovirus type 14, 37.5 percent for respiratory syncytial virus, 33.6 percent for rhinovirus type 9, and 23.3 percent for rhinovirus type 2. Finally, subjects sharing an apartment with an infected subject had more colds (40.9 percent) than those without an infected apartment mate (26.4 percent). Although they were associated with the development of clinical colds, none of these three variables was reliably associated with the stress index (highest F = 1.44, P<0.22).

As is apparent in Figure 1, the rate of clinical colds increased in a dose–response manner with increases in the stress-index score (b [±SE] = 0.10±0.04, P<0.02, n = 394; odds ratio for the comparison of the highest and lowest quartile groups = 1.98 [95 percent confidence interval, 1.10 to 3.56]). Moreover, entering the standard control variables into the equation before the stress index (adjusted rates are shown in Fig. 1) did not alter this association (b = 0.10±0.05, P<0.04, n = 394; odds ratio = 2.16 [95 percent confidence interval, 1.11 to 4.23]).

As is apparent in Figure 2, the rates of infection also increased with increases in the stress index (b = 0.15±0.05, P<0.005, n = 394; odds ratio for the comparison of the highest and lowest quartile groups = 3.45 [95 percent confidence interval, 1.51 to 7.87]). This relation was similarly unaltered by the inclusion of standard control variables in the equation (b = 0.17±0.06, P<0.004; odds ratio = 5.81 [95 percent confidence interval, 2.12 to 15.91]). The level of stress was not, however, reliably associated with the rate of clinical colds among infected persons (b = 0.07±0.04, P = 0.13; including the control variables: b = 0.06±0.05, P = 0.24, n = 325). Hence, the relation between stress and colds was primarily attributable to an increased rate of infections among subjects with higher stress-index scores, rather than to an increase in clinical colds among infected persons with higher stress scores.

The similar effect of stress at the various levels of each standard control variable (i.e., the lack of interaction between stress and each control variable) has already been mentioned. Of special importance in interpreting this study is the fact that stress had the same effects in all the challenge-virus groups regardless of the infectious status of apartment mates or prechallenge serologic status. The consistent effect of stress among the five viruses is illustrated in Figures 3 and 4, which present the rates of colds and infection (adjusted for standard control variables) according to challenge virus for subjects below the median value of the stress index (low stress) and above the median (high stress). That the effects of stress were similar for all viruses suggests the biologic generality of the effect. Table 1 presents similar data for base-line serologic status and the infectious status of subjects sharing the same apartment. The data on subjects housed together indicate that greater person-to-person transmission among subjects with higher stress-index scores cannot explain the association between stress

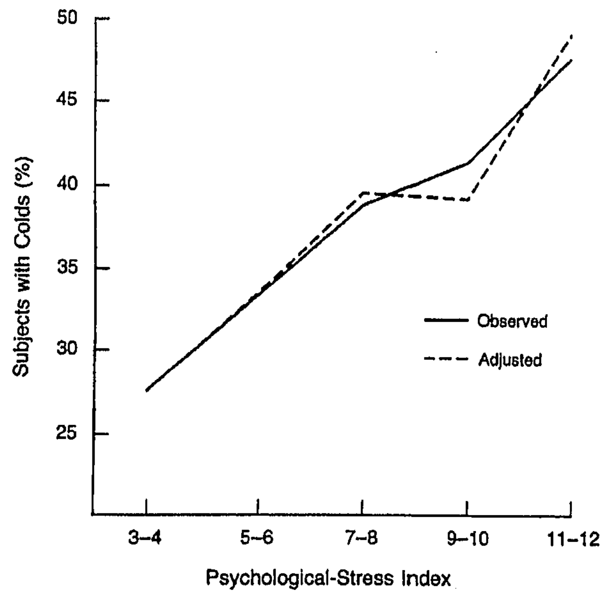


Figure 1. Observed Association between the Psychological-Stress Index and the Rate of Clinical Colds and the Association Adjusted for Standard Control Variables.

For an explanation of the psychological-stress index, see the text. Only the 394 subjects who received virus are included.

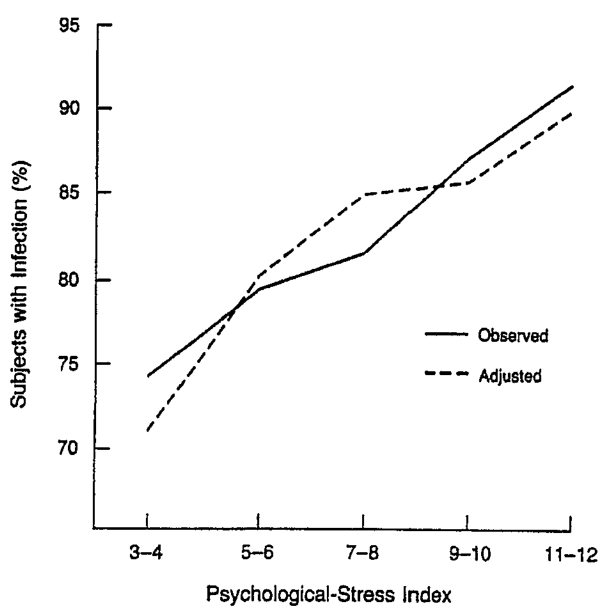


Figure 2. Observed Association between the Psychological-Stress Index and the Rate of Infection and the Association Adjusted for Standard Control Variables.

Only the 394 subjects who received virus are included.

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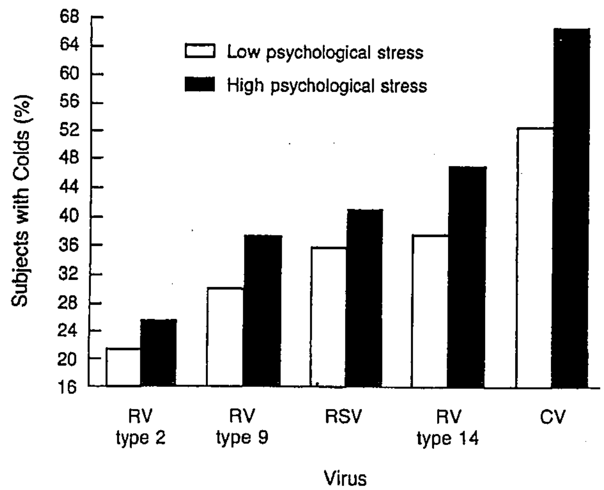


Figure 3. Subjects with Low Degrees of Psychological Stress (Index Values below the Median) and High Degrees of Stress (Values above the Median) Who Had Colds, According to Challenge-Virus Group.

The rates have been adjusted for the standard control variables. RV denotes rhinovirus, RSV respiratory syncytial virus, and CV coronavirus. Only the 394 subjects who received virus are included.

and colds (such transmission was possible only if the subject had an infected apartment mate). Finally, consistency among groups defined by prechallenge serologic status suggests that if an immune mechanism is the mediator of the relation between stress and colds, it is a primary and not a secondary (immune-memory) mechanism.

Additional analyses tested the possible roles of immunity, health practices, and personality variables in the relation between stress and clinical colds. In the first analysis, we assessed the possibility that measures of white-cell populations (differentials), total immunoglobulin levels, or health practices operate as pathways through which psychological stress is related to clinical illness. These variables were entered together, along with the standard controls, in the first step of a regression equation, with the stress index entered in the second step. The stress index continued to add to the predictive power of the equation even after the additional controls were entered ($b = 0.14 \pm 0.05$, $P<0.01$). Hence, none of these variables were responsible for the association between stress and illness in this study.

In the second analysis, we assessed the possibility that effects of stress might actually reflect differences in personality rather than reactions to environmental stressors. Two personality variables associated with stress (self-esteem, $r = -0.52$, $P<0.001$; and sense of personal control, $r = -0.25$, $P<0.001$) and another previously associated with susceptibility to infection (introversion–extraversion, r with stress $= -0.04$, $P = 0.46$) were added to the first step of the regression (with standard controls, health practices, and immune controls), and the stress index was entered in the second step. The stress index continued to produce a unique contribution to the explanation of colds ($b = 0.13 \pm 0.06$, $P<0.04$). Thus, none of the personality characteristics we studied could account for the relation between stress and illness.

Table 1. Rates of Infection and Colds among Subjects with High and Low Stress-Index Scores, According to Prechallenge Serologic Status and the Infectious Status of Apartment Mates.*

| | Infection | | Colds | |
|---|---|---|---|---|
| | Low Stress Index | High Stress Index | Low Stress Index | High Stress Index |
| | *incidence (%)* | | | |
| Prechallenge serologic status | | | | |
| Positive (n = 171) | 67.2 | 79.8 | 18.7 | 25.5 |
| Negative (n = 223) | 86.2 | 92.4 | 43.7 | 55.2 |
| Infectious status | | | | |
| Not infectious (n = 91) | 68.7 | 81.4 | 20.8 | 32.6 |
| Infectious (n = 303) | 81.2 | 88.3 | 37.2 | 44.6 |

*Rates of infection and clinical colds have been adjusted for standard control variables. The categorization of low and high degrees of stress is based on whether the subjects' stress-index scores fell below or above the median value. The infectious status of subjects sharing the same housing is considered "infectious" if any person housed with the subject was infected.

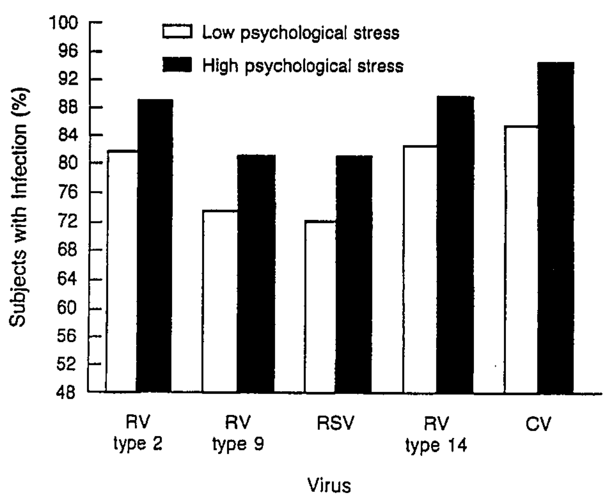


Figure 4. Subjects with Low Degrees of Psychological Stress (Index Values below the Median) and High Degrees of Stress (Values above the Median) Who Were Infected, According to Challenge-Virus Group.

The rates have been adjusted for the standard control variables. RV denotes rhinovirus, RSV respiratory syncytial virus, and CV coronavirus. Only the 394 subjects who received virus are included.

## Discussion

Psychological stress was associated with an increased risk of acute infectious respiratory illness in a dose–response manner; this risk was attributable to increased rates of infection. Although there was some person-to-person transmission of virus in this study, the effect of stress on colds was independent of whether such transmission was possible (i.e., whether a subject shared housing with another infected subject). Moreover, the relation between stress and colds was similar for those with and without infected apartment mates. In short, the stress index was associated with host resistance and not with differential exposure to virus.

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The relation between stress and colds also proved to be independent of a variety of health practices. If the increased risk of illness for subjects with higher stress-index scores was not due to associations between stress and exposure to virus or between stress and health practices, what accounts for this relation? Evidence from both human and animal studies indicates that stress modulates immunity.[7-9] Although the immune measures assessed in this study (prechallenge white-cell counts and antibody levels) did not explain the relation between stress and colds, these are quantitative measures; qualitative (functional) measures of immunity were not assessed. Because the effects of stress were the same for both subjects who were seropositive at base line and those who were seronegative, an explanation of the association between stress and illness would need to focus on primary rather than secondary immune responses. Some examples of primary immune functions that could have a role in this association are endothelial or lymphocyte production of interferon, mucus production, and natural-killer-cell activity.[34]

The association between stress and clinical illness was limited (adjusted odds ratio = 2.16), and the detection of the effect required a large sample. The relation between stress and infection, however, is stronger (adjusted odds ratio = 5.81). Moreover, the consistency of the stress–illness relation among three very different viruses — rhinovirus, coronavirus, and respiratory syncytial virus (as well as among rhinovirus types) — was impressive. This observation suggests that stress is associated with the suppression of a general resistance process in the host, leaving persons susceptible to multiple infectious agents, or that stress is associated with the suppression of many different immune processes, with similar results.

Although psychological stress is conceptualized here as a response to environmental events, our measures may also reflect personality characteristics that are independent of environmental factors. However, self-esteem and personal control, two personality characteristics strongly associated with stress, did not account for the effect of stress in this study. Another personality characteristic previously found to predict susceptibility to infection, introversion–extraversion, similarly did not account for the effect of stress. Because the psychological stress index assesses negative cognitive and emotional states rather than environmental stress factors, however, it is possible that it reflects other, individual traits not controlled for in the current study.

The results of research on stress as a risk factor in verified infectious disease have been inconsistent.[10] This inconsistency may be due to insensitive techniques for detecting a relatively small effect on clinical illness. Our data suggest that a relation between stress and susceptibility to illness may be best detected in studies that incorporate control for important demographic and biologic characteristics, reliable and broadly defined indexes of stress, controlled exposure to the infectious agent, and relatively large samples.

We are indebted to S. Bull, J. Greenhouse, M. Jarvis, H. Parry, M. Russell, M. Sargent, J. Schlarb, S. Trickett, the medical, nursing, and technical staff of the Common Cold Unit, and the volunteers for their contributions to the research; and to J. Cunnick, R. Dawes, D. Klahr, K. Kotovsky, K. Matthews, B. Rabin, and M. Scheier for comments on an earlier draft of the manuscript.

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Received 3 March 2007; accepted 13 August 2007. published online 17 September 2007.

## Abstract

Stress is thought to influence human eating behavior and has been examined in animal and human studies. Our understanding of the stress-eating relation is confounded by limitations inherent in the study designs; however, we can make some tentative conclusions that support the notion that stress can influence eating patterns in humans. Stress appears to alter overall food intake in two ways, resulting in under- or overeating, which may be influenced by stressor severity. Chronic life stress seems to be associated with a greater preference for energy- and nutrient-dense foods, namely those that are high in sugar and fat. Evidence from longitudinal studies suggests that chronic life stress may be causally linked to weight gain, with a greater effect seen in men. Stress-induced eating may be one factor contributing to the development of obesity. Future studies that measure biological markers of stress will assist our understanding of the physiologic mechanism underlying the stress-eating relation and how stress might be linked to neurotransmitters and hormones that control appetite.

**Keywords:** Stress, Eating behavior, Sucrose, Fat, Rat, Weight gain, Obesity

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PII: S0899-9007(07)00249-3

doi:10.1016/j.nut.2007.08.008



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# 1

# Strategies for Measuring Stress in Studies of Psychiatric and Physical Disorders

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Stress has long been a major focus among researchers interested in environmental and psychosocial influences on health. However, the way in which the term "stress" has been used in this voluminous literature has not been consistent. Indeed, some commentators have gone as far as to argue that the term stress has so many different meanings that it has become a useless concept (Ader, 1980; Elliot & Eisdorfer, 1982). Although we disagree with this premise, we recognize that there is confusion about the meaning and measurement of stress. This volume attempts to clear up some of that confusion by providing conceptual and practical advice for formulating questions about the relation between stress and disease and for selecting appropriate stress measures to test these questions.

## What Is Stress?

As noted above, there is disagreement about the meaning of the term "stress." Numerous definitions have been provided, varying in the extent to which they emphasize stressful events, responses, or individual appraisals of situations as the central characteristic of stress (e.g., Appley & Trumbull, 1967; Mason, 1975; McGrath, 1970). We have no illusions that we can resolve the differences among these perspectives in this volume. However, we do see a strong commonality among these approaches that allows them to be integrated in a theoretical model of the role of stress in disease. They all share an interest in a process in which *environmental demands tax or exceed the adaptive capacity of an organism, resulting in psychological and biological changes that may place persons at risk for disease.*

Three broad traditions of assessing the role of stress in disease risk can be distinguished. The environmental tradition focuses on assessment of environmental events or experiences that are normatively (*objectively*) associated with substantial adaptive demands. The psychological tradition focuses on individuals' *subjective* evaluations of their abilities to cope with the demands posed by specific events or experiences. Finally, the biological tradition focuses on activation of specific physiological systems that have been repeatedly shown to be modulated by both psychologically and physically demanding conditions. The following sections provide a brief orientation to these traditions and attempt to distill the central assumptions of each. We then present an organizational model of the stress process that shows how these traditions relate to one another. Our premise is that each tradition focuses on a different stage of the process through which environmental demands are translated into psychological and biological changes that place people at risk for disease. Finally, we discuss the conceptual and practical issues involved in selecting appropriate categories of stress measurement. Once appropriate categories are selected, subsequent chapters of this volume can be consulted to help select measures within each category.

Throughout the volume we use the term stress exclusively to refer to the general process through which environmental demands result in outcomes deleterious to health. However, we distinguish between the components of the process by referring to environmental experiences as *environmental demands, stressors, or events;* to subjective evaluations of the stressfulness of a situation as *appraisals or perceptions of stress;* and to affective, behavioral, or biological responses to stressors or appraisals as *stress responses.*

## The Environmental Stress Perspective

Most evidence on the role of stressors in human disease has derived from interest in stressful life events. Interest in the role of life events in illness began with the work of Adolf Meyer in the 1930s. Meyer advocated that physicians fill out a life chart as part of their medical examination of ill patients (Lief, 1948; Meyer, 1951). Meyer believed that the life events elicited in this way could be shown to have etiologic importance for a variety of physical illnesses. Meyer's ideas were highly influential and led to a substantial body of research which, by the late 1940s, had documented that stressful life events were associated with a variety of physical illnesses (see review by Wolff, Wolf, & Hare, 1950). Although some of this early work was based on inadequate research designs, a number of studies were quite impressive. The work of Wolff and his associates, for example, followed a large sample of telephone operators over many years and documented that illness was much more likely to occur during periods of inordinate demands, frustrations, and losses than at other times (Hinkle & Wolff, 1958).

An important advance in this area of research came in 1957 when Hawkins and his collaborators developed the Schedule of Recent Experiences (SRE) in an effort to systematize Meyer's life chart (Hawkins, Davies, & Holmes, 1957). This instrument was used by a great many researchers over the next decade to document associations between stressful life events and heart disease, skin disease, and many others (reviewed by Holmes & Masuda, 1974). In a subsequent modification of the SRE, the Social Readjustment Rating Scale (SRRS), each event was assigned a standardized weight based on judges' ratings of the degree of difficulty required to adjust to the event (Holmes & Masuda, 1974). These weights were called "life change units" (LCU). The summing of LCUs associated with reported events allowed for a summary measure of environmental stressors (Holmes & Rahe, 1967). This instrument had an enormous impact on research on the relations between life events and illness, due in large part to the documentation of dramatic associations, such as an effect of stressful life events on sudden cardiac death (Rahe & Lind, 1971). It also had an important conceptual impact on the field in advancing the notion of the life change unit and the conceptual model underlying the creation of this metric, which argued that the effects of stressors operate largely through the creation of excessive adaptive demands. This conception led users of the SRRS to be more concerned with the magnitude of life change than with whether the change was positive (e.g., a promotion) or negative (e.g., a job loss).

Beginning in the 1970s, a new generation of stressful life event researchers began to challenge many of the basic assumptions involved in the construction and scoring of the SRRS. New ideas were advanced about the implications of different means of weighting and summing multiple events into cumulative scales (Shrout, 1981). A subjective element was introduced into some modifications of the SRRS by having individuals estimate the stressfulness of their own experiences as a way of generating measures that are more sensitive indicators of event stressfulness than judges' ratings (e.g., Sarason, Johnson, & Siegel, 1978). More drastic differences are reflected in the development of a life event interview in which investigators rate the importance of events while taking into account the context in which they occur (Brown & Harris, 1978). The investigator-based rating is an attempt to estimate the impact of an event in a specific context for the average person, avoiding individual subjective reactions. A major distinction among competing measures of life events in the current literature is between these contextual measures and more traditional checklist measures (Brown & Harris, 1989; Dohrenwend, Raphael, Schwartz, Stueve, & Skodol, 1993). Separate chapters on these two approaches are included in Section II of this volume.

New concerns were also raised during this period that existing life event scales may not include an adequate and representative sample of the major events that occur in people's lives. Newer checklists were developed to expand the range of experiences evaluated (Dohrenwend, Askenasy, Krasnoff, & Dohrenwend, 1978). Scales were also developed to assess stressful events in specific populations whose experiences might be different from those represented on the more general SRRS. These included scales for children (e.g., Sandler & Ramsay, 1980), adolescents (e.g., Newcomb, Huba, & Bentler, 1981) and the elderly (e.g., Murrell, Norris, & Hutchins, 1984).

The basic assumptions of the SRRS, that the effects of all stressful events are cumulative and that the change per se is the most important dimension of stressors, were also challenged during the same time period (Paykel, 1974). Some newer life-event scales were based on a multidimensional conception of stressors that separately assessed the extent of threat, loss, danger, and other aspects of stressful events (Brown & Harris, 1978).

On the substantive side, there has been a continuation of basic research to document the effects of stressful events on a variety of physical and mental health outcomes using newer stressful life event measures (Chapters 2 & 3, this volume).

There also has been interest in studying the cumulative effects of experiencing two or more stressful life events in the same short interval of time (McGonagle & Kessler, 1990) and the joint effects of experiencing a stressful event in the context of an ongoing chronic stressor in the same life domain (Wheaton, 1990).

In addition, there is now considerable interest in studying *vulnerability factors*—characteristics that make people more or less susceptible to stressor-induced disease. This interest derives from the repeated finding that although environmental stressors are often associated with illness onset, the majority of people confronted with extreme or traumatic stressful events do not become ill (Thoits, 1983). Differential vulnerability to the health-damaging effects of environmental stressors has been documented in a number of investigations (see review by Kessler, Price, & Wortman, 1985). A search for the determinants of this differential vulnerability has become the main focus of researchers interested in the role of life events in illness. In addition, the decade of the 1980s saw a movement away from an earlier tradition of focusing exclusively on the acute health-damaging effects of discrete life events toward an investigation of the long-term health-damaging effects of chronic stressors (Chapter 5, this volume). Work stressors (Neilson, Brown, & Marmot, 1989), marital disharmony (Beach, Sandeen, & O'Leary, 1990), and work–family conflicts (Eckenrode & Gore, 1990) have been the primary areas of investigation in research on chronic stressor effects. In addition, there is a new interest in the cumulative effects of minor daily stressors on both emotional health (Bolger, DeLongis, Kessler, & Schilling, 1989) and physical health (Chapter 4, this volume; Stone, Reed, & Neal, 1987). In all of this work, the researcher attempts to identify characteristics of the environment that promote illness. In the initial stages of this work the focus is on description. As the work evolves, the focus shifts to the processes involved in creating the observed association, the topic of Parts III and IV of this volume.

Finally, although stressful events have been studied primarily as risk factors for disease, it is becoming increasingly clear that confronting and adapting to stressful events can result in positive outcomes such as personal growth, reprioritization of life goals, increased feelings of self-esteem and self-efficacy, and strengthening of social networks. A greater emphasis on the benefits of stressful events for successful adaptors is likely in the future and would broaden our understanding of the stress process.

## The Psychological Stress Perspective

The psychological stress tradition places emphasis on the *organism's perception and evaluation* of the potential harm posed by objective environmental experiences. When their environmental demands are perceived to exceed their abilities to cope, individuals label themselves as stressed and experience a concomitant negative emotional response. Psychological models of stress argue that events influence only those persons who appraise them as stressful—that is, perceive stress. It is important to emphasize that stress appraisals are determined not solely by the stimulus condition or the response variables, but rather by persons' interpretations of their relationships to their environments. That is, the perception that one is experiencing stress is a product of both the interpretation of the meaning of an event and the evaluation of the adequacy of coping resources.

The most influential model of the appraisal process has been the one proposed by Lazarus (Lazarus & Folkman, 1984). In the original formulation of his model, Lazarus (1966) argued that an appraisal of a stimulus as threatening or benign, termed *primary appraisal*, occurs between stimulus presentation and stress reaction. In his later writings, Lazarus (1977, 1981) argued that a situation will also result in a stress reaction if it is evaluated as a harm/loss, threat, or challenge. Primary appraisal is presumed to depend on two classes of antecedent conditions: the perceived features of the stimulus situation and the psychological structure of the individual. Some stimulus factors affecting primary appraisal include the imminence of harmful confrontation, the magnitude or intensity of the stimulus, the duration of the stimulus, and the potential controllability of the stimulus. Factors within individuals that affect primary appraisal include their beliefs about themselves and the environment, the pattern and strength of their values and commitments, and related personality dispositions. When a stimulus is appraised as requiring a coping response, individuals evaluate their resources in order to determine whether they can cope with the situation—that is, eliminate or at least lessen the effects of a stressful stimulus. This process is termed "secondary appraisal." Coping responses may involve actions designed to directly alter the threatening conditions (e.g., fight or flight) or thoughts or actions whose goals are to relieve the emotional stress response (i.e., body or psychological disturbances). The latter group of responses, referred to as "emotionally focused" coping, may be somatically oriented —for example, the use of tranquilizers, or intrapsychic responses such as denial of danger (Lazarus, 1975). If one perceives that effective coping responses are available, then the threat is short-circuited and no stress response occurs. If, on the other hand, one is uncertain that she or he is capable of coping with a situation that has been appraised as threatening or otherwise demanding, stress is experienced. It is important to note that this process of evaluating the demands of a situation and evaluating one's ability to cope not only occurs at the onset of a stressful event but often recurs during the course of the event (cf. Folkins, 1970; Lazarus, 1981). Thus, an event that is initially appraised as threatening may be later reappraised as benign, and coping strategies that are initially found to be lacking may later be found to be adequate. Conversely, events that one initially evaluates as nonthreatening may be later reevaluated as stressful. Although it is recognized that certain events are almost universally appraised as stressful (e.g., the death of a loved one), the impact of even these events can be expected to depend on an individual's appraisal of the threat entailed and his or her ability to cope with it. For example, the death of a spouse for someone with neither family nor friends may be experienced as more severe than the same event for someone with close ties to family and friends.

As suggested earlier, appraisals of threat elicit negative emotional responses. They also can elicit a range of other outcomes including self-reported annoyance, changes in health practices such as smoking, drinking alcohol, diet, exercise, and sleeping; changes (usually deficits) in performance of complex tasks; and alterations in interpersonal behaviors (Cohen, Evans, Krantz, & Stokols, 1986). Unfortunately, psychological stress models tend to be vague in their predictions of the particular measures that will be affected in any instance, and of the nature of the relations among these outcome measures.

## The Biological Stress Perspective

The biological perspective focuses on the activation of physiological systems that are particularly responsive to physical and psychological demands. Prolonged or repeated activation of these systems is thought to place persons at risk for the development of a range of both physical and psychiatric disorders. Two interrelated systems that are viewed as the primary indicators of a stress response are the sympathetic–adrenal medullary system (SAM) and the hypothalamic–pituitary–adrenocortical axis (HPA). Although detailed descriptions of these two systems and their relations to each other are beyond the scope of this chapter (see Baum, Singer, & Baum, 1981; Levi, 1972; and Chapter 8, this volume), each is discussed in brief in order to provide a basic understanding of their roles in the stress process.

### Sympathetic–Adrenal Medullary System

Interest in the impact of SAM activation on bodily reactions to emergency situations may be traced to Walter Cannon's early work on the flight or flight response (Cannon, 1932). Cannon proposed that the SAM system reacts to various emergency states with increased secretion of the hormone epinephrine. There is a large body of evidence indicating increased output of epinephrine and norepinephrine in response to a wide variety of psychosocial stressors (Levi, 1972). Other components of the SAM response elicited by stressors include increased blood pressure, heart rate, sweating, and constriction of peripheral blood vessels. It has been claimed that if SAM activation is excessive, is persistent over a period of time, or is repeated too often, it may result in a sequence of responses that culminate in illness. The responses include functional disturbance in various organs and organ systems (cf. Dunbar, 1954) and ultimately permanent structural changes of pathogenic significance at least in predisposed individuals (e.g., Raab, 1971). Particularly culpable in this regard is the secretion of the hormones epinephrine and norepinephrine by the adrenal medulla and/or sympathetic nerve endings. Excessive discharge of these substances is believed to induce many of the pathogenic states associated with the perception of stress including (1) suppression of cellular immune function (e.g., Rabin, Cohen, Ganguli, Lysle, & Cunnick, 1989); (2) hemodynamic effects, such as increased blood pressure and heart rate (McCubbin, Richardson, Obrist, Kizer, & Langer, 1980); (3) provocation of variations in normal heart rhythms (ventricular arrhythmias) believed to lead to sudden death (Herd, 1978); and (4) production of neurochemical imbalances that contribute to the development of psychiatric disorders (Anisman & Zacharko, 1992).

Hypothalamic–Pituitary–Adrenocortical Axis (HPA)

The hormonal responses of the HPA axis were emphasized in Hans Selye's (e.g., 1956, 1974) influential description of a nonspecific (general) physiological reaction that occurs in response to excessive stimulation. Selye argued that pathogens, physical stressors (e.g., shock or noise), and psychosocial stressors all elicit the same pattern of physiological response. This response is said to proceed in a characteristic three-stage pattern referred to as the general adaptation syndrome (GAS). During the first stage of the GAS, the *alarm stage*, the organism's physiological changes reflect the initial reactions necessary to meet the demands made by the stressor agent. The anterior pituitary gland secretes adrenocorticotrophic hormone (ACTH), which then activates the adrenal cortex to secrete additional hormones (corticosteroids [primarily cortisol in humans]). The hormone output from the adrenal cortex increases rapidly during this stage. The second stage, *resistance*, involves a full adaptation to the stressor with consequent improvement or disappearance of symptoms. The output of corticosteroids remains high but stable during the resistance stage. Finally, the third stage, *exhaustion*, occurs if the stressor is sufficiently severe and prolonged to deplete somatic defenses. The anterior pituitary and the adrenal cortex lose their capacity to secrete hormones, and the organism can no longer adapt to the stressor. Symptoms reappear, and, if the stress response continues unabated, vulnerable organs (determined by genetic and environmental factors) will break down. This breakdown results in illness and ultimately death. Selye argued that any noxious agent, physical or psychosocial in nature, would mobilize a similar GAS response. In contrast, critiques of Selye's model suggest that each stressor elicits its own distinct physiogical reactions (Lazarus, 1977; Mason, 1975). These authors agree that there is a nonspecific physiological response to stressors. They argue, however, that the response is a concomitant of the *emotional reaction* that occurs when situations are appraised as stressful. When conditions are designed to reduce the psychological threat that might be engendered by laboratory procedures, there is no nonspecific reaction to a physical stressor (Mason, 1975). For example, by minimizing competitive concerns and avoiding severe exertion, the danger that young men would be threatened by treadmill exercise was reduced, and the GAS pattern was not found. It is noteworthy that, in Selye's later work (1974, 1980) he acknowledged that there are both specific as well as general (nonspecific) factors in physiological response to a stressor but maintained that the nonspecific response is not always psychologically mediated. He also suggested that the GAS does not occur (or is at least not destructive) in response to all kinds of stressors. For example, he suggested that there may be a pleasant stress of fulfillment and victory and a self-destructive distress of failure, frustration, and hatred. However, there is little empirical evidence to support this position.

Since the late 1970s, interest in the biological bases of psychiatric disorders has stimulated an alternative focus on the HPA. Most of this work has pursued the possible role of HPA disregulation in depression. Relatively pronounced HPA activation is common in depression, with episodes of cortisol secretion being more frequent and of longer duration among depressed than among other psychiatric patients and normals (Stokes, 1987). However, it is still unclear whether the hyper-HPA activation is a cause or effect of depressive disorders. HPA regulation may play a role in other psychiatric disorders as well. For example, anxious patients tend to have higher cortisol levels than normal controls (Sachar, 1975).

### Other Stress Associated Changes

Although hormones of the SAM and HPA are those most often discussed as the biochemical substances involved in stress responses, alterations in a range of other hormones, neurotransmitters, and brain substances have also been found in response to stress and may play an important role in stress influences on health. These include stressor-associated elevations in growth hormone and prolactin secreted by the pituitary gland, and in the natural opiates beta endorphin and enkephalin released in the brain (see Chapter 8, this volume; also Baum, Grunberg, & Singer, 1982). These substances are also thought to play a role in both immune-mediated (Rabin et al., 1989) and psychiatric diseases (Stokes, 1987).

## A Unifying Model of the Stress Process

The perspectives represented by the three traditions discussed earlier can be viewed as emphasizing different points in the process through which objective environmental experiences can influence disease. A model integrating these approaches is presented in Figure 1.1. The sequential relations between the central components of the model (dark arrows) can be described as follows. When confronting environmental demands, people evaluate whether the demands pose a potential threat and whether sufficient adaptive capacities are available to cope with them. If they find the environmental demands taxing or threatening, and at the same time view their coping resources as inadequate, they perceive themselves as under stress. The appraisal of stress is presumed to result in negative emotional states. If extreme, these emotional states may directly contribute to the onset of affective psychiatric disorders. They may also trigger behavioral or physiological responses that put a person under risk for psychiatric and physical illness. This model implies that each sequential component of the stress process is more proximal to and hence more predictive of the illness outcome. For example, a disease-relevant biological stress-response measure should be a better predictor of a disease outcome than measures of stressful life events or perceived stress.

We thought it important that the model also represent the possibility that environmental demands can put persons at risk for disorder even when appraisal does not result in perceptions of stress and negative emotional responses. This is represented by the arrow directly linking environmental demands to physiological or behavioral responses. For example, it has been argued that the process of coping itself (even when it is successful and environmental demands are appraised as benign) may *directly* result in physiological and behavioral changes that place persons at risk for disease (Cohen et al., 1986; Cohen, Tyrrell, & Smith, 1993).

We want to emphasize that this is a *heuristic model* designed to illustrate the

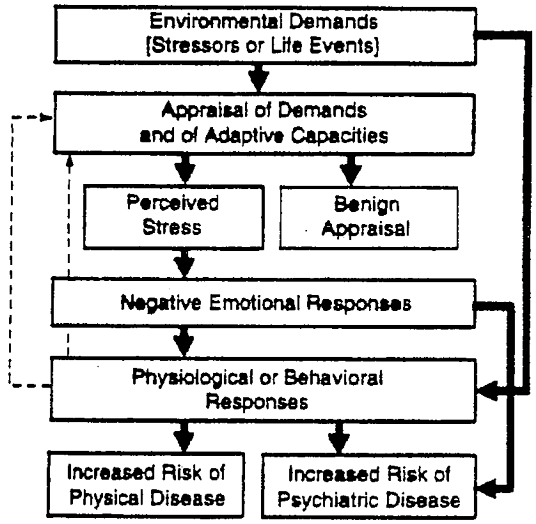


*Figure 1.1* A heuristic model of the stress process designed to illustrate the potential integration of the environmental, psychological, and biological approaches to stress measurement.

potential integration of the environmental, psychological, and biological approaches to stress measurement. The model is primarily unidirectional (flowing from environmental demands to disease) and does not include all possible pathways linking these concepts. We identified two of *many possible* feedback loops (dashed lines) to illustrate the potential role of feedback in the model. One of the loops suggests that emotional states may alter appraisals. For example, depressed affect may result in negatively biased views of either the threat posed by stressors or the adequacy of one's own resources. The other loop suggests that physiological arousal may alter appraisals and emotional responses: For example, persons may mistakenly attribute arousal that was elicited by exercise, drugs, or nonrelevant emotional responses to a stressor (Schachter & Singer, 1962). The exclusion of alternative paths is not intended to reflect hypotheses about their existence.

Historically, the environmental, psychological, and biological traditions have each focused on a specific part of the model, thus often ignoring other parts. For example, sociologists and epidemiologists have addressed the question of whether life events increase disease risk but usually ignore the psychological and biological pathways through which this influence might occur. Psychologists have focused on the role of appraisal and emotional response in disease risk, with less emphasis on the environmental causes of these states and the biological pathways responsible for links between psychological states and disease. Finally, biological stress researchers have focused primarily on the links between stressors and hormonal and cardiovascular response, and between these responses and disease risk, without concerning themselves with the psychological pathways through which stressors might influence biological states.

## How Could Stress Influence Disease?

We have provided a generic model of the stress process. In this section, we elaborate the implications of the generic model for physical and psychiatric illness. Our hope is that this presentation of how various conceptions of stress can influence illness will help generate appropriate questions and, consequently, the selection of measures and research designs.

### Stress and Physical Illness

In general, stressors are thought to influence the pathogenesis of physical disease by causing negative affective states (such as anxiety and depression) which in turn exert direct effects on biological processes or behavioral patterns that influence disease risk (see Cohen et al., 1986; Krantz, Glass, Contrada, & Miller, 1981). The primary biological pathway linking emotions to disease is thought to be hormonal. Hormonal responses associated with stressful experiences include elevations in the catecholamines epinephrine and norepinephrine secreted by the adrenal medulla, in cortisol secreted by the adrenal cortex, in growth hormone and prolactin secreted by the pituitary gland, and in the natural opiates beta endorphin and enkephalin released in the brain (see Baum, Grunberg, & Singer, 1982). A number of these hormones have been implicated in the pathogenesis of cardiovascular disease (Herd, 1986) and diseases involving the immune system including cancer, infectious diseases, and autoimmune diseases (Cohen & Williamson, 1991; Laudenslager, 1988; Rabin et al., 1989). Emotionally induced responses of the cardiovascular system such as increased heart rate and blood pressure have also been implicated in the development of cardiovascular disease and of immune changes that might alter susceptibility to immune-mediated disease (Herbert et al., 1994; Manuck et al., 1992). As discussed earlier, emotional responses are not always required for stressful events to influence disease processes (Cohen, Tyrrell, & Smith, 1993). The effort involved in actively coping with a stressor may also alter many of the same biological processes influenced by the emotional response and hence influence the development of disease independently of the emotional response (Cohen et al., 1986).

Behavioral changes occurring as adaptations or coping responses to stressors may also influence disease risk. For example, persons exposed to stressors or viewing themselves as under stress tend to engage in poor *health practices*. They may smoke more, drink more alcohol, eat poorly, exercise less, and sleep less (e.g., Cohen & Williamson, 1988; Conway, Vickers, Ward, & Rahe, 1981). Smoking, drinking alcohol, and poor diets have been established as risk factors for a range of different physical illnesses. Both stressors and negative affect have also been associated with failure to *comply* with medical regimens. Such failure could result in more severe and longer-lasting illness, either because undesirable behaviors aggravate existing problems or because failure to perform desirable behaviors (e.g., following medication regimens) results in disease progression. Other stressor-elicited behaviors—for example, unsafe sexual practices or poor hygienic practices—could also increase exposure to infectious agents.

## Stress and Illness Behaviors

Stress may also influence behaviors that appear to be manifestations of a disease state. Of particular interest is the role of stress in recognizing and acting on symptoms. The recognition and reporting of symptoms, and seeking of medical care often indicate underlying pathology. However, stress and other psychological factors can independently influence these behaviors (Cohen & Williamson, 1991). Because appraised stress often triggers physiological arousal, people under stress may be more (possibly overly) attentive to their internal physical states (Pennebaker, 1982). Stress may also facilitate the labeling of sensations as symptoms because people are reminded (in cognitive parlance, a schema is triggered) of previous times when stress was associated with symptoms or simply because they believe that stress triggers symptoms. Alternatively, stressors or stress appraisals may result in physical sensations whose causes are mistakenly attributed to disease symptoms rather than the stressor (e.g., Mechanic, 1972; Schachter & Singer, 1962). Labeling symptom constellations as disease may similarly be activated by stress–disease schemas. For example, it is widely believed that stressors cause the recurrence of oral herpes. Under stress, a minor oral lesion that would be ignored under nonstressful conditions may be defined as disease recurrence. Reports of symptoms and illness are also ways to avoid stressful situations (Mechanic, 1977). The prototypical example is the child who reports symptoms to avoid attending school on an especially stressful day (playing ill). Finally, stressors or stress appraisals may influence the decision to seek medical care when persons label themselves as ill. The perception of stress could interfere with deciding whether it is necessary to seek care, increasing care-seeking for minor symptoms or decreasing care-seeking for serious ones. Persons under stress may also seek medical care unnecessarily because medical providers are viewed as persons to whom one can confide problems. Stressors could also *decrease* care-seeking because the time demands of many stressors make such visits inconvenient (Schulz, Visintainer, & Williamson, 1990).

## Stress and Psychiatric Illness

As noted above, most models of the relations between stress and physical illness postulate an intervening link through negative affective states such as anxiety and depression. But how is it that stressors cause these affective states, particularly those that are so extreme and enduring that they are considered disorders in their own right? There are two broad perspectives on this question. One holds that stressful experiences are sometimes so extreme that they naturally lead to enduring fear or sadness. This is the notion, for example, underlying the diagnosis of post-traumatic stress disorder, a disorder defined by the American Psychiatric Association as one in which there is enduring distress related to recurrent recollections of a traumatic event that is so far "outside the range of usual human experience . . . that (it) would be markedly distressing to almost anyone" who experienced it (American Psychiatric Association, 1987:250). The second perspective holds that stressful events lead to psychiatric disorder only in the presence of some preexisting personal vulnerability. A number of different vulnerability factors have been postulated for different disorders. Some of these are thought to be environmental in origin (U.S. Congress Office of Technology Assessment, 1992). For example, some researchers believe that exposure to abnormal parental attachment behaviors early in life can lead children to develop disturbed interpersonal styles which persist throughout their lives and create vulnerability to depression (Kessler & Magee, 1993). This vulnerability is thought to be triggered by stressful experiences associated with interpersonal loss, such as death of a loved one, divorce, or forced residential relocation. Other vulnerabilities are thought to be biological in origin. For example, there is evidence consistent with the possibly that HPA abnormalities are involved in vulnerability to depression (Anisman & Zacharko, 1992; Checkley, 1992) and that these HPA abnormalities may be under genetic control (Checkley, 1992).

## Temporal Characteristics of Stressors, Appraisals, and Stress Responses

One of the most challenging issues in the measurement of stress is the characterization of the temporal course of stressors, appraisals, and stress responses. Most of the discussion of the role of stress duration focuses on the chronicity of stress. Although the terms "acute" and "chronic" stress are used liberally in the literature, there have been few attempts (for an exception, see Brown & Harris, 1989) to set even arbitrary standard cutoffs delimiting acute from chronic durations. Our own view is that such cutoffs should be attempted only in the context of considering the implications for a specific outcome. For example, 3 months of persistent stress might prove important in risk for depression, and prove inconsequential for a disease that develops over years such as coronary artery disease. Assuming we were correct about the implications of these durations, it might be appropriate to define 3 months of persistent stress as "chronic" in the study of depression, but it would be uninformative to call 3 months of stress chronic in the study of heart disease (see Cohen & Matthews, 1987; Cohen, Kaplan, & Manuck, 1994).

A view of temporal characteristics of stress consistent with the process model discussed earlier is proposed by Baum and his colleagues (Baum, Cohen, & Hall, 1993). They categorize stress duration through the use of a $2 \times 2 \times 2$ matrix that crosses duration of event exposure (i.e., event present for short or long duration), duration of perceived threat (i.e., appraised threat or demand present for short or long duration), and duration of stress responding (i.e., behavioral, emotional, or physiological stress responses present for short or long duration). This procedure suggests a more sensitive approach to understanding the role of stress duration. For example, consider the difference between a persistent stressful event that is no longer appraised as stressful or responded to with a stress response, and a stressful event that has terminated but continues to be appraised as stressful and responded to with a stress response (e.g., traumatic experiences).

Other work highlights some of the complexities of this issue by emphasizing the importance of temporal characteristics other than duration such as continuousness or repetitiveness. The following classification of stressful events (from Elliott & Eisdorfer, 1982) provides an indication of the complexity of this issue: (1) *acute time-limited events* (e.g., awaiting surgery); (2) *stressful event sequences*—when one event initiates a series of different events that occur over an extended period of time (e.g., bereavement or being fired from a job); (3) *chronic intermittent stressful events*—events that occur periodically (once a week, once a month, or once a year; e.g., sexual difficulties or conflicts with neighbors); and (4) *chronic stress conditions*—situations that may or may not be initiated by a discrete event (e.g., being disabled, chronic job stress).

The temporal course of events, stress appraisals, and stress responses have multiple implications for understanding the risk for disease. For example, one can ask how long an exposure, appraisal, or response is required to alter a disease process. Does persisting exposure result in a greater impact or in habituation? Are stress responses maintained over long periods, or do response mechanisms fatigue or trigger feedback mechanisms? What roles do repetitiveness and interval between repetitions play in these processes? Also of interest is the role that chronic stressors play in moderating the effect of more acute stressors. Unfortunately, there are few domains in which we know very much about the temporal role of stress. It is hoped that future longitudinal research addressing specific questions about the temporal course of stress will begin to provide us with a better understanding about how these issues should be treated.

## Matching Measures, Designs, and Research Questions

The choice of appropriate stress measures depends on the *disease* (or stage of disease) under study, on the *specific question* posed by the investigator about the relation between stress and disease, and on other *methodological and practical issues*. Although we discuss each of these criteria separately, all three criteria need to be optimized if the most appropriate measure is to be selected.

### Matching the Temporal Courses of the Stress Measure and Disease

Choosing an appropriate stress measure requires investigators to be informed about the disease outcome they are studying. Of particular importance is an understanding of the *temporal course* of the disease or disease stage under investigation (Cohen, Kaplan, & Manuck, 1994; Cohen & Matthews, 1987). Take, for example, the possible role of stressors in coronary artery disease (CAD). Atherosclerosis (occlusion of the coronary arteries) does not occur suddenly, over a few weeks or months, or even over several years. Instead it develops over decades. What kind of stressor measure would be most appropriate in studying the potential impact of stressors on CAD? Answering this question requires the investigator first to specify plausible pathways through which stressors might influence the development of the disease. Logically, there are two primary ways in which stressors could play a part in a disease with this course of development. First, a traumatic stressful event or events might trigger behavioral or biological processes that contribute to the *onset* of a disease process. After this process is set into action, the disease could then develop over many years. In this case, the trigger could occur at any time in the life course. Testing this assumption would require a technique that allows for reporting and timing of traumatic events over several decades, such as appropriately adapted event interviews or checklists. Second, long-term exposure to a chronic stressful experience might facilitate the development of disease during stressor exposure. Exposure to a chronic stressor might result in permanent or at least long-term psychological, biological, and behavioral responses that alter the progression of the disease. This hypothesis assumes exposure to chronic stressor(s) and hence requires measurement of chronic stressor experiences. Alternative types of measures include event interviews focusing on chronic experiences and scales designed to assess specific chronic stressors such as marital discord, unemployment, and disability. Obviously, measures assessing acute stressful events such as daily events, or acute stress perceptions or stress responses such as perceived stress, and negative affect measures would be inappropriate in testing either of these hypotheses. An alternative example is the role of stressors in triggering heart attacks (myocardial infarctions). The assumption in this case is that sudden and acute stressful experiences trigger coronary events (Cohen, Kaplan, & Manuck, 1994). Here, acute measures of life events, perceived stress, and negative affect would be appropriate, whereas chronic strain measures covering months or years would be inappropriate.

Other models are possible, and these are intended only as examples. Our point is that investigators need to understand enough about the course of a disease outcome to be able to generate hypotheses about the *duration and timing* of stressor, appraisal, or stress-response exposure required to influence disease onset or progression. With this information, they can choose a stress measure with a temporal span that matches that of the disease process. Different hypotheses may imply very different types of measures as well as different research designs.

## Posing a Specific Question About the Relations Between Stress and Disease

The most important issue in designing a research study is to state clearly the question an investigator wants to answer. The more specific the question, the more guidance it provides for choice of instruments and study design. Global questions—for example, What role do stress-related physiological responses play in overall health?—are important. However, a specific question—for example, Does increased heart rate responsivity mediate the relationship between environmental stressors and the development of cardiovascular disease?—is required for the development of a research protocol and selection of appropriate instruments.

The model in Figure 1.1 suggests a variety of questions one might ask about the relation between stress and disease. In this section, we give examples of some of these questions and of the types of measures one would use for each.

When studying the relation between *environmental demands* and health, the focus is on characterizing the environment or environmental/social changes that influence the onset or progression of disease. As discussed earlier, the majority of research in this area has focused on stressful life events. Event characteristics can include the type or domain of events, the magnitude of events, the temporal characteristics of events, or the nature of relations between combinations of events. Part II of this volume addresses different approaches to assessing environmental demands including checklist life event measurement (Chapter 2), interview measurement of stressful events (Chapter 3), daily and within-day event measurement (Chapter 4), and chronic stressor measurement (Chapter 5). Life event measures, whether checklist or interview, are generally used to assess the *cumulative* impact of events over a prolonged period (ranging from 3 months to a life-time, although these measures most often span a period of 6 months to 2 years). Sophisticated versions of these measures can also provide additional information about the context in which the events occurred to aid in determining the potential impact of the events. For example, in the case of a natural disaster, some people will lose all of their possessions and perhaps even some of their loved ones, whereas others will suffer only minor property loss or be fortunate enough to avoid any loss whatsoever. One would expect this variability to influence the stress perceptions and responses. The sensitivity of event measurement can be improved to the extent that a measurement technique allows this kind of information to be obtained.

Chronic stressor measures generally assess the impact of *individual* stressors that last for prolonged (but often unspecified) periods—for example, enduring economic, work, or marital problems. Although such measures can focus solely on environmental events, they also include assessments of long-lasting appraisals or affective responses to specific environmental characteristics. Finally, daily and within-day event measures are generally used to assess the cumulative impact of the events that occur during a single day. Most of these events (or hassles) are so small that they would not be considered contributors to perceived stress and stress-responses when the other, more chronic approaches to event measurement are employed. Daily event measures have many of the same characteristics of major event measures. For example, they can be used to examine the importance of specified domains of events and to elicit information about the meaning and impact of individual events. They are generally employed in studies of the role of very acute (simultaneous or 1- or 2-day lag) changes in health. However, if administered over long periods of time, they can also be used to assess persistent difficulties and nagging day-to-day problems that continue for long periods of time.

As discussed earlier, appraisals refer to the psychological interpretation of events as demanding, threatening, or challenging as opposed to benign (Lazarus & Folkman, 1984). The study of stress appraisal focuses on what are often termed *vulnerability factors*—the nature of persons and their contexts that make them more or less vulnerable to stress-induced disease. For example, variables such as social support and feelings of control that are thought to contribute to adaptive capacities and hence to protect persons from the pathogenic effects of stressful events are thought to act by short-circuiting the appraisal of stress. Alternatively, variables like type A behavior pattern are thought to increase vulnerability to stressful event-induced disease by accentuating stressor appraisal (Cohen & Edwards, 1989). One can also address whether the type of (or reason for) appraisal plays a role in disease risk. For example, events can be viewed as stressful because of the excessive demands they represent, potential bodily or psychological harm, or because of a high level of challenge (Lazarus & Folkman, 1984). Like stressor measures, measures of appraisal may also assess cumulative perceptions of stress combining responses to multiple events or may assess responses to specific individual events. Measurement of stressor appraisal is discussed in Chapter 6.

Environmental demands that are appraised as stressful are generally thought to influence disease risk through negative emotional responses. Although this association is commonly accepted, there are many interesting unanswered questions about the role of emotion in the stress process. For example, do different stressors produce different emotions? Do the same stressors produce different emotions in different people? Are certain types of emotional response associated with certain types of biological responses or diseases? Do positive and negative emotional responses have the same or opposite effects on biological responses and disease risk? There are several alternative approaches to categorizing emotions that are represented by different measurement techniques. For example, emotions can be categorized on the basis of valence (positive or negative), level of associated arousal, or emotional states such as anxiety, depression, and anger. Choice of the appropriate scale should be based on how close a specific breakdown approximates the question about emotional response that the investigator is concerned with. For example, a study of the role of stress in depressive disorder may focus on a measure of depressed mood, whereas a study of emotion as a pathway linking events to immunity or physical disease may require an assessment of the whole range of emotions. A discussion of the different approaches to the measurement of emotional response to stress is presented in Chapter 7 of this volume.

Similar questions can be asked about physiological responses to stress. Do different stressors have similar influences on responses of the cardiovascular, endocrine, and immune systems? Do the same stressors produce different physiological responses in different people? Do different kinds of appraisal produce differential physiological responses? Endocrine and cardiovascular measures have traditionally been used as biological indicators of stress. As discussed earlier, a variety of hormones have been found to be altered by stressors, appraisals, and negative affective responses, and these hormones have been implicated in the pathogenesis of a wide range of mental and physical disease outcomes. However, there are tremendous differences in the characteristic response of different hormones and in their potential importance for specific disease outcomes. One important response characteristic that is essential in choosing a hormonal measure is the temporal course of the response. Some hormones respond quickly or return to baseline quickly, whereas others have a delayed response or slow recovery. Chapter 8 discusses issues in choosing hormone measures. Cardiovascular measures also differ in their importance as potential precursors of different cardiovascular disorders and in their sensitivity and course of response. These measures are discussed in Chapter 9. Immune measures have not traditionally been viewed as indicators of stress. In fact, it is only recently that stressors, appraisals, and negative affect have been closely tied to immune response (see reviews by Herbert & Cohen, 1993a; 1993b). We include a chapter on immune response here because of the increased interest in the role of stress associated immune changes in physical and psychiatric disorders (Rabin et al., 1989). Individual immune measures differ substantially in both their associations with other categories of stress measures, and their implications for disease susceptibility. Chapter 10 discusses these differences and suggests appropriate criteria for choosing immune measures.

Up to now, our discussion has focused primarily on the questions that can be asked within each of the traditional perspectives. However, our hope is that the model we have presented will encourage broader views of the stress process. In particular, it suggests the possibility of studies integrating multiple perspectives. At the simplest level, one could test the basic assumptions of the model. For example, do stressful events that result in perceptions of stress increase disease risk through changes in biological responses and health practices? Studies combining perspectives have the potential to answer many of the most important questions about the role of stress in disease.

## Methodological and Practical Considerations

We feel that it is inappropriate to discuss measurement as if it were the most important issue in designing studies of the relation between stress and illness. We consider appropriate and unbiased sampling, study designs that maximize the ability to make causal inferences, and appropriate statistical analyses equally important criteria for any study (e.g., Cohen et al., 1986; Kessler, 1987). Our choice, in this volume, to focus on measurement is based on our perception that the literature has failed to deal adequately with issues involved in the appropriate selection of stress measures and that compendia of available instruments are lacking. Our focus on measurement, however, does not imply that we feel that measurement is more important than any of these other considerations. Good measurement does not compensate for weak or poor study design.

Because of limitations of space and our desire to maintain a coherent focus on measurement, we cannot adequately address the issues involved in designing studies of stress and disease. However, there are design issues that influence the choice of a measure and hence need to be raised in this context. The central concern is the importance of the interplay of the stress measure and the outcome. We introduced this problem earlier in the discussion of the need to match the temporal courses of the stress measure and the disease. However, there are other issues as well. A common problem is the use of stress and outcome measures that assess closely related if not identical concepts. This overlap (or confounding) is often a problem in studies of psychiatric symptoms since measures of symptoms and stress appraisal often include similar if not identical items (Dohrenwend & Shrout, 1985). Similarly, stressful life event scales often include serious illness and hospitalization as events. These (and other) items overlap with outcome measures assessing serious physical or psychiatric illness (Rabkin & Struening, 1976). The possibility of this type of bias is maximized in cross-sectional designs, and minimized in prospective designs where a stress measurement is used to predict changes in the outcome from the point of measurement to a follow-up. It can also be minimized by selecting stress measures that are not confounded with an outcome or by carefully removing items from a scale that are potentially confounded with an outcome. This last procedure must be done with great care since dropping items may alter the psychometric characteristics of the scale or bias the domain that the scale assesses. For example, removing hospitalization decreases the overlap of the life event and disease measures, but also results in the omission of a potentially important and impactful stressful event.

Another problem is the potential for shared response biases that occur when the same type of measurement method is used to assess both stress and outcome. Take, for example, paper-and-pencil self-reports. These types of measures are influenced by a range of idiosyncratic response biases such as responding positively and avoiding extreme responses. If this method is used in assessing both stress and outcome, the relation between these measures will be artificially inflated because it will reflect the identical bias tendencies picked up by both measures. This problem can be avoided by using different methods—for example, a paper-and-pencil stress measure and biological or behavioral outcome.

Realistically, practical limitations and limited resources often prevent the use of measures of stress that one would choose based solely on the conceptual and methodological issues discussed earlier. Primary among these considerations is the amount of *time required from subjects*. Studies employing multiple measures, those conducted over the phone, and those with samples to whom there is limited access or among whom there is limited interest, often require stress measures that take a minimal amount of time. As a consequence, interview measures and detailed self-report measures may not be appropriate in these cases. *Cost of administration* is another important consideration. For example, although interview measures of stressful events provide more sensitive measurement of events and their contexts, they require hours of effort by trained personnel, including the interview process itself as well as labor-intensive coding of materials. Choices based on the cost and time of instrument administration require the researcher to balance these constraints with the need for measurement accuracy.

## Moderators of the Relation Between Stressors and Disease Risk

Correlations between life events and illness have rarely risen above .30, suggesting that life events may account for less than 10 percent of the variance in illness. A number of investigators have proposed that relations between stress and illness vary with preexisting vulnerability factors (see reviews by Cohen & Edwards, 1989; Cohen & Wills, 1985; Kessler & McLeod, 1985). That is, differences in social support systems, skills, attitudes, beliefs, and personality characteristics render some persons relatively immune to stress-induced illness and others relatively susceptible. Although this book does not directly address the issues of moderation, interest in moderation does have implications for the choice of stress measurement. As we noted earlier, moderators are often thought to act through their effects of stress appraisal. For example, a person may not view potentially threatening events as stressful if they believe that their social network will aid them in coping. However, moderators could act at any stage in the stress process. For example, social networks may enforce norms about both emotional and behavioral responses to events that are appraised as stressful. By specifying the point in the stress process where moderation is thought to occur, one can choose the type of stress measure most likely to demonstrate moderation. Again, the choice of the appropriate assessment tool depends on the questions under consideration.

## Purpose and Organization of the Book

The purpose of the proposed volume is to serve as a resource for state-of-the-art assessment of stress in studies of physical and psychiatric illness in humans. Our major goal in producing the volume is to aid researchers in making decisions about the appropriate measures to use in specific studies. In this chapter we provided a broad conceptual overview of stress and its relation to psychiatric and physical disorder. We have addressed the conceptualization of stress and how environmental, psychological, and biological approaches can answer different questions about the stress process. The overall theme of this chapter and of the volume is that the measures one selects should reflect the kinds of questions being asked and research designs employed. In Parts II through IV of the volume, we address three broadly defined types of stress measurement: environmental demands, psychological stress, and biological stress. We do not attempt to cover all the measures that might broadly be construed as falling in these categories. Instead we choose those that we believe will be of interest to the broadest possible audience. For example, we do not discuss measures of physical environment such as noise and air pollution, behavior changes such as deficits in task performance, or maladaptive coping responses such as smoking and drinking, or alternative biological stress responses such as skin conductance, eye movement and pupillary diameter, or muscle tension. The exclusion of these measures does not imply that they are not as important as or more important than those we discuss. It merely reflects our decision to address a few of the most central categories of measures in depth rather than try to cover all possible measures superficially.

Each chapter provides a conceptual underpinning of the approach it addresses, discusses the important measures within the approach, the kinds of studies suited to each, and the various costs and benefits of using each alternative measure. The purpose of these chapters is to aid researchers in making decisions about the appropriate measures to use in specific studies. Questions addressed in each chapter include: What kinds of questions about the relation between stress and illness can be answered using this kind of measure? Under what conditions would an investigator use one version of a measure versus another? What are the kinds of study designs in which this particular measure works well? What are the logistical issues that must be considered in using this measure? What is known about the psychometrics of these kinds of measures (and, when appropriate, specific measures)? Are these measures population sensitive, and are appropriate measures available for different populations? What are the key references for finding the measures, the psychometrics, and instructions for use? Our intent is to provide valuable information for audiences with a wide range of expertise; to aid persons without extensive experience, but at the same time to provide sufficient information for experts to select state-of-the-art measurement instruments.

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American Psychologist, Vol 55(1), Jan 2000, 110-121.

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Positive emotional states may promote healthy perceptions, beliefs, and physical well-being itself. To explore potential mechanisms linking pleasant feelings and good health, the authors consider several lines of research including (a) direct effects of positive affect on physiology, especially the immune system, (b) the information value of emotional experiences, (c) the psychological resources engendered by positive feeling states, (d) the ways in which mood can motivate health-relevant behaviors, and (e) the elicitation of social support. As anticipated by the Greek physician Hippocrates, positive emotions and healthy outcomes may be linked through multiple pathways. (PsycINFO Database Record (c) 2010 APA, all rights reserved)

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# Stress-induced changes in cerebral metabolites, hippocampal volume, and cell proliferation are prevented by antidepressant treatment with tianeptine

Boldizsár Czéh*, Thomas Michaelis†, Takashi Watanabe†, Jens Frahm†, Gabriel de Biurrun*, Marja van Kampen*, Alessandro Bartolomucci*, and Eberhard Fuchs*‡

+ Author Affiliations

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Communicated by Bruce S. McEwen, The Rockefeller University, New York, NY (received for review June 16, 2001)

## Abstract

Stress-induced structural remodeling in the adult hippocampus, involving debranching and shortening of dendrites and suppression of neurogenesis, provides a cellular basis for understanding the impairment of neural plasticity in the human hippocampus in depressive illness. Accordingly, reversal of structural remodeling may be a desirable goal for antidepressant therapy. The present study investigated the effect of tianeptine, a modified tricyclic antidepressant, in the chronic psychosocial stress model of adult male tree shrews (*Tupaia belangeri*), a model with high validity for research on the pathophysiology of major depression. Animals were subjected to a 7-day period of psychosocial stress to elicit stress-induced endocrine and central nervous alterations before the onset of daily oral administration of tianeptine (50 mg/kg). The psychosocial stress continued throughout the treatment period of 28 days. Brain metabolite concentrations were determined *in vivo* by proton magnetic resonance spectroscopy, cell proliferation in the dentate gyrus was quantified by using BrdUrd immunohistochemistry, and hippocampal volume was measured post mortem. Chronic psychosocial stress significantly decreased *in vivo* concentrations of *N*-acetyl-aspartate (−13%), creatine and phosphocreatine (−15%), and choline-containing compounds (−13%). The proliferation rate of the granule precursor cells in the dentate gyrus was reduced (−33%). These stress effects were prevented by the simultaneous administration of tianeptine yielding normal values. In stressed animals treated with tianeptine, hippocampal volume increased above the small decrease produced by stress alone. These findings provide a cellular and neurochemical basis for evaluating antidepressant treatments with regard to possible reversal of structural changes in brain that have been reported in depressive disorders.

neurogenesis||proton magnetic resonance spectroscopy||depression||hippocampus||tree shrew

## Footnotes

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See commentary on page 12320.

### Abbreviations

MRS,
: magnetic resonance spectroscopy;

NAA,
: *N*-acetyl-aspartate;

Cr,
: creatine and phosphocreatine;

Cho,
: choline-containing compounds;

Ins,
: *myo*-inositol;

HPA,
: hypothalamic-pituitary-adrenal;

NMDA,
: *N*-methyl-D-aspartate

Received June 16, 2001.
Accepted August 14, 2001.



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Vol. 19, No. 3, 2001

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Functional Gastrointestinal Disorders.
Editor: Peter Malfertheiner, Magdeburg

*Review Article*

## Role of Stress in Functional Gastrointestinal Disorders

### Evidence for Stress-Induced Alterations in Gastrointestinal Motility and Sensitivity

H. Mönnikes[a], J.J. Tebbe[b], M. Hildebrandt[a], P. Arck[a], E. Osmanoglou[a], M. Rose[a], B. Klapp[a], B. Wiedenmann[a], I. Heymann-Mönnikes[a]

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*Dig Dis* 2001;19:201-211 (DOI: 10.1159/000050681)

### Key Words

- Stress
- Functional gastrointestinal disorder
- Visceral sensitivity
- Gastrointestinal motility
- Irritable bowel syndrome

### Abstract

Psychological stress is widely believed to play a major role in functional gastrointestinal (GI) disorders, especially irritable bowel syndrome (IBS), by precipitating exacerbation of symptoms. The available data clearly demonstrate that inhibition of gastric emptying and stimulation of colonic transit is the most consistent pattern in the motility response of the GI tract to acute or short-term stress. Thus, one might propose that these alterations might play a pathophysiological role in dyspeptic symptoms and alterations in stool frequency and consistency in patients with stress-related functional GI disorders. Taken together, the above-mentioned studies suggest that the colonic motor response to stress is exaggerated in IBS. There is evidence that an increased emotional response is associated with this difference in colonic, and perhaps also gastric motor responses to certain stressors. However, almost no valid data are available so far from human studies addressing the question if differences in motility responses to stress between patients with functional GI disorders and healthy subjects are due to an altered stress response associated with an imbalance of the autonomic nervous system or increased stress susceptibility. We can summarize that in experimental animals the most consistent pattern of GI motor alterations induced by various psychological and physical stressors is that of delaying gastric emptying and accelerating colonic transit. Endogenous corticotropin-releasing factor (CRF) in the brain plays a significant role in the central nervous system mediation of stress-induced inhibition of upper GI and stimulation of lower GI motor function through activation of brain CRF receptors. The inhibition of gastric emptying by CRF may be mediated by interaction with the CRF-2 receptor, while CRF-1 receptors are involved in the colonic and anxiogenic responses to stress. Endogenous serotonin, peripherally released in response to

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stress, seems to be involved in stress- and central CRF-induced stimulation of colonic motility by acting on 5HT-3 receptors. Taken together, the limited data available from investigations in healthy subjects and patients with functional GI disorders provide some evidence that stress affects visceral sensitivity in humans. Acute psychological stress seems to facilitate increased sensitivity to experimental visceral stimuli, if the stressor induces a significant emotional change. In summary, studies in experimental animals suggest that stress-induced visceral hypersensitivity is centrally mediated by endogenous CRF and involvement of structures of the emotional motor system, e.g. the amygdala. Stress-induced activation or sensitization of mucosal mast cells in the GI tract seem to be involved in stress-associated alterations of visceral sensitivity.



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### Article Information

Number of Print Pages : **11**
Number of Figures : **0**, Number of Tables : **2**, Number of References : **91**



00001671

Review

# The Concepts of Stress and Stress System Disorders

**Overview of Ph**



George P. Chrousos, MD; Philip W. Gold, MD



From the Developmental Endocrinology Branch, National Institute of Child Health and Human Development (Dr Chrousos), and the Clinical Neuroendocrinology Branch, National Institute of Mental Health (Dr Gold), National Institutes of Health, Bethesda, Md.

*JAMA*. 1992;267(9):1244-1252. doi: 10.1001/jama.1992.03480090092034

## ABSTRACT

**Objective.** —This article defines stress and related concepts and reviews their historical development. The notion of a stress system as the effector of the stress syndrome is suggested, and its physiologic and pathophysiologic manifestations are described. A new perspective on human disease states associated with dysregulation of the stress system is provided.

**Data Sources.** —Published original articles from human and animal studies and selected reviews. Literature was surveyed utilizing MEDLINE and the *Index Medicus*.

**Study Selection.** —Original articles from the basic science and human literature consisted entirely of controlled studies based on verified methodologies and, with the exception of the most recent studies, replicated by more than one laboratory. Many of the basic science and clinical studies had been conducted in our own laboratories and clinical research units. Reviews cited were written by acknowledged leaders in the fields of neurobiology, endocrinology, and behavior.

**Data Extraction.** —Independent extraction and cross-referencing by the authors.

**Data Synthesis.** —Stress and related concepts can be traced as far back as written science and medicine. The stress system coordinates the generalized stress response, which takes place when a stressor of any kind exceeds a threshold. The main components of the stress system are the corticotropin-releasing hormone and locus ceruleus-norepinephrine/autonomic systems and their peripheral effectors, the pituitary-adrenal axis, and the limbs of the autonomic system. Activation of the stress system leads to behavioral and peripheral changes that improve the ability of the organism to adjust homeostasis and increase its chances for survival. There has been an exponential increase in knowledge regarding the interactions among the components of the stress system and between the stress system and other brain elements involved in the regulation of emotion, cognitive function, and behavior, as well as with the axes responsible for reproduction, growth, and immunity. This new knowledge has allowed association of stress system dysfunction, characterized by sustained hyperactivity and/or hypoactivity, to various pathophysiologic states that cut across the traditional boundaries of medical disciplines. These include a range of psychiatric, endocrine, and inflammatory disorders and/or susceptibility to such disorders.

**Conclusions.** —We hope that knowledge from apparently disparate fields of science and medicine integrated into a working theoretical framework will allow generation and testing of new hypotheses on the pathophysiology and diagnosis of, and therapy for, a variety of human illnesses reflecting systematic alterations in the principal effectors of the generalized stress response. We predict that pharmacologic agents capable of altering the central apparatus that governs the stress response will be useful in the treatment of many of these illnesses.

(*JAMA*. 1992;267:1244-1252)

## FOOTNOTES

Reprint requests to National Institutes of Health, Bldg 10, Room 10N262, Bethesda, MD 20892 (Dr Chrousos).

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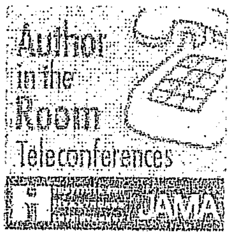


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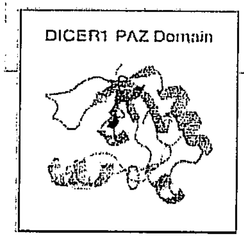


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# Chronic Fatigue Syndrome and High Allostatic Load: Results From a Population-Based Case-Control Study in Georgia

American Psychosomatic Society

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HighWire

Elizabeth M. Maloney, DrPH, MS, Roumiana Boneva, MD, PhD, Urs M. Nater, PhD and William C. Reeves, MD, MSc

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## Abstract

Objective: To confirm the association of chronic fatigue syndrome (CFS) with high allostatic load (AL) level, examine the association of subsyndromal CFS with AL level, and investigate the effect of depression on these relationships and the association of AL with functional impairment, fatigue, symptom severity, fatigue duration, and type of CFS onset. AL represents the cumulative physiologic effect of demands to adapt to stress.

Methods: Population-based case-control study of 83 persons with CFS, 202 persons with insufficient symptoms or fatigue for CFS (ISF), and 109 well controls living in Georgia. Unconditional logistic regression was used to generate odds ratios (ORs) as measures of the association of AL with CFS.

Results: Relative to well controls, each 1-point increase in allostatic load index (ALI) was associated with a 26% increase in likelihood of having CFS ($OR_{adjusted}$ = 1.26, 95% Confidence Interval (CI) = 1.00, 1.59). This association remained in the presence and absence of depression ($OR_{adjusted}$ = 1.35, CI = 1.07, 1.72; $OR_{adjusted}$ = 1.35, CI = 1.10, 1.65). Compared with the ISF group, each 1-point increase in ALI was associated with a 10% increase in likelihood of having CFS ($OR_{adjusted}$ = 1.10, CI = 0.93, 1.31). Among persons with CFS, the duration of fatigue was inversely correlated with ALI ($r = -.26$, $p = .047$).

Conclusions: Compared with well controls, persons with CFS were significantly more likely to have a high AL. AL increased in a gradient across well, ISF, and CFS groups.

CFS allostatic load case-control population-based Georgia SF-36

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# Perspectives

*Nature Reviews Immunology* **5**, 243-251 (March 2005) | doi:10.1038/nri1571

# Stress-induced immune dysfunction: implications for health

**Ronald Glaser & Janice K. Kiecolt-Glaser**

**Folk wisdom has long suggested that stressful events take a toll on health. The field of psychoneuroimmunology (PNI) is now providing key mechanistic evidence about the ways in which stressors — and the negative emotions that they generate — can be translated into physiological**

**changes. PNI researchers have used animal and human models to learn how the immune system communicates bidirectionally with the central nervous and endocrine systems and how these interactions impact on health.**

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**Janice K. Kiecolt-Glaser**



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# Stress and the Individual

## Mechanisms Leading to Disease

Bruce S. McEwen, PhD; Eliot Stellar, PhD

*Arch Intern Med.* 1993;153(18):2093-2101.

### Abstract

Objective
This article presents a new formulation of the relationship between stress and the processes leading to disease. It emphasizes the hidden cost of chronic stress to the body over long time periods, which act as a predisposing factor for the effects of acute, stressful life events. It also presents a model showing how individual differences in the susceptibility to stress are tied to individual behavioral responses to environmental challenges that are coupled to physiologic and pathophysiologic responses.

Data Sources
Published original articles from human and animal studies and selected reviews. Literature was surveyed using MEDLINE.

Data Extraction
Independent extraction and cross-referencing by us.

Data Synthesis
Stress is frequently seen as a significant contributor to disease, and clinical evidence is mounting for specific effects of stress on immune and cardiovascular systems. Yet, until recently, aspects of stress that precipitate disease have been obscure. The concept of homeostasis has failed to help us understand the hidden toll of chronic stress on the body. Rather than maintaining constancy, the physiologic systems within the body fluctuate to meet demands from external forces, a state termed *allostasis*. In this article, we extend the concept of allostasis over the dimension of time and we define *allostatic load* as the cost of chronic exposure to fluctuating or heightened neural or neuroendocrine response resulting from repeated or chronic environmental challenge that an individual reacts to as being particularly stressful.

Conclusions
This new formulation emphasizes the cascading relationships, beginning early in life, between environmental factors and genetic predispositions that lead to large individual differences in susceptibility tc stress and, in some cases, to disease. There are now empirical studies based on this formulation, as well as new insights into mechanisms involving specific changes in neural, neuroendocrine, and immune systems. The practical implications of this formulation for clinical practice and further research are discussed.

(Arch Intern Med. 1993;153:2093-2101)

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From the Department of Psychology, Yale University, New Haven, Conn.



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**Health Psychology: Psychological Factors and Physical Disease from the Perspective of Human Psychoneuroimmunology**

Journal article by Sheldon Cohen, Tracy B. Herbert; Annual Review of Psychology, Vol. 47, 1996

## Journal Article Excerpt See below...





**Health psychology: psychological factors and physical disease from the perspective of human psychoneuroimmunology.**

by Sheldon Cohen , Tracy B. Herbert

INTRODUCTION

Much of psychoneuroimmunology's popularity with both the public and the psychological community derives from its promise to explore and explain the common belief that our personalities and emotions influence our health. Can depression, anxiety, psychological distress, social support, or an optimistic view alter our ability to resist infection, autoimmune diseases, or cancer? What are the biological pathways through which psychological characteristics and states yield physical changes? Can we alter immunity and hence disease susceptibility through psychological intervention? Several hundred studies published in the past decade address the relation of psychological characteristics and states to immune function and to health outcomes thought to be determined by immune alterations. In this chapter we highlight what we have learned about the importance of immunity as a link between the mind and the body.

WHAT IS PSYCHONEUROIMMUNOLOGY?

Psychoneuroimmunology (PNI) is the study of the interrelations between the central nervous system and the immune system. The term interrelations is used because the assumption is that the relations are bidirectional. Work with animals has advanced our understanding of this bidirectionality and has provided evidence for nerves connecting the central nervous system (CNS) and the immune system (e.g. Felten et al 1985), for neuroendocrine-induced alterations of specific immune functions (e.g. Shavit et al 1984), and for the existence of chemicals called cytokines that are produced by the immune system, cross the blood-brain barrier, and alter the function of the CNS (review in Rabin et al 1989). An important step in establishing that the CNS and immune system interact was accomplished by psychologists working with animal models who demonstrated that immune system change could be induced by classically conditioned stimuli (review in Ader & Cohen 1993).

The interests of psychoneuroimmunologists working with humans overlap with those of animal researchers, but human psychoneuroimmunologists' emphases are different. Examples of overlap in focus include studies of classical conditioning of human immune response (e.g. Bovbjerg et al 1990, Buske-Kirschbaum et al 1992) and demonstrations of immune-system effects on the CNS as reflected in human performance (Smith et al 1988). The most obvious difference, however, is that the human literature is primarily concerned with behavior and psychological traits and states as drivers of CNS and immune response. The major foci of human studies include establishing whether there is an association between psychological traits and states and immunity, what the biological and behavioral pathways are that are responsible for such relations, and whether psychologically induced changes in immunity are responsible for changes in susceptibility to immune system-mediated disease.

WHAT IS IMMUNE FUNCTION?

The Immune System

The immune system protects the body from damage by invading microorganisms--bacteria, viruses, fungi, and parasites. These foreign materials are called antigens. Most immune system cells are located in the bone marrow, thymus, lymph nodes, spleen, tonsils, appendix, and Peyer's patches (clumps of immune tissue in the small intestines). Because there is no easy way to access the cells of these organs, PNI work with humans is primarily limited to the study of immune processes occurring in circulating peripheral blood. Circulating blood transports immune components between organs of the immune system and sites of inflammation. Components of the immune system that circulate in blood (e.g. some types of white blood cells and antibody) survey for and combat against invading antigens. Therefore, peripheral blood plays a key role in inflammatory and immune processes.

Tests of Immune Function

In this section, we describe the immune system tests most commonly used in human PNI research. Most of the tests evaluate the role of immune cells in peripheral blood.

ENUMERATIVE TESTS The enumerative assay most often used involves simply counting the numbers or percentages of different kinds of white blood cells in the peripheral blood. The white blood cells relevant to this chapter are neutrophils, monocytes, and lymphocytes, including natural killer (NK), T, and B lymphocytes. Quantifying the number of circulating cells is important both because the body cannot respond adequately to antigenic response without a minimum number of each type of immune cell and because an optimal response requires a balance of the various cell types. Both increases and decreases in numbers of circulating cells suggest alterations in the immune system. However, the changes found in the PNI literature are usually quite small, and whether these changes indicate compromised immune function is theoretically unclear.

FUNCTIONAL TESTS Immune response can be divided into cellular immunity, in which immune cells directly combat antigens, and ...



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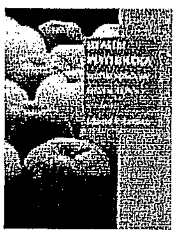
# Health psychology : biopsychosocial interactions, (5th Ed.)

## Auteur : SARAFINO Edward P



Prix indicatif 51,39 €
Date de parution : 04-2005
Langue : ANGLAIS
576p. 23.9x19.5 Hardback
Disponible chez l'éditeur (délai d'approvisionnement : 10 jours).

## Résumé de *Health psychology : biopsychosocial interactions, (5th Ed.)*

This highly readable overview of health psychology emphasizes health maintenance and illness prevention, describing complicated physiological processes in a clear and engaging manner. It integrates contemporary research in biology, psychology, anthropology and sociology, utilizing the biopsychosocial model as the basic explanatory theme for health and health care. Along with numerous case vignettes and illustrations, the book also offers well-referenced material and intriguing discussions of important studies and conceptual models.

## Sommaire de *Health psychology : biopsychosocial interactions, (5th Ed.)*



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System. Clinical Methods and Issues: Biofeedback Treatment for Paralysis. Module 2: The Endocrine System. The Endocrine and Nervous Systems Working Together. Adrenal Glands. Other Glands. Module 3: The Digestive System. Foods Journey Through Digestive Organs. Highlight: Our Physiological Individuality. Using Nutrients in Metabolism. Assess Yourself: How Many Calories Do You BurnWhile Resting? Module 4: The Respiratory System. The Respiratory Tract. Respiratory Function and Disorders. Module 5: The Cardiovascular System. The Heart and Blood Vessels. Blood Pressure. Blood Composition. Cardiovascular Disorders. Module 6: The Immune System. Antigens. The Organs of the Immune System. Highlight: When Immune Functions Are Absent. Soldiers of the Immune System. Defending the Body with an Immune Response. Less-Than-Optimal Defenses. . **Part 2: Stress, Illness, and Coping .** Chapter 3. StressIts Meaning, Impact, and Sources. Experiencing Stress in Our Lives. What Is Stress? Appraising Events as Stressful. Clinical Methods and Issues Posttraumatic Stress Disorder. Dimensions of Stress. Biopsychosocial Aspects of Stress. Biological Aspects of Stress. Psychosocial Aspects of Stress. Sources of Stress Throughout Life. Sources Within the Person. Sources in the Family. Highlight: Gender Differences in Caregiving? Sources in the Community and Society. Measuring Stress. Physiological Arousal. Life Events. Daily Hassles. Assess Yourself: Hassles in Your Life. Can Stress Be Good for You? Chapter 4. Stress, Biopsychosocial Factors, and Illness. Psychosocial Modifiers of Stress. Social Support. Assess Yourself: How Much Emotional Support Do You Get? A Sense of Personal Control. Clinical Methods and Issues: Social Support, Therapy, and Cognitive Processes. A Hardy Personality. Type A and Type B Behavior Patterns. How Stress Affects Health. Stress, Behavior, and Illness. Stress, Physiology, and Illness. Highlight: Sudden Death. Psychoneuroimmunology. Psychophysiological Disorders. Digestive System Diseases. Asthma. Recurrent Headache. Other Disorders. Stress and Cardiovascular Disorders. Hypertension. Coronary Heart Disease. Stress and Cancer. Chapter 5. Coping with and Reducing Stress. Coping with Stress. What Is Coping? Functions and Methods of Coping. Assess Yourself: Your Focuses in Coping. Reducing the Potential for Stress. Enhancing Social Support. Improving Ones Personal Control. Organizing Ones World Better. Highlight: The Amish Way of Social Support in Bereavement. Exercising: Links to Stress and Health. Preparing for Stressful Events. Reducing Stress Reactions: Stress Management. Medication. Behavioral and Cognitive Methods. Clinical Methods and Issues: The Case of . Massage, Meditation, and Hypnosis. Using Stress Management to Reduce Coronary Risk. Modifying Type A Behavior. Treating Hypertension. . **Part 3: Lifestyles to Enhance Health and Prevent Illness .** Chapter 6. Health-Related Behavior and Health Promotion. Health and Behavior. Lifestyles, Risk Factors, and Health. Highlight: Two Health Behaviors: Breast and Testicular Examinations. Interdisciplinary Perspectives on Preventing Illness. Problems in Promoting Wellness. What Determines Peoples Health-Related Behavior. General Factors in Health-Related Behavior. The Role of Beliefs and Intentions. The Role of Less Rational Processes. Developmental, Gender, and Sociocultural Factors in Health. Development and Health. Gender and Health. Sociocultural Factors and Health. Programs for Health Promotion. Methods for Promoting Health. Clinical Methods and Issues: Dialogues to Help People Stop Smoking. Promoting Health in the Schools. Worksite Wellness Programs. Community-Based Wellness Programs. Assess Yourself: Your Knowledge about AIDS. Prevention with Specific Targets: Focusing on AIDS. Chapter 7. Substance Use and Abuse. Substance Abuse. Addiction and Dependence. Processes Leading to Dependence. Smoking Tobacco. Who Smokes, and How Much? Why People Smoke. Smoking and Health. Highlight: Does Someone Elses Smoking Affect Your Health? Alcohol Use and Abuse. Who Drinks, and How Much? Assess Yourself: Whats True About Drinking? Why People Use and Abuse Alcohol. Assess Yourself: Do You Abuse Alcohol? Drinking and Health. Drug Use and Abuse. Highlight: Types and Effects of Drugs. Who Uses Drugs, and Why? Drug Use and Health. Reducing Substance Use and Abuse. Preventing Substance Use. Quitting a Substance without Therapy. Treatment Methods to Stop Substance Use and Abuse. Highlight: Where Should Alcohol and Drug Abuse Treatment Occur, and What Should Be the Goals and Criteria for Success? Clinical Methods and Issues: Behavioral Methods for Treating Substance Abuse. Dealing with the Relapse Problem. Chapter 8. Nutrition, Weight Control and Diet, Exercise, and Safety. Nutrition. Components of Food. What People Eat. Nutrition and Health. Weight Control and Diet. Desirable and Undesirable Weights. Becoming Overly Fat. Dieting and Treatments to Lose Weight. Highlight: Which to Avoid. Clinical Methods and Issues: Problem-Solving Training to Control Weight. Anorexia and Bulimia. Assess Yourself: Your Weight Control Patterns. Exercise. Highlight: Types and Amounts of Healthful Exercise. The Health Effects of Exercise.

## Thème de *Health psychology : biopsychosocial interactions, (5th Ed.)*

- MEDECINE / SPECIALITES MEDICALES & CHIRURGICALES / Psychiatrie, Psychanalyse

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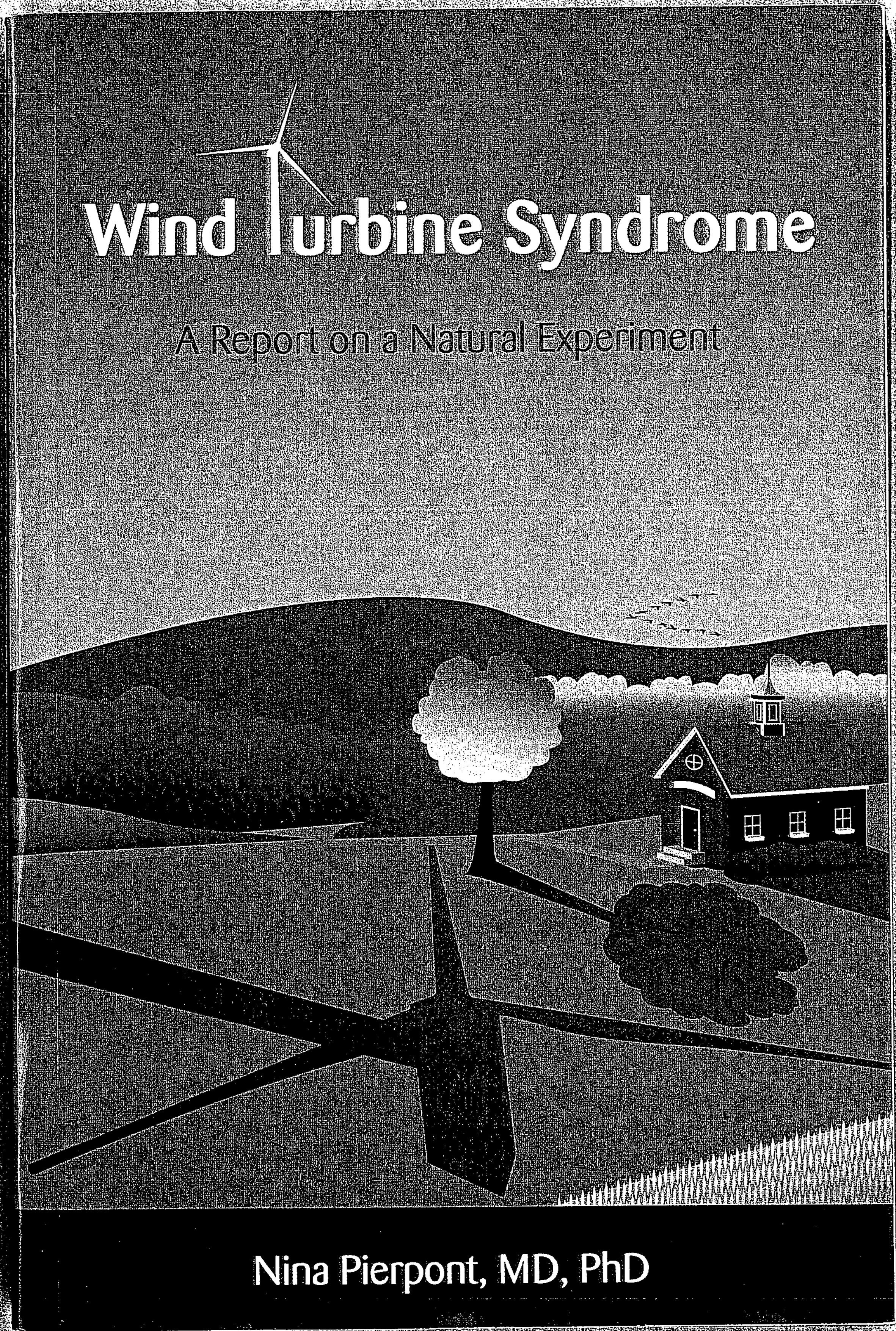
Wind Turbine Syndrome
A Report on a Natural Experiment
Nina Pierpont, MD, PhD

Designed and set in Warnock type by Jordan Klassen.
Printed in the United States of America by King Printing, Lowell, Mass.

**Publisher's Cataloging-in-Publication Data**
***(Provided by Quality Books, Inc.)***

Pierpont, Nina.
Wind turbine syndrome : a report on a natural experiment / Nina Pierpont.
p. cm.
Includes bibliographical references.
ISBN-13: 978-0-9841827-0-1
ISBN-10: 0-9841827-0-5

1. Vestibular apparatus—Diseases. 2. Wind turbines—Health aspects. 3. Syndromes. I. Title.

RF260.P54 2009 617.8'82
QBI09-600120

10 9 8 7 6 5 4 3 2 1



# Contents

# *Wind Turbine Syndrome: A Report on a Natural Experiment*

Nina Pierpont, MD, PhD

## *Executive Summary*

12/20/2009

The core of the book is a scientific report presenting original, primary research on symptomatic people living near large industrial wind turbines (1.5-3 MW) erected since 2004.

These are the findings:

1) Wind turbines cause Wind Turbine Syndrome. We know this because people have symptoms when they are close to turbines and the symptoms go away when they are away from turbines. The study families themselves figured out that they had to move away from turbines to be rid of their symptoms, and nine out of ten have moved. Some sold and some abandoned their homes.

2) People do not abandon their homes out of "annoyance." Reported symptoms, such as sleep deprivation, dizziness, and nausea, cannot be dismissed as "annoyances."

3) The symptom cluster is consistent from person to person, hence the term "syndrome."

4) The symptoms are sleep disturbance and deprivation, headache, tinnitus (ringing in ears), ear pressure, dizziness, vertigo (spinning dizziness), nausea, visual blurring, tachycardia (fast heart rate), irritability, problems with concentration and memory, and panic episodes associated with sensations of movement or quivering inside the body that arise while awake or asleep.

5) Children are affected as well as adults, especially older adults.

6) People with pre-existing migraine disorder, motion sensitivity, or damage to inner ear structures (such as hearing loss from industrial noise exposure) are more susceptible than other people to Wind Turbine Syndrome. These results are statistically significant ($p < 0.01$).

7) Wind Turbine Syndrome symptoms are not statistically associated with pre-existing anxiety or other mental health disorders.

8) The sample size of 10 families/38 people was large enough for statistical significance with regard to susceptibility or risk factors.

9) The susceptibility factors are clues to the pathophysiology of Wind Turbine Syndrome. The symptom complex resembles syndromes caused by vestibular (inner ear balance organ)

dysfunction. The proposed mechanism is disturbance to balance and position sense by noise and/or vibration, especially low frequency components of the noise and vibration.

10) An extensive review of recent medical literature reveals how balance-related neural signals affect a variety of brain areas and functions, including spatial awareness, spatial memory, spatial problem-solving, fear, anxiety, autonomic functions (like nausea and heart rate), and aversive learning. These known neural relationships provide a robust anatomic and physiologic framework for Wind Turbine Syndrome.

11) Medical and technical literature on the resonance of sound or vibration within body cavities (chest, skull, eyes, throat, ears) is reviewed, since study subjects experience these effects.

12) Published studies of documented low frequency noise exposure (both experimental and environmental) are reviewed. These demonstrate effects on people similar or identical to Wind Turbine Syndrome. Indeed, one study from Germany in 1996 may indeed be Wind Turbine Syndrome.

13) Recent mail-in survey studies of people who live near wind turbines in Sweden and the Netherlands are reviewed. These show that people are severely annoyed at noise from wind turbines at much lower A-weighted noise levels than for traffic, train, or aircraft noise.

14) Published literature documenting the effects of environmental noise on cardiovascular health and children's learning are reviewed. For health reasons, the World Health Organization recommends lower thresholds for nighttime noise than are currently observed in most countries —especially when the noise has low-frequency components.

15) Wind Turbine Syndrome gives a name and medical description to a set of symptoms severe enough to drive people from their homes and establishes medical risk factors for such symptoms. This study and other studies reviewed in the report indicate that safe setbacks will be at least 2 km (1.24 miles) and even longer for larger turbines and in more varied topography. Further research is needed to clarify physical causes and physiologic mechanisms, explore other health effects of living near wind turbines, determine how many people are affected, and investigate effects in special populations, including children. Government funding and moratoria are appropriate.

The book further includes:

A) Full case histories—the words and experiences of all the study subjects (including children), presented in an organized tabular format.

B) The report presented again in non-scientific, layman's language, explaining the medical, technical, and statistical aspects of the study. This section is illustrated.

C) Peer reviews and commentary by scientists and university physicians.

D) Introduction, complete list of scientific and medical references, glossary, and list of abbreviations.

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UMATILLA COUNTY
PLANNING DEPARTMENT

May 11, 2011

Umatilla County Commissioners
216 SE 4th Avenue
Pendleton, Oregon 97801

Dear Sirs,

Following a review of the Commissioner's "Yellow Paper" (proposed wind energy development codes) and a review of the recent work session as presented by Councilor Chesnut, the City Council of Milton-Freewater directed me to submit the following comments for inclusion in the record of your public hearing regarding the proposed wind energy development codes.

The City Council continues to be concerned that current development codes, and some of the proposed codes, do not adequately protect the residents and existing businesses in Umatilla County from the "off project" burdens which result from the siting of industrial wind energy facilities nearby.

The Council supports the inclusion/retention of the requirement for a socio-economic impact assessment as part of the permit application for a wind energy project. Such an assessment should address the socio-economic impacts of the wind project on the area surrounding the project. The "off project" negative business impacts to the established vineyard/winery/wine tourism industry in, and around, Milton-Freewater could be significant if wind projects are sited in visually important areas. In a study presented to the County Planning Commission, Dr. Bruce Sorte calculated the vineyard/winery businesses in the Milton-Freewater area contribute up to $53,475 of gross returns per acre of annual community economic effects. (see attached page, 7 of 10, from Dr. Sorte's presentation) Such a valuable, local, agricultural and tourism based industry deserves to be considered when decisions about siting commercial wind energy projects are being reviewed. The requirement for a socio-economic impact assessment as part of the permit application data helps assure that "off-project" property owners and business owners are not unintentionally burdened by the proposed commercial wind energy development.

The Council has also noted several items contained in the existing UCDC (Umatilla County Development Codes) and the Comprehensive Plan which place value on scenic resources in EFU and GF zones in the county and which inventory a specific "view shed" which is important to the City of Milton-Freewater and the previously mentioned ag-tourism businesses.

PHONE (541) 938-5531 FAX (541) 938-8224
www.milton-freewater-or.gov

00001696

## EFU, EXCLUSIVE FARM USE ZONE

*Sub-Sections*



### § 152.055 DESCRIPTION AND PURPOSE.

The purposes of the EFU, Exclusive Farm Use Zone, are to preserve and maintain agricultural lands for farm use, including range and grazing uses, consistent with existing and future needs for agricultural products, forest and open spaces; to conserve and protect scenic resources; to maintain and improve the quality of air, water and land resources of the county and to establish criteria and standards for farm uses and related and supportive uses which are deemed appropriate. It is also the purpose of this use zone to provide the automatic farm use valuation for farms, which qualify under the provisions of ORS Chapter 308.

## GF, GRAZING/FARM ZONE

*Sub-Sections*



### § 152.080 DESCRIPTION AND PURPOSE.

The GF Grazing/Farm zone is designed to protect grazing lands, forest uses, and inclusions of agricultural land that are found within the county's mixed use farm/forest areas. The predominant use of the land is for grazing of livestock; however, there are some areas that are under agricultural cultivation and other areas where forest uses occur. The zone is also designed to conserve and protect watersheds, wildlife habitat and scenic values and views within the Blue Mountains. Certain land uses may be allowed conditionally. It is also the purpose of this zone to provide the automatic farm use valuation for farms and ranches which qualify under the provisions of ORS Chapter 308. Please see definition of farm use in § 152.003.

It is not a new concern for a public body to wish to protect scenic resources, as is evidenced by the "Description and Purpose" of the EFU and GF zones of Umatilla County. It is the Council's understanding that the above codes have been in place since approximately 1983.

The Council also requests the Umatilla County Board of Commissioners to review the County Comprehensive Plan and Technical Report for information regarding the listing of views from Highway 204. (see attached, page 273 of 739 of the pdf digital file of the Technical Report) To this date, the Council has seen little reason to be confident that this 30-plus year old listing, will result in effective limitation of siting of wind energy projects in that view shed. Encroachment on this viewscape has already been allowed, most notably by the Stateline 3 and Combine Hills wind projects. Further, if recreational homes are a conflicting use in this viewscape, how can tens or hundreds of 400 ft.(plus) tall machines with rotating parts and flashing lights not be a conflicting use? This is a part of the reason the City has previously requested a 15 mile visual setback from the UGB. However, if the Highway 204 viewscape is accorded protection from the siting of tens or hundreds of giant wind turbines, then a major portion of the concerns of the council can probably be eased.

As predicted by Councilor Chesnut during the work session, the Council takes no comfort from the proposal in the Commissioner's "Yellow Paper" which would allow cities to request a set back from the UGB. A request which may, or may not, be approved. The Council is far more interested in a 2 mile or 20 times grade to blade tip height minimum setback from the UGB. The city is required to plan 20 years out for growth. The UGB defines the location of future homes and businesses within the city. It makes sense to limit the siting of wind turbines near such planned future residential areas. The Council can find no adequate reason which supports not defining a minimum setback from the UGB immediately. Further, the Council can find no justification for not defining a setback from the UGB which is at least equal to the setback recommended by the Planning Commission from rural homes. The Council has confirmed it would accept the same sort of "waiver" language as is currently proposed for a rural home setback, since that language might open the possibility of negotiating a larger setback with a developer in a specific direction/area.

The Council is concerned about depending upon the Oregon noise statutes to protect its citizens from the adverse effects of siting wind turbines too close to homes and businesses. Siting of turbines based on noise models will likely result in errors which place citizens (or cities) in the position of having to spend their own resources to prove a noise infraction. There is no practical way to eliminate the potential for "dueling experts" when a noise infraction case arises – and one of those experts will have to be hired by the local private citizen (or city). By comparison, the recommendation of the Planning Commission for a 2 mile or 20 times grade to blade tip height – with waiver potential – is not excessive and meeting the standard can be clearly documented BEFORE construction.

Submitted at the direction of the City Council of Milton-Freewater by,

Linda Hall
City Manager

Attachments: Inventory Sheet of Outstanding Sites and Views
OSU – Umatilla County Adaptive Farms: An Economic Analysis

Table D-XVII (cont'd)

DESCRIPTION OF OUTSTANDING SITES AND VIEWS (Revised)

| SITES / QUALITIES OR POTENTIALS | GOAL 5 ANALYSIS | QUALITY OF INTEREST: Water | Geology | Vegetation | "Desert" | Human | HOW ENJOYED: To Look Upon | To Look From | To Travel Through | To Be In or Beside | EVALUATION: Developed For Scenic Value | Potential Conflicts With Scenic Value | Additional Values (uses) | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Minnehaha | 1A | | | X | | | | | | X | NO | | Residences, Hobby Farms | Attractive Suburban Vistas |
| Cooney Lane | 1A | | | X | | | | | | X | NO | | Residences, Hobby Farms | Attractive Suburban Vistas |
| Westland School | 1A | | | | | X | X | | | X | NO | Industrial Area, Billboards | Possible Museum Historic | |
| McKay Reservoir | 3C | X | | X | | | X | | X | X | NO | Summer draw-down | Recreation; Wildlife Refuge | |
| Oregon Trail | 1A | | | | | X | X | X | | X | partial | Residential and or Agriculture Development | Recreational | Public/ Private |
| Langdon Lake | 3C | X | | X | | | X | | | X | NO | | Recreation Recreational Homesites | Private Forest Service Campground on West |
| Umatilla Forks Forest Campgrounds | 1A | X | | X | | | | | X | X | | Logging Operations | Camping Fishing Hiking | U.S.F.S. Managed |
| Cabbage Hill Vista | 1A | | X | X | | | | X | | | X | | Picknicking | On Indian Reservation |
| Squaw Creek Vista | 1A | | X | X | | | | X | | | X | | Picknicking | On Indian Reservation |
| Table Rock Lookout Tower | 1A | | X | X | | | | X | | | | | U.S.F.S. Fire Lookout Tower | In National Forest |
| High Ridge Lookout | 1A | | X | X | | | | X | | | | | U.S.F.S. Fire Lookout Tower | In National Forest |
| Goodman Ridge Lookout | 1A | | X | X | | | | X | | | | | U.S.F.S Fire Lookout Tower | In National Forest |
| Earnest S. Haney Vista | 3C | | X | X | | | | X | | | X | Logging Activities | Picknicking | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| State Highway 204 | 3C | | | X | | | | X | X | X | | Recreational Homesites | Important Transportation Route | Scenic Highway |
| Elephant Rock | 3C | | X | | | | X | | | | NO | | Historic | |

Page 273 of 739 in the pdf format of the Technical Report



00001699

OSU Oregon State University

Rural Studies Program

# Umatilla County Adaptive Farms: An Economic Analysis

- Profile current agricultural production by region
- Describe likely adaptive farming operations
- Estimate the financial feasibility and economic effects of each type of adaptive farm
- Discuss the findings with the public and scientists
- Summarize the findings in a final report and a PowerPoint presentation.

*Questions or Suggestions Contact:*
Bruce Sorte, Community Economist
OSU Rural Studies Program
Phone: 541.962.3228
Email: bruce.sorte@oregonstate.edu

Oregon State University

Rural Studies Program

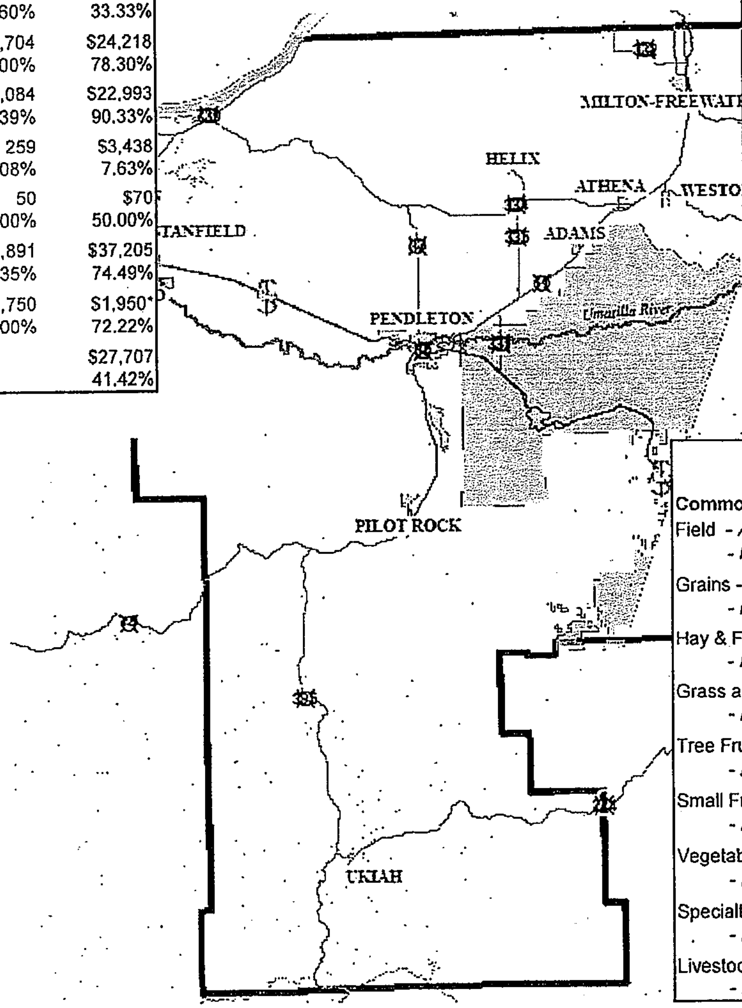
# Limitations

- Can, will, could and should
- Enterprise budgets – examples and guides
- Outrunning the market
- Sweet cherries
- Blueberries
- Wine

# Vn bujmmb Dpvouz Bhsjdvmuvsbm Qspevdujpo cz Sfhjpo

| Commodity | Acres Harvested | Value of Production ($000) |
|---|---|---|
| Field - *Amt.* | 17,152 | $55,332 |
| - *Percentage* | 77.65% | 94.15% |
| Grains - *Amt.* | 79,873 | $32,372 |
| - *Percentage* | 27.60% | 33.33% |
| Hay & Forage - *Amt.* | 16,704 | $24,218 |
| - *Percentage* | 80.00% | 78.30% |
| Grass and Legumes - *Amt.* | 14,084 | $22,993 |
| - *Percentage* | 90.39% | 90.33% |
| Tree Fruit & Nuts - *Amt.* | 259 | $3,438 |
| - *Percentage* | 6.08% | 7.63% |
| Small Fruit & Berries - *Amt.* | 50 | $70 |
| - *Percentage* | 50.00% | 50.00% |
| Vegetables & Truck Crops - *Amt.* | 13,891 | $37,205 |
| - *Percentage* | 45.35% | 74.49% |
| Specialty Products - *Amt.* | 1,750 | $1,950* |
| - *Percentage* | 100.00% | 72.22% |
| Livestock - *Amt.* | | $27,707 |
| - *Percentage* | | 41.42% |

*Includes greenhouse production




| Commodity | Acres Harvested | Value of Production ($000) |
|---|---|---|
| Field - *Amt.* | 2,368 | $2,666 |
| - *Percentage* | 10.72% | 4.54% |
| Grains - *Amt.* | 68,373 | $21,332 |
| - *Percentage* | 23.63% | 21.96% |
| Hay & Forage - *Amt.* | 2,276 | $3,736 |
| - *Percentage* | 10.90% | 12.08% |
| Grass and Legumes - *Amt.* | 1,497 | $2,462 |
| - *Percentage* | 9.61% | 9.67% |
| Tree Fruit & Nuts - *Amt.* | 3,997 | $41,619 |
| - *Percentage* | 93.92% | 92.37% |
| Small Fruit & Berries - *Amt.* | 50 | $70 |
| - *Percentage* | 50.00% | 50.00% |
| Vegetables & Truck Crops - *Amt.* | 16,640 | $12,398 |
| - *Percentage* | 54.32% | 24.82% |
| Specialty Products - *Amt.* | 0 | $750* |
| - *Percentage* | 0.00% | 27.78% |
| Livestock - *Amt.* | | $10,055 |
| - *Percentage* | | 15.03% |

*Includes greenhouse production

| Commodity | Acres Harvested | Value of Production ($000) |
|---|---|---|
| Field - *Amt.* | 2,568 | $772 |
| - *Percentage* | 11.63% | 1.31% |
| Grains - *Amt.* | 141,105 | $43,421 |
| - *Percentage* | 48.77% | 44.71% |
| Hay & Forage - *Amt.* | 1,900 | $2,975 |
| - *Percentage* | 9.10% | 9.62% |
| Grass and Legumes - *Amt.* | 0 | $0 |
| - *Percentage* | 0.00% | 0.00% |
| Tree Fruit & Nuts - *Amt.* | 0 | $0 |
| - *Percentage* | 0.00% | 0.00% |
| Small Fruit & Berries - *Amt.* | 0 | $0 |
| - *Percentage* | 0.00% | 0.00% |
| Vegetables & Truck Crops - *Amt.* | 102 | $341 |
| - *Percentage* | 0.33% | 0.68% |
| Specialty Products - *Amt.* | 0 | $0 |
| - *Percentage* | 0.00% | 0.00% |
| Livestock - *Amt.* | | $29,129 |
| - *Percentage* | | 43.55% |

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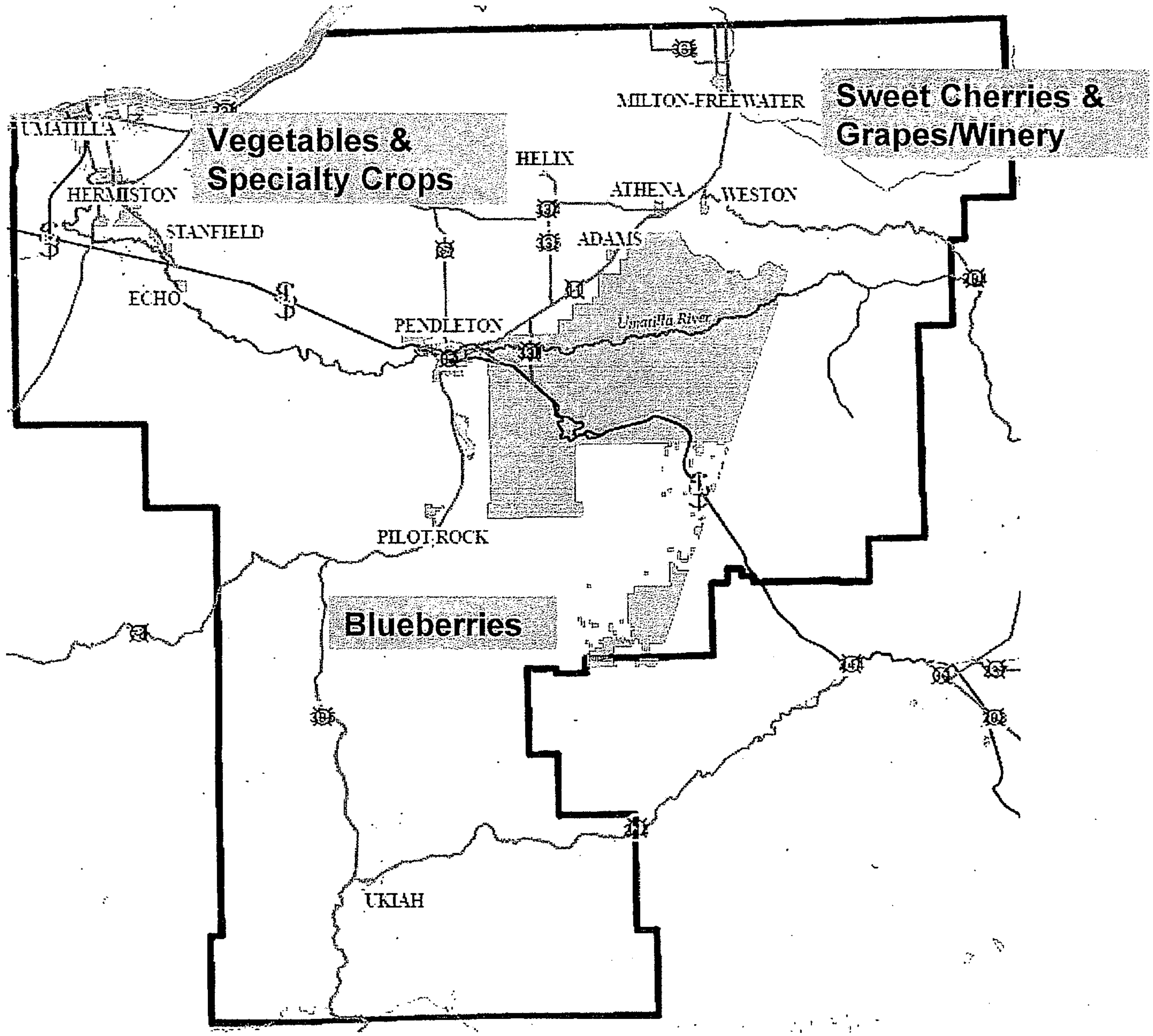
Sweet Cherries &
Grapes/Winery
Vegetables &
Specialty Crops
Blueberries
UMATILLA
HERMISTON
STANFIELD
ECHO
HELIX
ATHENA
WESTON
MILTON-FREEWATER
ADAMS
PENDLETON
Umatilla River
PILOT ROCK
UKIAH

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# Approach

- **Visit** with scientists, producers, planners, and a farmers' market organizer.
- **Study** current literature on possible crops and their production functions.
- **Select crops** that could be grown with no more than modest risk and could provide **net returns** equal to half of the Umatilla County median household income of **$20,387**.
- Choose **examples with conservative returns** and that could have value added to achieve retail prices.
- Use IM*pact* PLAN*ning* (IMPLAN) **economic model** to estimate the community economic effects in total sales.
- **Respect** the economic importance of the **existing** conventional **farms and ranches**.
- Discuss the **compatibility** between adaptive farms and larger farms and ranches looking toward the larger farms and ranches historical precedence.

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# Net Returns Per Acre

| | |
|---|---|
| Vegetables | $2,000 |
| Specialty Crops | $1,283 |
| Sweet Cherries | $2,083 |
| Grapes w/winery | $7,992 |
| Blueberries | $4,242 |
| Wheat | $100 |

# Gross Returns Per Acre/Community Economic Effects

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| | |
|---|---|
| Vegetables | $4,670/$6,600 |
| Specialty Crops | $3,165/$4,699 |
| Sweet Cherries | $11,900/$17,397 |
| Grapes/Winery | $39,438/$53,475 |
| Blueberries | $14,670/$16,764 |
| Wheat | $325/$450 |

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# Considerations

- **Diverse** businesses and economies can be more **resilient** than concentrated businesses and economies.
- **Adaptive farms** of 10-40 acres with the benefits of 21st technology and hard work can be successful and persist.
- Challenges that need to be addressed at the time of siting include: **compatibility** with larger farms, **water, and market development.**
- Strengthening the adaptive farming portion of agriculture along with local foods initiatives has the potential to **draw visitors and potential residents** from a segment of consumers that may not be well acquainted with Umatilla County.

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# What's next?

- Please contact me, if you want to visit about this study at 541.962.3228 or bruce.sorte@oregonstate.edu.
- In September we will publish the report.
- Thank you very much for spending your time this evening. I will do my best to include your ideas in the report.

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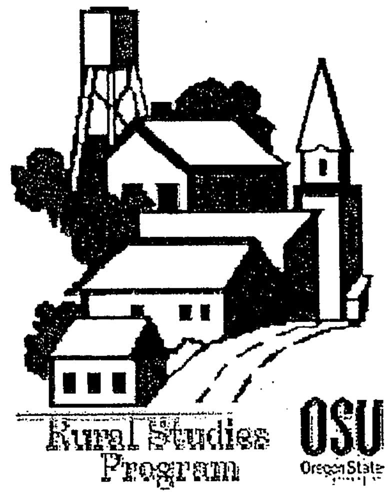
Rural
Studies
Program

# Rural Studies Program

**http://arec.oregonstate.edu/ruralstudies**




**Oregon State University**

**213 Ballard Extension Hall**

**Corvallis, OR 97331**

**(541) 737-1442**

**rsp@oregonstate.edu**

82

**Subject:** Re: Umatilla County wind energy development code
**From:** Tamra Mabbott <tamra@co.umatilla.or.us>
**Date:** Tue, 10 May 2011 12:46:56 -0700
**To:** Marcia Akes <marsalee@bmi.net>, Carol Johnson <carol@co.umatilla.or.us>

Mr. and Mrs. Akes - thank you for your comments. We will add your comments to the record.
Cordially, Tamra

On 5/9/2011 6:16 PM, Marcia Akes wrote:

> Planning Director Tamra Mabbott
>
> Regarding the placement of wind turbines in Umatilla County, we are writing in support of the Planning Commission document with the 2 mile setback from ALL homes because 1 mile isn't enough. People choose to live in the country for peace and quite and there are plenty of places in the county for the companies to place wind turbines, and where they already have wind turbines, that does not disrupt the lives of people who live in rural areas.
>
> Also – PLEASE keep the wind turbines OUT of our wonderful Blue Mountains, that are famous for their beauty. Again, there are plenty of places that are just as good, and many that are better, to place the turbines; and there is no reason to ruin what so many of us enjoy and what has become a tourist attraction for our area.
>
> We want to go on record as supporting the 2 mile setback from homes – that has been suggested.
>
> Thank you for your time and consideration in this matter.
>
> Chuck & Marcia Akes
> 52898 Akes Lane
> Milton-Freewater, OR 97862
> marsalee@bmi.net
> 541-938-6218

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*Tamra Mabbott, Planning Director*
Umatilla County Department of Land Use Planning
216 SE 4th ST | Pendleton, OR 97801
Phone: 541-278-6246| Fax: 541-278-5480
http://www.umatillacounty.net/planning - Visit our website for copies of planning documents, permit applications and other helpful information.

*Please Be Aware* - Documents such as emails, letters, maps, reports, etc. sent from or received by the Umatilla County Department of Land Use Planning are subject to Oregon Public Records law and are NOT CONFIDENTIAL. All such

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81

RECEIVED

MAY 09 2011

UMATILLA COUNTY
PLANNING DEPARTMENT

May 9, 2011

Umatilla County Board of Commissioners
Umatilla County Courthouse
Pendleton, Oregon 9701

Re: Additional Information Post May 3, 2010 Meeting – Wind Energy Standards

SOCIO-ECONOMIC ASSESSMENT

The Socio-Economic assessment requirement has been taken out, put back in to the proposed process several times, as if it is an insignificant part of the decision making process. I maintain that it is a significant part of this decision making process and should be left in as an important part of information necessary for a sound decision.

We must ask what purpose does the Socio-economic Assessment serve? It should identify impacts, both positive and negative to county business's, industry, local and county revenues, and property values, what changes could be anticipated from proposed windmill projects. These changes need to be displayed over time. For example, if changes in revenue to the county are displayed over time, it will show the largest increases in the early years of operation and declining to minimal levels some years later. It is not a consistent amount from year to year.

It needs to show the change in property value assessments. Participating land owners will show a positive gain, while adjacent landowners will show a loss. The addition of a multimillion dollar wind mill project to Umatilla County raises the question, how much will that add to the property assessment value?

The bottom line in Socio-economic assessment is to make information available to the decision makers, to allow adequate consideration of these issues for a good sound decision and most importantly making the pros and cons of these issues available to the people of Umatilla County.

SET BACKS

Setbacks should be based on experience, research and facts, not personal desires, emotions or guesswork. Mr. Reeder and the Planning Commission Committee have spent an inordinate amount of time, working on this very issue. Much to their credit, they have done a tremendous amount of work showing us a way in dealing with this issue. Why then would we not use this resource on which to base a sound decision and move forward? How can the decision makers ignore data which deals with Health issues and Noise requirements? Do we want a sound and workable decision or not? The data presented by this committee is not something pulled out of the air. Mr. Reeder and the Planning Commission Committee have played a large part, to be sure but, data also came from existing operating windmill projects and wind companies themselves. If the decision makers choose not to utilize these resources, then dealing with and settling these issues will be left to adjacent landowners and wind companies; that is limited resources vs. unlimited resources. Is this a good solution?

To establish a Linear Setback is only part of the solution. The turbines and how they have progressed from .6Mw turbines 15 years ago to 3.0MW today and industry projections are for 3.6Mw turbines in 2012.; what do you think the impacts on Health and Noise issues will be in the future? Linear setbacks will not in itself, resolve the issue.

CUMMULATIVE EFFECTS

The other essential part of this problem is Cumulative Effects. We are to the point where new projects, are adjacent to existing project, of which some are planning to expand by more generating capacity. When the big picture of Cumulative Effects is examined, it is literally overwhelming.

An example exists with the proposed Helix Project and the proposed Helix addendum. If you examine the projected 36dbA line from the proposed Helix Project, you will find that the line goes right through existing turbines. How will this impact adjacent landowners caught up in this dilemma? Adjacent landowners will be faced not only with dealing with proposed impacts but, proposed impacts on top of existing impacts. If this situation is to be dealt with it will take a pre-project credible noise study to determine where we are before anything is done with the proposed project and to assist in mitigation efforts. There could be in such a case where no mitigation solution is possible, due to a combined Noise Level that exceeds 50dbA.

*(IMPORTANT DECISIONS IN A TIMELY MANNER)*

I commend the Board of Commissioners for taking the time to make a good decision on these issues. However there has been several months involved in this process and it may take several more months to reach a decision. We are to the point where the policy to "Grandfather" future applications , while this decision is being made. This should be rescinded. We are dealing with significant issues that cannot wait much longer. All one has to grasp the magnitude of this is to look at maps showing high potential lands that are under lease for development to assess what will happen. If we delay long enough, we may render the upcoming decision meaningless to the well being of citizens of Umatilla County.

Respectfully submitted,

Dave & Judy Price
80488 Zerba Road
Athena, OR 97813

#95

Kirk Terjeson and Gunder Terjeson (Helix,Oregon) May 7th, 2011

Umatilla County Commissioners:

This letter pertains to issues discussed at the May 2nd, 2011 work session. We are also providing an updated letter we sent to EFSC concerning the Helix Wind Power Facility Amendment that addressed some of these matters.

One thing was noticeably absent from the May 2nd work shop. No representative from the wind industry was at the panel table. I think we all know why. Their lawyers would have had a field day with the Planning Commission. I thought it was kind of funny when the panel or planning staff didn't know the answer for a distance from a cultural site. A staff person had to ask the wind energy people sitting in the audience for the correct answer.

The Planning Commission, and Mr. Reeder in particular, reference findings based on the writings of Dr. Nina Pierpont. If Dr. Pierpont's studies are the best facts the Planning Commission can come up with, they need some serious help. Her self-published writings, which do not appear in any peer-reviewed scientific or medical journals, are based on a small study of 10 families reporting symptoms. There are no comparison groups. This small sample is considered insignificant in comparison to the tens of thousands who live near wind farms worldwide. Dr. Pierpont is a known campaigner against the wind industry.

Mr. Reeder stated that another concern (either of his or the Planning Commission as a whole) is that there is an unfair advantage for farmers with wind turbines proposed on their land over neighbors without wind turbines. Oregon law states that wind turbines are allowed on EFU land. It does not indicate that this is an unfair advantage. As far as it being unfair economically, we farm some 45 bushel per acre land that costs as much or more to farm than Mr. Reeder's 75 to 80 bushel per acre ground, close to Adams. He takes advantage of the more abundant free rainfall in that area as opposed to Butler Grade (where wind is more abundant). In the 20 years we have owned this ground, not once has Mr. Reeder offered to give us some of his grain to even up the playing field. Perhaps more odd, according to the Planning Commission, is that we have not ever asked to be compensated for this discrepancy. What happens if a neighbor wins the lottery? Shouldn't we all share? I don't believe all the people on the Planning Commission are advocating this Socialistic view. The Planning Commission and Mr. Reeder, as a member of this public commission, needs to put aside personal biases and represent all the views of Umatilla County. The Planning Commission seemingly has focused only on the negative. We have provided many positive aspects of the wind industry, not only in the Helix area, where it has provided proven benefits for over 10 years, but for Umatilla County as a whole. (See our attached letter to EFSC).

To help understand the financial contributions to the county and state, we asked Paul Chalmers of the Umatilla County Tax Assessors Office to provide us with some numbers. For the time period of May 5, 2002 through March 17, 2011, Florida Power & Light, Nextera, &

Combine Hill II have made available $718,633.51 in "Community Service Fees". ("HELP" to the Helix Community). (See attachment 2)

From 2002 through 2010, Umatilla County has received tax revenues totaling $11,388,551.00 from area wind projects. (See attachment 3)

Mr. Chalmers said for the 2010-2011 tax year, that without wind, there would be an assessed value increase of 1% versus an assessed value increase of 3.4% with wind. (See attachment 3)

In Oregon, wind companies have invested over $4.5 billion. Umatilla, Morrow, Union, Gilliam and Sherman Counties have benefited from over $54 million in Property Taxes in the years 1999-2010. As the Board of Commissioners know, these are substantial amounts of much needed revenues for our local schools and tax districts.

Mr. Reeder's facts on property values are not correct in Umatilla County. In Umatilla, Morrow, and Gilliam counties, I've heard of no cases, when you follow EFSC standards, that you would have a decline in home values. The only house I know of, in the Helix Wind Power Facility area that's been sold in the last 3 years, has gone up in value. Also in the last three years, before the Helix Wind Power Facility Amendment, a sale of wheat ground 2.5 miles from my house, had a sales stipulation, that wind rights or portion of the wind rights were not for sale with the land. WIND has become a valuable commodity in our area! Gunder's and my house are located close to the Vansycle Ridge wind farm and we have land located between the Stateline Wind Project and the Vansycle wind farm and our house and land values have increased in the past 12 years. We have no fear that they will decline due to new wind projects. In fact, we strongly believe our ground is more valuable today, than it has ever been, because of the value of wind. By following current EFSC regulations, we are confident our property rights will be protected and our land and home values will not decline because of a wind project.

As for community discord over wind issues: I have heard more discord from people in public leadership roles, voicing their own agenda, than from local residents, whether they are for or against the wind project. People in the Helix area respect each other while having the right to disagree. What they don't respect are people trying to stir up a problem to help their own cause in the name of caring for everyone.

At the May 2nd work session, the panel had a member of the Milton-Freewater city council, who is also a member of the Blue Mountain Alliance. Do the people of Milton-Freewater know where the funds recently came from to keep their ambulance service going? The money came from the county tax fund received from the wind projects in Umatilla County.

I heard from the Milton-Freewater councilman and Blue Mountain Alliance member how the wind industry is hurting their fledgling tourism industry in the Walla Walla Valley, namely, the wine industry. I'm not sure how true that statement is or what facts back up this theory. I don't believe all the wineries have issues with the wind industry, since I know of at least 3 wineries that also have an interest in Wind Farms in Umatilla County. I would guess the wine industry will survive regardless of the wind industry. I would think the wine industry along with other Walla Walla and Milton-Freewater tourism businesses are grateful to have ambulance services available again for their employees and patrons as well as the local residents.

Perhaps not in Milton-Freewater, but in other communities, Wind Farms are producing clean energy that the state and federal governments mandate and have also become a fledgling tourism industry in their own right. We farm next to Butler Grade, which borders Vansycle Ridge, the original wind farm in Umatilla County, near Helix. There are frequently cars stopped on the road side taking pictures or just watching the turbines in action. Many come to our farm asking directions to the Stateline Project, which we border on our west side, or to the wind project near Athena. These are local people as well as visitors from across the United States that are fascinated and intrigued by these Wind Farms.

I talked recently with a person that is familiar with the Wild Horse Wind Farm that is owned by Puget Sound Energy, near Ellensburg, Washington. They recently had their 50,000$^{th}$ tourist come thru their visitor center, which is now called the Renewable Energy Center (REC). The center was opened in 2008. They have between 10,000-15,000 visitors a year and it is only opened from April 1$^{st}$ to Nov. 30$^{th}$.

As for fire concerns: The wind farms now provide gravel roads that run perpendicular to prevailing wind patterns across what were hard to access ridges for fire trucks. Not only do they provide fire breaks (where before there were none), they are helpful in getting fire equipment closer to the troubled areas and faster than driving through dirt fields or around long, steep ridges. I can't see where wind farm infrastructure would do anything but help in the prevention and fighting of fires in the area. We are lucky to have them. Even before wind farms became a part of our landscape, there have been fires started by lightning, hunters, and machinery in our area. Some lasted for several days. Some forest fires last for weeks. At least now we have good roads to help fight these fires. I also want to thank the communities of Helix, Touchet, Walla Walla, Echo, Weston, and the CTUIR for sending their fire crews and equipment to fight our wheat field fires..... at least before we had wind towers.

I don't believe their participation is now going to stop once we put wind towers on this ground. There have also been many private fire fighting companies that have responded. I think they all do a great job. Some people may not agree with me but I'm thankful to all those who respond to the fires in our area. I also want to thank the wind companies for how they have improved our community fire departments, through increased tax revenues. We would never have been able to afford the new fire equipment if it were not for these increased revenues provided by the wind projects,in the Helix area. Once again, thank you area fire crews and area farmers for providing a hand in the prevention and control of fires, regardless of how they start.

At some of the meetings, I've heard about the silt coming off the new roads constructed by the wind projects. What I've actually seen are roads built that are of the quality of county roads in Umatilla County. That's one of the reasons I want to establish a wind farm on our ground. Everything is top quality. I've not seen the wind project workers do anything other than drive on the gravel roads, never across the stubble or fallow fields. I have seen hunters that do not have permission to hunt go where they please.

I think you'll hear today, not only is the Planning Commission being too stringent while trying to run off wind development in the county, but that they are also attempting to break laws along the way. I won't get into which laws now, but will refer you to read, Attorney, Wendie L. Kellington's, letter to the Board of Commissioners (March 17th letter), one more time. I'm not sure how well versed in the law these Planning Commissioners are, so I hope you are confident in all their research. Whatever you decide needs to be supported by credible evidence.

In closing, for Umatilla County to prosper into the future, Terjeson Ranches recommends that they stay with their current setback regulations or adopt the EFSC regulations as stated in our letter to EFSC at the April 27th meeting in Helix. EFSC does not use arbitrary setback numbers such as 1 or 2 miles. Their regulations are based on science.

Thank you for your time.

Kirk Terjeson and Gunder Terjeson

From: Whitney, Chase
Sent: Tuesday, April 05, 2011 1:10 PM
To: Carol Johnson
Cc: Tamra Mabbott; Clinton B. Reeder; Parsons, Sara McMahon; Mark.Bastasch@CH2M.com; ERALBRICH@stoel.com; DEFILIPPI@stoel.com
Subject: RE: Helix Wind Project Setbacks

attachment 1

Carol,

The Helix project will comply with EFSC conditions 100-102 copied below, which will result in a much larger setback from non-participating rural residences than the 1,320 ft required by EFSC condition 43. Because the project must demonstrate compliance with the DEQ noise rules, distances from turbine strings to non-participating homes would range from approximately 3800 to 8500 feet (0.7 to 1.6 miles) based on a turbine with maximum sound power level of 106 dBA. This number depends on a variety of factors, such as turbine maximum sound power level as well as the number and location of turbines in proximity to the residence. It is for these reasons that EFSC requires a detailed site specific analysis prior to construction to demonstrate compliance with the DEQ noise rules, as a standard setback distance is not sufficiently robust to ensure compliance with the restrictive DEQ noise rules at rural residences. While the resulting setback from a rural home to a string of towers is likely greater than the setback to a single tower, there is no hard and fast setback distance for rural homes from strings as compared to single towers, EFSC and DEQ rules recognize that a more rigorous process is required based on the various factors described above

| | | |
|---|---|---|
| 43 | Setbacks | The certificate holder shall construct all facility components in compliance with the following setback requirements:<br>(a) All facility components must be at least 3,520 feet from the property line of properties zoned residential use or designated in the Umatilla County Comprehensive Plan as residential.<br>(b) Where (a) does not apply, the certificate holder shall maintain a minimum distance of 110-percent of maximum blade tip height, measured from the centerline of the turbine tower to the nearest edge of any public road right-of-way. The certificate holder shall assume a minimum right-of-way width of 60 feet.<br>(c) Where (a) does not apply, the certificate holder shall maintain a minimum distance of 1,320 feet, measured from the centerline of the turbine tower to the center of the nearest residence existing at the time of tower construction.<br>(d) Where (a) does not apply, the certificate holder shall maintain a minimum distance of 110-percent of maximum blade tip height, measured from the centerline of the turbine tower to the nearest boundary of the certificate holder's lease area. |
| 86 | Transmission Lines | The certificate holder shall take reasonable steps to reduce or manage human exposure to electromagnetic fields, including but not limited to: |
| | | (a) Constructing all aboveground transmission lines at least 200 feet from any residence or other occupied structure, measured from the centerline of the transmission line. |
| | | etc |
| 100 | Noise Abatement | To reduce construction noise impacts at nearby residences, the certificate holder shall: |
| | | (a) Confine the noisiest operation of heavy construction equipment to the daylight hours. |
| | | (b) Require contractors to install and maintain exhaust mufflers on all combustion engine-powered equipment; and |
| | | (c) Establish a complaint response system at the construction manager's office to address noise complaints. |
| 101 | Turbine Noise | Before beginning construction, the certificate holder shall provide to the Department: |
| | | (a) Information that identifies the final design locations of all turbines to be built at the facility. |
| | | (b) The maximum sound power level for the substation transformers and the maximum sound power level and octave band data for the turbines selected for the facility based on manufacturers' warranties or confirmed by other means acceptable to the Department. |
| | | (c) The results of noise analysis of the facility to be built according to the final design performed in a manner consistent with the requirements of OAR 340-035-0035(1)(b)(B)(iii) (IV) and (VI) demonstrating to the satisfaction of the Department that the total noise generated by the facility (including the noise from turbines and substation transformers) would meet the ambient degradation test and maximum allowable test at the appropriate measurement point for all potentially-affected noise sensitive properties. |
| | | (d) For each noise-sensitive property where the certificate holder relies on a noise waiver to demonstrate compliance in accordance with OAR 340-035-0035(1)(b)(B)(iii)(III), a copy of the a legally effective easement or real covenant pursuant to which the owner of the property authorizes the certificate holder's operation of the facility to increase ambient statistical noise levels L10 and L50 by more than 10 dBA at the appropriate measurement point. The legally-effective easement or real covenant must include a legal description of the burdened property (the noise sensitive property) |



00001717

attachment 2 (page 1) "Community Service Fee" "Included"

1603 - 1003 - HELP

| Date | Description | Amount In | | Amount Out | | Balance | |
|---|---|---|---|---|---|---|---|
| 05/21/02 | Contribution #1 | $ | 50,000.00 | | | $ | 50,000.00 |
| 06/30/02 | Interest Earned | $ | 42.90 | | | $ | 50,042.90 |
| 11/08/02 | Helix School - Doors/Hot Water | | | $ | 25,000.00 | $ | 25,042.90 |
| 12/12/02 | Helix - Roof | | | $ | 25,000.00 | $ | 42.90 |
| 01/30/03 | Contribution #2 | $ | 50,000.00 | | | $ | 50,042.90 |
| 05/22/03 | Helix - Roof | | | $ | 6,375.75 | $ | 43,667.15 |
| 06/30/03 | Interest Earned | $ | 700.85 | | | $ | 44,368.00 |
| 08/12/03 | Helix School | | | $ | 25,000.00 | $ | 19,368.00 |
| 12/18/03 | Helix | | | $ | 13,212.00 | $ | 6,156.00 |
| 12/31/03 | Contribution #3 | $ | 50,000.00 | | | $ | 56,156.00 |
| 01/08/04 | Helix | | | $ | 906.14 | $ | 55,249.86 |
| 06/30/04 | Interest Earned | $ | 488.62 | | | $ | 55,738.48 |
| 08/31/04 | Helix Return Funds | $ | 8,900.00 | | | $ | 64,638.48 |
| 12/29/04 | Contribution #4 | $ | 50,000.00 | | | $ | 114,638.48 |
| 01/27/05 | Helix | | | $ | 1,405.11 | $ | 113,233.37 |
| 03/03/05 | Helix School | | | $ | 25,000.00 | $ | 88,233.37 |
| 03/03/05 | Helix School | | | $ | 8,900.00 | $ | 79,333.37 |
| 06/30/05 | Interest Earned | $ | 1,783.17 | | | $ | 81,116.54 |
| 09/01/05 | Helix - Sidewalk | | | $ | 23,211.00 | $ | 57,905.54 |
| 11/10/05 | Helix - Sidewalk | | | $ | 27,076.00 | $ | 30,829.54 |
| 12/30/05 | Contribution #5 | $ | 50,000.00 | | | $ | 80,829.54 |
| 05/31/06 | HELP Correction | $ | 999.90 | | | $ | 81,829.44 |
| 05/31/06 | HELP Correction | | | $ | 999.90 | $ | 80,829.54 |
| 06/30/06 | Interest Earned | $ | 2,968.95 | | | $ | 83,798.49 |
| 12/28/06 | Helix | | | $ | 9,252.23 | $ | 74,546.26 |
| 12/29/06 | Contribution #6 | $ | 50,000.00 | | | $ | 124,546.26 |
| 02/22/07 | Helix - Flood | | | $ | 8,391.75 | $ | 116,154.51 |
| 03/08/07 | Helix School | | | $ | 22,450.11 | $ | 93,704.40 |
| 06/21/07 | Helix School | | | $ | 21,870.00 | $ | 71,834.40 |
| 06/30/07 | Interest Earned | $ | 5,389.46 | | | $ | 77,223.86 |
| 08/24/07 | Helix - FWDP | | | $ | 2,072.45 | $ | 75,151.41 |
| 10/11/07 | Helix | | | $ | 3,292.36 | $ | 71,859.05 |
| 10/18/07 | Helix - Park | | | $ | 25,731.44 | $ | 46,127.61 |
| 10/25/07 | Hermiston Chamber - Farm Fair | | | $ | 150.00 | $ | 45,977.61 |
| 12/26/07 | Contribution #7 | $ | 50,000.00 | | | $ | 95,977.61 |
| 06/12/08 | Helix School | | | $ | 5,679.89 | $ | 90,297.72 |
| 06/12/08 | Helix School | | | $ | 24,881.17 | $ | 65,416.55 |
| 06/30/08 | Interest Earned | $ | 3,917.84 | | | $ | 69,334.39 |
| 12/30/08 | Contribution #8 | $ | 50,000.00 | | | $ | 119,334.39 |
| 12/31/08 | Interest Earned | $ | 2,319.68 | | | $ | 121,654.07 |
| 02/12/09 | Correction AWERE | | | $ | 999.90 | $ | 120,654.17 |
| 02/12/09 | Correction BCC - Farm fair | $ | 150.00 | | | $ | 120,804.17 |
| 04/01/09 | Helix School Dist Project | | | $ | 23,945.49 | $ | 96,858.68 |

attachment 2 (page 2)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 06/29/10 | City of HELIX 2010 | | | $ | 21,362.73 | $ | 102,284.31 |
| 08/26/10 | Helix Comm Chruch | | | $ | 13,325.00 | $ | 88,959.31 |
| 12/02/10 | Helix 08-09 | | | $ | 10,149.35 | $ | 78,809.96 |
| 12/22/10 | Contribution #10 | $ | 50,000.00 | | | $ | 128,809.96 |
| 12/30/10 | NEXTERA 2010 | $ | 190,360.50 | | | $ | 319,170.46 |
| 12/30/10 | COMBINE HILLS | $ | 8,363.30 | | | $ | 327,533.76 |
| 02/17/11 | Helix School - Facility 2010 | | | $ | 4,490.00 | $ | 323,043.76 |
| 02/17/11 | Helix School - Kitchen 2010 | | | $ | 4,255.74 | $ | 318,788.02 |
| 02/17/11 | Helix School - Playground 2010 | | | $ | 1,500.00 | $ | 317,288.02 |
| 02/17/11 | Helix School - Technology | | | $ | 14,500.00 | $ | 302,788.02 |
| 02/17/11 | Helix School - Trees 2010 | | | $ | 1,100.00 | $ | 301,688.02 |
| 03/17/11 | Interest Earned | $ | 785.94 | | | $ | 302,473.96 |
| | | | | | | $ | 302,473.96 |
| | | | | | | $ | 302,473.96 |
| | | | | | | $ | 302,473.96 |

FPL 10@50,000 — $ 500,000.00

COMBINE HILLS II 2010 — 8363.30

NEXTERA 2010 — 190360.50

INTEREST — 19909.71

718.633,51

00001719

attachment 3

FOR 2010-11 TAX YEAR
Without Wind = 1% Inc
With Wind = 3.4% Inc

WIND POWER COMPARISON

| ACCOUNT | YEAR | % of New | VALUE | VALUE PER TOWER | PERCENT CHANGE | TOTAL TAX | COUNTY TAX |
|---|---|---|---|---|---|---|---|
| 158187 | 2002 | | 68,063,000 | 540,183 | | $688,157.78 | $193,891.07 |
| FPL VANSYCLE | 2003 | | 89,315,000 | 493,453 | 91.35% | $907,395.76 | $254,431.64 |
| (STATELINE) | 2004 | | 88,640,000 | 489,724 | 99.24% | $892,179.34 | $252,508.77 |
| 126 TOWERS @ 660 KW EA FOR 2002 VALUE | 2005 | | 83,000,000 | 458,564 | 93.64% | $836,731.30 | $236,442.10 |
| 55 ADDED FOR THE 2003 VALUE | 2006 | | 62,580,000 | 345,746 | 75.40% | $631,200.67 | $178,271.65 |
| CODE AREA 01-02 | 2007 | | 56,893,000 | 314,326 | 90.91% | $572,770.28 | $162,071.09 |
| | 2008 | | 58,097,000 | 320,978 | 102.12% | $584,891.55 | $165,500.92 |
| | 2009 | | 47,563,000 | 262,779 | 81.87% | $478,840.50 | $135,492.72 |
| | 2010 | 57.27% | 38,979,000 | 215,354 | 81.95% | $392,421.08 | $111,039.48 |
| | | | | | | $5,984,588.26 | $1,689,649.43 |
| 159512 | 2004 | | 39,996,000 | 975,512 | | $392,800.72 | $113,936.61 |
| EURUS COMBINE | 2005 | | 39,000,000 | 951,220 | 97.51% | $381,392.70 | $111,099.30 |
| 41 TOWERS@ 1 MW ea | 2006 | | 32,623,000 | 795,683 | 83.65% | $312,759.96 | $92,933.14 |
| CODE AREA 07-12 | 2007 | | 29,176,000 | 711,610 | 89.43% | $275,981.62 | $83,113.67 |
| | 2008 | | 25,896,000 | 631,610 | 88.76% | $244,955.44 | $73,769.94 |
| | 2009 | | 27,020,000 | 659,024 | 104.34% | $255,587.58 | $76,971.87 |
| | 2010 | 65.46% | 26,182,000 | 638,585 | 96.90% | $247,660.77 | $74,584.66 |
| | | | | | | $2,111,138.80 | $626,409.19 |
| 155672 | 1999 | | 24,700,000 | 650,000 | | $251,112.55 | $70,362.89 |
| ESI VANSYCLE | 2000 | | 24,800,000 | 652,632 | 100.40% | $249,056.48 | $70,647.76 |
| 38 TOWERS @ 660KW ea | 2001 | | 23,800,000 | 626,316 | 95.97% | $239,013.88 | $67,799.06 |
| CODE AREA 01-02 | 2002 | | 23,000,000 | 605,263 | 96.64% | $228,824.01 | $65,520.10 |
| | 2003 | | 21,811,000 | 573,974 | 94.83% | $216,994.80 | $62,133.00 |
| | 2004 | | 21,620,000 | 568,947 | 99.12% | $215,094.57 | $61,588.89 |
| | 2005 | | 21,000,000 | 552,632 | 97.13% | $208,926.27 | $59,822.70 |
| | 2006 | | 14,104,000 | 371,158 | 67.16% | $140,318.86 | $40,178.06 |
| | 2007 | | 15,127,000 | 398,079 | 107.25% | $150,496.56 | $43,092.28 |
| | 2008 | | 16,560,000 | 435,789 | 109.47% | $164,753.29 | $47,174.47 |
| | 2009 | | 16,972,000 | 446,632 | 102.49% | $168,852.22 | $48,348.14 |
| | 2010 | 64.78% | 16,000,000 | 421,053 | 94.27% | $159,181.92 | $45,579.20 |
| | | | | | | $2,392,625.41 | $682,246.56 |
| 2008 totals | | | 100,553,000 | | | $994,600.28 | $286,445.33 |
| 2009 totals | | | 91,555,000 | | | $903,280.31 | $260,812.73 |
| 2010 totals | | | 159,143,000 | | | $1,699,462.61 | $453,350.66 |
| **TOTAL TAX YTD** | | | | | | **$11,388,551.31** | **$3,220,452.50** |



00001720

# An impact on wildlife

79

## ODFW recommends against turbines in particular zone of wind farr

**COMMUNITY COMMENT**
CHARLIE GILLIS

On March 1, the Oregon Department of Fish and Wildlife in a letter to the Oregon Department of Energy recommended against the issuance of a site certificate for the Antelope Ridge Wind Farm proposed by Horizon Wind Energy for development above Union.

Fifty pages long, the letter is rich in detail and includes the use of dozens of acronyms. However, I encourage anyone interested in the proposed wind energy facility to read the document carefully. I believe that the letter reveals that Horizon has demonstrated a repeated pattern of critical failures: failure to negotiate in good faith with ODFW, failure to provide ODFW with requested information and failure to effectively accommodate ODFW's concerns for the impact of the project on the area's wildlife. All statements within quotations are taken from the letter.

The letter initially describes ODFW's responsibility to assure wind energy developers' compliance with Oregon's laws and regulations regarding wildlife. The letter then states that the ARWF is "one of the first wind power projects in Oregon proposed to be sited in critical big game winter range and very productive wildlife habitat, resulting in the potential construction of a large industrial facility that negatively impacts Oregon's wildlife." Despite the wide array of negative impacts to the area's wildlife, which are listed throughout in great detail, the letter states. "Unfortunately, after a number of meetings, Horizon withdrew from the discussions (with ODFW)."

The letter describes an area within the proposed project boundary called the Zone of Multiple Biological Values within which ODFW recommended that "no construction of wind turbines, associated road systems or associated infrastructure take place." ODFW recommended not developing the area for wind energy because the area is so rich in wildlife (listed in detail) that "Mitigation for impacts to this habitat and species dependent on it, while not impossible, will be very difficult to achieve."

The letter states that during the earlier development of the Elkhorn Wind Energy Facility near North Powder, Horizon agreed not to place turbines within the zone. However, "Despite ODFW's concerns and recommendations not to develop on the (zone) during siting of (Elkhorn) ...the applicant continues to propose turbine sitings on Ramo Flat and on the low elevation bench southwest of Union as part of the ARWF — the heart of the Zone of Multiple Biological Values." That is, despite Horizon's earlier acknowledgement of the zone as an area too biologically sensitive for development, the corporation has chosen to make the ecologically fragile zone the "heart" of the Antelope Ridge Wind Energy Facility.

**I WAS UNAWARE** of the fragile nature of bats until I read in the letter of the threat posed to this economically important species by the proposed wind development. "Bats are long-lived (up to 31 years) with low productive rates. Females usually only have one to two young per year, depending on the species. Young are entirely dependent on parental care ... the death of an adult female would therefore also cause the death of her dependent young."

The letter states that. "The ARWF Monitoring and Mitigation Plan (offered by Horizon) fails to address any actions that may minimize direct impacts to bats. It only suggests monitoring bat fatalities and including those number in project reports."

The significance of Horizon's failure t offer greater protection to bats is reveale in a later paragraph which states. "The cumulative effects of sustained high mort ity from ever-increasing wind energy proj ects and the introduction of White-nose Syndrome, a devastating disease that has killed over a million bats in the eastern U.S. and is moving westward, could be ca strophic to populations of hibernating ba in the west. Avoiding or minimizing bat fatalities is essential to prevent populatio crashes that could lead to Endangered Species Act listing of the hardest hit species, some of which are already in decline."

In regards to the impact to elk and de within the proposed energy development the letter states. "ODFW manages wildlif in a manner that is compatible with the p mary uses of the land. In the case of plac ing a wind farm in established big game habitat, the primary use of the land changes. A large industrial site in produc tive wildlife habitat is a significant alteration of the current primary use. The Applicant (Horizon) fails to address how big game use will be mitigated."

"Most of the proposed project is on either big game winter range or big gam critical wildlife habitat, and extremely cri cal to the continued welfare of the deer and elk dependent on it."

Any reader, pro or anti-Antelope Ridg will be impressed with the amount of wo and research that went into the writing o this letter. Their recommendation is the product of thoughtful effort and they deserve the thanks of every Union Count resident.

*Charlie Gillis is a La Grande attorney who represents Friends of the Grande Ronde Valley.*

EXECUTIVE ORDER NO. EO - 96 - 30

STATE/TRIBAL GOVERNMENT-TO-GOVERNMENT RELATIONS

There are nine federally recognized Indian tribal governments located in the State of Oregon. These Indian tribes were in existence prior to the formation of the United States of America, and thus retain a unique legal status. The importance of recognizing the relationship that exists between the tribes and state government can not be underestimated.

As sovereigns the tribes and the State of Oregon must work together to develop mutual respect for the sovereign interests of both parties. The relationships between our governmental structures can only be built through trust and mutual respect.

The purpose of formalizing the government-to-government relationship that exists between Oregon's Indian tribes and the State is to establish a process which can assist in resolving potential conflicts, maximize key inter-governmental relations and enhance an exchange of ideas and resources for the greater good of all of Oregon's citizens, whether tribal members or not.

IT IS ORDERED AND DIRECTED:

1. That the Governor's Legal Counsel, or such other person as the Governor may from time to time designate, shall be accountable to the Governor for the implementation of this Executive Order and be responsible for convening an annual meeting where representatives of the State and the nine federally recognized Oregon tribal governments will work together to achieve mutual goals.

2. That the head of each Cabinet level department who is either appointed by the Governor or who reports to gubernatorial appointees and is made subject to this Order by the Governor ( hereinafter "department") shall be accountable to the Governor's office for adopting a departmental State/Tribal Government statement that:

   a. Recognizes that Oregon Indian tribal governments are interested in the development of state policy that affects tribal interests (hereinafter "state policy") and recognizes the desirability of dialogue between tribal governments and the state, with regard to those state policies;

   b. Identifies key personnel of the department as a "key contact[s]" responsible for coordination with tribal governments;

   c. Establishes a process for the identification of those state policies by designated tribal representatives and key contacts ;

   d. promotes dialogue between Oregon departments and tribal governments on those state policies ; and

   e. That advances the government-to-government relationship by notifying staff and employees of this Executive Order.

3. Through the process established under this Executive Order the key contacts and designated tribal representatives shall identify issues of mutual concern arising from state policy. The departments and each tribal government shall make reasonable efforts to design solutions and develop programs to achieve mutual goals in relation to state policy.

4. That each department shall recognize the opportunity to use a number of tools to achieve mutual cooperation including but not limited to use of cooperative agreements with Indian tribal governments as provided for in ORS 190.110 when it is appropriate to do so.

5. That each department shall provide key managers with periodic training which enables them to better recognize Indian issues and to understand and respect the legal status of tribal governments and of American Indians as citizens of Oregon who also have their own unique and distinct culture. It is important as well for the tribes to develop tribal training so its members will better understand the workings and process of state government. It is the hope of the state that these training's will enable the tribes and the state to learn about each other's cultures and improve our mutual ability to communicate our interests more clearly. The key contact and designated tribal representatives shall consult on the scope and content of training as well as the coverage of its cost.

6. That the departments shall work cooperatively to accomplish the goals of this order.

It is the hope of the state and the tribes that this executive order will result in improving the quality of communication between our sovereign governments. The tribes and the state recognize that this order cannot and is not intended to create a forum for resolution of all issues between the tribes and the state. Nor is it meant to replace presently existing lines of communications. Both the tribes and the state recognize that issues that are the subject of litigation or that are likely to become the subject of litigation are inappropriate for discussion in this process.

Nothing in this order shall require the state or any of its agencies to violate or ignore any laws, rules, directives or other legal requirements or obligations imposed by state or federal law including but not limited to state Public Records laws, Public Meetings laws and provisions of the state Administrative Procedures Act.

This document has been adopted for the sole purpose of enhancing communication and mutual cooperation between the State of Oregon and the tribal governments and is not intended to, and does not, create any right to administrative or judicial review, or any other right or benefit or responsibility, substantive or procedural, enforceable by a party against the State of Oregon, its agencies or instrumentality's, its officers or employees, its subdivisions or any other persons.

Done at Salem, Oregon this 22nd day of May 1996.

GOVERNOR

Attest:

SECRETARY OF STATE

RECEIVED

MAY 06 2011

UMATILLA COUNTY
PLANNING DEPARTMENT

EXECUTIVE ORDER NO. EO 99-01

THE OREGON PLAN FOR SALMON AND WATERSHEDS

The purpose of the Oregon Plan for Salmon and Watersheds (the "Oregon Plan") as stated in the Plan and reaffirmed in this Executive Order is to restore Oregon's wild salmon and trout populations and fisheries to sustainable and productive levels that will provide substantial environmental, cultural, and economic benefits and to improve water quality. The Oregon Plan is a long-term, ongoing effort that began as a focused set of actions by state, local, tribal and private organizations and individuals in October of 1995. The Oregon Plan first addressed coho salmon on the Oregon Coast, was then broadened to include steelhead trout on the coast and in the Lower Columbia River, and is now expanding to all at-risk wild salmonids throughout the state. The Oregon Plan addresses all factors for decline of these species, including watershed conditions and fisheries, to the extent those factors can be affected by the state. The Oregon Plan was endorsed and funded by the Oregon Legislature in 1997 through Oregon Senate Bill 924 (1997 Or. Laws, ch. 7) and House Bill 3700 (1997 Or. Laws, ch. 8). The Oregon Plan is described in two principal documents: "The Oregon Plan," dated March 1997, and "The Oregon Plan for Salmon and Watersheds, Supplement I -- Steelhead," dated January 1998. As used in this Executive Order, the Oregon Plan also incorporates the Healthy Streams Partnership (Oregon Senate Bill 1010, 1993 Or. Laws, ch. 263).

The Oregon Plan is a cooperative effort of state, local, federal, tribal and private organizations and individuals. Although the Oregon Plan contains a strong foundation of protective regulations -- continuing existing regulatory programs and speeding the implementation of others -- an essential principle of the Plan is the need to move beyond prohibitions and to encourage efforts to improve conditions for salmon through non-regulatory means. Many of the most significant contributions to the Oregon Plan are private and quasi-governmental efforts to protect and restore salmon on working landscapes, including efforts by watershed councils.

Salmon and trout restoration requires action and sacrifice across the entire economic and geographic spectrum of Oregon. The commercial and sport fishing industries in Oregon have been heavily affected by complete or partial closures of fisheries. The forest industry operates under the Oregon Forest Practices Act, and has contributed substantially to salmon recovery through habitat restoration projects on private lands and by funding a large part of the state recovery efforts. The agriculture and mining industries are also taking actions that will protect and restore salmon and trout habitat and improve water quality (including financial support of restoration efforts by the mining industry). Urban areas are developing water conservation programs, spending funds for wastewater treatment improvements to reduce point source pollution, reducing non-point source pollution and reducing activities that degrade riparian areas. All citizens of Oregon share responsibility for declining populations of wild salmon and trout, and it is important that there be both a broad commitment to reversing these historic trends and a sense that the burdens of restoration are being shared by all of society.

It is also important that there be independent scientific oversight of the Oregon Plan. This oversight is being provided by the Independent Mutidisciplinary Science Team (IMST), established under Oregon Senate Bill 924 (1997 Or. Laws, ch. 7). Additional legislative oversight for the Oregon Plan is being provided by the Joint Legislative Committee on Salmon and Stream Enhancement (the "Joint Committee").

Under the federal Endangered Species Act (ESA) the U.S. Fish & Wildlife Service (F&WS) and the National Marine Fisheries Service (NMFS) are responsible for identifying species that are threatened or endangered, and for developing programs to conserve and recover those species. F&WS and NMFS have now listed salmonids under the ESA on the entire Oregon Coast, the lower Columbia River (including most of the Portland metropolitan area), the Klamath River basin, and in the upper Columbia and Snake River basins. More listings are expected within the next year.

To date, the F&WS and NMFS generally have not had the resources to develop and implement effective recovery plans for fisheries. In addition, in many areas a large proportion of the habitat that listed salmonids depend on is located on private lands, where the regulatory tools under the ESA are relatively ill-defined and indirect. Finally, federal agencies alone, even if they take an active regulatory approach to recovery, will not restore listed salmonids. The federal ESA may work to prohibit certain actions, but there is simply too much habitat on private lands for restoration to succeed without pro-active involvement and incentives for individuals, groups, and local governments to take affirmative actions to restore habitat on working landscapes.

In April, 1997 the State of Oregon and NMFS entered into a Memorandum of Agreement (MOA) under which the State agreed to continue existing measures under the March 1997 Oregon Plan and to take certain additional actions to protect and restore coho salmon on the Oregon Coast. On May 6, 1997, NMFS determined that the Oregon Coast Evolutionarily Significant Unit (ESU) of coho salmon did not warrant listing as a threatened or endangered species under the ESA.

On June 2, 1998, the U.S. District Court for Oregon ordered NMFS to reconsider its decision without taking into account any parts of the Oregon Plan or MOA that are not "current enforceable measures." The U.S. District Court for Oregon also held that the MOA was speculative, due to the fact that it provided for termination by either party on thirty days notice, and that therefore the MOA could not be considered by NMFS in its listing decision.

Under court order, NMFS reconsidered its decision without taking into account the application in the future of the harvest and hatchery measures contained in the Oregon Plan, or the habitat improvement programs being undertaken under the Oregon Plan, or the commitments made by the State of Oregon in the MOA for improvement of applicable habitat measures. Accordingly, NMFS listed Oregon Coast coho as threatened under the ESA on or about October 2, 1998.

The MOA provided for the State of Oregon to take actions necessary to ensure that Oregon Coast coho did not warrant listing as a threatened or endangered species under the federal ESA. Now that Oregon Coast coho are listed as a threatened species as a result of the U.S. District Court's order, the central purpose of the MOA has been eliminated. Due to the uncertainties created by the District Court's decision and the increasing extent of salmonids listed or proposed for listing under the federal ESA, it is important that the status of the State of Oregon's substantive commitments under the MOA and the purpose of the Oregon Plan be clarified.

Through this Executive Order, the State of Oregon reaffirms its intent to play the leading role in protecting and restoring Oregon Coast coho and other salmonids through the implementation of the Oregon Plan. This Executive Order provides the framework and direction for state agencies to implement (to the extent of their authorities) the Oregon Plan in a timely and effective manner. This Executive Order also provides a framework for extending the state's efforts beyond a focus on Oregon Coast coho, to watersheds and fisheries statewide. Consistent with the principle of adaptive management, this Order applies the experience gained to date in implementing the Oregon Plan to provide additional detailed direction to state agencies. Finally, this Executive Order establishes a public involvement process to prioritize continuing efforts under the Oregon Plan.

**NOW THEREFORE, IT IS HEREBY ORDERED AND DIRECTED:**

**(1) Overall Direction**

(a) Agencies of the State of Oregon will, consistent with their authorities, fully implement the state agency efforts described in the Oregon Plan and in this Executive Order.

(b) The overall objective for state agencies under the Oregon Plan and this Executive Order is to protect and restore salmonids and to improve water quality.

(c) The Governor will, in cooperation with the Joint Committee, IMST, affected state agencies, watershed councils, and other affected local entities and persons develop and implement a process to set biological and habitat goals and objectives to protect and restore salmonids on a basin or regional basis as soon as practicable. Once these goals and objectives are established, they will be used by state agencies to evaluate their regulatory and non-regulatory programs and measures relating to the protection and restoration of salmonids. Through this on-going evaluation, state agencies will determine any changes to their programs or measures that may be necessary to meet the biological and habitat goals and objectives. In the interim, the following objectives in subsections (d) and (e) shall apply to agencies' implementation of the Oregon Plan and this Executive Order.

(d) Actions that state agencies take, fund and/or authorize that are primarily for a purpose other than restoration of salmonids or the habitat they depend upon will, considering the anticipated duration and geographic scope of the actions:

(A) to the maximum extent practicable minimize and mitigate adverse effects of the actions on salmonids or the habitat they depend on; and

(B) not appreciably reduce the likelihood of the survival and recovery of salmonids in the wild.

(e) State agencies will take, fund and/or authorize actions that are primarily for the purpose of restoring salmonids or the habitat they depend upon, including actions implementing the Oregon Plan, with the goal of producing a conservation benefit that (if taken together with comparable and related actions by all persons and entities within the range of the species) is likely to result in sustainable population levels of salmonids in the foreseeable future, and in population levels of salmonids that provide substantial environmental, cultural and economic benefits to Oregonians in the long term.

(f) With the broadening of the Oregon Plan, prioritizing all agency actions according to coho core areas is no longer appropriate. Each state agency participating in the Oregon Plan, in consultation with ODFW and other partners involved in the implementation of the Plan and through a public involvement process, will modify their existing work programs in the Oregon Plan to prioritize agency measures to protect and restore salmonids in a timely and effective manner. The work programs will continue to identify key specific outcomes, refine and improve designations of priority areas, and establish completion dates. These modifications will be submitted to the Governor, the Joint Committee, and to the appropriate boards and commissions as soon as possible, but in no event later than June 1, 1999. Progress reports on action plans will be submitted to the Governor, the Joint Committee, and to the appropriate boards and commissions on an annual basis. In prioritizing their efforts, state agencies shall consider how to maximize conservation benefits for salmonids and the habitat they depend on within limited resources and whether their actions are likely to increase populations of salmonids in the foreseeable future.

(g) State agencies will work cooperatively with landowners, local entities and other persons taking actions to protect or restore salmonids.

(h) As the Oregon Plan grows in geographic scope and in intensity of activity, there is a growing need to streamline and prioritize state agency activity at the regional level. One proposal has been to organize state natural resource agency field operations along hydrologic units. Therefore, state agencies will consider this proposal and, through the collective efforts of state agency directors, develop an organization plan that focuses state agency field effort on the activities and areas of highest priority under the Oregon Plan.

(i) State agencies will continue to encourage and work with agencies of the U.S. government to implement the federal measures described in the Oregon Plan. In addition, the state agencies will work with the federal government to develop additional means of protecting and restoring salmonids. Where appropriate, state agencies will request that federal agencies obtain incidental take permits under Section 7 of the federal ESA for state actions that are funded or authorized by a federal agency.

(j) State agencies will help support efforts to evaluate watershed conditions, and to develop specific strategic plans to provide for flood management, water quality improvement, and salmonid restoration in basins around the state, including the Willamette basin through the Willamette Restoration Initiative.

(k) The IMST will continue to provide oversight to ensure the use of the best scientific information available as the basis for implementation of and for adaptive changes to the Oregon Plan. State agencies will ensure that the IMST receives data and other information reasonably required for its functions in a timely manner. The Governor's Natural Resources Office (GNRO) has requested that the IMST's initial priority be review of the freshwater habitat needs of coho and the relationship between population levels, escapement levels, and habitat characteristics. The GNRO also will continue to request that the IMST annually review monitoring results and identify where the Oregon Plan warrants change for scientific or technical reasons and make recommendations to the appropriate agency on those adjustments that appear necessary. Agencies will report their responses to any recommendations by the IMST to the Governor and to the Joint Committee. Any other changes identified by the IMST as necessary to achieve properly functioning riparian and aquatic habitat conditions required to protect and restore salmonids will be forwarded to the appropriate governmental entity for its consideration of the adoption of new, changed, or supplemental measures as rapidly as possible while providing for public involvement. Each state agency, by June 1, 1999, will ratify a monitoring team charter through an interagency memorandum. A draft of the charter is contained in the 1998 Oregon Plan Annual Report.

(l) Monitoring is a key element of the Oregon Plan. Each state agency will actively support the monitoring strategy described in the Oregon Plan. Each affected agency will participate on the monitoring team to coordinate activities and integrate analyses. Each agency will implement an appropriate monitoring program to assess the effectiveness of their programs and measures in meeting the objectives set forth in the Oregon Plan on an annual basis. In addition, agencies with regulatory programs that are included in the Oregon Plan will determine levels of compliance with regulatory standards and identify and act on opportunities to improve compliance levels.

(m) If information gathered regarding the effectiveness of measures in the Oregon Plan shows that existing strategies within state control are not achieving expected improvements and objectives, the agency(ies) responsible for those measures will seek appropriate changes in their regulations, policies, programs, measures and other areas of the Oregon Plan, as required to protect and restore coho and other salmonids. Such modification or supplementation will be done as rapidly as possible, consistent with public involvement.

(n) Agencies are using geographically-referenced data in their efforts under the Oregon Plan, and will be using Geographic Information Systems (GIS) in the analysis of these data. In doing so, the State GIS Plan, developed by the Oregon Geographic Information Council (OGIC) (see Executive Order 96-40) will be followed, with specific adherence to the Plan guidance on data documentation, coordination and data sharing. The agency with primary responsibility for gathering and updating the specific data will be responsible for meeting the requirements of the Plan, and to ensure coordination with OGIC, the State Service Center for GIS and other cooperating agencies. In addition, state agencies will cooperate with the Governor's Watershed Enhancement Board (GWEB), Soil and Water Conservation Districts (SWCDs), local watershed councils, landowners and others in making these essential data available.

(o) Geographically-based strategies to assess and achieve habitat needs and adequate escapement levels will be used, and the state agencies will continue with the development of standardized watershed assessment protocols, including a cumulative effects assessment. State agencies will also continue with the development of habitat restoration guides to evaluate and direct habitat restoration efforts.

**(2) Continuation and Expansion of Existing Efforts.** Without limiting the generality of section (1)(a) of this Executive Order, the following subsections of this Executive Order describe some of the many efforts in the Oregon Plan where the initial phase of work has been completed, and where efforts will be continued.

(a) The Oregon Fish & Wildlife Commission (OFWC), the Oregon Department of Fish & Wildlife (ODFW), and the Pacific Fishery Management Council (PFMC) are managing ocean and terminal fisheries according to the measures set forth in the Oregon Plan (ODFW I-A.1 and III-A.1). These measures set a maximum mortality rate (resulting from other fisheries) for any of four disaggregated stocks of coho of fifteen percent (15%) under poor ocean conditions. In 1997, the mortality rate from harvest is estimated to have been between nine and eleven percent (9-11%). ODFW and OFWC will continue these measures in state waters, and will actively support

continued implementation of the ocean harvest measures by the PFMC (Amendment 13 to the Council's salmon management plan) until and unless a different management regime agreeable to NMFS is adopted.

(b) The OFWC and ODFW will ensure that the fish hatchery measures set forth in the Oregon Plan are continued by the OFWC and ODFW. ODFW is marking all hatchery coho on the Oregon Coast. This marking will allow increased certainty in estimating hatchery stray rates beginning in 1999. Available data on hatchery stray rates for coho and steelhead are being provided to NMFS on an annual basis. The number of hatchery coho released is estimated to have been 1.7 million in 1998 -- substantially below the level called for in the Oregon Plan. This number will be reduced to 1.2 million in 1999. In addition, ODFW has, and will continue to provide annual reports regarding: (i) the number of juvenile hatchery coho that are released by brood year, locations and dates of release, life stage, and broodstock origin; (ii) the number of adult coho taken for broodstock for each hatchery, the location and date of collection, and the origin (hatchery or natural); (iii) the number of hatchery coho estimated to have spawned in natural habitat by basin; (iv) the estimated percentage of hatchery coho in the total natural spawning population; and (v) the mortality of naturally-spawning coho resulting from each fishery. NMFS may provide comments about hatchery programs affecting coho to ODFW, with any concerns to be resolved between NMFS and ODFW.

(c) In addition to recent modifications to hatchery practices and programs, a new vision is needed for how Oregon will utilize hatcheries in the best and most effective manner. Therefore, the ODFW and the OFWC shall engage in a process to create a strategic plan for fish hatcheries in Oregon over the next decade (including state and federally-funded hatcheries, private hatcheries, and the STEP program). The essential elements of this process are as follows: (i) Impartial analysis -- conduct an impartial analysis of the scientific bases, and the social and economic effects of Oregon hatchery programs utilizing existing analyses and review where feasible, but conducting new analyses if necessary; (ii) Review the Wild Fish Management Policy (WFMP) -- because the future plan for hatcheries in Oregon is dependent on implementation of the WFMP, ODFW shall conduct a science and stakeholder review to determine if this significant policy should be revised and shall make any revision by July 2000; (iii) Frame alternative strategies -- convene a group of stockholders to frame alternative strategies, including outcomes and descriptions, of how hatcheries will be used in Oregon over the next decade (these strategies will address the use of hatcheries for wild fish population recovery including supplementation, research and monitoring, public education, and sport and commercial fishing opportunities); (iv) Public review and selection of a strategy -- the OFWC shall, after public review and comment, adopt a strategic plan to guide development of future hatchery programs, incorporating the strategy developed and adopted in accordance with subpart (iii) of this paragraph.

(d) Criteria and guidelines directing the design of projects that may affect fish passage have been established in a Memorandum of Understanding (MOU) between the Oregon Department of Transportation (ODOT), ODFW, the Oregon Department of Forestry (ODF), the Oregon Department of Agriculture (ODA), the Division of State Lands (DSL) and the Federal Highway Administration. These guidelines apply to the design, construction and consultations of projects affecting fish passage. Under the MOU, projects requiring regulatory approvals that follow these criteria and guidelines are expedited. Oregon agencies will continue to provide technical assistance to ensure that the criteria and guidelines are applied appropriately in restoration projects, as well as any other projects that may affect fish passage through road crossings and similar structures. ODFW will work with state agencies, local governments, and watershed councils to ensure that Oregon's standards for fish passage set forth in Exhibit A to the MOU are understood and are implemented.

(e) Fish presence, stream habitat, road and culvert surveys have been conducted for roads within ODOT jurisdiction and county roads in coastal basins, the Lower Columbia basin, the Willamette basin, and the Grande Ronde/Imnaha basins. Among the results of



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these surveys is the finding that culvert barriers to fish passage affect a substantial quantity of salmonid habitat. For example, surveys of county and state highways in western Oregon found over 1,200 culverts that are barriers to passage. As a result, ODOT is placing additional priority on restoring fish access. For 1998, ODOT repaired or replaced 35 culverts restoring access to 101 miles of salmonid habitat. For 1999, the Oregon Transportation Commission will be asked to fund approximately $4.0 million for culvert modification. ODOT and the Commission will continue to examine means to speed restoration of fish passage and to coordinate priorities with ODFW.

(f) Draft watershed assessment protocols have been developed and are being field tested. Beginning in 1999, SWCDs, watershed councils and others will be able to use the protocols as the basis for action plans to identify and prioritize opportunities to protect and restore salmonids. Watershed action plans have already been completed in a number of basins including the Rogue, Coos, Coquille and Grande Ronde. State agencies will work to support these watershed assessments and plans to the maximum extent practicable. Where watershed action plans have been developed under the protocols, GWEB will ensure that projects funded through the Watershed Improvement Grant Fund are consistent with watershed action plans, and other state agencies will work with SWCDs and watershed councils to ensure that activities they authorize, fund or undertake are consistent with watershed action plans to the maximum extent practicable.

(g) The State of Oregon has developed interim aquatic habitat restoration and enhancement guidelines for 1998. State agencies involved with restoration activities (ODFW, ODF, DSL, ODA, DEQ, and GWEB) will continue to develop and refine the interim guidelines for final publication in April 1999. The guidelines will be applied in restoration activities funded or authorized by state agencies. The purpose of the guidelines will be to define aquatic restoration and to identify and encourage aquatic habitat restoration techniques to restore salmonids.

(h) ODA and ODF have each entered into a Memorandum of Understanding with the Oregon Department of Environmental Quality relating to the development of Total Maximum Daily Loads (TMDLs) and Water Quality Management Area Plans (WQMAPs). ODA will adopt and implement WQMAPs (through the Healthy Streams Partnership) and ODF will review the adequacy of forest practices rules to meet water quality standards. ODF and ODA will evaluate the effectiveness of these measures in achieving water quality standards on a regular basis and implement any changes required to meet the standards.

(i) Agencies are implementing a coordinated monitoring program, as described in the Oregon Plan. This program includes technical support and standardized protocols for watershed councils, stream habitat surveys, forest practice effectiveness monitoring, water withdrawal monitoring, ambient water quality monitoring, and biotic index studies, as well as fish presence surveys and salmonid abundance and survival monitoring in selected subbasins. State agencies are also working to coordinate monitoring efforts by state, federal, and local entities, including watershed councils. State agencies will work actively to ensure that the monitoring measures in the Oregon Plan are continued.

(j) GWEB has put into place new processes for identifying and coordinating the delivery of financial and technical assistance to individuals, agencies, watershed councils and soil and water conservation districts as they implement watershed restoration projects to improve water quality and restore aquatic resources. Over $25 million has been distributed for watershed restoration projects in the last ten years. During the present (1997-99 biennium) GWEB has awarded over $12 million dollars in state and federal funds for technical assistance and watershed restoration activities to implement the Oregon Plan. GWEB and state agencies will continue to seek financial resources to be allocated by GWEB for watershed restoration activities at the local and statewide levels.

(k) State agencies will continue to encourage, support and work to provide incentives for local, tribal, and private efforts to implement the Oregon Plan. In addition, state agencies will continue to provide financial assistance to local entities for projects to protect and restore salmonids to the extent consistent with their budgetary and legal authorities, and consistent with their work programs in the Oregon Plan. To the maximum extent practicable, state agencies will also provide technical assistance and planning tools to provide local conservation groups to assist in and target watershed restoration efforts. These efforts (during 1996 and 1997) are reported in "The Oregon Plan for Salmon and Watersheds: Watershed Restoration Inventory, 1998." Just a few of the important efforts that have been completed include:

(A) Eighty-two watershed councils have joined with forty-five Soil and Water Conservation Districts as well as private and public landowners to implement on-the-ground projects to protect and restore salmonids. During 1996 and 1997, a reported $27.4 million was spent on 1,234 watershed restoration projects on non-federal lands. Both the amount spent and the number of projects represent significant increases (of over 300 percent) over prior years. In 1996-97, watershed councils, SWCDs and other organizations and individuals completed: (i) 138 stream fencing projects, involving at least 301 miles of streambank; (ii) 196 riparian area planting projects, involving at least 111 miles of streams; and (iii) 458 instream habitat improvement projects.

(B) Private and state forest landowners are implementing key efforts under the Oregon Plan, including the road risk and remediation program (ODF-1 and 2). Under this effort in 1996 and 1997, close to 4,000 miles of roads have been surveyed to identify

risks that the roads may pose to salmonid habitat. As the risks are identified, they are then prioritized for remediation following an established protocol. Already, 52 miles of forest roads have been closed, 843 miles of road repair and reconstruction projects to protect salmonid habitat have been completed,
and an additional 14 miles of roads have been decommissioned or relocated. In addition, 530 culverts have been replaced, upgraded or installed for fish passage purposes, improving access to a reported 146 stream miles.

(C) Organizations working in Tillamook County have developed the Tillamook County Performance Partnership. The Partnership is implementing the Tillamook Bay National Estuary Program by addressing water quality, fisheries, floodplain management and economic development in the county. Among the actions that the Partnership has already accomplished are: (i) the closure of seven miles of degraded forest roads and the rehabilitation of 469 miles of roads to meet current standards, at a cost of $18 million; (ii) the fencing of 53 miles of streambank, and the construction of three cattle bridges and 100 alternative cattle watering sites, at a cost of $214,000; and (iii) the completion of 24 instream restoration projects and 34 barbs protecting 4,200 feet of streambank, at a cost of $1.3 million dollars.

(D) The Confederated Tribes of the Grande Ronde Community of Oregon have completed a forest management plan that establishes standards for the protection of aquatic resources that are comparable to those found in the Aquatic Conservation Strategy of the Northwest Forest Plan.

(E) A combination of funding from the Oregon Wildlife Heritage Foundation and the National Fish and Wildlife Heritage Foundation (private, non-profit organizations) is providing support for seven biologists to design restoration projects. These projects are prioritized based on stream surveys, and are carried out with the voluntary participation and support of landowners. A ten-year monitoring plan has been funded and implemented to determine project effectiveness.

(F) The Oregon Cattlemen's Association has implemented its WESt Program that is designed to help landowners better understand their watersheds and stream functions through assessments and monitoring. The WESt Program brings landowners together along stream reaches, and offers a series of workshops, conducted on a site specific basis, free of charge. The workshops include riparian ecology, setting goals and objectives, Proper Functioning Condition (PFC), data collection and monitoring. Over 25 workshops have been held, with attendance ranging from 5 to 30 landowners per workshop. The WESt Program is sponsored by the Oregon Cattlemen's Association, DEQ, Oregon State University, and GWEB.

(G) Within the Tillamook State Forest road network 1,902 culverts have been replaced or added to improve road drainage and to disconnect storm water runoff from roads reducing stream sediment impacts. Additionally, some of these culverts also improved fish passage at stream crossings. In this process, ODF has also replaced six culverts with bridges improving fish passage to approximately four miles of stream. The Tillamook State Forest in conjunction with many partners, such as the Association of Northwest Steelheaders, GWEB, Simpson Timber Company, Tillamook County, the FishAmerica Foundation, Hardrock Construction Company, the Oregon Wildlife Heritage Foundation, the F&WS, the Oregon Youth Conservation Corps, Columbia Helicopters and Terra Helicopters, has also recently completed instream placement of over 400 rootwads, trees and boulders at a cost of $300,000 for habitat enhancement.

**(3) Key Agency Efforts**. Continuation and completion of the following state agency efforts is critical to the success of the Oregon Plan. State agencies will make continuation or completion (as appropriate) of the following efforts a high priority.

(a) The State of Oregon and the U.S. Department of Agriculture have entered into a Conservation Reserve Enhancement Program (CREP). This cost-share program, one of the first of its kind, will be used to reduce the impacts of agricultural practices through water quality and habitat improvement. The objectives of the CREP are to: (i) provide incentives for farmers and ranchers to establish riparian buffers; (ii) protect and restore at least 4,000 miles of stream habitat by providing up to 95,000 acres of riparian buffers; (iii) restore up to 5,000 acres of wetlands that will benefit salmonids; and (iv) provide a mechanism for farmers and ranchers to comply with Oregon's Senate Bill 1010 (1993 Or. Laws, ch. 263).

(b) ODF will work with non-industrial forest landowners to administer the Stewardship Incentive Program and the Forest Resources Trust programs to protect and restore riparian and wetland areas that benefit salmonids.

(c) The Oregon Board of Forestry will determine, with the assistance of an advisory committee, to what extent changes to forest practices are needed to meet state water quality standards and to protect and restore salmonids. A substantial body of information regarding the effectiveness of current practices is being developed. This information includes: (i) the IMST report regarding the role of forest practices and forest habitat in protecting and restoring salmonids; and (ii) a series of monitoring projects that include the Storms of 1996 study, a riparian areas study, a stream temperature study, and a road drainage study. Using this information, as well as other available scientific information including scientific information from NMFS, the advisory committee will make recommendations to the Board at both site and watershed scales on threats to salmonid habitat relating to sediment, water temperature, freshwater habitat needs, roads and fish passage. Based on the advisory committee's recommendations and other scientific information, the Board will make every effort to make its determinations by June 1999. The Board may determine that the most effective means of achieving any necessary changes to forest practices is through regulatory changes, statutory changes or through other programs including programs to create incentives for forest landowners. In the event that the Board determines that legislative changes are necessary to carry out its determinations, the Board will transmit any recommendations for such changes to the Governor and to the Joint Committee at the earliest possible date.

(d) Consistent with administrative rule, and statutory and constitutional mandates for the management of state forests, ODF State Forest management plans will include an aquatic conservation strategy that has a high likelihood of protecting and restoring properly functioning aquatic habitat for salmonids on state forest lands.

(e) ODF will present to NMFS a Habitat Conservation Plan (HCP) under Section 10 of the federal ESA that includes the Clatsop and Tillamook State Forests. ODF has already completed scientific review and has public review underway for this draft HCP. The scientific and public review comments will be considered by ODF in completing the draft HCP. The draft HCP will be presented to NMFS by June 1999. An HCP for the Elliott State Forest was approved by the U.S. Fish & Wildlife Service in 1995. In October of 1997, ODF and DSL forwarded the Elliott State Forest HCP to NMFS with the request that it be reviewed to determine whether it has a high likelihood of protecting and restoring properly functioning aquatic habitat conditions on state forest lands necessary to protect and restore salmonids. Based on discussions surrounding the NMFS review, ODF and DSL will determine what revisions, if any, are required to the Elliott HCP and/or Forest Management Plan to ensure a high likelihood of protecting and restoring properly functioning aquatic habitat for salmonids.

(f) Before the OFWC adopts and implements fishery regulations that may result in taking of coho, ODFW will provide NMFS with all available scientific information and analyses pertinent to the proposed regulation where the harvest measures are not under the jurisdiction of the PFMC, including results of the Oregon Plan monitoring and evaluation program. This information, together with the proposed regulation and supporting analysis, will be provided at least two weeks prior to the OFWC's action, to give NMFS time to review and comment on the proposed regulations.

(g) ODFW will evaluate the effects of predation on salmonids, and will work with affected federal agencies to determine whether changes to programs and law relating to predation are warranted in order to protect and restore salmonids.

(h) Under Oregon Senate Bill 1010 (1993 Or. Laws, ch. 263), ODA will adopt Agricultural Water Quality Management Area Plans (AWQMAPs) for Tier I and Tier II watersheds by the end of 2002. The AWQMAPs will be designed and implemented to meet load allocations for agriculture needed to achieve state water quality standards. In addition, ODA will work with ODFW, DEQ, GWEB, SWCDs, federal agencies and watershed councils to determine to what extent additional measures related to achieving properly functioning riparian and aquatic habitat on agricultural lands are needed to protect and restore salmonids, giving attention first to priority areas identified in the Oregon Plan. In the event ODA is unable to reach a consensus regarding such measures, ODA will ask the IMST to review areas of substantive scientific disagreement and to make recommendations to ODA regarding how they should be resolved. In the event that legislative changes are needed to implement such measures, ODA will transmit any recommendations for such changes to the Governor and to the Joint Committee at the earliest possible date. In addition, any measures identified as needed by ODA will be implemented at the earliest practicable time.

(i) ODFW will expedite its applications for instream water rights and OWRD will process such applications promptly where flow deficits are identified as adversely affecting salmonids, and where such rights are not already in place. The Oregon Water Resources Department (OWRD) and the Oregon Water Resources Commission (OWRC) will also seek to facilitate flow restoration targeted to streams identified by OWRD and ODFW as posing the most critical low-flow barriers to salmonids. In addition, where necessary, OWRD will continue to work with the Oregon State Police to provide enforcement of water use. Where illegal water uses are identified, OWRD will ensure outcomes consistent with maintenance and restoration of flows.

(j) The Oregon Environmental Quality Commission (EQC) and DEQ will evaluate and will make every effort to utilize their authorities to continue to provide additional protection to priority areas (as determined under section 1(f) of this Executive Order), including in-stream flow protection under state law, and antidegradation policy under the federal Clean Water Act (including Outstanding Resource Waters designations and high quality waters designations).

(k) DSL has proposed to adopt changes to its Essential Salmonid Habitat rules that will provide additional protection for spawning and rearing areas of anadromous salmonids. In addition, ODFW and DSL will consult with the OWRC to determine where it is necessary to administratively close priority areas (including work under General Authorizations) to fill and removal activities in order to protect salmonids. DSL, ODFW, ODF and ODA also will work together to identify means of regulating the removal of organic material (such as large woody debris) from streams where such removal would adversely affect salmonids and would not be contrary to other agency mandates.

(l) DSL will seek the advice of the IMST regarding whether gravel removal affects gravel and/or sediment budgets in a manner that adversely affects salmonids.

(m) The Department of Land Conservation and Development (DLCD), and the Land Conservation and Development Commission (LCDC) will evaluate and, to the extent feasible, speed implementation of existing Goal 5 requirements for riparian corridors.

(n) DLCD, DEQ, ODF, ODA, ODFW, and DSL and their respective boards and commissions will evaluate and implement programs to protect and restore riparian vegetation for the purposes of achieving statewide water quality standards and protecting and restoring aquatic habitat for salmonids.

(o) DLCD, with the assistance of DSL and ODFW, and in consultation with coastal cities and counties, shall review the requirements of Statewide Planning Goal 16 as they pertain to estuarine resources important to the restoration of salmonids, and shall, report its findings to LCDC for its consideration.

(p) The Oregon State Police will work to facilitate the existing cooperative relationship with the NMFS Office of Law Enforcement, as well as to maintain cooperation with other enforcement entities, in order to enhance law enforcement, public awareness and voluntary compliance related to harvest, habitat and other issues addressed in the Oregon Plan.

(q) The Oregon Parks and Recreation Department will continue to work to provide information and education to the public on salmon and steelhead needs through park programs and interpretive aids.

(r) The Oregon Marine Board will work to ensure fish friendly boating and to develop boating facilities that protect salmonids.

(s) State natural resource agencies will continue, to the extent feasible, to support watershed councils by providing technical assistance to develop watershed assessments, restoration plans and to develop watershed priorities to benefit salmonids. In addition, state natural resource agencies will work on a larger watershed scale to develop basin-wide restoration priorities.

**(4) Future Modifications; Public Involvement for the Oregon Plan Generally.** The GNRO will solicit public comments and input from participants in the Oregon Plan regarding whether there are refinements or changes to the Plan and/or the organizational framework for implementing the Plan that are necessary or desirable based on the experience gained over the past three years, or resulting from the widespread listings and proposed listings of salmon and trout under the federal ESA. Based on this public involvement, the GNRO will provide a report and recommendations to the Governor and the Joint Committee regarding whether modifications are necessary to the Oregon Plan in order to protect and restore coho and other salmonids.

**(5) Definitions.** For purposes of this Executive Order:

(a) The "Oregon Plan" means the Oregon Coastal Salmon Recovery Initiative, dated March 1997, and the Steelhead Supplement, dated January 1998. "Oregon Plan," as used in this Order, is intended to be consistent with the definition of the Oregon Coastal Salmon Recovery Initiative in Oregon Senate Bill 924 (1997 Or. Laws, ch. 7), and to include the Healthy Streams Partnership (1993 Or. Laws, ch. 263).

(b) "Protect" has the meaning given in section (1)(d) of this Executive Order.

(c) "Restore" has the meaning given in section (1)(e) of this Executive Order. Restore necessarily includes actions to manage salmonids to provide for adequate escapement levels, and actions to increase the quantity and improve the quality of properly functioning habitat upon which salmonids depend.

(d) "Coho" means native wild coho salmon found in rivers and lakes along the Oregon Coast.

(e) "Salmonids" means native wild salmon, char and trout in the State of Oregon.

**(6) Effective Date; Relation to Federal ESA.** This Executive Order will take effect on the date that it is filed with the Secretary of State. The State of Oregon will continue to work with NMFS to determine the appropriate relationship between the Oregon Plan and NMFS's efforts under the federal ESA.

Done at Salem, Oregon, this 8th day of January, 1999.

/S/ ______________________________
John A. Kitzhaber, M.D.
GOVERNOR

ATTEST:

/S/ ___________________________
Suzanne Townsend
DEPUTY SECRETARY OF STATE

RECEIVED

MAY 06 2011

UMATILLA COUNTY
PLANNING DEPARTMENT

# Draft

# Walla Walla Agricultural Water Quality Management Area Plan

## Guidance Document
## and
## Administrative Rules

**Developed by**
**The Walla Walla Local Agricultural Water Quality Advisory Committee**

**With assistance from**
**The Oregon Department of Agriculture**
**and**
**The Umatilla County**
**Soil and Water Conservation District**

## September 24, 2001

**Local Advisory Committee Members**

Tom Darnell, Chr.
Craig Buchanan
Jim Burns
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Bob Lewis
Ed Leahy
Jessica Pottenger
Dennis Rea
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Brent Stevenson
Jerry Weidert
Ray Williams
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# ACRONYMS

| | |
|---|---|
| AgWQM | Agricultural Water Quality Management |
| CAFO | Confined Animal Feeding Operation |
| CCRP | Continuous Conservation Reserve Program |
| cfs | Cubic Feet Per Second |
| CREP | Conservation Reserve Enhancement Program |
| CRP | Conservation Reserve Program |
| CWA | Clean Water Act |
| DEQ | Oregon Department of Environmental Quality |
| EQIP | Environmental Quality Incentives Program |
| HEL | Highly Erodible Land |
| LAC | Local Advisory Committee |
| LMA | Local Management Agency |
| NRCS | Natural Resources Conservation Service |
| OACD | Oregon Association of Conservation Districts |
| OAR | Oregon Administrative Rules |
| ODA | Oregon Department of Agriculture |
| ODFW | Oregon Department of Fish and Wildlife |
| ORS | Oregon Revised Statutes |
| OSU | Oregon State University |
| RUSLE | Revised Universal Soil Loss Equation |
| SB 1010 | Senate Bill 1010 |
| SWCD | Soil and Water Conservation District |
| TMDL | Total Maximum Daily Load |
| USDA | United States Department of Agriculture |

# Walla Walla Agricultural Water Quality Management Area Plan

## I FOREWORD

This Agricultural Water Quality Management (AgWQM) Area Plan provides guidance for addressing agricultural water quality issues in the Walla Walla Agricultural Water Quality Management Area. The purpose of this Area Plan is to identify strategies to reduce water pollution from agricultural lands through a combination of educational programs, suggested land treatments, management activities, and monitoring.

The provisions of this Area Plan do not establish legal requirements or prohibitions.

The Oregon Department of Agriculture (ODA) will exercise its enforcement authority for the prevention and control of water pollution from agricultural activities under administrative rules for the Walla Walla subbasin (Oregon Administrative Rules 603-095-1700 through 603-095-1760) and state-wide enforcement procedures provided in OARs 603-090-0060 through 603-090-0120.

This Area Plan will be used by local management agencies for guiding implementation, outreach, and assistance efforts and by landowners to enhance their awareness and understanding of water quality issues.

## II INTRODUCTION

The AgWQM Program in the ODA's Natural Resources Division is responsible for addressing water pollution associated with agricultural lands and activities.

In 1993, the Oregon Legislature passed Senate Bill 1010 (SB 1010), which directs the Oregon Department of Agriculture to be the lead state agency working with agriculture to address water pollution. Through SB 1010, the ODA is authorized to develop and carry out a water quality management plan for agricultural or rural lands when state or federal law requires a water quality management plan. In 1995, the Oregon Legislature passed SB 502, that stipulates that ODA shall develop and implement any program or rules that directly regulate farming practices that are for the purpose of protecting water quality and that are applicable to areas of the state designated as exclusive farm use zones or other agricultural lands. The implications of the legislation are that in Oregon, ODA is the agency responsible for regulating agricultural activities as they affect water quality.

AgWQM Area Plans help identify and control water pollution caused by activities on agricultural and rural lands. These Area Plans recognize that the best way to prevent or control pollution from agricultural and rural land is to work to reduce the conditions on that land that cause pollution.

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This Area Plan was developed by volunteer members of the Walla Walla AgWQM Local Advisory Committee (LAC) with assistance from the ODA and the Umatilla Soil and Water Conservation District (SWCD). It represents the efforts of the LAC, the ODA and the SWCD, in consultation with members of the community, to address water quality as it may be affected by conditions on agricultural and rural land in the planning area. Members are:

| | |
|---|---|
| Tom Darnell: Chairman; OSU Extension; M-F | Vern Rodighiero: M-F; orchard crops, WWBWC |
| Craig Buchanan: M-F; dryland & irrigated crops | Brent Stevenson: M-F; irrigation district |
| Jim Burns: M-F; WWBWC, forestry, fruit | Ray Williams: dairy, livestock, irrigated crops |
| Cheri Cosper: M-F; horses, SWCD | Jerry Weidert: Athena; dryland crops |
| Ed Leahy: M-F; dryland crops | Jerry Zahl: College Place, WA; ag. consultant |
| Jessica Pottenger: Weston; Smith Foods; environmental | Bob Lewis: Alternate; M-F; irrigated crops, consultant |
| Dennis Rea: M-F; dryland & irrigated crops, livestock | |

The operational boundaries of this Area Plan include all private agricultural and rural land in Oregon that drains into the Walla Walla River and its tributaries. Federally managed land and those activities subject to the Oregon Forest Practices Act are exempted from this Area Plan but are subject to water quality management plans developed by the respective designated management agencies. This Area Plan applies to agricultural lands in current use and those lying idle or on which management has been deferred. This Area Plan also applies to rural lands not in agricultural use such as private roads and rural residential properties.

Area Rules will be formally adopted as part of Oregon Administrative Rules (OAR) to implement this Area Plan. Area Rules will define the planning area, provide prevention and control measures to protect water quality, provide exceptions to the prevention and control measures and describe a complaint resolution process. Area Rules are presented in this Area Plan and indicated by bold type within a border.

**Proposed Administrative Rule**

**603-095-1700**

**Purpose**

(1) These rules have been developed to implement a water quality management area plan for the subbasin pursuant to authorities vested in the department through ORS 568.900-568.933, and ORS 561.191-561.191. The area plan is known as the Walla Walla Agricultural Water Quality Management Area Plan.

(2) The purpose of these rules is to outline requirements for landowners in the Walla Walla Agricultural Water Quality Management Area, for the prevention and control of water pollution from agricultural activities and soil erosion. Compliance with Division 95 rules is expected to aid in the achievement of applicable water quality standards in the Walla Walla Agricultural Water Quality Management Area.

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# III Geographic Area and Physical Setting

## Location

The Walla Walla River Basin, located in southeast Washington and northeast Oregon, encompasses 1758 square miles (1,125,120 acres). The portion of the basin in Oregon is 27% or 480 square miles. The Oregon Walla Walla River subbasin is bounded by the Oregon-Washington State line (on the north), by the Blue Mountains (on the east and the south), and by Umatilla River Basin and the Columbia River (on the west). The Walla Walla River originates in the Blue Mountains and flows north-westerly, crossing into Washington State at river mile 40, and entering the Columbia River at Wallula, WA (RM 313). The Oregon portion of the subbasin has six watersheds: mainstem Walla Walla River (including branches of the Little Walla Walla River), South Fork Walla Walla River, North Fork Walla Walla River, Pine Creek, Dry Creek, and Couse Creek. Three other watersheds lying partially in Oregon, Birch Creek, Cottonwood Creek, and Mill Creek, are included in the plan area.

## Climate

The climate in the basin is continental where winters are cold, but generally not severe, and summer days are hot, but nights are fairly cool. Average daytime high temperatures generally decrease with increasing elevation. Lower elevation area temperatures average 50 degrees to 55 degrees Fahrenheit with extreme temperatures of 115 degrees and -21 degrees Farenheit recorded in recent years. Precipitation ranges from less than 10 inches in a narrow band along the Columbia River to more than 40 inches at high elevations in the Blue Mountains. Most precipitation occurs between October and May with snow in the upper elevations.

## Geology

Elevations in the Walla Walla River basin are about 270 feet at the Columbia River, about 3000 feet along the base of the Blue Mountains, and up to 6,000 feet at mountain crests. The elevation of Milton-Freewater is about 950 feet. Multiple lava flows exceeding 2,500 feet in thickness, known as the "Columbia River Basalt," underlie nearly the entire subbasin. The river basin is divided into two physiographic regions, the Deschutes-Umatilla Plateau and the Blue Mountains.

The Deschutes-Umatilla Plateau is a broad upland plain formed by flow upon flow of basalt, which dip gently northward from the Blue Mountains to the Columbia River. The Blue Mountain region includes the extreme northern extension of the Blue Mountains of Oregon. It was formed by uplifting, folding, faulting, and erosion of a variety of volcanic, sedimentary and metamorphic rock and is characterized by flat-topped ridges, steep-walled canyons, and forested mountain slopes.

The Walla Walla syncline (a broad U-shaped fold) forms the center of the Walla Walla subbasin and forms a deposition basin between the upland areas. These numerous sedimentary deposits include both areas of clay and gravels deposited on top of the basalt. Younger sedimentary deposits overlie the clay and gravel units. *Umatilla Basin Report, 1988*

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## Hydrology

The Walla Walla River and its tributaries drain about 480 square miles, in Oregon Water availability in the Walla Walla River basin is dependent on high-elevation snowpack in the Blue Mountains. Runoff occurs anytime during the precipitation period of October through May, with peaks occurring in April. Flows diminish rapidly after May, reaching their lowest levels in August and September. Streamflows increase in late fall and winter in response to storms migrating in from the Pacific Ocean.

## Soils

An extensive deposit of silty clay known as the Palouse Formation covers much of the uplands. Recent alluvium, consisting of clay, silt, sand, and gravel deposited by present-day rivers and streams is common in river valleys and flood plains. *Umatilla Basin Report, 1988*

A deep deposit of loess (windblown silt and fine sand) covers much of the subbasin that is used for agricultural purposes. Loess is highly erodible, yielding sediment, particularly in the middle and lower reaches of the main stem Walla Walla River. *Watershed Assessment, Upper Walla Walla River Subbasin, 1997.*

See Attachment 2 for more detailed description of general soil types. The *Soil Survey of Umatilla County Area, Oregon, 1988,* provides more information about the characteristics of specific soil types found in the area.

## Vegetation

Currently, vegetation in the headwaters of the drainage is primarily evergreen forest, dominated in the higher elevations by Douglas fir and grand fir with an understory of shrubs, grasses, and forbs. In the lower elevation, there is a more open forest dominated by ponderosa pine.

Mid-elevation lands are characterized by stands of timber changing into brush and grass as the elevation declines. Past land management has eliminated much of the native sagebrush and bunchgrass; these have widely been replaced by noxious weeds and other undesirable grasses, shrubs, and broadleaf weeds. Large mid-lower elevation areas have been converted into dryland farming. This is a transition zone, where farmland is intermingled with range. Often, the north slopes will be farmed while the west and south slopes, with their shallower soils, are used as range.

A riparian community dominated by cottonwood, alder, willow, and various shrubs occurs throughout the river basin. Cultivation, logging, domestic livestock grazing, residential and commercial development, and flood control activities have affected riparian vegetation throughout much of the mid-lower elevation reaches of the subbasin.

## Land Ownership and Land Use

According to the Umatilla Basin Report, 1988, the total acreage in the Oregon portion of the Walla Walla basin is 311,982 acres. Land in private ownership is 256,111 acres (81.7%), mostly in cropland or rangeland. The public owns 55,871 acres (17.8%), 53,588 acres are managed by US Forest Service (17.2%), 1942 acres are managed by the Bureau of Land Managment (.6%), and 41 acres by the State (.01%). The US Forest Service has 136 acres of land in the Wenaha-Tucannon Wilderness Area that lie within the Walla Walla River basin.

Agriculture and related trades and industries are the economic base for the area. Production of a number of important food crops has led to the development of a large food-processing complex in the valley. Since farm-gate value is reported for Umatilla County as a whole ($250 million), it is difficult to determine an exact economic value for agriculture in the Walla Walla River basin alone. 1999 statistics, from the Oregon State University (OSU) Extension Information Office, indicate the value of tree fruit crops and alfalfa seed, which are grown almost exclusively in the Walla Walla basin, at $8.2 million.

There are about 133,000 acres of cropland in the Walla Walla River basin. Grains, predominantly wheat, account for about 50 percent of crops grown and are located primarily on the higher dryland areas. Green peas account for about 13% and are grown on the drylands where the rainfall is adequate, usually in rotation with wheat. Commercial vegetable and fruit production, concentrated north of Milton-Freewater account for about 9% of the acreage; pasture, alfalfa and other hay account for about 15%; and the remainder is idle or fallow. Approximately 20,000 acres are irrigated with water that is withdrawn from wells and from surface sources.

Livestock production is important in the valley. Most of the estimated 4800 cow-calf pairs are raised on irrigated pastures with summer grazing on the slopes of the Blue Mountains. There are some small feedlots and dairies in the subbasin.

Forested land in the subbasin is about 88,200 acres. National forests comprise about 54%, private holdings about 43% and State and local government less the 3%. Most forestland has been logged at least once.

## Water Yield and Flow

The hydrology of the Walla Walla drainage is complex due to its geology and extensive development. The Walla Walla River's flow comes largely from two tributaries: the North and South Forks Walla Walla River. Both forks emerge from deep basaltic canyons and join to form the Walla Walla River mainstem about five miles southeast of Milton-Freewater.

Active gages are maintained on the North and South Forks of the Walla Walla River. The South Fork is the larger of the two streams. Average annual yield of the South Fork is more than three times that of the North Fork. Together, they yield about 198,000 acre feet per year.

The Walla Walla River has created an extensive alluvial fan from the gravels supplied by its forks and its channel. Once it flows out of the bedrock canyons of its headwaters, the Walla Walla dissipates much of its flow into the gravels it has deposited. The multiple channels, including the Little Walla Walla River, are used as natural irrigation ditches to carry water to the farms and orchards spreading across the alluvial fan. _Umatilla Basin Report_

On an average year, by June or early July, the Walla Walla River is dry near the state line because of irrigation withdrawals, seasonally low flows, channel bed water and evaporative losses. Irrigation return flows yield live flow in the Washington section of the Walla Walla River. Increases noted in some wells that pump from the shallow gravel aquifer during the irrigation season are attributed to groundwater recharge from irrigation.

## Water Use

The first irrigation was believed to have occurred in 1846. The earliest water rights of record date to the early 1860's. Some of these rights were established by court decree in the Walla Walla adjudication in 1933. In 1986, the Water Resources Commission withdrew the Walla Walla River and tributaries from further appropriation from the Little Walla Walla diversion to the state-line. Ground water development for irrigation dates back to the early 1900's.

A general provision of law, ORS 537.811, prohibits out-of-state diversions of water without consent of the Oregon Legislature. A 1936 U. S. Supreme Court decision allows Oregon users to divert the entire flow of the Walla Walla River before it enters Washington. Other judicial stipulations require water distribution on interstate tributaries as if the state line did not exist.

Approximately 50% of the surface irrigation water in the Oregon portion of the basin is delivered through two irrigation districts - the Walla Walla River Irrigation District and the Hudson Bay District Improvement Company. The combined water rights for the two districts is approximately 280 cubic feet per second (cfs) with the combined diversion rate peaked at about 150 cfs during June and drops to approximately 60 cfs in September.

The Walla Walla River Irrigation District was formed in 1995 by the consolidation of 5 existing irrigation companies. Almost 500 water rights with priority dates in the late 1800's make up the Walla Walla River Irrigation District, which allow for year around diversion. It delivers water to 3600 acres with water rights from the Walla Walla River. It maintains 4 diversion sites and 10 canals and ditches totalling 30.4 miles. The irrigation season is from mid-March to mid October. Irrigation water is applied mostly by sprinklers. This application method is most efficient in the prevalent coarse soils. In general, water rights in the Walla Walla River Irrigation District provide for a diversion of 16.8 gpm per acre though modern application methods and current crops may require less water.

The Hudson Bay District Improvement Company was formed in 1952 and took over existing irrigation facilities. It delivers water to approximately 6900 acres with Walla Walla River surface rights. The water is diverted at the Little Walla Walla diversion and redistributed at the "frog", a centralized distribution facility. The Walla Walla River Irrigation District maintains five canals and ditches with a combined length of 35.6 miles.

The Little Walla Walla River is a former braided stream section of the Walla Walla River and is used as a primary component of the district's water delivery system. It is considered by court order to be a natural stream even though the flows are regulated by headgates and fish screens are present. Water diverted by other basin users, above Milton-Freewater, is done by individual or small group diversions that do not have organized irrigation districts. Current projects are being implemented to improve the efficiency of these diversions including improved headgates and flow measuring devices, fish screens, removal or modification of gravel push-up dams, conversion to pump systems and conversion from flood to sprinkler systems. These projects are being carried out by the Irrigation Districts, the Walla Walla Basin Watershed Council, and the Water Resources Department.

## Groundwater

Fractured basalt provides a major ground-water source throughout the river basin. The basalt aquifer is thought to contain ancient water with limited recharge occurring mainly in the Blue Mountains. A major alluvial aquifer underlies approximately 120,000 acres of the central river subbasin (the Milton-Freewater/Walla Walla area). Alluvial aquifers are recharged by streams, precipitation, the basalt aquifer, and infiltration of irrigation water. *Watershed Assessment*

Gravels are the major water-conducting material overlying the basalts in the Walla Walla subbasin. Recharge to the gravels occurs from precipitation, infiltration from riverbeds, canals, ditches, and irrigation loss. The water moves down gradient, which is usually down slope along porous and permeable zones in the gravels. Approximately 50,000 acre feet of water moved through the gravels in an average year during the 1930's and 1940's. *Umatilla Basin Report*

The gravel aquifer provides both domestic and irrigation water. Ground water levels vary from near land surface in the winter to as low as 50 feet below land surface in late summer. Annual fluctuations of 20 to 25 feet are common in some wells. *Umatilla Basin Report*

Because the gravel aquifer is shallow and the soils are highly permeable, it is susceptible to degradation from fertilizers, pesticides and septic systems. *Umatilla Basin Report.* A groundwater quality study, conducted in April 1999 by the Oregon Department of Environmental Quality (DEQ) in the area north and west of Milton-Freewater, found no contaminants at or above levels of concern. However, occasional elevated levels of bacteria and nitrates do indicate a need for further study and awareness.

## Fish Resources

The Walla Walla River subbasin is home to several anadromous and resident fish species. Steelhead are present with migration coinciding with the higher streamflows of November through May. In recent years between 275 and 450 adult steelhead have returned to the Walla Walla River. Oregon Department of Fish and Wildlife (ODFW) fish biologists suggest that the steelhead population is near the river's rearing or carrying capacity. Spawning occurs in the early spring and smolt out-migration takes place during winter and spring.

Bull trout are found in the Upper Walla Walla River and Mill Creek. Their population shows both migratory and resident life history patterns. Migration moves fish downstream in fall into larger streams and upstream in spring into tributaries triggered by water temperature. Spawning takes place during fall in the upper watershed. Based on spawning surveys, bull trout numbers are increasing with a population of 4000 estimated in the upper Walla Walla River.

Pacific lampreys are thought to be present in extremely small numbers, are anadromous and migrate as juveniles, returning to the headwaters to spawn. Western Brook lampreys are also present. Little is known about their lifecycles.

Resident fish include redband trout, mountain whitefish and margined and paiute sculpin in the upper watershed and northern pikeminnows, chiselmouth, redside shiners, largescale suckers and speckled dace in the lower basin.

The Confederated Tribes of the Umatilla Indian Reservation reintroduced spring chinook salmon to the basin in September 2000 and August 2001.

Both streamflow and temperature are factors limiting the production of fish in this subbasin. Resident and anadromous fish habitat in the subbasin is generally good. Mainstem habitat is limited between Milton-Freewater and the state-line because of low flows, U.S. Army Corps of Engineers levees, and diversions. Above Milton-Freewater, habitat is rated as moderate or better and nearly all habitat is used by steelhead. Migration is limited during May - July. Most major migration barriers have been removed or altered. Completion of the new Nursery Bridge Dam fish ladder, in 2001, removed the last structural barrier in the Walla Walla River. All diversions in the mainstem are screened and diversion structures are being improved to make them more efficient and fish friendly.

Both steelhead and bull trout are listed as threatened under the federal Endangered Species Act. Measures are being taken by local irrigators, tribes, and agencies to develop a Bi-State Habitat Conservation Plan for protection of these wild fish. To protect irrigation district patrons from liability and to leave adequate water instream to protect and improve fish habitat, yearly agreements are being negotiated by the irrigation districts with the National Marine Fisheries Service and the US Fish and Wildlife Service.

## Geographic and Programmatic Scope

The operational boundaries of this Area Plan include all agricultural and rural lands that drain to the Walla Walla River and its tributaries within Oregon, except federally managed land and activities subject to the Oregon Forest Practices Act. This plan also applies to agricultural lands in current use and those lying idle or on which management has been deferred. This Area Plan applies to rural lands not in agricultural use such as private roads, and addresses soil erosion on recreational areas and residential property. The operational boundaries of the plan area are defined in rule OAR 603-095-1720.

**603-095-1720**
**Geographic and Programmatic Scope**

(1) The Walla Walla Agricultural Water Quality Management Area includes the area in Oregon that drains into the Walla Walla River. The physical boundaries of the Walla Walla River Subbasin are indicated on the map included as Appendix 1 of these rules.

(2) Operational boundaries for the land base under the purview of these rules include all lands within the Walla Walla Agricultural Water Quality Management Area in agricultural use and agricultural and rural lands which are lying idle or on which management has been deferred, with the exception of public lands managed by federal agencies and activities that are subject to the Oregon Forest Practices Act.

(3) The provisions of these rules apply to all agricultural land whether or not in current productive agricultural use.

(4) The provisions and requirements outlined in these rules may be adopted by reference

by Designated Management Agencies with appropriate authority and responsibilities in other geographic areas of the Walla Walla River Subbasin.

(5) For lands in agricultural use within other Designated Management Agencies' or state agency jurisdictions, the department and the appropriate Local Management Agency shall work with these Designated Management Agencies to assure that provisions of these rules apply, and to assure that duplication of any services provided or fees assessed does not occur.

# IV WATER QUALITY ISSUES

The Federal Clean Water Act (CWA) requires that each state designate beneficial uses, decide which parameters to measure to determine whether beneficial uses are being met, and to set criteria for those parameters. Section 303(d) of the CWA directs states to develop a list of water quality limited streams, which are streams that violate water quality standards and do not support their beneficial uses. The CWA also directs states to develop Total Maximum Daily Loads (TMDL) for 303(d) listed streams. These TMDLs will result in allocations of pollutant loads, e.g. degrees of temperature or milligrams/liter of sediment, to different sources such as private agriculture, urban areas, and federal lands. Because there is no TMDL yet for the Walla Walla subbasin, this AgWQM Area Plan will address water quality issues as they are currently understood. Once an allocation is given, this Area Plan will be modified, if necessary, to meet the allocation.

## Beneficial Uses

Water quality in the Walla Walla AgWQM Area is managed to protect recognized beneficial uses. Beneficial uses of water in the Walla Walla basin are: public and private water supply, industrial water supply, irrigation, livestock watering, anadromous fish passage, salmonid fish rearing and spawning, resident fish and aquatic life, wildlife and hunting, fishing, boating, water contact recreation and aesthetic quality. Beneficial uses that are adversely affected, according to current data, include: salmonid fish rearing and spawning, anadromous fish passage, resident fish and aquatic life, irrigation, and fishing.

## Water Quality Parameters of Concern

The Federal Clean Water Act requires each state to determine water quality by: 1) identifying beneficial uses for each water body; 2) designating parameters to monitor for each beneficial use; and 3) establishing a standard for each parameter. The state is also required to report findings to Congress every two years, and to correct water quality problems.

Section 303(d) of the CWA requires each state to develop a list of water bodies that do not meet the standards designed to protect the most sensitive beneficial use. Water bodies that do not meet standards are placed on the 303(d) water quality limited list.

Four river segments in the Walla Walla subbasin were declared "water quality limited," under section 303(d) of the CWA when the DEQ last updated the listing in 1998. Water quality standards

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violations occur for temperature on all four segments and flow modification on the North Fork. Refer to Attachment 1 for complete list of 1998 listed streams or stream segments.

Most assessments of the conditions of the Walla Walla subbasin indicate that sediment is a major water quality concern affecting beneficial uses

Of the beneficial uses of water in the Walla Walla River Basin, the most sensitive use for most waters and parameters of concern is spawning and rearing of cold-water fisheries. The following discussion of water quality parameters of concern in the watershed addresses the Clean Water Act requirements that require standards be established for the most sensitive beneficial use.

## Temperature

Temperature is primarily a summer concern for rearing of anadromous fish species, resident trout and for bull trout. Water temperatures above 70°F can be immediately lethal to salmonids due to a breakdown in their respiration and circulation systems. Temperatures between the mid 60's°F to 70°F are stressful to salmonids, and fish survival is reduced as the salmonids are more susceptible to a variety of other agents. The sub-lethal effects associated with higher than optimum temperatures are disease, reduced metabolic energy for feeding, and reduced growth or reproductive behavior due to avoidance of areas with high temperatures. High water temperatures can also create barriers to migration and prevent normal movement of both juvenile and adult fish. Current DEQ standards (OAR 340-041-0602) state that a seven day rolling average maximum temperature shall not exceed 64 °F, or 55°F during times and in waters that support salmon spawning, egg development, and fry emergence from the egg and from gravel. In waters that support native bull trout population, surface water temperatures shall not exceed 50°F. No measurable surface water temperature increase resulting from anthropogenic (man-caused) activities is allowed when the above temperatures are exceeded. *DEQ 1998*.

## Flow Modification

Water withdrawal reduces the amount of water available for aquatic habitat, especially in spawning and rearing areas. Fish migration patterns can also be affected. Reduced amounts of water in the stream channel can contribute to increased stream temperatures as well as increased concentrations of pollutants. Stream flow reduction may also affect riparian vegetation growth, which provides multiple contributions to improving and maintaining water quality. Streams are listed as violating this standard if all four of the following conditions are met: 1) beneficial uses are impaired (based on aquatic community status or fishery data); 2) there are established or applied for Instream Water Rights; 3) documentation that flows are not frequently being met (based on actual flow measurements); 4) identification of human contribution to the reduction of instream flows below acceptable levels.

## Sediment

Sediment includes fine silt and organic particles suspended in the water column, settled particles, and larger gravel and boulders that move at high flows. Sediment movement and deposition is a natural occurrence but high levels of sediment can degrade fish habitat by filling pools, creating a wider and shallower channel and covering spawning gravels. Suspended sediment or turbidity in the water can cause physical damage to fish and other aquatic life, modify behavior and increase temperature by absorbing incoming sunlight. Sediment comes from erosion on range and croplands, erosion from streambanks and streambeds, and runoff from roads and developed areas. Nutrients, pesticides and toxic substances can also be attached to sediment particles.

Ongoing efforts are being carried out by land managers to reduce soil erosion and sediment delivery to streams. However, current U.S. Department of Agriculture (USDA) farm programs do not require soil erosion reduction on the majority of Walla Walla area soils because they are not classified as "highly erodible" and are capable of maintaining productivity while losing up to five tons per acre per year.

## Sources of Impairment and Conditions Affecting Water Quality

Both point and nonpoint sources contribute to water pollution. The accumulation of point and nonpoint source pollution results in water quality impairments. Point sources discharge pollutants into the water through a pipe or conveyance. In contrast, nonpoint source pollution is pollution emanating from landscape scale sources and typically cannot be tracked to a single point of discharge. Nonpoint sources of pollution in the area can include runoff and erosion from agricultural and forest lands, leaching of pollutants to groundwater, eroding stream banks, and runoff from roads and urban areas. Pollutants from nonpoint sources can be carried to the surface water or groundwater through the actions of rainfall, snowmelt, irrigation, and leaching. Increased heat input due to vegetation removal, seasonal flow reduction, changes in channel shape, and floodplain alteration are major sources of water quality impairment. Channelization and bank instability may alter gradient, width/depth ratio, and sinuosity, thereby causing undesirable changes in sediment transport regime, erosional and depositional characteristics, and elevated temperature.

The high stream temperatures and low summer streamflows are the main water quality problems in the Walla Walla River subbasin. Stream temperatures can increase from various types of land management activities and natural disturbances, that cause the removal of riparian vegetation or changes in channel morphology, from hydrological factors such as groundwater recharge and discharge and from other factors such as high sediment loads

Protection of riparian and streamside areas for moderation of stream temperatures will be the subject of rules created from this Area Plan. Low summer streamflows often result from channel loss and water withdrawals for beneficial uses, primarily irrigation, along with normal seasonal reductions of streamflow. Water withdrawals are regulated by the Oregon Water Resources Department and will not be addressed by rule or in this Area Plan.

# V STRATEGIES FOR ACHIEVING PLAN GOALS AND OBJECTIVES

## Goal

The goal of this Area Plan is to establish a framework to protect and maintain beneficial uses and to minimize agriculture's impact on water quality within the Walla Walla AgWQM Area. The Area Plan establishes procedures to identify and control factors that may contribute to pollution originating on agricultural and rural lands.

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## Objectives

To maintain water quality, an effective strategy must increase awareness of the problems and the range of potential solutions, motivate appropriate voluntary action, and provide for technical and financial assistance to plan and implement effective water pollution prevention and control measures. The following objectives will be employed at the local level by Umatilla County SWCD and the Walla Walla Basin Watershed Council in cooperation with landowners, and other agencies and organizations.

1. Work to maintain and improve the quality of water in the Management Area through planning and implementation of technically sound and economically feasible management practices that contribute to meeting plan goals.
   A. Control pollution that may be caused by agricultural activities, as close to the source as possible, by controlling soil erosion and sediment delivery to streams.
   B. Demonstrate reduction in potential sources of pollution from agricultural and rural lands through scientifically valid monitoring and periodic surveys of stream reaches and associated lands, as funds are available.
   C. Promote implementation of successful practices for streambank stabilization; reduction in high summer water temperatures, where economically and biologically practical; restoration and enhancement of wetlands and riparian areas; and improved fish habitat.
   D. Promote implementation of conservation practices to improve irrigation water use and conveyance efficiency to reduce the potential of polluted return flows.
   E. Promote adaptive management, which encourages adjustments in management based on feedback or monitoring and changing environmental and economic conditions.

2. Create a high level of awareness and an understanding of water quality issues among the agricultural community and rural public in a manner that minimizes conflict and encourages cooperative efforts by providing education and technical assistance activities.
   A. Incorporate implementation of the Area Plan as a priority element in the Umatilla County SWCD Annual Work Plan and Long Range Plan and the Walla Walla Basin Watershed Council Action Plan, with support from partner organizations.
   B. Showcase successful practices and systems and conduct annual tours for landowners and media.
   C. Recognize successful projects and practices through appropriate media and newsletters.
   D. Promote cooperative on-the-ground projects to solve critical problems identified by landowners and operators and in cooperation with partner organizations.
   E. Conduct educational programs to promote public awareness of water quality.
   F. Evaluate current research and scientifically valid monitoring results and conduct such monitoring as may be necessary to better quantify current conditions and objectives contained in this Area Plan in preparation for biannual plan reviews.

3. Encourage active participation by the agricultural community and rural public in the process of solving water quality problems.
   A. Provide assistance to landowners in development of individual water quality plans and the implementation of best management practices adopted in those plans.

B. Review research and development needs with agriculture assistance agencies and consultants to promote the continued development, evaluation, and adoption of practices and technologies that enhance water quality in an efficient, effective, and economic manner.

C. Annually identify water quality funding needs with agencies providing cost-share and technical assistance to agricultural operations and promote incentive and cost-share programs to assist implementation of plans and related practices.

4. Achieve plan goals and objectives by encouraging adequate funding and administration of the program to support systematic, long range planning and focussing of coordinated efforts on full-scale, watershed-based approaches, identifying needs, developing projects, actively seeking funding, and ensuring successful implementation of funded projects.

The Oregon Department of Agriculture and the SWCD's primary strategies to reduce amounts of pollution from agricultural and rural lands lie in the reduction of runoff and erosion through a combination of educational programs, implementation of sound management practices, and monitoring of implementation effectiveness. This will be accomplished by the adoption and compliance with Prevention and Control Measures directly related to water quality.

## Prevention and Control Measures

A landowner or operator's responsibility under this Area Plan is to implement measures that prevent and control the sources of water pollution associated with agricultural activities and rural lands. The sections that follow describe more detailed information related to potential agricultural water quality concerns, provides definitions of commonly used terms, provides dates when rules are effective, and provides some exemptions to the rules. Criteria will be applied with consideration of agronomic, horticultural and economic impacts.

**603-095-1740**
**Prevention and Control Measures**

**(1) Limitations:**

(a) All landowners or operators conducting activities on agricultural lands are provided the following exemptions from the requirements of OAR 603-095-1740 (Prevention and Control Measures).

(A) A landowner or operator shall be responsible for only those conditions caused by activities conducted on land managed by the landowner or operator.

(B) A landowner or operator is not responsible for conditions resulting from unusual weather events or other uncontrollable circumstances.

(C) The Department will allow temporary exceptions when a specific integrated pest management plan is in place to deal with certain weed or pest problem.

(b) These rules may be modified as a result of the biennial review of the progress of implementation of the Walla Walla Agricultural Water Quality Management Area Plan.

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## Waste Management

A landowner or operator's responsibility under this Area Plan is to prevent the introduction of waste materials into nearby bodies of water. These requirements are consistent with existing water quality regulations and are enforceable by designated management agencies.

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| **603-095-1740**<br>**(2) Waste Management**<br>Effective on rule adoption, no person subject to these rules shall violate any provision of ORS 468B.025 or 468B.050. |

Current Oregon Law, ORS 468B.025(1) states:
...no person shall:
(a) Cause pollution of any waters of the state or place or cause to be placed any wastes in a location where such wastes are likely to escape or be carried into the waters of the state by any means.
(b) Discharge any wastes into the waters of the state if the discharge reduces the quality of such waters below the water quality standards established by rule for such waters by the Environmental Quality Commission.

ORS 468B.050 identifies the conditions when a permit is required. A permit is required for Confined Animal Feeding Operations (CAFO) that confine animals for more than 4 months per year and have a wastewater treatment facility. This requirement is being modified in accordance with legislation passed by the 2001 state legislature to bring Oregon's CAFO program into compliance with federal regulations.

ORS 468B.005 provides the following definitions:
"Wastes," means sewage, industrial wastes, and all other liquid, gaseous, solid, radioactive or other substances, which will or may cause pollution or tend to cause pollution of any waters of the state. Additionally, OAR 603-095-0010(53) includes but is not limited to commercial fertilizers, soil amendments, composts, animal wastes, vegetative materials or any other wastes.

"Pollution or water pollution" means such alteration of the physical, chemical or biological properties of any waters of the state, including change in temperature, taste, color, turbidity, silt or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive or other substance into any waters of the state, which will or tends to, either by itself or in connection with any other substance, create a public nuisance or which will or tends to render such waters harmful, detrimental or injurious to public health, safety or welfare, or to domestic, commercial, industrial, agricultural, recreational or other legitimate beneficial uses or to livestock, wildlife, fish or other aquatic life or the habitat thereof.

"Water or the waters of the state" include lakes, bays, ponds, impounding reservoirs, springs, wells, rivers, streams, creek, estuaries, marches, inlets, canals, the Pacific Ocean within the territorial limits of the State of Oregon and all other bodies of surface or underground waters, natural or artificial, inland or coastal, fresh or salt, public or private (except those private waters which do not combine or effect a junction with natural surface or underground waters), which are wholly or partially within or bordering the state or within its jurisdiction.

## Stream-Side and Riparian Area Management

Areas near water bodies are especially important to water quality and sensitive to management activities because of the natural ecological functions they perform such as water infiltration, waste filtration, erosion control, water storage, and moderation of temperature.

Summer water temperatures above the optimal levels for aquatic species survival are a concern in some reaches of the Walla Walla subbasin. Moderation of high summer water temperatures is an objective of this Area Plan. Water temperature can best be influenced by activities that encourage the development and protection of vegetation along streams to provide shade, narrowing and deepening of the channel, and water infiltration and storage within the streambanks. Increasing summer streamflows would also lead to reduced water temperatures. However, issues dealing directly with increasing streamflow are beyond the scope of this Area Plan.

**603-095-1740**
**(3) Streamside and Riparian Area Management**

(a) Except as provided in OAR 603-095-1740(3)(b), effective January 1, 2006, streamside area management must have allowed the establishment, growth and maintenance of riparian vegetation to promote habitat and protect water quality by filtering sediment, stabilizing streambanks, naturally storing water, and providing shade consistent with the vegetative capability of the site.

(b) OAR 603-095-1740(3)(a) does not apply to irrigation water conveyance systems, including, but not limited to, irrigation canals, ditches, laterals, and waterways, such as the Little Walla Walla system, that in the normal course of operation have no return flow into perennial streams where coldwater fish species are present.

The streamside area is generally defined as the area near the stream, riparian area, wetland, or other waterbody, depending on slope, soil type, stream size and morphology, where management practices can most directly influence the conditions of the water. This area usually ranges from 10 feet to 100 feet from the water.

The riparian area, as defined in OAR 141-110-0020(28), is a zone of transition from an aquatic to a terrestrial system, dependent upon surface or subsurface water, that reveals through the zone's existing or potential soil-vegetation complex the influence of such surface or subsurface water. A riparian area may be located adjacent to a lake, reservoir, estuary, pothole, spring, bog, wet meadow, muskeg, slough, or ephemeral, intermittent or perennial stream.

Water is the distinguishing characteristic of these areas but soil, vegetation and landform also exert strong influence on these systems. In a healthy riparian ecosystem, these four components interact to produce a wide variety of conditions.

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Healthy riparian areas provide several important ecological functions. These include:

- Floodwater retention and ground water recharge
- Stabilization of streambanks through plant root mass
- Development of diverse channel characteristics providing pool depth, cover, and variations in water velocity necessary for fish production
- Support of biodiversity
- Moderation of solar heat input by shade
- Recruitment of large woody debris for aquatic habitat

Indicators to determine improvement of this condition include:

- Recruitment of desirable riparian plant species
- Maintenance of established beneficial vegetation
- Maintenance or recruitment of woody vegetation -- both trees and shrubs
- Streambank integrity capable of withstanding 25-year flood events

Factors available to evaluate improvement of the streamside area condition could include:

- Expansion of riparian area as evidenced by development of riparian vegetation and plant vigor
- Reduction in actively eroding streambank length beyond that expected of a dynamic stream system
- Plant community composition changes reflecting increases in grass-sedge-rush, shrubs, and litter and decreases in bare ground
- Plant community composition reflecting decreases in noxious plant species
- Stream channel characteristics showing a narrowing and deepening of the channel
- Shade patterns consistent with site capability
- Stubble height of herbaceous (grass) species and leader (new) growth of shrubs and trees

Characteristics of a healthy riparian area condition evaluation:

- Actively eroding streambank of no more than 20-25% of total streambank length
- Shade levels of 50-70% at midday on 4th order or less streams
- Stubble height measurements, dependent on species, of 4 to 6 inches of herbaceous species left prior to spring runoff
- Growth and recruitment of shrubs and trees - no more than 50% utilization of annual growth of shrubs and trees.

The Local Advisory Committee has determined that the irrigation canals and ditches in the area served by the Walla Walla River Irrigation District and the Hudson Bay District Improvement Company should be exempt from the riparian vegetation requirement. These waterways are maintained for the delivery of irrigation water to cropland within the boundaries of the Districts. There is no overland return flow of water from these irrigation canals and ditches back into perennial streams and these ditches are screened to prevent the introduction of fish. Therefore, since there are no adverse impacts to fish spawning and rearing streams within the canal system, moderation of water temperature is not required. Water that does infiltrate into the gravel aquifer and recharges groundwater or re-emerges as streamflow usually is cooler than the receiving stream water.

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All other irrigation diversions in the Walla Walla River basin must prevent overland return flows that may carry pollutants into the receiving streams.

## Uplands Management and Soil Erosion

A landowner or operator should implement measures that prevent and control water pollution from upland runoff and soil erosion. This includes agricultural and rural lands that may not be in close proximity to water bodies.

Cropland managed to meet Highly Erodible Land (HEL) will satisfy the required reductions in sheet and rill erosion if it is farmed in a manner that meets the requirements of an approved Food Security Act HEL compliance plan. Non-HEL cropland will satisfy the required reductions if it meets the same requirements as would be included in a HEL compliance plan for cropland with similar Revised Universal Soil Loss Equation (RUSLE) inputs, e.g. rainfall, erodibility, slopes and cropping sequence.

**603-095-1740**
**(4) Soil Erosion and Sediment Control**

(a) Sheet and rill erosion on all cropland, not just land designated as Highly Erodible Land, must be reduced as set forth below. The Revised Universal Soil Loss Equation will estimate average annual sheet and rill erosion rates over a cropping rotation, with supporting data from the NRCS Field Office Technical Guide and similar data from other credible source. The baseline reference standard is the predicted erosion rate based on the RUSLE for cropland under conventional, mechanical tillage systems without the application of conservation practices and management systems.

(A) Effective January 1, 2006, average sheet and rill erosion must be reduced by 50% from the baseline condition or to "T"; whichever is the less stringent standard.

(B) Effective January 1, 2010, average sheet and rill erosion must be reduced by 75% from the baseline condition or to "T"; which ever is the less stringent standard.

(b) Effective January 1, 2006, agricultural land management must control active channel or gully erosion.

(c) Effective January 1, 2006, rangeland and pasture management must allow, within the capability of the site, vegetation sufficient to protect water quality by providing water infiltration, filtering of sediment and animal wastes, and controlling erosion.

Upland areas are the rangelands, forests and croplands, upslope from the riparian areas. These areas extend to the ridge tops of watersheds. Vegetation and soils are distinguishing characteristics of upland areas. With a protective cover of crops, grass (herbs), shrubs or trees, consistent with site capability, these areas will capture, store and safely release precipitation, thereby reducing the potential of excessive soil erosion or delivery of soil or pollutants to the receiving stream or other waters. Vegetation is dependent on physical characteristics including soil, geology, landform, water and other climate factors. Healthy uplands maintain productivity over time and are resilient to stresses caused by variations in physical and climatic conditions.

Healthy upland areas provide several important ecological functions. These include:

- Capture, storage, and safe release of precipitation
- Provide for plant health and diversity that support habitat (cover and forage) for wildlife and livestock
- Filtration of sediment
- Filtration of polluted runoff
- Provide for plant growth, particularly root mass that utilizes nutrients and stabilizes soil against erosion

Indicators of these conditions include:

- Recruitment of beneficial plant species
- Groundcover to limit runoff of nutrients and sediment
- Cropland cover that is sufficient to limit movement of nutrients and sediment
- Roads and related structures designed, constructed and maintained to limit sediment delivery to streams
- Noxious weed and insect pest populations contained - see state weed laws and county weed regulations to determine weed species that must be controlled

Factors to evaluate upland area condition may include:

- Vegetation utilization through stubble height measurements
- Plant species composition to measure plant health and diversity
- Ground cover (live plants, standing plant litter and ground litter) as a measure of potential erosion
- Evidence of overland flow (pattern and quantity)
- Site productivity (domestic livestock and wildlife carrying capacity)
- Soil erosion potential through prediction models available through NRCS

Cropland management systems should be designed to control sheet and rill erosion and gully erosion on all cropland, not just land designated as Highly Erodible Land (HEL). The Revised Universal Soil Loss Equation (RUSLE) can estimate average annual sheet and rill erosion rates over a cropping rotation, with supporting data from the NRCS Field Office Technical Guide and similar data from other credible sources. The baseline reference standard is the predicted erosion rate based on the RUSLE for cropland under conventional, mechanical tillage systems without the application of conservation practices and management systems.

Rangeland and pasture management should allow vegetation sufficient to protect water quality by providing water infiltration, filtering of sediment and animal wastes, and controlling soil erosion within the capability of the site.

Private roads on rural lands or roads used for agricultural activities should be constructed and maintained to limit runoff of sediment into waters of the state. Roads used for activities subject to the Oregon Forest Practice Act are regulated by Forest Practice Act rules. Homesteads, farmsteads and other non-crop areas should be managed to control runoff of sediment and animal wastes into waters of the state.

For more information on effective management practices for prevention and control of runoff from upland areas, see Attachment 3.

## Irrigation Management

A landowner or operator should implement measures that prevent and control water pollution from irrigation activities. Diversion of water for irrigation and the return of water to the stream are activities that have potential for contributing to water quality problems by affecting channel stability and carrying pollutants to the stream through overland return flows.

Administrative Rule 603-095-1740(2) is applicable to any pollution caused by irrigation practices which allow wastes to enter waters of the state through overland return flows.

Irrigated lands are those lands, either riparian, floodplain or uplands, upon which water is applied for the purpose of growing crops. Diversion of water from a waterbody to be applied on land for the purpose of growing crops is a recognized beneficial use of water. Irrigation water use is regulated by the Oregon Water Resources Department in the form of water rights, which specify the rate and amount of water that can be applied to a particular parcel of land. Refer to Oregon Water Resources Department laws and rules (OAR 690 and ORS 536 through 543) for more details.

Irrigation in this basin is done primarily by sprinkler application though there is some flood, furrow and drip irrigation. Water usually is diverted from a surface source (stream or pond) but may also be from groundwater sources. Irrigation management in this basin recognizes the positive benefits that occur from irrigation application including flow augmentation for late season as water returns back to the stream, cooling and filtering of water through underground percolation, and the recharge of shallow wells and springs due to the connectivity of surface water to ground water sources. Irrigation water may be used more than once as it returns to the stream or irrigation conveyance ditch and is available for instream uses or by other irrigators. Ultimately, streamflows will be enhanced by upland and riparian management practices promoting natural upstream storage and properly functioning floodplains that catch, store, and safely release precipitation for beneficial uses during summer months.

Characteristics of an irrigation system that has minimal effect on water quality include:

- Efficient delivery of water to the land within legal water rights
- Minimal overland return flows
- Return flow routing that provides for settling, filtering and infiltration
- Minimal effect on stability of streambanks and minimal soil erosion
- Appropriate scheduling of water application to the site considering soil conditions, crop needs, climate and topography
- Diversion structures that are installed and managed in a way that controls erosion and sediment delivery and protect the stability of streambanks. If funding becomes available, temporary diversions, which must be reinstalled every year, should be replaced with suitable permanent diversions (i.e. pumping stations, infiltration galleries, ponds, dams).
- Diversions that are adequately screened and provide fish passage. (Refer to ORS 498.268)

Refer to Attachment 3 for more information on effective management for protection of irrigation return flows.

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### Livestock Management

A landowner or operator must implement measures as needed to prevent and control water pollution from livestock enterprises. Careful management of areas used for grazing, feeding and handling are critical to the success of livestock operations and have potential to affect water quality by the runoff of sediment and animal wastes containing bacteria, nutrients, and pathogens.
Oregon Administrative Rules 603-095-1740(2) and (3) apply to runoff of animal waste and streamside or riparian vegetation conditions.

Grazing of livestock can be done in a manner that limits soil erosion and minimizes the delivery of sediment and animal wastes to nearby streams. A grazing management system will promote and maintain adequate vegetative cover, for protection of water quality, by consideration of intensity, frequency, duration, and season of grazing.

Managed grazing near streams will prevent negative impacts to streambank stability, allow for recovery of plants, and leave adequate vegetative cover to ensure protection of riparian functions including shade and habitat. Offstream watering systems, upland water developments, feed, salt and mineral placement are effective ways to reduce impacts of livestock to streamside areas.

Livestock confinement areas need adequate measures to prevent and control runoff of sediment and animal waste. Certain confinement areas, as defined in ORS 468B.200 -230, are required to have permits issued by the department.

Factors used to evaluate effectiveness of management may include:

- Safe diversion or containment of runoff
- Protection of clean water sources
- Off stream watering systems
- Lot maintenance - smoothing, mounding, seeding
- Structural measures -i.e. filter strips, catch basins, berms
- Waste collection, storage and application methods

For more information on effective management practices for prevention and control of pollution from livestock operations refer to Attachment 3.

## Implementation Strategies

The following guidelines will apply for public participation in implementation and review of the Area Plan. The ODA and the SWCD intend to encourage participation in this water quality improvement program by:

- Providing educational programs to raise public awareness and understanding of water quality issues and solutions
- Providing incentives for the development and implementation of effective agricultural management practices for prevention and control of agricultural pollution
- Offering technical assistance for the development and implementation of Voluntary Water Quality Farm Plans
- Developing a monitoring program to identify current and potential water quality problems

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- Following up on any water quality complaints and provide assistance in solving identified problems

## Education Programs

As resources allow, the SWCD, Watershed Council, and OSU Extension Service, in partnership with other agencies and local organizations, will develop educational programs to improve the awareness and understanding of water quality and quantity issues. They will strive to provide the most current information in a manner which avoids conflict and encourages cooperative efforts to solve problems. The following is a list of action items that will be considered in developing educational programs.

- Showcase successful practices and systems and conduct annual tours for landowners and media
- Recognize successful projects and practices through appropriate media and newsletters
- Promote cooperative on-the-ground projects to solve critical problems identified by landowners/operators and in cooperation with partner organizations
- Conduct educational programs to promote public awareness of water quality
- Evaluate current research and scientifically valid monitoring results and conduct such monitoring as may be necessary to better quantify current conditions and objectives contained in this Area Plan in preparation for biannual plan reviews

Implementation of this Area Plan is a priority element in the Umatilla County Soil and Water Conservation District Annual Work Plan and Long Range Plan and the Walla Walla Basin Watershed Council Action Plan. Both organizations hold regular monthly public meetings, publish newsletters, and sponsor special events that will often focus on water issues. In cooperation with OSU Extension and the irrigation districts, community meetings will continue to be encouraged as needed to provide a forum for current water issues.

## Water Quality Management Practices

Effective water quality management practices for water pollution control are those management practices and structural measures that are determined to be the most effective, practical means of controlling and preventing pollution from agricultural activities.

Appropriate management practices for individual farms may vary with the specific cropping, topographical, environmental, and economic conditions existing at a given site. Due to these variables, it is not possible to recommend any uniform set of management practices to improve water quality relative to agricultural practices.

Management practices and land management changes are most effective when selected and installed as integral parts of a comprehensive resource management plan based on natural resource inventories and assessment of management practices. The result is a system using the management practices and land management changes that are designed to be complementary, and when used in combination are more technically sound than each practice separately.

A detailed listing of a number of specific practices and management measures that can be employed to control or reduce the risk of agricultural pollution are contained in other documents such as the Field Office Technical Guide, available for reference at the local the NRCS office. While not exhaustive or all-inclusive, Attachment 3 contains a list of practices that may typically be used in the Walla Walla River basin for effective prevention and control of soil erosion, sediment delivery to streams, and water pollution from agricultural activities.

## Voluntary Water Quality Farm Plans

This Area Plan recognizes that planning for water quality is only part of a successful plan for overall management of agricultural and rural land, and that other personal and public objectives must also be considered in total farm or resource management planning.

Landowners and operators have flexibility in choosing management approaches and practices to address water quality issues on their lands. They may implement management systems on their own without a plan or may develop a plan that suits the needs of their operation. The local management agency recommend that voluntary water quality plans be developed to assist the landowners and operators to assess the conditions on their lands, identify problems or potential problems on their land and to describe measures and resources needed to address those problems.

Voluntary water quality plans describe the management systems and schedule of conservation practices that the landowner will use to conserve soil, water, and related plant and animal resources on all or part of a farm or ranch unit. Voluntary water quality plans may be developed by landowners or operators, consultants, or technicians available through the SWCD or NRCS. An effective individual water quality plan will outline specific measures necessary to prevent or control water pollution and soil erosion from agricultural activities and to address the "Prevention and Control Measures" outlined in this AgWQM Area Plan.

## Technical & Financial Assistance

It is not the intent of this Area Plan to impose a financial hardship on any individual. It is the responsibility of the landowner or operator to request technical and/or financial assistance and to develop a reasonable timeframe for addressing potential water quality problems.

As resources allow, the SWCD, NRCS, and other natural resource agency staff are available to assist landowners in evaluating effective practices for reducing runoff and soil erosion on their farms, and incorporating these practices into voluntary individual water quality plans. Personnel in these offices can also design and assist with implementation of practices, and assist in identifying sources of cost-sharing or grant funds for the construction and use of some of these practices.

Technical and cost-sharing assistance for installation of certain management practices may be available through current USDA conservation programs such as the Environmental Quality Incentives Program (EQIP), Conservation Reserve Program (CRP), Conservation Reserve Enhancement Program (CREP), Continuous CRP (CCRP), Environmental Protection Agency's (EPA) non-point source implementation grants, or state programs such as the Oregon Watershed Enhancement Board. The Walla Walla Basin Watershed Council and several other federal and state agencies are also available to provide technical assistance or financial assistance to private landowners.

Farm planning assistance is available from these and other sources:

- Technical Assistance
  - Natural Resources Conservation Service
  - Soil and Water Conservation District Technical Watershed Specialist
- Workbooks and publications
  - Voluntary Conservation On Your Land, NRCS/Oregon Association of Conservation Districts (OACD)
  - Oregon Small Acreages Conservation Toolbox, NRCS/OACD
  - WESt Program Workbook, Oregon Cattleman's Association/Extension
  - Ranch Water Quality Planning Workbook, Extension
- Programs
  - Farm*A*Syst Program, OSU Extension
  - Stream*A*Syst Program, OSU Extension
  - Home*A*Syst Program, OSU Extension

## Monitoring and Evaluation

The progress and success of implementation efforts will be assessed through determination of changes in land management systems and the measurement of water quality improvement over time.

Monitoring activities are integral components of AgWQM Area Plans. When effectively used, monitoring activities can provide valuable information on how much effect a plan is having, how extensively it is being implemented, and where more efforts are needed in a basin. For the purposes of AgWQM Area Plans, four main types of monitoring are appropriate. These are:

1. Baseline condition monitoring;
2. Compliance monitoring;
3. Water quality trend monitoring; and
4. Effectiveness monitoring.

A complete monitoring program should involve all these types of monitoring to some degree.

Currently, the Walla Walla Basin Watershed Council, in cooperation with DEQ, the Confederated Tribes of the Umatilla Indian Reservation and other agencies, are conducting a comprehensive monitoring program to gather water quality data to be used in development of the TMDL. This data will be available to establish baseline conditions for determining effectiveness of the Area Plan.

The Oregon Department of Agriculture, with the cooperation and assistance of the SWCD, the LAC, and DEQ, will assess the progress of Area Plan implementation toward achievement of plan goals and objectives. These assessments will include:

1. An accounting of the numbers and acreage of operations with approved Voluntary Individual Water Quality Farm Plans and the calculated amount of soil erosion and pollution prevented.
2. Identification of additional sources of sediment, heat inputs, and other contributors to non-attainment of all applicable water quality standards.
3. An evaluation of available current water quality monitoring data.
4. An evaluation of outreach and education programs designed to provide public awareness and understanding of water quality issues.

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5. A review of projects, demonstrations, and tours used to showcase successful management practices and systems.
6. An evaluation of the effectiveness of technical and financial assistance sources available to the agricultural community.
7. Review of load allocations as found in the Walla Walla subbasin TMDL and effectiveness of this Area Plan in meeting load allocations as described in the TMDL for the Walla Walla River basin.

Based on these assessments, the LAC, Umatilla County SWCD, and the ODA, in consultation with the State Board of Agriculture will consider making appropriate modifications to the Area Plan and the associated Oregon Administrative Rules.

## Resolution of Complaints and Enforcement Action

The ODA will investigate complaints against landowners and operators who are alleged to be out of compliance with the rules associated with this Area Plan. If the landowner is found to be out of compliance, ODA will consult with the SWCD, using the Field Office Technical Guide, to develop solutions and timelines. The authority and procedures for complaint investigation rests with the ODA under provisions of OAR 603-095-1760.

The ODA will use enforcement mechanisms where appropriate and necessary to gain compliance with the prevention and control measures. Any enforcement action will be pursued only when reasonable attempts at voluntary solutions have failed. Authority for any enforcement action rests with ODA under provisions in OAR 603-090-0060 through 603-090-0120.

**603-095-1760**
**Complaints and Investigations**

(1) When the department receives notice of an alleged occurrence of agricultural pollution through a written complaint, its own observation, through notification by another agency, or by other means, the department may conduct an investigation. The department may, at its discretion, coordinate inspection activities with the appropriate Local Management Agency.

(2) Each notice of an apparent occurrence of agricultural pollution shall be evaluated in accordance with the criteria in ORS 568.900 through 568.933 or any rules adopted thereunder to determine whether an investigation is warranted.

(3) Any person allegedly being damaged or otherwise adversely affected by agricultural pollution or alleging any violation of ORS 568.900 through 568.933 or any rules adopted thereunder may file a complaint with the department.

(4) The department will evaluate or investigate a complaint filed by a person under section OAR 603-095-1760(3) if the complaint is in writing, signed and dated by the complainant and indicates the location and description of:

(a) The property or waters of the state allegedly being damaged or impacted; and

(b) The property allegedly being managed under conditions violating criteria described in ORS 568.900 through 568.933 or any rules adopted thereunder.

(5) As used in section OAR 603-095-1760(4), "person does not include any local, state or federal agency.

(6) Notwithstanding OAR 603-095-1760(4), the department may investigate at any time any complaint if the department determines that the violation alleged in the complaint may

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present an immediate threat to the public health or safety.

(7) If the department determines that a violation of ORS 568.900 through 568.933 or any rules adopted thereunder has occurred, the landowner may be subject to the enforcement procedures of the department outlined in OAR 603-090-0060 through 603-090-0120.

# VI Administrative Roles and Responsibilities

## Designated Management Agency

The ODA is the Designated Management Agency for water pollution control activities on agricultural and rural lands in the Walla Walla Water Quality Management Area. The ODA is authorized to develop and carry out a water quality management plan for any agricultural or rural lands where state or federal law requires such a plan.

Umatilla County Soil and Water Conservation District is the Local Management Agency (LMA) designated by ODA for development and implementation of the Agricultural Water Quality Management Area Plan and projects in the Management Area. The Walla Walla Basin Watershed Council will assist the LMA in implementation and review of the Area Plan and related projects. Implementation priorities will be established on a periodic basis through annual work plans developed jointly by the SWCD and ODA with input from partner agencies.

The Director of the ODA, in consultation with the State Board of Agriculture, appointed a Local Advisory Committee (LAC) representing local agricultural producers, landowners, agencies, tribes, environmental organizations and the District, for the purpose of assisting with the development of this Area Plan and the associated Oregon Administrative Rules to implement core elements of the Area Plan.

The LMA and LAC will participate in biennial review of Area Plan implementation progress. Any future amendments to the administrative rules will be subject to the public participation process outlined in Oregon law.

## Total Maximum Daily Loads

The Oregon Department of Environmental Quality is required by federal law to establish formal "Total Maximum Daily Loads" (TMDLs) for pollutants in waters designated as "water quality limited." The TMDL will set maximum limits on the amount of pollutants allowed to enter in the area waters. This loading capacity is calculated to achieve water quality standards.

Each jurisdiction in the Walla Walla AgWQM Area will be allotted a portion of the TMDLs, representing the maximum amount of pollutant, that may be discharged daily, from the lands managed by the respective jurisdiction to the Walla Walla River system. This amount is the jurisdiction's "Load Allocation" (LA). The DEQ has requested appropriate Designated Management Agencies in the basin develop pollution control plans and programs designed to achieve the load

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allocations. Oregon Administrative Rules Chapter 340, Division 41, sections 026, 120 and 642 requires these AgWQM Area Plans and sets the water quality standards.

Consistent with this Area Plan and the memorandum of understanding between DEQ and ODA, an objective of this Area Plan will be to meet Walla Walla River load allocations. At the time of publication of this Area Plan, these loads are not available. The periodic 2-year review for this Area Plan will enable modifications as needed to implement management that reduces pollution as indicated by the load allocations.

# ATTACHMENTS

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# Attachment 1 - Water Quality Limited Reaches in the Walla Walla Subbasin

| Name | Description | Parameter |
|---|---|---|
| Mill Creek | Washington border to Tiger Creek | Temperature: Bull Trout (summer) |
| Walla Walla River | Mouth to confluence of North and South Forks | Temperature (summer) |
| North Fork, Walla Walla River | Mouth to Headwaters | Flow Modification<br>Temperature: Bull Trout (summer) |
| South Fork, Walla Walla River | Mouth to Headwaters | Temperature (summer) |

From the 1998, 303(d) list

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## Attachment 2 - Soils

**Alluvial** soils are on nearly level to gently sloping valley bottoms near the rivers and creeks, fanning northwest from Milton-Freewater. They vary from excessively to poorly drained. These soils are often irrigated and are adapted to a wide variety of crops. Several unconsolidated sedimentary layers have been deposited. A clay layer up to 500 feet thick was deposited on top of the basalts in the central portion of the subbasin. A thick (10-300 feet) composite alluvial fan was deposited directly on the basalts along the margins of the Walla Walla subbasin. Composed mainly of gravel, the fan material becomes finer toward the center of the basin where it interfingers with the clay unit. The gravel is composed mainly of well-rounded pebble, cobble, and boulder sized basaltic material. Compaction of the alluvial fan with a mixture of silt and sand make the gravels semi-consolidated. In places, calcareous cement also bonds the gravels.

**Athena-Palouse-Waha** association of soils occur east of Milton-Freewater on the lower slopes of the Blue Mountains. Most of the Athena and Palouse and a part of Waha are cultivated in annual cropping rotation of winter wheat and green peas or other legumes. The remainder of these soils are in range with a dominant native vegetation of Idaho Fescue and bluebunch wheatgrass. These soils are well adapted to irrigation except in areas of unfavorable topography.

**Ritzville-Starbuck** association of soils is developed from loess and found mostly on the northwestern end of the subbasin. Most of the Starbuck and some Ritzville are used for range. Ritzville soils are well adapted for irrigation.

**Sagemoor-Quincy-Taunton** association of soils is formed on the medium-textured glacial sediments and also located in the northwestern corner of the subbasin. Winter range for sheep is the principal use of these soils with the vegetation being bluebunch wheatgrass, annual grasses, and sagebrush. A small portion of Sagemoor is producing wheat successfully. These soils are reasonably well adapted to irrigation.

**Tolo-Klicker** association occurs in the eastern subbasin, in the high country of the Blue Mountains with nearly level to gently sloping uplands, which break off to very steeply sloping canyon walls. Most of these soils support forest or mixed-forest-grass type vegetation, which is used for summer grazing of livestock. Minor areas of all the deep soils are cultivated and produce small grains, legumes, grass, and berries. The shallow, stony soils are used for range.

**Waha-Snipe** association is found on the lower slopes of the Blue Mountains from nearly level to very steep slopes. These soils are used mostly for relatively high-producing range. The major vegetation is Idaho fescue, bluebunch wheatgrass, and shrubs.

The **Walla Walla** series of soils has four phases, each developed from loess. Two are present in the subbasin - Walla Walla and Walla Walla high rainfall - and are used for wheat production in both a wheat-fallow rotation and a wheat-green pea rotation. Both would be very well adapted for irrigation.

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## Attachment 3 - Effective Water Quality Management Practices

These practices and many others may be considered in development of a management system that is appropriate for prevention and control of pollution caused by agricultural activities on an individual parcel of land. Management practices and land management changes are most effective when selected and installed as integral parts of a comprehensive resource management plan based on natural resource inventories and assessment of management practices. The result is a system using management practices and land management changes which are designed to be complementary, and when used in combination, are more technically sound than each practice separately.

**For soil erosion and sediment control**

- Conservation Tillage (Crop Residue Management)
  -reduced tillage, minimum tillage, direct seeding, modified conventional tillage, reservoir tillage, subsoiling, or deep chiseling
- Cover Crops
  - perennial, annual
- Contour Farming Practices
  - strip cropping, divided slopes, terraces (level and gradient), contour tillage
- Crop Rotations
- Early or Double Seeding in Critical Areas
- Vegetative Buffer Strips
  - filter strips, grassed waterways, field borders, contour buffer strips
- Irrigation Scheduling
  - soil moisture monitoring
  - application rate monitoring
- Prescribed Burning
- Weed Control
- Grazing Management Plans
- Range Plantings
- Livestock Distribution
- Road Design and Maintenance
- Sediment Retention Basins and Runoff Control Structures

**For prevention and control of impacts to stream side areas:**

- Critical Area Planting
- Vegetative Buffer Strips
  - Continuous CRP, CREP, riparian buffers, riparian forest buffers
- Livestock Management
  - fencing - exclusion, temporary
  - seasonal grazing
- Water Developments
  - off stream watering, water gaps, spring development
- Conservation Tillage Practices
- Weed Control

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- Nutrient and Chemical Application Scheduling
- Road, Culvert, Bridge, and Crossing Maintenance
- Wildlife Management

**<u>For prevention and control of impacts from livestock</u>**

- Grazing Management or Scheduling
  - intensity, duration, frequency, season
  - pasture rotations, rest/deferral
- Vegetation Management
  - grass seeding, weed control, controlled burning
- Fencing
  - temporary, cross, exclosure
- Watering Facilities
  - spring development, water gaps, off-stream water, (may require water rights, refer to ORS 537.141)
- Salt and Mineral Distribution
- Waste Management Systems
  - clean water diversions; waste collection, storage, and utilization; facilities operation and maintenance

**<u>For prevention and control of impacts from irrigation</u>**

- Irrigation Scheduling
  - crop needs, soil type, climate, topography, infiltration rates
- Irrigation System Efficiency and Uniformity
  - flood, sprinkler, drip, pivot
- Diversion Maintenance
  - push-up dam management, screens
- Return Flow Management
- Backflow Devices
- Reservoir Tillage
- Cover Crops

**<u>For nutrient and farm chemical application</u>**

- Nutrient Budgeting
  - soil testing, tissue testing, plant needs
  - water testing
- Application Methods
- Application Timing
- Tail Water Management
- Hydraulic Connectivity
- Label Requirements
- Irrigation Scheduling
- Integrated Pest Management Practices

**For channel and drain management**

- Vegetation Management
    - Burning, chemical, clipping
- Streambank Stabilization
    - structural, bioengineeried
- Critical Area Planting
- Channel Management
- Obstruction Removal
- Wetland Development
- Outfall Protection
- Offstream or Headwater Storage

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## Attachment 4 — References


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Water Resources ODA Rules (OAR 690 and ORS 536 through 543)
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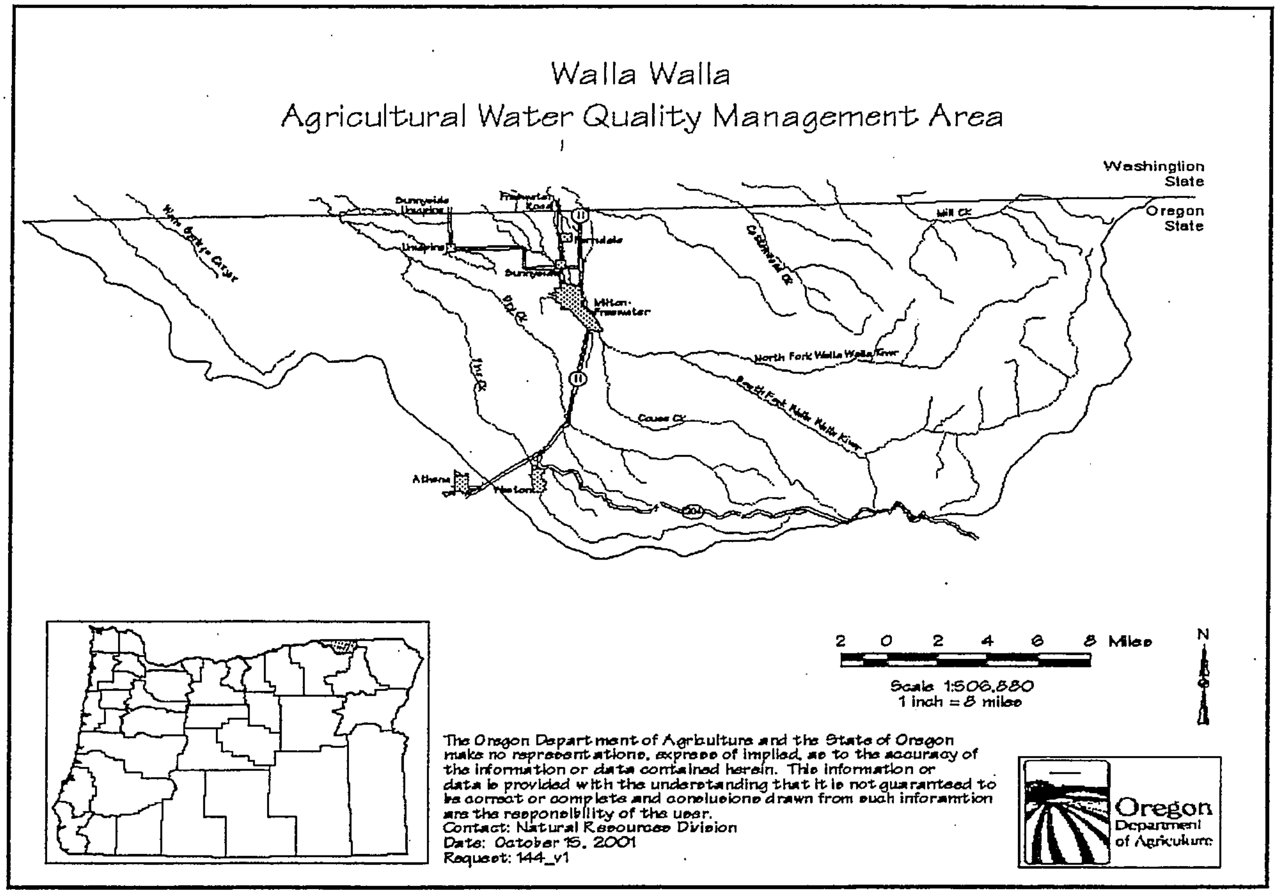
# Attachment 5 — Map

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March 01, 2011

Ms. Sue Oliver
Oregon Department of Energy
245 Main Street, Suite C
Hermiston, OR 97838

Dear Ms. Oliver;

The Oregon Department of Fish and Wildlife (ODFW) previously provided comments on Horizon Energy's (Horizon or Applicant) Notice of Intent to Apply for an Energy Facility Site Certificate (June 01, 2009); Preliminary Application for Site Certificate (December 02, 2009); and Response to Oregon Department of Energy's (ODOE) First Request for Additional Information (May 09, 2010) for the Antelope Ridge Wind Farm (ARWF or Project). Within those comments, ODFW identified several Project siting concerns and recommended modifications to Project siting to minimize impacts to fish and wildlife and their habitats. The majority of ODFW's concerns and recommendations, however, were not addressed or incorporated into the Final Application for Site Certificate (ASC).

The ODFW received Horizon's Final ASC January 06, 2011. Based on ODFW's review of the Final ASC, serious concerns with the proposed siting of the Project remain:

1. The Project as proposed does not avoid impacts to wildlife habitat classified as Category 1 under the Habitat Mitigation Rules;
2. Horizon's proposed mitigation measures are insufficient to avoid or mitigate anticipated impacts of the Project to fish and wildlife in habitat classified as Category 2.
3. The preponderance of the evidence in the record does not support the legal findings necessary for issuance of a site certificate (concerning compliance with the Habitat Mitigation Rules and protection of listed species).

As result, ODFW must recommend against issuance of a site certificate for the project as currently described in the Final ASC. ODFW believes issuance can occur if the ASC is modified to reflect the mitigation recommendations in Attachment 1.

ODFW is responsible for reviewing the ASC and assuring it complies with statutes, rules, policies and management plans related to Oregon's fish, wildlife, and their habitats. Therefore, ODFW met with Horizon staff on multiple occasions in 2009 and 2010 to discuss Project siting, study needs and protocols, impacts, and mitigation. ODFW and Horizon discussed the avoidance, protection, and enhancement measures that we believed were necessary for the Project to be issued a site certificate. Unfortunately, after a number of meetings, Horizon withdrew from the discussions.

The siting of a wind energy project is the most important element in avoiding or minimizing impacts to fish and wildlife species and their habitats. Despite previous recommendations by ODFW, a substantial part of the proposed facility siting is on either big game winter range or big game critical wildlife habitat. It is also located on sage-grouse breeding and wintering habitat and within ½ mile from multiple sensitive raptor species nests. During wildlife surveys conducted throughout the Site Boundary, 20 state sensitive species (one state threatened bird, four state-critical birds, 12 state vulnerable birds, two state vulnerable mammals, and one state endangered mammal) and nine federal species-of-concern were recorded. In addition, sixty-five active and thirty-one inactive raptor nests were located within the analysis area, and seventy-five species were identified during the forest breeding bird surveys.

The Project is one of the first wind power projects in Oregon proposed to be sited in critical big game winter range and very productive wildlife habitat, resulting in the potential construction of a large industrial facility that negatively impacts Oregon's wildlife. Horizon proposes to erect turbines in an area referred to by ODFW as the Zone of Multiple Biological Values (ZMBV), comprised of habitat classified as either Category 1 or 2 under the Habitat Mitigation Policy rules (OAR chapter 635, division 415). Category 2 habitat in this area has been identified since the 1980's when Union County adopted the county comprehensive land use plan.

The number and diversity of sensitive species and critical habitats present, coupled with the importance of the ZMBV to terrestrial species result in significant concerns with proposed Project siting. These concerns warrant implementing elevated post-construction surveying and monitoring requirements and a higher standard for mitigating impacts to fish and wildlife resources compared to what would occur with development of wind power projects on a previously disturbed site (e.g. wheat fields). This is consistent with recommendations in the Oregon wind energy siting guidelines.

As such, attached are ODFW's comments on Horizon's ASC, including mitigation measures ODFW believes are necessary for the proposed Project to be in compliance with statutes, rules, policies and management plans related to Oregon's fish, wildlife, and their habitats. Also enclosed are ODFW's recommendations for monitoring that will be necessary to estimate actual Project impacts and evaluate adequacy of mitigation.

These impacts, mitigation measures, and monitoring proposals include:

1. No construction in the ZMBV due to significant impacts to wildlife in a large block of native habitat without substantially increasing mitigation for impacts beyond Horizon's current proposal.

2. An estimated 12–93 raptor fatalities per year including golden eagles.

3. Disturbance to six active golden eagle nest sites.

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4. A potential sage-grouse lek discovered within the ZMBV on Ramo Flat.

5. An estimated 650 bat fatalities per year from direct and indirect impacts and mitigation for these fatalities.

6. An estimated 377-930 non-raptor bird fatalities per year and mitigation for these fatalities.

7. A directed survey for goshawk nests.

8. A 0.25 - 0.5 mile setback from raptor nests and the edge of rims and ridges.

9. Mitigation for displacement of elk and mule deer. After construction of the Elkhorn Valley Wind Project, deer and elk were displaced up to 1000 – 3000 meters from the tower strings. Displacement effectively removes between 25,000 – 59,000 acres of big game habitat.

The avoidance, protection, and enhancement measures identified by ODFW and included in the attachment are necessary to minimize impacts to fish, wildlife, and their habitats and to provide mitigation and monitoring measures that are consistent with statues, rules, policies, and mitigation plans related to Oregon's fish, wildlife, and their habitats. Unless included in any site certificate issued for the Project, the certificate will not meet the legal standards for issuance.

Please contact me if you have any questions on the comments provided or need additional information from ODFW.

Sincerely,

Jon Germond
Habitat Resources Program Manager
Wildlife Division

cc: Ron Anglin, Wildlife Division
Craig Ely, Northeast Region
Gary Miller, FWS
Valerie Franklin, Horizon Energy

Attachments: ODFW Comments on Horizon's final Application for Site Certificate

**Attachment 1**

# ODFW'S COMMENTS ON HORIZON'S FINAL APPLICATION FOR SITE CERTIFICATE AND RECOMMENDED TERMS AND CONDITIONS FOR ISSUANCE OF A SITE CERTIFICATE

## Introduction

Direct, indirect, and cumulative impacts occur from wind project development. Direct effects include blade strikes, barotrauma, loss of habitat, and "displacement". Indirect effects include increase in predators or predation pressure; decreased survival or reproduction of the species; and decreased use of the habitat that may result from effects of the project or resulting "habitat fragmentation". The presence of wind turbines may alter the landscape so that wildlife use patterns are affected, displacing wildlife away from the project facilities and suitable habitat. Displacement could occur through habitat loss and fragmentation for forest-dependent species, increased human activity, disturbance of habitats in proximity to turbines, and loss and fragmentation of habitat for wide ranging species. Animals displaced from wind energy facilities may move to areas with fewer disturbances, but with poorer quality habitat. The overall effect could impact reproductive success. The area of influence of a wind project is not limited to the project footprint. The impacts of the ARWF will extend beyond the project footprint.

To evaluate potential impacts of the Project and sufficiently mitigate for these impacts, an accurate designation of fish and wildlife habitat is necessary. However, despite numerous meetings with ODFW and ODFW's comments on the NOI, preliminary ASC and the Applicant's response to ODOE's First Request for Additional Information, the Applicant continues to inaccurately interpret the ODFW's Fish and Wildlife Habitat Mitigation Policy (OAR 615-415-0000). This has resulted in the Applicant inaccurately categorizing habitat in the Project area.

An accurate assessment of Project impacts also requires a cumulative effects analysis that includes the proposed ARWF, the adjacent Elkhorn Valley Wind Project (EVWP), and other foreseeable developments in the region. The Applicant, however, fails to analyze whether construction of the ARWF is contributing cumulatively along with other causes to population declines of birds, bats or other wildlife species, and their habitats. Instead the Applicant references the EVWP only in terms of mortality of birds and bats as a gauge of mortality that can be expected at the ARWF, without proposing mitigation for mortality to any species at the Project. Instead, the Applicant concludes that because population level impacts are not anticipated, mitigation is unnecessary. Population estimates, however, are not provided and likely unknown for most species in the Project area.

Therefore, ODFW recommends substantial modifications to the Applicant's proposed 1) siting of the Project; 2) assessment of Project impacts; and 3) mitigation and monitoring measures. These modifications should be included in any cite certificate issued for this Project to be consistent with Oregon and ODFW statutes, rules, policies, and mitigation plans.

## ODFW Management Authorities

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Some of the Oregon Department of Fish and Wildlife's (ODFW) goals, objectives and management authorities for the fish and wildlife populations affected by the Project are found in the following Oregon Revised Statutes (ORS), Oregon Administrative Rules (OAR) and associated plans; and are summarized below.

- Energy Facility Siting Council Siting Standards – Fish and Wildlife Habitat (OAR 345-022-0060)
  This standard requires that the design, construction and operation of a proposed facility (including mitigation) be consistent with the habitat mitigation goals and standards in OAR chapter 635, division 415. Oregon's Energy Facility Siting Council (EFSC) must determine whether the applicant has done appropriate site-specific studies to characterize the fish and wildlife habitat at the site and nearby. If impacts cannot be avoided, the applicant must provide a habitat mitigation plan. The plan must provide for appropriate mitigation measures, depending on the habitat categories affected by the proposed facility. The plan may require setting aside and improving other land for fish and wildlife habitat to make up for the habitat removed by the facility.

- Energy Facility Siting Council Siting Standards – Threatened and Endangered Species (OAR 345-022-0070)
  To issue a site certificate, EFSC must (after consultation with ODFW) that the design, construction and operation of the proposed facility, taking into account mitigation, are not likely to cause a significant reduction in the likelihood of survival or recovery of a species listed under the Oregon Endangered Species Act. This standard seeks to avoid harmful impacts to plant and animal species identified as threatened or endangered under state law. In practice, this means that the applicant must provide appropriate studies of the site to identify threatened or endangered species that the proposed facility could affect. ODFW determines the state-listed threatened or endangered wildlife species. If a potential risk to the survival or recovery of a threatened or endangered species exists, the applicant must redesign or relocate the facility to avoid that risk or propose appropriate mitigation measures.

- Wildlife Policy (ORS 496.012)
  Establishes wildlife management policy to prevent serious depletion of any indigenous species and maintain all species of fish and wildlife at optimum levels for future generations.

- State Endangered Species Act (ORS 496.171-182)
  Requires conservation and recovery of wildlife species that are classified as endangered or threatened. Authorizes ODFW to develop conservation and recovery plans for listed wildlife species. At ORS 498.026(1), prohibits "taking" of any listed species. Illegal take is a violation of the wildlife laws, subject to criminal prosecution as a Class A misdemeanor or violation pursuant to ORS 496.992.

- Prohibition of harassment, etc. of wildlife (ORS 498.006)
  Prohibits chasing, harassment, molestation, worrying or disturbing any wildlife, except as the Fish and Wildlife Commission may allow by rule.

- Criminal penalties for wildlife violations (ORS 496.992)
  Makes violation of any wildlife statute or Fish and Wildlife Commission rule subject to prosecution as a Class A misdemeanor or violation.
- Fish and Wildlife Habitat Mitigation Rule (OAR 635-415-0000-0025)
  Governs ODFW's provision of biological advice and recommendations concerning mitigation for losses of fish and wildlife habitat caused by development actions. Based on standards in the rule, ODFW determines the appropriate category to apply to land where a development action is proposed. If ODFW determines that such land is Category 1, ODFW must recommend that impacts to the habitat be avoided. If impacts cannot be avoided, ODFW must recommend against the development action. If ODFW determines that such land is Category 2, ODFW must recommend that impacts to the habitat be avoided. If impacts cannot be avoided, ODFW must recommend a high level of mitigation (as specified in more detail in the rule). If such mitigation is not required, ODFW must recommend against the development action.

- Wildlife Diversity Plan (OAR 635-100-0001 through 0030)
  Establishes a plan to maintain Oregon's wildlife diversity by protecting and enhancing populations and habitats of native wildlife at self-sustaining levels throughout natural geographic ranges.

- Oregon Conservation Strategy Plan (Adopted by Commission)
  A blueprint for conservation of the state's native fish and wildlife and their habitats, the Strategy provides information on at-risk species and habitats, identifies key issues affecting them and recommends actions. The Conservation Strategy emphasizes proactively conserving declining species and habitats to reduce the possibility of future federal or state listings.

- Oregon Plan for Salmon and Watersheds (ORS 541.405)
  Establishes plan to restore native fish populations, and the aquatic systems that support them, to productive and sustainable levels that will provide environmental, cultural, and economic benefits.

- ODFW's Fish Passage Law (ORS 509.580 - 509.645)
  Requires upstream and downstream passage at all artificial obstructions in those Oregon waters in which migratory native fish are currently or have historically been present.

- General Fish Management Goals (OAR 635-007-0510)
  Establishes the goals that fish be managed to take full advantage of the productive capacity of natural habitats, and that ODFW address losses in fish productivity due to habitat degradation through habitat restoration.

- Native Fish Conservation Policy (OAR 635-007-0502-0535)
  Protects and promotes natural production of indigenous fishes.

- Trout Management (OAR 635-500-0100-0120)

Requires maintenance of genetic diversity and integrity of wild trout stocks, and the protection, restoration, and enhancement of trout habitat.

- Oregon's Mule Deer Management Plan (OAR 635-190-0000-0030)
  Establishes a plan to protect and enhance mule deer populations in Oregon, to provide optimum balance among recreational uses, habitat availability, primary land uses and other wildlife species.

- Oregon's Elk Management Plan (OAR 635-160-0000-0030)
  Establishes a plan to protect and enhance elk populations in Oregon, to provide optimum recreational benefits to the public and be compatible with habitat capability and primary land uses.

- Oregon's Wolf Conservation and Management Plan (OAR 635-110-0000-0040)
  Establishes measures ODFW will take to conserve and manage the species. This includes actions that could be taken to protect livestock from wolf depredation and address human safety concerns.

- Recommendations for Greater Sage-Grouse Habitat Classification Under Oregon Department of Fish and Wildlife's Fish and Wildlife Habitat Mitigation Policy (OAR 635-140-0000)

This document provides policy direction, consistent recommendations and supporting rationale to guide ODFW habitat mitigation recommendations associated with impacts to greater sage-grouse habitat from energy development, its associated infrastructure, or other industrial/commercial development.

## Natural Resources Work Group

**Recommendation: The Applicant should establish a Natural Resources Work Group comprised of technical representatives from the certificate holder, ODFW, and the USFWS.**

ODFW recommends that the Applicant establish a Natural Resources Work Group (NRWG). The NRWG should be strictly comprised of the certificate holder and technical representatives of state and federal fish and wildlife agencies with natural resources expertise including the ODFW and the US Fish and Wildlife Service (USFWS). The main function of the NRWG should be to review and provide information to the ODOE related to 1) mitigation recommendations and compliance; 2) proposals for additional studies; and 3) operational considerations. The Applicant holder should consult with the NRWG on design of restoration, protection, management and monitoring plans and measures, and in the development of adaptive management or other recommendations. Lastly, the NRWG should be responsible for reviewing results of monitoring data and making suggestions to ODOE and resource agencies regarding the need to adjust mitigation and monitoring requirements based on results of initial monitoring data and available data from other projects.

The NRWG will facilitate communication and consultation between the Applicant and agencies for implementation and monitoring of the protection, mitigation, and enhancement measures throughout this site certificate. Timely and effective communications and coordination between the Applicant and the NRWG are crucial to the successful implementation of the site certificate and achievement of resource goals and objectives. Annual work plans and progress reports, plan or strategy updates, recognition and acceptance of the respective participant roles and responsibilities, and ongoing and active participation from all parties, are essential to good communications and coordination.

The Applicant will be responsible for ensuring that the NRWG meets at least once per year, generally in March-April, to review the previous year's activities and achievements, and to discuss and approve a final annual work plan for the current year. The NRWG may choose to meet at other times of the year, as needed, for example to address unanticipated matters or circumstances. Prior to each meeting, the Applicant should provide up-to-date progress reports including results of ongoing research and monitoring, schedules of planned maintenance, report on unplanned maintenance, and general operations information. Specific ground rules for the NRWG should be developed and at a minimum, these ground rules should include reporting requirements, define the extent to which public attendance and participation is allowed and information disseminated to the public, provide for a neutral note taker and meeting facilitator, and detail expectations of member contribution and behavior at the meetings. The ground rules should also include a timeframe for summarizing findings of surveys and studies, providing draft and final reports, and providing draft and final meeting minutes.

## Zone of Multiple Biological Values

**Recommendation: No construction of wind turbines, associated road systems, and associated Project infrastructure should take place in the Zone of Multiple Biological Values as delineated by ODFW.**

Within its comments on the Preliminary ASC and Horizon's Response to the First Additional Information Request, ODFW defined an area called the Zone of Multiple Biological Values (ZMBV). ODFW recommended that no construction of wind turbines, associated road systems, or associated infrastructure take place in this area for several reasons, including:

1. A potential sage-grouse lek site;
2. The presence of sage-grouse and year-round sage-grouse habitat;
3. Virtually all of the ZMBV is classified as Big Game Critical Wildlife Habitat (Category 2 habitat according to ODFW's Fish and Wildlife Habitat Mitigation Policy);
4. Many of the deer and elk that were displaced by the EVWP moved north into the ZMBV and into areas proposed for development;
5. The orientation of Craig Mountain could act as a pathway between the large open valleys for migrating raptors and other birds;
6. The presence of two burrowing owl nests (a state critical species);
7. Four known active golden eagle nests;
8. Five known active raptor nests, four red-tailed hawk and one Swainson's hawk, a state vulnerable species; and

9. Mitigation for impacts to this habitat and species dependent on it, while not impossible, will be very difficult to achieve.

ODFW first identified the importance of land within the ZMBV to the Applicant in 2002. During the planning and siting process for the EVWP, ODFW recommended no development in the area ODFW refers to as the ZMBV (Jim Cadwell, ODFW wildlife biologist, personal communication). After extensive negotiations, turbine strings proposed by the Applicant (Zilkha Renewable Energy, which was later renamed Horizon Wind Energy) on Ramo Flat and the bench southwest of Union, both in the ZMBV, were not included in the EVWP.

Despite ODFW's concerns and recommendations to not develop on the ZMBV during siting of the EVWP and within comments on the NOI, preliminary ASC for the Antelope Ridge Wind Farm (ARWF or Project), and the Applicant's response to the ODOE's first request for additional information, the Applicant continues to propose turbine strings on Ramo Flat and on the low elevation bench southwest of Union as part of the ARWF – the heart of the ZMBV. Most of the turbines proposed in the ZMBV are on lower elevation Big Game Critical Wildlife Habitat. Again, these turbines are proposed in the same areas removed from the EVWP and within the same areas for which ODFW has identified substantial wildlife concerns. Because of these substantial wildlife concerns, ODFW continues to recommend that no project construction occur in the ZMBV.

If the Project is sited in the ZMBV, ODFW believes substantial impacts will occur as discussed further in these comments and substantial mitigation will be required. As demonstrated by the EVWP big game study, these impacts will extend a considerable distance beyond the immediate footprint of the project itself.

Activities associated with construction of the EVWP displaced deer and elk into the ZMBV. In addition, the ZMBV includes sage-grouse, big game critical wildlife habitat, burrowing owl nests, four golden eagle nests, and a large number of sensitive species and raptor nests. This area is Category 2 habitat under ODFW's Habitat Mitigation Policy. If development occurs in this critical wildlife habitat, impacts will be very difficult to mitigate.

The diversity of sensitive species found and high habitat value found in the ZMBV to terrestrial species, and the significant wildlife concerns with project siting here, warrant implementing elevated post-construction surveying and monitoring requirements and a higher standard for mitigating impacts to fish and wildlife resources, consistent with recommendations in the Oregon wind energy siting guidelines. Any proposed mitigation must provide a net benefit in habitat and functions and values. ODFW includes mitigation measures below that will need to be included in a site certificate for the ARWF if construction occurs in the ZMBV. ODFW believes these measures are necessary for suitable protection of resources and to mitigate for likely impacts to aquatic and terrestrial species in compliance with Oregon statues, rules, policies, and management plans.

**Habitat Mitigation Policy:**
The ZMBV is largely Category 2 habitat, with localized areas of Category 1 habitat such as sensitive species raptor nests, as classified under the Fish and Wildlife Habitat Mitigation Rules

(OAR 635-415-0000 to 0025). It is essential and limited habitat for deer and elk, sage-grouse, golden eagles, Swainson's hawks, burrowing owls. The mitigation goal for Category 2 habitat if impacts are unavoidable is "reliable in-kind, in-proximity habitat mitigation to achieve no net loss of either pre-development habitat quantity or quality. In addition, a net benefit of habitat quantity or quality must be provided. Progress towards achieving the mitigation goals and standards shall be reported on a schedule agreed to in the mitigation plan performance measures. The fish and wildlife mitigation measures shall be implemented and completed either prior to or concurrent with the development action." If avoidance or the no net loss and net benefit mitigation standard cannot be achieved, "the Department shall recommend against...the proposed development action." [OAR 635-415-0025 (2)(b)(B) and (c)] The proposed mitigation measures for impacts to the ZMBV in Horizon's Final ASC fail to achieve the level of mitigation necessary to meet the Category 2 habitat mitigation standard. Therefore, ODFW is required by rule to recommend against the project as currently proposed.

As to the localized areas of Category 1 habitat, the habitat mitigation rules require that ODFW recommend against any development in those areas. Because the project continues to propose development actions that would impact those localized Category 1 areas, ODFW is required by rule to recommend against the project as currently proposed.

## Bald Eagles

**Recommendation: The Applicant should obtain an Incidental Take Permit for bald eagles from the ODFW.**

The bald eagle is known to occur in the analysis area. Twenty-two bald eagles were observed during the baseline studies (Jeffery et al. 2009, Enk et. al. 2010) and 21 bald eagle observations have been recorded during the post-construction surveys at the Elkhorn facility (Jeffrey et al. 2009). Bald eagles were observed in all seasons in the analysis area, but most observations occurred during the winter and spring periods. No nests or roosts were documented during baseline surveys (Jeffery et al. 2009, Enk et. al. 2010), and there are no records of historic nests in the analysis area (ORNHIC 2010). The bald eagle observations in the analysis area were primarily concentrated near Jimmy Creek Reservoir.

Though federally delisted, bald eagles are listed as threatened under the Oregon Endangered Species Act (ESA). As such, take of this species is generally prohibited by ORS 498.026(1). To avoid illegal take (and potential prosecution), the project would need to obtain from ODFW an Incidental Take Permit (ITP). To issue such a permit, ODFW would have to determine that the project's incidental take of bald eagles will not adversely impact the long-term conservation of the species or its habitat. The department may issue the permit under such terms, conditions and time periods necessary to minimize the impact on the species or its habitat. (OAR 635-110-0170). Although bald eagles are common in Union County, there are no identified nests or roosts occurring within the proposed project area. However, fatalities associated with the proposed project are a possibility.

## Golden Eagles

**Recommendation: Conduct golden eagle studies requested by the US Fish and Wildlife Service, and implement US Fish and Wildlife Service siting recommendations resulting from those studies prior to Project construction.**

Although no information on golden eagle studies is provided in the ASC, according to the FWS' Comments on the Final ASC, the FWS has actively initiated efforts with Horizon to better understand and study golden eagle use of the Project area. Golden eagle use studies are scheduled to begin in the spring of 2011, and will begin to provide additional insights into golden eagle use in the Project area.

ODFW has not been consulted on development of the golden eagle studies. However, based on recent conversations with the FWS, ODFW understands that two years of pre-project assessment will/should be conducted to obtain baseline information on eagle nest locations and productivity; use of feeding, roosting, nesting or wintering areas; eagle movements in relation to each proposed turbine location (including an analysis of spatial use in relation to rotor swept zone); numbers of eagles moving through the Project area; movements in relation to weather conditions; and phenology of movements. Also, eagle movement studies will be conducted for at least 20 days for two years during nesting season (June through early October) when adult eagles and their fledged young are most active.

ODFW believes these studies are necessary to help site the Project to minimize fatality and displacement impacts to golden eagles. Therefore, the Applicant should use data from eagle movement studies to carefully site Project turbines to avoid illegal eagle take. As such, final siting and construction of the Project, if issued a site certificate, should not occur prior to the these studies being conducted and conclusions reached.

**Recommendation: Develop an Avian and Bat Protection Plan (ABPP) for the Project in consultation with, and for approval by, ODFW. Prior to finalization of an ABPP, the significant bat and bird issues of concern should be thoroughly addressed by Horizon.**

Although no information on the drafting of an Avian and Bat Protection Plan (ABPP) is included in the final ASC, according to the FWS' comments on the final ASC, the FWS has actively initiated efforts with Horizon to develop a draft ABPP for the Project, that has an emphasis on golden eagles. ODFW has not been consulted on development of the ABPP.

According to the FWS, the draft ABPP's stated goals and objectives include avoidance, minimization, and mitigation of any unintentional take of golden eagles during construction and operation of the Project. However, the draft ABPP currently lacks specificity as to Horizon's commitments for avoidance and minimization measures for golden eagle, as well as any other compensatory mitigation measures for unavoidable take.

Because ODFW has not been consulted on development of the ABPP, it is impossible to determine if it will comply with ODFW policies. Oregon's Wildlife Diversity Plan (OAR 635-100-0001 through 0030) establishes a plan to maintain Oregon's wildlife diversity by protecting and enhancing populations and habitats of native wildlife at self-sustaining levels throughout natural geographic ranges.

Without the ABPP plan included in the ASC, the ASC does not provide suitable protection or mitigation measures for golden eagles. To ensure compliance with Oregon's Wildlife Diversity Plan, the Applicant should consult with ODFW to develop an ABPP that includes study requirements and site-specific measures to avoid, minimize, and mitigate adverse impacts to golden eagles.

**Recommendation: Employ micrositing measures for the Project's turbines (including ZMBV and other locations) to avoid impacts to eagles, including removal of proposed turbines and turbine strings that are at high risk of golden eagle impact.**

**Recommendation: If issued a site certificate, Project construction and operation should not begin until golden eagle studies are completed and an Avian and Bat Protection Plan are completed.**

Golden eagle populations are believed to be declining throughout their range in the contiguous United States. Wind projects sited in important eagle-use areas pose risks through collision and disturbance that results in loss of productivity at nearby nests or even loss of a nesting territory from construction, operation, and maintenance activities (Hunt 2002, Krone 2003, Chamberlain *et al.* 2006). Additionally, disturbances near areas that are important for roosting or foraging may result in reproductive failure or mortality elsewhere.

The importance of the Project area for golden eagles was demonstrated during baseline surveys conducted by the Applicant. For example, five golden eagle nests were located within two miles of the Project area and a total of 107 observations of golden eagles were documented during the baseline surveys, 32 observations during sensitive species surveys and 75 observations during other surveys or incidentally. Additionally, 86% of golden eagle observations were within the rotor swept height, suggesting golden eagles that use the Project area fly within the same spatial area where turbine blades spin the majority of the time.

As proposed, the Project is located in areas that pose considerable risk of injury and mortality to golden eagles. The proposed locations of Project turbine strings are closer to active golden eagle nests than at the adjacent EVWP. The proposed ARWF is three times larger than the adjacent EVWP, and the proposed locations of Project turbines indicate more risk to golden eagles from the Project's operations than at the EVWP. Given that four golden eagle mortalities have already been documented at the EVWP, ODFW considers the likelihood of golden eagle fatality and disturbance to be high at the ARWF.

Based on raptor use and collision mortality at 13 new generation wind facilities, the Applicant estimates that four raptor mortalities per year for each 100 megawatts of wind energy development at the ARWF. With a generating capacity of approximately 300 megawatts, an average of 12 raptor mortalities per year is expected to occur at the ARWF. Using the 90% prediction interval, the raptor fatalities could be as high as 93 raptor fatalities per year (31 fatalities/100 MW/year) for the Project.

An estimated 102 golden eagles, 23 bald eagles, and 54 Swainson's hawks were observed in the analysis area during surveys. Based on relative abundance and the high exposure index, there is a higher potential for golden eagle and red-tailed hawk fatalities than other raptor species. Because active nesting of red-tailed hawks, golden eagles, and Swainson's hawks occur within the analysis area, some fatalities of these species will occur over the life of the project. Golden eagles are protected under the Bald and Golden Eagle Protection Act, and Swainson's hawks are a state vulnerable species.

Because of the anticipated mortality of 12-93 raptors including numerous state-sensitive species, and because golden eagle studies will begin in 2011, project siting and construction should not occur prior to studies and an ABPP being completed.

**Recommendation: Restrict construction and maintenance activities to times outside January 1 through July 15 within 0.5 miles of an active golden eagle nest to avoid Project access-related disturbance impacts to nesting golden eagles.**

Most studies and guidelines (Pagel et al. 2010, Kochert et al. 2002) suggest limiting disturbance during critical periods such as courting and nesting. Therefore, ODFW recommends restricting maintenance activities from January 1 through July 15. The window timing is based on documented periods of golden eagle courtship and nesting in the intermountain west region (Beebe 1974, Kochert et al. 2002, Watson and Whalen 2003). Fatalities of golden eagles are very likely to occur at the ARWF. These fatalities, when combined with fatalities at the EVWP, could result in population level effects to golden eagles. Oregon's Wildlife Diversity Plan (OAR 635-100-0001 through 0030) establishes a plan to maintain Oregon's wildlife diversity by protecting and enhancing populations and habitats of native wildlife at self-sustaining levels throughout natural geographic ranges. Therefore, minimizing other impacts such as disturbance and potential nest abandonment are critical.

**Recommendation: Prevent construction of wind turbines within 0.25 miles of the edge of rims and ridges within the Project area**

McGrady *et al.* (2002) and Watson and Davies (2009) indicated nesting territories of golden eagles extend to at least four miles from their nests. The Project's baseline studies identified a possible golden eagle flyway, whereby golden eagle flight paths tended to show affinity toward steep ridgelines. In addition, the flight paths of golden eagles observed in the Project area show use beyond the proposed 50 m setback from the edge of Craig Mountain (Attachment P-7, Page 116, Figure 8f). Given this use beyond the proposed setback, the majority of the golden eagles observed flying within the rotor swept height, and use of steeps ridgeline slopes within the Project, ODFW believes to minimize the very high risk of mortality to golden eagles, construction of turbines should occur greater than 0.25 miles from the edge of rims and ridges.

Again, ODFW believes minimizing impacts are necessary to prevent population declines and to remain in compliance with Oregon's Wildlife Diversity Plan.

**Recommendation: Design or site all new roads and any other roads that will be used for the construction or operation of the Project at least 0.5 miles away from any active or inactive golden eagle nests to avoid Project access-related disturbance impacts to nesting golden eagles.**

Disturbance of golden eagles is also very likely from proposed Project road construction and use of these roads. An estimated 20,000 heavy duty round-trip truck deliveries are expected during Project construction (Page U-18). This level of use will likely have significant disturbance impacts on individual golden eagles, their nests, and nesting success. Furthermore, a proposed main transporter route identified for Project construction is located immediately adjacent to one known golden eagle nest and is approximately one mile from a second known golden eagle nest.

To avoid Project access related impacts to nesting golden eagles, all new roads should be designed and sited at least one mile away from any active or inactive nests.

## Gray Wolves

**Recommendation: The Applicant should immediately report any wolf sightings to the Oregon Department of Fish and Wildlife.**

The Applicant reports two separate incidences of wolves being sighted in the Project area by project biologists in 2009 (Page Q-13). ODFW requests that any future sightings of wolves be reported immediately to ODFW so that sightings can be verified.

Gray wolves are listed as endangered under Oregon's ESA. Oregon's wolf population is low and ODFW does not have data which suggests the project area has resident wolves. The documentation of multiple wolves within the project boundary by the Applicant, however, suggests the area is potentially important for wolves.
Within ODFW's Wolf Conservation and Management Plan, ODFW encourages reports of wolf locations to ODFW. The cite certificate should direct the reporting of gray wolf locations to aid in the implementation of the Management Plan.

**Recommendation: To minimize the potential for wolf conflicts with humans and wolf depredation of livestock, ODFW's recommendations for big game protection and mitigation should be included as conditions in the Project's Site Certificate**

As habitat generalists, it is unknown if the proposed project will impact wolf distribution. The Oregon Wolf Conservation and Management Plan (2010) identifies sufficient prey availability and human tolerance as two key factors which will affect wolf recovery in Oregon. Thus, the potential effects of the proposed project on prey species (primarily deer and elk) distribution and abundance may significantly affect wolf recovery in Oregon. If big game species are displaced to lower elevation agricultural lands it is expected that wolves will also use these lands, thereby increasing the potential for human conflicts. For the purpose of minimizing wolf-human conflicts it will be important to implement ODFW's big game recommendations (towards the end of this document) relating to the displacement of deer and elk as a result of this project.

## Sage Grouse

***The following comments and recommendations pertain to the potential lek site identified in Horizon's Application for Site Certificate for the ARWF only, and should not be construed as applying to any other potential lek sites that may be identified for this Project or any other project.***

**Recommendation: A management area, with a 1.4 mile radius surrounding the potential sage-grouse lek site, featuring no turbines or meteorological towers, provided that the Applicant identifies and mitigates at a 2:1 ratio for impacts within a 3-mile radius of the potential lek.**

Greater sage-grouse are a state sensitive-vulnerable species and an Oregon Conservation Strategy species for the Blue Mountain Region. The proposed Project has the potential to impact sage-grouse population abundance and habitat in the project area. Live birds, fresh scat, and a potential lek site were identified during pre-construction surveys for the EVWP and the ARWF.

Based on the best available science, ODFW believes that the fragmentation of habitat from wind development, the direct loss of habitat, the disturbance caused by activity associated with wind development, and the general avoidance caused by tall structures on the landscape will negatively affect the sage-grouse population located near the ARWF.

ODFW and the Applicant met April 9, 2010 to discuss the Applicant's response to ODOE's Request for Additional Information and ODFW's comments on its proposed sage-grouse protection measures included in a White Paper developed for ODFW consideration. At this meeting, ODFW and the Applicant tentatively agreed to no construction of turbines, towers, or transmission lines within 1.4 mi of this site, if the Applicant provides mitigation for impacts within a 3-mile radius of the potential lek site at a 2:1 ratio. This mitigation would be for impacts to sage-grouse only. However, within the Final ASC, the Applicant has modified the siting proposal to no tall structures (turbines, meteorological towers, and overhead transmission lines), in **suitable sagebrush habitat only** within 1.4 miles of the potential sage-grouse lek site and no mitigation for impacts within a 3-mile radius is proposed, except as mitigation for the Project footprint rather than impact to sage-grouse.

In an effort to protect breeding habitat, ODFW's current policy direction is to establish habitat protection areas of no development around (3-mile radius) occupied leks. Because the potential lek site has not been confirmed, ODFW was willing to consider Horizon's proposal for a management area with a 1.4 mile radius surrounding this potential lek site, featuring no turbines or meteorological towers, provided that Horizon provides suitable mitigation for sage-grouse. To identify impacts and mitigation measures, ODFW discussed with the Applicant that identification of impacts and mitigation measures should be developed in consultation with, and recommended for approval by, ODFW prior to issuance of a Site Certificate. Horizon, however, did not consult with ODFW to identify impacts and recommend mitigation for impacts within a 3-mile radius of this potential lek site.

Without a 1.4 mile radius surrounding the potential sage-grouse lek site featuring no turbines or meteorological towers, regardless of habitat type and without sage-grouse specific mitigation provided at a 2:1 ratio for impacts within a 3-mile radius of the potential lek, ODFW must consider this Category 1 habitat for sage-grouse. The mitigation goal for Category 1 habitat is avoidance of impacts or no authorization of the development action if impacts cannot be avoided [OAR 635-415-0025 (1)(b)(A) and (B)]. ODFW's Recommendations for Greater Sage-Grouse Habitat Classification under Oregon Department of Fish and Wildlife's Fish and Wildlife Habitat Mitigation Policy (OAR 635-415-0000) recommends limiting construction of wind farms to no closer than a 3 mile radius of sage-grouse lek sites. Therefore, no development should occur within 3 miles of the potential lek site.

**Recommendation: A setback for all surface development of ≥0.5 miles from the potential sage-grouse lek site.**

Oregon sage-grouse numbers have declined over the long-term (1957-2009; See Hagen 2005). Reasons for these losses include the cumulative effects of habitat loss and degradation, changes in predator control methods, and increases in human disturbance.

Sage-grouse use large landscapes often traveling over vast areas to fulfill various seasonal habitat requirements. They require specific vegetation types, and or structure, to meet daily nutritional and protection needs. ODFW's overarching habitat goals for sage-grouse are to 1) maintain or enhance the current range and distribution of sagebrush habitats in Oregon, and to 2) manage those habitats in a range of structural stages to benefit sage-grouse. Attaining population objectives is largely dependent upon achieving habitat goals.

In an effort to protect breeding habitat, ODFW recommends no development within a 3 mile radius of occupied leks. At the February meeting, Horizon indicated that a 3 mile set back for the potential lek would remove 45-65 turbines from the project. Therefore, Horizon proposed avoidance, minimization, and mitigation measures, in lieu of the 3 mile setback, for the potential sage-grouse lek associated with the ARWF. Horizon's proposal was included in a white paper filed with its response to the ODOE's Request for Additional Information on February 19, 2010.

ODFW and the Applicant met April 9, 2010 to discuss the Applicant's response to ODOE's Request for Additional Information and ODFW's comments on the Applicant's proposed sage-grouse protection measures included in its White Paper. At this meeting, ODFW and the Applicant agreed to no surface disturbance, including road construction, within 0.5 mi of the potential lek site.

ODFW's "Recommendations for Greater Sage-Grouse Habitat Classification under Oregon Department of Fish and Wildlife's Fish and Wildlife Habitat Mitigation Policy" recommends limiting construction of wind farms to no closer than a 3 mile radius of sage-grouse lek sites; 2) recommends buffers of 0.5 miles for winter and brood rearing habitats; and 3) recommends that ground level structures (e.g. roads and buried power lines) not be sited within 0.5 miles of the nearest lek site. Therefore, ODFW recommends a setback for all surface development of ≥0.5 miles.

**Recommendation: Construction activities and scheduled maintenance activities should be restricted during the breeding period, March 1 to June 30, within a two-mile radius of active leks.**

Horizon proposes restricting construction activities and scheduled maintenance activities during the breeding period, March 15 to June 30, within a two-mile radius of active leks. To be consistent with ODFW's policy guidance, this date should be modified to March 01 to June 30.

Timing restrictions in ODFW's Recommendations for Greater Sage-Grouse Habitat Classification are identified as March 1 through June 30. March 1 through June 30 is also identified by ODFW as the sage-grouse breeding season in Oregon. Therefore, construction activities and scheduled maintenance activities should be restricted March 1 to June 30, within a two-mile radius of active leks.

**Recommendation: ODFW supports the Applicant's proposed timely removal of all garbage and food items to discourage corvid and eagle presence in potential sage grouse habitat.**

**Recommendation: ODFW supports the Applicant's proposal to employ perch guards on all power lines present within one mile of the potential lek site to discourage perching by raptors and ravens.**

Increased abundance of raptors and corvids within occupied sage-grouse habitats may result in predation rates outside the range of natural variation (Coates 2007). Perching on power poles and transmission structures increases a raptor or corvid's range of vision, allowing for greater speed and effectiveness in searching for and acquiring prey. Transmission structures may also provide nesting sites for corvids and raptors in habitats with low vegetation and relatively flat terrain. Thus, raptors and corvids may preferentially seek out transmission structures in areas where natural perches and nesting sites are limited.

If corvid use is identified as an issue of concern at the Project once these measures are implemented, the Applicant should consult with ODFW to identify and implement further measures to decrease corvid use and concerns.

<u>Monitoring</u>

**Recommendation: The potential lek site and other suitable lekking habitat should be monitored annually for seven years post construction.**

ODFW defines a lek site as an area with one or more males observed displaying in two or more of the seven previous years. A total of 12 greater sage-grouse were observed during baseline studies in the analysis area (Jeffery et al. 2009, Enk et. al. 2010). During aerial lek surveys conducted on March 24, 2009, a single greater sage-grouse was documented on the western slopes of Clark Mountain. No sage-grouse were observed during a second flight on April 14, 2009. Four follow-up ground surveys were conducted between April 6, 2009 and April 20, 2009 to observe the location of the bird detected during the first aerial survey. On April 13, two males and one female were observed exhibiting mating behavior at the site, which was classified as a potential lek site. No sage grouse were observed at the site during the other three surveys in 2009 or during a series of ten ground surveys conducted in April 2010.

Survey methods utilized for this study should come from the lek search procedures described in the ODFW Greater Sage-grouse Conservation Assessment and Strategy for Oregon (Hagen 2005; Appendix A).

## Bats

**Recommendation: The Applicant should develop a Bird and Bat Protection Plan in consultation with, and for approval by, ODFW. This Plan should include all mitigation and monitoring measures for bats, raptors, and non-raptor bird species included in this attachment.**

Although no information on the drafting of an Avian and Bat Protection Plan (ABBP) is included in the final ASC, according to the FWS' comments on the final ASC, the FWS has actively initiated efforts with Horizon to develop a draft ABPP for the Project, that has an emphasis on golden eagles. ODFW, however, has not been consulted on development of the ABBP.

Because ODFW has not been consulted on development of the ABPP, ODFW is not able to determine if it and the ASC will comply with ODFW policies. Oregon's Wildlife Diversity Plan (OAR 635-100-0001 through 0030) establishes a plan to maintain Oregon's wildlife diversity by protecting and enhancing populations and habitats of native wildlife at self-sustaining levels throughout natural geographic ranges.

Thirteen of the 15 bat species in Oregon may occur in the proposed Project area, 11 of which are considered Special Status Species. Nine of these bat species are designated as Federal Species of Concern, 6 are on the State Sensitive List, and 8 are Oregon Conservation Strategy Species. The Silver-haired bat is a Federal Species of Concern, State Sensitive, and an Oregon Conservation Strategy Species, and accounted for 39.7% of all bat fatalities in the first year of monitoring at the neighboring EVWP. Also at the EVWP, 41% of bat fatalities were of the Hoary Bat, a State Sensitive and Oregon Conservation Strategy Species. Expected annual mortality at the ARWF is between 117 and 738 bats, with no mitigation proposed.

Without the ABPP plan included in the ASC, the ASC does not provide suitable protection or mitigation measures for bats and birds. ODFW believes that mortality and habitat fragmentation, particularly when evaluated cumulatively with impacts from the EVWP, will result in population level effects to some of Oregon's sensitive bat species. To ensure compliance with Oregon's Diversity Plan, the Applicant should consult with ODFW to develop an ABPP that includes study requirements and site-specific measures to avoid or minimize and reduce risk to bats and bird and their habitats, and mitigate adverse impacts in the Project area.

**Recommendation: To mitigate for an anticipated 450 bat fatalities per year as a result of collision or barotraumas, the Applicant shall protect and enhance 473 acres of forested**

**habitat in-proximity to the Project which includes documented roosting areas, natal colony sites and/or hibernacula for the species affected.**

The Project area's combination of conifer forest, deciduous trees, grasslands, shrub-steppe, rocky outcrops and water sources including streams and ponds makes the proposed Project area ideal for bats. This diversity provides habitat edges preferred by bats for foraging, access to water, and a variety of secure day roosts, maternity roosts and hibernation sites for multiple species of bats.

Based on information presented by the Applicant regarding bat fatalities per MW per year at other wind projects in the Pacific Northwest, expected annual mortality at the ARWF is between 117 and 738 bats. Based on mortality observed at the EVWP, a minimum of 378 bat moralities per year are expected at the ARWF. However, additional mortality per MW at the ARWF is expected because, as the Applicant writes, turbines constructed next to coniferous areas may experience higher levels of bat mortality. The ARWF is proposed for native habitat with approximately 10% of the project sited in coniferous forest.

Therefore, ODFW expects the fatality rate at the ARWF will be approximately 1.50 bats per MW per year. This is within the range of 0.39 – 2.46/MW/year cited for all Pacific Northwest wind energy projects (Page P-58) and reflects the expectation, for reasons described above, of a higher fatality rate at this Project than at the EVWP (1.26/MW/year). If fatality monitoring shows a fatality rate higher than 1.50/MW/year or 450 bats, additional compensatory mitigation may be necessary and the Applicant will need to consult with ODFW and ODOE to determine mitigation needed beyond that being proposed by ODFW to benefit the affected species.

Bats are long-lived (up to 31 years) with low reproductive rates. Females usually only have 1-2 young per year, depending on the species. Young are entirely dependent on parental care. Approximately 45% of all fatalities documented at the EVWP occurred during summer when young would still be dependent on parental care. The death of an adult female would therefore also cause the death of her dependent young. In species with naturally low reproductive rates, the loss of individuals above natural mortality rates is a blow to the reproductive potential of the population. Bats are dependent upon communities in equilibrium and "almost any alteration of the environment might be expected to have a deleterious effect on them" (Verts and Carraway 1998, p 75). Therefore, sustained, high fatality rates from collisions with wind turbines and barotraumas could have potentially significant impacts to bat populations due to low reproductive rates and the long dependency of young.

Although 400+ bat mortalities per year are expected at the ARWF, no mitigation is proposed by the Applicant for direct losses of bats. The applicant indicates that mitigation may be appropriate if annual fatality rates exceed a "Threshold of Concern". The Applicant writes of low anticipated impacts to bats and cites numbers of bats killed per MW per year at other projects in the Pacific Northwest with the implication that fatality rates within the range found elsewhere would or should be acceptable. The Applicant further writes that fatalities over the life of the Project "...are not likely to result in any population-level effects to sensitive bat species" (Page P-60). Given that little data exists to quantify bat population numbers or demographics in Oregon, and with eight species already considered at-risk (Oregon Conservation Strategy Species), it is impossible to predict what level of additional mortality the populations can withstand without negative consequences. Furthermore, little is known of impacts of wind energy projects on bats from habitat loss, population displacement, and/or disruption of community social structure.

Mortality caused by the proposed Project will be additive to impacts from the EVWP. Given that mortality from wind projects and other development is cumulative and that the population level effects of that mortality are unknown, it is unknown what level of fatality per turbine or per MW the population can withstand. It is, therefore, important to avoid bat fatalities whenever possible and to minimize mortality when it can not be avoided. The ARWF Monitoring and Mitigation Plan fails to address any actions that may minimize direct impacts to bats, it only suggests monitoring bat fatalities and including those numbers in Project reports.

The Monitoring and Mitigation Plan does offer a potential mitigation package of $10,000 per year for three years to Bat Conservation International or other bat conservation group if 750 plus bats are killed per year at the ARWF. While such a contribution to improve understanding of the impacts of wind energy on bat populations is admirable and encouraged, it does not meet the standard of compensatory mitigation resulting in in-kind and in-proximity mitigation and a net benefit to the species, nor does it offset the annual bat mortality that will continue for the life of the Project. Such contributions should be considered minimization measures by helping to explain why so many bats are killed by wind turbines and thereby suggesting ways to minimize those losses. However, the Applicant provides no justification for potentially providing a mitigation package for bats only if 750 plus bats per year are killed nor any information to suggest that this level of mortality will not have population level effects, particularly when added to mortalities occurring without mitigation at the EVWP. In addition, the 750 bat threshold appears to be upper limit of the 90 CI for average expected mortality of bats at Pacific Northwest wind facilities.

Compensatory mitigation should focus on actions that directly benefit the species such as protection and enhancement of critical habitat features and/or sites occupied by the affected species. As compensatory mitigation for expected losses to bats resulting from construction and operation of the ARWF, ODFW recommends the Applicant protect and improve in perpetuity and in-proximity, forested habitat that includes documented roosting areas, natal colony sites and/or hibernacula in northeast Oregon for the species affected. Sites protected and improved through acquisition or permanent easement should, in aggregate, house numbers equivalent to or greater than the expected annual fatalities at ARWF (1.5/MW multiplied by 300 MW equal 450 bats annually) and should emphasize sites for the species most affected by the Project. Mitigation actions of this type will have a real benefit to the species by preventing development from further eroding population viability in the protected sites.

Bat critical habitat, including roosts, maternity colonies, and hibernacula are identified as Category 1 habitat in the *Oregon Columbia Plateau Ecoregion Wind Energy Siting and Permitting Guidelines*. ODFW considers forested habitat in the Project area Category 2 habitat, because it is essential habitat for multiple bat and bird species and limited in the Project area. Approximately 157 acres of coniferous forest will be permanently lost or temporarily impacted from Project construction and operation. To mitigate for 450 direct bat fatalities, and direct non-raptor mortalities caused by Project operations, ODFW recommends protection and enhancement of 473 acres of forested habitat, which roughly equals a 3:1 mitigation ratio.

ODFW recommends that mitigation be required in the Site Certificate to compensate for expected levels of bat mortality. If fatality monitoring reveals higher than expected mortality to bats, then additional compensatory mitigation may be appropriate. Additional compensatory mitigation would be determined in consultation with ODFW and must result in a net benefit to the affected species.

**Recommendation: Turbine operations should be reduced at low wind speeds and/or turbine cut-in speeds should be raised to 5.0 or 6.5 m/s.**

It is unknown what level of fatality per turbine or per MW local bat populations can withstand. It is, therefore, important to avoid bat fatalities whenever possible and to minimize mortality when it can not be avoided.

Efforts should first be made to minimize impacts and fatalities to bats at ARWF. Reducing turbine operation at low wind speeds can reduce bat fatalities at individual turbines by up to 82% with minimal loss of power generation annually (Baerwald et al. 2009; Arnett et al. 2010). Methods include raising turbine cut-in speeds to 5.0 m/s or 6.5 m/s, or use of a low-speed idle strategy to minimize the time blades are rotating at low wind speeds, the period of highest bat fatality rates. If operational changes are made that reduce turbine operation at low wind speeds, the expected fatality rate may be reduced substantially.

The cumulative effects of sustained high mortality from ever-increasing wind energy projects and the introduction of White-nose Syndrome, a devastating disease that has killed over a million bats in the eastern U.S. and is moving westward, could be catastrophic to populations of hibernating bats in the west. Avoiding or minimizing bat fatalities is essential to prevent population crashes that could lead to ESA listing of the hardest hit species, some of which are already in decline.

**Recommendation: Use all non-guyed meteorological towers.**

The use of non-guyed meteorological towers is a positive step toward minimizing bird and bat collisions. ODFW recommends the Applicant forgo the use of temporary guyed meteorological towers to avoid this additional source of mortality to birds and bats.

**Monitoring**

**Recommendation: Fatality monitoring should begin no more than two weeks after Project turbines begin operating.**

Within the Monitoring and Mitigation Plan, the Applicant proposes that fatality monitoring begin "within approximately one month of the Facility becoming commercially operational." Bird and bat fatalities may begin to occur immediately upon Project start-up and may, in fact, be significant in that early period as wildlife that have become accustomed to stationary towers, suddenly experience operational turbines. For that reason, ODFW recommends that fatality monitoring begin no more than two weeks after Project turbines begin to operate. Monitoring should take place within the search frequency period appropriate for the season as described by the Applicant. The fatality monitoring year would thus begin on the day of the first fatality search effort and would conclude twelve months later.

**Recommendation: A minimum of 2 consecutive years of fatality monitoring in shrub-steppe and riparian habitats and 3 years in forested habitat, then every three to five years thereafter.**

On page 4 of the Monitoring and Mitigation Plan, the Applicant proposes two complete years of fatality monitoring while on page 2, "at least one year" is proposed. ODFW does not believe one year of monitoring is sufficient to assess Project impacts given year to year differences in vegetation, weather, operational variations, and other factors. Because of the high use of the Project area by Special Status Species, the large size of the Project (300 MW), and the lack of information on mortality in conifer forest areas, ODFW recommends a minimum of 2 consecutive years of fatality monitoring in shrub-steppe and riparian habitats and 3 years in forested habitat. Fatality monitoring would then continue every three to five years, with frequency determined based on previous study results and Applicant consultation with ODFW.

**Recommendation: Fatality searches should be conducted once per week during spring migration, summer/breeding, and fall migration season.**

Due to evidence of a summer breeding population of hoary bats in the Project area and the high level of bat mortality during summer at the EVWP, ODFW recommends fatality search frequency during the summer equal to the frequency during migration. Thus, fatality searches should be conducted once per week during spring migration, summer/breeding, and fall migration season.

**Recommendation: Small rodents, such as *Microtus* spp., should be used in lieu of small bird carcasses during carcass removal and searcher efficiency trials.**

Regarding carcass removal and searcher efficiency trials, the Applicant proposes to use small bird carcasses as a surrogate for bats, unless fresh bat carcasses are available. It is probable that bird carcasses, with feathers and feather shafts that decompose slowly, would persist in the environment longer than bats, with no such tissues. In the Fatality Monitoring Search Protocol, a carcass condition category is included for a "feather spot" acknowledging the expectation that feathers will persist when other tissues have decomposed or been removed. Additionally, when a bird is scavenged, feathers may remain even if other tissues have been consumed by the scavenger. If a bat carcass is scavenged, it is unlikely that much, if any, of the carcass would remain to be found by searchers. For this reason, ODFW suggests that birds are a poor surrogate for bat carcasses and small rodents such as *Microtus* spp would offer a more realistic correction factor for both carcass removal and searcher efficiency. Rodents with fur are marginally similar in appearance to bats, and would better approximate searcher efficiency for bat carcasses when used in trials.

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**Recommendation: Compare fatality data with pre-construction acoustic survey data to determine if fatality rates are correlated with bat activity zones.**

Bat fatality data should be compared with pre-construction acoustic survey data to determine whether and to what extent fatality rates are correlated with bat activity zones documented prior to Project start-up. This information would help inform future efforts on the part of the Applicant or others to design wind energy projects with minimum impacts to bats.

**Recommendation: Monitoring of bat presence and activity throughout construction, post construction and start up of the project and at least 2 consecutive years after the Project becomes operational, should be conducted.**

The Monitoring and Mitigation Plan for Antelope Ridge only includes fatality monitoring for bats. There is no mention of monitoring actual bat species presence, population density, roosts, or breeding activity in the vicinity of the project. The Plan does propose to monitor raptors and passerine birds in the Project area, but no equivalent surveys for bats are described.

Fatality monitoring alone, without the context of actual bat density and/or activity in the area is insufficient for determining the impact of the project on bat populations in the Project area. The ARWF is proposed for native habitat with approximately 10% of the project sited in coniferous forest. The Applicant writes in Exhibit P of the final application that the effect on bats of wind energy facilities in coniferous forested habitats is relatively unknown. Therefore, ODFW recommends monitoring bat presence and activity throughout construction, post construction and start up of the project and at least two consecutive years after the Project becomes operational, then every three to five years thereafter.

Monitoring should include bat acoustic surveys using a combination of Pettersson and AnaBat bat detectors at a minimum of ten sites in the proposed Project area, with at least one site in each of the major habitat types, particularly the conifer forest zones. While many wind energy projects use AnaBat detectors for acoustic bat surveys to compare to other projects, the resolution of the collected calls is low and limits species discrimination to acoustic groups or to the level of genus. The standard for collecting acoustic bat data in the Pacific Northwest is time expansion data such as that collected with Pettersson bat detectors allowing for better species discrimination and consistency with other data collection efforts. Post-construction surveys should be designed to determine changes in bat migratory patterns and local use patterns compared with pre-construction surveys and to locate breeding colonies, roost sites or any other sites with high density use by bats.

The ASC fails to develop an adequate habitat mitigation plan that complies with OAR 345-022-0060. The proposed ASC mitigation is to pay for three years into a Bat International Conservation group only after reaching the "Threshold of Concern" in bat mortality. The proposed mitigation does not have any sort of protection for future bat losses on site or in close proximity to the project (Oregon's Mitigation Policy). In addition, bat losses will occur every year of ARWF operations not just for three years. ODFW believes the ASC did not meet the mitigation and habitat standards for bat losses.

## Raptors

**Recommendation: A 0.5 mile setback area around all sensitive raptor nest sites (excluding golden eagles) which includes all permanent and temporary disturbances associated with the proposed Project. Golden eagle protection and mitigation measures are discussed earlier.**

The Applicant identifies Category 1 Habitat for nest sites of golden eagle, Swainson's hawk, goshawk, and burrowing owl. However, the Applicant considers these point habitats with no associated acreage. While this approach is convenient, it is inconsistent with historical regulatory measures (e.g., forestry practices) regarding sensitive and threatened and endangered wildlife species in Oregon. In the Columbia Basin, Category 1 Habitat associated with Washington ground squirrel colonies were defined as the occupied area AND its associated use area. This approach recognizes the importance of the area surrounding a natal site as integral to the continued use of the site (i.e., wildlife need more than a specific point to be successful). Because of this, ODFW recommends a ½ mile setback area (no impact) around all sensitive raptor nest sites (excluding golden eagles). This buffer should include all permanent and temporary disturbances associated with the proposed project, not simply turbines.

**Recommendation: A minimum setback of 0.25 miles from the rim of Craig Mountain.**

ODFW is concerned with the Applicant's proposal of only a 50 meter setback along the Craig Mountain rim as a mitigation measure for raptor collisions. This area was shown to be used by golden eagles during surveys, and the applicant acknowledges that use of rim edges by eagles is not uncommon. Golden eagles did exhibit some flyway affinity towards steep slopes and ridgelines, for example the east slopes of Craig Mountain (Page P-48).

Given the height of the turbines (328'-475'), the proposed 50 meter setback (approximately half the height of a single turbine) is insufficient. Lacking any specific data from the Applicant on the adequacy of this type of mitigation, ODFW recommends a minimum setback of .25 mile from the rim to reduce potential collisions, similar to the proposed Jimmy Creek Reservoir setback.

The documented raptor use of the site based on sampling efforts (not a complete inventory) is significant. This is not unexpected due to the location of the project in relation to surrounding geography (nearby high elevation mountainous terrain and low elevation valley bottom) and the variety of unique habitats (identified in Attachment P-2) within the project boundary. In addition, the high number of nesting raptors (65 nests identified during surveying) within the project boundary indicates a higher possibility of raptor fatalities.

Therefore, ODFW is concerned with the Applicant's general assessment that raptor mortality will be low based on estimators derived from other wind power projects. Specifically, the use of the nearby EVWP project as a comparator is misleading because the proposed ARWF is roughly three times the size of the Elkhorn project. In addition, it is unknown if the 0 .04 /MW projected raptor mortality rate is an acceptable level of raptor mortality – it is likely dependent on which raptor species are killed. Based on the supplied calculations in the application raptor fatalities at Antelope Ridge will be double that of Elkhorn. Given the species of raptor mortalities documented to date at the EVWP (i.e., golden eagles and Swainson's hawks) the projected fatality estimates are of great concern to ODFW. This concern is compounded with the data supplied by the applicant that 47.3% of the birds observed flying within the zone of risk during pre-construction surveys at Antelope Ridge were raptors.

Several of the Applicant's comments state that raptor mortality, particularly of golden eagles and red-tailed hawks, are few and that these species exhibit little disturbance from wind projects. However, the four golden eagle fatalities at the EVWP are substantially higher than at any other wind project in Oregon, where no eagle mortalities have been recorded.

Although mean raptor use in the analysis area is considered low, raptor nest density within the Site Boundary is moderately high relative to other wind facilities. Raptor nest density in the Project area is .28/mi$^2$, compared to 10 other western U.S. wind facilities (ranging from .03 to .30). Based on raptor use and collision mortality at 13 new generation wind facilities, the Applicant estimates that four raptors per year for each 100 MW of wind energy development will be fatalities at the ARWF. With a generating capacity of approximately 300 MW, an average of 12 raptor mortalities per year is expected at the ARWF.

The Applicant estimates that the majority of the fatalities of diurnal raptors will likely consist of red-tailed hawk, American kestrel, and golden eagle. Because active nesting of red-tailed hawk, golden eagles, and Swainson's hawks occur within the analysis area, some fatalities of these species will occur over the life of the project. Golden eagles are protected under the Bald and Golden Eagle Protection Act and Swainson's hawks are a state vulnerable species.

The Applicant proposes surrounding known nests with buffers when siting turbines to reduce potential impacts. The Applicant, however, does not propose any mitigation for fatalities or impacts from displacement.

The Applicant states that "no adverse population-level impacts are expected". ODFW is concerned that this assessment is not supported with documentation or analysis of the cumulative impacts of this and neighboring projects. Simply put, without adequate population data for many of the potentially affected raptor species – especially the low density raptors (e.g., burrowing owls, goshawk, and golden eagle), ODFW is unable to determine if the combined impacts to these species are sustainable to local populations of these species. Oregon's wildlife

The ASC lacks adequate population information on raptors. Several species have been identified as sensitive species and the estimated annual raptor mortality could be as high as 93 birds at the ARWF. During the first 10 years of ARWF operations an estimated 120- 93 raptors will be killed. The Applicant does not propose any mitigation for direct raptor fatalities nor does it provide information indicating this level of mortality is sustainable for state sensitive species. Because the Applicant reports that golden eagles, along with red-tailed hawk and American Kestrels, are expected to comprise a large proportion of the raptor fatalities ODFW believes the Project as proposed will result in serious declines of golden eagles and potentially Swainson's hawks.

ODFW is also concerned with the selection of threshold criteria that is proposed in the ASC. For example, it is difficult to understand why 60 state sensitive bird species must be killed by the project per year before mitigation options are considered. ODFW previously requested justification for these threshold numbers, but none has been provided.

ODFW questions the sustainability of this approach. Exceeding the projected threshold does not trigger mitigation, rather it appears to be an alert that more raptors are being killed than was anticipated and may indicate "if mitigation is appropriate".

**Recommendation: If studies indicate that the Project has a negative effect on raptor nesting success, nest use, or nest distribution mitigation should be developed in consultation with ODFW and implemented by the Applicant.**

Varying levels of avoidance or lower nesting levels near turbines has been reported for raptors (Page P-59). The Applicant claims that there will be limited nesting displacement of raptors at the Facility, and that creation of a buffer surrounding known nests when siting turbines will further reduce any potential impact. However, little information on changes in nest densities with distance from the turbines is provided.

According to the Applicant, "If the analysis shows that mitigation is appropriate" it will consult with ODFW and ODOE on mitigation for the affected species. If a nesting displacement or a reduction in either nesting success or nest use occurs because of the Project, mitigation will be necessary and should be developed in consultation with ODFW.

Sensitive species nest sites are considered Category 1 habitat. Other raptor species nest sites are considered Category 2 habitat. ODFW's Fish and Wildlife Habitat Mitigation Policy first requires avoidance of impacts through alternatives to the proposed development action to protect Category 1 or 2 habitats. Therefore, changes in operations or removal of turbines could be required. For Category 2 habitat, any mitigation required would need to be provided in-kind and in-proximity to the area of impact. Contributing to overall scientific knowledge or participating in research projects would not be considered in-kind mitigation.

The Applicant indicates that if mitigation is necessary, it should be designed to benefit the affected species or contribute to overall scientific knowledge. Also, that it could include additional raptor nest monitoring, protection of nest sites from disturbance, or participation in research projects. ODFW does not consider additional monitoring as mitigation without including an adaptive management component. As defined in ODFW's Fish and Wildlife Habitat Mitigation Policy, "mitigation" means taking one or more of the following actions listed in order of priority [OAR 635-415-0005 (16)]:

(a) Avoiding the impact altogether by not taking a certain development action or parts of that action;
(b) Minimizing impacts by limiting the degree or magnitude of the development action and its implementation;
(c) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;

(d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the development action and by monitoring and taking appropriate corrective measures;
(e) Compensating for the impact by replacing or providing comparable substitute resources or environments.

Therefore, the Applicant will need to consult with ODFW to avoid and mitigate unavoidable impacts to nesting success, nest use, or nest distribution.

**Monitoring**

**Recommendation: To accurately assess impacts to raptors from construction and operation of the ARWF and to determine suitability of mitigation, raptor nest surveys should occur the first two consecutive years following Project construction, then every 3-5 years thereafter.**

As proposed, the raptor nest survey will be conducted to estimate the size of the local breeding populations of tree or other above-ground-nesting raptor species in the vicinity of the Facility and to determine whether operation of the Facility may have an impact on nesting activity or nesting success in the local populations of raptors. To accomplish this, two years of post-construction surveys are proposed. One survey will occur in the first nesting season after construction is completed. The second survey will be conducted as late as four years post construction.

ODFW does not believe one year of monitoring is sufficient to assess Project impacts given year to year differences in vegetation, weather, operational variations, and other factors. Because of the high use of the Project area by Special Status Species, the large size of the Project (300 MW), and the lack of information on mortality in conifer forest areas, ODFW recommends a minimum of 2 consecutive years of fatality monitoring. Two successive years of nesting surveys should provide a sufficient baseline to compare with long term monitoring results to help determine impacts to raptors and suitability of mitigation measures.

To accurately assess impacts to raptors from construction and operation of the ARWF, and to determine suitability of mitigation, raptor nest surveys should occur in the first two years following Project construction, then every 3-5 years thereafter.

ODFW supports the Applicant's proposal to conduct long-term raptor nest surveys at five year intervals for the life of the facility. However, ODFW believes raptor nest surveys should be conducted in two successive years immediately following initial start up of the Project. Based on results of first two years of study, ODFW may recommend monitoring occur more frequently then every five years. As such, the first long-term raptor nest survey would occur no later than the seventh year after construction is completed..

The Applicant indicates that given the relatively low raptor nest densities of target species in the area, impacts may have to be judged based on trends in the data, results from other wind facilities, and regional literature. Horizon should consult with ODFW to identify Project impacts to nesting raptor and to identify what, if any, mitigation is required.

## Passerines

**Recommendation: Mitigation for expected bird fatality should be provided and combined with bat fatality mitigation discussed earlier in the attachment. To mitigate for expected passerine fatalities at the ARWF, the Applicant shall protect and enhance 473 acres of forested habitat in-proximity to the Project.**

The Applicant indicates that mitigation may only be appropriate if fatality rates exceed some hypothetical threshold of concern. The Applicant provides no biological justification for these thresholds of concerns, although it says they were developed based on previous site certificates and current knowledge of the species that are likely to use the habitat in the area of the facility. In addition, the Applicant indicates that mitigation may be appropriate if fatality rates for individual species (especially State Sensitive Species) are higher than expected AND at a level of biological concern.

It appears the Applicant chose these thresholds of concern because they are in other EFSC issued certificates rather than based on scientific information that considers the species that could be affected by the ARWF and the habitat types found in the Project area. The thresholds of concern also appear to simply be the Applicant's best guess of expected mortality based on mortality at other wind projects in the country.

Two separate thresholds of concerns for eagles are included, 0.09 and 0.06 annual fatalities per MW. This would mean 18 to 27 raptors including eagles we need to be killed before mitigation may be appropriate. This would result in illegal take for bald and golden eagles per the Bald and Golden Eagle Management Plan.

Furthermore, the Applicant proposes that mitigation may be appropriate for sate sensitive species if annual fatalities are above 60 per year. These species are state sensitive because of their low numbers. Any take of state sensitive species is considered an impact.

Therefore, ODFW recommends that mitigation be provided based on the expected level of fatality attributed to the ARWF, and based on information provided in the application and observed levels of passerine mortality at the EVWP. Please see ODFW recommended mitigation section in this letter for specific mitigation needs. Mitigation will also need to provide in-kind and in-proximity positive benefits to affected species. Contributions to research funds, although valuable information could be gained, would not constitute in-kind and in-proximity mitigation.

Because of the large expected mortality of birds at the ARWF, compounded by the cumulative effects of unmitigated bird mortality at the EVWP, the lack of any biological justification provided by the Applicant for its "Threshold of Concerns", the lack of population information to support the Applicant's claims that mortality will not have population level effects or be of biological concern, and the lack of mitigation for anticipated bird fatality at the ARWF, the final ASC is not consistent with Oregon and ODFW statures, rules, and policies.

Direct impacts to birds from wind energy facilities occur due to collisions with turbines, met tower guy wires, or vehicles and from loss of habitat or project construction site clearing. Using mortality data from a 10-year period from wind facilities throughout the United States, the Applicant estimated that the average number of bird collision fatalities was 3.1 per MW per year or 2.3 per turbine per year. That translates into an estimated 377-930 bird fatalities per year at the ARWF.

Based on the proportion observed during baseline studies, passerines are likely to comprise a large proportion of fatalities within the Site Boundary. Passerines identified by the Applicant as most at risk include mountain bluebird, American robin, European starling, and American goldfinch.

Some wind turbines will be sited within forested areas. The Applicant indicates that it is unknown if these areas may experience greater mortality levels of migrant and breeding birds.

The Applicant reports that fatality estimates for the EVWP are in the lower range of estimates compared to other regional wind projects. ODFW believes this low rate of mortality may be due to the macro and micro-siting efforts of the Applicant and ODFW to avoid canyons, cliffs, and reservoirs and clustering of turbine strings.

**Recommendation: If displacement of forest breeding birds is documented, suitable mitigation shall be determined in consultation with and for approval by ODFW.**

The site boundary includes approximately 10% forested habitat.

ODFW supports a breeding bird displacement study. However, ODFW believes the proposal to limit the study to two post-construction years, year 1 and year 5 of facility operation, is insufficient. Instead ODFW recommends that 3 successive years or forest breeding bird surveys be conducted and begin the first spring/early summer season after ARWF begins operation. Surveys should then be repeated every 5 years for the life of the Project.

If displacement of forest breeding birds is documented, mitigation will be necessary to offset these impacts. The Applicant, however, does not propose any mitigation for displacement affects, rather only that it will include an analysis of the data in reports.

Considering the number of turbines and area covered by the proposed ARWF, the Applicant should mitigate for bird displacement at the project.

Wind energy facility construction can cause small-scale local displacement of grassland passerines due to birds avoiding turbine noise and maintenance activities. Construction also reduces habitat effectiveness because of the presence of access roads and large gravel pads around turbines. According to the Applicant, turbines placed in grasslands and shrub areas will likely have some level of displacement on grassland and shrub nesting species in close proximity to the facilities. The Applicant reports that bird displacement away from turbines in other studies ranged from 50 to 180 meters (Pages P 57-58). However, the Applicant does not, but should, propose mitigation to mitigate for passerine fatalities at the ARWF.

Because the literature indicates a significant number of displacement effects on various bird species, especially grassland birds and raptors, the Applicant should implement mitigation of the Site Certificate so that these displacement effects can begin mitigated upon the construction of the project. In the event that displacement occurs beyond the estimated 50-180 m, mitigation should be expanded.

## Monitoring

### *Avian Fatality Monitoring*

**Recommendation: Avian fatality monitoring should begin no more than two weeks after Project turbines begin operating**

Within the Wildlife Monitoring and Mitigation Plan, the Applicant proposes that fatality monitoring begin "within approximately one month of the Facility becoming commercially operational." Bird and bat fatalities may begin to occur immediately upon Project start-up and may, in fact, be significant in that early period as wildlife that have become accustomed to stationary towers, suddenly experience operational turbines. For that reason, ODFW recommends that fatality monitoring begin no more than two weeks after Project turbines begin to operate. Monitoring should take place within the search frequency period appropriate for the season as described by the Applicant. The fatality monitoring year would thus begin on the day of the first fatality search effort and would conclude twelve months later. If additional turbines are added to the Project at any time in the future, additional monitoring should occur at a frequency and duration similar to the original Project turbines.

**Recommendation: A minimum of two consecutive years of fatality monitoring in shrub-steppe and riparian habitats and three full and three consecutive years of monitoring in forested habitat, then every three to five years thereafter.**

On page 4 of the Monitoring and Mitigation Plan the Applicant proposes two complete years of fatality monitoring, while on page 2, "at least one year" is proposed. ODFW does not believe one year of monitoring is sufficient to assess Project impacts given year to year differences in vegetation, weather, operational variations, and other factors. Because of the high use of the Project area by Special Status Species, the large size of the Project (300 MW), and the lack of information on mortality in conifer forest areas, ODFW recommends a minimum of 2 consecutive years of fatality monitoring in shrub-steppe and riparian habitats and 3 years in forested habitat.

**Recommendation: Fatality monitoring should occur at each turbine in the Project during the first three years of monitoring. Numbers and locations of towers to be monitored in subsequent years should be determined by the NRWG.**

The Applicant's proposed monitoring for mortalities in search plots is insufficient to determine the level of bird mortality attributable to the Project. The Applicant indicates that fatality monitoring during the monitoring year will occur at approximately one-third of the turbines, which are representative of habitat in different parts of the facility. Because each turbine in the

Project area will occupy a slightly different microsite (e.g., proximity to rock outcrops, conifer forest, etc.) each turbine may have an impact on bird fatalities completely independent of other turbines. Therefore, to gauge the true impact of turbines on birds, ODFW recommends fatality monitoring at each turbine in the Project. Thus, if a turbine or group of turbines is shown to have an impact greater than the rest of the Project, steps may be taken to mitigate that impact.

Passerines (primarily perching birds) have been the most abundant bird fatality at wind energy projects outside California (Erickson et al. 2001a, Erickson et al. 2002), often comprising more than 80% of the bird fatalities. Both migrant and resident passerine fatalities have been observed.

The Applicant's avian use surveys indicated that the coniferous forest habitats within the analysis area, Craig and Clark Mountains in particular, were used by migrant and breeding passerine songbirds, as well as several other bird species. These areas with mixed forest including coniferous trees and deciduous trees, and a diverse mix of understory shrubs, are considered important-stopover habitats for migrating passerines and neo-tropical migrants.

Passerines and nocturnal migrants are common fatalities at wind facilities studied in the Pacific Northwest. However, information for the Pacific Northwest is from wind facilities that are not sited in forested ridge tops. Approximately 10% of the ARWF will be sited within coniferous forest habitat. It is unknown if these areas may experience greater mortality levels of migrant and breeding birds. Therefore, the first 1-3 years of monitoring should occur at all turbines to determine annual bird fatality, particularly in and near forested habitat, and to also determine if there are any trouble or hot spots. If monitoring results indicate a specific turbine or group of turbines is responsible for impacts significantly greater that the remainder of the Project, turbine removal should be considered

**Recommendation: All meteorological towers should be monitored for two successive years, beginning no more than two weeks after Project turbines begin operating. Based on results of this monitoring, additional monitoring may need to be conducted every three to five years.**

The Applicant does not propose fatality monitoring at meteorological towers, indicating they are known to cause little, if any, bird mortality. To verify that meteorological towers are not causing fatalities at the Project, two full, successive years of monitoring should be conducted at all meteorological towers. Based on results of this monitoring, additional monitoring every three or more years may be warranted.

**Recommendation: Removal and Searcher Efficient Trial and Fatality Monitoring Search Protocols should be developed in consultation with and approved by ODFW.**

Prior to initiation of fatality monitoring, detailed study protocols should be developed in consultation with, and for approval by, ODFW.

*Forest Breeding Bird Displacement Study*

**Recommendation: ODFW recommends that the Applicant conduct a before-after comparison of pre- and post-construction breeding bird surveys in and near forested**

**habitat to determine if displacement impacts occur, due to the high bird use and sensitive species found.**

Four of the 11 state-sensitive bird species are grassland birds (burrowing owls, Swainson's hawk, grasshopper sparrow, long-gilled curlew). The applicant correctly presents a number of studies that indicate displacement of this species group with distances ranging from 164 to 600 feet from turbines. Yet the application contains no provisions to utilize this information in a way to protect or enhance local bird populations

ODFW recommends that the Applicant conduct a before-after comparison of pre- and post-construction breeding bird surveys in and near forested habitat to determine if displacement impacts occur, due to the high bird use and sensitive species found. The Applicant has already conducted the baseline study.

**Recommendation: Three successive years or forest breeding bird surveys be conducted and begin the first spring/early summer season after ARWF begins operation. Surveys should then be repeated every 5 years for the life of the Project.**

Mitigation Policy – As proposed, the proposed project will impact Category 1 habitat for raptors and Category 2 and 4 habitats for passerines as classified under the Fish and Wildlife Habitat Mitigation Policy (OAR 635-415-0000 to 0025). For raptors, it is essential, limited, and irreplaceable. The mitigation goal for Category 1 habitat is "Avoidance of impacts through alternatives to the proposed development action; or no authorization of the proposed development action if impacts cannot be avoided" [OAR 635-415-0025 (1)(b)(A) and (B)]. For passerines, nesting habitat is considered essential and limited and for other use area the habitat is considered important, and therefore, categorized as Category 4 habitat. The mitigation goal for Category 4 habitat, if impacts are unavoidable "is no net loss in either existing habitat quantity or quality...through reliable in-kind or out-of-kind, in-proximity or off-proximity habitat mitigation to achieve no net loss in either pre-development habitat quantity or quality. Progress towards achieving the mitigation goals and standards shall be reported on a schedule agreed to in the mitigation plan performance measures. The fish and wildlife mitigation measures shall be implemented and completed either prior to or concurrent with the development action" [OAR 635-415-0025 (4)(a) and (b)(B)].

## Goshawks

**Recommendation: Goshawk surveys should be conducted to thoroughly assess the resident population of goshawks and potential impacts from construction and operation of the ARWF**

The single goshawk nest appears to have been discovered incidentally within the proposed project boundary. The survey protocol for the other bird species is likely inadequate to accurately determine the number of goshawk nests that may occur on the site. In addition, the Applicant states that ponderosa pine habitat represents sub-optimal habitat for goshawk. This is inaccurate as many goshawk nests are known to occur in ponderosa pine habitats where canopy cover is sufficient. Furthermore, the Applicant acknowledges that much of the forested habitat type in the proposed project area is mixed conifer which may contain additional nests. Because the site is occupied by nesting goshawks, ODFW recommends that additional survey efforts be conducted to thoroughly assess the resident population of goshawks and any possible effects from the construction of the Project.

## Burrowing Owls

**Recommendation - A 0.25 mile setback from burrowing owl nests which includes all permanent and temporary disturbances associated with the proposed Project.**

The Applicant proposes a 0.25 mile setback from burrowing owl nests for turbines only. ODFW, however, recommends the 0.25 mile setback include all permanent and temporary disturbances. ODFW also recommends that the Applicant avoid impacts to owls during the breeding season, generally February 1 through August 31.

Burrowing owls are present and likely breeding within the project area. The Applicant believes that because of behavior and low abundance of burrowing owls on site, the impacts are not expected to be significant. However, burrowing owls have been documented as fatalities in the western United States. Since the abundance is low in the Project area, any mortality or disturbance causing nesting failure would be compounded. Therefore, nesting areas should be avoided by implementing an appropriate buffer for roads and turbines. In addition, there should be no disturbing or clearing of habitat outside of the breeding season within these buffers.

**Monitoring**

**Recommendation: To assess potential impacts to burrowing owls, surveys of known burrowing owls nests should occur the first two years following construction of the Project, and every 3-5 years thereafter. New or suspected burrowing owl nests should also be surveyed.**

Surveys for burrowing owls are not proposed by the Applicant in the ASC. Instead, the Applicant proposed to monitor below ground nests as found incidentally during other survey efforts. Burrowing owls are a state sensitive species and burrowing owl nests have been found within the Project boundary. To assess potential impacts to this state sensitive species, surveys of known burrowing owls nests should occur in the first two years following construction of the Project, and every 3-5 years thereafter. New or suspected burrowing owl nests should also be surveyed. Without targeted surveys for nests for this state sensitive species, impacts to this population cannot be adequately identified and mitigation, if necessary, implemented.

ODFW believes that burrowing owl nest sites are a Category 1 habitat type (Mitigation Policy OAR 635.415-0000-0025) and the ASC proposes a 0.25 mile setback. Because burrowing owls are a state sensitive species, ODFW recommends a minimum 0.25 mile setback with no disturbance.

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## Big Game

**Recommendation: To mitigate for displacement impacts to big game on both summer and winter range, acquisition and enhancement of 25,500 acres of low elevation winter range and 10,130 acres of summer range in-proximity to the proposed ARWF should occur.**

Based on the proposed number and location of turbines within the project, ODFW expects to see a significant displacement of big game from primary use areas. Work previously conducted on the Elkhorn Valley Wind Project documented a statistically significant change in big game use patterns around turbine locations. During 2005 pre-construction surveys, the average distance to the proposed turbine sites was 344 m for mule deer and 1,326 m for elk. For post-construction data, the actual average distance to turbine was 3,073 m for deer and 3,497 m for elk.

In addition, mule deer counted within the Elkhorn Valley project area indicated an overall decrease in animal use. Preconstruction counts resulted in 1,560 deer counted in three flights (average of 520 per flight) in 2004-2005 decreasing to 1,170 counted in four flights in 2008-2009 (average of 293 per flight). These counts when coupled with the radio telemetry data indicate that deer likely moved out of the project area. Based on the information presented and analyses conducted, ODFW believes facility presence and human disturbance impacted big game distribution and habitat selection.

Compared to pre construction use, counts of mule deer during post construction surveys showed reduced use of habitats in the first seven distance bands evaluated, 0 to 500 m out to 3,000 to 3,500 m. This shift in distribution of mule deer is consistent with deer response to natural gas development in Wyoming (Sawyer et al. 2009), where mule deer avoided liquefied gathering systems and selected areas greater than 2.6 to 4.35 km from a well pad.

Much of the high-use area used by mule deer post-construction of the EVWP is included in the proposed ARWF. ARWF turbine strings will be placed directly on areas that were identified as big game high use areas and deer displaced to from the EVWP. These deer will die, disperse, or habituate to the activity. Based on work completed in Wyoming evaluating mule deer responses to natural gas field development in which deer avoided the area, population numbers declined (Sawyer et al. 2009, Sawyer and Nielson 2010) and they did not habituate to field development and operations over the 10 years of monitoring, deer will not habituate to the ARWF.

If further displacement occurs as a result of the construction of the Antelope Ridge project, OFDW expects animals to move onto private agricultural lands in the Grande Ronde Valley. Any significant shifts of deer and elk onto these lower elevation agricultural lands will result in increased damage problems associated with crop lands, hay stacks and pastures. The ODFW is required to manage big game populations in a manner that is compatible with other land management practices. In order to do so biological, social, and political factors are considered in establishing management objectives for big game in Oregon. Local work groups are convened to establish these management objectives that are then adopted into OAR by the Fish and Wildlife

Commission. One key factor used to establish management objectives has been deer or elk damage impacts to private lands. Big game impacts can have a significant financial impact to private landowners. With a consequence of animal displacement and increased wildlife damage to private agricultural lands, ODFW may have to adjust its management objectives downward. This is not desirable since it will decrease the number of big game available for both consumptive and non-consumptive users. A decrease in hunting opportunity will have an impact on local economies that depend on the expenditures made by hunters. It may also decrease revenue the state receives from the sale of big game hunting licenses and tags.

Any significant displacement of mule deer and elk from winter range may ultimately lead to population level effects. Some of these animals will be displaced onto summer range or poorer quality winter range where survival will be compromised.

Locating wind turbines on ridges where wind currents are strongest and most consistent; also creates an immediate area of potential disturbance, as in the winter these are the same areas that would have more bare ground and less snow pack because of the scouring effects of the persistent wind. Thus, one would predict that areas immediately adjacent to wind turbines prior to construction would have higher densities of deer and elk compared to areas where wind was not as strong resulting in deeper or more persistent snow pack. If there was no effect of either the turbines or human activities associated with the wind development, winter counts should be equivalent to predevelopment conditions. Because winter counts of mule deer on the Elkhorn Valley project decreased post construction, the presence of turbines and/or associated human activities likely influenced mule deer distribution.

There is a lack of published literature on the effects of wind-turbines on elk and mule deer. Best science for activities of similar size and extent are found, however, for mule deer responses to natural gas development (Sawyer et al. 2009, Nielson et al. 2009). Sawyer et al. (2009) found that mule deer avoided roads and natural gas facilities and effects extended out 4.6 km. Sawyer and Nielson (2010) updated results presented by Sawyer et al. (2009) and found mule deer continued to avoid additional areas of winter range as the field continued to be developed and that mule deer populations within the gas field declined faster and did not recover at the same rates as either a control area or within the entire mule deer population indicating that as the habitat was degraded, the population declined. Their protocol for monitoring was reviewed by a blue-ribbon committee of wildlife biologists (Bissonette et al. 2010) who concluded that population monitoring was an essential part of monitoring for industrial impacts to wildlife. How mule deer and elk are displaced by other types of disturbance provides a reasonable means of understanding how wildlife will respond to wind turbine development and associated activities (Wyoming Game and Fish Commission 2010).

Results from the Elkhorn Valley project big game study illustrate the dynamic nature of mule deer distribution and may be used to begin making predictions of how deer may respond to the development of the ARWF. Literature on energy development is also valuable for predicting big game response to development of the ARWF

Based on results of the Elkhorn Valley project big game study and literature cited above, construction of the ARWF will likely displace deer and elk from 1000 – 3000 meters from the tower strings. Displacement will effectively remove between 25,000 – 59,000 acres of big game habitat. Displacement out to 1,000 m amounts to a loss of habitat of 25,550 acres of winter range and 10,132 acres of summer range.

## Draft Big Game Winter Range and Critical Wildlife Habitat Management and Monitoring Plan

**Recommendation: The Draft Big Game Winter Range and Critical Wildlife Habitat Management and Monitoring Plan should be revised to incorporate ODFW's big game mitigation and monitoring requirements included in these comments.**

The proposed management and monitoring plan is insufficient to Comply with Oregon and ODFW statutes, rules, policies, and management plans.

The proposed management and monitoring plan indicates that "The potential impacts for the proposed Facility will be mitigated in favor of the resource through monitoring, **off-site habitat mitigation** (emphasis added), and management techniques, as discussed below" (Page 1). To be consistent with ODFW's Fish and Wildlife Habitat Mitigation Policy, monitoring must include a commitment to "taking appropriate corrective measures" [OAR 635-415-0005 (16)(d)]. Furthermore, mitigation for impacts to Category 2 and 3 habitats must be provided through reliable in-kind, in-proximity habitat mitigation, with a net benefit accrued to Category 2 habitat [OAR 635-425-0025 (2)(b)(B) and (3)(b)(B)].

The off-site mitigation as proposed may not be in compliance with ODFW's Fish and Wildlife Habitat Mitigation Policy. The proposal includes off-site mitigation at a minimum of a 2:1 ratio for impacts to Big Game Critical Wildlife Habitat and Big Game Winter Range (Page 6). The proposed mitigation includes acquisition of a 2,000 acre or 5,000 acre parcel in a nearby area. Without knowledge of these specific parcels, ODFW cannot evaluate whether they are adequate to offset any portion of the impacts from the proposed Project. Again, mitigation for Category 2 habitat, which includes big game winter range, must be provided in-kind and in-proximity. Additionally as previously mentioned, ODFW has identified a project footprint of over 35,000 acres that would need to be considered for mitigation.

### Preservation Techniques

**Recommendation: ODFW recommends the Minimization Techniques and Best Management Practices included in the Draft Monitoring and Mitigation Plan be included in the Final Plan and incorporated as conditions of the Site Certificate, with modification to Seasonal Restrictions.**

**Recommendation: To avoid disturbance to big game during winter months, the Applicant should not conduct routine scheduled preventative maintenance from December 1 to April 15 in designated Big Game Winter Range or Big Game Critical Wildlife Habitat.**

**Recommendation: To minimize impacts to wintering big game, the Applicant should construct as much of the facility as possible outside of the winter period.**

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The big game wintering period is generally early December through mid-April. During the winter period, animals are under a tremendous amount of stress. Any disturbance can compromise an animal's ability to survive a winter.

**Monitoring**

**Recommendation: Population monitoring of mule deer and elk should be conducted annually to adequately determine ARWF effects on local big game populations.**

The Applicant should be commended for agreeing to conduct a big game telemetry study to evaluate the habitat selection and distribution patterns of elk and mule deer before construction and during operations of the facility.

The telemetry study should contain two key elements, 1) distribution and 2) population trends, for mule deer and elk in the Project area. Placing GPS collars on elk and mule deer is a good first-step to evaluating the habitats elk and mule deer select as the Project is developed and placed into operation. Unfortunately the plan for monitoring elk and mule deer population size as currently proposed is inadequate.

The population monitoring plan should be designed to detect any distribution shifts by deer or elk onto adjacent agricultural lands. Additionally the population monitoring plan needs to be able to detect and determine the overall shift by animals off of the project site into other areas.

Because no estimate of abundance of either deer or elk will be made, evaluating effects of wind turbine development and determining if mitigation is sufficient will be more difficult. Therefore, ODFW recommends that estimating deer and elk abundance be added to the Big Game Winter Range and Critical Wildlife Habitat Management and Monitoring Plan.

**Big Game associated Policies**

The ASC assessment for big game does not meet a number of Oregon's statutes, Administrative Rules, Polices and Management Plans. Listed are the statutes, rules, policy and plan references where the ASC does not meet Oregon's standards.

**Oregon Revised Statutes**

The Wildlife Policy (ORS496.012) (1) and (5) direct ODFW to manage wildlife in a manner that prevents serious depletion of indigenous species: (1) maintain all species of wildlife at optimum levels and (5) regulate wildlife in a manner that is compatible with primary uses of lands and waters of the state. Proposed mitigation in the ASC will fail to maintain big game populations at the optimum because of the loss of critical winter range habitat. The direct effect on the big game population level because of displacement is not discussed in the ASC. ODFW believes big game will be forced off established summer and winter ranges toward private property resulting in a negative population effect. The management tool available to ODFW is to reduce the population because of damage on agriculture crops.

ODFW manages wildlife in a manner that is compatible with the primary uses of the land. In the case of placing a wind farm in established big game habitat, the primary use of the land changes.

A large industrial site in productive wildlife habitat is a significant alteration of the current primary use. The Applicant fails to address how big game use will be mitigated.

In addition to the anticipated big game population effect, the Applicant fails to address Oregon's Damage Statues (ORS 498.012) or the ODFW's Damage Policy. The Damage Policy is the on the ground guidance for implementing the Damage Statutes. Since Oregon does not pay for direct damage to agricultural crops, ODFW uses a number of tools in the Policy for responding to big game damage. The displacement of big game from Project operations will result in more agriculture damage. Within the ASC, the Applicant does not recognize that big game damage will rise as the result of project operations.

**Management Plans**

The Oregon Fish and Wildlife Commission adopted by Administrative Rule the Mule Deer Plan (OAR 635-160-0000-0030) and Elk Plan (OAR 635-190-0000-0031). Both plans identify the economic importance of deer and elk to Oregon's economy. In a recent survey (Dean Runyon Associates, 2008) of Oregon's Hunting Public, an estimated $9.95 million dollars per year of travel generated expenditures were associated with overnight hunting trips to Baker and Union Counties.

The Deer and Elk Management Plans describe the importance of managing big game populations to provide optimum recreational benefit for the public within the habitat compatibility and primary land uses. In addition, the plans go on to raise the importance of maintaining high quality winter range. During the winter period, animals are under a tremendous amount of stress and any change can compromise the ability to survive a winter. The loss or degradation of winter range or displacement of animals due to disturbance may lead to declines in big game populations and increased conflicts on private property.

**Oregon Administrative Rules**

The EFSC Siting Standards (OAR 345-022-0060) require that a proposed facility comply with the habitat mitigation goals and standards of ODFW. ODFW staff analyzed the EVWP Big Game Study data and determined that big game displacement from construction and operation of the Project was at a minimum 1,000 meters from the tower string. The Applicant, however, only proposed to mitigate for the actual footprint of the Project. ODFW considers Big game winter range Category 2 habitat because it is essential and limited (Mitigation Policy 635-415-0000-0025). Mitigation for impacts to Category 2 habitat must be provided in kind and in-proximity, and also provide a net benefit of either habitat quantity or quality. The proposal to mitigate for the project footprint is insufficient to meet the requirements of either the Siting Standard or the Mitigation Policy. A minimum of 25,000 acres of winter range and 10,000 acres of summer range is projected to be affected by the Project.

**Antelope Ridge Wind Farm Habitat Mitigation Plan (September 2010)**

**Recommendation: A Revised Habitat Mitigation Plan Incorporating ODFW Habitat Categories and Mitigation Requirements Drafted in Consultation With, and for Approval by, ODFW Prior to Issuance of a Site Certificate**

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Per OAR 635-415-0000, "Mitigation Plan" means a written plan or statement that thoroughly describes the manner in which the impact of a development action will be reduced or eliminated over time, avoided, and/or minimized; and the affected environment, including fish and wildlife habitat, monitored, restored, rehabilitated, repaired and/or replaced or otherwise compensated for in accordance with OAR 635-415-0010 of these rules. A written mitigation plan shall include the information required in OAR 635-415-0020 (a)-(d); and (b) Describe the mitigation actions which shall be taken to achieve the fish and wildlife habitat mitigation goals and standards of OAR 635-415-0025; and (c) Describe and map the location of the development action and mitigation actions including the latitude and longitude, township, range, section, quarter section and county; (d) Complement and not diminish mitigation provided for previous development actions; and (e) Include protocols and methods, and a reporting schedule for monitoring the effectiveness of mitigation measures. Monitoring efforts shall continue for a duration and at a frequency needed to ensure that the goals and standards in OAR 635-415-0025 are met, unless the Department determines that no significant benefit would result from such monitoring; and (f) Provide for future modification of mitigation measures that may be required to meet the goals and standards of OAR 635-415-0025; and (g) Be effective throughout the project life or the duration of project impacts whichever is greater; (h) Contain mitigation plan performance measures including: (A) Success Criteria. The mitigation plan must clearly define the methods to meet mitigation goals and standards and list the criteria for measuring success; (B) Criteria and a timeline for formal determination that the mitigation goals and standards have been met; (C) Provisions for long-term protection and management of the site if appropriate; and (D) A reporting schedule for identifying progress toward achieving the mitigation goals and standards and any modification of mitigation measures. Mitigation goals and standards must be achieved within a reasonable timeframe to benefit the affected fish and wildlife species.

As drafted, Habitat Mitigation Plan does not meet the standards of ODFW's Fish and Wildlife Habitat Mitigation Policy nor does it provide sufficient mitigation for the proposed Project. Because this plan only proposes mitigation for the Project "footprint", the majority of the Project impacts are not identified or addressed.

Additionally there appears to be confusion over the amount of acres impacted in Category 2 and 3 habitats. Table 1 should be updated to reflect winter range and sage-grouse wintering and brood-rearing habitat as Category 2 habitat.

The Habitat Mitigation Plan only addresses impacts from the footprint of the facility. An accurate estimate of footprint acreage, however, should also include the transmission line right of way (ROW). As such, permanent acres lost in Table 1 should increase by 218 acres to 523 acres (12 mile transmission line with a 150' right of way).

As mitigation for impacts from the Project footprint, minus transmission line ROW clearing, the Habitat Mitigation Plan includes proposals to either acquire or donate a mitigation area to ODFW for protection and enhancement or protection and enhancement of a mitigation area through a conservation easement or similar conveyance. The Applicant indicates it will select a mitigation area in proximity to the facility and that it has identified suitable options including a 2,000 acre parcel in a relatively remote setting on High Valley, a 2,000 acre parcel bordering the

Elkhorn Wildlife Management Area, and a 5,000 acre parcel that could be purchased in partnership with the Rocky Mountain Elk Foundation. The Applicant does not provide any information on these parcels particularly how they provide in-kind mitigation, therefore their sufficiency for meeting ODFW's Fish and Wildlife Habitat Mitigation policy cannot be determined at this time.

ODFW is concerned that the proposed habitat mitigation ratios may not be sufficient. Further analysis of the overall footprint of the project and the various habitat categories will be required. Only then can the appropriate ratios be developed that would adequately address the "no net loss" and "net benefit" standards within the Habitat Mitigation Policy.

The Applicant provides a list of enhancement actions to be implemented. No information, however, is provided to verify enhancements will provide in-kind mitigation. For example, 10% of the Project will be sited in forested habitat, but no information is provided that indicates that mitigation will include forested habitat.

To ensure mitigation meets ODFW's mitigation standards, ODFW recommends that all mitigation areas be identified, in consultation with, and approved by ODFW. In addition, a management plan should be developed for each mitigation area.

If land acquisition is selected as a mitigation action, any parcels will have to be carefully analyzed to ensure that the lands are capable of meeting the "no net loss" and/or "net benefit" standards of the Habitat Mitigation Policy. Simple acquisition of lands may not yield a net benefit and in some cases may also require investments in operations and management of those lands.

Changes in grazing practices may be used to benefit big game, but will need to be evaluated closely on a case by case basis.

The monitoring strategy does not specify monitoring procedures for mitigation areas. Instead, monitoring is proposed annually for the first five years, with any continued monitoring occurring as necessary. This language is too ambiguous to ensure sufficient mitigation and monitoring of mitigation areas occurs.

The Applicant's success criteria do not address the location of the habitat mitigation, whether it will be in proximity or whether the mitigation will be provided in-kind, both are requirements for compliance with ODFW's Fish and Wildlife Mitigation Policy.

***Sage-grouse Habitat***

ODFW's *Recommendations for Greater Sage-Grouse Habitat Classification Under Oregon Department of Fish and Wildlife's Fish and Wildlife Habitat Mitigation Policy* (August 7, 2009, ODFW Sage-Grouse White Paper) provides policy direction, consistent recommendations, and supporting rationale to guide ODFW's habitat mitigation recommendations associated with impacts to greater sage-grouse habitat from energy development, its associated infrastructure, or other industrial or commercial development. The objective of these recommendations is to protect essential habitats to meet habitat and population objectives in the cooperatively developed *Greater Sage-Grouse Conservation Assessment and Strategy for Oregon.*

Within its ASC, the Applicant has categorized sagebrush/shrub-steppe habitat that is in a grazed condition and shorter, less mature and less dense big sagebrush species as Category 3 habitat. The ASC notes that "The Category 3 sagebrush habitat type was considered important habitat for sagebrush obligate species, including the greater sage-grouse which may use these areas infrequently throughout the year, particularly in winter for foraging".

Sage-grouse are sagebrush "obligates", meaning they are dependent on sagebrush for reproductive success and year-round survival. Major causes of sage-grouse population decline include the conversion or loss of sagebrush habitat, which includes winter, breeding, and nesting habitat, and development. The availability of sagebrush above the snow pack is critical to winter survival of sage-grouse. Winter habitat can vary from low sagebrush exposed on wind swept ridges to tall dense stands of basin big sagebrush in valley bottoms.

Winter foraging and brood rearing habitat for sage-grouse is essential and limited as outlined in ODFW's Sage-Grouse White Paper. Sage-grouse feed exclusively on sagebrush during winter, and temporally its availability is limited. Therefore, ODFW considers sagebrush habitat used for winter foraging Category 2 habitat, with "no net loss" of either habitat quantity or quality and a net benefit of habitat quantity or quality provided through mitigation paramount if protection is not possible. All sagebrush identified as sage-grouse winter habitat and brood rearing habitat is Category 2 habitat not Category 3 habitat as identified within the ASC.

**Recommendation: The Applicant should consult with ODFW to identify suitable acquisition options. Acquisition of all mitigation lands is to be completed within the first three years of license issuance.**

The plan does not include a timeframe for meeting mitigation goals. ODFW recommends that no later than three years post certification, the Applicant acquire all mitigation lands with management plans for each parcel completed no later than year 3 post certification.

**Recommendation: For each mitigation parcel acquired, the Certificate Holder should develop, in consultation with and for approval by ODFW, a land enhancement and mitigation plan.**

A critical component of the land enhancement and mitigation plan will be documenting current and future habitat conditions. The Applicant needs to describe how baseline conditions and habitat enhancements will be measured and how it will be determined that mitigation has been achieved. ODFW recommends use of Habitat Evaluation Procedures (HEP) or other methodology approved by ODFW. The FWS developed HEP for use in impact assessment and project planning. HEP is used to mitigate impacts to terrestrial resources caused by development and operation of the Columbia River hydropower system.

Develop mitigation plan for property that is approved by ODOE and funding necessary to achieve the mitigation requirements. Funding level should be sufficient for the Applicant to meet its mitigation requirements for fish and wildlife species and their habitat. Therefore, there should be no funding cap and contingencies included in the plan in case enhancement projects do not provide sufficient mitigation for project impacts. It is the sole responsibility of the Applicant to meet its mitigation requirements.

**Recommendation: The Certificate Holder should fund implementation of the land enhancement and mitigation plan.**

**Recommendation: The Certificate Holder should fund maintenance and enhancement of acquired mitigation parcels beginning in year one through the length of license.**

ODFW shall recommend mitigation consistent with the goals and standards of OAR 635-415-0025, and based on the following considerations:

a) The location, physical and operational characteristics, and duration of the proposed development action; and
b) The alternatives to the proposed development action; and
c) The fish and wildlife species and habitats which will be affected by the proposed development action; and
d) The nature, extent, and duration of impacts expected to result from the proposed development action.

**Recommendation: An accurate estimate of acreage by Habitat Category should be provided by the Applicant.**

ODFW's Habitat Mitigation Policy is based on the premise that habitats can have varying levels of "relative importance" or influence on the survival of fish and wildlife species. This variability depends on the ecological condition and physical setting of habitat at a specific site, and the needs and sensitivity of fish and wildlife species using the habitat. The physical and biological components of ecosystems produce the diversity, abundance, and productivity of plant and animal species. The combination of suitable habitats and necessary ecological functions forms the ecosystem structure and conditions needed to provide the desired abundance and productivity of specific species. Loss of species and their functions lessens the ability of the ecosystem to withstand disturbance and change.

Therefore, the Habitat Mitigation Policy describes six levels of habitat categories ranging from irreplaceable, essential habitat to low potential to become essential or important habitat. "Essential habitat" refers to habitats that contain the physical and biological conditions necessary to support the most critical life history functions of the fish and wildlife species being considered. These habitats are those that species are dependent upon for long-term population maintenance. Generally, essential habitats will be those that provide critical support to the population or species for reproduction, rearing, forage and dispersal necessary for the completion of one or more life history functions. "Limited habitat" refers to the lack of an adequate amount of habitat necessary to sustain, over time, the fish and wildlife species or populations being considered. This concept requires that the relative availability of suitable habitats to support important life history functions be considered at variable scales that may go beyond the project site. In the case of relatively mobile species, the presence and abundance of suitable habitats may need to be assessed at the watershed or regional scale.

As mentioned previously, ODFW does not agree with some of the habitat categorizations. The ODFW is willing to provide the habitat categorizations consistent with Fish and Wildlife Commission adopted plans and OARs for use in evaluation of the application and the mitigation requirements.

***Big Game Winter Range***

Every county in the state east of the Cascades has identified big game winter range in its Comprehensive Plan as a significant Goal 5 resource. There is a long history of ODFW comments to these counties, including Union County, that Goal 5 big game Critical Wildlife Habitat and Winter Range resources are Category 2 habitat. Only eight areas within Union County are classified as Big Game Critical Wildlife Habitat. Portions of three of these areas (North Craig Mountain, East Craig Mountain, and Catherine Creek/High Valley) fall within the ZMBV. These areas are extremely critical to the continued welfare of the wildlife that are dependent on them, and were identified by ODFW in 1978.

ODFW worked very closely with each county in the state to legally designate big game habitat in each county based on site-specific conditions. Therefore, ODFW bases its big game winter range habitat recommendations on that legal designation within each county.

Mule deer experts throughout the western United States and Canada have delineated mule deer habitat at the state level. Winter range was identified as that part of the overall range where 90% of the individuals are located during the average five winters out of ten from the first heavy snowfall to spring green-up, or during a site-specific period of winter. A severe winter range definition includes areas within the winter range where 90% of the individuals are located when annual snow pack is at its maximum and/or temperatures are at a minimum in the two worst winters out of ten.

Winter concentration area were identified as that part of the winter range where densities are at least 200% greater than the surrounding winter range density during the same period used to define winter range in the average five winters out of ten. Based on the expertise of wildlife biologists throughout the western United States and Canada, as proposed, the ARWF will be located in a winter concentration area, impacting one of the most important deer winter ranges in the entire area. Winter range delineations generated out of the county planning process overlay very closely with what mule deer experts identified as winter range.

Big game winter range is usually in the lower elevation areas where deer and elk spend the winter months as a result of heavy snow in the higher elevations. Critical big game winter range is those areas where large concentrations of big game are known to occur during winters with normal to above normal amounts of snow, or normal amounts of snow during periods of extremely low temperatures. A large portion of the annual mortality of mule deer populations in the Intermountain West occurs while deer are concentrated on winter range.

Most of the proposed project is on either big game winter range or big game critical wildlife habitat, and extremely critical to the continued welfare of the deer and elk dependent upon it. ODFW is recommending against development only on the most important areas within the ZMBV. There are portions of Big Game Critical Wildlife Habitat in the project with proposed turbines to which ODFW has not objected.

Because winter habitat is a critical component of the mule deer and elk's annual habitat requirements, ODFW considers winter range habitat as essential and limited for deer and elk, and has consistently classified winter range as Category 2 habitat. Winter range has been used as an example of Category 2 habitat for over 10 years. At every wind project in Oregon, ODFW has considered winter range Category 2 habitat. Therefore, at the proposed ARWF, ODFW considers big game winter range Category 2 habitat. Because winter range is classified as Category 2 habitat, ODFW recommends that mitigation for unavoidable impacts to this habitat from project construction and operation result in no net loss of either habitat quantity or quality and a net benefit of habitat quantity or quality.

The Applicant should also recalculate acres of impact based on correct habitat categorizations to accurately reflect impacts from temporary and permanent facilities.

### Wildlife Monitoring and Mitigation Plan

ODFW supports the Applicant's conducting wildlife monitoring at the ARWF. However, the monitoring included in the Wildlife Monitoring and Mitigation Plan may be insufficient to accurately determine wildlife fatality attributable to the Project, and population level effects of the Project on birds, bats, or big game.

**Recommendation: The Applicant should develop detailed protocols for all monitoring and studies in consultation with, and for approval by, ODFW. These protocols should be approved prior to Project construction.**

ODFW supports the Applicant's recommendation that detailed protocols will be developed prior to implementation of the Wildlife Monitoring and Mitigation Plan. ODFW should approve these protocols prior to their being implementing. To ensure mitigation is not delayed by protocol development, all protocols should be developed and approved prior to construction.

**Recommendation: A detailed study plan and survey protocol should be developed in coordination with, and for approval by, ODFW prior to operation of the Project.**

To ensure information collected can be used to identify potential Project effects on nesting raptors, a detailed study plan and survey protocol should be developed in coordination with, and for approval by, ODFW prior to operation of the Project.

**Recommendation: All monitoring data should be provided to ODFW annually.**

The Applicant indicates that monitoring data and analysis will be provided to ODOE. All monitoring data should be provided to ODFW annually. Monitoring information is needed annually to determine additional monitoring needs, project impacts, and to evaluate adequacy of mitigation measures for meeting state and ODFW statutes, rules, policies, and management plans.

## Fish & Aquatic Species

**Recommendation: The Applicant should continue to work with ODFW to identify all stream crossings requiring in-stream work.**

Based on Tim Bailey's (ODFW District Fish Biologist) site visit in April of 2010, fish passage is being appropriately addressed by the Applicant. ODFW requests that the Applicant continue to work with ODFW to identify all stream crossings requiring in-stream work.

**Recommendation: The Applicant should mitigate impacts to riparian habitat by enhancing 4.5 acres of low elevation riparian habitat in-proximity to the ARWF.**

The Proposed project will impact a total of 1.51 acres (65,570 sq ft) of riparian zone for all streams in the site boundary, of which .44 acres is impacts within the riparian zone of Class 1 streams – in response to Union County Zoning, Partition, and Subdivision Ordinance (UCZPSO). The Applicant, however, does not propose mitigation due to its determination that it is poor quality habitat. ODFW considers riparian habitat Category 2 Habitat according to ODFW's Fish and Wildlife Habitat Mitigation Policy (essential and limited for the fish species that reside in those streams). Therefore, ODFW recommends that the Applicant provide mitigation for riparian habitat lost and provide a net benefit in habitat quantity or quality, including in-kind and in-proximity.

Low elevation riparian areas are especially prone to disturbance from human activities associated with recreation, roads, and O&M activities. Riparian zones are significant in ecology and environmental management because of their role in soil conservation, their habitat biodiversity, and the influence they have on fauna and aquatic ecosystems. In the western United States, riparian plant communities account for less than 1% of the total western landscape. Riparian habitat is often structurally complex and, as a consequence, supports a wider variety of bird species than surrounding uplands (Knopf 1988). Also, riparian vegetation attracts a greater number and variety of bird species during migration than during breeding season. Woody riparian vegetation provides cover and food during winter for a variety of small birds and may be critical to local populations during the stressful months (Lewke and Buss 1977).

Either of the Applicants proposed methods to mitigate wetland impacts would be acceptable. ODFW's preference is to implement the mitigation as part of the Grande Ronde Model Watershed Project (GRMW) on Catherine Creek. This project was implemented in the fall of 2010.



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**Recommendation: Mitigation for riparian habitat should be combined with that of wetland habitat.**

ODFW recommends that mitigation for riparian habitat be combined with that of wetland habitat, preferably as part of the Grande Ronde Model Watershed mitigation option.

**Note:** Inaccurate information regarding fish use within the project boundary is provided in the ASC. On pages P-35 and P-65 a statement is made that, "ODFW does not currently have any data on the seasonal presence/absence of redband trout or other native migratory species within the Site Boundary". Assistant District Fish Biologist Nadine Craft conducted a fish salvage project resulting from a fuel spill on Ladd Canyon (Brush Creek) in August of 2010 in the vicinity of Exit 273. She collected approx. 25 *Oncorhynchus mykiss*, 50-60 mm long from Ladd Canyon (Brush Creek). Therefore, redband trout are present and spawning occurs as these juveniles would not have been able to pass upstream through downstream passage barriers on Brush Creek. On page P-36 the document states that suitable spawning habitat is not present within the site boundary. This is incorrect per Nadine's finding.

**Recommendation: Monitoring of stream and wetland mitigation sites should occur for the first five years post enhancement, with periodic monitoring and inspections of mitigation sites for the life of the wind project every three to five years.**

The Applicant indicates that monitoring of any stream and wetland mitigation will be conducted for a period of up to 5 years following completion of mitigation activities to meet the monitoring requirements of ODFW, ODSL, and other applicable agencies (Page P-78). ODFW believes 5 years of monitoring may be insufficient. Recovery of plant species can take several years. To verify in-kind mitigation has been achieved, mitigation will be necessary for the life of the Project. Therefore, ODFW recommends periodic monitoring and inspections of mitigation sites for the life of the wind project to ensure mitigation is achieved.

## Wetlands

**Recommendation: The Applicant should consult with ODFW and the Grande Ronde Model Watershed to identify, implement, and fund 1 acre of wetland restoration project(s) in the Grande Ronde Basin to mitigate for impacts of the ARWF on wetland and stream habitat.**

The Project will impact 0.28 acres of potentially jurisdictional wetlands and waters due to the need to cross them with access roads and culverts. These crossings will require a total of 384 cubic yards of fill in wetlands and 1,135 cubic yards of fill in streams (Page J-6). The Applicant proposes wetland restoration, creation, and enhancement or wetland conservation to offset functional losses associated with proposed impacts to 0.28 acres of wetlands and waters.

The Applicant's preferred method of mitigation is to contribute funding to the GRMW for a stream and wetland restoration project to be located in the same watershed as the Antelope Ridge project impact sites, as an in-proximity mitigation that would have great ecological benefits by providing mitigation in the context of a larger mitigation project site than is required to mitigate for the Antelope Ridge project.

The Applicant indicates it met with the GRMW to discuss the proposed project partnership on April 14, 2010 and November 11, 2010 and received a positive reception during both meetings. Also, that in the Applicant's meeting with DSL and GRMW held November 16, 2010, the DSL gave a positive reception to the prospective partnership between GRMW and Applicant.

As a secondary option, the Applicant proposes meeting its compensatory wetland mitigation (CWM) obligations through the payment-in-lieu program. In the conversations referenced previously on September 13, 2010 and November 16, 2010, DSL indicated that payment-in-lieu would be an appropriate option for CWM for the Facility due to the small amount of impacts.

ODFW considers wetlands Category 2 habitat because they are essential for fish and wildlife species and limited in the Project area (Mitigation Policy OAR 635.415-0000-0025). Mitigation of impacts, if unavoidable, should occur through reliable in-kind, in-proximity habitat mitigation to achieve no net loss of either pre-development habitat quantity or quality. Contributing funding to at least one acre of wetland restoration project(s) in the Grande Ronde Basin mitigates for impacts of the ARWF on wetland and stream habitat

## Weed Control Plan

**Recommendation: A Weed Control Plan developed in consultation with ODFW and Union County and approved by ODOE prior to commencement of construction.**

A Weed Control Plan should be developed and implemented to prevent, suppress, contain, and eradicate nonnative invasive plants and noxious weeds in the Project area. The Plan should include inventory, prevention and early detection, treatment and restoration, and monitoring and evaluation.

Noxious weeds have the potential to displace native or desired vegetation and plant communities. Project area operations and maintenance, trails, roadways and traffic are considered primary contributors to the spread of noxious weeds. Ground disturbance associated with the Project will provide favorable habitat for the establishment and spread of noxious weeds. Movement of Applicant or contractor vehicles and machinery around the Project area greatly increases the potential for introduction of new weeds. Transmission lines also provide ready pathways for translocation of weed seed to other areas.

## Revegetation Plan

**Recommendation: Implementation of the Revegetation Plan in consultation with ODFW.**

This plan describes the onsite activities that the certificate holder will undertake during construction and immediately after construction of the ARWF to address temporarily disturbed areas. This Revegetation Plan focuses solely on the revegetation efforts of the temporarily disturbed locations.

An inventory/survey of current native vegetation would help determine which native species are likely to survive and are best used for revegetation. This inventory should assess all or a majority of the plant species present. If the site is primarily composed of noxious weeds, the pre-construction inventory should note that and rehabilitation efforts must be designed to address those issues.

**Recommendation: ODFW recommends using native seed, with introduced species only used in small quantities as necessary.**

The appropriate seed mix to use in restoration of each habitat type should contain native species. ODFW believes native seed will be available, though use of some introduced species can be beneficial if used in small percentages.

**Recommendation: All bare soil and disturbed areas should be restored and reseeded to prevent the introduction and spread of invasive species and noxious weeds.**

The Applicant indicates that after construction activities are completed, disturbed areas will be evaluated to determine whether restoration seeding is needed. ODFW believes any disturbance in this area will encourage the establishment and spread of invasive species. Therefore, the applicant should reseed all disturbed areas.

The Applicant also indicates that seeding will not be done in areas where the pre-construction condition was bare soil. Construction activities will involve moving from site to site with the potential to spread weed seed. Therefore, ODFW recommends that the applicant reseed all bare soil areas.

ODFW believes the applicant should emphasize fall or early winter seeding, depending on moisture availability.

**Recommendation: Restored and reseeded sites should be inspected annually with fixed photo points with follow up treatments as needed.**

The Applicant indicates that following seeding, sites will be examined after the first growing season, then at year three and year five to determine the success of the restoration. ODFW believes annual inspections with fixed photo points are needed and would be more beneficial. Following inspections, follow up treatments should be conducted on an as needed basis.

**Recommendation: Revegetation and monitoring reports should be provided annually to ODFW.**

The Applicant indicates that revegetation records will be available to ODOE at the time the annual report is submitted, as required under the certificate. The Applicant should provide ODFW annual revegetation records including dates the construction activity was completed in the area to be restored, a description of the affected area (location, acres affected and pre-disturbances condition), the date the revegetation work began, and a description of the work done within the affected area.

### Management of Hazardous Substances

**Recommendation: A Spill Prevention and Control Plan should be developed in consultation with ODFW and approved by ODOE prior to commencement of construction.**

The Applicant indicates that it anticipates a Spill Prevention Control Plan will be submitted and approved by EFSC prior to commencement of construction. Spills and mismanagement of hazardous substances can have catastrophic impacts on aquatic and terrestrial habitats and species utilizing those habitats. Therefore, ODFW believes it is important for the Certificate Holder to consult with ODFW and also ODEQ on development of a Spill Prevention Control Plan and have that plan approved by EFSC before any construction begins on the Project.

### Decommissioning

**Recommendation: Financial security for decommissioning of facilities should be provided to ensure they will be removed when the facility reaches the end of its useful operational period of time.**

**Recommendation: The certificate holder should consult with ODFW to determine appropriate site restoration actions upon Project retirement.**

In response to OAR 345-021-0010(1)(w) the Applicant includes Exhibit W, Facility Retirement and Site Restoration in its Final ASC. Exhibit W includes specific actions and tasks the certificate holder will undertake to restore the site to a useful, non-hazardous condition. At Project retirement, ODFW should be consulted to ensure site restoration is accomplished and meets ODFW standards.



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#90

Upper Dry Creek Ranch

Robert and Cheryl Cosner
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(541)938-6262

5 May 2011

Umatilla County
Board of Commissioners
216 SE 4th Street
Pendleton, OR 97801

Dear Board of County Commissioners,

This letter is to provide my written comment opposing the setback standards proposed in Amendment USDC 152.616 (HHH.)

- To adopt this proposal would summarily end wind development in Umatilla County and its potential economic benefits to the county, school districts, fire districts and other taxing districts.

- The proposed residential setbacks are extreme and arbitrary. Federal and State standards have been developed with input from all stakeholders and are adequate for Umatilla County.

- These proposed amendments place undue restrictions on land use by landowners. Continued erosion of landowner's property rights significantly reduces entrepreneurial activity and decreases landowner revenue and tax base.

- To adopt this amendment would interfere with already existing leases between landowners and wind developers. These partnerships were created based on an environment that allowed wind development within the county.

As a landowner, I ask that you oppose the adoption of Amendment USDC 152.616 (HHH) and support property rights in Umatilla County.

Regards,

*Cheryl Williams-Cosner*

Cheryl Williams-Cosner
Landowner

**UMATILLA COUNTY BOARD OF COMMISSIONERS**
**Work Session of Tuesday, May 3, 2011**
**9:00 a.m., Umatilla County Justice Center, Media Room**
**Pendleton, Oregon**

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| **COMMISSIONERS PRESENT:** | Dennis Doherty, Larry Givens, Bill Hansell (Chairman). |
| **ABSENT:** | None. |
| **COUNTY COUNSEL:** | Doug Olsen. |
| **STAFF:** | Tamra Mabbott, Carol Johnson, Gina Miller. |
| **GUESTS:** | Clinton Reeder, Ed Chesnut, Jeff Newtson. |

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**NOTE: THE FOLLOWING IS A SUMMARY OF THE WORK SESSION. A RECORDING OF THE MEETING IS AVAILABLE AT THE PLANNING DEPARTMENT OFFICE.**

## CALL TO ORDER:

Commissioner Hansell called the work session to order at 9:05 a.m.

## WORK SESSION:

County Counsel Doug Olsen explained the legal standing of this work session. He stated that the Board was present for a work session, not a public hearing. There would be no public testimony taken today, but the Board could request information as needed.

Commissioner Hansell advised that the hearing would be continued on Tuesday, May 12, 2011 at 9 a.m. in the Media Room of the Umatilla County Justice Center. The record is still open to submit materials for that hearing.

Commissioner Hansell welcomed the panel guests, staff and County Counsel and thanked them for their participation at this work session. The panel guests are Clinton Reeder, representing the Umatilla County Planning Commission, Ed Chesnut, representing the Milton-Freewater City Council, and Jeff Newtson, a local farmer.

Commissioner Hansell commented that there would be two presentations this morning, followed by discussion among the Board of Commissioners and panel, but no decisions would be entertained today.

Commissioner Hansell introduced the 'Yellow Paper', a document drafted following meetings with Mr. Reeder and the planning staff. He covered the changes that they made to the draft document from the February 24, 2011 version recommended by the Planning Commission. These changes appear in orange on the 'Yellow Paper' document.

Page 1:10; There were no suggestions or changes on this page.

Page 2:10 (1)(A); There is a suggested change to clarify the procedure and add language to clarify that the process applies to county permitted projects only, not those permitted by EFSC (Energy Facility Siting Council).

Page 2:10 (4); Language added to clarify that only state agencies with appropriate and requisite jurisdiction would be involved in the permitting process. Each agency does not need to be separately identified.

Page 3:10 (D)(2); Changes made to clarify that the developer would identify mitigation for both possible impacts to farm and forest lands as well as neighboring rural homes. This replaces language that only identified impacts to rural residences.

Page 3 (F); Language was added to the revegetation and erosion control plan that would be developed in consultation with the Umatilla Public Works Department, Umatilla County Soil and Water Conservation District, and the appropriate watershed council. This eliminates additional agency consultation and adds language that the developer may need to reimburse the agencies for their involvement in the development of the plan.

Page 3:10 (6); Language added back that allows the wind farm owner to request waiving the requirement of a monitoring committee. The request can be made, but that does not guarantee that it will be granted by the county.

Page 4:10 (~~H~~)(I); Language was clarified pertaining to noxious weeds. The county has an existing noxious weed list, and they do not need to be individually listed in this chapter.

Page 4:10 (J); Remove Bracket J language, as the SIP agreement now replaces the need for this code.

Page 4:10 (K)(5); New language clarifying the open space, scenic, historic and archeological resources. The applicant will be required to provide information on those resources that are identified in the Comprehensive Plan. This also creates a new category (Bracket 6) that specifically lists resources that are significant to the CTUIR (Confederated Tribes of the Umatilla Indian Reservation). The new bracket also encourages the applicant to work directly with CTUIR on developing an inventory of these resources.

Page 4:10 (K)(~~L~~); Change in language pertaining to restoration of project components. The word restoration replaces rehabilitation in this code.

Page 5:10 (K)(1); Major changes in language to setbacks from the Urban Growth Boundary. A setback can be required if requested by a city. This would make the request from the city a recommendation for consideration by the county, but not mandatory. This eliminates the "one size fits all" problem for the cities.

Page 5:10 (K)(2); Homes in the UC (Unincorporated Community) zone are rural homes, and in developing setback consistency for homes in other rural areas, they will have the same setback as rural homes outside the project boundary.

Page 5:10 (K)(3); Setbacks for rural homes within the project boundary will be changed to ½ mile and the rural residence on a neighboring property not leased for towers will be one mile.

Page 5:10 (K)(4); This change combines (4) and (5) so setbacks from county roads, state or interstate highways will be the same standard as applied by EFSC. This standard of a setback of 110% of the overall blade tower-to-tip height provides safety and operational protection.

Page 5:10 (K)(~~6~~5); Change to a setback of 110% of the overall blade tower-to-tip for known archeological and cultural sites, unless a lesser setback is recommended by CTUIR. Setbacks from other archeological sites such as the Oregon Trail are included in this change.

Page 5:10 (C); This language specifies CTUIR as the Native American Tribe.

Page 6:10 (J)(2); Remove the words 'independent' and 'civil engineer', as they are vague and confusing. Certification by a civil engineer should not require another "independent" civil engineer review.

Page 8:10 (~~D~~C)(4); Re-worded to clarify how private access roads will be restored after the project is retired.

Commissioner Hansell concluded his presentation and introduced Clinton Reeder to make his presentation.

Mr. Reeder stated that the heart of the conflict is the contest between those who want the most towers possible and those who don't want any at all. The challenge is to find a way to recognize the interests of both groups. He will focus on the setback issue, but will also explore the growing health affects issue. Mr. Reeder commented that he is not ignoring the economics of the issue, nor the community benefits provided by wind. His charge has been to understand the process from a human side and consider the impact to community relationships. As a member of the Planning Commission, he strives to represent the interests of all the citizens of the county, both for and against wind projects.

Mr. Reeder discussed his letter to the Board of Commissioners, dated May 3, 2011. He had been asked by the Planning Commission to clarify that the recommended 2-mile setback was not designed to limit or stop wind development. It was meant to empower the adjoining landowner who did not want towers near their property. The property owner could either negotiate a noise easement with the developer or choose not to waive this right at all. The Planning Commission also wants the public to be well informed, so Mr. Reeder asked that all the materials he has provided, including the two tool kits, be added to the record. The Planning Commission also seeks to address the issue of health effects to people living near wind projects, and to protect the rights of property owners who don't want wind development near their property.

Mr. Reeder stated that the Planning Commission also wanted to address the adequacy of the EFSC siting standards, with a quarter mile setback. All wind developers want a quarter mile setback, while other individuals want a larger setback. There is a significant difference between what the developers want and what the property owners living near the projects want. He discussed whether or not the noise standards can be trusted as a setback standard, and referenced an e-mail from Iberdrola Renewables. Mr. Reeder stated that the newer issue of adverse health effects must also be considered and researched thoroughly, and addressed in the county siting standards. He explained the decibel measurement system and how it works. It is a logarithmic scale on a base of 10.

Mr. Reeder discussed the setbacks from roads and buildings. He commented that the ice throw distance from a wind tower has been measured as far as 1,600 feet. A ten pound block of ice coming off the blade tip traveling more than 100 M.P.H. would have greater momentum and potential for damage than the standard of 1.5 times the height of the tower would allow for. The risk increases with the height of the tower for debris fields. He recommended a setback of 2-3 times the blade height for a safety boundary to address ice throw and possible debris from a damaged blade.

Mr. Reeder referenced a book written about adverse medical effects caused by wind energy projects, written by Dr. Nina Pierpont. He described the author, and the content of the book and how it related to the topic at hand. The book is about symptoms experienced by people that lived near wind towers that did not seem to have a definable cause. There has been a significant increase in the amount of attention and information available since 2005 about the adverse health effects of wind towers on people. There was an international symposium in 2010 held in Ontario, Canada on relating wind power to adverse human health effects. In February 2011, Australia hosted a national inquiry relative to wind power and health issues. Awareness is growing both locally and internationally about this issue, and it is not going away. He feels that this is something that should not be ignored by the county during this process.

Noise standards are being addressed differently now than they were 10 years ago. Mr. Reeder compared the 'wind turbine syndrome' to the 'sick building syndrome' and the similar symptoms associated to them. The low frequency noise that is produced by fans (A/C, airplane engines, and fan-based equipment) has been identified as a cause of health impairment by medical measuring devices available today. These devices determine the effects that this particular stimulus has on the human brain. Sound has been shown to interrupt Stage 2 sleep without the person even knowing it, leaving the person less rested and vulnerable to other deprivation symptoms. Mr. Reeder stated that it won't be long until there are workplace laws in place that will regulate the exposure people have to low frequency noise on the job. He described the physiological effects on the human body caused by low frequency noise.

Mr. Reeder referenced Page 9 of the summary he submitted to the Board of Commissioners, on the topic of property value guarantees. The developer guarantees the property value to the property owner for a short period of time to determine if the property owner can tolerate living near the wind project. If they cannot tolerate the conditions, they can exercise the property value option with the developer and the developer buys the property from them, and they can move elsewhere. This practice is being used in other areas of growing wind development. The community challenge will be to determine how to mitigate the effects of a wind projects on the population when there is a relatively small percentage of rural property owners directly affected.

Mr. Reeder discussed Exhibit F. He proposed a two-mile mitigation boundary; any person living within two miles would be eligible for property value mitigation payment on a sliding scale basis. Using linear proximity as the basis for the scale, the closer the property to the wind project, the higher the mitigation payment would be. The values would be figured based on pre-project appraised property values.

Mr. Newtson asked Mr. Reeder if his presentation was based on his personal opinion about the topic, or was he representing the Planning Commission. Mr. Reeder replied that the concept of a mitigation boundary was the only personal idea he presented, the balance of his presentation was derived from the recommendation approved by the Planning Commission. The Planning Commission had charged him to deliver the message that they stand behind their recommendation of a two-mile setback made to the Board of Commissioners. Mr. Reeder also advised that he had been asked by the Board of Commissioners to provide additional input on this topic. He stated that this is a matter of global concern and he has done his best to assemble information that reflects current concerns, risks and impacts.

Commissioner Doherty stated that he had requested a list of all public hearings and work sessions that have been held to date on the topic of wind development in Umatilla County. The work began in August 2008 and there have been 16 work sessions or public hearings where wind development has been reviewed since that time. He clarified that Mr. Reeder is here to represent the Planning Commission's effort in their recommendation. Mr. Reeder stated that he has read every page of testimony from all the hearings and work sessions, over 3000 pages of internet information and all of the information submitted by the developers.

Commissioner Givens commended Mr. Reeder and the Planning Commission for their efforts. He agreed that health effects must be discussed, but he wants to ensure that the environmental impacts are addressed as well. This is an area of great concern for a large community of people as well. The decision made on this issue will affect everyone in the county to some extent. It will be a tough decision to balance health, wildlife, and money and not everyone will be happy with the outcome.

Mr. Chesnut stated that he was present to represent the City Council of Milton-Freewater, and their interests. He also sits on the Walla Walla Basin Watershed Council as a board director, and wanted to share concerns from that agency as well. He is a member of the Blue Mountain Alliance, a group that is interested in improving the siting standards for Umatilla County for wind development. He wanted to make it clear that he is not authorized to change the stance of the three groups he is representing, nor can he negotiate on their behalf. He would like to identify the middle ground, where business needs and private property owner rights are protected on both sides.

Mr. Newtson stated that he is a landowner in the Juniper Canyon area and wants wind development on his property. He is upset that the idea of negative health effects is being thrown around and states that he can find just as many internet articles that debunk the claims that wind development can cause negative health effects. He stated that the information needs to be factually based, with data to back up the claims. He hopes they thoroughly review the information before making a decision that affects the citizens of Umatilla County.

Commissioner Hansell called for a brief recess at 10:10 a.m. The work session was reconvened at 10:27 a.m.

Commissioner Hansell stated that they will be working from the proposal submitted by the Planning Commission from the February 24th draft, Mr. Reeder's supplemental data, and the 'Yellow Paper' drafted by Commissioner Hansell.

Commissioner Hansell went over the February 24th draft page by page.

Page 1:10; No changes on this page.

Page 2:10 (1); Under the county permitting procedure, this was broke out to bracket A and added "county procedural requirements" language to the ordinance. Mrs. Mabbott explained that EFSC is required by state statute and administrative rule to consider, but not necessarily follow, the county's requirements. EFSC has a different procedure to follow for applicants and they do not have a timeline to adhere to like the county does for processing applications.

Mr. Chesnut asked about the language in the new Bracket (1)(A) being very similar to the prior language in Chapter (1). Commissioner Hansell explained that they wanted to break this out for clarity purposes, and to identify that this referred to procedural requirements and not siting standards.

Page 2:10 (4); The language of "state agencies with requisite jurisdiction" was added to also clarify the intent of the ordinance. Mrs. Mabbott explained that state agencies are required to respond to applications, but may not have staffing available to do so. This language will memorialize this requirement, without naming specific state agencies.

Page 2:10 (5)(D); A sentence was added to address conflict mitigation for farming practices and neighboring rural homes. Mrs. Mabbott explained that this language was more specific about mitigation requirements on rural homes, but is also true for farming practices. This allows for flexibility to the developer to explain what kind of mitigation they would propose in the application. Mrs. Mabbott reviewed the pre-application and application process. Staff and developers review maps for their proposed development, and identify what information needs to be a part of the application. Agencies are identified that would need to be involved in mitigation. Each project is different from the next project, and the size of the project may establish the level of detail required in the application requirements accordingly. Discussion followed on using "could be" versus "may be" in the ordinance language. Mr. Reeder commented that the setbacks will not establish the mitigation; they identify the boundaries of the conflict.

Page 3:10 (F); Mr. Reeder commented that the Oregon Department of Agriculture (ODA) is charged by state statute to deal with erosion from rural land and enforce the Clean Water Act. The Soil and Water Conservation District (SVCD) is the local management and enforcement agency for that state law. Commissioner Hansell asked if the applicant were to work with the local district, would that be enough. Mr. Reeder explained that the ODA has to sign off any application. Discussion followed on the role of the local district along side the ODA.

Mr. Chesnut asked about the reimbursement language, and should the Soil and Water Conservation District be added to the reimbursement list. Mr. Reeder clarified that the ordinance requires the applicant to consult with the SWCD on their plan, not to create the plan. Commissioner Givens indicated that monitoring would indicate action required, and this would result in staff time and expense. Commissioner Hansell stated that the intent of the reimbursement requirement was to help other agencies with costs if the county required their involvement in a developer's application process. The developer would be required to reimburse other agencies for their participation in the application process. Mr. Chesnut asked that the Walla Walla Watershed Council be added to this reimbursement list. Discussion followed on what agencies should be on the list, and if there needs to be a list. Commissioner Doherty commented that if agencies were reimbursed for their consultant participation, they would be proactive and provide good information. This process shifts the cost away from the agency to the developer/applicant and ensures good cooperation from the agency. Mr. Reeder commented that the SWCD has the enforcement ability, supported through the ODA.

Mr. Newtson asked why the National Pollution Discharge Elimination System Permit (NPDES) was eliminated from the language. Mr. Reeder explained that the Department of Environmental Quality (DEQ) has limited monitoring of pollution discharge only during the construction phase of the project. There is no further monitoring by DEQ of the project site post-construction, but the threat still remains of siltation and erosion from access and maintenance roads throughout the wind projects. ODA would be the agency to provide post-construction enforcement of any silt or erosion complaints and impacts to the watershed. The land owner and developer are responsible for any damage to the watershed.

Mrs. Mabbott stated that during the October 2010 work session with the Planning Commission and natural resource agencies, it was learned that the DEQ did not provide monitoring for the NPDES permit once construction is completed. The ODA and SWCD permit for the farming and the roads and the DEQ permits for the turbines during the construction period. The new language in the ordinance addresses this. Mr. Reeder commented that the Walla Walla Watershed Council has spent millions of dollars correcting damage done to the Walla Walla River by siltation caused by the past management practices, and they do not want to see this progress threatened. The Endangered Species Act states that even the threat of siltation in the watershed would result in a violation of this act.

Mr. Newtson commented that he sees this language as being additional red tape to the developers, and it bothered him. Mr. Chesnut explained that it has been established that any new road is a primary contributor to siltation and erosion, so that is why this language is vital to the ordinance. Other state and federal natural resource agencies have similar rules for best management practices in place. The biggest concern is that developers are looking to develop projects in very sensitive water shed areas, so this is even more reason to have this language in place.

Page 3:10 (G) (6); Mr. Chesnut commented that his question about this change had already been answered. He wanted to highlight that even if the developer were to ask to waive the monitoring committee, that decision would still be up to the county. Commissioner Doherty asked what the minimum size would be for a project to be considered a commercial energy facility. Mrs. Mabbott replied it would be 1 megawatt. Anything larger than 105 megawatts would be processed by EFSC. Commissioner Doherty asked if this language would overburden the smaller projects with procedural requirements. Mrs. Mabbott replied that she didn't think so, as the county has already successfully processed two such applications for smaller projects. The Planning Commission considers the smaller projects under a Conditional Use Permit (CUP) process and decides what agencies need to be consulted and how much detail needs to be submitted. The Planning Commission can choose to waive requirements for avian and wildlife studies based on the size and location of the project.

Commissioner Doherty asked about the monitoring plan for avian and wildlife studies and Mrs. Mabbott confirmed that information would be reviewed during the annual reporting process required of each project. Mrs. Mabbott explained that the technical oversight committee remained in existence for the life of the project, under the current code. Mr. Reeder stated that he has served on three of the monitoring committees for wind projects in Umatilla County and has reviewed the requirements for pre-construction monitoring and post-construction monitoring. There is a growing interest in the cumulative effects and impacts to avian and wildlife populations. Umatilla County has a large migration path for bats running through it. This information became known as the result of one of these monitoring committees. Commissioner Givens commented that there have been times when the Planning Commission did require additional information from developers based on the pre-construction monitoring reports.

Commissioner Doherty expressed concern that any on-going monitoring required by county ordinance would not over-extend the county resources. Mr. Reeder explained that the developer is responsible for providing the monitoring data, and that the county has not incurred any financial obligations for this. Mrs. Mabbott asked if there should be clarification in the code that it is the developer's responsibility to pay for any annual monitoring. She also pointed out that the current code does not give the county any enforcement power or regulatory authority, should the annual reporting process reveal problems with unreasonable avian or wildlife mortality rates or impact. Mr. Chesnut commented that the Blue Mt. Alliance is troubled with the developer providing the monitoring data, and likened it to the "fox guarding the henhouse". Commission Givens commented that another problem is when a research company providing the monitoring data is being paid by the developer. They will not want to provide data that reflects negatively on the company paying their cost. Discussion followed on the merits of having the developer pay for annual monitoring or requiring an independent third party to provide the data. Mr. Chesnut commented that the requirement for annual avian and wildlife monitoring should not be waived, as it is essential to the preservation of the sensitive areas in Umatilla County. Mr. Reeder stated that this current annual review process has worked well up until now, with minimal financial impact to the county.

Page 4:10 (I); Commissioner Hansell stated that this language was changed because Umatilla County has an established noxious weed list, and the weeds do not need to be listed separately in this code. Commissioner Doherty asked for clarification on the words 'direct' and 'indirect', pertaining to this section of the code. Mrs. Mabbott explained that they didn't want to make the developers responsible for weeds on adjoining lands that resulted from another land owner not maintaining adequate weed control on their property. This new language narrows the responsibility of the developer and land owners. Discussion followed on the liability or responsibility of noxious weeds control.

Commissioner Doherty asked about using the word 'restoration' instead of 'rehabilitation'. Mr. Reeder explained that this is the language used by EFSC in their standards. He stated that restoration better defines the intent of what the code is meant to describe. It was decided to use 'restoration' on a consistent basis throughout the ordinance.

Page 4:10 (J); Mr. Chesnut commented that he understood the SIP process as a way to identify additional tax incentives for developers and how money will be distributed to the areas affected by the wind projects. It has nothing to do with any pre-construction studies to determine if the project should be built or not. The city of Milton-Freewater is extremely concerned about the socio-economic impacts to the view shed and the growing industry of vineyards and wineries there. The wine industry is currently producing $53,475.00 per acre of community benefit to the Milton-Freewater area, and they are committed to protecting this for the community. The City of Milton-Freewater supports the requirement of a socio-economic impact study as part of the permitting process for wind development, but the Watershed Council would like to see an environmental impact statement produced. Commissioner Doherty stated that he concurs with this sentiment, and also feels that the SIP process comes too late in the overall process to adequately evaluate the socio-economic impact. He stated that the SIP process is not a sufficient replacement for the socio-economic impact study.

Commissioner Hansell commented that the socio-economic study was felt to be too subjective to be effective. Mrs. Mabbott stated that it is the county's goal to make application requirements and standards clear and objective. Sometimes this does not happen, and that is why there is a Planning Commission and an appeal process in place. She stated that the socio-economic standard could be seen as subjective, as it is not clear to the applicant if they have met the criteria or not. This presents a challenge to all involved parties.

Commissioner Doherty commented that there is a high level of tension in the county pertaining to the benefits and downfalls of wind development. There needs to be a way of determining the down side of having wind development here and what can be done about it. Mrs. Mabbott stated that if this were to be an application requirement, it would have to be matched with a standard and a purpose. If a socio-economic standard is required, there needs to be a statement that this is to be used as a tool to assess community consensus. Mr. Reeder stated that there needs to be clear and objective standards and criteria to avoid appeals and lengthy consideration of applications. The Planning Commission is not trying to bypass the socio-economic study, but find a way to acknowledge the impact exists and to create specific requirements for information so clear and objective standards and criteria can be established. Developers are asked to identify potential conflicts with surrounding farming practices and rural homes, and suggest mitigation measures.

Mr. Chesnut commented that the city is concerned about the devaluing of property and business in the city and the Urban Growth Area if wind development were allowed to be too close. Commissioner Givens agreed that a socio-economic study is very hard to define, but stated that the potential impact to tourism is a valid concern and it needs to be addressed in the ordinance.

Mr. Newtson commented that the SIP payments have been very helpful to their communities, and he feels the SIP process is a good idea.

Commissioner Doherty stated that Deschutes County had to deal with this issue several years ago, and they decided not to allow wind development in their county because of the overall negative impact to their tourism industry. He also stated that the farming economy is changing, and this will affect how land owners will lease their property to wind developers. He wants to make sure that there is a place in the process to evaluate and deal with the long term economic changes.

Mr. Reeder commented that they are not just putting wind towers up, they are making semi-permanent changes to the character of the neighborhood by allowing an industrial overlay on farm ground and this will forever alter the character of the zone. Commissioner Doherty asked Mr. Reeder what he suggested could be done in anticipation of these long range problems. Mr. Reeder suggested that a cumulative effects analysis should be completed. There is sufficient historical information on affected wildlife and communities to start looking at the long range effects to make better short term decisions.

Mr. Newtson commented that it is not the county's job to level the playing field, and it's the American way of doing business. Commissioner Doherty stated that this issue cannot be wrapped up in the American flag. It is the governmental responsibility to protect the public, and they should not make a rush to judgment. The commissioners need to know that their decision will be good for the people for 25 years and more. He supports taking a broad look at this issue, as there are both up and down sides to it. Commissioner Doherty supports the socio-economic study being a part of the siting standards, so they can start heading off these emerging problems. Commissioner Hansell stated that the requirement for a socio-economic study will be left in the code. Commissioner Givens stated that there will always be farmers who have an advantage over others for many different reasons, and this should not be tied to wind development. Mr. Chesnut commented that the large property owners who want to have wind development on their land should not be allowed to trample over the rights of the smaller land owners. Mrs. Mabbott asked for clarification that the socio-economic study requirement will be re-inserted into the ordinance.

Mr. Chesnut stated that the Blue Mt. Alliance, the Watershed Council and the City of Milton-Freewater all feel that current proposed language adequately addresses the potential for development along the face of the Blue Mountains. This region is a unique environmental area, and should not be considered under the Columbia Plateau eco-region guidelines.

Mr. Reeder suggested a special overlay zone for the Blue Mountains for development standards that are different from the rest of the county. He stated that if the ordinance were to require a socio-economic study, it would have to be clear what they hoped to accomplish with the information. Commissioner Doherty stated that he was open to options for a socio-economic study that will help them address the concerns being raised. Mr. Reeder explained that there is a trend in this part of the county to capitalize on smaller farms, and the face of the Blue Mountains is a unique region with different emerging issues.

Mr. Chesnut commented on the goals described in the EFU ordinance, specifically the goal to protect open spaces and how this is enforced. Mrs. Mabbott read aloud from the EFU ordinance and the description of purpose for the EFU zone. Mr. Chesnut stated that if the open spaces are not inventoried, there is no way to protect this resource. Mrs. Mabbott explained that there is a separate set of standards under Goal 5 for the protection of significant resources. These would be considered by the Planning Commission on a case by case basis, on how these resources would be mitigated.

Commissioner Doherty stated that Mr. Chesnut's comments reflected the crux of the conflict and that their challenge is to find a way to capture the benefits of the wind industry without compromising or defeating other values in the process. He supports the overlay zone idea for the Blue Mountains that have enhanced standards for development in the sensitive areas. Mrs. Mabbott explained that Goal 5 resource inventories were identified nearly 30 years ago and are listed in the counties technical report or comprehensive plan.

Mr. Newtson asked who made the decision on what is a protected Goal 5 resource. Mr. Reeder explained the process of designating a Goal 5 resource and the state standards that must be met in order to do this. Discussion followed on the inventories of Goal 5 resources in Umatilla County.

Mr. Reeder requested that the word "these" be added back into the suggested language after the word "of" and before the word "resources", so the sentence would read; "The applicant is encouraged to work with CTUIR on developing an inventory of these resources". Mr. Chesnut stated that he was fine with this change, but still was not comfortable with the opening sentence language being limited when referring to open and scenic resources. He would prefer to see this resource inventoried to ensure adequate protection.

Page 5:10 (K)(~~L~~); Commissioner Hansell explained that the word restoration has replaced the word rehabilitation for the sake of consistency with state language throughout the ordinance. Mrs. Mabbott confirmed that EFSC stated similar standards for decommissioning.

Page 5:10 (A)(1); Commissioner Hansell explained that the proposal cited in the "Yellow Paper" states that the setbacks from a city urban growth boundary would not be specified unless a specific setback was requested by that city.

Mr. Chesnut commented that the City of Milton-Freewater would not be comfortable with this language. They are not comfortable with having to "request" a setback, with no guarantee that they will receive this setback standard. They support the Planning Commission proposed standard of a 2 mile setback. Discussion followed on how the different cities regard wind development near their city limits. There is great concern from Milton-Freewater that wind projects could be built too close to the Urban Growth Boundary, thus limiting their potential to expand the city limits in the future. Discussion followed on what language could protect the city and still offer flexibility on requesting larger setbacks.

Page 5:10 (A)(2); Commissioner Hansell read the proposed language for Unincorporated Communities (UC). Mrs. Mabbott clarified what areas of the county this includes; Reith, Umapine and Meacham. Mr. Newtson asked where the 1 mile standard came from. He suggests using the EFSC decibel system for setbacks. Mr. Chesnut stated that the issue is not only noise, but visibility, health impacts and property values. Discussion followed on the definition of the zone UC (Unincorporated Community), and what establishes the boundary. Mr. Reeder asked if they could combine (2) and (3) as being the same standard. Discussion followed on how combining these two standards would affect vacant lots of UC zoned property. It was decided that it would be just the same as a rural home setback standard.

Page 5:10 (A)(3); Mr. Reeder asked about the language, "within the project boundary." He asked if this meant a property that will have a tower or will not have a tower. If the property owner has a lease with a wind developer and signs the waiver, will this affect the setback. Discussion followed on leased properties versus non-leased properties, and how this will affect the setback standard. Mr. Reeder stated that the intent of this language was to let the property owner who chooses to be closer to a tower than the setback distance sign a waiver. Mrs. Mabbott clarified that the project boundary is a subset of the leased properties. The noise study area is different from this boundary and will most likely exceed the leased property areas. This specific setback standard does not address the noise boundary.

Commissioner Hansell stated that if the property owner is going to lease their property to a developer, they could sign the waiver to allow smaller setbacks. But if an adjacent land owner did not want the towers near them, they could refuse to sign the waiver. Discussion followed on leased properties that do not have a residence. Mr. Newtson stated that some property owners in the project boundary are not receiving payments, and this should not be in the language.

Mr. Chestnut stated that the 1 mile setback for this section of the ordinance is not acceptable to a significant portion of county residents. They support the 2 mile setback as proposed by the Planning Commission, and feel this will serve to better protect their rural living environment.

Page 5:10 (A)(4); Commissioner Hansell stated that the intent of this language was to have a uniform state/interstate highways setback for roads thru the county. Mr. Reeder stated that there is no documentation to support the 110% of the overall tower-to-blade tip height setback for roads, but he did find data to show 1600 feet as more in line with adequate safety measures. A 1600 foot setback would equate to 3 times the current proposed language of 110% times the blade height.

Page 5:10(A)(5); Commissioner Hansell explained that this language applied the same standard of 110% of the overall tower-to-blade tip height for cultural resource setbacks for CTUIR sites. Discussion followed on state cultural resource setbacks.

Mr. Chesnut asked about setbacks for tower placement in regards to actual property lines. He stated that there is no clear, defined setback in the language that clarifies how far back a tower should be from a property line. There should be some sort of physical setback for safety reasons. Discussion followed on property line setbacks. Mr. Olsen stated that there is a remedy for an adjoining landowner if a tower should fall across a property line and do damage to the adjoining property. The landowner with the tower and developer would have the liability to protect the adjoining landowner.

Page 6:10 (C); Commissioner Hansell explained that the wording was changed to clarify the significant tribal landmarks and to specifically recognize the CTUIR and their ceded territory in our area. Mr. Newtson commented that he preferred the previous language, and felt that the "will protect" language was too rigid. Discussion followed on what language should be used and what the intent was behind the language. Commissioner Hansell suggested keeping "will protect" and adding "with reasonable effort" to the language. Commissioner Givens asked if the language would open the situation to possible litigation.

Commissioner Doherty asked for clarification of the word "facility". Mrs. Mabbott explained that this term was inclusive of all the components to a wind project; the towers, substations, pads, and transmission lines within the project boundaries. Discussion followed on using consistent terminology throughout the ordinance.

Commissioner Doherty asked why the annual reporting requirement was being named separately in Section (C). Mrs. Mabbott explained that there has been significant concern over the last several years from different groups about impact to wildlife and avian resources. This language may be redundant, but was kept in the proposed ordinance to address these concerns and memorialize the need for these annual reports. Mr. Olsen added that mitigation measures were added in this proposed language as well. Mr. Reeder commented that this language was added to the proposal as a result of public concern expressed over the years. Discussion followed on this section. Commissioner Hansell and Commissioner Doherty asked the Planning staff to offer options about this bracket, and to try to add the language, "reasonable effort", back into the proposed draft.

Page 6:10 (J)(2); Commissioner Hansell read the proposed changes on the project roads section. The language, "independent civil engineer", was removed from the proposal. Mr. Chesnut commented that it is important to have good roads, because they can be large contributors to siltation, and wind projects add many miles of roads. Mr. Reeder asked if the developers were using local engineers who know the area or are they using their own staff members for this task. They need additional input from wind developers about this draft proposal. Mr. Olsen confirmed that the county can be more restrictive on project roads. The land owner can retain the roads after the project is completed, but the roads must continue to meet the county road standards.

Commissioner Hansell asked if there were any other issues that needed to be discussed during the work session.

Mr. Chesnut commented that the Watershed Council has been working for a decade to find a cooperative way to handle the problems with endangered species in the Walla Walla River basin. Their efforts have been recognized nationally by other watershed councils, and they want to ensure that they remain in compliance with federal regulations. They hope that this ordinance will help them protect the sensitive area they have worked so hard to restore. Mr. Chesnut also noted that cumulative effects should be addressed in the proposed ordinance, along with the endangered species act. He is concerned that the rush to develop wind projects because of the tax incentives has not left much consideration of environmental impact issues.

Mr. Newtson commented on the draft proposal Section (A)(7), Setbacks. He asked if this proposed standard was trying to make the county ordinance more stringent than the noise standard established by the state. He wants to know what is meant by credible noise study, and what the purpose for the noise study is. Mr. Reeder replied that this requirement is a way to determine if the projected noise standards are satisfied by the finished product. Mrs. Mabbott further clarified that this requirement of modeling was to ensure that the standard would be met, prior to project construction. She cited another county that did not have this modeling requirement, and found that a wind project submitted inaccurate information and did not comply with the noise standard after the project was built. This language was added to prevent this same thing from happening in Umatilla County. The industry standard is to complete a noise study prior to construction. Mrs. Mabbott commented that credible meant the study should be completed by someone who has verifiable credentials and expertise in this industry. The burden of providing the credible noise study is meant to be placed on the developer and not on the affected landowner after the fact.

Mr. Reeder recommended that a noise study should be required for all wind development projects sited in Umatilla County. Many of the conflict issues that have come out of this process have been due to the noise concerns, and this would be very useful information to have on record.

Mr. Chesnut expressed concern over the credibility of noise studies that are submitted with applications, and asked who would be conducting the studies. If the modeling is not correct, and the project is built, it will be very difficult to move the towers after the fact. He states that the two-mile setback will help solve this problem, if the noise study proves to be inadequate at protecting the rural home owners. The two-mile setback is an easily identifiable standard prior to construction.

Commissioner Hansell asked if there were any further comments, and no one responded. He stated that the hearing will be reconvened on May 12, 2011. All materials submitted to date will be submitted into the record at that time, and further public testimony will be heard. The goal will be to close the record then, so the Board of Commissioners can begin to review the substantial amount of materials submitted. There is no deadline for a decision, as this is a legislative action. He stated that the decision they make will have long term effects, so they need to make the best decision they can.

Commissioner Hansell thanked the panel members for their participation in the work session. Commissioner Givens asked people to provide their input on this issue to the Board of Commissioners. He encouraged people to try and work together, and not let this process become a punitive tool against neighbors.

Commissioner Hansell adjourned the work session at 1:29 p.m.

Respectfully submitted,

Gina Miller

Gina Miller, secretary

(adopted by the Board of Commissioners on June 14, 2011)

# Proposed Amendments to UCDC 152.615 & 616 (HHH)

*Version: May 3, 2011, replaces all previous versions.*

**§ 152.615 ADDITIONAL CONDITIONAL USE PERMIT RESTRICTIONS.**

In addition to the requirements and criteria listed in this subchapter, the Hearings Officer, Planning Director or the appropriate planning authority may impose the following conditions upon a finding that circumstances warrant such additional restrictions:

(A) Limiting the manner in which the use is conducted, including restricting hours of operation and restraints to minimize such a environmental effects as noise, vibration, air pollution, water pollution, glare or odor;

(B) Establishing a special yard, other open space or lot area or dimension;

(C) Limiting the height, size or location of a building or other structure;

(D) Designating the size, number, location and nature of vehicle access points;

(E) Increasing the required street dedication, roadway width or improvements within the street right of way;

(F) Designating the size, location, screening, drainage, surfacing or other improvement of a parking or loading area;

(G) Limiting or otherwise designating the number, size, location, height and lighting of signs;

(H) Limiting the location and intensity of outdoor lighting and requiring its shielding;

(I) Requiring diking, screening, landscaping or other methods to protect adjacent or nearby property and designating standards for installation and maintenance.

(J) Designating the size, height, location and materials for a fence;

(K) Protecting and preserving existing trees, vegetation, water resources, air resources, wildlife habitat, or other ~~significant~~ natural resources;

(L) Parking area requirements as listed in §§ 152.560 through 152.562 of this chapter.
(Ord. 83-4, passed 5-9-83; Ord. 2005-02, passed 1-5-2005)

**§ 152.616 STANDARDS FOR REVIEW OF CONDITIONAL USES AND LAND USE DECISIONS.**

The following standards shall apply for review by the Hearings Officer, the Planning Director or appropriate planning authority of the specific conditional uses and land use decisions listed in this chapter:

(HHH) *Commercial Wind Power Generation Facility.*

(1) *County Permit Procedure.*
The procedure for taking action on the siting of a facility is a request for a conditional use. A public hearing pursuant to Sections ~~152.750-755 and~~ 152.771 shall be held to determine if the applicant meets the siting requirements for a Wind Power Generation Facility.

(A) The county procedural requirement

for a hearing will not apply to proposed Wind Power Generation Facilities for which Energy Facility Siting Council is making the land use decision.

[Former # (2) moved to # (5)]

(2) *Pre-application Meeting.*
A pre-application meeting(s) is required. The applicant will be expected to bring preliminary information about the application components described in Application Requirement (5) below. County staff will arrange the meeting and will invite local, state, federal and other agency representatives and individuals with pertinent expertise. The purpose of the pre-application meeting will be to identify potential impacts and opportunities and to advise on the level of detail required in each of the application components described in (5) below, and establish technical oversight requirements for monitoring plans.

(3) *Conditions of Approval.*
Umatilla County may impose clear and objective conditions in accordance with the County Comprehensive Plan, County Development Code and state law, which Umatilla County considers necessary to protect the best interests of the surrounding area, or Umatilla County as a whole.

(4) *Permits.*
Prior to commencement of any construction, all other necessary preconstruction permits shall be obtained, including but not limited to a conditional use permit, ~~e.g. Umatilla County~~ Zoning Permit~~,~~ and road access ~~and other~~ permits from ~~the~~ Umatilla County ~~Public Works Department~~, and ~~from the Oregon Department of Transportation.~~ other ~~permits from~~ state agencies with the requisite jurisdiction.

(5) ~~(2)~~ *Application Requirements.*

The following information shall be provided as part of the application:

(A) (1) A general description of the proposed Wind Power Generation Facility~~,~~;
(2) A~~a~~ tentative construction schedule~~,~~;
(3) T~~t~~he legal description of the property on which the Wind Power Generation F~~f~~acility will be located~~,~~; and
(4) I~~i~~dentification of the general area for all components of the proposed Wind Power Generation Facility~~,~~.

(B) A ~~including a~~ map showing the location of components.

(C) (1) Nonproprietary evidence of wind monitoring data qualifying the wind resources within the project boundary, such as a description of procedures and process for wind study.

(2) Evidence of active utility transmission interconnect requests and/or process and description of same.

(3) Route and plan for transmission facilities connecting the project to the grid.

~~(B)~~ (D) Identify~~ication of~~ potential conflicts, if any, with:
(1) Accepted farming practices as defined in ORS 215.203~~(2) (c)~~ and forest practices as provided in ORS 527.620 through 527.990 on adjacent lands devoted to farm and/or forest uses; and
(2) Neighboring rural homes. Explain how conflicts could be mitigated for (1) and (2) above. ~~and the steps to mitigate such conflicts e.g., noise easements. Other resource operations and practices on adjacent lands except for wind power generation facilities on such adjacent lands; and (3) Accepted farm or forest practices on surrounding EFU/GF or NR land, including~~

~~the nature and the extent of the impact of the proposed facility on the cost of such practices.~~

~~(C)~~ (E) A Transportation Plan, with proposed recommendations, if any, reflecting the guidelines provided in the Umatilla County Transportation System Plan (TSP) and the transportation impacts of the proposed Wind Power Generation Facility upon the local and regional road system during and after construction, after consultation with Umatilla County Public Works Director. The plan will designate the size, number, location and nature of vehicle access points.

Further discussion needed on including reimbursement for review by watershed.

**~~(G)~~ (F) ~~An~~ revegetation and erosion control plan, developed in consultation with the Umatilla County Public Works Department~~,~~ Soil and Water Conservation District (SWCD) and appropriate Watershed Council~~,~~ ~~the Oregon Agricultural Water Quality Management Program (administered by the Oregon Department of Agriculture), the Department of Environmental Quality and the Confederated Tribes of the Umatilla Indian Reservation.~~ At a minimum, ~~T~~the plan shall ~~should~~ include the seeding of all road cuts or related bare road areas as a result of all construction, demolition and rehabilitation with an appropriate mix of native vegetation or vegetation suited to the area. ~~This requirement will be satisfied if the applicant has an NPDES (National Pollution Discharge Elimination System) permit.~~ The plan shall also address monitoring during and post construction. The applicant shall reimburse SWCD for their involvement.**

~~(D)~~ (G) ~~An~~ fish, wildlife and avian impact monitoring plan. The ~~avian~~ monitoring plan shall be designed and administered by the Wind Power Generation Facility owner/operator's ~~applicant's~~ wildlife professionals. [See HHH (2), above] ~~For projects being sited by EFSC, compliance with EFSC's avian monitoring requirements will be deemed to meet this requirement~~. The plan shall include the formation of a technical oversight committee to review the plan, and consist of the following persons:

(1) The landowners/farm tenants.

(2) Wind Power Generation Facility owner/operator representative. (Chair)

(3) Oregon Department of Fish and Wildlife representative, if the agency chooses to participate.

(4) Two Umatilla County residents with no direct economic interest in the project and recommended by the applicants for appointment by the Umatilla County Board of Commissioners.

(5) U.S. Fish and Wildlife representative, if the agency chooses to participate.

(6) Umatilla County Planning Commission member.

At the request of Wind Power Generation Facility owner/operator ~~applicant~~, this committee requirement may be waived or discontinued by the County.
[Former (2) (E) moved to (6) (I)]

~~(F)~~ (H) A~~n~~ ~~fire prevention and~~ emergency management ~~response~~ plan for all phases of the life of the Wind Power Generation ~~F~~facility. The plan shall address the major concerns associated with the site, including but not necessarily limited to terrain, dry conditions, ~~and~~ fire hazards, ~~limited~~ access~~.~~, available water, and emergency response.

(1) The plan shall verify the fire district and/or contract fire department responsible for providing emergency services. High rise rescue is the responsibility of the Wind Power Generation Facility owner/operator with local emergency responders providing ground level assistance.

(2) A spill prevention, control and counter measure plan (SPCC) shall be provided. The plan shall include verification that a local emergency service provider has equipment, training and personnel to respond to spills.

(3) An Operations and Maintenance Plan detailing expected work force, local response capability, (contract or otherwise) controlled access, and in the case of transmission lines proof of emergency response capability in accordance with OPUC rules governing operation and maintenance of such lines.

(4) An Emergency Response Plan for responding to natural and/or man made emergencies or disasters.

~~(H)~~ (I) A weed control plan addressing prevention and control of all Umatilla County identified noxious weeds ~~and other weeds such as thistles which distribute weed seed while blowing across nearby lands following maturity,~~ directly resulting from the Wind Power Generation Facility during preparation, construction, operation and demolition/~~rehabilitation~~ restoration.

~~(I)~~ (J) A socioeconomic impact assessment of the Wind Power Generation Facility, evaluating such factors as, but not limited to, the project's effects upon the social, economic, public service, cultural, visual, and recreational aspects of affected communities and/or individuals. These effects can be viewed as either positive or negative. In order to maximize potential benefits and to mitigate outcomes that are viewed as problematic, decision makers need information about the socioeconomic impacts that are likely to occur.

[New (6) (K) below moved from (2) (K)]

(K) Information pertaining to the impacts of the Wind Power Generation Facility on:

(1) Wetlands and streams, including intermittent streams and drainages;

(2) Fish, Avian and Wildlife (all potential species of reasonable concern~~)~~, including but not limited to federally listed threatened and endangered species);

(3) Fish, Avian and Wildlife Habitat;

(4) Criminal Activity (vandalism, theft, trespass, etc). Include a plan and proposed actions~~, if any,~~ to avoid, minimize or mitigate negative impacts.

(5) Open space, scenic, historic, cultural and archaeological resources.

(6) ~~This includes~~ Historical, cultural ~~resources~~ and , archaeological sites, ~~archaeological objects, historic sites, and sites of historic or religious importance to Native American tribes.~~
The applicant is encouraged to work with the CTUIR on developing an inventory of these resources.

[New (5) (L) below moved from (2) (L)]

(L) A dismantling, ~~and~~ decommissioning and restoration ~~rehabilitation~~ plan of all components of the Wind Power Generation Facility, as provided in §152.616 (HHH) (7).

(6) ~~(5)~~ *Standards/Criteria of Approval.* The following requirements and restrictions apply to the siting of a facility:

Further discussion needed on setback standards.

(A) Setbacks.

**The minimum setback shall be a buffer distance of no less than the following: ~~The Wind Power Generation Facility shall be on property zoned EFU/GF or NR, and no portion of the facility shall be within 3,520 feet of properties zoned residential use or designated on the Comprehensive Plan as residential. (For clarification purposes of this section, EFU/GF/NR zones are not considered zoned for residential use.)~~**

**(1) Setbacks ~~F~~from tower to the City Urban Growth Boundary considered if requested by a city governing body.~~2 miles or 20 times the overall tower-to-blade tip height, whichever is greater.~~**

**(2) From tower to land zoned Unincorporated Community (UC) 1 mile. ~~10 times the overall tower-to-blade tip height.~~**

**(3) From tower to a rural home site within the project boundary ½ mile; and to rural homes outside of the project boundary 1 mile. ~~to off site rural homes. 2 miles or 20 times the overall tower-to-blade tip height, whichever is greater, unless a written waiver is obtained from the landowner and recorded in the County Deed Records.~~**

**(4) From tower to the boundary right-of-way of county roads, state and interstate highways 110% of ~~(gravel or paved) 2 times~~ the overall tower-to-blade tip height.**

**~~(5) From tower to the boundary right-of-way of State or Interstate Highways 3 times the overall tower-to-blade tip height.~~**

**(5) ~~(6)~~ From tower to known Archeological, Historical, or Cultural Sites 110% of ~~2 times~~ the overall tower-to-blade tip height unless a lesser setback is recommended by CTUIR.**

*Note: The overall tower-to-blade tip height is the vertical distance measured from grade to the highest vertical point of the blade tip.*

(6) ~~(7)~~ New electrical transmission lines associated with the project shall not be constructed closer than 500 feet to an existing residence without prior written approval of the homeowner, said written approval to be recorded with deed records. Exceptions to the 500 feet setback include transmission lines placed in a public right of way. *Note: Transmission and distribution lines constructed and owned by the applicant that are not within the project boundary are subject to a separate land use permit.*

(7) ~~(E)~~ The turbine/towers shall be of a size and design to help reduce noise or other detrimental effects. At a minimum, the Wind Power Generation Facility shall be designed and operated within the limits of noise standard(s) established by the State of Oregon. A credible noise study may be required to verify noise impacts in all wind directions are in compliance with the State noise standard.

(B) Reasonable efforts shall be made to blend the wind ~~facility~~ turbine/towers with the natural surrounding area in order to minimize impacts upon open space and the natural landscape.

(C) The Development and Operation of the Wind Power Generation Facility will include ~~R~~reasonable efforts to protect and ~~to~~ preserve existing trees, vegetation, water resources, wildlife, wildlife habitat, fish and avian resources, historical, cultural and archaeological sites identified by ~~and objects, sites of historic or religious significance to Native American Tribes~~ the CTUIR. ~~or other significant natural resources.~~ Compliance with this standard may require mitigation and/or submission of an annual monitoring report.

(D) The turbine towers shall be designed and constructed to discourage bird nesting and wildlife attraction.

[Former (5) (E) was moved to (6) (A) (5)]

~~(F)~~ (E) Private access roads established and controlled by the Wind Power Generation Facility shall be gated and signed to protect the Wind Power Generation ~~F~~facility and property owners from illegal or unwarranted trespass, illegal dumping and hunting and for emergency response.

~~(G)~~ (F) Where practicable the electrical cable collector system shall be installed underground, at a minimum depth of 3 feet; elsewhere the cable collector system shall be installed to prevent adverse impacts on agriculture operations.

~~(H)~~ (G) Required permanent maintenance/operations buildings shall be located off-site in one of Umatilla County's appropriately zoned areas, except that such a building may be constructed on-site if:

(1) ~~T~~the building is designed and constructed generally consistent with the character of similar buildings used by commercial farmers or ranchers, and

(2) ~~T~~the building will be removed or converted to farm use upon decommissioning of the Wind Power Generation Facility consistent with the provisions of § 152.616 (HHH) (7).

~~(I)~~ (H) A Wind Power Generation Facility shall comply with the Specific Safety Standards for Wind Facilities delineated in OAR 345-024-0010 (as adopted at time of application).

[New (6) (I) below, moved from (2) (E)]

~~(E)~~ (I) A Covenant Not to Sue with regard to generally accepted farming practices shall be recorded with the County. Generally accepted farming practices shall be consistent with the definition of Farming Practices under ORS 30.930. The Wind Power Generation Facility owner/operator ~~applicant~~ shall covenant not to sue owners, operators, contractors, employees, or invitees of property zoned for farm use for generally accepted farming practices.

(J) Roads.

(1) County Roads.

A Road Use Agreement with Umatilla County regarding the impacts and mitigation on county roads shall be required as a condition of approval.

(2) Project Roads.

Layout and design of the project roads shall use best management practices in consultation with the Soil Water Conservation District. The project road design shall be reviewed and certified by an ~~independent~~ civil engineer. Prior to road construction the applicant shall contact the State Department of Environmental Quality and if necessary, obtain a storm water permit (NPDES).

[New (6) (K) below, moved from (2) (J)]

~~(J)~~ (K) Demonstrate ~~All Wind Power Generation Facilities must show~~ compliance with the standards found in OAR 660-033-0130 (37).

~~(6) To the extent feasible, the county will accept information presented by an application for an EFSC proceeding in the form and on the schedule required by EFSC.~~

~~(7)~~ (L) Submit a plan for ~~The applicants~~ dismantling of uncompleted construction and/or decommissioning ~~plan for~~ and/or re-powering of the Wind Power Generation Facility ~~shall include the following information:~~ as described in §152.616 (HHH) (7).

[New (6) (M) below, moved from # (8)]

(M) ~~(8)~~ A surety bond ~~or letter of credit~~ shall be established to cover ~~for~~ the cost of dismantling ~~of~~ uncompleted construction and/or decommissioning of the Wind Power Generation F~~f~~acility~~.~~, and site rehabilitation pursuant to ~~(See~~ § 152.616 (HHH) (7) &(8). The intent of this requirement is to guarantee performance (not just provide financial insurance) to protect the public interest and the county budget from unanticipated, unwarranted burden to decommission wind projects. ~~For projects being sited by the State of Oregon's Energy Facility Siting Council (EFSC), the bond or letter of credit required by EFSC will be deemed to meet this requirement.~~

[New (6) (N) below, moved from # (9)]

~~(9)~~ (N) The actual latitude and longitude location or Stateplane NAD 83(91) (suitable for GPS mapping) coordinates of each turbine tower, connecting lines, O & M building, substation, project roads and transmission lines, shall be provided to Umatilla County on or before starting ~~once commercial~~ electrical production ~~begins~~.

(O) An Operating and Facility Maintenance Plan shall be submitted and subject to county review and approval.

[New (6) (P) below, moved from (10)]

~~(10)~~ (P) A summary of as built changes to the original plan ~~in the facility from the original plan~~, if any, shall be provided by the Wind Power Generation Facility owner/operator~~.~~ within 90 days of starting electrical production.

[New (7) below was formerly (7) (A)]

(7) ~~(A)~~ *Dismantling/Decommissioning.* A plan for dismantling and/or decommissioning that provides for completion of dismantling or decommissioning of the Wind Power Generation F~~f~~acility without significant delay and protects public health, safety and the environment in compliance with the restoration requirements of this section.

~~(B)~~ (A) A description of actions the Wind Power Generation F~~f~~acility owner/operator proposes to take to restore the site to a useful, non-hazardous condition, including options for post-dismantle or decommission land use, information on how impacts on fish, wildlife, avian populations and the environment would be minimized during the dismantling or decommissioning process, and measures to protect the public against risk or danger resulting from post-decommissioning site conditions in compliance with the requirements of this section.

~~(C)~~ (B) A current detailed cost estimate, a comparison of that estimate with present funds, the bond ~~set-aside~~ for dismantling or decommissioning, and a plan for ~~assuring guaranteeing~~ the availability of adequate funds for completion of dismantling or decommissioning. The cost estimate will be reviewed and be updated by the Wind Power Generation F~~f~~acility owner/operator on a 3 ~~5~~ year basis~~.~~, unless material changes have been made in the overall facility that would materially increase or decrease these costs. If so, the report must be revised within 120 days of completion of such changes.

~~(D)~~ (C) Restoration of the site shall consist of the following:

(1) Dismantle turbines, towers, pad-mounted transformers, meteorological towers and related aboveground equipment. All concrete turbine pads shall be removed to a depth of at least three feet below the surface grade.

(2) The underground collection and communication cables need not be removed if at a depth of three feet or greater. These cables at a depth of three feet or greater can be abandoned in place if they are deemed not a hazard or interfering with agricultural use or other ~~consistent~~ resource uses of the land.

(3) Gravel shall be removed from areas surrounding turbine pads.

(4) Private ~~A~~ access roads shall be restored ~~removed~~ by removing gravel and restoring the surface grade and soil.

(5) After removal of the structures and roads, the area shall be graded as close as is reasonably possible to its original contours and the soils shall be restored to a condition compatible with farm uses or consistent with other resource uses. Re-vegetation shall include planting by applicant of native plant seed mixes, planting by Wind Power Generation Facility owner/operator ~~applicant~~ of plant species suited to the area, or planting by landowner of agricultural crops, as appropriate, and shall be consistent with the weed control plan approved by Umatilla County.

(6) Roads, cleared pads, fences, gates, and improvements may be left in place if a letter from the land owner is submitted to Umatilla County indicating said land owner will be responsible for, and will maintain said roads and/or facilities for farm or other purposes as permitted under applicable zoning.

[New # (8) below was formerly (7) (E)]

(8) ~~(E)~~ *Decommissioning Fund.*
The ~~applicant (~~Wind Power Generation F~~f~~acility owner/operator~~)~~ shall submit to Umatilla County a bond ~~or letter of credit~~ acceptable to the County, in the amount of the decommissioning fund naming Umatilla County ~~and the landowner as~~ beneficiary or payee.

(A) ~~(1)~~ The calculation of present year dollars shall be made using the U. S. Gross Domestic Product Implicit Price Deflator as published by the U. S. Department of commerce, Bureau of Economic Analysis, or any successor agency (the Aindex.@). The amount of the bond ~~or letter of credit~~ account shall be changed up or down if the change in the Index moves by more than ~~change if the Index changes be increased at~~

~~such time when the cumulative percentage increase in the Index exceeds~~ 10 percent from the last change, and then the amount shall be increased or decreased by the cumulative percentage ~~increase~~ change. If at any time the Index is no longer published, Umatilla County and the Wind Power Generation Facility owner/operator ~~applicant~~ shall select a comparable calculation of present year dollars. ~~The amount of the bond or letter of credit account shall be pro-rated within the year to the date of decommissioning.~~

(B) ~~(2)~~ The ~~decommissioning~~ bond ~~fund~~ shall not be subject to revocation or unjustified reduction before decommissioning of the Wind Power Generation Facility~~.~~ and restoration of the site/s.

(C) ~~(3)~~ The Wind Power Generation F~~f~~acility owner/operator shall describe the status of the ~~decommissioning~~ bond ~~fund~~ in the annual report submitted to ~~the~~ Umatilla County.

~~(F) If any disputes arise between Umatilla County and the landowner on the expenditure of any proceeds from the bond or the letter of credit, either party may request non-binding arbitration. Each party shall appoint an arbitrator, with the two arbitrators choosing a third. The arbitration shall proceed according to the Oregon statutes governing arbitration. The cost of the arbitration (excluding attorney fees) shall be shared equally by the parties.~~

~~(D) (G) For projects sited by EFSC, compliance with EFSC's financial assurance and decommissioning standards shall be deemed to be in compliance with the dismantling and decommissioning requirements of this § 152.616 (HHH)(7) & (8).~~

[Former # (8) moved to (6) (M)]

[Former # (9) moved to (6) (N)]

[Former # (10) moved to (6) (P)]

[New # (9) below, moved from # (12)]

(9) ~~(12)~~ *Annual Reporting.* Within 120 days after the end of each calendar year the Wind Power Generation F~~f~~acility owner/operator shall provide Umatilla County a~~n~~ written and oral annual report including the following information:

(A) Energy production by month and year.

(B) Non-proprietary information about wind conditions, (e. g., monthly averages, high wind events, bursts).

(C) A summary of changes to the Wind Power Generation F~~f~~acility that do not require ~~facility requirement~~ amendments.

(D) A summary of the fish, wildlife and avian monitoring program – bird injuries, casualties, positive impacts on area wildlife and any recommendations for changes in the monitoring program.

(E) Employment impacts to the community and Umatilla County during and after construction.

(F) Success or failures of weed control practices.

(G) Status of the ~~decommissioning~~ bond ~~fund~~.

(H) Summary of erosion control activities and its effectiveness.

[New (I) below was formally (H) above]

(I) Summary comments –

(1) ~~any~~ P~~p~~roblems with the projects, any adjustments needed, or any suggestions.

(2) The annual report requirement may be modified ~~discontinued or required at a less frequent schedule~~ by the County~~.~~ as warranted by project conditions, circumstances and compliance. The reporting requirement and/or reporting schedule shall be reviewed, and possibly altered, at the request of the Wind Power Generation F~~f~~acility owner/operator. For Wind Power Generation F~~f~~acilities under EFSC jurisdiction and for which an annual report is required, the annual report to EFSC satisfies this requirement.

[New # (10) below, moved from # (11)]

(10) ~~(11)~~(A) *Permit Amendments.* The Wind Power Generation Facility requirements shall be facility specific, but can be amended as long as the Wind Power Generation F~~f~~acility does not exceed the boundaries of the Umatilla County conditional use permit where the original Wind Power Generation F~~f~~acility was constructed.

(B) An amendment to the conditional use permit shall be subject to the standards and procedures found in § 152.611. Additionally, any of the following would require an amendment to the conditional use permit ~~required if proposed facility changes would~~:

(1) ~~Increase the land area taken out of agricultural production by an additional 20 acres or more; (2) Increase the land area taken out of agricultural production sufficiently to trigger taking a Goal 3 exception; (3) Require an~~ Expansion of the established Wind Power Generation F~~f~~acility boundaries; (2) ~~(4)~~ Increase the number of towers; (3) ~~(5)~~ Increase generator output by more than 25 percent relative to the generation capacity authorized by the initial permit due to the repowering or upgrading of power generation capacity~~.~~; or (4) Changes to project private roads or access points to be established at or inside the project boundaries.

(C) In order to assure appropriate timely response by emergency service providers, ~~N~~notification (by the Wind Power Generation F~~f~~acility owner/operator) to the Umatilla County Planning Department of changes not requiring an amendment such as a change in the project owner/operator of record, a change in the emergency plan or change in the maintenance contact are ~~encouraged, but not~~ required to be reported immediately. An amendment to a Site Certificate issued by EFSC will be governed by the rules for amendments established by EFSC.

[# (12) moved to # (9)]

(Ord. 83-4, passed 5-9-83; Ord. 2002-02, passed 5-20-2003; Ord. 2005-02, passed 1-5-2005; Ord. 2009-09, passed 12-8-09)

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# Yellow Paper

Draft Changes for Board of Commissioners
Consideration at May 3, 2011 Work Session

LEGEND

- Green underlined text indicate changes recommended by the Planning Commission at the January 13th work session
- Blue underlined text indicate previously proposed changes
- ~~Red strikethrough text~~ is proposed to be omitted
- Purple underlined text indicates changes recommended by the Planning Commission at the February 24th hearing.
- Orange text, underlined and ~~strikethrough~~ are new changes for consideration of the Board of Commissioners at the May 3, 2011, work session.

| Proposed Change | Comment |
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| *Proposed Amendments, Feb 24, 2011 Version, page 2*<br><br>(1) *County Permit Procedure.*<br>The procedure for taking action on the siting of a facility is a request for a conditional use. A public hearing pursuant to Sections ~~152.750 -755 and~~ 152.771 shall be held to determine if the applicant meets the siting requirements for a Wind Power Generation Facility.<br>(A) The county procedural requirement for a hearing will not apply to proposed facilities for which EFSC is making the land use decision. | Clarify procedure. Add language to clarify that the process applies to a county permit review only, not EFSC. |
| *Proposed Amendments, Feb 24, 2011 Version, page 2*<br><br>(4) *Permits.*<br>Prior to commencement of any construction, all other necessary preconstruction permits shall be obtained, including but not limited to a conditional use permit, ~~e.g. Umatilla County~~ Zoning Permit~~,~~ and road access ~~and other~~ permits from ~~the~~ Umatilla County ~~Public Works Department~~, and ~~from the Oregon Department of Transportation.~~ other ~~permits from~~ state agencies with the requisite jurisdiction. | Clarifies that state agencies participating in permit review are only those agencies with appropriate/requisite jurisdiction. |
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| *Proposed Amendments, Feb 24, 2011 Version, page 2*<br><br>~~(B)~~ (D) Identify~~ication~~ ~~of~~ potential conflicts, if any, with:<br>(1) Accepted farming practices as defined in ORS 215.203~~(2) (c)~~ and forest practices as provided in ORS 527.620 through 527.990 on adjacent lands devoted to farm and/or forest uses; and<br>(2) Neighboring rural homes. Explain how conflicts could be mitigated for (1) and (2) above. ~~and the steps to mitigate such conflicts e.g., noise easements. Other resource operations and practices on adjacent lands except for wind power generation facilities on such adjacent lands; and (3) Accepted farm or forest practices on surrounding EFU/GF or NR land, including the nature and the extent of the impact of the proposed facility on the cost of such practices.~~ | Changes language so that developer would identify mitigation for both possible impacts to farm and forest land as well as to neighboring rural homes. Replaces language that requires mitigation be explained only for possible impacts to rural residences. |
| *Proposed Amendments, Feb 24, 2011 Version, page 3*<br><br>~~(G)~~ (F) A~~n~~ revegetation and erosion control plan, developed in consultation with the Umatilla County Public Works Department~~.~~, Soil and Water Conservation District (SWCD) and appropriate Watershed Council~~,~~. ~~the Oregon Agricultural Water Quality Management Program (administered by the Oregon Department of Agriculture), the Department of Environmental Quality and the Confederated Tribes of the Umatilla Indian Reservation.~~ At a minimum, ~~T~~the plan shall ~~should~~ include the seeding of all road cuts or related bare road areas as a result of all construction, demolition and rehabilitation with an appropriate mix of native vegetation or vegetation suited to the area. ~~This requirement will be satisfied if the applicant has an NPDES (National~~ | Changes list so that the revegatation and erosion control plan would be developed in consultation with Umatilla County Public Works, Umatilla County SWCD and appropriate Watershed Council. Eliminates additional agency consultation. Adds language that states that the developer may need to reimburse the agencies for their involvement in development of the plan. |



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| ~~Pollution Discharge Elimination System) permit.~~ The plan shall also address monitoring during and post construction. The applicant shall reimburse SWCD for their involvement. | |
| *Proposed Amendments, Feb 24, 2011 Version, page 3*<br><br>(6) Umatilla County Planning Commission member.<br>~~At the request of applicant, this committee requirement may be waived or discontinued by the County.~~ (Add back) At the request of applicant, this committee requirement may be waived or discontinued by the County. | Add back the earlier language that allows the wind farm owner to make a request to waive the requirement or discontinue, after a period of time, the requirement for a monitoring committee. |
| *Proposed Amendments, Feb 24, 2011 Version, page 4*<br><br>~~(H)~~ (I) A weed control plan addressing prevention and control of all Umatilla County identified noxious weeds ~~and other weeds such as thistles which distribute weed seed while blowing across nearby lands following maturity,~~ directly resulting from the Wind Power Generation Facility during preparation, construction, operation and demolition/rehabilitation. | Noxious weeds include thistles and other problematic weeds. |
| *Proposed Amendments, Feb 24, 2011 Version, page 4*<br><br>(Remove and renumber.)<br>~~(I) (J) A socioeconomic impact assessment of the Wind Power Generation Facility, evaluating such factors as, but not limited to, the project's effects upon the social, economic, public service, cultural, visual, and recreational aspects of affected communities and/or individuals. These effects can be viewed as either positive or negative. In order to maximize potential benefits and to mitigate outcomes that are~~ | Since implementation of the SIP agreement process it is believed that the SIP replaces this code requirement and section. |

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| ~~viewed as problematic, decision makers need information about the socioeconomic impacts that are likely to occur.~~ | |
| *Proposed Amendments, Feb 24, 2011 Version, page 4*<br>(5) Open space, scenic, historic, cultural and archaeological resources as identified in the Comprehensive Plan.<br><br>(6) ~~This includes~~ Historical, cultural, ~~resources~~ and archaeological sites. ~~archaeological objects, historic sites, and sites of historic or religious importance to Native American tribes.~~<br>The applicant is encouraged to work with CTUIR on developing an inventory of resources. | New language (5) clarifies that the open space, scenic, historic and archaeological resources that an applicant is required to provide information on are those resources that are identified in the County Comprehensive Plan. Also creates a new category (6) that specifically lists tribal, historic, cultural and archaeological resources of significance to the CTUIR. New number (6) also encourages the applicant to work directly with the CTUIR in identifying these resources. |
| *Proposed Amendments, Feb 24, 2011 Version, page 4*<br><br>(K) ~~(L)~~ A dismantling, ~~and~~ decommissioning and restoration ~~rehabilitation~~ plan of all components of the Wind Power Generation Facility, as provided in §152.616 (HHH) (7). | Changes wording for clarification only, pertains to restoration of project components. |
| *Proposed Amendments, Feb 24, 2011 Version, page 5*<br><br>(1) Setbacks ~~F~~from tower to the City Urban Growth Boundary considered if requested by a city governing body. ~~2 miles or 20 times the overall tower-to-blade tip height, whichever is greater.~~<br><br>(2) From tower to land zoned Unincorporated Community (UC) 1 mile. ~~10 times the overall tower-to-blade tip height.~~<br><br>(3) From tower to a rural home site within the project boundary ½ mile; and to rural homes outside of the project boundary 1 mile. ~~to off site rural homes. 2~~ | Changes language so that the setback from a city urban growth boundary would not be specified but could be required if a setback is requested by a city. Language would make the city setback a recommendation for consideration by the county, not mandatory.<br><br>Homes within the UC zone are rural homes. In developing setback consistency, homes within the UC zone are proposed to have the same setback (1 mile) as rural homes identified as located outside of the project boundary.<br><br>Changes setback from a rural home so that setback from a residence located on a |



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| ~~miles or 20 times the overall tower-to-blade tip height, whichever is greater, unless a written waiver is obtained from the landowner and recorded in the County Deed Records.~~<br><br>(4) From tower to the boundary right-of-way of county roads, state and interstate highways 110% of ~~(gravel or paved) 2 times~~ the overall tower-to-blade tip height.<br><br>~~(5) From tower to the boundary right-of-way of State or Interstate Highways 3 times the overall tower-to-blade tip height.~~<br><br>(5) ~~(6)~~ From tower to known Archeological, Historical, or Cultural Sites 110% of ~~2 times~~ the overall tower-to-blade tip height unless a lesser setback is recommended by CTUIR. | project site would be one half mile and setback from a rural residence on a neighboring property (land without lease or wind turbines) would be one mile.<br><br>Combines number (4) and (5) so setback from county road, state or interstate highway is the same as setback applied by EFSC, 110% of tower-to-blade tip height. Standard provides safety and operational protection.<br><br>Changes setback to 110% of tower-to-blade tip height from "known" archeological and cultural sites, unless a lesser setback is recommended by the CTUIR. Also adds setback from historic sites, e.g. Oregon Trail. |
| *Proposed Amendments, Feb 24, 2011 Version, page 5*<br><br>(C) The Development and Operation of the Facility will ~~Reasonable efforts shall be taken to~~ protect and ~~to~~ preserve existing trees, vegetation, water resources, wildlife, wildlife habitat, fish, avian, historical, identified by ~~archaeological sites and objects, sites of historic or religious significance to Native American Tribes~~ CTUIR ~~or~~ and other ~~significant~~ natural resources. Compliance with this standard may require mitigation and/or submission of an annual monitoring report. | Clarify wording and specifically identify CTUIR as the Native American Tribe. |
| *Proposed Amendments, Feb 24, 2011 Version, page 6*<br><br>(2) Project Roads.<br>Layout and design of the project roads shall use best management practices in | Removes word "independent" which is vague and could cause confusion. Certification by a civil engineer should not require another "independent" civil engineer review. |

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| consultation with the Soil Water Conservation District. The project road design shall be reviewed and certified by an ~~independent~~ civil engineer. Prior to road construction the applicant shall contact the State Department of Environmental Quality and if necessary, obtain a storm water permit (NPDES). | |
| *Proposed Amendments, Feb 24, 2011 Version, page 8*<br><br>(4) Private ~~A~~ access roads shall be restored ~~removed~~ by removing gravel and restoring the surface grade and soil. | Reworded for clarity only. Pertains to how private access roads will be restored after project is retired. |