To the Umatilla County Planning Commission

Received 1/28/16

Re: Conditional Use Permit Request #C-1252-15

We would like to comment on the proposed Wind project and transmission line on Ferguson Ranch and the line proposed along Staggs Road and York Road. We are owners of land along Staggs Road, Tax lot 4702, and farm tax lot 4701,4700, 4500 and 5400. We own property on York Road, tax lot 3001, and farm tax lot 3000, 2801, 2902, and 2600 . We would like to state our objection to using Staggs Road for any part of this project. We are concerned about the potential loss of ground at the corner of York Road and Johnson Road if the blades and towers come from Highway 11, requiring the widening of that corner. York Road will undoubtedly have to be resurfaced as it is a simple tar and gravel county road, not built for such heavy usage. We also own land along Schrimpf Road and are concerned about the impediment to farming along there if they chose to bring all these wind tower parts that way.

Staggs Road is a dead end road that is 1 ½ miles in length, providing field access for 5 farmers to reach land owned by 10 different landowners. While wheat is the primary crop raised by farmers on this road, and is what I raise, one farmer does raise peas. Two of the fields can be accessed from Ferguson Road, the rest are totally dependent on access via Staggs Road. Of the 5 farmers using this road, 3 are conventional farming operations, and 2 are no-till operations. This road is only minimally maintained by the county, and not open at all in the winter when the snow drifts. There are high banks along this road in a few places making it vulnerable to drifting problems. When the county busts drifts on the road where we live, they push the snow up onto the field, killing wheat underneath that snow pile. We accept this because we want them to get us out, but this is an added long term consequence for us to having Staggs road be the access to the towers for maintenance. This project will result in widening and rebuilding Staggs Road, and extending the road beyond its current length.

Let me take you on a comparison of my operation schedule with their construction schedule. They plan to begin road building in May. That will result in lots of trucks hauling rock and gravel, and road building equipment such as road graders, with Staggs Road being closed to our use at times. In my experience with a county road being rebuilt south of Weston, the road was closed to all farmers until the job was completely finished. It also required placing heavy rock and gravel, grading and rolling just like Staggs Road will. I had another access route to my fields as did the other farmers in this area. We do not have that option on Staggs Road. **In early spring, March & April, I will have sprayed summer fallow fields and my wheat fields. By May, the fields will be ready for me to cultivate, bringing my tractor and cultivator down York and Staggs Roads and back. When weeds start growing, I will need to come in to the same fields with my tractor and rod weeder to work the summer fallow. In June I will be needing to fertilize to prepare for next year's wheat crop, bringing in a tractor and fertilizer applicator,**

along with a truck to service the applicator. Every week I like to come out and check the wheat for diseases and bugs, spot spray for noxious weeds with a utility vehicle. Next on the application schedule comes the wind turbines and towers and blades to be transported on York and Staggs Road in July and August. **We often rod weed before wheat harvest in July, so another trip in and out with the tractor and rod weeder. This is followed by harvesting the wheat, coming in with a big class 9 combine, 3 wheat trucks, fire- fighting equipment, tractor and disc, pickups. We usually haul a truck load of wheat out every 20-30 minutes down Staggs Road, York Road to Highway 11 to Athena. After the wheat is harvested, the straw is baled, so in come swathers and service trucks, followed by balers and service trucks, followed by stackers that stack the bales at the edge of the field. At some point in time, a loader will come in and semi-trucks with double trailers to remove the stack of straw.** In their schedule, they say they will be finished by November. At some point in time, they will be digging a ditch to place the transmission line, installing some marker posts along it, and hopefully putting service boxes underground with subsurface covers rated for vehicle and equipment crossings. **After harvest, I will need to come in and spray for morning glory, bringing a tractor and sprayer, and later come in again with my tractor and rod weeder before I seed the wheat. When I seed in early October, I will come in with the tractor and drills, and a truck that needs to go get more seed wheat from time to time.** This is just what I do. Multiply that by all the other farm operations along these roads, plus the pea operation needing to get in to plant peas in April, with his pre-and post-planting operations, and then several pea combines and lots of trucks coming in in June, and you have quite a lot of traffic on these roads. The farmers all get along, are courteous to each other if we are on the road at the same time, we have not had any problems. Add all the traffic of this construction, and we expect a lot of congestion this summer. My past experience with wind projects has not been good when the blades and towers came in. A pilot car literally ran me off the road into the ditch to tell me to get out of the way on a state highway west of Athena. Other people reported the same treatment. They blew stop signs, and were not courteous to anyone. I reported these incidents to the state police, but with no license numbers, only descriptions, there was no follow up.

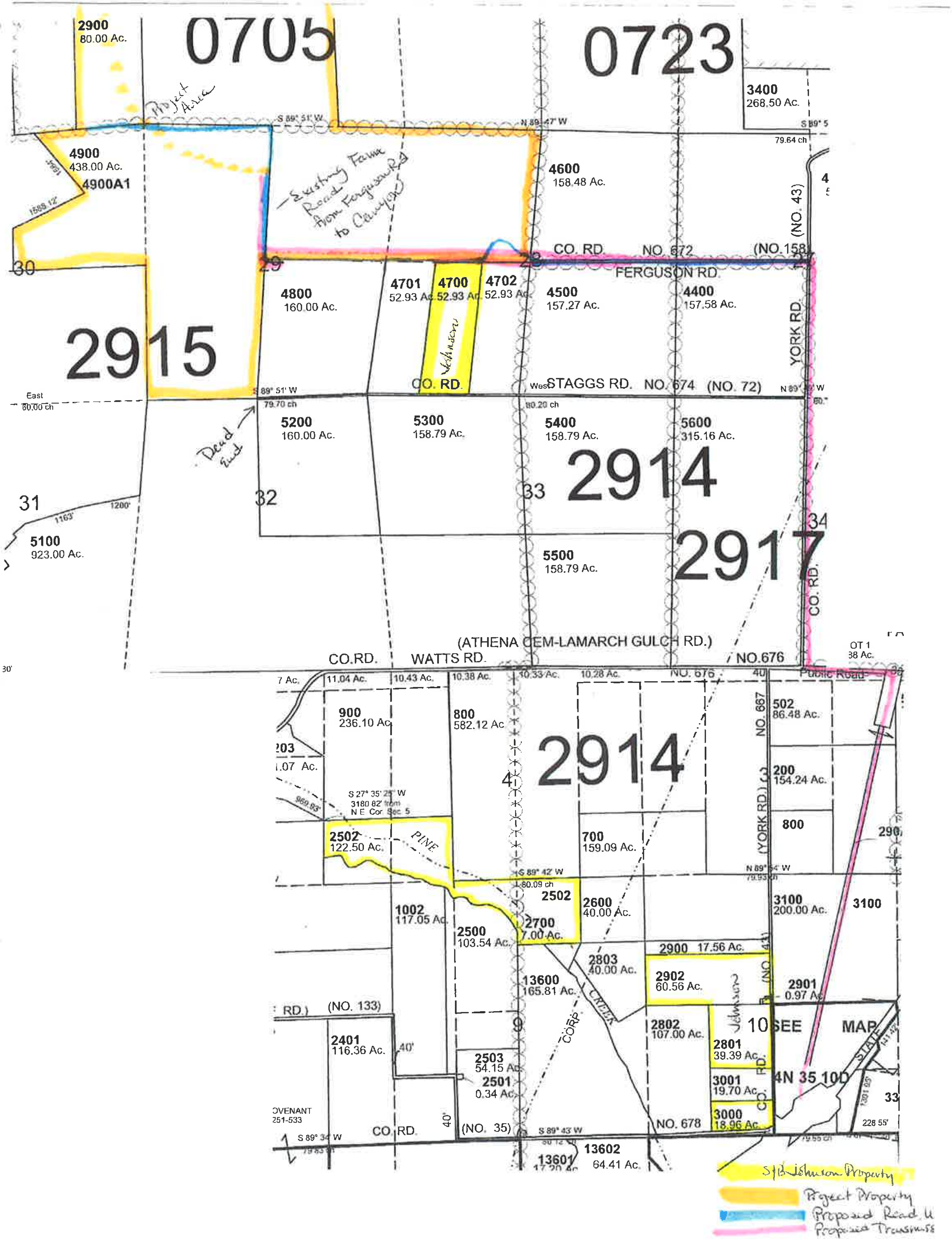
We would like to propose a different location for all the construction and power line instead of Staggs Road. We think Ferguson Road is a much better location as it is closer to the towers, only 1 farmer operates off of that road without another access, he is a no-till farmer which means less trips to his field than conventional farmers need, and he only has to travel ½ mile to his field. The road is wider and already maintained better by the county and kept open in the winter with minimal drifting problems as the field banks are close to the road and flat compared to Staggs Road. There is already a field access road from Ferguson's barn lot near the county road to the area where the towers will be placed. We have a map to illustrate this. There would only have to be a short extension of this field road to the county road, and rock and gravel would have to be added to the field road. We feel since Fergusons are the only beneficiary of this project, the entire project should be on their place and this road, and not involved the neighbors. We saw where a home owner signed a waver for the line to be closer than 500 feet from his house near where the sub-station will be, so it should be no problem to get a waver from the Fergusons to run an underground power line within 500 feet of their house.

We think the power line should go down Ferguson Road to York Road, but at Watts Road it should go east to the Railroad Right of Way, and use that directly to the sub-station near Weston. It would not require any digging in anyone's fields along the south part of York road, would not cause any equipment partially blocking the south part of York road along that long straight stretch from Watts Road to Johnson Road, would go under the Highway 11 overhead along [redacted] the railroad right of way and avoid any need to dig through a line under Johnson Road or the approach to the overhead on Highway 11. Smith Frozen Foods already has an agreement and a water line along this right of way all the way from the plant to the circles in the vicinity of Watts/York/Staggs roads. Trains rarely use the track. Smith has someone drive the water line area periodically to make sure there are no leaks. It would not interfere with any farmer/landowner or road traffic along the south portion of York Road.

We have known the Ferguson family all our lives, and our parents and grandparents were friends. We believe in the right of property owners to do what they want with their land as long as it does not hinder other's rights. We have been good neighbors in allowing them to access their fence at the back of our property, and helped pay for the fencing. However, we think this project hinders our right to our property and farming operation, and think all the construction and power line should be on their property and Ferguson Road and leave Staggs road as the field access road it currently is.

Thank you for your time and consideration of our point of view on this project

Jess and Granella Thompson


0705
0723
2915
2914
2917
Project Area
Existing Farm Road from Ferguson Rd to Canyon
Dead End
CO. RD. NO. 672 (NO. 158)
FERGUSON RD.
STAGGS RD. NO. 674 (NO. 72)
YORK RD.
(NO. 43)
(ATHENA CEM-LAMARCH GULCH RD.)
CO.RD. WATTS RD.
NO.676
PINE
CORP
CREEK
NO. 678
(NO. 133)
(NO. 35)
4N 35 10D
SEE MAP
2900 80.00 Ac.
3400 268.50 Ac.
4900 438.00 Ac.
4900A1
4600 158.48 Ac.
4800 160.00 Ac.
4701 52.93 Ac.
4700 52.93 Ac.
4702 52.93 Ac.
4500 157.27 Ac.
4400 157.58 Ac.
5200 160.00 Ac.
5300 158.79 Ac.
5400 158.79 Ac.
5600 315.16 Ac.
5100 923.00 Ac.
5500 158.79 Ac.
900 236.10 Ac
800 582.12 Ac
502 86.48 Ac.
200 154.24 Ac.
800
2502 122.50 Ac.
700 159.09 Ac.
1002 117.05 Ac
2502
2700 7.00 Ac.
2500 103.54 Ac.
2600 40.00 Ac.
3100 200.00 Ac.
3100
2900 17.56 Ac.
2803 40.00 Ac.
2902 60.56 Ac.
2901 0.97 Ac
13600 165.81 Ac.
2802 107.00 Ac.
2801 39.39 Ac.
3001 19.70 Ac.
3000 18.96 Ac.
2401 116.36 Ac.
2503 54.15 Ac
2501 0.34 Ac
13602 64.41 Ac.
13601
Johnson
S/B Johnson Property
Project Property
Proposed Road
Proposed Transmiss

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Received 1/28/16

UMATILLA COUNTY PLANNING COMMISSION HEARING
JANUARY 28, 2016

CHOPIN WIND PROJECT
DEVELOPMENT APPLICATION
SUBMITTED – AUGUST 13, 2015

Wind Energy has been around Umatilla County for 20 plus years and expanded to the point of wind projects from the Athena/Helix area north and west to the Columbia River and beyond. Wind Energy projects expanded to the point of causing serious concerns in Umatilla County.

An effort to recognize these concerns was identified with the need to revise the county ordinances. After many hearings, testimony, and much time, effort and expense, the County Ordinance Revision of 152.616 HHH was completed and approved in June, 2011. Legal challenges delayed implementation until November, 2013.

The Revised Ordinance 152.616 HHH is very important to Umatilla County and it is expected to be **implemented fully and without exception**. I commend the county and the applicant for their efforts to assure this proposed project will comply with 152.616 HHH and other applicable Umatilla County Ordinances.

That is not to say that there are no concerns. While the application at face value appears to comply, there are some areas that are cause for caution in approving this application. While the information presented does demonstrate full compliance with the 2 mile setback, there are a few residences that are outside the distance limit but, very close to the limit. Experience has shown that previous projects **"proposed"** location of projects rarely are the same **"as constructed"** locations.

As several of these residences are close to the limit, this becomes a concern as to final turbine location. There is very limited flexibility in turbine location. To recognize this concern, it is suggested that a verification **of final turbine location** be a Condition of Approval for the Conditional Use Permit.

The Wildlife Section of the Application uses data from the original application, which is five to six years old. It is recognized that the proposed project is a scaled down version of the original application. The newly submitted Wildlife Section should be adequate. However, in Attachment #12 in a letter submitted by West, Inc. dated March 12, 2015, West recommends "A Raptor Nest Survey before construction begins", **as well as a Post Construction Monitoring of Impacts** in order to minimize and avoid mitigation potential development impacts." I believe that this issue is adequately addressed in Chapter 5, Attachment 7, Page 8 of the application.

The Transmission Section of the application apparently raised concerns from adjacent land owners about the impact on Agriculture Operations. Based on the present proposed application, the applicant has proposed an underground transmission system to mitigate these concerns. I commend the applicant on their efforts to settle these concerns and other issues pertaining to the transmission proposed.

This Application submitted by Bay Wa represents a new era for Wind Energy in Umatilla County. The effort and cooperation the applicant has demonstrated is commendable.
Umatilla County expended a large amount of resources and effort to achieve the Revised Ordinance 152.616 HHH. The respect and cooperation demonstrated by Bay Wa is encouraging.

Sincerely,

Dave Price
80488 Zerba Road
Athena, Oregon 97813

BayWa r.e.
renewable energy

PROJECT CHOPIN

REFERENCE STUDIES

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BayWa r.e.
renewable energy

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LBNL-6362E

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BERKELEY NATIONAL LABORATORY

A Spatial Hedonic Analysis of the Effects of Wind Energy Facilities on Surrounding Property Values in the United States

Ben Hoen, Jason P. Brown, Thomas Jackson, Ryan Wiser, Mark Thayer and Peter Cappers

Environmental Energy Technologies Division

August 2013

This work was supported by the Office of Energy Efficiency and Renewable Energy (Wind and Water Power Technologies Office) of the U.S. Department of Energy under Contract No. DE-AC02-05CH1123.

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Disclaimer

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LBNL-6362E

A Spatial Hedonic Analysis of the Effects of Wind Energy Facilities on Surrounding Property Values in the United States

Prepared for the

Office of Energy Efficiency and Renewable Energy
Wind and Water Power Technologies Office
U.S. Department of Energy

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August 2013

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Abstract

Previous research on the effects of wind energy facilities on surrounding home values has been limited by small samples of relevant home-sale data and the inability to account adequately for confounding home-value factors and spatial dependence in the data. This study helps fill those gaps. We collected data from more than 50,000 home sales among 27 counties in nine states. These homes were within 10 miles of 67 different wind facilities, and 1,198 sales were within 1 mile of a turbine—many more than previous studies have collected. The data span the periods well before announcement of the wind facilities to well after their construction. We use OLS and spatial-process difference-in-difference hedonic models to estimate the home-value impacts of the wind facilities; these models control for value factors existing before the wind facilities' announcements, the spatial dependence of unobserved factors effecting home values, and value changes over time. A set of robustness models adds confidence to our results. Regardless of model specification, we find no statistical evidence that home values near turbines were affected in the post-construction or post-announcement/pre-construction periods. Previous research on potentially analogous disamenities (e.g., high-voltage transmission lines, roads) suggests that the property-value effect of wind turbines is likely to be small, on average, if it is present at all, potentially helping to explain why no evidence of an effect was found in the present research.

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1. Introduction

In 2012, approximately 13 gigawatts (GW) of wind turbines were installed in the United States, bringing total U.S. installed wind capacity to approximately 60 GW from more than 45,000 turbines (AWEA, 2013). Despite uncertainty about future extensions of the federal production tax credit, U.S. wind capacity is expected by some to continue growing by approximately 5–6 GW annually owing to state renewable energy standards and areas where wind can compete with natural gas on economics alone (Bloomberg, 2013); this translates into approximately 2,750 turbines per year.[1] Much of that development is expected to occur in relatively populated areas (e.g., New York, New England, the Mid-Atlantic and upper Midwest) (Bloomberg, 2013).

In part because of the expected wind development in more-populous areas, empirical investigations into related community concerns are required. One concern is that the values of properties near wind developments may be reduced; after all, it has been demonstrated that in some situations market perceptions about an area's disamenities (and amenities)[2] are capitalized into home prices (e.g., Boyle and Kiel, 2001; Jackson, 2001; Simons and Saginor, 2006). The published research about wind energy and property values has largely coalesced around a finding that homes sold after nearby wind turbines have been constructed do not experience statistically significant property value impacts. Additional research is required, however, especially for homes located within about a half mile of turbines, where impacts would be expected to be the largest. Data and studies are limited for these proximate homes in part because setback requirements generally result in wind facilities being sited in areas with relatively few houses, limiting available sales transactions that might be analyzed.

This study helps fill the research gap by collecting and analyzing data from 27 counties across nine U.S. states, related to 67 different wind facilities. Specifically, using the collected data, the study constructs a pooled model that investigates average effects near the turbines across the sample while controlling for the local effects of many potentially correlated independent variables. Property-value effect estimates are derived from two types of models: (1) an ordinary

[1] Assuming 2-MW turbines, the 2012 U.S. average (AWEA, 2013), and 5.5 GW of annual capacity growth.

[2] Disamenities and amenities are defined respectively as disadvantages (e.g., a nearby noxious industrial site) and advantages (e.g., a nearby park) of a location.

least squares (OLS) model, which is standard for this type of disamenity research (see, e.g., discussion in Jackson, 2003; Sirmans et al., 2005), and (2) a spatial-process model, which accounts for spatial dependence. Each type of model is used to construct a difference-in-difference (DD) specification—which simultaneously controls for preexisting amenities or disamenities in areas where turbines were sited and changes in the community after the wind facilities' construction was announced—to estimate effects near wind facilities after the turbines were announced and, later, after the turbines were constructed.[3]

The remainder of the report is structured as follows. Section 2 reviews the current literature. Section 3 details our methodology. Section 4 describes the study data. Section 5 presents the results, and Section 6 provides a discussion and concluding remarks.

2. Previous Literature

Although the topic is relatively new, the peer-reviewed literature investigating impacts to home values near wind facilities is growing. To date, results largely have coalesced around a common set of non-significant findings generated from home sales after the turbines became operational. Previous Lawrence Berkeley National Laboratory (LBNL) work in this area (Hoen et al., 2009, 2011) found no statistical evidence of adverse property-value effects due to views of and proximity to wind turbines after the turbines were constructed (i.e., post-construction or PC). Other peer-reviewed and/or academic studies also found no evidence of PC effects despite using a variety of techniques and residential transaction datasets. These include homes surrounding wind facilities in Cornwall, United Kingdom (Sims and Dent, 2007; Sims et al., 2008); multiple wind facilities in McLean County, Illinois (Hinman, 2010); near the Maple Ridge Wind Facility in New York (Heintzelman and Tuttle, 2011); and, near multiple facilities in Lee County, Illinois (Carter, 2011). Analogously, a 2012 Canadian case found a lack of evidence near a wind facility in Ontario to warrant the lowering of surrounding assessments (Kenney v MPAC, 2012). In contrast, one recent study did find impacts to land prices near a facility in North Rhine-Westphalia, Germany (Sunak and Madlener, 2012). Taken together, these results imply that the

[3] Throughout this report, the terms "announced/announcement" and "constructed/construction" represent the dates on which the proposed wind facility (or facilities) entered the public domain and the dates on which facility construction began, respectively. Home transactions can either be pre-announcement (PA), post-announcement/pre-construction (PAPC), or post-construction (PC).

PC effects of wind turbines on surrounding home values, if they exist, are often too small for detection or sporadic (i.e., a small percentage overall), or appearing in some communities for some types of properties but not others.

In the post-announcement, pre-construction period (i.e., PAPC), however, recent analysis has found more evidence of potential property value effects: by theorizing the possible existence of, but not finding, an effect (Laposa and Mueller, 2010; Sunak and Madlener, 2012); potentially finding an effect (Heintzelman and Tuttle, 2011)[4]; and, consistently finding what the author terms an "anticipation stigma" effect (Hinman, 2010). The studies that found PAPC property-value effects appear to align with earlier studies that suggested lower community support for proposed wind facilities before construction—potentially indicating a risk-averse (i.e., fear of the unknown) stance by community members—but increased support after facilities began operation (Gipe, 1995; Palmer, 1997; Devine-Wright, 2005; Wolsink, 2007; Bond, 2008, 2010). Similarly, researchers have found that survey respondents who live closer to turbines support the turbines more than respondents who live farther away (Braunholtz and MORI Scotland, 2003; Baxter et al., 2013), which could also indicate more risk-adverse / fear of the unknown effects (these among those who live farther away). Analogously, a recent case in Canada, although dismissed, highlighted the fears that nearby residents have for a planned facility (Wiggins v. WPD Canada Corporation, 2013)

Some studies have examined property-value conditions existing before wind facilities were announced (i.e., pre-announcement or PA). This is important for exploring correlations between wind facility siting and pre-existing home values from an environmental justice perspective and also for measuring PAPC and PC effects more accurately. Hoen et al. (2009, 2011) and Sims and Dent (2007) found evidence of depressed values for homes that sold before a wind facility's announcement and were located near the facility's eventual location, but they did not adjust their PC estimates for this finding. Hinman (2010) went further, finding value reductions of 12%–20% for homes near turbines in Illinois, which sold prior to the facilities' announcements; then using these findings to deflate their PC home-value-effect estimates.

[4] Heintzelman and Tuttle do not appear convinced that the effect they found is related to the PAPC period, yet the two counties in which they found an effect (Clinton and Franklin Counties, NY) had transaction data produced almost entirely in the PAPC period.

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Some research has linked wind-related property-value effects with the effects of better-studied disamenities (Hoen et al., 2009). The broader disamenity literature (e.g., Boyle and Kiel, 2001; Jackson, 2001; Simons and Saginor, 2006) suggests that, although property-value effects might occur near wind facilities as they have near other disamenities, those effects (if they do exist) are likely to be relatively small, are unlikely to persist some distance from a facility, and might fade over time as home buyers who are more accepting of the condition move into the area (Tiebout, 1956).

For example, a review of the literature investigating effects near high-voltage transmission lines (a largely visual disturbance, as turbines may be for many surrounding homes) found the following: property-value reductions of 0%–15%; effects that fade with distance, often only affecting properties crossed by or immediately adjacent to a line or tower; effects that can increase property values when the right-of-way is considered an amenity; and effects that fade with time as the condition becomes more accepted (Kroll and Priestley, 1992). While potentially much more objectionable to residential communities than turbines, a review of the literature on landfills (which present odor, traffic, and groundwater-contamination issues) indicates effects that vary by landfill size (Ready, 2010). Large-volume operations (accepting more than 500 tons per day) reduce adjacent property values by 13.7% on average, fading to 5.9% one mile from the landfill. Lower-volume operations reduce adjacent property values by 2.7% on average, fading to 1.3% one mile away, with 20%–26% of lower-volume landfills not having any statistically significant impact. A study of 1,600 toxic industrial plant openings found adverse impacts of 1.5% within a half mile, which disappeared if the plants closed (Currie et al., 2012). Finally, a review of the literature on road noise (which might be analogous to turbine noise) shows property-value reductions of 0% –11% (median 4%) for houses adjacent to a busy road that experience a 10-dBA noise increase, compared with houses on a quiet street (Bateman et al., 2001).

It is not clear where wind turbines might fit into these ranges of impacts, but it seems unlikely that they would be considered as severe a disamenity as a large-volume landfill, which present odor, traffic, and groundwater-contamination issues. Low-volume landfills, with an effect near 3%, might be a better comparison, because they have an industrial (i.e., non-natural) quality, similar to turbines, but are less likely to have clear health effects. If sound is the primary concern, a 4% effect (corresponding to road noise) could be applied to turbines, which might correspond to a 10-dBA increase for houses within a half mile of a turbine (see e.g., Hubbard and Shepherd, 1991). Finally, as with transmission lines, if houses are in sight but not within sound distance of turbines, there may be no property-value effects unless those homes are immediately adjacent to the turbines. In summary, assuming these potentially analogous disamenity effects can be entirely transferred, turbine impacts might be 0%–14%, but more likely might coalesce closer to 3%–4%.

Of course, wind turbines have certain positive qualities that landfills, transmission lines, and roads do not always have, such as mitigating greenhouse gas emissions. no air or water pollution, no use of water during the generation of energy, and no generation of solid or hazardous waste that requires permanent storage/disposal (IPCC, 2011). Moreover, wind facilities can, and often do, provide economic benefits to local communities (Lantz and Tegen, 2009; Slattery et al., 2011; Brown et al., 2012; Loomis et al., 2012), which might not be the case for all other disamenities. Similarly, wind facilities can have direct positive effects on local government budgets through property tax or other similar payments (Loomis and Aldeman, 2011), which might, for example, improve school quality and thus increase nearby home values (e.g., Haurin and Brasington, 1996; Kane et al., 2006). These potential positive qualities might mitigate potential negative wind effects somewhat or even entirely. Therefore for the purposes of this research we will assume 3-4% is a maximum possible effect.

The potentially small average property-value effect of wind turbines, possibly reduced further by wind's positive traits, might help explain why effects have not been discovered consistently in previous research. To discover effects with small margins of error, large amounts of data are needed. However, previous datasets of homes very near turbines have been small. Hoen et al. (2009, 2011) used 125 PC transactions within a mile of the turbines, while others used far fewer PC transactions within a mile: Heintzelman and Tuttle (2012) ($n \sim 35$); Hinman (2010) ($n \sim 11$), Carter (2011) ($n \sim 41$), and Sunak and Madlener (2012) ($n \sim 51$). Although these numbers of observations are adequate to examine large impacts (e.g., over 10%), they are less likely to reveal small effects with any reasonable degree of statistical significance. Using results from Hoen et al. (2009) and the confidence intervals for the various fixed-effect variables in that study, estimates for the numbers of transactions needed to find effects of various sizes were obtained.

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Approximately 50 cases are needed to find an effect of 10% and larger, 100 cases for 7.5%, 200 cases for 5%, 350 cases for 4%, 700 cases for 3%, and approximately 1,000 cases for a 2.5% effect.[5] Therefore, in order to detect an effect in the range of 3%–4%, a dataset of approximately 350–700 cases within a mile of the turbines will be required to detect it statistically, a number that to-date has not been amassed by any of the previous studies.

As discussed above, in addition to being relatively small on average, impacts are likely to decay with distance. As such, an appropriate empirical approach must be able to reveal spatially diminishing effects. Some researchers have used continuous variables to capture these effects, such as linear distance (Hoen et al., 2009; Sims et al., 2008) and inverse distance (Heintzelman and Tuttle, 2012; Sunak and Madlener, 2012), but doing so forces the model to estimate effects at the mean distance. In some cases, those means can be far from the area of expected impact. For example, Heintzelman and Tuttle (2012) estimated an inverse distance effect using a mean distance of more than 10 miles from the turbines, while Sunak and Madlener (2012) used a mean distance of approximately 1.9 miles. Using this approach weakens the ability of the model to quantify real effects near the turbines, where they are likely to be stronger. More importantly, this method encourages researchers to extrapolate their findings to the ends of the distance curve, near the turbines, despite having few data at those distances to support these extrapolations. This was the case for Heintzelman and Tuttle (2012), who had fewer than 10 cases within a half mile in the two counties where effects were found and only a handful that sold in those counties after the turbines were built, yet they extrapolated their findings to a quarter mile and even a tenth of a mile, where they had very few (if any) cases. Similarly, Sunak and Madlener (2012) had only six PC sales within a half mile and 51 within 1 mile, yet they extrapolated their findings to these distance bands.

One way to avoid using a single continuous function to estimate effects at all distances is to use a spline model, which breaks the distances into continuous groups (Hoen et al., 2011), but this method still imposes structure on the data by forcing the ends of each spline to tie together. A second and more transparent method is to use fixed-effect variables for discrete distances, which imposes little structure on the data (Hoen et al., 2009; Hinman, 2010; Carter, 2011; Hoen et al.,

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[5] This analysis is available upon request from the authors.

2011). Although this latter method has been used in a number of studies, because of a paucity of data, the resulting models are often ineffective at detecting what might be relatively small effects very close to the turbines. As such, when using this method (or any other, in fact) it is important that the underlying dataset is large enough to estimate the anticipated magnitude of the effect sizes.

Finally, one rarely investigated aspect of potential wind-turbine effects is the possibly idiosyncratic nature of spatially averaged transaction data used in the hedonic analyses. Sunak and Madlener (2012) used a geographically weighted regression (GWR), which estimates different regressions for small clusters of data and then allows the investigation of the distribution of effects across all of the clusters. Although GWR can be effective for understanding the range of impacts across the study area, it is not as effective for determining an average effect or for testing the statistical significance of the range of estimates. Results from studies that use GWR methods are also sometimes counter-intuitive.[6] As is discussed in more detail in the methodology section, a potentially better approach is to estimate a spatial-process model that is flexible enough to simultaneously control for spatial heterogeneity and spatial dependence, while also estimating an average effect across fixed discrete effects.

In summary, building on the existing literature, further research is needed on property-value effects in particularly close proximity to wind turbines. Specifically, research is needed that uses a large set of data near the turbines, accounts for home values before the announcement of the facility (as well as after announcement but before construction), accounts for potential spatial dependence in unobserved factors effecting home values, and uses a fixed-effect distance model that is able to accurately estimate effects near turbines.

3. Methodology

The present study seeks to respond to the identified research needs noted above, with this section describing our methodological framework for estimating the effects of wind turbines on the value of nearby homes in the United States.

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[6] For example, Sunak and Madlener (2012) find larger effects related to the turbines in a city that is farther from the turbines than they find in a town which is closer. Additionally, they find stronger effects in the center of a third town than they do on the outskirts of that town, which do not seem related to the location of the turbines.

3.1. Basic Approach and Models

Our methods are designed to help answer the following questions:

1. Did homes that sold prior to the wind facilities' announcement (PA)—and located within a short distance (e.g., within a half mile) from where the turbines were eventually located—sell at lower prices than homes located farther away?
2. Did homes that sold after the wind facilities' announcement but before construction (PAPC)—and located within a short distance (e.g., within a half mile)—sell at lower prices than homes located farther away?
3. Did homes that sold after the wind facilities' construction (PC)—and located within a short distance (e.g., within a half mile)—sell at lower prices than homes located farther away?
4. For question 3 above, if no statistically identifiable effects are found, what is the likely maximum effect possible given the margins of error around the estimates?

To answer these questions, the hedonic pricing model (Rosen, 1974; Freeman, 1979) is used in this paper, as it has been in other disamenity research (Boyle and Kiel, 2001; Jackson, 2001; Simons and Saginor, 2006). The value of this approach is that is allows one to disentangle and control for the potentially competing influences of home, site, neighborhood, and market characteristics on property values, and to uniquely determine how home values near announced or operating facilities are affected.[7] To test for these effects, two pairs of "base" models are estimated, which are then coupled with a set of "robustness" models to test and bound the estimated effects. One pair is estimated using a standard OLS model, and the other is estimated using a spatial-process model. The models in each pair are different in that one focuses on all homes within 1 mile of an existing turbine (*one-mile* models), which allows the maximum number of data for the fixed effect to be used, while the other focuses on homes within a half mile (*half-mile* models), where effects are more likely to appear but fewer data are available. We assume that, if effects exist near turbines, they are larger for the *half-mile* models than the *one-mile* models.

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[7] See Jackson (2003) for a further discussion of the Hedonic Pricing Model and other analysis methods.

As is common in the literature (Malpezzi, 2003; Sirmans et al., 2005), a semi-log functional form of the hedonic pricing model is used for all models, where the dependent variable is the natural log of sales price. The OLS *half-mile* model form is as follows:

$$\ln(SP_i) = \alpha + \sum_a \beta_1(T_i \bullet S_i) + \beta_2(W_i) + \sum_b \beta_3(X_i \bullet C_i) + \beta_4(D_i \bullet P_i) + \varepsilon_i \quad (1)$$

where

SP_i represents the sale price for transaction i,

α is the constant (intercept) across the full sample,

T_i is a vector of time-period dummy variables (e.g., sale year and if the sale occurred in winter) in which transaction i occurred,

S_i is the state in which transaction i occurred,

W_i is the census tract in which transaction i occurred,

X_i is a vector of home, site, and neighborhood characteristics for transaction i (e.g., square feet, age, acres, bathrooms, condition, percent of block group vacant and owned, median age of block group),[8]

C_i is the county in which transaction i occurred,

D_i is a vector of four fixed-effect variables indicating the distance (to the nearest turbine) bin (i.e., group) in which transaction i is located (e.g., within a half mile, between a half and 1 mile, between 1 and 3 miles, and between 3 and 10 miles),

P_i is a vector of three fixed-effect variables indicating the wind project development period in which transaction i occurred (e.g., PA, PAPC, PC),

$B_{1\text{-}3}$ is a vector of estimates for the controlling variables,

B_4 is a vector of 12 parameter estimates of the distance-development period interacted variables of interest,

ε_i is a random disturbance term for transaction i.

This pooled construction uses all property transactions in the entire dataset. In so doing, it takes advantage of the large dataset in order to estimate an average set of turbine-related effects across all study areas, while simultaneously allowing for the estimation of controlling characteristics at

[8] A "block group" is a US Census Bureau geographic delineation that contains a population between 600 to 3000 persons.

the local level, where they are likely to vary substantially across the study areas.[9] Specifically, the interaction of county-level fixed effects (C_i) with the vector of home, site, and neighborhood characteristics (X_i) allows different slopes for each of these independent variables to be estimated for each county. Similarly, interacting the state fixed-effect variables (S_i) with the sale year and sale winter fixed effects variables (T_i) (i.e., if the sale occurred in either Q1 or Q4) allows the estimation of the respective inflation/deflation and seasonal adjustments for each state in the dataset.[10] Finally, to control for the potentially unique collection of neighborhood characteristics that exist at the micro-level, census tract fixed effects are estimated.[11] Because a pooled model is used that relies upon the full dataset, smaller effect sizes for wind turbines will be detectable. At the same time, however, this approach does not allow one to distinguish possible wind turbine effects that may be larger in some communities than in others.

As discussed earlier, effects might predate the announcement of the wind facility and thus must be controlled for. Additionally, the area surrounding the wind facility might have changed over time simultaneously with the arrival of the turbines, which could affect home values. For example, if a nearby factory closed at the same time a wind facility was constructed, the influence of that factor on all homes in the general area would ideally be controlled for when estimating wind turbine effect sizes.

To control for both of these issues simultaneously, we use a difference-in-difference *(DD)* specification (see e.g., Hinman, 2010; Zabel and Guignet, 2012) derived from the interaction of

[9] The dataset does not include "participating" landowners, those that have turbines situated on their land, but does include "neighboring" landowners, those adjacent to or nearby the turbines. One reviewer notes that the estimated average effects also include any effects from payments "neighboring" landowners might receive that might transfer with the home. Based on previous conversations with developers (see Hoen et al, 2009), we expect that the frequency of these arrangements is low, as is the right to transfer the payments to the new homeowner. Nonetheless, our results should be interpreted as "net" of any influence whatever "neighboring" landowner arrangements might have.

[10] Unlike the vector of home, site, and neighborhood characteristics, sale price inflation/deflation and seasonal changes were not expected tovary substantially across various counties in the same states in our sample and therefore the interaction was made at the state level. This assumption was tested as part of the robustness tests though, where they are interacted at the county level and found to not affect the results.

[11] In part because of the rural nature of many of the study areas included in the research sample, these census tracts are large enough to contain sales that are located close to the turbines as well as those farther away, thereby ensuring that they do not unduly absorb effects that might be related to the turbines. Moreover each tract contains sales from throughout the study periods, both before and after the wind facilities' announcement and construction, further ensuring they are not biasing the variables of interest.

the spatial (D_i) and temporal (P_i) terms. These terms produce a vector of 11 parameter estimates (β_4) as shown in Table 1 for the *half-mile* models and in Table 2 for the *one-mile* models. The omitted (or reference) group in both models is the set of homes that sold prior to the wind facilities' announcement and which were located more than 3 miles away from where the turbines were eventually located (A3). It is assumed that this reference category is likely not affected by the imminent arrival of the turbines, although this assumption is tested in the robustness tests.

Using the *half-mile* models, to test whether the homes located near the turbines that sold in the PA period were uniquely affected (*research question 1*), we examine A0, from which the null hypothesis is A0=0. To test if the homes located near the turbines that sold in the PAPC period were uniquely affected (*research question 2*), we first determine the difference in their values as compared to those farther away (B0-B3), while also accounting for any pre-announcement (i.e., pre-existing) difference (A0-A3) and any change in the local market over the development period (B3-A3). Because all covariates are determined in relation to the omitted category (A3), the null hypothesis collapses B0-A0-B3=0. Finally, in order to determine if homes near the turbines that sold in the PC period were uniquely affected (*research question 3*), we test if C0-A0-C3=0. Each of these *DD* tests are estimated using a linear combination of variables that produces the "net effect" and a measure of the standard error and corresponding confidence intervals of the effect, which enables the estimation of the maximum (and minimum) likely impacts for each research question. We use 90% confidence intervals both to determine significance and to estimate maximum likely effects (*research question 4*).

Following the same logic as above, the corresponding hypothesis tests for the *one-mile* models are as follows: *PA*, A1=0; *PAPC*, B1-A1-B3=0; and, *PC,* C1-A1-C3=0.

Table 1: Interactions between Wind Facility Development Periods and Distances – ½ Mile

Wind Facility Development Periods	Distances to Nearest Turbine: Within 1/2 Mile	Between 1/2 and 1 Mile	Between 1 and 3 Miles	Outside of 3 Miles
Prior to Announcement	A0	A1	A2	A3 (Omitted)
After Announcement but Prior to Construction	B0	B1	B2	B3
Post Construction	C0	C1	C2	C3

Table 2: Interactions between Wind Facility Development Periods and Distances - 1 Mile

Wind Facility Development Periods	Distances to Nearest Turbine: Within 1 Mile	Between 1 and 3 Miles	Outside of 3 Miles
Prior to Announcement	A1	A2	A3 (Omitted)
After Announcement but Prior to Construction	B1	B2	B3
Post Construction	C1	C2	C3

3.2. Spatial Dependence

As discussed briefly above, a common feature of the data used in hedonic models is the spatially dense nature of the real estate transactions. While this spatial density can provide unique insights into local real estate markets, one concern that is often raised is the impact of potentially omitted variables given that this is impossible to measure all of the local characteristics that affect housing prices. As a result, spatial dependence in a hedonic model is likely because houses located closer to each other typically have similar unobservable attributes. Any correlation between these unobserved factors and the explanatory variables used in the model (e.g., distance to turbines) is a source of omitted-variable bias in the OLS models. A common approach used in the hedonic literature to correct this potential bias is to include local fixed effects (Hoen et al., 2009, 2011; Zabel and Guignet, 2012), which is our approach as described in formula (1).

In addition to including local fixed effects, spatial econometric methods can be used to help further mitigate the potential impact of spatially omitted variables by modeling spatial dependence directly. When spatial dependence is present and appropriately modeled, more accurate (i.e., less biased) estimates of the factors influencing housing values can be obtained. These methods have been used in a number of previous hedonic price studies; examples include the price impacts of wildfire risk (Donovan et al., 2007), residential community associations (Rogers, 2006), air quality (Anselin and Lozano-Gracia, 2009), and spatial fragmentation of land use (Kuethe, 2012). To this point, however, these methods have not been applied to studies of the impact of wind turbines on property values.

Moran's I is the standard statistic used to test for spatial dependence in OLS residuals of the hedonic equation. If the Moran's I is statistically significant (as it is in our models – see Section 5.1.2), the assumption of spatial independence is rejected. To account for this, in spatial-process models, spatial dependence is routinely modeled as an additional covariate in the form of a spatially lagged dependent variable *Wy*, or in the error structure $\mu = \lambda W\mu + \varepsilon$, where ε is an identically and independently distributed disturbance term (Anselin, 1988). Neighboring criterion determines the structure of the spatial weights matrix *W*, which is frequently based on contiguity, distance criterion, or *k*-nearest neighbors (Anselin, 2002). The weights in the spatial-weights matrix are typically row standardized so that the elements of each row sum to one.

The spatial-process model, known as the SARAR model (Kelejian and Prucha, 1998)[12], allows for both forms of spatial dependence, both as an autoregressive process in the lag-dependent and in the error structure, as shown by:

$$\begin{aligned} y &= \rho Wy + X\beta + \mu, \\ \mu &= \lambda W\mu + \varepsilon. \end{aligned} \quad (2)$$

[12] SARAR refers to a "spatial-autoregressive model with spatial autoregressive residuals".

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Equation (2) is often estimated by a multi-step procedure using generalized moments and instrumental variables (Arraiz et al., 2009), which is our approach. The model allows for the innovation term ε in the disturbance process to be heteroskedastic of an unknown form (Kelejian and Prucha, 2010). If either λ or ρ are not significant, the model reduces to the respective spatial lag or spatial error model (SEM). In our case, as is discussed later, the spatial process model reduces to the SEM, therefore both *half-mile* and *one-mile* SEMs are estimated, and, as with the OLS models discussed above, a similar set of *DD* "net effects" are estimated for the PA, PAPC, and PC periods. One requirement of the spatial model is that the x/y coordinates be unique across the dataset. However, the full set of data (as described below) contains, in some cases, multiple sales for the same property, which consequently would have non-unique x/y coordinates.[13] Therefore, for the spatial models, only the most recent sale is used. An OLS model using this limited dataset is also estimated as a robustness test.

In total, four "base" models are estimated: an OLS *one-mile* model, a SEM *one-mile* model, an OLS *half-mile* model, and a SEM *half-mile* model. In addition, a series of robustness models are estimated as described next.

3.3. Robustness Tests

To test the stability of and potentially bound the results from the four base models, a series of robustness tests are conducted that explore: the effect that outliers and influential cases have on the results; a micro-inflation/deflation adjustment by interacting the sale-year fixed effects with the county fixed effects rather than state fixed effects; the use of only the most recent sale of homes in the dataset to compare results to the SEM models that use the same dataset; the application of a more conservative reference category by using transactions between 5 and 10 miles (as opposed to between 3 and 10 miles) as the reference; and a more conservative

[13] The most recent sale weights the transactions to those occurring after announcement and construction, that are more recent in time. One reviewer wondered if the frequency of sales was affected near the turbines, which is also outside the scope of the study, though this "sales volume" was investigated in Hoen et al. (2009), where no evidence of such an effect was discovered. Another correctly noted that the most recent assessment is less accurate for older sales, because it might overestimate some characteristics of the home (e.g., sfla, baths) that might have changed (i.e., increased) over time. This would tend to bias those characteristics' coefficients downward. Regardless, it is assumed that this occurrence is not correlated with proximity to turbines and therefore would not bias the variables of interest.

reference category by using transactions more than 2 years PA (as opposed to simply PA) as the reference category. Each of these tests is discussed in detail below.

3.3.1. Outliers and Influential Cases

Most datasets contain a subset of observations with particularly high or low values for the dependent variables, which might bias estimates in unpredictable ways. In our robustness test, we assume that observations with sales prices above or below the 99% and 1% percentile are potentially problematic outliers. Similarly, individual sales transactions and the values of the corresponding independent variables might exhibit undue influence on the regression coefficients. In our analysis, we therefore estimate a set of Cook's Distance statistics (Cook, 1977; Cook and Weisberg, 1982) on the base OLS *half-mile* model and assume any cases with an absolute value of this statistic greater than one to be potentially problematic influential cases. To examine the influence of these cases on our results, we estimate a model with both the outlying sales prices and Cook's influential cases removed.

3.3.2. Interacting Sale Year at the County Level

It is conceivable that housing inflation and deflation varied dramatically in different parts of the same state. In the base models, we interact sale year with the state to account for inflation and deflation of sales prices, but a potentially more-accurate adjustment might be warranted. To explore this, a model with the interaction of sale year and county, instead of state, is estimated.

3.3.3. Using Only the Most Recent Sales

The dataset for the base OLS models includes not only the most recent sale of particular homes, but also, if available, the sale prior to that. Some of these earlier sales occurred many years prior to the most recent sale. The home and site characteristics (square feet, acres, condition, etc.) used in the models are populated via assessment data for the home. For some of these data, only the most recent assessment information is available (rather than the assessment from the time of sale), and therefore older sales might be more prone to error as their characteristics might have

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changed since the sale.[14] Additionally, the SEMs require that all x/y coordinates entered into the model are unique; therefore, for those models only the most recent sale is used. Excluding older sales therefore potentially reduces measurement error, and also enables a more-direct comparison of effects between the base OLS model and SEM results.

3.3.4. Using Homes between 5 and 10 Miles as Reference Category

The base models use the collection of homes between 3 and 10 miles from the wind facility (that sold before the announcement of the facility) as the reference category in which wind facility effects are not expected. However, it is conceivable that wind turbine effects extend farther than 3 miles. If homes outside of 3 miles are affected by the presence of the turbines, then effects estimated for the target group (e.g., those inside of 1 mile) will be biased downward (i.e., smaller) in the base models. To test this possibility and ensure that the results are not biased, the group of homes located between 5 and 10 miles is used as a reference category as a robustness test.

3.3.5. Using Transactions Occurring More than 2 Years before Announcement as Reference Category

The base models use the collection of homes that sold before the wind facilities were announced (and were between 3 and 10 miles from the facilities) as the reference category, but, as discussed in Hoen et al. (2009, 2011), the announcement date of a facility, when news about a facility enters the public domain, might be after that project was known in private. For example, wind facility developers may begin talking to landowners some time before a facility is announced, and these landowners could share that news with neighbors. In addition, the developer might erect an anemometer to collect wind-speed data well before the facility is formally "announced," which might provide concrete evidence that a facility may soon to be announced. In either case, this news might enter the local real estate market and affect home prices before the formal facility announcement date. To explore this possibility, and to ensure that the reference category

[14] As discussed in more detail in the Section 4, approximately 60% of all the data obtained for this study (that obtained from CoreLogic) used the most recent assessment to populate the home and site characteristics for all transactions of a given property.

is unbiased, a model is estimated that uses transactions occurring more than 2 years before the wind facilities were announced (and between 3 and 10 miles) as the reference category.

Combined, this diverse set of robustness tests allows many assumptions used for the base models to be tested, potentially allowing greater confidence in the final results.

4. Data

The data used for the analysis are comprised of four types: wind turbine location data, real estate transaction data, home and site characteristic data, and census data. From those, two additional sets of data are calculated: distance to turbine and wind facility development period. Each data type is discussed below. Where appropriate, variable names are shown in *italics*.

4.1. Wind Turbine Locations

Location data (i.e., x/y coordinates) for installed wind turbines were obtained via an iterative process starting with Federal Aviation Administration obstacle data, which were then linked to specific wind facilities by Ventyx[15] and matched with facility-level data maintained by LBNL. Ultimately, data were collected on the location of almost all wind turbines installed in the U.S. through 2011 ($n \sim 40{,}000$), with information about each facility's announcement, construction, and operation dates as well as turbine nameplate capacity, hub height, rotor diameter, and facility size.

4.2. Real Estate Transactions

Real estate transaction data were collected through two sources, each of which supplied the home's sale price (*sp*), sale date (*sd*), x/y coordinates, and address including zip code. From those, the following variables were calculated: natural log of sale price (*lsp*), sale year (*sy*), if the sale occurred in winter (*swinter*) (i.e., in Q1 or Q4).

The first source of real estate transaction data was CoreLogic's extensive dataset of U.S. residential real estate information.[16] Using the x/y coordinates of wind turbines, CoreLogic

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[15] See the EV Energy Map, which is part of the Velocity Suite of products at www.ventyx.com.

[16] See www.corelogic.com.

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selected all arms-length single-family residential transactions between 1996 and 2011 within 10 miles of a turbine in any U.S. counties where they maintained data (not including New York – see below) on parcels smaller than 15 acres.[17] The full set of counties for which data were collected were then winnowed to 26 by requiring at least 250 transactions in each county, to ensure a reasonably robust estimation of the controlling characteristics (which, as discussed above, are interacted with county-level fixed effects), and by requiring at least one PC transaction within a half mile of a turbine in each county (because this study's focus is on homes that are located in close proximity to turbines).

The second source of data was the New York Office of Real Property Tax Service (NYORPTS),[18] which supplied a set of arms-length single-family residential transactions between 2001 and 2012 within 10 miles of existing turbines in any New York county in which wind development had occurred prior to 2012. As before, only parcels smaller than 15 acres were included, as were a minimum of 250 transactions and at least one PC transaction within a half mile of a turbine for each New York county. Both CoreLogic and NYORPTS provided the most recent home sale and, if available, the prior sale.

4.3. Home and Site Characteristics

A set of home and site characteristic data was also collected from both data suppliers: 1000s of square feet of living area (*sfla1000*), number of acres of the parcel (*acres*), year the home was built (or last renovated, whichever is more recent) (*yrbuilt*), and the number of full and half bathrooms (*baths*).[19] Additional variables were calculated from the other variables as well: log of 1,000s of square feet (*lsfla1000*),[20] the number of acres less than 1 (*lt1acre)*,[21] age at the time of sale (*age*), and age squared (*agesqr*).[22]

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[17] The 15 acre screen was used because of a desire to exclude from the sample any transaction of property that might be hosting a wind turbine, and therefore directly benefitting from the turbine's presence (which might then increase property values). To help ensure that the screen was effective, all parcels within a mile of a turbine were also visually inspected using satellite and ortho imagery via a geographic information system.

[18] See www.orps.state.ny.us

[19] *Baths* was calculated in the following manner: full bathrooms + (half bathrooms x 0.5). Some counties did not have *baths* data available, so for them *baths* was not used as an independent variable.

[20] The distribution of *sfla1000* is skewed, which could bias OLS estimates, thus *lsfla1000* is used instead, which is more normally distributed. Regression results, though, were robust when *sfla1000* was used instead.

Regardless of when the sale occurred, CoreLogic supplied the related home and site characteristics as of the most recent assessment, while NYORPTS supplied the assessment data as of the year of sale.[23]

4.4. Census Information

Each of the homes in the data was matched (based on the x/y coordinates) to the underlying census block group and tract via ArcGIS. Using the year 2000 block group census data, each transaction was appended with neighborhood characteristics including the median age of the residents (*medage*), the total number of housing units (*units*), the number vacant (*vacant*) homes, and the number of owned (*owned*) homes. From these, the percentages of the total number of housing units in the block group that were vacant and owned were calculated, i.e., *pctvacant* and *pctowned.*

4.5. Distances to Turbine

Using the x/y coordinates of both the homes and the turbines, a Euclidian distance (in miles) was calculated for each home to the nearest wind turbine (*tdis*), regardless of when the sale occurred (e.g., even if a transaction occurred prior to the wind facility's installation).[24] These were then broken into four mutually exclusive distance bins (i.e., groups) for the base *half-mile* models: inside a half mile, between a half and 1 mile, between 1 and 3 miles, and between 3 and 10 miles. They were broken into three mutually exclusive bins for the base *one-mile* models: inside 1 mile, between 1 and 3 miles, and between 3 and 10 miles.

4.6. Wind Facility Development Periods

After identifying the nearest wind turbine for each home, a match could be made to Ventyx' dataset of facility-development announcement and construction dates. These facility-development dates in combination with the dates of each sale of the homes determined in which

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[21] This variable allows the separate estimations of the 1st acre and any additional acres over the 1st.

[22] *Age* and *agesqr* together account for the fact that, as homes age, their values usually decrease, but further increases in age might bestow countervailing positive "antique" effects.

[23] See footnote 13.

[24] Before the distances were calculated, each home inside of 1 mile was visually inspected using satellite and ortho imagery, with x/y coordinates corrected, if necessary, so that those coordinates were on the roof of the home.

of the three facility-development periods (*fdp*) the transaction occurred: *pre-announcement* (PA), *post-announcement-pre-construction* (PAPC), or *post-construction* (PC).

4.7. Data Summary

After cleaning to remove missing or erroneous data, a final dataset of 51,276 transactions was prepared for analysis.[25] As shown in the map of the study area (Figure 1), the data are arrayed across nine states and 27 counties (see Table 4), and surround 67 different wind facilities.

Table 3 contains a summary of those data. The average unadjusted sales price for the sample is $122,475. Other average house characteristics include the following: 1,600 square feet of living space; house age of 48 years[26]; land parcel size of 0.90 acres; 1.6 bathrooms; in a block group in which 74% of housing units are owned, 9% are vacant, and the median resident age is 38 years; located 4.96 miles from the nearest turbine; and sold at the tail end of the PA period.

The data are arrayed across the temporal and distance bins as would be expected, with smaller numbers of sales nearer the turbines, as shown in Table 5. Of the full set of sales, 1,198 occurred within 1 mile of a then-current or future turbine location, and 376 of these occurred post construction; 331 sales occurred within a half mile, 104 of which were post construction. Given these totals, the models should be able to discern a post construction effect larger than ~3.5% within a mile and larger than ~7.5% within a half mile (see discussion in Section 2). These effects are at the top end of the expected range of effects based on other disamenities (high-voltage power lines, roads, landfills, etc.).

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[25] Cleaning involved the removal of all data that did not have certain core characteristics (sale date, sale price, *sfla*, *yrbuilt, acres, median age*, etc.) fully populated as well as the removal of any sales that had seemingly miscoded data (e.g., having a *sfla* that was greater than *acres*, having a *yrbuilt* more than 1 year after the sale, having less than one *bath*) or that did not conform to the rest of the data (e.g., had *acres* or *sfla* that were either larger or smaller, respectively, than 99% or 1% of the data). OLS models were rerun with those "nonconforming" data included with no substantive change in the results in comparison to the screened data presented in the report.

[26] Age could be as low as -1(for a new home) for homes that were sold before construction was completed.

Figure 1: Map of Transactions, States, and Counties

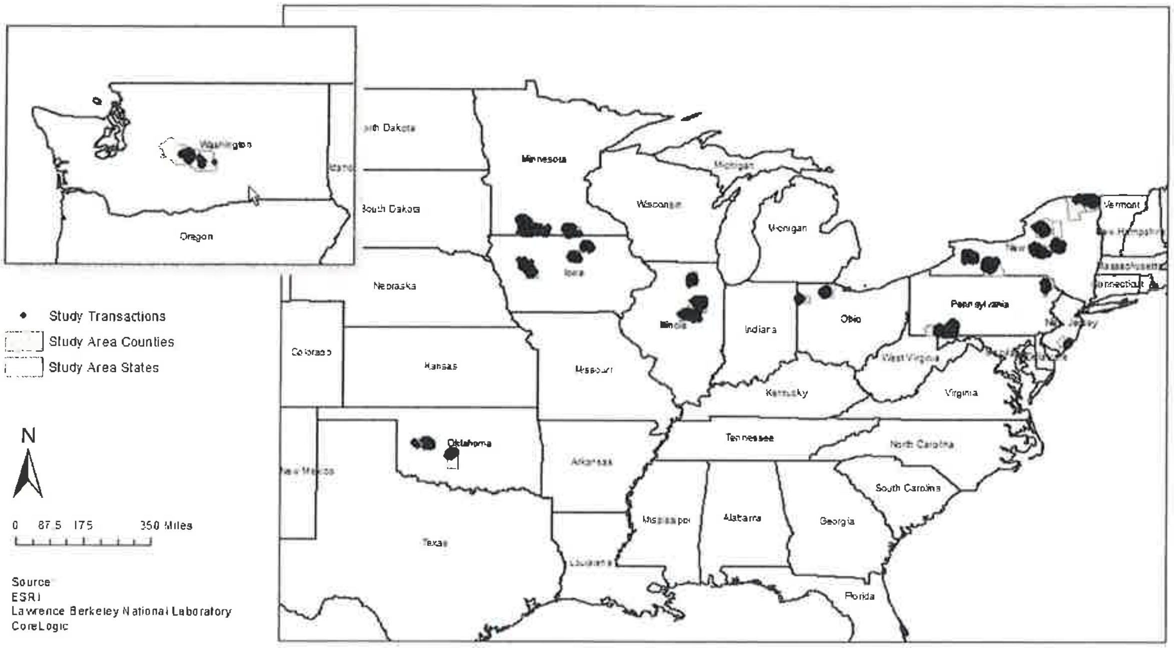

Table 3: Summary Statistics

Variable	Description	Mean	Std. Dev.	Min	Max
sp	sale price in dollars	$ 122,475	$ 80,367	$ 9,750	$ 690,000
lsp	natural log of sale price	11.52	0.65	9.19	13.44
sd	sale date	1/18/2005	1,403 days	1/1/1996	9/30/2011
sy	sale year	2005	3.84	1996	2011
sfla1000	living area in 1000s of square feet	1.60	0.57	0.60	4.50
lsfla1000	natural log of sfla1000	0.41	0.34	-0.50	1.50
acres	number of acres in parcel	0.90	1.79	0.03	14.95
acreslt1*	acres less than 1	-0.58	0.34	-0.97	0.00
age	age of home at time of sale	48	37	-1	297
agesq	age squared	3689	4925	0	88209
baths**	number of bathrooms	1.60	0.64	1.00	5.50
pctowner	fraction of house units in block group that are owned (as of 2000)	0.74	0.17	0.63	0.98
pctvacant	fraction of house units in block group that are vacant (as of 2000)	0.09	0.10	0.00	0.38
med_age	median age of residents in block group (as of 2000)	38	6	20	63
tdis	distance to nearest turbine (as of December 2011) in miles	4.96	2.19	0.09	10.00
fdp***	facility development period of nearest turbine at time of sale	1.94	0.87	1.00	3.00

Note: The number of cases for the full dataset is 51,276

** acreslt1 is calculated as follows: acres (if less than 1) * - 1*

*** Some counties did not have bathrooms populated; for those, these variables are entered into the regression as 0.*

**** fdp periods are: 1, pre-announcement,; 2, post-announcement-pre-construction; and, 3, post-construction.*

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Table 4: Summary of Transactions by County

County	State	<1/2 mile	1/2-1 mile	1-3 miles	3-10 miles	Total
Carroll	IA	12	56	331	666	1,065
Floyd	IA	3	2	402	119	526
Franklin	IA	8	1	9	322	340
Sac	IA	6	77	78	485	646
DeKalb	IL	4	8	44	605	661
Livingston	IL	16	6	237	1,883	2,142
McLean	IL	18	88	380	4,359	4,845
Cottonwood	MN	3	10	126	1,012	1,151
Freeborn	MN	17	16	117	2,521	2,671
Jackson	MN	19	28	36	149	232
Martin	MN	7	25	332	2,480	2,844
Atlantic	NJ	34	96	1,532	6,211	7,873
Paulding	OH	15	58	115	309	497
Wood	OH	5	31	563	4,844	5,443
Custer	OK	45	24	1,834	349	2,252
Grady	OK	1	6	97	874	978
Fayette	PA	1	2	10	284	297
Somerset	PA	23	100	1,037	2,144	3,304
Wayne	PA	4	29	378	739	1,150
Kittitas	WA	2	6	61	349	418
Clinton	NY	4	6	49	1,419	1,478
Franklin	NY	16	41	75	149	281
Herkimer	NY	3	17	354	1,874	2,248
Lewis	NY	5	6	93	732	836
Madison	NY	5	26	239	3,053	3,323
Steuben	NY	5	52	140	1,932	2,129
Wyoming	NY	50	50	250	1,296	1,646
Total		331	867	8,919	41,159	51,276

Table 5: Frequency Crosstab of Wind Turbine Distance and Development Period Bins

	<1/2 mile	1/2-1 mile	1-3 miles	3-10 miles	total
PA	143	383	3,892	16,615	21,033
PAPC	84	212	1,845	9,995	12,136
PC	104	272	3,182	14,549	18,107
total	331	867	8,919	41,159	51,276

As shown in Table 6, the home sales occurred around wind facilities that range from a single-turbine project to projects of 150 turbines, with turbines of 290–476 feet (averaging almost 400 feet) in total height from base to tip of blade and with an average nameplate capacity of 1,637 kW. The average facility was announced in 2004 and constructed in 2007, but some were announced as early as 1998 and others were constructed as late as 2011.

Table 6: Wind Facility Summary

	mean	min	25th percentile	median	75th percentile	max
turbine rotor diameter (feet)	262	154	253	253	269	328
turbine hub height (feet)	256	197	256	262	262	328
turbine total height (feet)	388	290	387	389	397	476
turbine capacity (kW)	1637	660	1500	1500	1800	2500
facility announcement year	2004	1998	2002	2003	2005	2010
facility construction year	2007	2000	2004	2006	2010	2011
number of turbines in facility	48	1	5	35	84	150
nameplate capacity of facility (MW)	79	1.5	7.5	53	137	300

Note: The data correspond to 67 wind facilities located in the study areas. Mean values are rounded to integers

4.8. Comparison of Means

To provide additional context for the analysis discussed in the next section, we further summarize the data here using four key variables across the sets of development period (*fdp*) and distance bins (*tdis*) used in the *one-mile* models.[27] The variables are the dependent variable log of sale price *(lsp)* and three independent variables: *lsfla100, acres*, and *age*. These summaries are provided in Table 7; each sub-table gives the mean values of the variables across the three *fdp* bins and three *tdis* bins, and the corresponding figures plot those values.

The top set of results are focused on the log of the sales price, and show that, based purely on price and not controlling for differences in homes, homes located within 1 mile of turbines had lower sale prices than homes farther away; this is true across all of the three development periods. Moreover, the results also show that, over the three periods, the closer homes appreciated to a somewhat lesser degree than homes located farther from the turbines. As a result, focusing only on the post-construction period, these results might suggest that home prices near turbines are

[27] Summaries for the *half-mile* models reveal a similar relationship, so only the *one-mile* model summaries are shown here.

adversely impacted by the turbines. After all, the logarithmic values for the homes within a mile of the turbines (11.39) and those outside of a three miles (11.72) translate into an approximately 40% difference, in comparison to an 21% difference before the wind facilities were announced (11.16 vs. 11.35).[28] Focusing on the change in average values between the pre-announcement and post-construction periods might also suggest an adverse effect due to the turbines, because homes inside of 1 mile appreciated more slowly (11.16 to 11.39, or 25%) than those outside of 3 miles (11.35 to 11.72, or 45%). Both conclusions of adverse turbine effects, however, disregard other important differences between the homes, which vary over the periods and distances. Similarly, comparing the values of the PA inside 1 mile homes (11.16) and the PC outside of 3 miles homes (11.72), which translates into a difference of 75%, and which is the basis for comparison in the regressions discussed below, but also ignores any differences in the underlying characteristics.

The remainder of Table 7, for example, indicates that, although the homes that sold within 1 mile are lower in value, they are also generally (in all but the PA period) smaller, on larger parcels of land, and older. These differences in home size and age across the periods and distances might explain the differences in price, while the differences in the size of the parcel, which add value, further amplifying the differences in price. Without controlling for these possible impacts, one cannot reliably estimate the impact of wind turbines on sales prices.

In summary, focusing solely on trends in home price (or price per square foot) alone, and for only the PC period, as might be done in a simpler analysis, might incorrectly suggest that wind turbines are affecting price when other aspects of the markets, and other home and sites characteristic differences, could be driving the observed price differences. This is precisely why researchers generally prefer the hedonic model approach to control for such effects, and the results from our hedonic OLS and spatial modeling detailed in the next section account for these and many other possible influencing factors.

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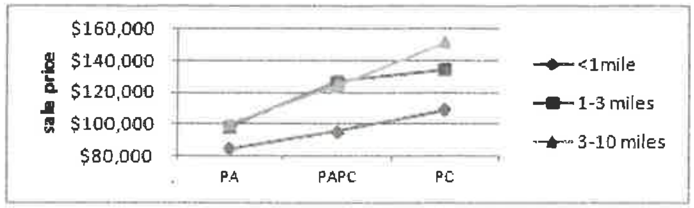
[28] Percentage differences are calculated as follows: exp(11.72-11.39)-1=0.40 and exp(11.35-11.16)-1=0.21.

Table 7: Dependent and Independent Variable Means

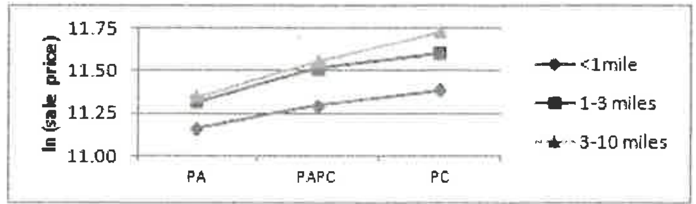
Sale Price

	<1mile	1-3 miles	3-10 miles
PA	$ 84,830	$ 98,676	$100,485
PAPC	$ 95,223	$127,054	$124,532
PC	$109,133	$134,647	$151,559



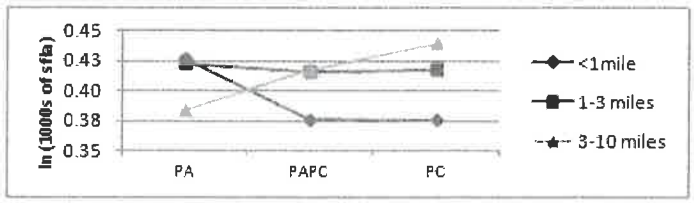
Log of Sale Price

	<1mile	1-3 miles	3-10 miles
PA	11.16	11.32	11.35
PAPC	11.30	11.52	11.56
PC	11.39	11.61	11.72



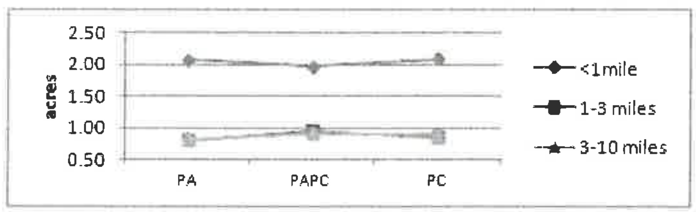
Log of Square Feet (in 1000s)

	<1mile	1-3 miles	3-10 miles
PA	0.43	0.42	0.38
PAPC	0.38	0.42	0.42
PC	0.38	0.42	0.44



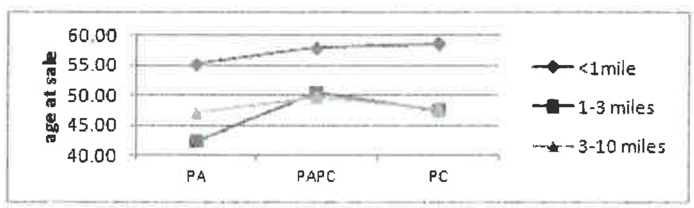
Number of Acres

	<1mile	1-3 miles	3-10 miles
PA	2.08	0.80	0.83
PAPC	1.98	0.94	0.90
PC	2.09	0.84	0.89



Age at the Time of Sale

	<1mile	1-3 miles	3-10 miles
PA	55.32	42.34	47.19
PAPC	58.01	50.34	49.73
PC	58.63	47.39	47.73



5. Results

This section contains analysis results and discussion for the four base models, as well as the results from the robustness models.

5.1. Estimation Results for Base Models

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Estimation results for the "base" models are shown in Table 8 and Table 9.[29] In general, given the diverse nature of the data, the models perform adequately, with adjusted R^2 values ranging from 0.63 to 0.67 (bottom of Table 9).

5.1.1. Control Variables

The controlling home, site, and block group variables, which are interacted at the county level, are summarized in Table 8. Table 8 focuses on only one of the base models, the *one-mile* OLS model, but full results from all models are shown in the Appendix. [30] To concisely summarize results for all of the 27 counties, the table contains the percentage of all 27 counties for which each controlling variable has statistically significant (at or below the 10% level) coefficients for the *one-mile* OLS model. For those controlling variables that are found to be statistically significant, the table further contains mean values, standard deviations, and minimum and maximum levels.

Many of the county-interacted controlling variables (e.g., *lsfla1000, lt1acre, age, agesqr, baths,* and *swinter*) are consistently (in more than two thirds of the counties) statistically significant (with a p-value < 0.10) and have appropriately sized mean values. The seemingly spurious minimum and maximum values among some of the county-level controlling variables (e.g., *lt1acre* minimum of -0.069) likely arise when these variables in particular counties are highly correlated with other variables, such as square feet (*lsfla1000*), and also when sample size is limited.[31] The other variables (*acres* and the three block group level census variables: *pctvacant, pctowner,* and *med_age*) are statistically significant in 33-59% of the counties. Only one variable's mean value—the percent of housing units vacant in the block group as of the 2000 census (*pctvacant*)—was counterintuitive. In that instance, a positive coefficient was estimated, when in fact, one would expect that increasing the percent of vacant housing would lower prices;

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[29] The OLS models are estimated using the areg procedure in Stata with robust (White's corrected) standard errors (White, 1980). The spatial error models are estimated using the *gstslshet* routine in the sphet package in R, which also allows for robust standard errors to be estimated. See: http://cran.r-project.org/web/packages/sphet/sphet.pdf

[30] The controlling variables' coefficients were similar across the base models, so only the *one-mile* results are summarized here.

[31] The possible adverse effects of these collinearities were fully explored both via the removal of the variables and by examining VIF statistics. The VOI results are robust to controlling variable removal and have relatively low (< 5) VIF statistics.

this counter-intuitive effect may be due to collinearity with one or more of the other variables, or possible measurement errors.[32]

The sale year variables, which are interacted with the state, are also summarized in Table 8, with the percentages indicating the number of states in which the coefficients are statistically significant. The inclusion of these sale year variables in the regressions control for inflation and deflation across the various states over the study period. The coefficients represent a comparison to the omitted year, which is 2011. All sale year state-level coefficients are statistically significant in at least 50% of the states in all years except 2010, and they are significant in two thirds of the states in all except 3 years. The mean values of all years are appropriately signed, showing a monotonically ordered peak in values in 2007, with lower values in the prior and following years. The minimum and maximum values are similarly signed (negative) through 2003 and from 2007 through 2010 (positive), and are both positive and negative in years 2003 through 2006, indicating the differences in inflation/deflation in those years across the various states. This reinforces the appropriateness of interacting the sale years at the state level. Finally, although not shown, the model also contains 250 fixed effects for the census tract delineations, of which approximately 50% were statistically significant.

[32] The removal of this, as well as the other block group census variables, however, did not substantively influence the results of the VOI.

Table 8: Levels and Significance for County- and State-Interacted Controlling Variables[33]

Variable	% of Counties/States Having Significant (*p* -value <0.10) Coefficients	Statistics for Significant Variables			
		Mean	St Dev	Min	Max
lsfla1000	100%	0.604	0.153	0.332	0.979
acres	48%	0.025	0.035	-0.032	0.091
lt1acre	85%	0.280	0.170	-0.069	0.667
age	81%	-0.006	0.008	-0.021	0.010
agesqr	74%	-0.006	0.063	-0.113	0.108
*baths**	85%	0.156	0.088	0.083	0.366
pctvacant	48%	1.295	3.120	-2.485	9.018
pctowner	33%	0.605	0.811	-0.091	2.676
med_age	59%	-0.016	0.132	-0.508	0.066
swinter	78%	-0.034	0.012	-0.053	-0.020
sy1996	100%	-0.481	0.187	-0.820	-0.267
sy1997	100%	-0.448	0.213	-0.791	-0.242
sy1998	100%	-0.404	0.172	-0.723	-0.156
sy1999	100%	-0.359	0.169	-0.679	-0.156
sy2000	88%	-0.298	0.189	-0.565	-0.088
sy2001	88%	-0.286	0.141	-0.438	-0.080
sy2002	67%	-0.261	0.074	-0.330	-0.128
sy2003	67%	-0.218	0.069	-0.326	-0.119
sy2004	75%	-0.084	0.133	-0.208	0.087
sy2005	67%	0.082	0.148	-0.111	0.278
sy2006	67%	0.128	0.158	-0.066	0.340
sy2007	67%	0.196	0.057	0.143	0.297
sy2008	56%	0.160	0.051	0.084	0.218
sy2009	50%	0.138	0.065	0.071	0.219
sy2010	33%	0.172	0.063	0.105	0.231

** % of counties significant is reported only for counties that had the baths variable populated (17 out of 27 counties)*

5.1.2. Variables of Interest

The variables of interest, the interactions between the *fdp* and *tdis* bins, are shown in Table 9 for the four base models. The reference (i.e., omitted) case for these variables are homes that sold prior to the wind facilities' announcement (PA) and are located between 3 and 10 miles from the

[33] Controlling variable statistics are provided for only the *one-mile* OLS model but did not differ substantially for other models. All variables are interacted with counties, except for sale year (sy), which is interacted with the state.

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wind turbines' eventual locations. In relation to that group of transactions, three of the eight interactions in the *one-mile* models and four of the 11 interactions in the *half-mile* models produce coefficients that are statistically significant (at the 10% level).

Across all four base models none of the PA coefficients show statistically significant differences between the reference category (outside of 3 miles) and the group of transactions within a mile for the *one-mile* models (OLS: -1.7%, *p*-value 0.48; SEM: -0.02%, *p*-value 0.94)[34] or within a half- or between one-half and one-mile for the *half-mile* models (OLS inside a half mile: 0.01%, *p*-value 0.97; between a half and 1 mile: -2.3%, *p*-value 0.38; SEM inside a half mile: 5.3%, *p*-value 0.24; between a half and 1 mile: -1.8%, *p*-value 0.60). Further, none of the coefficients are significant, and all are relatively small (which partially explains their non-significance). Given these results, we find an absence of evidence of a PA effect for homes close to the turbines (*research question 1*). These results can be contrasted with the differences in prices between within-1-mile homes and outside-of-3-miles homes as summarized in Section 4.8 when no differences in the homes, the local market, the neighborhood, etc. are accounted for. The approximately 75% difference in price (alone) in the pre-announcement period 1-mile homes, as compared to the PC 3-mile homes, discussed in Section 4.8, is largely explained by differences in the controlling characteristics, which is why the pre-announcement distance coefficients shown here are not statistically significant.

Turning to the PAPC and PC periods, the results also indicate statistically insignificant differences in average home values, all else being equal, between the reference group of transactions (sold in the PA period) and those similarly located more than 3 miles from the turbines but sold in the PAPC or PC periods. Those differences are estimated to be between -0.8% and -0.5%.

The results presented above, and in Table 8, include both OLS and spatial models. Prior to estimating the spatial models, the Moran's I was calculated using the residuals of an OLS model that uses the same explanatory variables as the spatial models and the same dataset (only the most recent transactions). The Moran's I statistic (0.133) was highly significant (*p*-value 0.00),

[34] p-values are not shown in the table can but can be derived from the standard errors, which are shown.

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which allows us to reject the hypothesis that the residuals are spatially independent. Therefore, there was justification in estimating the spatial models. However, after estimation, we determined that only the spatial error process was significant. As a result, we estimated spatial error models (SEMs) for the final specification. The spatial autoregressive coefficient, lambda (bottom of Table 9), which is an indication of spatial autocorrelation in the residuals, is sizable and statistically significant in both SEMs (0.26, *p*-value 0.00). The SEM models' variable-of-interest coefficients are quite similar to those of the OLS models. In most cases, the coefficients are the same sign, approximately the same level, and often similarly insignificant, indicating that although spatial dependence is present it does not substantively bias the variables of interest. The one material difference is the coefficient size and significance for homes outside of 3 miles in the PAPC and PC periods, 3.3% (*p*-value 0.000) and 3.1% (*p*-value 0.008), indicating there are important changes to home values over the periods that must be accounted for in the later DD models in order to isolate the potential impacts that occur due to the presence of wind turbines.

Table 9: Results of Interacted Variables of Interest: *fdp* and *tdis*

		one-mile	*one-mile*	*half-mile*	*half-mile*
		OLS	SEM	OLS	SEM
fdp	tdis	β (se)	β (se)	β (se)	β (se)
PA	< 1 mile	-0.017	0.002		
		(0.024)	*(0.031)*		
PA	1-2 miles	-0.015	0.008		
		(0.011)	*(0.016)*		
PA	> 3 miles	Omitted	Omitted		
		n/a	*n/a*		
PAPC	< 1 mile	-0.035	-0.038		
		(0.029)	*(0.033)*		
PAPC	1-2 miles	-0.001	-0.033.		
		(0.014)	*(0.018)*		
PAPC	> 3 miles	-0.006	-0.033***		
		(0.008)	*(0.01)*		
PC	< 1 mile	0.019	-0.022		
		(0.026)	*(0.032)*		
PC	1-2 miles	0.044***	-0.001		
		(0.014)	*(0.019)*		
PC	> 3 miles	-0.005	-0.031**		
		(0.010)	*(0.012)*		
PA	< 1/2 mile			0.001	0.053
				(0.039)	*(0.045)*
PA	1/2 - 1 mile			-0.023	-0.018
				(0.027)	*(0.035)*
PA	1-2 miles			-0.015	0.008
				(0.011)	*(0.016)*
PA	> 3 miles			Omitted	Omitted
				n/a	*n/a*
PAPC	< 1/2 mile			-0.028	-0.065
				(0.049)	*(0.056)*
PAPC	1/2 - 1 mile			-0.038	-0.027
				(0.033)	*(0.036)*
PAPC	1-2 miles			-0.001	-0.034.
				(0.014)	*(0.017)*
PAPC	> 3 miles			-0.006	-0.033***
				(0.008)	*(0.009)*
PC	< 1/2 mile			-0.016	-0.036
				(0.041)	*(0.046)*
PC	1/2 - 1 mile			0.032	-0.016
				(0.031)	*(0.035)*
PC	1-2 miles			0.044***	-0.001
				(0.014)	*(0.018)*
PC	> 3 miles			-0.005	-0.031**
				(0.010)	*(0.012)*
lambda			0.247 ***		0.247 ***
			(0.008)		*(0.008)*

*Note: p-values: < 0.1 *, < 0.05 **, <0.01 ***.*

n	51,276	38,407	51,276	38,407
adj R-sqr	0.67	0.64	0.67	0.64

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5.1.3. Impact of Wind Turbines

As discussed above, there are important differences in property values between development periods for the reference group of homes (those located outside of 3 miles) that must be accounted for. Further, although they are not significant, differences between the reference category and those transactions inside of 1 mile in the PA period still must be accounted for if accurate measurements of PAPC or PC wind turbine effects are to be estimated. The DD specification accounts for both of these critical effects.

Table 10 shows the results of the DD tests across the four models, based on the results for the variables of interest presented in Table 9.[35] For example, to determine the net difference for homes that sold inside of a half mile (drawing from the *half-mile* OLS model) in the PAPC period, we use the following formula: PAPC half-mile coefficient (-0.028) less the PAPC 3-mile coefficient (-0.006) less the PA half-mile coefficient (0.001), which equals -0.024 (without rounding), which equates to 2.3% difference,[36] and is not statistically significant.

None of the DD effects in either the OLS or SEM specifications are statistically significant in the PAPC or PC periods, indicating that we do not observe a statistically significant impact of wind turbines on property values. Some small differences are apparent in the calculated coefficients, with those for PAPC being generally more negative/less positive than their PC counterparts, perhaps suggestive of a small announcement effect that declines once a facility is constructed. Further, the inside-a-half-mile coefficients are more negative/less positive than their between-a-half-and-1-mile counterparts, perhaps suggestive of a small property value impact very close to turbines.[37] However, in all cases, the sizes of these differences are smaller than the margins of error in the model (i.e., 90% confidence interval) and thus are not statistically significant. Therefore, based on these results, we do not find evidence supporting either of our two core hypotheses (*research questions 2 and 3*). In other words, there is no statistical evidence that homes in either the PAPC or PC periods that sold near turbines (i.e., within a mile or even a half

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[35] All DD estimates for the OLS models were calculated using the post-estimation "lincom" test in Stata, which uses the stored results' variance/covariance matrix to test if a linear combination of coefficients is different from 0. For the SEM models, a similar test was performed in R.

[36] All differences in coefficients are converted to percentages in the table as follows: exp(coef)-1.

[37] Although not discussed in the text, this trend continues with homes between 1 and 2 miles being less negative/more positive than homes closer to the turbines (e.g., those within 1 mile).

mile) did so for less than similar homes that sold between 3 and 10 away miles in the same period.

Further, using the standard errors from the DD models we can estimate the maximum size an average effect would have to be in our sample for the model to detect it (*research question 4*). For an average effect in the PC period to be found for homes within 1 mile of the existing turbines (therefore using the *one-mile* model results), an effect greater than 4.9%, either positive or negative, would have to be present to be detected by the model.[38] In other words, it is highly unlikely that the true average effect for homes that sold in our sample area within 1 mile of an existing turbine is larger than +/-4.9%. Similarly, it is highly unlikely that the true average effect for homes that sold in our sample area within a half mile of an existing turbine is larger than +/-9.0%.[39] Regardless of these maximum effects, however, as well as the very weak suggestion of a possible small announcement effect and a possible small effect on homes that are very close to turbines, the core results of these models show effect sizes that are not statistically significant from zero, and are considerably smaller than these maximums.[40]

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[38] Using the 90% confidence interval (i.e., 10% level of significance) and assuming more than 300 cases, the critical t-value is 1.65. Therefore, using the standard error of 0.030, the 90% confidence intervals for the test will be +/-0.049.

[39] Using the critical t-value of 1.66 for the 100 PC cases within a half mile in our sample and the standard error of 0.054.

[40] It is of note that these maximum effects are slightly larger than those we expected to find, as discussed earlier. This likely indicates that there was more variation in this sample, causing relatively higher standard errors for the same number of cases, than in the sample used for the 2009 study (Hoen et al., 2009, 2011).

Table 10: "Net" Difference-in-Difference Impacts of Turbines

fdp	tdis	< 1 Mile OLS b/se	< 1 Mile SEM b/se	< 1/2 Mile OLS b/se	< 1/2 Mile SEM b/se
PAPC	< 1 mile	-1.2% ^{NS}	-0.7% ^{NS}		
		(0.033)	*(0.037)*		
PC	< 1 mile	4.2% ^{NS}	0.7% ^{NS}		
		(0.030)	*(0.035)*		
PAPC	< 1/2 mile			-2.3% ^{NS}	-8.1% ^{NS}
				(0.060)	*(0.065)*
PAPC	1/2 - 1 mile			-0.8% ^{NS}	2.5% ^{NS}
				(0.039)	*(0.043)*
PC	< 1/2 mile			-1.2% ^{NS}	-5.6% ^{NS}
				(0.054)	*(0.057)*
PC	1/2 - 1 mile			6.3% ^{NS}	3.4% ^{NS}
				(0.036)	*(0.042)*

*Note: p-values: > 10% ^{NS}, < 10% *, < 5% **, <1 % ****

5.2. Robustness Tests

Table 11 summarizes the results from the robustness tests. For simplicity, only the DD coefficients are shown and only for the *half-mile* OLS models.[41] The first two columns show the base OLS and SEM *half-mile* DD results (also presented earlier, in Table 9), and the remaining columns show the results from the robustness models as follows: exclusion of outliers and influential cases from the dataset (*outlier*); using sale year/county interactions instead of sale year/state (*sycounty*); using only the most recent sales instead of the most recent and prior sales (*recent*); using homes between 5 and 10 miles as the reference category, instead of homes between 3 and 10 miles (*outside5*); and using transactions occurring more than 2 years before announcement as the reference category instead of using transactions simply *before* announcement (*prior*).

[41] Results were also estimated for the *one-mile* OLS models for each of the robustness tests and are available upon request: the results do not substantively differ from what is presented here for the *half-mile* models. Because of the similarities in the results between the OLS and SEM "base" models, robustness tests on the SEM models were not prepared as we assumed that differences between the two models for the robustness tests would be minimal as well.

The robustness results have patterns similar to the base model results: none of the coefficients are statistically different from zero; all coefficients (albeit non-significant) are lower in the PAPC period than the PC period; and, all coefficients (albeit non-significant) are lower (i.e., less negative/more positive) within a half mile than outside a half mile.[42] In sum, regardless of dataset or specification, there is no change in the basic conclusions drawn from the base model results: there is no evidence that homes near operating or announced wind turbines are impacted in a statistically significant fashion. Therefore, if effects do exist, either the average impacts are relatively small (within the margin of error in the models) and/or sporadic (impacting only a small subset of homes). Moreover, these results seem to corroborate what might be predicted given the other, potentially analogous disamenity literature that was reviewed earlier, which might be read to suggest that any property value effect of wind turbines might coalesce at a maximum of 3%–4%, on average. Of course, we cannot offer that corroboration directly because, although the size of the coefficients in the models presented here are reasonably consistent with effects of that magnitude, none of our models offer results that are statistically different from zero.

[42] This trend also continues outside of 1 mile, with those coefficients being less negative/more positive than those within 1 mile.

Table 11: Robustness Half-Mile Model Results

				Robustness OLS Models				
		Base OLS	Base SEM	outlier	sycounty	recent	outside5	prior
fdp	tdis	β (se)	β (se)	β (se)	β (se)	β (se)	β (se)	β (se)
PAPC	< 1/2 mile	-2.3% ^{NS}	-8.1% ^{NS}	-4.7% ^{NS}	-4.2% ^{NS}	-5.6% ^{NS}	-1.7% ^{NS}	0.1% ^{NS}
		(0.060)	*(0.065)*	*(0.056)*	*(0.060)*	*(0.066)*	*(0.060)*	*(0.062)*
PAPC	1/2 - 1 mile	-0.8% ^{NS}	2.5% ^{NS}	-1.7% ^{NS}	-2.5% ^{NS}	2.3% ^{NS}	-0.2% ^{NS}	0.4% ^{NS}
		(0.039)	*(0.043)*	*(0.036)*	*(0.039)*	*(0.043)*	*(0.039)*	*(0.044)*
PC	< 1/2 mile	-1.2% ^{NS}	-5.6% ^{NS}	-0.5% ^{NS}	-1.8% ^{NS}	-4.3% ^{NS}	-0.3% ^{NS}	1.3% ^{NS}
		(0.054)	*(0.057)*	*(0.047)*	*(0.054)*	*(0.056)*	*(0.054)*	*(0.056)*
PC	1/2 - 1 mile	6.3% ^{NS}	3.4% ^{NS}	6.2% ^{NS}	3.8% ^{NS}	4.1% ^{NS}	7.1% ^{NS}	7.5% ^{NS}
		(0.036)	*(0.041)*	*(0.033)*	*(0.036)*	*(0.042)*	*(0.036)*	*(0.041)*

*Note: p-values: > 0.1 ^{NS}, < 0.1 *, <0.5 **, <0.01 ****

n	51,276	38,407	50,106	51,276	38,407	51,276	51,276
adj R-sqr	0.67	0.64	0.66	0.67	0.66	0.67	0.67

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6. Conclusion

Wind energy facilities are expected to continue to be developed in the United States. Some of this growth is expected to occur in more-populated regions, raising concerns about the effects of wind development on home values in surrounding communities.

Previous published and academic research on this topic has tended to indicate that wind facilities, after they have been constructed, produce little or no effect on home values. At the same time, some evidence has emerged indicating potential home-value effects occurring after a wind facility has been announced but before construction. These previous studies, however, have been limited by their relatively small sample sizes, particularly in relation to the important population of homes located very close to wind turbines, and have sometimes treated the variable for distance to wind turbines in a problematic fashion. Analogous studies of other disamenities—including high-voltage transmission lines, landfills, and noisy roads—suggest that if reductions in property values near turbines were to occur, they would likely be no more than 3%–4%, on average, but to discover such small effects near turbines, much larger amounts of data are needed than have been used in previous studies. Moreover, previous studies have not accounted adequately for potentially confounding home-value factors, such as those affecting home values before wind facilities were announced, nor have they adequately controlled for spatial dependence in the data, i.e., how the values and characteristics of homes located near one another influence the value of those homes (independent of the presence of wind turbines).

This study helps fill those gaps by collecting a very large data sample and analyzing it with methods that account for confounding factors and spatial dependence. We collected data from more than 50,000 home sales among 27 counties in nine states. These homes were within 10 miles of 67 different then-current or existing wind facilities, with 1,198 sales that were within 1 mile of a turbine (331 of which were within a half mile)—many more than were collected by previous research efforts. The data span the periods well before announcement of the wind facilities to well after their construction. We use OLS and spatial-process difference-in-difference hedonic models to estimate the home-value impacts of the wind facilities; these models control for value factors existing prior to the wind facilities' announcements, the spatial dependence of home values, and value changes over time. We also employ a series of robustness

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models, which provide greater confidence in our results by testing the effects of data outliers and influential cases, heterogeneous inflation/deflation across regions, older sales data for multi-sale homes, the distance from turbines for homes in our reference case, and the amount of time before wind-facility announcement for homes in our reference case.

Across all model specifications, we find no statistical evidence that home prices near wind turbines were affected in either the post-construction or post-announcement/pre-construction periods. Therefore, if effects do exist, either the average impacts are relatively small (within the margin of error in the models) and/or sporadic (impacting only a small subset of homes). Related, our sample size and analytical methods enabled us to bracket the size of effects that would be detected, if those effects were present at all. Based on our results, we find that it is *highly unlikely* that the actual average effect for homes that sold in our sample area within 1 mile of an existing turbine is larger than +/-4.9%. In other words, the average value of these homes could be as much as 4.9% higher than it would have been without the presence of wind turbines, as much as 4.9% lower, the same (i.e., zero effect), or anywhere in between. Similarly, it is highly unlikely that the average actual effect for homes that sold in our sample area within a half mile of an existing turbine is larger than +/-9.0%. In other words, the average value of these homes could be as much as 9% higher than it would have been without the presence of wind turbines, as much as 9% lower, the same (i.e., zero effect), or anywhere in between.

Regardless of these potential maximum effects, the core results of our analysis consistently show no sizable statistically significant impact of wind turbines on nearby property values. The maximum impact suggested by potentially analogous disamenities (high-voltage transmission lines, landfills, roads etc.) of 3%-4% is at the far end of what the models presented in this study would have been able to discern, potentially helping to explain why no statistically significant effect was found. If effects of this size are to be discovered in future research, even larger samples of data may be required. For those interested in estimating such effects on a more micro (or local) scale, such as appraisers, these possible data requirements may be especially daunting, though it is also true that the inclusion of additional market, neighborhood, and individual property characteristics in these more-local assessments may sometimes improve model fidelity.

7. References

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8. Appendix – Full Results

Variables	OneMile OLS coef	OneMile OLS se	HalfMile OLS coef	HalfMile OLS se	OneMile SEM coef	OneMile SEM se	HalfMile SEM coef	HalfMile SEM se
Intercept	11.332***	(0.058)	11.330***	(0.058)	11.292***	(0.090)	11.292***	(0.090)
fdp3tdis3_11	-0.017	(0.024)			0.002	(0.031)		
fdp3tdis3_12	-0.015	(0.011)			0.008	(0.016)		
fdp3tdis3_21	-0.035	(0.029)			-0.038	(0.033)		
fdp3tdis3_22	-0.001	(0.014)			-0.033*	(0.017)		
fdp3tdis3_23	-0.006	(0.008)			-0.033***	(0.009)		
fdp3tdis3_31	0.019	(0.026)			-0.022	(0.031)		
fdp3tdis3_32	0.044***	(0.014)			-0.001	(0.018)		
fdp3tdis3_33	-0.005	(0.010)			-0.031***	(0.012)		
fdp3tdis4_10			0.001	(0.039)			0.053	(0.045)
fdp3tdis4_11			-0.023	(0.027)			-0.018	(0.035)
fdp3tdis4_12			-0.015	(0.011)			0.008	(0.016)
fdp3tdis4_20			-0.028	(0.049)			-0.065	(0.056)
fdp3tdis4_21			-0.038	(0.033)			-0.027	(0.036)
fdp3tdis4_22			-0.001	(0.014)			-0.034*	(0.017)
fdp3tdis4_23			-0.006	(0.008)			-0.033***	(0.009)
fdp3tdis4_30			-0.016	(0.041)			-0.036	(0.046)
fdp3tdis4_31			0.032	(0.031)			-0.016	(0.035)
fdp3tdis4_32			0.044***	(0.014)			-0.001	(0.018)
fdp3tdis4_33			-0.005	(0.010)			-0.031***	(0.012)
lsfla1000_ia_car	0.750***	(0.042)	0.749***	(0.042)	0.723***	(0.045)	0.722***	(0.045)
lsfla1000_ia_flo	0.899***	(0.054)	0.900***	(0.054)	0.879***	(0.060)	0.88***	(0.060)
lsfla1000_ia_fra	0.980***	(0.077)	0.980***	(0.077)	0.932***	(0.083)	0.934***	(0.083)
lsfla1000_ia_sac	0.683***	(0.061)	0.683***	(0.061)	0.633***	(0.065)	0.633***	(0.064)
lsfla1000_il_dek	0.442***	(0.037)	0.441***	(0.037)	0.382***	(0.040)	0.38***	(0.040)
lsfla1000_il_liv	0.641***	(0.030)	0.641***	(0.030)	0.643***	(0.046)	0.643***	(0.046)
lsfla1000_il_mcl	0.512***	(0.019)	0.512***	(0.019)	0.428***	(0.029)	0.428***	(0.029)
lsfla1000_mn_cot	0.800***	(0.052)	0.800***	(0.052)	0.787***	(0.077)	0.787***	(0.077)
lsfla1000_mn_fre	0.594***	(0.028)	0.595***	(0.028)	0.539***	(0.031)	0.539***	(0.031)
lsfla1000_mn_jac	0.587***	(0.101)	0.587***	(0.101)	0.551***	(0.102)	0.55***	(0.102)
lsfla1000_mn_mar	0.643***	(0.025)	0.643***	(0.025)	0.603***	(0.029)	0.603***	(0.029)
lsfla1000_nj_atl	0.421***	(0.012)	0.421***	(0.012)	0.389***	(0.014)	0.389***	(0.014)
lsfla1000_ny_cli	0.635***	(0.044)	0.635***	(0.044)	0.606***	(0.045)	0.606***	(0.045)
lsfla1000_ny_fra	0.373***	(0.092)	0.375***	(0.092)	0.433***	(0.094)	0.436***	(0.094)
lsfla1000_ny_her	0.520***	(0.034)	0.520***	(0.034)	0.559***	(0.035)	0.559***	(0.035)
lsfla1000_ny_lew	0.556***	(0.054)	0.556***	(0.054)	0.518***	(0.057)	0.518***	(0.057)
lsfla1000_ny_mad	0.503***	(0.025)	0.503***	(0.025)	0.502***	(0.025)	0.502***	(0.025)
lsfla1000_ny_ste	0.564***	(0.032)	0.564***	(0.032)	0.534***	(0.034)	0.534***	(0.034)
lsfla1000_ny_wyo	0.589***	(0.034)	0.589***	(0.034)	0.566***	(0.034)	0.566***	(0.034)
lsfla1000_oh_pau	0.625***	(0.080)	0.624***	(0.080)	0.567***	(0.090)	0.565***	(0.090)
lsfla1000_oh_woo	0.529***	(0.030)	0.529***	(0.030)	0.487***	(0.035)	0.487***	(0.035)
lsfla1000_ok_cus	0.838***	(0.037)	0.838***	(0.037)	0.794***	(0.046)	0.793***	(0.046)
lsfla1000_ok_gra	0.750***	(0.063)	0.750***	(0.063)	0.706***	(0.072)	0.706***	(0.072)
lsfla1000_pa_fay	0.332***	(0.111)	0.332***	(0.111)	0.335***	(0.118)	0.334***	(0.118)
lsfla1000_pa_som	0.564***	(0.025)	0.564***	(0.025)	0.548***	(0.031)	0.548***	(0.031)
lsfla1000_pa_way	0.486***	(0.056)	0.486***	(0.056)	0.44***	(0.063)	0.44***	(0.063)
lsfla1000_wa_kit	0.540***	(0.073)	0.540***	(0.073)	0.494***	(0.078)	0.494***	(0.078)

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	OneMile OLS		HalfMile OLS		OneMile SEM		HalfMile SEM	
Variables	**coef**	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**
acres_ia_car	0.033	(0.030)	0.033	(0.030)	0.013	(0.032)	0.013	(0.032)
acres_ia_flo	0.050***	(0.014)	0.050***	(0.014)	0.044***	(0.014)	0.044***	(0.014)
acres_ia_fra	-0.008	(0.022)	-0.008	(0.022)	-0.009	(0.022)	-0.009	(0.022)
acres_ia_sac	0.064***	(0.014)	0.064***	(0.014)	0.054***	(0.015)	0.054***	(0.015)
acres_il_dek	0.068**	(0.027)	0.064**	(0.027)	0.055*	(0.029)	0.048*	(0.029)
acres_il_liv	0.023	(0.014)	0.023	(0.014)	0.014	(0.018)	0.014	(0.018)
acres_il_mcl	0.091***	(0.010)	0.091***	(0.010)	0.092***	(0.011)	0.092***	(0.011)
acres_mn_cot	-0.030***	(0.011)	-0.030***	(0.011)	-0.024*	(0.013)	-0.024*	(0.013)
acres_mn_fre	-0.002	(0.007)	-0.002	(0.007)	0.002	(0.008)	0.002	(0.008)
acres_mn_jac	0.019	(0.016)	0.020	(0.016)	0.03*	(0.016)	0.03*	(0.016)
acres_mn_mar	0.020**	(0.008)	0.020**	(0.008)	0.017*	(0.009)	0.017*	(0.009)
acres_nj_atl	-0.041	(0.031)	-0.041	(0.031)	-0.013	(0.026)	-0.013	(0.026)
acres_ny_cli	0.019***	(0.007)	0.019***	(0.007)	0.022***	(0.007)	0.022***	(0.007)
acres_ny_fra	0.009	(0.010)	0.009	(0.010)	0.014	(0.011)	0.014	(0.011)
acres_ny_her	-0.004	(0.008)	-0.004	(0.008)	0.012	(0.008)	0.012	(0.008)
acres_ny_lew	0.014*	(0.008)	0.014*	(0.008)	0.014	(0.009)	0.014	(0.009)
acres_ny_mad	0.021***	(0.003)	0.021***	(0.003)	0.021***	(0.004)	0.021***	(0.004)
acres_ny_ste	0.009*	(0.005)	0.009*	(0.005)	0.007	(0.005)	0.007	(0.005)
acres_ny_wyo	0.016***	(0.004)	0.016***	(0.004)	0.019***	(0.004)	0.019***	(0.004)
acres_oh_pau	-0.010	(0.020)	-0.010	(0.020)	0.01	(0.024)	0.009	(0.024)
acres_oh_woo	-0.007	(0.010)	-0.007	(0.010)	0.002	(0.010)	0.002	(0.010)
acres_ok_cus	-0.037*	(0.019)	-0.037*	(0.019)	-0.034	(0.022)	-0.034	(0.022)
acres_ok_gra	0.014	(0.010)	0.014	(0.010)	0.019*	(0.011)	0.019*	(0.011)
acres_pa_fay	-0.006	(0.023)	-0.006	(0.023)	0.01	(0.023)	0.01	(0.023)
acres_pa_som	0.003	(0.009)	0.004	(0.009)	0.009	(0.010)	0.009	(0.010)
acres_pa_way	0.017**	(0.007)	0.017**	(0.007)	0.024***	(0.007)	0.024***	(0.007)
acres_wa_kit	0.009	(0.010)	0.009	(0.010)	0.014	(0.011)	0.014	(0.011)
acreslt1_ia_car	0.446***	(0.136)	0.448***	(0.136)	0.559***	(0.144)	0.56***	(0.143)
acreslt1_ia_flo	0.436***	(0.112)	0.435***	(0.112)	0.384***	(0.118)	0.383***	(0.118)
acreslt1_ia_fra	0.670***	(0.124)	0.668***	(0.124)	0.684***	(0.139)	0.68***	(0.139)
acreslt1_ia_sac	0.159	(0.115)	0.160	(0.115)	0.222*	(0.123)	0.221*	(0.123)
acreslt1_il_dek	0.278***	(0.066)	0.285***	(0.066)	0.282***	(0.073)	0.294***	(0.073)
acreslt1_il_liv	0.278***	(0.063)	0.276***	(0.063)	0.383***	(0.088)	0.38***	(0.088)
acreslt1_il_mcl	-0.069***	(0.021)	-0.070***	(0.021)	-0.007	(0.032)	-0.007	(0.032)
acreslt1_mn_cot	0.529***	(0.093)	0.529***	(0.093)	0.466***	(0.120)	0.465***	(0.120)
acreslt1_mn_fre	0.314***	(0.053)	0.314***	(0.053)	0.294***	(0.061)	0.293***	(0.061)
acreslt1_mn_jac	0.250*	(0.144)	0.247*	(0.145)	0.169	(0.146)	0.162	(0.146)
acreslt1_mn_mar	0.452***	(0.062)	0.452***	(0.062)	0.461***	(0.069)	0.462***	(0.069)
acreslt1_nj_atl	0.135***	(0.048)	0.135***	(0.048)	0.044	(0.047)	0.043	(0.047)
acreslt1_ny_cli	0.115***	(0.044)	0.115***	(0.044)	0.108**	(0.047)	0.108**	(0.047)
acreslt1_ny_fra	0.118	(0.100)	0.118	(0.100)	0.113	(0.115)	0.113	(0.115)
acreslt1_ny_her	0.364***	(0.047)	0.364***	(0.047)	0.331***	(0.050)	0.332***	(0.050)
acreslt1_ny_lew	0.119*	(0.061)	0.120**	(0.061)	0.117*	(0.067)	0.117*	(0.067)

	OneMile OLS		HalfMile OLS		OneMile SEM		HalfMile SEM	
Variables	coef	se	coef	se	coef	se	coef	se
acreslt1_ny_mad	0.017	(0.031)	0.018	(0.031)	0.043	(0.032)	0.043	(0.032)
acreslt1_ny_ste	0.100**	(0.042)	0.100**	(0.042)	0.18***	(0.047)	0.18***	(0.047)
acreslt1_ny_wyo	0.144***	(0.035)	0.144***	(0.035)	0.137***	(0.039)	0.137***	(0.039)
acreslt1_oh_pau	0.426***	(0.087)	0.425***	(0.087)	0.507***	(0.120)	0.507***	(0.120)
acreslt1_oh_woo	0.124***	(0.034)	0.124***	(0.034)	0.114***	(0.041)	0.114***	(0.041)
acreslt1_ok_cus	0.103	(0.070)	0.104	(0.070)	0.091	(0.092)	0.093	(0.092)
acreslt1_ok_gra	-0.038	(0.054)	-0.038	(0.054)	-0.065	(0.066)	-0.065	(0.066)
acreslt1_pa_fay	0.403***	(0.153)	0.403***	(0.153)	0.42**	(0.165)	0.42**	(0.164)
acreslt1_pa_som	0.243***	(0.039)	0.243***	(0.039)	0.223***	(0.047)	0.223***	(0.047)
acreslt1_pa_way	0.138**	(0.062)	0.138**	(0.062)	0.108	(0.077)	0.109	(0.077)
acreslt1_wa_kit	0.335**	(0.134)	0.335**	(0.134)	0.342**	(0.164)	0.342**	(0.164)
age_ia_car	-0.013***	(0.001)	-0.013***	(0.001)	-0.011***	(0.001)	-0.011***	(0.001)
age_ia_flo	-0.013***	(0.002)	-0.013***	(0.002)	-0.013***	(0.002)	-0.013***	(0.002)
age_ia_fra	-0.012***	(0.003)	-0.012***	(0.003)	-0.011***	(0.003)	-0.011***	(0.003)
age_ia_sac	-0.013***	(0.003)	-0.013***	(0.003)	-0.011***	(0.003)	-0.011***	(0.003)
age_il_dek	-0.004***	(0.001)	-0.004***	(0.001)	-0.004***	(0.001)	-0.004***	(0.001)
age_il_liv	-0.001	(0.001)	-0.002	(0.001)	-0.003	(0.002)	-0.003	(0.002)
age_il_mcl	-0.004***	(0.001)	-0.004***	(0.001)	-0.006***	(0.001)	-0.006***	(0.001)
age_mn_cot	-0.021***	(0.003)	-0.021***	(0.003)	-0.013***	(0.005)	-0.013***	(0.005)
age_mn_fre	-0.013***	(0.001)	-0.013***	(0.001)	-0.012***	(0.002)	-0.012***	(0.002)
age_mn_jac	-0.018***	(0.005)	-0.018***	(0.005)	-0.018***	(0.005)	-0.018***	(0.005)
age_mn_mar	-0.010***	(0.001)	-0.010***	(0.001)	-0.009***	(0.002)	-0.009***	(0.002)
age_nj_atl	-0.004***	(0.000)	-0.004***	(0.000)	-0.003***	(0.001)	-0.003***	(0.001)
age_ny_cli	-0.005***	(0.001)	-0.005***	(0.001)	-0.005***	(0.001)	-0.005***	(0.001)
age_ny_fra	-0.004	(0.003)	-0.005	(0.003)	-0.005*	(0.003)	-0.005*	(0.003)
age_ny_her	-0.008***	(0.001)	-0.008***	(0.001)	-0.008***	(0.001)	-0.008***	(0.001)
age_ny_lew	-0.008***	(0.001)	-0.008***	(0.001)	-0.009***	(0.001)	-0.009***	(0.001)
age_ny_mad	-0.006***	(0.001)	-0.006***	(0.001)	-0.006***	(0.001)	-0.006***	(0.001)
age_ny_ste	-0.006***	(0.001)	-0.006***	(0.001)	-0.007***	(0.001)	-0.007***	(0.001)
age_ny_wyo	-0.006***	(0.001)	-0.006***	(0.001)	-0.006***	(0.001)	-0.006***	(0.001)
age_oh_pau	0.003	(0.003)	0.003	(0.003)	0.003	(0.004)	0.003	(0.004)
age_oh_woo	0.008***	(0.001)	0.008***	(0.001)	0.01***	(0.001)	0.01***	(0.001)
age_ok_cus	-0.000	(0.002)	-0.000	(0.002)	0.002	(0.003)	0.002	(0.003)
age_ok_gra	-0.000	(0.002)	-0.000	(0.002)	0.001	(0.002)	0.001	(0.002)
age_pa_fay	0.010**	(0.004)	0.010**	(0.004)	0.01**	(0.005)	0.01**	(0.005)
age_pa_som	-0.006***	(0.001)	-0.006***	(0.001)	-0.008***	(0.001)	-0.008***	(0.001)
age_pa_way	0.006***	(0.002)	0.006***	(0.002)	0.007***	(0.002)	0.007***	(0.002)
age_wa_kit	0.010***	(0.003)	0.010***	(0.003)	0.014***	(0.003)	0.014***	(0.003)
agesq_ia_car	0.034***	(0.011)	0.034***	(0.000)	0.022*	(0.012)	0.022*	(0.012)
agesq_ia_flo	0.040***	(0.016)	0.040**	(0.016)	0.044***	(0.016)	0.044***	(0.016)
agesq_ia_fra	0.025	(0.022)	0.025	(0.022)	0.02	(0.023)	0.021	(0.023)
agesq_ia_sac	0.032	(0.022)	0.032	(0.022)	0.025	(0.023)	0.025	(0.023)
agesq_il_dek	0.008	(0.010)	0.008	(0.010)	0.013	(0.012)	0.013	(0.011)
agesq_il_liv	-0.023**	(0.009)	-0.023**	(0.009)	-0.011	(0.014)	-0.011	(0.014)
agesq_il_mcl	0.005	(0.007)	0.005	(0.007)	0.021*	(0.011)	0.021*	(0.011)
agesq_mn_cot	0.109**	(0.043)	0.109**	(0.043)	0.032	(0.069)	0.033	(0.069)
agesq_mn_fre	0.046***	(0.010)	0.045***	(0.010)	0.044***	(0.012)	0.044***	(0.012)
agesq_mn_jac	0.103***	(0.035)	0.104***	(0.035)	0.1***	(0.034)	0.101***	(0.034)
agesq_mn_mar	0.012	(0.012)	0.012	(0.012)	0.006	(0.014)	0.006	(0.014)

Variables	OneMile OLS coef	OneMile OLS se	HalfMile OLS coef	HalfMile OLS se	OneMile SEM coef	OneMile SEM se	HalfMile SEM coef	HalfMile SEM se
agesq_nj_atl	0.010***	(0.003)	0.010***	(0.003)	0.003	(0.005)	0.003	(0.005)
agesq_ny_cli	0.011*	(0.006)	0.011*	(0.006)	0.011*	(0.006)	0.011*	(0.006)
agesq_ny_fra	-0.011	(0.022)	-0.011	(0.022)	-0.002	(0.020)	-0.002	(0.020)
agesq_ny_her	0.022***	(0.005)	0.022***	(0.005)	0.022***	(0.006)	0.022***	(0.006)
agesq_ny_lew	0.031***	(0.006)	0.031***	(0.006)	0.032***	(0.007)	0.032***	(0.007)
agesq_ny_mad	0.017***	(0.003)	0.017***	(0.003)	0.023***	(0.003)	0.023***	(0.003)
agesq_ny_ste	0.013**	(0.005)	0.013**	(0.005)	0.018***	(0.005)	0.018***	(0.005)
agesq_ny_wyo	0.016***	(0.005)	0.016***	(0.005)	0.017***	(0.005)	0.017***	(0.005)
agesq_oh_pau	-0.044**	(0.022)	-0.045**	(0.022)	-0.043	(0.028)	-0.043	(0.028)
agesq_oh_woo	-0.074***	(0.007)	-0.074***	(0.007)	-0.091***	(0.009)	-0.091***	(0.009)
agesq_ok_cus	-0.091***	(0.019)	-0.091***	(0.019)	-0.113***	(0.026)	-0.113***	(0.026)
agesq_ok_gra	-0.081***	(0.023)	-0.081***	(0.023)	-0.097***	(0.029)	-0.097***	(0.029)
agesq_pa_fay	-0.112***	(0.032)	-0.112***	(0.032)	-0.105***	(0.034)	-0.106***	(0.034)
agesq_pa_som	0.000	(0.008)	0.002	(0.008)	0.016*	(0.009)	0.016*	(0.009)
agesq_pa_way	-0.000***	(0.012)	-0.052***	(0.012)	-0.053***	(0.014)	-0.053***	(0.014)
agesq_wa_kit	-0.000***	(0.027)	-0.097***	(0.027)	-0.132***	(0.031)	-0.132***	(0.031)
bathsim_ia_sac	-0.050	(0.073)	-0.050	(0.073)	-0.082	(0.077)	-0.081	(0.077)
bathsim_il_dek	-0.005	(0.015)	-0.005	(0.015)	0.001	(0.018)	0.001	(0.018)
bathsim_ny_cli	0.090***	(0.025)	0.090***	(0.025)	0.087***	(0.024)	0.087***	(0.024)
bathsim_ny_fra	0.246***	(0.062)	0.245***	(0.062)	0.213***	(0.064)	0.212***	(0.064)
bathsim_ny_her	0.099***	(0.022)	0.099***	(0.022)	0.079***	(0.022)	0.079***	(0.022)
bathsim_ny_lew	0.168***	(0.030)	0.167***	(0.030)	0.142***	(0.031)	0.142***	(0.031)
bathsim_ny_mad	0.180***	(0.014)	0.180***	(0.014)	0.157***	(0.013)	0.157***	(0.013)
bathsim_ny_ste	0.189***	(0.019)	0.189***	(0.019)	0.166***	(0.020)	0.166***	(0.020)
bathsim_ny_wyo	0.107***	(0.021)	0.107***	(0.021)	0.1***	(0.021)	0.1***	(0.021)
bathsim_oh_pau	0.095*	(0.051)	0.095*	(0.051)	0.149***	(0.057)	0.149***	(0.057)
bathsim_oh_woo	0.094***	(0.017)	0.094***	(0.017)	0.092***	(0.019)	0.092***	(0.019)
bathsim_pa_fay	0.367***	(0.077)	0.367***	(0.077)	0.301***	(0.082)	0.302***	(0.082)
bathsim_pa_way	0.082**	(0.036)	0.082**	(0.036)	0.081**	(0.041)	0.081**	(0.041)
pctvacant_ia_car	-2.515*	(1.467)	-2.521*	(1.468)	-2.011	(1.936)	-2.019	(1.937)
pctvacant_ia_flo	0.903	(1.152)	0.921	(1.152)	1.358	(1.409)	1.339	(1.410)
pctvacant_ia_fra	8.887**	(3.521)	8.928**	(3.518)	-2.596	(1.703)	-2.6	(1.703)
pctvacant_ia_sac	0.672	(0.527)	0.673	(0.527)	1.267***	(0.377)	1.266***	(0.377)
pctvacant_il_dek	0.052	(0.639)	0.062	(0.638)	0.037	(0.964)	0.069	(0.961)
pctvacant_il_liv	-0.475	(0.474)	-0.476	(0.474)	-0.699	(0.872)	-0.701	(0.872)
pctvacant_il_mcl	-0.365	(0.397)	-0.366	(0.397)	0.445	(0.670)	0.442	(0.670)
pctvacant_mn_cot	1.072*	(0.592)	1.072*	(0.592)	0.272	(1.039)	0.273	(1.039)
pctvacant_mn_fre	-1.782**	(0.703)	-1.787**	(0.703)	-1.372	(0.965)	-1.384	(0.965)
pctvacant_mn_jac	-1.345	(0.883)	-1.318	(0.884)	-1.285	(1.084)	-1.313	(1.084)
pctvacant_mn_mar	2.178***	(0.502)	2.175***	(0.502)	1.53**	(0.622)	1.528**	(0.622)
pctvacant_nj_atl	-0.054	(0.062)	-0.054	(0.062)	0.096	(0.085)	0.095	(0.085)
pctvacant_ny_cli	0.709***	(0.224)	0.709***	(0.224)	0.842***	(0.251)	0.841***	(0.251)
pctvacant_ny_fra	6.173***	(2.110)	6.104***	(2.113)	0.519	(0.710)	0.499	(0.709)
pctvacant_ny_her	-1.226***	(0.247)	-1.226***	(0.247)	-1.347***	(0.288)	-1.347***	(0.288)
pctvacant_ny_lew	-0.125	(0.127)	-0.125	(0.127)	-0.266*	(0.159)	-0.266*	(0.159)
pctvacant_ny_mad	0.750***	(0.196)	0.752***	(0.196)	0.767***	(0.246)	0.765***	(0.246)
pctvacant_ny_ste	0.280	(0.190)	0.281	(0.190)	0.039	(0.242)	0.04	(0.242)
pctvacant_ny_wyo	0.179*	(0.101)	0.178*	(0.101)	0.225*	(0.119)	0.224*	(0.119)
pctvacant_oh_pau	-1.473	(1.498)	-1.473	(1.499)	-1.341	(1.951)	-1.256	(1.952)

Variables	OneMile OLS coef	se	HalfMile OLS coef	se	OneMile SEM coef	se	HalfMile SEM coef	se
pctvacant_oh_woo	-0.565	(0.400)	-0.565	(0.400)	-0.304	(0.563)	-0.306	(0.563)
pctvacant_ok_cus	-0.127	(0.358)	-0.140	(0.359)	-0.167	(0.521)	-0.189	(0.521)
pctvacant_ok_gra	1.413*	(0.777)	1.414*	(0.777)	0.537	(1.045)	0.536	(1.045)
pctvacant_pa_fay	0.227	(0.596)	0.229	(0.596)	0.232	(0.807)	0.235	(0.807)
pctvacant_pa_som	0.517***	(0.098)	0.516***	(0.098)	0.562***	(0.138)	0.562***	(0.138)
pctvacant_pa_way	0.445***	(0.156)	0.444***	(0.156)	0.446**	(0.175)	0.446**	(0.175)
pctvacant_wa_kit	-0.076	(0.546)	-0.075	(0.546)	-0.377	(0.282)	-0.377	(0.281)
pctowner_ia_car	-0.225	(0.244)	-0.225	(0.244)	-0.156	(0.324)	-0.156	(0.324)
pctowner_ia_flo	0.579**	(0.238)	0.578**	(0.238)	0.75***	(0.290)	0.75***	(0.290)
pctowner_ia_fra	0.207	(0.310)	0.206	(0.310)	0.172	(0.393)	0.169	(0.393)
pctowner_ia_sac	0.274	(0.585)	0.261	(0.586)	-0.34	(0.545)	-0.345	(0.545)
pctowner_il_dek	0.075	(0.088)	0.073	(0.087)	0.032	(0.123)	0.028	(0.123)
pctowner_il_liv	0.176	(0.140)	0.176	(0.140)	0.265	(0.200)	0.264	(0.200)
pctowner_il_mcl	0.389***	(0.051)	0.388***	(0.051)	0.331***	(0.101)	0.331***	(0.101)
pctowner_mn_cot	0.375***	(0.138)	0.375***	(0.138)	0.609**	(0.254)	0.609**	(0.254)
pctowner_mn_fre	-0.119	(0.090)	-0.120	(0.090)	-0.072	(0.124)	-0.073	(0.124)
pctowner_mn_jac	-0.206	(0.474)	-0.205	(0.474)	-0.175	(0.569)	-0.185	(0.570)
pctowner_mn_mar	0.262***	(0.076)	0.262***	(0.076)	0.151	(0.103)	0.151	(0.103)
pctowner_nj_atl	-0.087**	(0.037)	-0.087**	(0.037)	-0.036	(0.052)	-0.037	(0.052)
pctowner_ny_cli	-0.229	(0.171)	-0.229	(0.171)	-0.305	(0.199)	-0.303	(0.199)
pctowner_ny_fra	2.743*	(1.500)	2.693*	(1.505)	-0.315	(1.447)	-0.398	(1.442)
pctowner_ny_her	0.246***	(0.095)	0.246***	(0.095)	0.213*	(0.109)	0.213*	(0.109)
pctowner_ny_lew	-0.034	(0.185)	-0.034	(0.185)	-0.126	(0.219)	-0.126	(0.219)
pctowner_ny_mad	0.750***	(0.075)	0.750***	(0.075)	0.723***	(0.084)	0.723***	(0.084)
pctowner_ny_ste	0.192	(0.128)	0.191	(0.128)	-0.083	(0.162)	-0.084	(0.162)
pctowner_ny_wyo	-0.089	(0.111)	-0.089	(0.111)	-0.109	(0.138)	-0.108	(0.138)
pctowner_oh_pau	-0.187	(0.347)	-0.185	(0.348)	-1.245***	(0.473)	-1.249***	(0.474)
pctowner_oh_woo	0.263***	(0.092)	0.264***	(0.092)	0.274**	(0.136)	0.274**	(0.136)
pctowner_ok_cus	0.068	(0.104)	0.068	(0.104)	-0.041	(0.146)	-0.043	(0.146)
pctowner_ok_gra	0.271*	(0.159)	0.271*	(0.159)	0.253	(0.217)	0.253	(0.217)
pctowner_pa_fay	-0.413	(1.736)	-0.420	(1.736)	-0.15	(2.037)	-0.165	(2.037)
pctowner_pa_som	0.171	(0.114)	0.170	(0.114)	0.098	(0.173)	0.098	(0.173)
pctowner_pa_way	-0.351	(0.441)	-0.348	(0.441)	-0.251	(0.345)	-0.252	(0.345)
pctowner_wa_kit	0.257	(2.139)	0.259	(2.139)	-0.358	(1.889)	-0.361	(1.890)
med_age_ia_car	0.002	(0.002)	0.002	(0.002)	0.003	(0.003)	0.003	(0.003)
med_age_ia_flo	0.003	(0.002)	0.003	(0.002)	0.004	(0.003)	0.004	(0.003)
med_age_ia_fra	0.066***	(0.015)	0.066***	(0.015)	0.014**	(0.006)	0.014**	(0.006)
med_age_ia_sac	0.028**	(0.014)	0.028**	(0.014)	0.012	(0.010)	0.012	(0.010)
med_age_il_dek	-0.001	(0.002)	-0.001	(0.002)	-0.001	(0.003)	-0.001	(0.003)
med_age_il_liv	-0.004	(0.004)	-0.004	(0.004)	-0.005	(0.005)	-0.005	(0.005)
med_age_il_mcl	-0.006***	(0.002)	-0.006***	(0.002)	-0.006**	(0.003)	-0.006**	(0.003)
med_age_mn_cot	0.017***	(0.005)	0.017***	(0.005)	0.018**	(0.008)	0.018**	(0.008)
med_age_mn_fre	0.012***	(0.002)	0.012***	(0.002)	0.013***	(0.002)	0.013***	(0.002)
med_age_mn_jac	0.013	(0.008)	0.013	(0.008)	0.012	(0.010)	0.012	(0.010)
med_age_mn_mar	0.013***	(0.003)	0.013***	(0.003)	0.012***	(0.003)	0.012***	(0.003)
med_age_nj_atl	0.010***	(0.001)	0.010***	(0.001)	0.016***	(0.002)	0.016***	(0.002)
med_age_ny_cli	0.020***	(0.004)	0.020***	(0.004)	0.02***	(0.004)	0.02***	(0.004)
med_age_ny_fra	-0.517***	(0.198)	-0.511***	(0.198)	0.008	(0.040)	0.01	(0.039)
med_age_ny_her	0.007*	(0.003)	0.007*	(0.003)	0.005	(0.003)	0.005	(0.003)

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	OneMile OLS		HalfMile OLS		OneMile SEM		HalfMile SEM	
Variables	coef	se	coef	se	coef	se	coef	se
med_age_ny_lew	0.013***	(0.005)	0.013***	(0.005)	0.008	(0.005)	0.008	(0.005)
med_age_ny_mad	0.004**	(0.002)	0.004**	(0.002)	0.004*	(0.002)	0.004*	(0.002)
med_age_ny_ste	0.012***	(0.003)	0.012***	(0.003)	0.001	(0.004)	0.001	(0.004)
med_age_ny_wyo	0.008	(0.005)	0.007	(0.005)	0.008	(0.006)	0.008	(0.006)
med_age_oh_pau	0.034***	(0.013)	0.034***	(0.013)	0.019	(0.012)	0.019	(0.012)
med_age_oh_woo	-0.004	(0.003)	-0.004	(0.003)	-0.004	(0.004)	-0.004	(0.004)
med_age_ok_cus	0.004	(0.002)	0.004	(0.002)	0.008**	(0.004)	0.008**	(0.004)
med_age_ok_gra	0.011	(0.009)	0.011	(0.009)	0	(0.006)	0	(0.006)
med_age_pa_fay	0.049	(0.073)	0.049	(0.073)	0.052	(0.095)	0.052	(0.095)
med_age_pa_som	0.008***	(0.002)	0.008***	(0.002)	0.012***	(0.004)	0.012***	(0.004)
med_age_pa_way	-0.005	(0.012)	-0.005	(0.012)	0.002	(0.007)	0.002	(0.007)
med_age_wa_kit	-0.015	(0.095)	-0.015	(0.095)	0.025	(0.034)	0.025	(0.034)
swinter_ia	-0.034**	(0.015)	-0.034**	(0.015)	-0.039***	(0.015)	-0.039***	(0.015)
swinter_il	-0.020**	(0.008)	-0.020**	(0.008)	-0.013	(0.012)	-0.013	(0.012)
swinter_mn	-0.053***	(0.009)	-0.053***	(0.009)	-0.057***	(0.011)	-0.057***	(0.011)
swinter_nj	-0.007	(0.006)	-0.007	(0.006)	-0.008	(0.007)	-0.008	(0.007)
swinter_ny	-0.030***	(0.007)	-0.030***	(0.007)	-0.026***	(0.007)	-0.026***	(0.007)
swinter_oh	-0.048***	(0.012)	-0.048***	(0.012)	-0.055***	(0.014)	-0.055***	(0.014)
swinter_ok	-0.039**	(0.015)	-0.039**	(0.015)	-0.024	(0.018)	-0.024	(0.018)
swinter_pa	-0.025*	(0.015)	-0.025*	(0.015)	-0.02	(0.017)	-0.02	(0.017)
swinter_wa	-0.004	(0.046)	-0.004	(0.046)	0.014	(0.051)	0.013	(0.051)
sy_1996_ia	-0.436***	(0.137)	-0.433***	(0.137)	-0.493***	(0.157)	-0.489***	(0.157)
sy_1996_il	-0.267***	(0.037)	-0.267***	(0.037)	-0.344***	(0.061)	-0.344***	(0.061)
sy_1996_mn	-0.521***	(0.058)	-0.521***	(0.059)	-0.585***	(0.065)	-0.585***	(0.065)
sy_1996_nj	-0.820***	(0.022)	-0.820***	(0.022)	-0.717***	(0.038)	-0.717***	(0.038)
sy_1996_oh	-0.298***	(0.042)	-0.298***	(0.042)	-0.43***	(0.053)	-0.43***	(0.053)
sy_1996_ok	-0.444***	(0.073)	-0.444***	(0.073)	-0.846***	(0.079)	-0.846***	(0.079)
sy_1996_pa	-0.584***	(0.060)	-0.584***	(0.060)	-0.604***	(0.067)	-0.604***	(0.067)
sy_1997_il	-0.242***	(0.036)	-0.242***	(0.036)	-0.234***	(0.052)	-0.232***	(0.052)
sy_1997_mn	-0.445***	(0.055)	-0.445***	(0.055)	-0.535***	(0.060)	-0.535***	(0.060)
sy_1997_nj	-0.791***	(0.021)	-0.791***	(0.021)	-0.686***	(0.038)	-0.686***	(0.038)
sy_1997_oh	-0.302***	(0.043)	-0.302***	(0.043)	-0.39***	(0.053)	-0.39***	(0.053)
sy_1997_pa	-0.458***	(0.057)	-0.458***	(0.057)	-0.51***	(0.066)	-0.51***	(0.066)
sy_1998_ia	-0.442***	(0.078)	-0.441***	(0.078)	-0.633***	(0.099)	-0.634***	(0.099)
sy_1998_il	-0.156***	(0.031)	-0.156***	(0.031)	-0.175***	(0.048)	-0.175***	(0.048)
sy_1998_mn	-0.391***	(0.054)	-0.391***	(0.054)	-0.484***	(0.059)	-0.484***	(0.059)
sy_1998_nj	-0.723***	(0.020)	-0.723***	(0.021)	-0.633***	(0.037)	-0.633***	(0.037)
sy_1998_oh	-0.217***	(0.040)	-0.217***	(0.040)	-0.302***	(0.047)	-0.302***	(0.047)
sy_1998_ok	-0.394***	(0.048)	-0.395***	(0.048)	-0.816***	(0.059)	-0.818***	(0.059)
sy_1998_pa	-0.481***	(0.059)	-0.480***	(0.059)	-0.554***	(0.068)	-0.552***	(0.067)
sy_1998_wa	-0.433***	(0.115)	-0.433***	(0.115)	-0.356**	(0.161)	-0.356**	(0.161)
sy_1999_ia	-0.347***	(0.085)	-0.345***	(0.086)	-0.568***	(0.117)	-0.565***	(0.117)
sy_1999_il	-0.155***	(0.031)	-0.156***	(0.031)	-0.215***	(0.046)	-0.214***	(0.046)
sy_1999_mn	-0.302***	(0.055)	-0.303***	(0.055)	-0.367***	(0.059)	-0.368***	(0.059)
sy_1999_nj	-0.679***	(0.020)	-0.679***	(0.020)	-0.583***	(0.036)	-0.583***	(0.036)
sy_1999_oh	-0.161***	(0.040)	-0.161***	(0.040)	-0.243***	(0.047)	-0.243***	(0.047)
sy_1999_ok	-0.347***	(0.044)	-0.348***	(0.044)	-0.743***	(0.050)	-0.743***	(0.050)
sy_1999_pa	-0.452***	(0.058)	-0.452***	(0.058)	-0.515***	(0.066)	-0.515***	(0.066)
sy_1999_wa	-0.432***	(0.114)	-0.432***	(0.114)	-0.454***	(0.166)	-0.453***	(0.165)

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Variables	OneMile OLS coef	OneMile OLS se	HalfMile OLS coef	HalfMile OLS se	OneMile SEM coef	OneMile SEM se	HalfMile SEM coef	HalfMile SEM se
sy_2000_ia	-0.165	(0.145)	-0.164	(0.146)	-0.246	(0.183)	-0.246	(0.183)
sy_2000_il	-0.088***	(0.031)	-0.088***	(0.031)	-0.172***	(0.045)	-0.171***	(0.045)
sy_2000_mn	-0.148***	(0.051)	-0.149***	(0.051)	-0.224***	(0.053)	-0.224***	(0.053)
sy_2000_nj	-0.565***	(0.020)	-0.565***	(0.020)	-0.461***	(0.036)	-0.462***	(0.036)
sy_2000_oh	-0.098**	(0.041)	-0.098**	(0.041)	-0.161***	(0.047)	-0.16***	(0.047)
sy_2000_ok	-0.330***	(0.050)	-0.331***	(0.050)	-0.748***	(0.059)	-0.749***	(0.059)
sy_2000_pa	-0.394***	(0.057)	-0.395***	(0.057)	-0.478***	(0.067)	-0.478***	(0.067)
sy_2000_wa	-0.463***	(0.115)	-0.463***	(0.115)	-0.403**	(0.160)	-0.402**	(0.160)
sy_2001_ia	-0.334***	(0.065)	-0.332***	(0.065)	-0.435***	(0.066)	-0.433***	(0.066)
sy_2001_il	-0.080**	(0.031)	-0.080***	(0.031)	-0.101**	(0.048)	-0.101**	(0.048)
sy_2001_mn	-0.119**	(0.050)	-0.119**	(0.050)	-0.204***	(0.051)	-0.204***	(0.052)
sy_2001_nj	-0.438***	(0.018)	-0.438***	(0.018)	-0.333***	(0.034)	-0.333***	(0.034)
sy_2001_oh	-0.033	(0.036)	-0.033	(0.036)	-0.078**	(0.040)	-0.078**	(0.040)
sy_2001_ok	-0.250***	(0.041)	-0.251***	(0.041)	-0.648***	(0.044)	-0.648***	(0.044)
sy_2001_pa	-0.402***	(0.055)	-0.402***	(0.055)	-0.446***	(0.063)	-0.447***	(0.063)
sy_2001_wa	-0.378***	(0.122)	-0.378***	(0.122)	-0.275*	(0.163)	-0.275*	(0.163)
sy_2002_ia	-0.130**	(0.059)	-0.128**	(0.059)	-0.264***	(0.064)	-0.261***	(0.064)
sy_2002_il	0.008	(0.030)	0.007	(0.030)	-0.013	(0.043)	-0.013	(0.043)
sy_2002_mn	-0.072	(0.050)	-0.072	(0.050)	-0.138***	(0.051)	-0.139***	(0.051)
sy_2002_nj	-0.330***	(0.019)	-0.330***	(0.019)	-0.195***	(0.035)	-0.195***	(0.035)
sy_2002_ny	-0.307***	(0.020)	-0.307***	(0.020)	-0.342***	(0.020)	-0.342***	(0.020)
sy_2002_oh	-0.022	(0.038)	-0.022	(0.038)	-0.053	(0.042)	-0.053	(0.042)
sy_2002_ok	-0.249***	(0.045)	-0.249***	(0.045)	-0.649***	(0.052)	-0.649***	(0.052)
sy_2002_pa	-0.313***	(0.053)	-0.313***	(0.053)	-0.355***	(0.059)	-0.354***	(0.059)
sy_2002_wa	-0.241**	(0.123)	-0.241**	(0.123)	-0.216	(0.166)	-0.216	(0.166)
sy_2003_ia	-0.195**	(0.081)	-0.194**	(0.081)	-0.311***	(0.085)	-0.314***	(0.084)
sy_2003_il	0.034	(0.030)	0.034	(0.030)	0.021	(0.040)	0.021	(0.040)
sy_2003_mn	0.034	(0.049)	0.034	(0.049)	-0.026	(0.049)	-0.026	(0.049)
sy_2003_nj	-0.119***	(0.017)	-0.119***	(0.017)	0.023	(0.033)	0.023	(0.033)
sy_2003_ny	-0.247***	(0.020)	-0.247***	(0.020)	-0.276***	(0.020)	-0.276***	(0.020)
sy_2003_oh	0.005	(0.036)	0.005	(0.036)	-0.019	(0.039)	-0.019	(0.039)
sy_2003_ok	-0.229***	(0.046)	-0.229***	(0.046)	-0.632***	(0.053)	-0.632***	(0.053)
sy_2003_pa	-0.191***	(0.052)	-0.191***	(0.052)	-0.213***	(0.054)	-0.213***	(0.054)
sy_2003_wa	-0.326***	(0.114)	-0.326***	(0.114)	-0.335**	(0.159)	-0.337**	(0.159)
sy_2004_ia	-0.209***	(0.076)	-0.208***	(0.076)	-0.307***	(0.087)	-0.308***	(0.087)
sy_2004_il	0.087***	(0.029)	0.087***	(0.029)	0.105***	(0.034)	0.105***	(0.034)
sy_2004_mn	0.082*	(0.049)	0.081*	(0.049)	0.036	(0.049)	0.036	(0.049)
sy_2004_ny	-0.179***	(0.019)	-0.179***	(0.019)	-0.2***	(0.020)	-0.2***	(0.020)
sy_2004_oh	0.059	(0.037)	0.059	(0.037)	0.067*	(0.039)	0.067*	(0.039)
sy_2004_ok	-0.143***	(0.041)	-0.143***	(0.041)	-0.511***	(0.044)	-0.511***	(0.044)
sy_2004_pa	-0.146***	(0.052)	-0.146***	(0.052)	-0.145***	(0.053)	-0.145***	(0.053)
sy_2004_wa	-0.144	(0.113)	-0.144	(0.113)	-0.082	(0.152)	-0.081	(0.152)
sy_2005_ia	-0.074**	(0.037)	-0.075**	(0.037)	-0.151***	(0.040)	-0.151***	(0.040)
sy_2005_il	0.125***	(0.027)	0.125***	(0.027)	0.139***	(0.032)	0.138***	(0.032)
sy_2005_mn	0.163***	(0.048)	0.162***	(0.048)	0.12**	(0.048)	0.119**	(0.048)
sy_2005_nj	0.278***	(0.018)	0.278***	(0.018)	0.453***	(0.034)	0.453***	(0.034)
sy_2005_ny	-0.110***	(0.019)	-0.111***	(0.019)	-0.122***	(0.019)	-0.122***	(0.019)
sy_2005_oh	0.112***	(0.036)	0.112***	(0.036)	0.099***	(0.037)	0.098***	(0.037)
sy_2005_ok	-0.018	(0.038)	-0.018	(0.038)	-0.354***	(0.038)	-0.354***	(0.038)

Variables	OneMile OLS coef	OneMile OLS se	HalfMile OLS coef	HalfMile OLS se	OneMile SEM coef	OneMile SEM se	HalfMile SEM coef	HalfMile SEM se
sy_2005_pa	-0.060	(0.051)	-0.060	(0.051)	-0.058	(0.053)	-0.058	(0.053)
sy_2005_wa	-0.070	(0.111)	-0.070	(0.111)	0.025	(0.153)	0.025	(0.153)
sy_2006_ia	-0.050*	(0.028)	-0.051*	(0.028)	-0.106***	(0.028)	-0.106***	(0.028)
sy_2006_il	0.192***	(0.026)	0.192***	(0.026)	0.215***	(0.030)	0.215***	(0.030)
sy_2006_mn	0.206***	(0.049)	0.206***	(0.049)	0.164***	(0.049)	0.164***	(0.049)
sy_2006_nj	0.340***	(0.017)	0.340***	(0.017)	0.514***	(0.032)	0.514***	(0.032)
sy_2006_ny	-0.066***	(0.019)	-0.066***	(0.019)	-0.073***	(0.019)	-0.073***	(0.019)
sy_2006_oh	0.147***	(0.034)	0.147***	(0.034)	0.144***	(0.035)	0.144***	(0.035)
sy_2006_ok	0.025	(0.039)	0.026	(0.039)	-0.3***	(0.037)	-0.3***	(0.037)
sy_2006_pa	0.008	(0.051)	0.008	(0.051)	-0.001	(0.052)	-0.001	(0.052)
sy_2006_wa	-0.066	(0.131)	-0.066	(0.131)	0.02	(0.160)	0.021	(0.160)
sy_2007_ia	0.013	(0.028)	0.012	(0.028)	-0.019	(0.028)	-0.019	(0.028)
sy_2007_il	0.218***	(0.025)	0.218***	(0.025)	0.251***	(0.028)	0.251***	(0.028)
sy_2007_mn	0.177***	(0.049)	0.177***	(0.049)	0.145***	(0.048)	0.144***	(0.048)
sy_2007_nj	0.297***	(0.017)	0.297***	(0.017)	0.459***	(0.031)	0.459***	(0.031)
sy_2007_ny	-0.020	(0.019)	-0.020	(0.019)	-0.022	(0.019)	-0.022	(0.019)
sy_2007_oh	0.144***	(0.035)	0.143***	(0.035)	0.138***	(0.036)	0.138***	(0.036)
sy_2007_ok	0.149***	(0.037)	0.150***	(0.037)	-0.154***	(0.034)	-0.154***	(0.034)
sy_2007_pa	0.030	(0.051)	0.030	(0.051)	0.067	(0.052)	0.067	(0.052)
sy_2007_wa	0.189*	(0.110)	0.189*	(0.110)	0.209	(0.147)	0.209	(0.147)
sy_2008_ia	0.011	(0.029)	0.010	(0.029)	-0.029	(0.029)	-0.029	(0.029)
sy_2008_il	0.219***	(0.026)	0.218***	(0.026)	0.217***	(0.029)	0.217***	(0.029)
sy_2008_mn	0.149***	(0.050)	0.149***	(0.050)	0.108**	(0.049)	0.108**	(0.049)
sy_2008_nj	0.195***	(0.018)	0.195***	(0.018)	0.35***	(0.032)	0.35***	(0.032)
sy_2008_ny	-0.000	(0.019)	-0.000	(0.019)	-0.008	(0.019)	-0.008	(0.019)
sy_2008_oh	0.084**	(0.036)	0.084**	(0.036)	0.061*	(0.037)	0.061*	(0.037)
sy_2008_ok	0.154***	(0.039)	0.153***	(0.039)	-0.145***	(0.035)	-0.145***	(0.035)
sy_2008_pa	0.044	(0.053)	0.044	(0.053)	0.055	(0.053)	0.056	(0.053)
sy_2008_wa	0.178	(0.117)	0.179	(0.117)	0.326**	(0.148)	0.325**	(0.148)
sy_2009_ia	-0.056	(0.036)	-0.057	(0.036)	-0.102***	(0.036)	-0.102***	(0.036)
sy_2009_il	0.158***	(0.026)	0.158***	(0.026)	0.176***	(0.028)	0.176***	(0.028)
sy_2009_mn	0.104**	(0.051)	0.104**	(0.051)	0.089*	(0.050)	0.089*	(0.050)
sy_2009_nj	0.071***	(0.019)	0.071***	(0.019)	0.238***	(0.032)	0.238***	(0.032)
sy_2009_ny	-0.005	(0.019)	-0.005	(0.019)	-0.013	(0.019)	-0.013	(0.019)
sy_2009_oh	0.036	(0.035)	0.036	(0.035)	0.028	(0.036)	0.028	(0.036)
sy_2009_ok	0.219***	(0.038)	0.219***	(0.038)	-0.102***	(0.034)	-0.101***	(0.034)
sy_2009_pa	0.009	(0.053)	0.010	(0.053)	0.0003	(0.054)	0.0004	(0.054)
sy_2010_ia	0.018	(0.029)	0.017	(0.029)	-0.004	(0.028)	-0.004	(0.028)
sy_2010_il	0.105***	(0.028)	0.105***	(0.028)	0.104***	(0.029)	0.104***	(0.029)
sy_2010_mn	0.181***	(0.050)	0.180***	(0.050)	0.137***	(0.049)	0.137***	(0.049)
sy_2010_nj	0.010	(0.019)	0.010	(0.019)	0.177***	(0.032)	0.178***	(0.032)
sy_2010_ny	0.003	(0.021)	0.003	(0.021)	-0.006	(0.020)	-0.006	(0.020)
sy_2010_oh	-0.017	(0.036)	-0.017	(0.036)	-0.024	(0.036)	-0.024	(0.036)
sy_2010_ok	0.231***	(0.038)	0.231***	(0.038)	-0.074**	(0.033)	-0.074**	(0.033)
sy_2010_pa	0.013	(0.057)	0.013	(0.057)	0.013	(0.057)	0.013	(0.057)
sy_2010_wa	0.207	(0.127)	0.207	(0.127)	0.305*	(0.165)	0.305*	(0.165)

note: *** p<0.01, ** p<0.05, * p<0.1

N	51,276	51,276	38,407	38,407
Adjusted R^2	0.66	0.66	0.64	0.64

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The Potential Health Impact of Wind Turbines

Chief Medical Officer of Health (CMOH) Report

May 2010

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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.

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).

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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.

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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.

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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.

CCL09

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.

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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.

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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.

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Appendix 1: List of Documents on Wind Turbines

Journal Articles and Books

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Wind farms and health: summary of main conclusions reached in 17 reviews of research literature

Wind power and the sound that wind farms produce have no proven effects on health. Read AWEA's overview of the subject, and find related studies here:

Compiled by Prof Simon Chapman, School of Public Health and Teresa Simonetti, Sydney University Medical School.

- 2012: Massachusetts Department of Environmental Protection. Independent Expert Science Panel Releases Report on Potential Health Effects of Wind Turbines.

- 2012: Oregon Wind Energy Health Impact Assessment.

- Fiumicelli D. Windfarm noise dose-response: a literature review. Acoustics Bulletin 2011; Nov/Dec:26-34 [copies available from S Chapman.]

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- 2010: UK Health Protection Agency Report on the health effects of infrasound http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1265028759369

- 2010: NHMRC Rapid Review of the evidence http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/new0048_evidence_review_wind_turbines_and_health.pdf

- 2010: Chief Medical Officer of Health in Ontario http://www.health.gov.on.ca/en/public/publications/ministry_reports/wind_turbine/wind_turbine.pdf

- 2010: UK Health Protection Agency. Environmental noise and health in the UK. A report by the Ad Hoc Expert Group on Noise and Health. (this report is about all environmental noise) http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1279888026747

- 2009: Minnesota Department of Health. Environmental Health Division. Public Health Impacts of Wind Turbines. http://www.health.state.mn.us/divs/eh/hazardous/topics/windturbines.pdf

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2009: Canadian Wind Energy Association. *Addressing Concerns with Wind Turbines and Human Health*. CanWEA, Ottawa http://www.canwea.ca/pdf/CanWEA%20-%20Addressing%20concerns%20with%20wind%20turbines%20and%20human%20health.pdf

- 2009: Colby et al. Wind Turbine Sound and Health Effects: An Expert Panel Review. http://199.88.77.35/EFiles/docs/CD/PlanCom/10_0426_IT_100416160206.pdf

- 2008: Chatham-Kent Public Health Unit http://www.harvestingwindsupport.com/blog/wp- content/uploads/2011/03/Chatham-KentHealth-and-Wind-.pdf

- 2007: National Research Council (USA): Impact of wind energy development on humans (Chapter 4: pp97-120) of: Environmental Impacts of Wind-Energy Projects.

- 2005: Jakobsen J. Infrasound emission from wind turbines. *Jf Low Frequency Noise, Vibration and Active Control* 2005; 24(3):145-155

- 2004: Leventhall G. Low frequency noise and annoyance. *Noise & Health 2004*;.6(23):59-72 **http://tinyurl.com/4yc3oht**

- 2003: Eja Pedersen's Review for the Swedish EPA http://www.naturvardsverket.se/Documents/publikationer/620-5308-6.pdf

Additional Resources

- 2014: Barnard M. Wind Health Impacts Dismissed in Court. Energy and Policy Institute 2014. http://www.energyandpolicy.org/wind-health-impacts-dismissed-in-court

Reviews of the evidence - extracted highlights

Direct health effects from noise and WTS

"There are no direct pathological effects from wind farms and that any potential impact on humans can be minimized by following existing planning guidelines."
Source: NHMRC 2010
http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/new0048_evidence_review_wind_turbines_and_health.pdf

"There is no evidence that the audible or sub-audible sounds emitted by wind turbines have any direct adverse physiological effects." *Source: Colby 2009 review*
http://199.88.77.35/EFiles/docs/CD/PlanCom/10_0426_IT_100416160206.pdf

"... surveys of peer-reviewed scientific literature have consistently found no evidence linking wind turbines to human health concerns." *Source: CanWEA*
http://www.canwea.ca/pdf/CanWEA%20-%20Addressing%20concerns%20with%20wind%20turbines%20and%20human%20healt h.pdf

"There is insufficient evidence that the noise from wind turbines is directly... causing health problems or disease." *Source: Massachusetts review*
http://www.mass.gov/dep/energy/wind/turbine_impact_study.pdf

"There is no reason to believe, based on the levels and frequencies of the sounds and... sound exposures in occupational settings, that the sounds from wind turbines could plausibly have direct adverse health consequences." *Source: Colby 2009 review*
http://199.88.77.35/EFiles/docs/CD/PlanCom/10_0426_IT_100416160206.pdf

"... 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..." *Source: Ontario CMOH Report*
http://www.health.gov.on.ca/en/public/publications/ministry_reports/wind_turbine/wind_turbine.pdf

"... the audible noise created by a wind turbine, constructed at the approved setback distance does not pose a health impact concern." *Source: Chatham-Kent Public Health Unit*
http://www.harvestingwindsupport.com/blog/wpcontent/uploads/2011/03/Chatham-KentHealth-and-Wind-.pdf

There is no evidence for a set of health effects, from exposure to wind turbines that could be characterized as a "Wind Turbine Syndrome." *Source: Massachusetts review*
http://www.mass.gov/dep/energy/wind/turbine_impact_study.pdf

"... there is not an association between noise from wind turbines and measures of psychological distress or mental health problems." *Source: Massachusetts review*
http://www.mass.gov/dep/energy/wind/turbine_impact_study.pdf

"Evidence that environmental noise damages mental health is... inconclusive." *Source: Ad Hoc Expert Group on Noise and Health*
http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1279888026747

"...no association was found between road traffic noise and overall psychological distress..."*Source: Ad Hoc Expert Group on Noise and Health*
http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1279888026747

"To date, no peer reviewed scientific journal articles demonstrate a causal link between people living in proximity to modern wind turbines, the noise (audible, low frequency noise, or infrasound) they emit and resulting physiological health effects." *Source: Knopper & Ollson review*
http://www.ehjournal.net/content/pdf/1476-069X-10-78.pdf

"... there is no scientific evidence that noise at levels created by wind turbines could cause health problems other than annoyance..." *Source: Eja Pedersen 2003 Review*
http://www.naturvardsverket.se/Documents/publikationer/620-5308-6.pdf

"None of the... evidence reviewed suggests an association between noise from wind turbines and pain and stiffness, diabetes, high blood pressure, tinnitus, hearing impairment, cardiovascular disease, and headache/migraine." *Source: Massachusetts review*
http://www.mass.gov/dep/energy/wind/turbine_impact_study.pdf

"...there are no evidences that noise from wind turbines could cause cardiovascular and psycho-physiological effects." *Source: Eja Pedersen 2003 Review*
http://www.naturvardsverket.se/Documents/publikationer/620-5308-6.pdf

"...there was no evidence that environmental noise was related to raised blood pressure..."*Source: Ad Hoc Expert Group on Noise and Health*
http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1279888026747

"The health impact of the noise created by wind turbines has been studied and debated for decades with no definitive evidence supporting harm to the human ear." *Source: Chatham-Kent Public Health Unit*
http://www.harvestingwindsupport.com/blog/wp- content/uploads/2011/03/Chatham-KentHealth-and-Wind-.pdf

"The electromagnetic fields produced by the generation and export of electricity from a wind farm do not pose a threat to public health..."*Source: NHMRC 2010*
http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/new0048_evidence_review_wind_turbines_and_health.pdf

"... no consistent associations were found between wind turbine noise exposure and symptom reporting, e.g. chronic disease, headaches, tinnitus and undue tiredness." *Source: Bolin et al 2011 Review*
http://iopscience.iop.org/1748-9326/6/3/035103/pdf/1748-9326_6_3_035103.pdf

"... low level frequency noise or infrasound emitted by wind turbines is minimal and of no consequence... Further, numerous reports have concluded that there is no evidence of health effects arising from infrasound or low frequency noise generated by wind turbines." *Source:*

NHMRC 2010
http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/new0048_evidence_review_wind_turbines_and_health.pdf

"... renewable energy generation is associated with few adverse health effects compared with the well documented health burdens of polluting forms of electricity generation..." *Source: NHMRC 2010*
http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/new0048_evidence_review_wind_turbines_and_health.pdf

"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." *Source: Chatham-Kent Public Health Unit*
http://www.harvestingwindsupport.com/blog/wp-content/uploads/2011/03/Chatham- KentHealth-and-Wind-.pdf

"What is apparent is that numerous websites have been constructed by individuals or groups to support or oppose the development of wind turbine projects, or media sites reporting on the debate. Often these websites state the perceived impacts on, or benefits to, human health to support the position of the individual or group hosting the website. The majority of information posted on these websites cannot be traced back to a scientific, peer-reviewed source and is typically anecdotal in nature. In some cases, the information contained on and propagated by internet websites and the media is not supported, or is even refuted, by scientific research. This serves to spread misconceptions about the potential impacts of wind energy on human health..." *Source: Knopper & Ollson review*
http://www.ehjournal.net/content/pdf/1476-069X-10-78.pdf

Annoyance

"... wind turbine noise is comparatively lower than road traffic, trains, construction activities, and industrial noise." *Source: Chatham-Kent Public Health Unit*
http://www.harvestingwindsupport.com/blog/wp-content/uploads/2011/03/Chatham- KentHealth-and-Wind-.pdf

"The perception of noise depends in part on the individual - on a person's hearing acuity and upon his or her subjective tolerance for or dislike of a particular type of noise. For example, a persistent "whoosh" might be a soothing sound to some people even as it annoys others." *Source: NRC 2007*
http://www.vawind.org/assets/nrc/nrc_wind_report_050307.pdf

"... some people might find [wind turbine noise 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." *Source: Ontario CMOH Report*
http://www.health.gov.on.ca/en/public/publications/ministry_reports/wind_turbine/wind_turbine.pdf

"... being annoyed can lead to increasing feelings of powerlessness and frustration, which is widely believed to be at least potentially associated with adverse health effects over the longer term." *Source: Ad Hoc Expert Group on Noise and Health*
http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1279888026747

"Wind turbine annoyance has been statistically associated with wind turbine noise, but found to be more strongly related to visual impact, attitude to wind turbines and sensitivity to noise." *Source: Knopper & Ollson review*
http://www.ehjournal.net/content/pdf/1476-069X-10-78.pdf

"... self-reported health effects like feeling tense, stressed, and irritable, were associated with noise annoyance and not to noise itself..." *Source: Knopper & Ollson review*
http://www.ehjournal.net/content/pdf/1476-069X-10-78.pdf

"... many of the self-reported health effects are associated with numerous issues, many of which can be attributed to anxiety and annoyance." *Source: Knopper & Ollson review*
http://www.ehjournal.net/content/pdf/1476-069X-10-78.pdf

"To date, no peer reviewed articles demonstrate a direct causal link between people living in proximity to modern wind turbines, the noise they emit and resulting physiological health effects. If anything, reported health effects are likely attributed to a number of environmental stressors that result in an annoyed/stressed state in a segment of the population." *Source: Knopper & Ollson review*
http://www.ehjournal.net/content/pdf/1476-069X-10-78.pdf

"... some community studies are biased towards over-reporting of symptoms because of an explicit link between...noise and symptoms in the questions inviting people to remember and report more symptoms because of concern about noise." *Source: Ad Hoc Expert Group on Noise and Health*
http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1279888026747

"... it is probable that some persons will inevitably exhibit negative responses to turbine noise wherever and whenever it is audible, no matter what the noise level." *Source: Fiumicelli review Fiumicelli article abstract*

"The major source of uncertainty in our assessment is related to the subjective nature of response to sound, and variability in how people perceive, respond to, and cope with sound." *Source: Oregon review* http://public.health.oregon.gov/HealthyEnvironments/TrackingAssessment/HealthImpactAssessment/Documents/Oregon%20Wind%20Energy%20HIA%20Public%20comment. pdf

"... 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." *Source: NHMRC 2010*
http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/new0048_evidence_review_wind_turbi

"Even noise that falls within known safety limits is subjective to the recipient and will be received and subsequently perceived positively or negatively."
Source: Chatham-Kent Public Health Unit
http://www.harvestingwindsupport.com/blog/wp- content/uploads/2011/03/Chatham-KentHealth-and-Wind-.pdf

"... annoyance was strongly correlated with a negative attitude toward the visual impact of wind turbines on the landscape..." *Source: NHMRC 2010*
http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/new0048_evidence _review_wind_turbines_and_health.pdf

"Respondents tended to report more annoyance when they also noted a negative effect on landscape, and ability to see the turbines was strongly related to the probability of annoyance."
Source: Minnesota Health Dept. 2009
http://www.health.state.mn.us/divs/eh/hazardous/topics/windturbines.pdf

"[It is proposed 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... Some people are very annoyed at quite low levels of noise, whilst other are not annoyed by high levels." *Source: NHMRC 2010*
http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/new0048_evidence _review_wind_turbines_and_health.pdf

"Further, sounds, such as repetitive but low intensity noise, can evoke different responses from individuals... Some people can dismiss and ignore the signal, while for others, the signal will grow and become more apparent and unpleasant over time... These reactions may have little relationship to will or intent, and more to do with previous exposure history and personality."
Source: Minnesota Health Dept 2009
http://www.health.state.mn.us/divs/eh/hazardous/topics/windturbines.pdf

"Stress and annoyance from noise often do not correlate with loudness. This may suggest [that other factors impact an individual's reaction to noise... individuals with an interest in a project and individuals who have some control over an environmental noise are less likely to find a noise annoying or stressful." *Source: Minnesota Health Dept 2009* http://www.health.state.mn.us/divs/eh/hazardous/topics/windturbines.pdf

"There is a possibility of learned aversion to low frequency noise, leading to annoyance and stress..." *Source: Leventhall 2005 review*
http://www.noiseandhealth.org/article.asp?issn=1463-1741;year=2004;volume=6;issue=23;spage=59;epage=72;aulast=Leventhall

"Noise produced by wind turbines generally is not a major concern for humans beyond a half mile or so because various measures to reduce noise have been implemented in the design of modern turbines." *Source: NRC 2007*

"Noise... levels from an onshore wind project are typically in the 35-45 dB(A) range at a distance of about 300 meters... These are relatively low noise or sound-pressure levels compared with other common sources such as a busy office (~60 dB(A)), and with nighttime ambient noise levels in the countryside (~20-40 dB(A))." *Source: NRC 2007*

"Complaints about low frequency noise come from a small number of people but the degree of distress can be quite high. There is no firm evidence that exposure to this type of sound causes damage to health, in the physical sense, but some people are certainly very sensitive to it." *Source: Ad Hoc Expert Group on Noise and Health*
http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1279888026747

"... there is the theoretical possibility that annoyance may lead to stress responses and then to illness. If there is no annoyance then there can be no mechanism for any increase in stress hormones by this pathway... if stress-related adverse health effects are mediated solely through annoyance then any mitigation plan which reduce annoyance would be equally effective in reducing any consequent adverse health effects. It would make no difference whether annoyance reduction was achieved through actual reductions in sound levels, or by changes in attitude brought about by some other means." *Source: Ad Hoc Expert Group on Noise and Health*http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1279888026747

Infrasound

"Claims that infrasound from wind turbines directly impacts the vestibular system have not been demonstrated scientifically... evidence shows that the infrasound levels near wind turbines cannot impact the vestibular system." *Source: Massachusetts review*
http://www.mass.gov/dep/public/press/0112wind.htm

"There is no evidence that infrasound ... [from wind turbines ... contributes to perceived annoyance or other health effects." *Source: Bolin et al 2011 Review*
http://iopscience.iop.org/1748-9326/6/3/035103/pdf/1748-9326_6_3_035103.pdf

"There is no consistent evidence of any physiological or behavioural effect of acute exposure to infrasound in humans." *Source: UK HPA Report*
http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1265028759369

"... self reported health effects of people living near wind turbines are more likely attributed to physical manifestation from an annoyed state than from infrasound." *Source: Knopper & Ollson review*
http://www.ehjournal.net/content/pdf/1476-069X-10-78.pdf

"... infrasound from current generation upwind model turbines [is 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." *Source: Ontario CMOH Report*
http://www.health.gov.on.ca/en/public/publications/ministry_reports/wind_turbine/wind_turbine.pdf

"It would appear... that infrasound alone is hardly responsible for the complaints... from people living up to two km from the large downwind turbines." *Source: Jakobsen 2005 review*
http://multi-science.metapress.com/content/w6r4226247q6p416/

"From a critical survey of all known published measurement results of infrasound from wind turbines it is found that wind turbines of contemporary design with the rotor placed upwind produce very low levels of infrasound. Even quite close to these turbines the infrasound level is far below relevant assessment criteria, including the limit of perception." *Source: Jakobsen 2005 review*
http://multi- science.metapress.com/content/w6r4226247q6p416/

"With older downwind turbines, some infrasound also is emitted each time a rotor blade interacts with the disturbed wind behind the tower, but it is believed that the energy at these low frequencies is insufficient to pose a health hazard." *Source: NRC 2007*

Shadow flicker

"Scientific evidence suggests that shadow flicker [from the rotating blades of wind turbines does not pose a risk for eliciting seizures as a result of photic stimulation." *Source: Massachusetts review* http://www.mass.gov/dep/energy/wind/turbine_impact_study.pdf

Shadow flicker from wind turbines... is unlikely to cause adverse health impacts in the general population. The low flicker rate from wind turbines is unlikely to trigger seizures in people with photosensitive epilepsy. Further, the available scientific evidence suggests that very few individuals will be annoyed by the low flicker frequencies expected from most modern wind turbines." *Source: Oregon review*http://public.health.oregon.gov/HealthyEnvironments/TrackingAssessment/HealthImpactAssessment/Documents/Oregon%20Wind%20Energy%20HIA%20Public%20comment. pdf

"Flicker frequency due to a turbine is on the order of the rotor frequency (i.e., 0.6-1.0 Hz), which is harmless to humans. According to the Epilepsy Foundation, only frequencies above 10 Hz are likely to cause epileptic seizures." *Source: NRC 2007*

Community & social response to wind turbines

The perception of sound as noise is a subjective response that is influenced by factors related to the sound, the person, and the social/environmental setting. These factors result in considerable variability in how people perceive and respond to sound... Factors that are consistently associated with negative community response are fear of a noise source... [and noise sensitivity..." *Source: Oregon review*
http://public.health.oregon.gov/HealthyEnvironments/TrackingAssessment/HealthImpactAssessment/Documents/Oregon%20Wind%20Energy%20HIA%20Public%20comment. pdf

"Wind energy developments could indirectly result in positive health impacts... if they increase local employment, personal income, and community-wide income and revenue. However, these positive effects may be diminished if there are real or perceived increases in income inequality within a community." *Source: Oregon review*
http://public.health.oregon.gov/HealthyEnvironments/TrackingAssessment/HealthImpactAssessment/Documents/Oregon%20Wind%20Energy%20HIA%20Public%20comment. pdf

"Effective public participation in and direct benefits from wind energy projects (such as receiving electricity from the neighboring wind turbines) have been shown to result in less annoyance in general and better public acceptance overall." *Source: Massachusetts review*
http://www.mass.gov/dep/energy/wind/turbine_impact_study.pdf

"... people who benefit economically from wind turbines [are less likely to report noise annoyance, despite exposure to similar sound levels as those people who [are not economically benefiting." *Source: NHMRC 2010*http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/new0048_evidence_review_wind_turbines_and_health.pdf

"Landowners... may perceive and respond differently (potentially more favorably) to increased sound levels from a wind turbine facility, particularly if they benefit from the facility or have good relations with the developer..." *Source: Oregon review*
http://public.health.oregon.gov/HealthyEnvironments/TrackingAssessment/HealthImpa

ctAssessment/Documents/Oregon%20Wind%20Energy%20HIA%20Public%20comment. pdf

"The level of annoyance or disturbance experienced by those hearing wind turbine sound is influenced by individuals' perceptions of other aspects of wind energy facilities, such as turbine visibility, visual impacts, trust, fairness and equity, and the level of community engagement during the planning process." *Source: Oregon review*
http://public.health.oregon.gov/HealthyEnvironments/TrackingAssessment/HealthImpactAssessment/Documents/Oregon%20Wind%20Energy%20HIA%20Public%20comment. pdf

"Wind energy facilities... can indirectly result in positive health impacts by reducing emissions of [green house gases and harmful air pollutants, and... Communities near fossil-fuel based power plants that are displaced by wind energy could experience reduced risks for respiratory illness, cardiovascular diseases, cancer, and premature death." *Source: Oregon review*
http://public.health.oregon.gov/HealthyEnvironments/TrackingAssessment/HealthImpactAssessment/Documents/Oregon%20Wind%20Energy%20HIA%20Public%20comment. pdf

"The environmental and human-health risk reduction benefits of wind-powered electricity generation accrue through its displacement of electricity generation using other energy sources (e.g., fossil fuels), thus displacing the adverse effects of those other generators." *Source: NRC 2007*

"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." *Source: Ontario CMOH Report*
http://www.health.gov.on.ca/en/public/publications/ministry_reports/wind_turbine/wind_turbine.pdf

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Photo Credit: Courtesy of Siemens Energy, Inc. © 2013

Project's status of Non Conflict with Goal 5 inventoried scenic road State Highway 204.

After careful review of the Umatilla County Comprehensive Plan Technical Report (Technical Report), dated May 1980, WKN Chopin, LLC finds that the development described in Conditional Use Permit application #C-1188-11 would not conflict with State Land Use Goal 5 inventoried scenic road State Highway 204. For the purposes of these Findings, only the portion of State Highway 204 located within Umatilla County will be discussed.

The Surrounding Green Vegetation makes Highway 204 scenic:

Table D-XVII includes Oregon State Highway 204 as a site or vista classified as "justifying limits to conflicting land uses". The areas and views identified in the table are commonly recognized as striking for their "geological features, green vegetation and water as major scenic features", as stated in the Technical Report.

Highway 204's "vegetation" is listed as its "quality of interest". Because of Umatilla County's dry shrub-steppe landscape, green vegetation is valued as important partly because of the limited number of occurrences in the county. In fact, Highway 204 is prized because of pine trees and other greenery which flank the highway on both sides for approximately 19 miles of the 22 ½ miles within Umatilla County. While the highway affords views of the Milton-Freewater and the foothills of the Blue Mountains, vegetation prevents substantial long range vistas until you reach the lower 3 miles as one pulls into Weston. It is only in these last few miles that a traveler on Highway 204 can see the existing wind turbines or the proposed Chopin wind project.

Table D-XVII has identified Highway 204 as having a scenic value with which "Recreational Homesites" would conflict. As approximately 85% of the highway is surrounded by forested and/or vegetated terrain, recreational activities such as hunting, fishing, and hiking have become a popular past time in land accessible by Highway 204. It is WKN Chopin, LLC's view that the intention of Goal 5's protection of Highway 204 is to prevent the loss of the scenic quality of the surrounding vegetation from the development of "Recreational Homesites". WKN Chopin, LLC will not impact the vegetation immediately surrounding Highway 204.

Protection through planning:

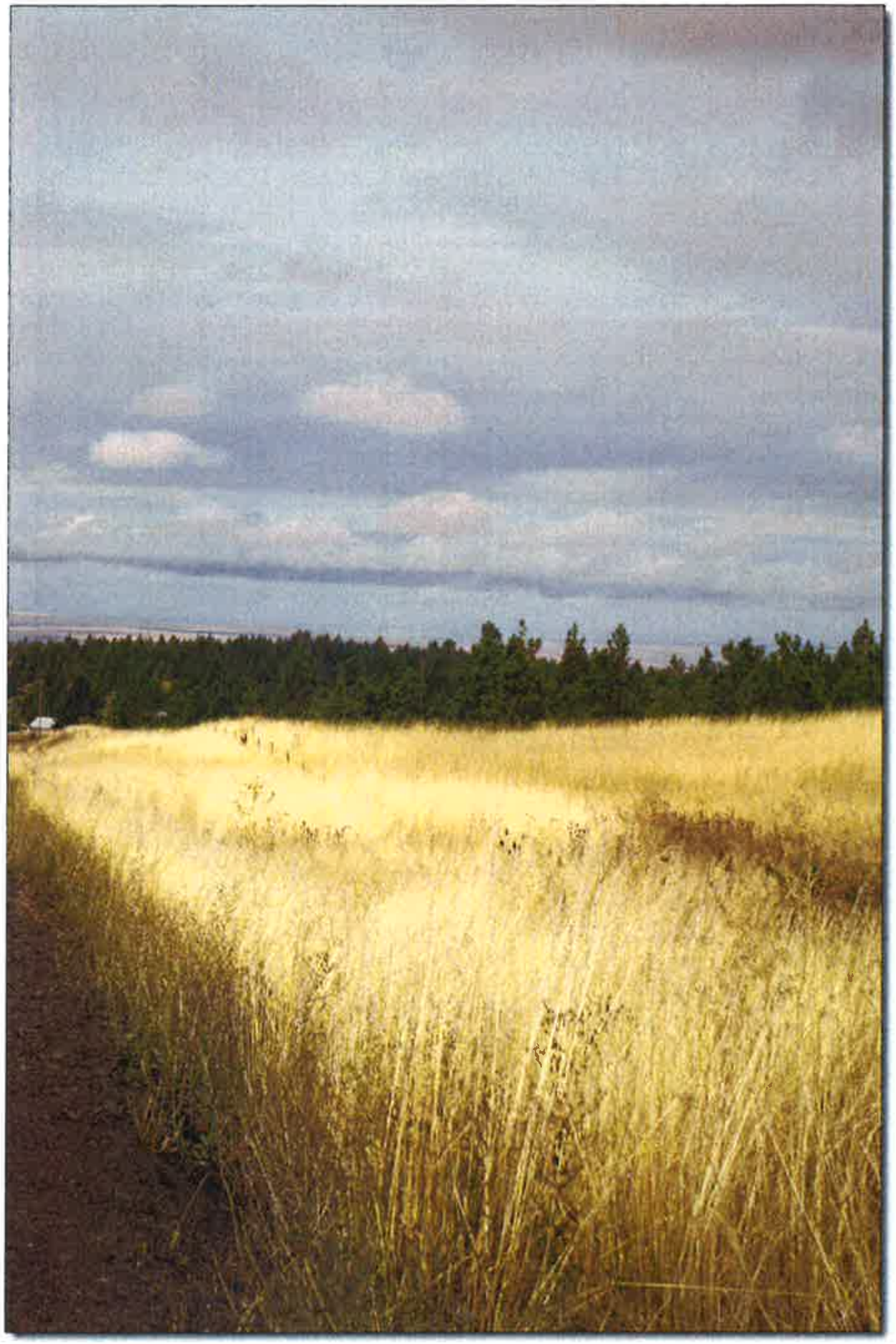
According the Technical Report:

"The comprehensive land use plan designations and zoning classifications adopted by the county are meant, in large part, to maintain the existing land use patterns which have resulted in the 'pleasant rural (or suburban) vistas,' etc. described in Table D-XVII. Thus, it is the position of the county that the plan designations and zoning already limit conflicts by limiting land uses or by mitigating conflicts through ordinance criteria".

The Technical Report then offers examples of these plan designations and zonings including "Conditional use criteria" through which WKN Chopin, LLC is permitting the project. As the Technical Report helped shape the Comprehensive Plan and thus the Development Code; and as it is stated that it is the position of the county that the plan designations and zoning already limit conflicts; it is apparent to the applicant that the by permitting the project through the county's Conditional Use Permit process, the scenic qualities of Highway 204 are protected.

Further evidence of the County's position that the plan designations and zoning already limit conflict is apparent as you travel through Highway 204. Just below Weston Mountain on Highway 204, cell towers have been permitted and erected within plain sight of the Highway but do not remove vegetation. Additionally from this same point on the road, one can see the Stateline III and Vansycle Ridge projects turbines. Once the permitted Helix wind project is built, this vantage point will offer views of its turbines though none of these installations will remove the protected vegetation around Highway 204. Although the Chopin Project turbines will likely not be visible until the lowest 3 miles of Highway 204, there is a solid precedence for allowing Conditional Use development of various kinds in the applicant's development area.

WKN Chopin LLC Wind Project - Visual Simulation Study
KOP 1 Photograph Location - Existing Condition



Vestas V112 3.0 MW
Hub Height 84 Meters
Blade Diamater 112 Meters

691

WKN Chopin LLC Wind Project - Visual Simulation Study
KOP 1 Photograph Location - Visual Simulation

Vestas V112 3.0 MW
Hub Height 84 Meters
Blade Diamater 112 Meters

692

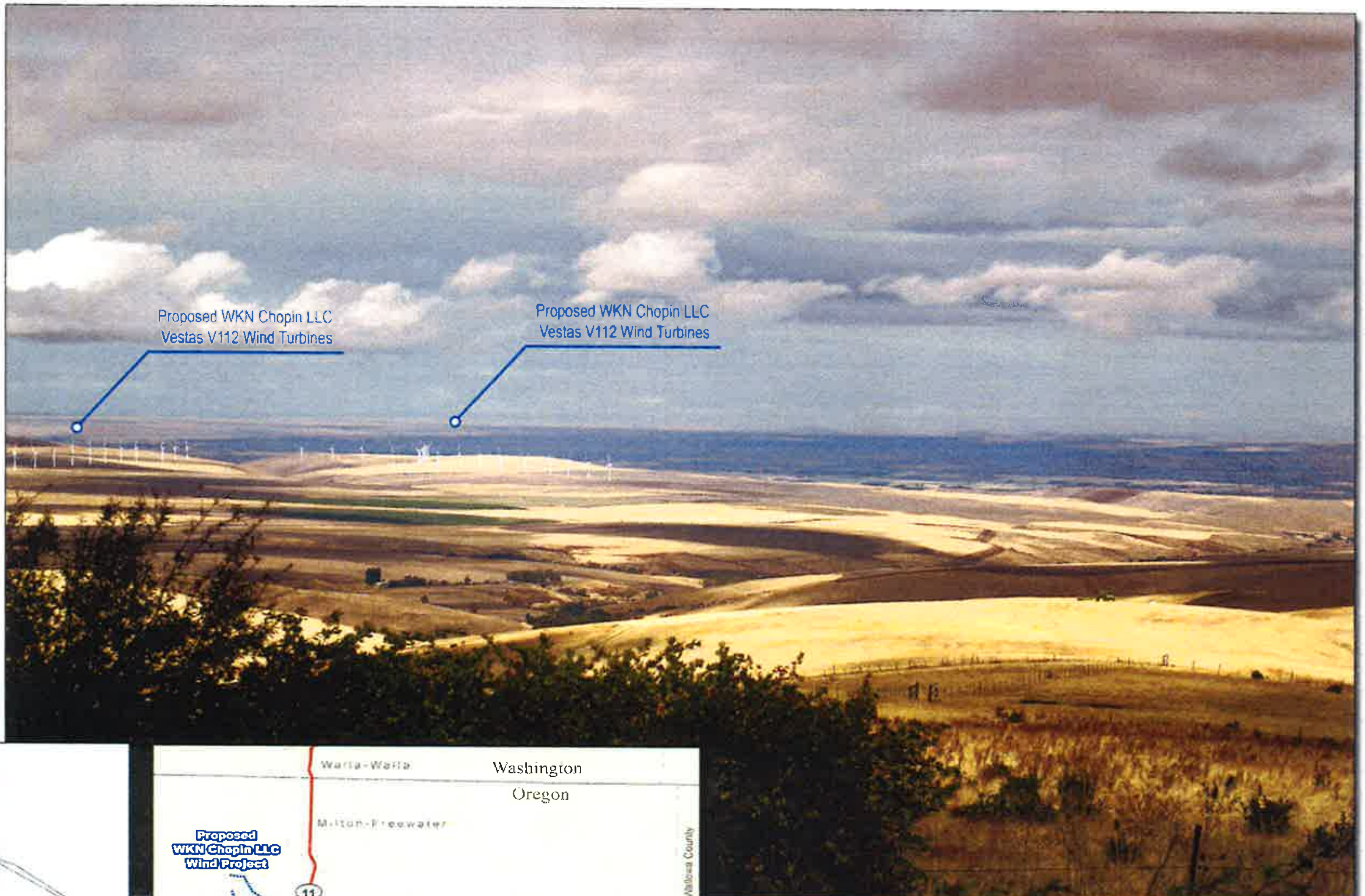
WKN Chopin LLC Wind Project - Visual Simulation Study
KOP 2 Photograph Location - Existing Condition

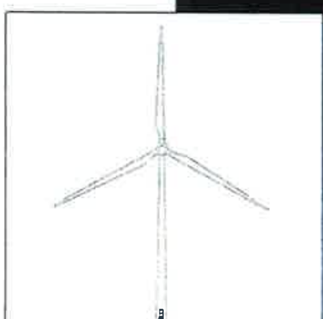
Vestas V112 3.0 MW
Hub Height 84 Meters
Blade Diamater 112 Meters

The Altum Group
Ctrl Z Studios
BayWa
WKN USA

WKN Chopin LLC Wind Project - Visual Simulation Study
KOP 2 Photograph Location - Visual Simulation

694





WKN Chopin LLC Wind Project - Visual Simulation Study
KOP 3 Photograph Location - Existing Condition

Vestas V112 3.0 MW
Hub Height 84 Meters
Blade Diamater 112 Meters

695

696

WKN Chopin LLC Wind Project - Visual Simulation Study
KOP 3 Photograph Location - Visual Simulation

Vestas V112 3.0 MW
Hub Height 84 Meters
Blade Diameter 112 Meters

WKN Chopin LLC Wind Project - Visual Simulation Study
KOP 4 Photograph Location - Existing Condition

Vestas V112 3.0 MW
Hub Height 84 Meters
Blade Diamater 112 Meters

BayWa
WKN USA
The Altum Group
STUDIOS

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WKN Chopin LLC Wind Project - Visual Simulation Study
KOP 4 Photograph Location - Visual Simulation

698

The Altum Group
STUDIOS
BayWa

OUTSTANDING SCENIC VIEWS AND SITES

There area areas and views which are commonly recognized as striking in their effect on those who experience them. Geological features, green vegetation, and water are major scenic features; human works and dry, shrub-steppe landscape are other attractions (Table D-XVII). So that areas do not lose their eye-catching attributes, plans attempt to identify "commonly recognized" scenic features, and suggest uses for these areas that minimize conflcits with the valuable features. Because of increased development and population pressures, some scenic areas in Umatilla County may lose their attractiveness as the beauty-sustaining elements are altered.

Certain developments or occurrences may conflict with scenic values. Industrial plants and energy facilities may create their own offensive scenic feature or obscure a natural scene. Residential subdivisions placed to take advantage of a view may be in turn more visible, covering higher ridges that are scenic features themselves.

Scenicly offensive development may ameliorate its effect by careful design, strategic placement of structures, and landscaping. Scenic regions that are lost to development may be found to be compensated by other benefits of the development for local society.

[NEW] Table D-XVII lists outstanding sites and views in Umatilla County. After Goal 5 analysis (OAR-16-000), 22 were determined to be not important enough to be included in the inventory, or not under the jurisdiction of the County (four in the Umatilla National Forest, two on the Indian Reservation, two within UGB's) ("1A"). Two other sites (Westland School and Oregon Trail) are discussed under the historical element of this chapter.

[NEW] Ten sites and vistas were classified as justifying limits to conflicting land uses ("3C"). The comprehensive land use plan designations and zoning classifications adopted by the county are meant, in large part, to maintain the

Table D-XVII

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
(Hat Rock)	3C	X	X	X			X	X		X	X	Adjacent Residential Dev.	State Park Historic Site	
Wallula Gap	3A	X	X		X		X		X		Partial	Potential Development, Aggregate	Recreational Development	Scenic Highway
Lake Wallula	3C	X					X			X	Partial		Power, Recreation, Transportation	
McNary Dam	1A	X				X	X				X			
Lake Umatilla	3C	X					X			X	X		Power, Recreation, Transportation	
Dam Viewpoint	1A	X	X			X		X			X	Urban Development		In UGB
Cold Springs Reservoir	3C	X		X			X	X		X	NO	Summer Drawdown	Irrigation, Wildlife Refuge	
Umatilla River downstream from Highway 207	1A	X		X			X			X	NO	Summer Low Flow	Irrigation, Fishing	Pleasant Rural Vistas
Umatilla/Echo Meadows	1A	X		X			X			X	NO		Floodplain, Agriculture	Pleasant Rural Vistas
Umatilla River upstream from Echo	1A	X	X	X					X		NO			
Canals	1A	X					X	X		X	NO	Liability Concerns, Seasonal Flows	Irrigation	
Umatilla Butte	1A		X		X		X	X			NO	Municipal Reservoir, Nearby Industry Billboards		BLM
Hermiston Butte	1A		X		X		X	X			NO		Radio Towers, Microwave Relay	In City
Emigrant Butte	1A		X		X		X	X			NO	Nearby Feed Lots		Private
Service Buttes	1A		X		X		X	X			NO	Hard to Distinguish	Grazing	Private
Columbia District	1A			X			X		X	X	NO		Residences, Hobby Farms	Pleasant Suburban Vistas
Westland District	1A			X			X		X	X	NO		Agriculture, Residences	Pleasant Suburban Vistas

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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 Campgrou on Wes
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	

existing land use patterns which have resulted in the "pleasant rural (or suburban) vistas," etc. described in Table D-XVII. Thus, it is the position of the county that the plan designations and zoning already limit conflicts by limiting land uses or by mitigating conflicts through ordinance criteria. Examples are:

a. Density requirements

b. Conditional use criteria

c. Overlay zones

d. Stream setbacks

e. Sign standards

f. Right-of-way, road, easement and driveway standards

However, to draw particular attention to "3C" designated areas, and to specifically address the potential conflicts noted earlier, the county should adopt a policy to insure special consideration of the following when reviewing a proposed change of land use:

a. Maintaining natural vegetation whenever possible.

b. Landscaping areas where vegetation is removed and erosion might result.

c. Screening unsightly land uses, preferably with natural vegetation or landscaping.

d. Limiting rights-of-way widths and numbers of roads intersecting scenic roadways to the minimum needed to safely and adequately serve the uses to which they connect.

e. Limiting signs in size and design so as not to distract from the attractiveness of the area.

f. Siting developments to be compatible with surrounding area development, and recognizing the natural characteristics of the location.

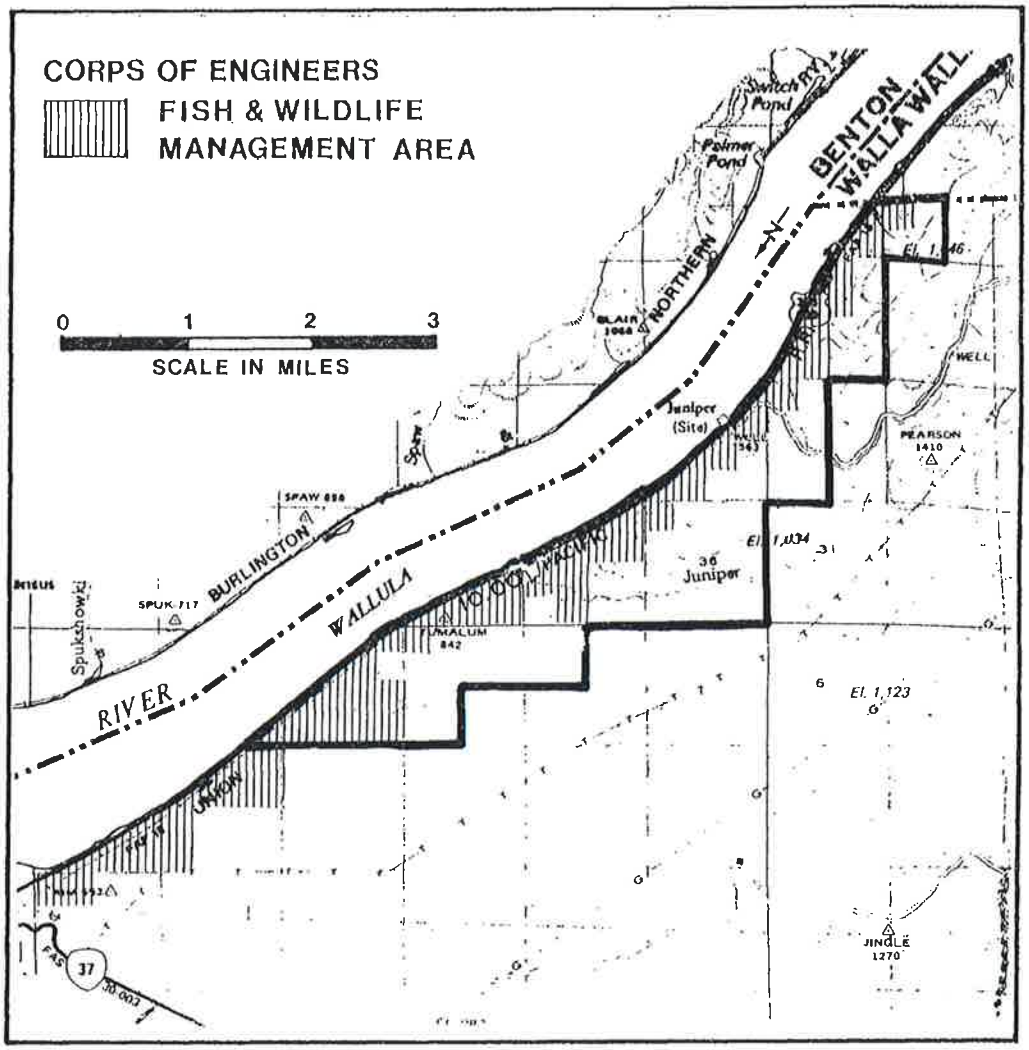
g. Limiting excavation and filling only to those areas where alteration of the natural terrain is necessary, and revegetating such areas as soon as possible.

INVENTORY

SIGNIFICANT SCENIC AREA

MAP: D-108 **AREA:** Wallula Gap

T/R: T5/6N R 30/31 EWM



Scenic Area: ▬▬┘ **Map Source: State Highway Div.**

Plan Designation: North County Agriculture

Zoning Designation: Exclusive Farm Use

Possible Land Use Conflicts: Recreational uses; rock pits. Part of area controlled by Corps of Engineers.

Goal 5 Analysis: 3A. Protect the resource

Management Program: Specific Comprehensive Plan policy; apply HAC Overlay Zone

h. Protecting vistas and other views which are important to be recognized because of their limited number and importance to the visual attractiveness of the area.

i. Concentrating commercial developments in areas where adequate parking and public services are available and discouraging strip commercial development.

[New] One area has been determined by the county as being so important, relative to conflicting uses, that the resource site should be protected and all conflicting uses prohibited ("3A"). The Wallula Gap is of great historic, geologic and scenic significance. It is the largest, most spectacular and most geologically significant of the several large water gaps in the Columbia River Basin. It has been a "landmark" for travelers since Lewis and Clark. The final environmental impact statement for the McNary Project states:

> Although the concept of beauty is subjective, most people would agree that the Wallula Gap area is one of special natural attraction. At this point, the Columbia River narrows and turns more westerly in its course to the Pacific Ocean. The Gap is dominated by steep, basalt formations rising nearly vertically from both banks of the river. Aside from its natural beauty, this area is of particular geological interest. (9a)

[New] The United States Department of Interior has designated a portion of Wallula Gap just north of Umatilla County in Walla Walla County, Washington, as "Wallula Gap National Natural Landmark." (9b) And the Corps of Engineers, in its McNary Master Plan, has classified its lands along the Columbia through Wallula Gap as an area for "moderate management" for fish and wildlife. (See map D-108).

Therefore, because of its significance sited above, the county should develop a policy to protect the scenic, historic, and geologic landmark quality of Wallula Gap.

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PACIFICORP

Understanding Electric & Magnetic Fields (EMF)

An electromagnetic field, sometimes referred to as EMF, is created by electrical charges. Electric charge creates electric fields. Moving charges create both electric fields and magnetic fields. There is an electric field when an appliance is plugged into the wall. When the appliance is turned on, current or charge flows creating both a magnetic field and an electric field. The term electromagnetic field refers to an electric field, or the magnetic field or both fields. Given the widespread use of electricity, electromagnetic fields or EMFs are present everywhere in our daily lives.

Safety practices and EMF exposure

Extensive research on EMF exposure and safety has been conducted by international and national scientists. The results from this research have been evaluated by reputable international and national scientific and public health organizations and agencies. The company relies on the evaluations from these organizations and agencies when assessing potential risks. All of our proposed transmission facilities follow the rules, regulations and standards for electromagnetic field exposure to provide safe and reliable electric service.

Electric and Magnetic Field (EMF) exposure

EMFs occur anywhere there is electric power. Most electromagnetic fields found in homes are power frequency (60-hertz), which is categorized as extremely low frequency (ELF). Common sources of electric and magnetic fields in the home are appliances, televisions, computers, and standard electrical wiring. Anything that has a voltage has an ELF electric field. When a device is turned on, electrical current flows, which also creates an ELF magnetic field.

The electric fields near outdoor transmission lines are typically stronger than those found in homes because they have a higher voltage than residential sources or appliances/devices. On the other hand, the magnetic fields around electrical appliances in homes can be as high as or higher than the magnetic fields near outdoor power lines. Because electromagnetic fields decrease significantly with distance from the source, EMF exposure from power lines is reduced significantly by the distance from the wires - including the height of the towers or poles that carry overhead transmission and distribution lines. Transmission line electric fields, but not magnetic fields, are also shielded by trees and homes, so that they are further reduced inside homes and buildings.

The chart below illustrates how the magnetic field exposure lessens with an increase in distance from typical electric sources at home.

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At home

(Measurements are in milligauss)

		1.2" away	12" away	39" away
	Microwave oven	750 to 2,000	40 to 80	3 to 8
	Clothes washer	8 to 400	2 to 30	0.1 to 2
	Electric range	60 to 2,000	4 to 40	0.1 to 1
	Fluorescent lamp	400 to 4,000	5 to 20	0.1 to 3
	Hair dryer	60 to 20,000	1 to 70	0.1 to 3
	Television	25 to 500	0.4 to 20	0.1 to 2

Source: Adapted from Gauger 1985

This chart describes the typical values of magnetic fields around distribution and transmission lines.

Outside

(Maximum values may be lower for some California utilities)

	Distribution lines	1 to 80 milligauss under the line
	Transmission lines	1 to 300 milligauss edge of right-of-way

Read more about what you can do within your home »

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PACIFICORP

Research Findings on EMF Exposure

We, like other utilities, rely on the assessment of scientific and public health expert panels which conduct EMF research and monitor this issue to evaluate potential health risks. Over 30 years of extensive data have been evaluated by international and national organizations including the World Health Organization (WHO), the International Agency for Research on Cancer (PDF) (IARC), the U.S. National Institute for Environmental Health Sciences (PDF) (NIEHS) and the U.S. National Academy of Sciences.

Key findings are listed below and in-depth reports can be found on their respective Web sites.

"Based on a comprehensive evaluation of published studies relating to the effects of power-frequency electric and magnetic fields on cells, tissues, and organisms (including humans), the conclusion of the committee is that the current body of evidence does not show that exposure to these fields presents a human-health hazard. Specifically, no conclusive and consistent evidence shows that exposures to residential electric and magnetic fields produce cancer, adverse neurobehavioral effects, or reproductive and developmental effects."

> **National Research Council Academy of Sciences**
> Committee on the Possible Effects of Electromagnetic Fields on Biologic System
> *(Possible Health Effects of Exposure to Residential Electric and Magnetic fields, 1997)*

"The NIEHS believes that the probability that ELF-EMF exposure is truly a health hazard is currently small. The weak epidemiological associations and lack of any laboratory support for these associations provide only marginal, scientific support that exposure to this agent is causing any degree of harm.

The NIEHS concludes that ELF-EMF exposure cannot be recognized as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. In our opinion, this finding is insufficient to warrant aggressive regulatory concern.

The National Toxicology Program routinely examines environmental exposures to determine the degree to which they constitute a human cancer risk and produces the "Report on Carcinogens" listing agents that are "known human carcinogens" or "reasonably anticipated to be human carcinogens." It is our opinion that based on evidence to date, ELF-EMF exposure would not be listed in the "Report on Carcinogens" as an agent "reasonably anticipated to be a human carcinogen."

> **National Institute of Environmental Health Sciences**
> NIEHS Report on Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields ,
> U.S. National Institute of Environmental Health Sciences (1999) NIH Publication No. 99-4493

"Scientific evidence suggesting that everyday, chronic low-intensity (above 0.3 - 0.4 μT) power-frequency magnetic field exposure poses a health risk is based on epidemiological studies demonstrating a consistent pattern of increased risk for childhood leukemia. Uncertainties in the hazard assessment include the role that control selection bias and exposure misclassification might have on the observed relationship between magnetic fields and childhood leukemia. In addition, virtually all of the laboratory evidence and the mechanistic evidence fail to support a relationship between low-level ELF magnetic fields and changes in biological function or disease status. Thus, on balance, the evidence is not strong enough to be considered causal, but sufficiently strong to remain a concern.

A number of other diseases have been investigated for possible association with ELF magnetic field exposure. These include cancers in children and adults, depression, suicide, reproductive dysfunction, developmental disorders, immunological modifications and neurological disease. The scientific evidence supporting a linkage between ELF magnetic fields and any of these diseases is much weaker than for childhood leukemia and in some cases (for example, for cardiovascular disease or breast cancer) the evidence is sufficient to give

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confidence that magnetic fields do not cause the disease.

...Furthermore, given both the weakness of the evidence for a link between exposure to ELF magnetic fields and childhood leukemia, and the limited impact on public health if there is a link, the benefits of exposure reduction on health are unclear. Thus the costs of precautionary measures should be very low."

World Health Organization
Extremely Low Frequency Fields Environmental Health Criteria Monograph No.238, 2007

"This review indicates that there is no convincing evidence in the published literature to support the contention that exposures to extremely low frequency electric and magnetic fields (ELF-EMF) generated by sources such as household appliances, video display terminals, and local power lines are demonstrable health hazards."

Utah Radiation Control Board
Excerpt from executive summary by Panel from Oak Ridge Associated Universities for the Committee on Interagency Radiation Research and Policy Coordination

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Possible Health Effects of Exposure to Residential Electric and Magnetic Fields (1997)

Chapter: Executive Summary

Executive Summary

CHARGE TO THE COMMITTEE

Public concern regarding possible health risks from residential exposures to low-strength, low-frequency electric and magnetic fields produced by power lines and the use of electric appliances has generated considerable debate among scientists and public officials. In 1991, Congress asked that the National Academy of Sciences (NAS) review the research literature on the effects from exposure to these fields and determine whether the scientific basis was sufficient to assess health risks from such exposures. In response to the legislation directing the U.S. Department of Energy to enter into an agreement with the NAS, the National Research Council convened the Committee on the Possible Effects of Electromagnetic Fields on Biologic Systems. The committee was asked "to review and evaluate the existing scientific information on the possible effects of exposure to electric and magnetic fields on the incidence of cancer, on reproduction and developmental abnormalities, and on neurobiologic response as reflected in learning and behavior." The committee was asked to focus on exposure modalities found in residential settings. In addition, the committee was asked to identify future research needs and to carry out a risk assessment insofar as the research data justified this procedure. Risk assessment is a well-established procedure used to identify health hazards and to recommend limits on exposure to dangerous agents.

CONCLUSIONS OF THE COMMITTEE

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Based on a comprehensive evaluation of published studies relating to the effects of power-frequency electric and magnetic fields on cells, tissues, and

organisms (including humans), the conclusion of the committee is that the current body of evidence does not show that exposure to these fields presents a human-health hazard. Specifically, no conclusive and consistent evidence shows that exposures to residential electric and magnetic fields produce cancer, adverse neurobehavioral effects, or reproductive and developmental effects.

The committee reviewed residential exposure levels to electric and magnetic fields, evaluated the available epidemiologic studies, and examined laboratory investigations that used cells, isolated tissues, and animals. At exposure levels well above those normally encountered in residences, electric and magnetic fields can produce biologic effects (promotion of bone healing is an example), but these effects do not provide a consistent picture of a relationship between the biologic effects of these fields and health hazards. An association between residential wiring configurations (called wire codes, defined below) and childhood leukemia persists in multiple studies, although the causative factor responsible for that statistical association has not been identified. No evidence links contemporary measurements of magnetic-field levels to childhood leukemia.

STUDY FINDINGS

Epidemiology

Epidemiologic studies are aimed at establishing whether an association can be documented between exposure to a putative disease-causing agent and disease occurrence in humans. The driving force for continuing the study of the biologic effects of electric and magnetic fields has been the

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persistent epidemiologic reports of an association between a hypothetical estimate of electric-and magnetic-field exposure called the wire-code classification and the incidence of childhood leukemia. These studies found the highest wire-code category is associated with a rate of childhood leukemia (a rare disease) that is about 1.5 times the expected rate.

A particular methodologic detail in these studies must be appreciated to understand the results. Measuring residential fields for a large number of homes over historical periods of interest is logistically difficult, time consuming, and expensive, so epidemiologists have classified homes according to the wire code (unrelated to building codes) to estimate past exposures. The wire-code classification concerns only outdoor factors related to the distribution of electric power to residences, such as the distance of a home from a power line and the size of the wires close to the home. This method was originally designed to categorize homes according to the magnitude of the magnetic field expected to be inside the home. Magnetic fields from external wiring, however, often constitute only a fraction of the field inside the home. Various investigators have used from two (high and low) to five categories of wire-code classifications. The following conclusions were reached on the basis of an examination of the epidemiologic findings:

- Living in homes classified as being in the high wire-code category is associated with about a 1.5-fold excess of childhood leukemia, a rare disease.
- Magnetic fields measured in the home after diagnosis of disease in a resident have not been found to be associated with an excess incidence of childhood leukemia or other cancers.

The link between wire-code rating and childhood leukemia is statistically significant (unlikely to have arisen from chance) and is robust in the sense that eliminating any single study from the group does not alter the conclusion that the association exists. How is acceptance of the link

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between wire-code rating and leukemia consistent with the overall conclusion that residential electric and magnetic fields have not been shown to be hazardous? One reason is that wire-code ratings correlate with many factors—such as age of home, housing density, and neighborhood traffic density—but the wire-code ratings exhibit a rather weak association with measured residential magnetic fields. More important, no association between the incidence of childhood leukemia and magnetic-field exposure has been found in epidemiologic studies that estimated exposure by measuring present-day average magnetic fields.

- Studies have not identified the factors that explain the association between wire codes and childhood leukemia.

Because few risk factors for childhood leukemia are known, formulating hypotheses for a link between wire codes and disease is very difficult. Although various factors are known to correlate with wire-code ratings, none stands out as a likely causative factor. It would be desirable for future research to identify the source of the association between wire codes and childhood leukemia, even if the source has nothing to do with magnetic fields.

- In the aggregate, epidemiologic evidence does not support possible associations of magnetic fields with adult cancers, pregnancy outcome, neurobehavioral disorders, and childhood cancers other than leukemia.

The preceding discussion has focused on the possible link between magnetic-field exposure and childhood leukemia because the epidemiologic evidence is strongest in this instance; nevertheless, many epidemiologists regard such a small increment in incidence as inherently unreliable. Although some studies have presented evidence of an association between magnetic-field exposure and various other types of cancer, neurobehavioral disorders, and adverse effects on reproductive function, the results have been inconsistent and contradictory and do not constitute reliable evidence of an association.

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Exposure Assessment

The purpose of exposure assessment is to determine the magnitudes of electric and magnetic fields to which members of the population are exposed.

The electromagnetic environment typically consists of two components, an electric field and a magnetic field. In general, for time-varying fields, these two fields are coupled, but in the limit of unchanging fields, they become independent. For frequencies encountered in electric-power transmission and distribution, these two fields can be considered independent to an excellent approximation. For extremely-low-frequency fields, including those from power lines and home appliances and wiring, the electric component is easily attenuated by metal elements in residential construction and even by trees, animals, and people. The magnetic field, which is not easily attenuated, is generally assumed to be the source of any possible health hazard. When animal bodies are placed in a time-varying magnetic field (as opposed to remaining stationary in the earth's static magnetic field), currents are induced to flow through tissues. These currents add to those that are generated internally by the function of nerve and muscle, most notably currents detected in the clinically useful electroencephalogram and the electrocardiogram. The currents produced by nerve and muscle action within the body have no known physiologic function themselves but rather are merely a consequence of the fact that excitable tissue (such as nerve and muscle) generate electric currents during their normal operation.

General conclusions from the review of the literature involving studies of exposure assessment and the physical interactions of electric and magnetic fields with biologic systems are the following:

- Exposure of humans and animals to external 60-hertz (Hz) electric and magnetic fields induces currents internally.

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The density of these currents is nonuniform throughout the body. The spatial patterns of the currents induced by the magnetic fields are different from those induced by the electric fields. Electric fields generally are measured in volts per meter and magnetic fields in microtesla (μT) or milligauss (mG) (1 μT = 10 mG).

- Ambient levels of 60-Hz (or 50-Hz in Europe and elsewhere) magnetic fields in residences and most workplaces are typically 0.01-0.3 μT (0.1-3 mG).

  Higher levels are encountered directly under high-voltage transmission lines and in some occupational settings. Some appliances produce magnetic fields of up to 100 μT (1 G) or more in their vicinity. For comparison, the static magnetic field of the earth is about 50 μT (500 mG). Magnetic fields of the magnitude found in residences induce currents within the human body that are generally much smaller than the currents induced naturally from the function of nerves and muscles. However, the highest field strengths to which a resident might be exposed (those associated with appliances) can produce electric fields within a small region of the body that are comparable to or even larger than the naturally occurring fields, although the magnitude of the largest locally induced fields in the body is not accurately known.

- Human exposure to a 60-Hz magnetic field at 0.1 μT (1 mG) results in the maximum current density of about 1 microampere per square meter ($\mu A/m^2$).

  The endogenous current densities on the surface of the body (higher densities occur internally) associated with electric activity of nerve cells are of the order

  of 1 mA/m^2. The frequencies associated with those endogenous currents within the brain range from less than 1 Hz to about 40 Hz, the strongest components being about 10 Hz. Therefore, the typical

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externally induced currents are 1,000 times less than the naturally occurring currents.

- Neither experimental nor theoretic data on locally induced current densities within tissues and cells are available that take into consideration the local variations in the electric properties of the medium.

  Because the mechanisms through which electric and magnetic fields might produce adverse health effects are obscure, the characteristics of the electric or magnetic fields that need to be measured for testing the linkage of these fields to disease are unclear. In most studies, the root-mean-square (rms) strength of the field, an average field-strength parameter, has been measured on the assumption that this measurement should relate to whatever field characteristics might be most relevant. As noted earlier, wire-code categories have been used in many epidemiologic studies as a surrogate measurement of the actual exposure.

- Exposure levels of electric fields and other characteristics of magnetic fields (harmonics,[1] transients,[2] spatial, and temporal changes) have received relatively little attention.

  Very little information is available on the ambient exposure levels to environmental electric fields other than the rms measurements of field strength. Those might vary from 5 to 10 volts per meter (V/m) in a residential setting to as high as 10 kilovolts per meter (kV/m) directly under power transmission lines. Likewise magnetic-field exposures are generally characterized only in terms of their rms field strengths with little or no information on such characteristics as the frequency and magnitude of transients and harmonics. Residential exposures to power-frequency electric and magnetic fields are generally on the order of a few milligauss.

- Indirect estimates of human exposure to magnetic fields (e.g., wiring configuration codes, distance to power lines, and calculated historical fields) have been used in epidemiology.

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These estimates of magnetic fields correlate poorly with spot measurements of residential 60-Hz magnetic fields, and their reliability in representing other characteristics of the magnetic field has not been established. Because of the many factors that affect exposure levels, great care must be taken in establishing electric-and magnetic-field exposures.

- Unless exposure systems and experimental protocols meet several essential requirements, artifactual results are likely to be obtained in laboratory animal and cell experiments.

1 Signals of nf_0, where n is an integer and f_0 is the fundamental frequency. For example, the higher harmonics of a 60-Hz signal will be 120 Hz, 180 Hz, 240 Hz, and so forth.

2 Short-duration signals containing a range of frequencies and appearing at irregular time intervals.

Many of the published studies either have used inferior exposure systems and protocols or have not provided sufficient information for their evaluation.

In Vitro Studies on Exposure to Electric and Magnetic Fields

The purpose of studies of in vitro systems is to detect effects of electric or magnetic fields on individual cells or isolated tissues that might be related to health hazards. The conclusions reached after evaluation of published in vitro studies of biologic responses to electric-and magnetic-field exposures are the following:

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- Magnetic-field exposures at 50-60 Hz delivered at field strengths similar to those measured for typical residential exposure (0.1-10 mG) do not produce any significant in vitro effects that have been replicated in independent studies.

When effects of an agent are not evident at low exposure levels, as has been the case for exposure to magnetic fields, a standard procedure is to examine the consequences of using higher exposures. A mechanism that relates clearly to a potential health hazard might be discovered in this way.

- Reproducible changes have been observed in the expression of specific features in the cellular signal-transduction pathways for magnetic-field exposures on the order of 100 μT and higher.

  Signal-transduction systems are used by all cells to sense and respond to features of their environments; for example, signal-transduction systems can be activated by the presence of various chemicals, hormones, and growth factors. Changes in signal transduction are very common in many experimental manipulations and are not indicative per se of an adverse effect. Notable in the experiments using high magnetic-field strengths is the lack of other effects, such as damage to the cell's genetic material. With even higher field strengths than those, a variety of effects are seen in cells.

- At field strengths greater than 50 μT (0.5 G), credible positive results are reported for induced changes in intracellular calcium concentrations and for more general changes in gene expression and in components of signal transduction.

No reproducible genotoxicity is observed, however, at any field strength. Again, effects of the sort seen are typical of many experimental manipulations and do not indicate per se a hazard. Effects are observed in very high field-strength exposures (e.g., in the therapeutic use of electromagnetic fields in bone healing).

The overall conclusion, based on the evaluation of these studies, is that exposures to electric and magnetic fields at 50-60 Hz induce changes in cultured cells only at field strengths that exceed typical residential field

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strengths by factors of 1,000 to 100,000.

In Vivo Studies on Exposure to Electric and Magnetic Fields

Studies of in vivo systems aim to determine the biologic effects of power-frequency electric and magnetic fields on whole animals. Studies of individual

cells, described above, are extremely powerful for elucidating biochemical mechanisms but are less well suited for discovering complicated effects that could be related to human health. For such extrapolation, animal experiments are more likely to reveal a subtle effect that might be relevant to human health. The obvious experiment is to expose animals, say mice, to high levels of electric or magnetic fields to observe whether they develop cancer or some other disease. The experiments of this sort that have been done have demonstrated no adverse health outcomes. Such experiments by themselves are inadequate, however, to discount the possibility of adverse effects from electric and magnetic fields, because the animals might not exhibit the same response and sensitivities as humans to the details of the exposure. For that reason, a number of animal experiments have been carried out to examine a large variety of possible effects of exposure. On the basis of an evaluation of the published studies in this area, the committee concludes the following:

- There is no convincing evidence that exposure to 60-Hz electric and magnetic fields causes cancer in animals.

  A small number of laboratory studies have been conducted to determine if any relationship exists between power-frequency electric-and magnetic-field exposure and cancer. In the few studies reported to date, consistent reproducible effects of exposure on the development of various types of cancer have not been evident. One

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area with some laboratory evidence of a health-related effect is that animals treated with carcinogens show a positive relationship between intense magnetic-field exposure and the incidence of breast cancer.

- There is no evidence of any adverse effects on reproduction or development in animals, particularly mammals, from exposure to power-frequency 50- or 60-Hz electric and magnetic fields.

- There is convincing evidence of behavioral responses to electric and magnetic fields that are considerably larger than those encountered in the residential environment; however, adverse neurobehavioral effects of even strong fields have not been demonstrated.

  Laboratory evidence clearly shows that animals can detect and respond behaviorally to external electric fields on the order of 5 kV/m rms or larger. Evidence for animal behavioral response to time-varying magnetic fields, up to 3 μT, is much more tenuous. In either case, general adverse behavioral effects have not been demonstrated.

- Neuroendocrine changes associated with magnetic-field exposure have been reported; however, alterations in neuroendocrine function by magnetic-field exposures have not been shown to cause adverse health effects.

  The majority of investigations of magnetic-field effects on pineal-gland function suggests that magnetic fields might inhibit nighttime pineal and blood melatonin concentrations; in those studies, the effective field strengths varied from 10 μT (0.1 G) to 5.2 mT (52 G). The experimental data do not compellingly

  support an effect of sinusoidal electric field on melatonin production. Other than the observed changes in pineal function, an effect of electric and magnetic fields on other neuroendocrine or endocrine functions has not been clearly shown in the relatively small number of

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experimental studies reported.

Despite the observed reduction in pineal and blood melatonin concentrations in some animals as a consequence of magnetic-field exposure, studies of humans provide no conclusive evidence to date that human melatonin concentrations respond similarly. In animals with observed melatonin changes, adverse health effects have not been shown to be associated with electric-or magnetic-field-related depression in melatonin.

- There is convincing evidence that low-frequency pulsed magnetic fields greater than 5 G are associated with bone-healing responses in animals.

  Although replicable effects have been clearly demonstrated in the bone-healing response of animals exposed locally to magnetic fields, the committee did not evaluate the efficacy of this treatment in clinical situations.

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