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7. Carol Black- critical area code landmarks and houses
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9. Energy Analysis and Environmental Impacts Division Larence Berkeley National Laboratory
10. Julie Clarkson Email- Sample Real Value Protection Plan
11. Real property value protection plan
12. Carol Black- County Code 9.05
13. Real Estate Consulting Report
14. Visual effect of Wind turbines on property value
15. Commercial Wind Turbine and Residential Home Values
16. Energy Policy: Wind turbines, solar farms, and house prices

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E-1

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Wind turbines, solar farms, and house prices[☆]

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ABSTRACT

This paper examines the effect of wind turbines and solar farms on house prices. Using detailed data from the Netherlands between 1985 and 2019, the results show that tall wind turbines have considerably stronger effects on house prices, as compared to small turbines. For example, a tall turbine (>150m) decreases house prices within 2 km by 5.4%, while a small turbine (<50m) has an effect of maximally 2% and the effect dissipates after 1 km. Further results indicate that solar farms lead to a decrease in house prices within 1 km of about 2.6%. By comparing the overall impact on house prices, we show that the external effects of solar farms per unit of energy output are comparable to those of wind turbines. Thus, building solar farms instead of wind turbines does not seem to be a way to avoid the external effects of renewable energy production.

1. Introduction

Renewable energy is on the rise. While global demand is still strongly increasing, the demand for fossil fuels has actually strongly declined (IEA, 2020). Furthermore, the current Covid-19 crisis has made clear the downsides of fossil fuels: the effective use of fossil fuels depend heavily on storage capacity and transportation (Science, 2020). Instead, renewable energy is typically produced locally and could be a viable alternative to fossil fuels. Two important sources of renewable energy production are wind turbines and commercial solar farms.

Renewable energy production may have external effects on local residents (Meyerhoff et al., 2010; Groth and Vogt, 2014). Wind turbines make noise, cast shadows, and create flickering. Moreover, turbines can visually pollute the landscape, particularly if they are tall. Solar panels can reflect sound and sunlight and are also usually not considered to be aesthetically pleasing. In line with a large literature on hedonic pricing, we would expect that such externalities capitalize into house prices. Increasing our understanding of these external effects is policy-relevant for at least two reasons. First, it provides insight in what could be a more efficient allocation of renewable energy production facilities (Rodman and Meentemeyer, 2006). Second, because the effects of wind turbines and solar farms are local, the effect on house prices is indicative that the burden of renewable energy production is not necessarily distributed equally within society.

The aim of this paper is to examine the effect of wind turbines and solar farms on house prices. We employ a quantitative revealed-preferences approach to measure this effect. We contribute to the existing literature in several ways. First, this paper explicitly focuses on the role of turbine height on house prices. In particular, we investigate whether tall turbines have a larger effect on house prices *and* at a larger distance. Given the substantial increase in wind turbine height in the last years, we would expect heterogeneity in the effect of turbines of different heights on house prices. This is important for spatial policies regarding the placement of wind turbines.[1]

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[1] Some studies find effects of turbines up to 14%, while others do not find any effect (see Appendix A.1 for an extensive review). One potential explanation is that previous studies did not take into account that large turbines may lead to larger decreases in housing values. A notable exception is Dröes and Koster (2016), who show that in the Netherlands turbines larger than 100m lead to an additional price decline of 2.2%. However, Dröes and Koster (2016) only analyze a handful of tall turbines and it remains unclear whether the spatial extent of negative externalities for turbines of different heights is the same.

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E-2

Second, to identify a causal effect of renewable energy production facilities on house prices is not straightforward, as turbines and solar farms are mostly located in sparsely populated areas with lower house prices. That is, the placement of renewable energy production sites is not random. To mitigate endogeneity concerns many studies use a differences-in-differences design based on comparison with a local control group (Gibbons, 2015; Dröes and Koster, 2016; Jensen et al., 2018). A key identifying assumption is that there are *parallel trends* between treated and control areas. This assumption may be restrictive and is hard to test.[2] Instead, we exploit *temporal variation* in the openings of turbines and solar farms. That is, we employ a hedonic regression design that compares price changes in areas that have received a wind turbine or solar farm; to areas that will receive a turbine or solar farm in the future. By examining the causal effect on *house prices* we aim to measure the (revealed) preferences of households regarding the placement of wind turbines and solar farms.[3]

Third, to the best of our knowledge, we are among the first to investigate the impact of solar farms on house prices. For solar farms, we use essentially the same identification strategy as for wind turbines. However, the effects of solar farms are expected to be more local than those of wind turbines, as visual pollution is likely to be more localized. Additionally, we compare the results of solar farms to those of wind turbines. Many previous studies only focus on a single type of renewable energy production facility.

This paper relies on detailed housing transactions data from the Netherlands between 1985 and 2019, which we combine with data on all wind turbines and solar farms that have been placed during this period. The Netherlands is typically seen as a fairly urbanized country and thus provides an ideal study area to examine the external effects of wind turbines and solar farms on house prices.[4]

The results in this paper show that the construction of a wind turbine leads to a decrease in local house prices of 1.8%. In particular, we find that a turbine taller than 150m decreases prices within 2 km by 5.4%, while the effect of small turbines (<50m) is statistically indistinguishable from zero. Also, the effect of tall wind turbines does not extend much beyond 2 km, but we do find evidence that the impact radius is smaller (<1 km) for low wind turbines. Various additional robustness checks support the main findings. Regarding solar farms, we find that house prices decrease by about 2.6% after opening. The effect is confined to 1 km, so it is more localized than that of wind turbines.

Finally, we show that the total loss in housing values as a result of the placement of wind turbines is about €5 billion, while solar farms imply a total loss of €800 million. Yet, 1% of the turbines cause almost 50% of the total loss in housing values. These are turbines that are placed too close to residential areas. The median loss per installed megawatt-hour (MWh) is €53, with taller turbines having a much lower median loss per MWh (*i.e.* €277 for a turbine <50m versus €11 for a turbine >150m). Hence, it seems much more efficient to build taller, more powerful, turbines. We further find that the average loss per MWh for a solar farm is of the same order of magnitude as that of a wind turbine.

From a policy perspective, our results thus imply that building solar farms instead of wind turbines will not mitigate the external effects of renewable energy production. Our results further highlight the importance of avoiding the placement of wind turbines and solar farms near urban areas.

The remainder of this paper is structured as follows. Section 2 provides a discussion of the international and Dutch policy context. Section 3 discusses the data, while the methodology is discussed in Section 4. Section 5 highlights the regression results and Section 6 concludes.

2. Policy context

Wind turbines are an important source of renewable energy with 30% of its capacity located in Europe and 17% in the U.S. in 2018. Especially China has invested heavily in wind energy, overtaking the E. U. already in 2015 as being the largest producer of wind energy. Currently, 36% of worldwide capacity is located in China (GWEC, 2019). Many other Western and Asian countries have been increasing their capacity over the past decades as well. Technological change fueled by an increased demand for energy has led wind turbines to become taller over time (as taller turbines produce more energy). Where turbines in the 1980s were still around 30m, the newest generation of wind turbines is currently well above 100m.[5]

A relatively new phenomenon is the commercial production of renewable energy via solar farms, which are large fields of solar panels. The first solar farm was constructed in 1982 in California. Yet, with advances in technology, it has become attractive to commercially exploit solar farms only in the last decade or so. Many countries, like India, China, and the United States have heavily invested in very large solar farms.[6]

In 2019, the renewable energy capacity captured 27% of total electricity production with solar photovoltaics capturing only 2.8% of the total production, about half that of wind turbines. Hydropower is still one of the largest contributors. By contrast, last year's growth in solar photovoltaics capacity was about twice that of wind turbines (REN21, 2020). Whether the current surge in the construction of tall wind turbines and solar farms will continue remains to be seen, but some countries have already suggested that the economic recovery after Covid-19 should be a green one (Associated Press, 2020).

In this study, we focus on the Netherlands (which is an E.U. member state). The E.U. has extended its energy efficiency directive in 2018 posing new targets for 2030. According to the national energy and climate plans of the different member states, many European countries will rely on wind and solar energy to meet those targets. In 2013, the Dutch government reached an energy agreement with many central stakeholders in the Dutch society (*i.e.* labor unions, environmental organizations, financial institutions) to reduce CO_2 emissions by 2020–2023. An important pillar of this agreement is to construct about 1300 wind turbines on land (SER, 2013).[7]

In 2019, this ambition was extended and a National Climate Agreement was reached to reduce CO_2 emissions by 49% in 2030 compared to 1990. To achieve this goal, about 50% of renewable energy production should be realized on land (35 of the 84 TWh), while the remainder will be produced offshore. Furthermore, a large-scale subsidy program is now in operation and 30 Dutch regions are required to develop energy production plans. From this, it is clear that wind and solar energy produced on land will play a major role in reaching the renewable energy goals (National Climate Agreement, 2019). Although the Dutch government aims to ensure the participation of local residents in developing renewable energy production sites, there have been a lot of protests, particularly against tall wind turbines (Telegraaf, 2020). Our study is

[2] For a more elaborate discussion, see Bertrand et al. (2004); Abadie (2005), and Donald and Lang (2007).

[3] More specifically, house prices are a useful monetary measure of household preferences (Rosen, 1974).

[4] The Netherlands (an E.U. member state) is more than twice the size of the San Francisco Bay Area (U.S.) but has a comparable population density (430/km^2 versus 488/km^2 for San Francisco).

[5] The average power a turbine <50m generates is 0.14 MW, while it is 4.15 MW for a turbines >150m. These are large differences in potential energy output.

[6] Currently, the largest solar farm in the world is 40 km^2, located in Bhadla, India.

[7] In 2019, the Dutch government lost a major court case against the non-profit environmental organization *Urgenda* because it did not fulfill its climate goals set for 2020. This event created a precedent for other related court cases in other E.U. member states (Supreme Court, 2019), and has created a sense of urgency to increase renewable energy production more quickly.

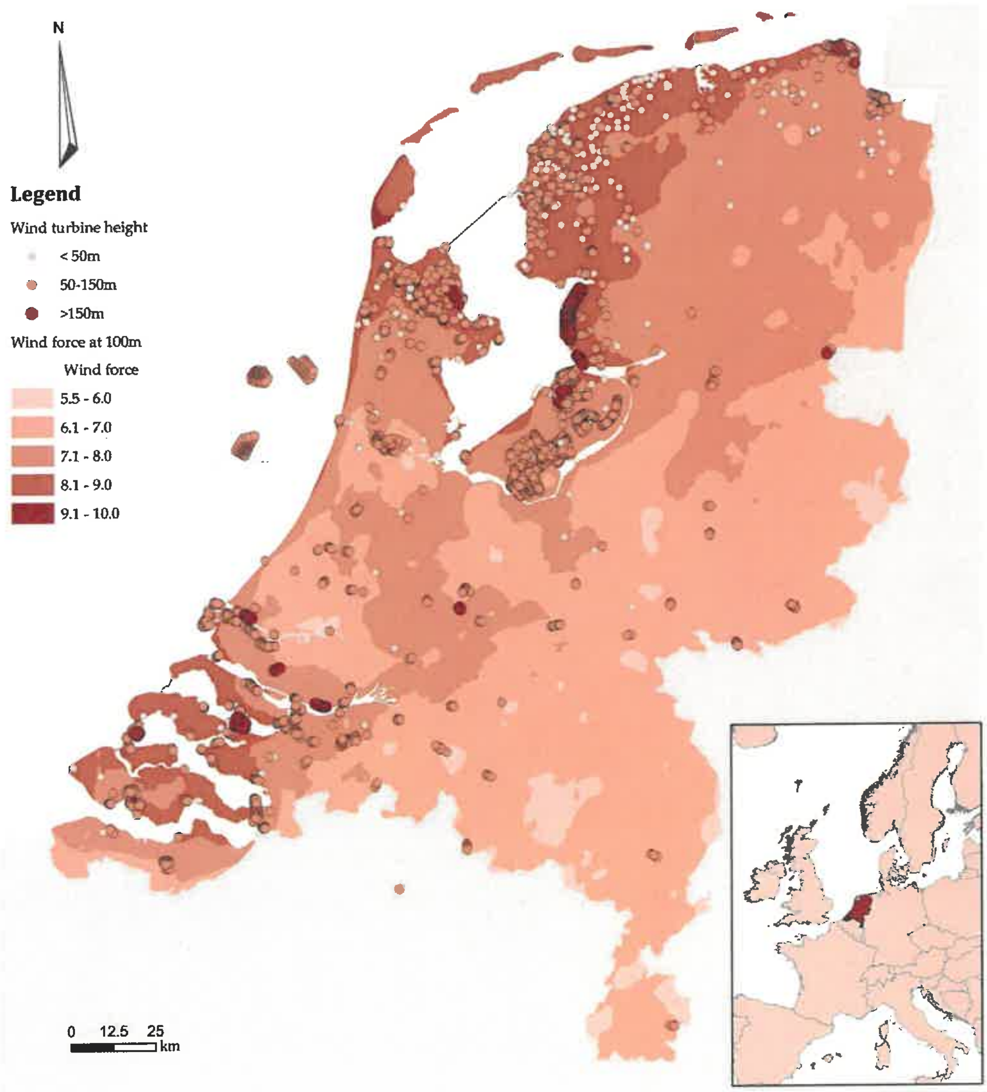


Fig. 1. The location of wind turbines
Notes: We obtain data on solar farms from windstats. Data on wind speeds is from the KNMI. The map is compiled by the authors.

therefore very societally relevant.

3. Data

3.1. Data on wind turbines and housing values

The locations of wind turbines, as well as the axis height, diameter of the blades, and the power (MW) of the turbine come from www.windstats.nl. We define *turbine height* as the axis height plus half the diameter of the rotor blades (*i.e.* the so-called tip height).[8] There is a very high correlation ($\rho = 0.918$) between height of the turbine and the power it generates. For example, a turbine of 3 MW (with a height of about 150m) produced 6.5 million kWh, while a turbine of 2 MW (115m) only provides 4.5 million kWh.

The total number of wind turbines up to and including mid-2019 is 2, 695. This study focuses on the 2, 406 turbines that have been built on land.[9] Of the turbines that have been built on land, 614 were built after 2011. Many of these new turbines are close to the locations where wind turbines have previously been installed. Fig. 1 shows the locations of wind turbines. The map highlights that wind turbines are often concentrated in coastal areas (which have a lot of wind). Fig. 2 shows that there is clearly an upward trend in the height of turbines. In 2000 the average height of new turbines was still around 80m. Towards the end of the sample period, the average height is about 140m with a maximum of 200m. Interestingly, the trend seems to stabilize as of 2016. Currently, low turbines (<50m) account for about 10% of the turbines, medium-sized (50–150m) for about 80% and tall turbines (>150) for the remaining 10%.

The dataset concerning house prices has been provided by Brainbay. The data cover approximately 70% of the market.[10] The data contain

[8] Dröes and Koster (2016) use axis height and the diameter of rotor blades separately, but the effect of these are difficult to measure as height and diameter of the blades are highly correlated (*i.e.* there are 'no high turbines' with tiny blades).

[9] The *Princess Amalia*, *Egmond aan Zee*, *Luchterduinen*, and *Gemini* offshore wind farms are therefore not included in our analysis, *Gemini* is missing from the map shown here because it is far from the coast.

[10] The sales that are not included are by real estate agents that are not a member of the NVM real estate organization, but most of them are.

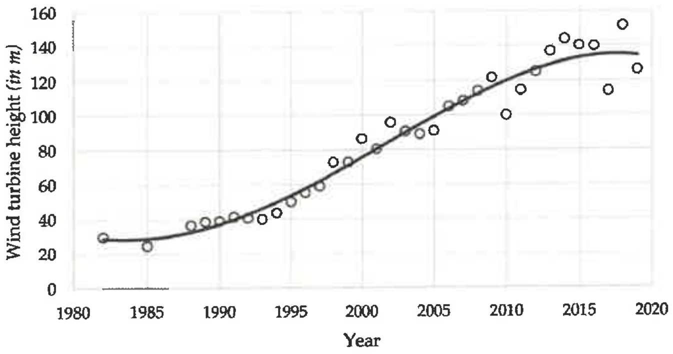


Fig. 2. Average height of new wind turbines
Notes: We obtain data on the height of wind turbines from Windstats. The solid line indicates the non-linear trend line.

sales of existing properties between 1985-(mid)2019. In addition to property prices, the dataset includes information on many different property features. Based on this, we can calculate the distance to the nearest existing wind turbine for each (transacted) home in our sample. The descriptive statistics are reported in Table 1.

The average house price between 1985 and 2019 is €214.178. This is based on more than 3 million transactions (2.7 million homes). The average house price is slightly lower (€206.658) within 2 km of an existing wind turbine, suggesting there is a slight tendency to built turbines in areas with lower prices. In Appendix A.2 we provide more details on differences between treated and control areas.

Finally, the average distance of properties to wind turbines in 2019 is 8.7 km. This distance has been decreasing for years; in 1995 for example the distance was still 26.6 km. However, for many households, wind turbines are still relatively far away. Only 5.1% of the housing transactions between 1985 and 2019 occur within 2 km wind turbines *after* they have become operational. Yet, the total number of transactions near all wind turbines present in 2019 is 290,002 (238,164 houses).

3.2. *Data on solar farms and housing values*

The data on solar farms come from Zon op Kaart, compiled by ROM3D. We have double-checked these data through OpenStreetMap. Furthermore, using OpenStreetMap, we geocode the data so that we have exact information on the size and geographic demarcation of solar farms. The number of solar farms (107) included in the analysis is much lower than the number of wind turbines.[11]

Fig. 3 shows the location and opening year of solar farms in the Netherlands until mid-2019. The first solar farm in our dataset is *Ecopark Waalwijk* (4.2 thousand panels) which opened in 2004. The locations of the solar farms are not randomly distributed in the Netherlands. As solar farms are land-intensive, many solar farms are located in areas with a low population density because of land availability.

The largest solar farm currently is located in Vlagtwedde (Groningen) and consists of 320,000 solar panels (approximately 1 km^2) with a total nominal peak power of 109 MWP.[12] It appears that new solar farms generally contain more panels, so the size of solar farms has increased over time. Using the data on property transactions, we calculate the distance of each property to the edge of the nearest solar farm.

Although the first solar farm was opened in 2004 we do not observe transactions within 1 km after the opening of this solar farm. 97 solar farms were opened in 2017, 2018, and 2019. Because almost all solar farms have been opened in recent years, we use the transactions data from the last 10 years (*i.e.* from 2009 to 2019). The descriptive statistics are reported in Table 2.

The average property price between 2009 and mid-2019 is €249, 586. The other descriptive statistics regarding housing characteristics are almost identical to those of wind turbines. The number of transactions in the Netherlands between 2009 and 2019 is about 1.5 million. Yet, there are not that many observations nearby solar farms. In particular, within 1 km there are 1,736 transactions *after* the placement of a solar farm (0.118% of the data). Fortunately, the total number of transactions within 1 km of all solar farms that are present in 2019 is 12,650 (11,843 houses).

Similarly to wind turbines, house prices within 1 km of a solar farms are lower (€226,000) than the sample average. These, and other descriptive statistics, are discussed in more detail in Appendix A.2.

Table 1
Descriptives: house prices and wind turbines.

	(1)	(2)	(3)	(4)
	Mean	St.dev.	Min	Max
Transaction price (€)	214,180	121,704	25,000	1,000,000
Wind turbine, <2 km	0.0506	0.2192	0	1
House size in m^2	117.9	37.71	26	250
Number of rooms	4.384	1.340	1	25
Terraced	0.317	0.465	0	1
Semi-detached	0.281	0.449	0	1
Detached	0.128	0.334	0	1
Garage	0.331	0.471	0	1
Garden	0.976	0.154	0	1
Maintenance state is good	0.866	0.341	0	1
Central heating	0.891	0.312	0	1
Listed building	0.00618	0.0784	0	1
Construction year 1945–1959	0.0717	0.258	0	1
Construction year 1960–1970	0.150	0.357	0	1
Construction year 1971–1981	0.169	0.374	0	1
Construction year 1981–1990	0.138	0.345	0	1
Construction year 1991–2000	0.126	0.332	0	1
Construction year >2000	0.109	0.311	0	1

Notes: The number of observations is 3,389,903. The data covers the period 1985-(mid)2019. Apartments are the reference group for the type of residence. Houses built before 1945 are the reference category for the building year.

4. Methodology

4.1. *Measuring the price effect of wind turbines*

To measure the effect of wind turbines on house prices, we employ a difference-in-differences hedonic price method in which house price developments nearby wind turbines are compared with house price developments further away. In particular, we estimate:

$$\log P_{it} = \beta w_{it-1} + \gamma X_{it} + \lambda_j + \lambda_t + \varepsilon_{it}, \quad (1)$$

where P_{it} is the transaction price of property i sold in year t, w_{it-1} is an indicator that is 1 if a property is sold within 2 km in all years *after* placement of a wind turbine (for now we focus on the nearest wind turbine), X_{it} are housing characteristics, λ_j are location fixed effects at the postcode 6-digit level (containing about a half a street and on average just over 20 households, but fewer in rural areas), λ_t are month and year time dummies that control for overall price trends and seasonality, ε_{it} contains characteristics of properties or locations that are unobserved. These are assumed to be uncorrelated with the placement of

[11] Importantly, we disregard solar panels on roofs of industrial or agricultural buildings and only consider land-based solar farms.

[12] This solar farm produces about $0.85 \times 1,000,000 \times 109 = 92$ million kWh per year (see Tenten Solar, 2019). For comparison purposes, an (average) wind turbine of 3 MW delivers around 8 million kWh; the park is therefore roughly equal to 14 wind turbines.

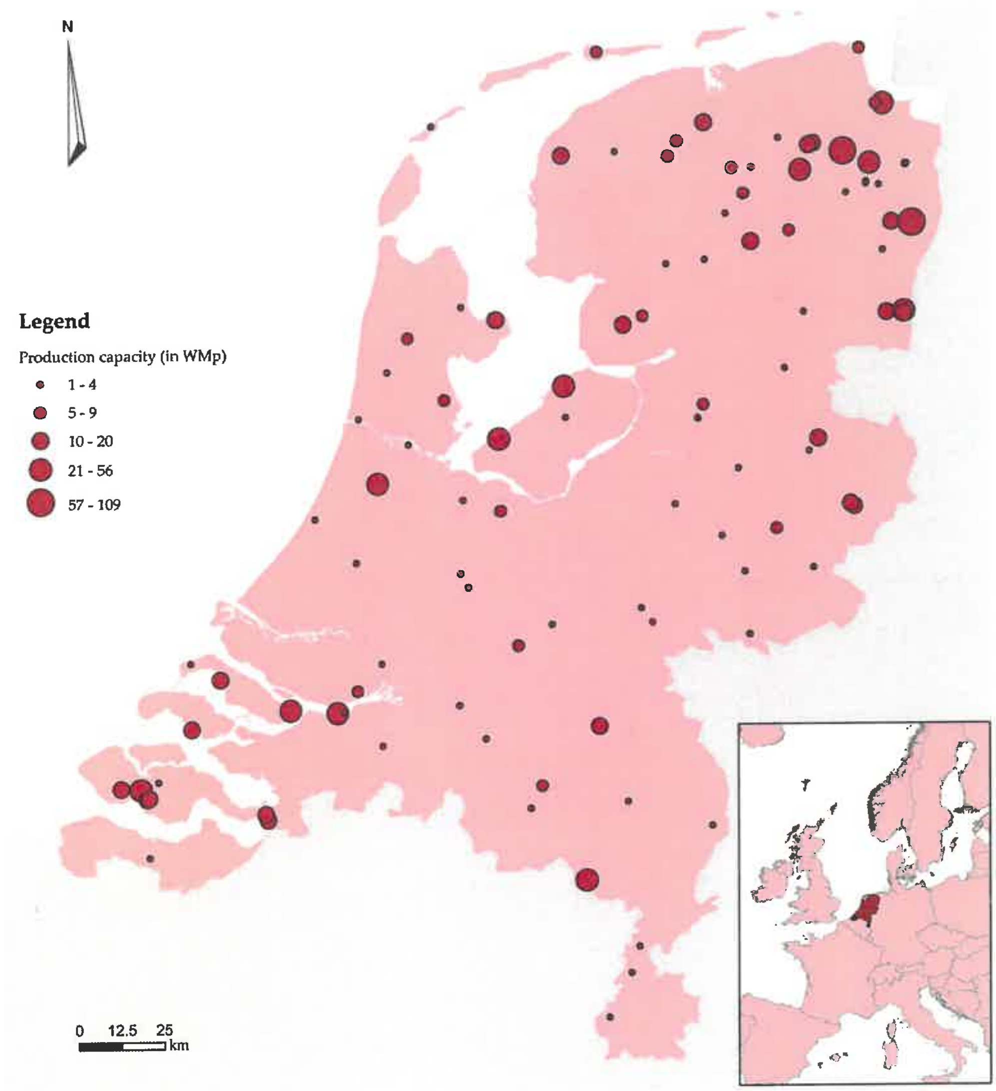


Fig. 3. The locations of solar farms (until mid-2019)
Notes: We obtain data on solar farms from ZonopKaart. The first solar farm was built in 2004. The map is compiled by the authors.

a turbine.[13]

We control for any time-constant price difference across locations. This is important as differences in prices may arise because amenities may differ between locations (for example, the presence of schools, etc.). To alleviate the concern that the location fixed effects are not detailed enough we will also show robustness using a repeat sales approach, completely absorbing time-invariant property and location characteristics. We use 2 km around turbines as treatment areas, as most of the noise (<500m), flickering (<1000m), and landscape pollution (< 2000m) typically falls within this area (Dröes and Koster, 2016). Nevertheless, we will also explicitly investigate whether the effect reaches beyond 2 km.

We are particularly interested in β, which measures *the percentage change in property value relative to a (local) control group*. We start our analysis by using transactions in the rest of the Netherlands as the control group and subsequently examine the effect using 3–5 km and 2–3 km as control group areas.

Still, one may be concerned that properties that are further away than 2 km may have different price trends. For example, they may be located closer to city centers, which are prone to relatively strong price increases due to inelastic housing supply and gentrification. Our preferred specification therefore only keeps observations within 2 km of a (future) wind turbine, implying that we only use the variation in the opening dates of wind turbines. We are then comparing the price development in areas in which wind turbines are opened to locations where they will be opened in the future. This is possible because there is variation in the opening date of wind turbines.

This approach is a version of a difference-in-differences strategy, but one in which unobserved price trends are much more likely to be very similar in treatment and control areas, and much less restrictive than the standard parallel trend assumption between spatially differentiated treatment and control groups that is usually applied in standard differences-in-differences methodologies. In particular, in Appendix A.3 we show that this is equivalent to a model with *non-parallel trends* (*i.e.* we implicitly control for differences in income, unemployment trends, etc.) between control and treatment groups.

Finally, it is important to control for housing characteristics because certain types of homes are more often located closer to wind turbines. A possible decrease in value could then mistakenly be attributed to the

[13] Note that the location fixed effects capture time-invariant price differences between control and treatment areas (*e.g.* the selection effect of wind turbines being placed in low-priced areas). The time fixed effects capture time trends, such as general economic trends affecting house prices. Time fixed effects also absorb any difference between real and nominal prices.

Table 2
Descriptives: house prices and solar farms.

	(1) Mean	(2) St.dev.	(3) Min	(4) Max
Transaction price (€)	249,586	124,274	25,000	1,000,000
Solar farm <1 km	0.00118	0.0343	0	1
House size in m^2	116.8	37.70	26	250
Number of rooms	4.453	1.398	1	24
Terraced	0.313	0.464	0	1
Semi-detached	0.277	0.448	0	1
Detached	0.122	0.327	0	1
Garage	0.314	0.464	0	1
Garden	0.970	0.170	0	1
Maintenance state is good	0.867	0.340	0	1
Central heating	0.881	0.323	0	1
Monumental status	0.00636	0.0795	0	1
Construction year 1945–1959	0.0704	0.256	0	1
Construction year 1960–1970	0.133	0.339	0	1
Construction year 1971–1981	0.139	0.346	0	1
Construction year 1981–1990	0.114	0.317	0	1
Construction year 1991–2000	0.119	0.324	0	1
Construction year > 2000	0.203	0.402	0	1

Notes: The number of observations is 1,470,808. The data is as of 2009. Apartments are the reference group for the type of residence. Houses built before 1945 are the reference category for the building year.

placement of a wind turbine. We will show various robustness tests showing the validity of our research design.

Furthermore, we are particularly interested to examine heterogeneity in the impact of wind turbines by allowing the price effect to differ between low (<50m), medium-sized (50–150m), and tall (>150) turbines. The specification to be estimated is then:

$$\log P_{it} = \sum_{h=1}^{3} \beta_h w_{iht-1} + \gamma X_{it} + \lambda_j + \lambda_t + \varepsilon_{it}, \tag{2}$$

where w_{iht-1} is a dummy that equals one when the nearest turbine falls in height category h and is within 2 km in $t-1$, and β_h are the coefficients to be estimated for each height category. We will also examine whether the impact radius differs for turbines with different heights.

4.2. *Measuring the price effect of solar farms*

For solar farms we initially assume an impact radius of 1 km, which we realize is somewhat arbitrary. We will therefore also investigate the spatial extent of the effect. To measure the impact of the opening of a solar farm on property values, we use the same methodology as that for wind turbines. We estimate the following equation:

$$\log P_{it} = \zeta s_{it-1} + \gamma X_{it} + \lambda_j + \lambda_t + \eta_{it}, \tag{3}$$

where P_{it} is again the transaction price of property i sold in year t, s_{it-1} is an indicator that is 1 if a property is sold within 1 km in all years after opening of a solar farm (again we look at the nearest solar farm), X_{it} are property characteristics, λ_j are postcode fixed effects, λ_t are month dummies, and η_{it} again captures unobserved heterogeneity.

We are particularly interested in ζ. This coefficient measures the percentage change in property values due to the placement of a solar farm relative to a (local) control group. The initial control group consists of transactions from the whole of the Netherlands. We improve on this by selecting transactions within 2–5 km and 1–2 km. As there are much fewer solar farms as compared to wind turbines, we expect that just using temporal variation in the opening of solar farms (*i.e.* only using observations within 1 km of a solar farm) will lead to somewhat imprecise estimates.

5. Results

5.1. *Baseline estimates: wind turbines and house prices*

Table 3 shows the regression results based on equation (1). In column (1) we use the whole dataset. The results suggest that the opening of a wind turbine within 2 km of the property is associated with a house price decrease of 1.9% ($= (e^{-0.0192} - 1) \times 100\%$). This effect is statistically significant at the 1% significance level. Using the whole of the Netherlands as a control group is unlikely to yield unbiased results, as price trends between rural areas (where turbines are often placed) and urban areas are most likely different.[14]

In columns (2) and (3) we change the control group to include transactions within 3–5 km and 2–3 km of a wind turbine, respectively. The effect becomes a bit higher(2.5%) using the 3–5 km control group and -2.1% in case of the 2–3 km control group. The fact that the effect we find is relatively robust and remains statistically significant even with a substantially smaller sample and different control groups suggests that it is plausible we are capturing a causal effect of the opening of wind turbines on house prices.

Finally, we estimate a version of equation (1) that is based on the sample of transactions within 2 km of all existing wind turbines in 2019. That is, we measure the effect conditional on the placement of wind turbines in particular areas. This should capture any selection effect concerning the location of wind turbines. The regression estimate in column (4) shows that house prices within 2 km of a wind turbine decrease by 1.8% *relative* to areas in which a wind turbine has not yet been constructed. The effect is statistically significant at the one percent significance level. We consider this to be strong evidence that wind turbines affect nearby house prices.[15]

5.2. *Robustness checks*

In Appendix A.3, we discuss several sensitivity analyses concerning the results. First, we estimate a repeat sales model, which conditions out all time-invariant housing and location characteristics by differencing prices between pairs of consecutive transactions of the same house. The estimated coefficient is still very close to the baseline estimate suggesting that the detailed location fixed effects we have used before seem to capture unobserved housing and location characteristics well.

Second, we test whether *anticipation effects* are important. Such anticipation effects may arise because house prices already adjust before the construction of a turbine, *e.g.* because the planning phase may take several years. We show that the treatment effect *controlling for any anticipation effects* is -2.1%. The effect is still statistically significant at the one percent significance level. Prices start to decline about 3 years before the opening of a turbine.

Third, we investigate whether regional trends may be correlated with the placement of turbines. We estimate a specification with travel-to-work-area (TTWA) fixed effects interacted with time trends. The treatment effect remains very stable (*i.e.* it is -2.1%).

Fourth, we examine wind turbine removals and show that house

[14] Yet, the equation including controls and fixed effects seems to capture a considerable amount of the variation in house prices, as we can explain 93% of the variation in house prices. This high fit is mainly due to the inclusion of highly detailed PC6 fixed effects.

[15] In principle, this specification is equivalent to a difference-in-differences model that allows for non-parallel trends between the control and treatment groups. In Appendix A.3 we show that a classical difference-in-differences (DID) model based on the model estimated in column (3) (2–3 km control group), but allowing for such non-parallel trends indeed yields identical point estimates. Only the standard errors are (marginally) smaller as they are (artificially) lowered by adding the control group transactions. We, therefore, prefer the results reported in Table 3, column (4).

Table 3
Average effect of wind turbines on house prices.

(Dependent variable: the logarithm of house prices)				
	(1)	(2)	(3)	(4)
	Full sample	*Control group*	*Control group*	*Temporal*
		(3–5 km)	*(2–3 km)*	*variation only*
Wind turbine placed, <2km	−0.0192*** (0.0041)	−0.0256*** (0.0045)	−0.0214*** (0.0048)	−0.0183*** (0.0068)
Housing characteristics	✓	✓	✓	✓
Postcode fixed effects	✓	✓	✓	✓
Year and month fixed effects	✓	✓	✓	✓
Observations	3,389,780	1,488,276	710,703	290,002
R^2	0.92	0.92	0.92	0.92

Notes: This table is based on data between 1985 and 2019. Standard errors are clustered at the neighborhood level and are in parentheses. Significance levels: ***p<0.01, **p<0.05, *p<0.10.

prices increase by 1.1% if a turbine is removed. However, due to a low number of removed turbines, the estimate is somewhat imprecise and not statistically significant at conventional levels.

Fifth, we study the effect of multiple turbines. We show that it is particularly the first turbine that has an effect on house prices. When more turbines are built within 2 km turbines, the additional turbines generally have a negative effect but the effect is less than 1% and statistically insignificant. From a policy perspective, these results imply that to reduce external effects on house prices it is best to cluster turbines in wind farms.

Finally, one may be concerned that the perception regarding wind turbines may have changed. We, therefore, test whether the willingness to pay to live nearby turbines is constant across the study period. It appears that we cannot reject the null hypothesis that the effect is constant over time.

5.3. *Demography and sorting*

One may wonder what type of households are the most affected by the placement of wind turbines. We explore this in Appendix A.4, where we gather data from Statistics Netherlands on various demographic characteristics at a very spatially disaggregated postcode 6-digit level. The results do confirm that turbines are built in sparsely populated areas with about 30% lower population densities. Interestingly, we find that the median income is only 2% lower within 2 km of a turbine. Hence, the households that are affected are not necessarily those at the lower end of the income distribution. Moreover, the share of people receiving income assistance is the same between treated and untreated areas.

Finally, we further investigate whether preference-based sorting occurs after the placement of a wind turbine. We find small changes in population density, household size, and the share of foreigners after a wind turbine is placed. Although statistically significant, these effects are economically small. Hence, we do not find evidence that the demographic composition changes considerably after turbine construction.

5.4. *Wind turbine height*

Up until now, we have ignored the effect of turbine height and assumed that the effect of turbines is confined to 2 km. As shown, turbines have become taller over time, which may, in turn, have exacerbated visual pollution, as well as the potential reach of noise pollution, flickering and shadow. We would expect that this increases the treatment effect and also affects the overall impact radius.[16] We, therefore, estimate several regression based on equation (2), using temporal variation only (see Table 3, column (4)), and show the results in several figures.[17]

In Fig. 4a we show that taller turbines indeed have a larger effect on house prices. Small turbines (<50m) on average have an effect of less than -1%. while this effect is not statistically significant. For a medium-sized turbine (50–150m) the effect is around 2% and statistically significant.[18] For turbines taller than 150m the effect is around 5% and also statistically significant, even though the confidence bands are a bit wider due to a lower number of observations.[19] The effect ranges between 3 and 7% and it is clear that the effect is considerably stronger than the effect of low turbines.

In Fig. 4b, we control for time-varying effects of turbines, as to control for any potential changes in perception over time. We find very similar effects for small, medium and tall wind turbines. The effect of a medium-sized turbine is now about − 3% and the effect of a tall turbine is also a bit larger and − 5.4%. These effects are still statistically significant, but note that the confidence bands are now somewhat wider.

5.5. *Impact area of turbines*

Distance to a wind turbine is likely an important factor in determining the possible decrease in prices. Within 5 times the axis height there is a possible effect of sound and for the average turbine up to 1 km there is also possible shadow. Up to 2 km (and beyond), there is potentially visual pollution.

In Fig. 5 we, therefore, show a specification where we interact the effect of turbines by 250m distance band dummies. Hence, we estimate the treatment effect for different distance bands. The number of observations increases as we now include housing transaction prices within 2.5 km of a (future) turbine. Fig. 5 shows that within 500m the confidence bands are large because the number of observations is low. Hence, we cannot precisely determine the effect of the opening of a wind turbine on transaction prices within short distances. Between 500 and 750m the effect is about − 3%. The effect gradually decreases until at 2500m the effect is small and indistinguishable from zero. Hence, the impact area of turbines seems to be maximally 2250m.

Although the average effect across all turbine heights is of interest, it is important to investigate whether the impact area is different for tall turbines. Therefore, we re-estimate the regression but now allow the effects to vary by wind turbine height *and* distance. Even with this large dataset, the number of observations for tall turbines is small. Hence, we aggregate the distance bins for the tallest turbines by 500m instead of 250m. The results are depicted in Fig. 6. Small turbines only have a statistically significant effect of about 2% at 1 km and the effect is essentially zero beyond 1 km. At 500m and 750m the effects are imprecisely measured.

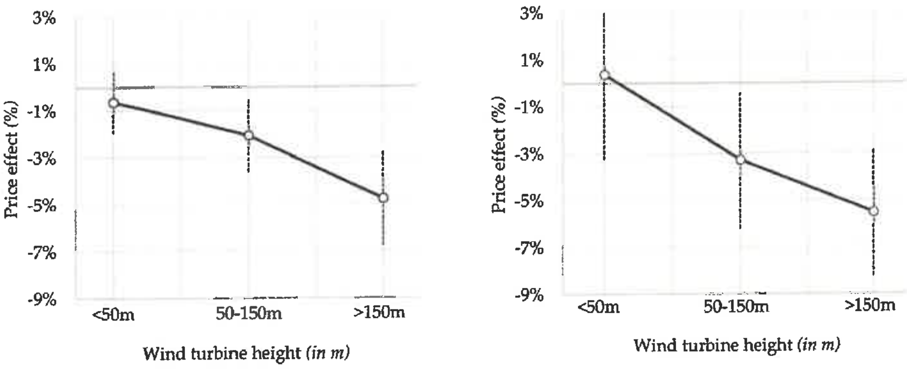
A turbine with a height between 50 and 150m yields a statistically significant effect of -3.4% at 750m. The effect decreases over distance, but at a relatively low rate. At 2500m the effect is no longer statistically

[16] For example, at a distance of 2 km a turbine of 100m in height has a perceived height of 5cm. Instead, a 200m high turbine at that distance has already a perceived height of 10cm. The view of such a turbine might well be less obscured by features of the (urban) landscape.

[17] The underlying regression table is reported in Appendix A.3.

[18] We also considered splitting this category up even further but did not find statistically significant differences between those turbines.

[19] In the Netherlands, turbines larger than 150m also need to have a flashing light (white during the day, red during the night). This might increase the experienced nuisance and visibility of those wind turbines.



(A) Unconditional effect of height (B) Controlling for time-varying effects

Fig. 4. Price effects for different turbine heights
Notes: The dotted lines represent the 95% confidence intervals. These regressions include observations within 2 km of a (future) turbine and control for housing characteristics, postcode fixed effects, as well as year and month fixed effects. The number of observations is 290,002 and the R^2 in both regressions is 0.92.

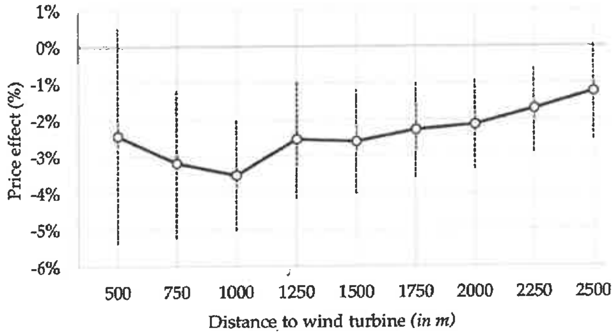


Fig. 5. Wind Turbines: Price effects at different distances (1985–2019)
Notes: The dotted lines represent the 95% confidence intervals. This regression includes observations within 2.5 km of a (future) turbine and controls for housing characteristics, postcode fixed effects, as well as year and month fixed effects. The number of observations is 491,337 and the R^2 is 0.92.

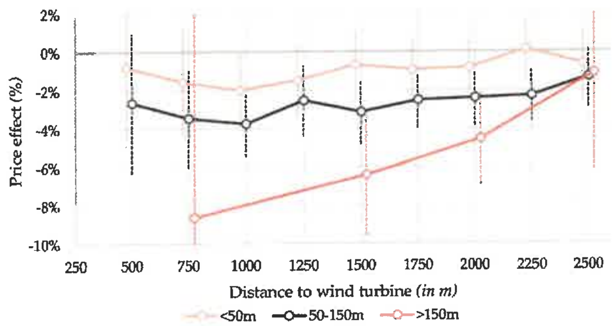


Fig. 6. Distance and wind turbine height
Notes: The dotted lines represent the 95% confidence intervals. This regression includes observations within 2.5 km of a (future) turbine and controls for housing characteristics, postcode fixed effects, as well as year and month fixed effects. The number of observations is 491,337 and the R^2 is 0.92.

significant. For the tallest wind turbines, the effect is again larger than for small turbines. At 750m the effect is -8.3%, albeit very imprecise due to the low number of observations (within 500m of a turbine exceeding 150m there are even no transactions available). The effect again decreases with distance, but more rapidly, and the effect is small and no longer statistically significant at 2500m. Note that the confidence bands for different heights are overlapping in most cases, except when comparing the largest and smallest turbines, which suggests that measuring the effect of height and distance to a turbine demands a lot from the data.

Overall, our results imply that taller turbines have higher effects on house prices and we find evidence that the effect also reaches just beyond 2 km, up to 2250m, but not beyond 2.5 km. Moreover, we show that low turbines (<50m) have a small impact on house prices that is confined to about 1 km.

5.6. Solar farms and house prices

In Table 4 we report results regarding solar farms, based on equation (3). Column (1) shows the effect of the opening of a solar farm within 1 km of a home using the full extent of our data. This effect is -3.7% ($=(e^{-0.0380}-1)\times 100\%$) and statistically significant at the 1% significance level. However, this specification does not take into account local price trends that may be correlated with the placement of solar farms. Moreover, it is not a priori clear that the effect is confined to 1 km.

To take these issues into account, a specification is estimated in column (2) in which the control group are transactions that take place within 2–5 km of a solar farm. The effect now becomes -4.6% and it is still highly statistically significant. Finally, in column (3) we decompose the effect for 500m distance bands. In Fig. 7 we show that the effect within 500m is -5.9%. It is -3.8% up to 1 km and it approaches zero and is no longer statistically significant beyond 1 km.

Next, we undertake some robustness checks. In column (4) we consider a more local control group by only including observations within 2 km of a (future) solar farm. The estimated coefficient is somewhat smaller: house prices decrease on average by 2.6% after the opening of a solar farm. The effect is highly statistically significant. We consider this estimate as our preferred estimate as it is rather conservative and the control group is more local.

Furthermore, it could be argued that the effect of solar farms picks up the effect of wind turbines, because they might be located close to each other. Hence, we add a dummy indicating whether there is a wind turbine within 2 km in column (5). The effect of solar farms is still -2.6%. This is not too surprising as the correlation between wind turbine locations within 2 km and solar farms within 1 km is only 0.005. The negative effect of wind turbines is statistically insignificant because the sample only includes very few turbines.

Finally, we identify the effect based on variation in the opening dates of solar farms only. The result is reported in column (6). In this case, the point estimate is still -1.5% but the effect is no longer statistically significant. This is not surprising as we include just 12,650 observations in the regression. More importantly, given the standard error, this estimate is not statistically significantly different from our preferred estimate.

We interpret these findings as robust evidence that property values decrease within 1 km of solar farms. The coefficient estimates range

Table 4
Average effects of solar farms on property prices (2009–2019).

	(Dependent variable: the logarithm of house prices)					
	(1)	(2)	(3)	(4)	(5)	(6)
	Whole Netherlands	*Control group 2-5 km*	*Distance profile*	*Control group 1-2 km*	*+ Wind turbine treatment*	*Temporal variation only*
Solar farm placed <1 km	−0.0380*** (0.0093)	−0.0469*** (0.0099)	see Fig. 7	−0.0263*** (0.0090)	−0.0263*** (0.0090)	−0.0156 (0.0253)
Wind turbine placed <2 km					0.0018 (0.0166)	
Housing characteristics	✓	✓	✓	✓	✓	✓
Postcode fixed effects	✓	✓	✓	✓	✓	✓
Year and month fixed effects	✓	✓	✓	✓	✓	✓
Observaties	1,470,808	355,235	405,164	62,579	62,579	12,650
R^2	0.90	0.90	0.90	0.89	0.89	0.90

Notes: This table is based on data between 2009 and 2019. Standard errors are clustered at the neighborhood level and are within parentheses. ***p< 0.01, **p< 0.05, *p<0.10.

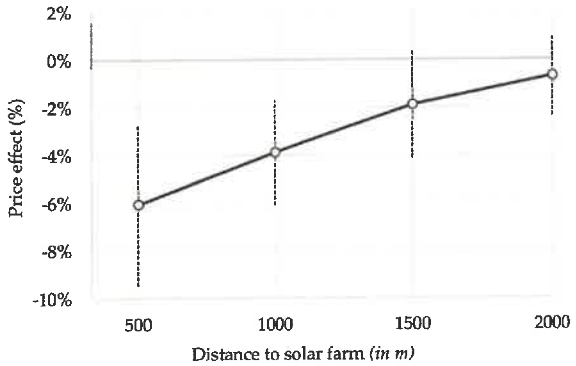


Fig. 7. Price effects at different distances, solar farms (2009–2019)
Notes: The dotted lines represent the 95% confidence intervals. This regression includes observations within 5 km of solar farms present in 2019 and controls for housing characteristics, postcode fixed effects, as well as year and month fixed effects. The number of observations is 405,164 and the R^2 is 0.90.

between -1.5% and -5.9%, depending on the specification. Again, we see the results in column (4) as our preferred model estimate: it takes into account possible unobserved trends and includes enough observations to accurately estimate the effect. The effect is of the same order of magnitude as for turbines, but more localized.

5.7. Overall losses in property values

Given the regression estimates, we can calculate the 'back-of-the-envelope' total loss in housing values as a result of the construction of wind turbines and solar farms in the Netherlands. For wind turbines, we use the estimates that discriminate between the height of a turbine and the distance of a property to the nearest turbine reported in Fig. 6. For solar farms, we rely on the estimate reported in column (4) in Table 4.

Using data from BAG (*i.e.* the Building Register) we calculate the number of residential properties in each distance band from each wind turbine and solar farm. Furthermore, we calculate real average house prices (in 2019 prices) within 2 km of a wind turbine and 1 km of each solar farm using the NVM data. We then multiply the estimated price effects with real prices and the number of residential properties around each turbine or solar farm. Before we move to the results, we caution that the numbers should be interpreted as back-of-the-envelope calculations as we have to make several simplifying assumptions. First, we assume that the relative price decrease estimated for the owner-occupied housing market carries over to the rental market. Second, we assume that the average price effects of turbines and solar farms apply to properties throughout the Netherlands; so we abstract from any heterogeneity in the price effect other than the heterogeneity in distance to and height of the wind turbine. The results are still informative as they point towards the overall economic magnitude of the effect.

Table 5
Wind turbines and solar farms: total effects on house prices.

	(1)	(2)	(3)	(4)	(5)
	Wind turbines				Solar farms
	All	≤50m	50-150m	≥150m	All
Total loss in € (*in millions*)	4993	427	3789	777	800
Average loss in € per turbine/ farm	4,153,672	2,102,069	4,271,443	6,939,494	7,477,965
Average loss in € per MWh	953.14	2191.89	1033.84	763.82	835.59
Median loss in € per turbine/ farm	140,175	250,599	114,562	116,652	1,901,138
Median loss in € per MWh	53.41	276.96	34.15	11.30	364.80

Notes: We assume that a wind turbine of 1 MW delivers $365 \times 24 \times 0.304 = 2,663$MWh, where 0.304 represents the capacity factor, which we obtain from the Energy Information Agency. A solar farm with a nominal peak power of 1 MWh delivers $0.85 \times 1,000,000 \times 1 = 0.85$ million kWh.

The results for wind turbines, reported in Table 5 show that the total loss in housing value is about €5 billion, which is substantial.[20] Because there are so few properties within 500m of a turbine, only 0.7% of the total loss accrues to properties within 500m of a turbine, while 10% of the loss is borne by properties within 1 km of a turbine. The average loss per turbine built on land is €4.1 million. The average loss per MWh is about €1 thousand. These results suggest that when placing wind turbines it is important to take into account the additional external costs.

However, the average loss per turbine may be somewhat misleading

[20] For comparison purposes, the Dutch GDP was about 725 billion in 2017.

as most of the total loss is due to a few turbines that are close to residential neighborhoods. More specifically, it appears that just 25 turbines account for almost 50% of the total loss. This shows that it is very important to build turbines not too close to residential properties. Indeed, the median loss per turbine is much lower and about €140 thousand, or about €53 per MWh. Given the construction costs of about €1.27 million per MW, we calculate the median loss in housing values as 16.5% of the construction costs.[21]

Note that the median loss per MWh varies considerably across turbines of different heights. For example, because tall turbines generate more power, the median loss per MWh is about €11, while it is €277 for low turbines. Hence, despite the smaller effects of low turbines, the loss in power does not make it more efficient to build low turbines.

Let us now consider the impact of solar farms. Because there are yet much fewer solar farms constructed, the total loss is just over €800 million. The *average loss* per solar farm is of the same order magnitude as the external costs of wind turbines. Here it also seems more informative to look at the median loss of a solar farm, which amounts to about €2 million, which is considerably larger than the median loss for one turbine. However, this is mainly because solar farms are generally larger and generate more energy. In addition, the median loss per MWh is €365, which is also considerably larger than the median loss of a wind turbine. The reason is that solar farms are often large so that it is hardly avoidable to have a solar farm that is not close to residential properties. Indeed, the median number of properties within 1 km is 178, while this is just 3 properties for wind turbines.[22]

These results seem to suggest that – even though the impact area is smaller – building solar farms does not mitigate the external effects of renewable energy production in comparison to wind turbines, at least given the current spatial distribution and available technology. Still, the large differences between the average and median loss per turbine/solar farm strongly confirm that choosing sparsely populated areas to build turbines/solar farms is important. For solar farms, these areas may be easier to find, as the impact area of solar farms seems to be confined to 1 km instead of about 2 km for turbines. On the other hand, the land beneath solar farms cannot be used for other purposes, while land close to turbines can be used for crops or livestock farming.

6. Conclusions and policy implications

Producing energy sustainably is an important step towards a climate-neutral economy with net-zero greenhouse gas emissions. Wind and solar energy are important sources of renewable energy. However, while reductions in CO_2 emissions benefit the whole population, external effects are borne only by households living close to production sites. Hence, insights into these external effects is paramount for renewable energy policy as the size of external effects is informative on whether there is local support for the opening of production sites, such as wind turbines and solar farms. In this study, a panel dataset on house prices between 1985 and 2019 from the Netherlands is used to measure the effect of the proximity of wind turbines and solar farms on property values.

Our results suggest that the opening of a wind turbine decreases local house prices by 1.8%. The impact of turbines does not reach beyond 2250m. It is particularly the first turbine that reduces house prices; hence to mitigate external effects, turbines should be concentrated in wind farms. Moreover, we are particularly interested in the effects of turbine height, as turbines have become much taller over time. For a turbine taller than 150m we find that the effect is on average -5.4%. The impact area is about 2 km. Instead, a small turbine below 50m has only a small effect which at most distances is statistically insignificant and quickly dissipates beyond 1 km. Thus, turbine height is an important source of heterogeneity in the effect of turbines on property values.

This study also investigates the impact of solar farms on house prices. Due to possible noise disturbance, the reflection of the sun, but also visual pollution, a solar farm can have a negative impact on property values. The effects of this are expected to be more local because these solar farms are less visible than wind turbines; and noise reflection also probably does not reach that far. We find evidence of a decrease in property values of about 2.6% after the placement of a solar farm. This effect is confined to 1 km.

Our back-of-the-envelope calculations document that the total loss in house value as a result of wind turbines is about €5 billion, which is about equal to the replacement costs. Interestingly, 1% of the turbines account for almost 50% of the loss in housing values. This confirms that the choice where to build turbines is key; to mitigate losses in housing values turbines should be placed in sparsely populated areas. The median loss per MWh produced is €53, but this varies considerably across turbines of different heights. For example, for tall turbines, the median loss per MWh is about €11. This suggests that it is worthwhile to build tall turbines. The median loss per MWh for solar farms is €365, which is much higher than the median loss for wind turbines (but note that the average losses are about the same). Hence, building solar farms instead of wind turbines will not mitigate the external effects of renewable energy production.[23]

The results in this paper highlight that careful placement of wind turbines and solar farms is paramount as the total loss in housing wealth can quickly increase if turbines and solar farms are built too close to residential properties. We argue that the external costs of wind turbines and solar farms should be taken into account when constructing such renewable energy production facilities and this study clarifies what those potential costs are. However, whether and to what extent homeowners should be compensated for the loss in housing values is a political question. Currently, the Dutch government compensates homeowners for losses in housing values due to area redevelopment exceeding 2% and this will be increased to 4% in 2022. Homeowners are only compensated for a loss in housing value over and above the threshold. We showed that only close to turbines or solar farms, the loss in housing values exceeds 4%, so that this compensation scheme, at least for most homeowners, will be of limited use in the future.

CRediT authorship contribution statement

Martijn I. Dröes: Methodology, Conceptualization, and, Formal analysis. **Hans R.A. Koster:** Methodology, Conceptualization, and, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.enpol.2021.112327.

[21] For each turbine, we calculate the loss per MW. We then take the median of this loss.

[22] Within 2 km of a turbine, the median number of properties is 15.5. This stark difference is also due to regulations that prohibit wind turbine construction close to residential properties.

[23] For future research and renewable energy policy, it would be useful to also compare the results with the potential negative external effects of other (non-renewable) energy production alternatives.

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Health Effects Related to Wind Turbine Noise Exposure: A Systematic Review

Jesper Hvass Schmidt , Mads Klokker Published: December 4, 2014 • https://doi.org/10.1371/journal.pone.0114183

Abstract

Background

Wind turbine noise exposure and suspected health-related effects thereof have attracted substantial attention. Various symptoms such as sleep-related problems, headache, tinnitus and vertigo have been described by subjects suspected of having been exposed to wind turbine noise.

Objective

This review was conducted systematically with the purpose of identifying any reported associations between wind turbine noise exposure and suspected health-related effects.

Data Sources

A search of the scientific literature concerning the health-related effects of wind turbine noise was conducted on PubMed, Web of Science, Google Scholar and various other Internet sources.

Study Eligibility Criteria

All studies investigating suspected health-related outcomes associated with wind turbine noise exposure were included.

Results

Wind turbines emit noise, including low-frequency noise, which decreases incrementally with increases in distance from the wind turbines. Likewise, evidence of a dose-response relationship between wind turbine noise linked to noise annoyance, sleep disturbance and possibly even psychological distress was present in the literature. Currently, there is no further existing statistically-significant evidence indicating any association between wind turbine noise exposure and tinnitus, hearing loss, vertigo or headache.

Limitations

Selection bias and information bias of differing magnitudes were found to be present in all current studies investigating wind turbine noise exposure and adverse health effects. Only articles published in English, German or Scandinavian languages were reviewed.

Conclusions

Exposure to wind turbines does seem to increase the risk of annoyance and self-reported sleep disturbance in a dose-response relationship. There appears, though, to be a tolerable level of around L_{Aeq} of 35 dB. Of the many other claimed health effects of wind turbine noise exposure reported in the literature, however, no conclusive evidence could be found. Future studies should focus on investigations aimed at objectively demonstrating whether or not measureable health-related outcomes can be proven to fluctuate depending on exposure to wind turbines.

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INFRASOUND AND ITS IMPACT ON PEOPLE

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Abstracts: The problem of the influence of infrasound radiation on living organisms is one of the important ones during the construction and operation of modern industrial complexes and structures with equipment that emits acoustic waves and vibration loads in this frequency range. Infrasound energy sources significantly worsen the ecological situation, the living conditions of living organisms and people in particular and also reduce the term of use of building structures and technical means. Features of the infrasound field, its physical mechanisms and sources of radiation are given. The impact of infrasound on the sensitive organs of the human body, its limit loads and threatening resonance frequencies are shown. According to the above results, it is recommended to avoid threatening infrasound parameters during the design and construction of modern industrial complexes and equipment that emit infrasound, or to reduce its intensity and increase the frequency range.

Keywords: infrasound, frequency range, sensitive organ, resonance frequency

In recent years, significant attention has been paid to the use of renewable energy sources in connection with the increase in energy consumption and the occurrence of the greenhouse effect, climate warming, and limiting the extraction of carbon-containing minerals. One of the most widely used renewable energy sources is wind power. Wind energy converters in the form of horizontal or vertical wind generators are built and operated both on land and in sea spaces. But these installations have one of the biggest drawbacks, namely that they generate acoustic waves and vibrations in the infrasound range. Research results have shown that this infrasound radiation has a significant impact on the environment, worsens ecology and has negative consequences for the health of living beings and, in particular, people who live and work near industrial wind turbines. Effects such as emotional/psychological disorders and sleep disturbances/failures, headaches, fatigue, decreased concentration and impact on quality of life are caused by local residence of wind energy facilities [1-3].

Infrasound refers to extreme bass waves or vibrations whose frequency is below the hearing range of the human ear (from 20 Hz to 22 kHz). Infrasound is elastic waves similar to sound waves, but with frequencies below the range of human hearing. Usually, the upper limit of the infrasound range is taken by frequencies of 16-25 Hz. The lower limit of the infrasound range is conventionally defined as 0.001 Hz. Infrasound is characterized by low absorption in various environments, as a result of which infrasound waves in air, water, and the earth's crust can spread over very long distances.

Throughout history, infrasound has played an important role, among which some very relevant developments should be highlighted [4]. The eruption of the Krakatoa volcano in Indonesia in 1883 was very peculiar, as the shock wave managed to go around the world several times. In addition, the fall of a meteorite in a Siberian forest in 1908, the nuclear bomb that exploded in Hiroshima and Nagasaki in 1945 during World War II, the Soviet nuclear bomb in 1949 during the Cold War, are examples of events when infrasound was generated [5].

Infrasound oscillations in the air are generated thunderstorms, strong winds, and solar flares. In the earth's crust, tremors and vibrations of infrasound frequencies are observed from a wide variety of sources. Infrasound can occur during the operation of vehicles, powerful equipment, machines, diesel engines, air compressors, fans, boiler rooms, all slowly operating machines, during gunshots, earthquakes, collapses, underground or underwater explosions. Also, infrasound constantly occurs during the operation of wind power plants. Cases of its occurrence in ventilation shafts have been recorded. Infrasound can be produced by wind, some types of earthquakes, ocean waves, and things like avalanches, volcanoes, and meteors. Elephants have the ability to emit infrasound that can be detected at a distance about 2 km. Even tigers generate infrasound.

Actually, infrasound is naturally produced by sea waves, avalanches, wind turbulence in the mountains, erupting volcanoes, earthquakes, etc. While such waves are only very slightly absorbed and - amplified by the high reflection from the ground and the refracting channel in the atmosphere - can travel thousands of kilometers, the pressure and frequencies are such that people cannot hear them, much less be adversely affected. Thunder has time-varying spectral peaks from infrasound to low-pitched sound, and of course it can be heard. Lower levels are created by wind turbines, air conditioners and ventilation, and inside cars or trucks; opening the window causes a noticeable increase in the infrasound area. In industry, low-frequency sound is produced by compressors, crushers, furnaces, etc. High levels were found in the ship's engine compartment.

Infrasound as a physical phenomenon is subject to the general patterns characteristic of sound waves, but it has a number of features related to the low frequency of oscillations of an elastic medium: a) infrasound has much larger amplitudes of oscillations than acoustic waves at equal powers of sound sources; b) infrasound spreads over long distances from the source of generation due to its weak absorption by the atmosphere; c) the long wavelength makes the phenomenon of diffraction characteristic of infrasound. Thanks to this, infrasound easily penetrates the room and bypasses obstacles that delay audible sounds; d) infrasound vibrations can cause vibration of large objects due to the phenomenon of their resonance.

It was stated in [6] that infrasound causes public concern. Part of this concern comes from the sources that produce these sounds, such as outdoor sources, including air conditioning systems and some industrial processes or wind turbines. It is also true that they are formed inside the body during breathing, heartbeat or coughing. There have been many studies, for example [7, 8], which have looked at how people perceive infrasound. Experiments were conducted in several places where infrasound is mainly observed, for example, under a bridge, inside a car and near a cooling tower. Subjects were asked whether they could feel infrasound as pressure in the ears and head and/or reverberation in the chest and abdomen. Response levels in the chest and abdomen were 6–9 dB higher than the total response from the ear, head, chest, and abdomen.

Although we cannot hear these waves, they can be felt and have been shown to cause a range of effects in some people, including anxiety, extreme grief and chills [9]. At sound frequencies, irritation, discomfort and pain are the result of an increase in the sound pressure level. Temporary hearing loss can develop into permanent hearing loss depending on the level, frequency, duration, etc.; at very high sound levels, even one or more short exposures can make a person partially or completely deaf. Outside of hearing, there may be some imbalance and unbearable sensations mainly in the chest. Blast waves from explosions with much higher excess pressure at close range can damage other organs, first the lungs, to the point of death.

If a person encounters infrasound in the range from 110 to 150 dB, various feelings of discomfort and functional changes in the body occur. This is a malfunction of the central nervous system, respiratory and cardiovascular systems, vestibular apparatus. Occurrence of migraine, ringing in the ears and head, perceptible movement of the eardrums, a sharp decrease in work capacity and attention, impaired balance, fainting, drowsiness, difficulty speaking, the occurrence of an uncontrolled feeling of fear, epileptic attacks, depressed state. Seasickness with dizziness, nausea and vomiting may occur. Infrasound from 5 to 8 Hz can cause cardiac arrest and death. Human organs, like any physical body, have their own resonant frequency. Under the influence of sound with this frequency, internal changes in the structure can be felt, up to the loss of performance. Also, if the impact of sound coincides with the rhythms of the brain, such as alpha - rhythm, beta - rhythm, gamma - rhythm, delta - rhythm, theta - rhythm, kappa - rhythm, mu - rhythm, sigma - rhythm, etc., a disturbance of activity may occur cerebral mechanisms of the brain.

From the point of view of biology, contact with different stimuli should cause different corresponding reactions of organs and systems. There is a zone of the gradient of the infrasound wave, in which the working capacity decreases, the frequency of the difference between sound pulses and light flashes decreases, the activity of the sympathetic link of the vascular system increases sharply, and the blood hypercoagulation reaction develops. This is a direct effect of infrasound on the walls of blood vessels.

Infrasound can cause unbearable sensations, affect labyrinths, dizziness, imbalance, etc.; resonances in internal organs, for example, the heart, with consequences up to death. It can cause loss of working capacity, disorientation, nausea, vomiting, intestinal spasms, resonances in body cavities that cause organ dysfunction, blurred vision, nausea - temporary discomfort until death; the effect ceases when the generator is turned off, with no lingering physical damage [10, 11].

As for the effects on humans, some of the claims are as follows: infrasound of 110-130 dB can cause intestinal pain and severe nausea. Extreme levels of irritation or distraction can result from minutes of exposure at 90 to 120 dB at low frequencies (5 to 200 Hz), severe physical trauma and tissue damage at 140 to 150 dB, and instantaneous blast injury at levels above 170 dB. At low frequencies, resonances in the body cause hemorrhage and spasms; in the middle sound range (0.5-2.5 kHz), resonances in the air cavities of the body cause nerve irritation, tissue injury and heating; high audio and ultrasonic frequencies (from 5 to 30 kHz) will lead to heating to a lethal body temperature, tissue burns and dehydration; and at high frequencies or with short pulses, bubbles are formed from cavitation and microdamages develop in the tissue.

Loud sound can temporarily or permanently reduce the ability to hear and affect the vestibular organ. At extreme levels, physical damage to the ear can occur with even brief exposure. At even higher levels, which occur practically only in pulses of excess pressure from explosions, other organs are damaged, and the lungs are the most sensitive.

Sound waves entering the auditory canal cause the eardrum to vibrate in the human ear [10]. This movement is connected by three ossicles of the middle ear to the oval window at the beginning of the labyrinth. The resulting pressure wave propagating in the cochlear perilymph bends the basilar membrane, which longitudinally separates the cochlea into vestibule and tympanic membrane; these two ducts are connected at the tip of the cochlea, and the latter leads back to the round window in the middle ear. The basilar membrane carries the organ of Corti, whose hair cells sense deformation and transmit this information via ganglion cells to the brain. The Eustachian tube connects the middle ear and the nasal cavity. Cavities and three semicircular canals of the vestibular organ are connected to the cochlea, which perceives the movement of the head and helps maintain balance [12].

The human ear consists of three parts [12]: the outer, middle and inner ear. Sound waves reflected from the auricle and passing through the ear canal cause the tympanic membrane (eardrum) to vibrate. The three bones of the middle ear (hammer, incus and stapes) transmit this movement - increasing the pressure - to the oval window at the entrance to the labyrinth and to the perilymph inside. The resulting pressure wave propagates into the cochlea, bending the basilar membrane, which longitudinally separates the cochlea and carries sensory hair cells. Their excitation is transmitted to the brain by the acoustic nerve. Equalization of pressure in the middle ear is possible through the Eustachian tube. Middle ear muscles can reduce transmission to the bony chain. The second part of the labyrinth is the vestibular organ with its cavities and semicircular canals for the sense of movement.

The vestibular system of the inner ear contains cavities (pills and sacs) with sensors for linear accelerations and three semicircular canals for determining angular accelerations. The vestibular system causes - through several, mostly subconscious channels in the central nervous system - eye movements and changes in posture, and also provides perception of movement and orientation. The vestibular system is one of the sensory modalities responsible for motion sickness [5].

For vertical vibration excitation of the human body while standing or sitting, below 2 Hz, the body moves as a whole. Above, amplification by resonances occurs at frequencies dependent on body parts, individuals, and posture. The main resonance is at a frequency of about 5 Hz, where it causes the most discomfort; the reason is the in-phase movement of all organs of the abdominal cavity with subsequent changes in the volume of the lungs and chest wall.

The construction and operation of multistory buildings, high single and multi-support spatial structures, which receive wind load and are surrounded by turbulent flow, leads to the separation of large-scale vortex structures, oscillations of structures and the generation of intense acoustic radiation and vibrations in the infrasound frequency range. Determining the features of the generation of the infrasound field of acoustic radiation and vibrations and its impact on the organisms of living beings require conducting scientific research with various types and designs of acoustic and vibration sensors and data processing and analysis systems [8, 13]. For this, systems of infrasound microphones, hydrophones, sensors of vibrations and pressure fluctuations [14-16] are used. With the help of group use of the same type or different types of sensors, acoustic radiation and vibration fields, characteristic features of infrasound radiation sources, as well as their aerohydrodynamic characteristics are determined. Processing and analysis of research results is carried out by methods of statistical analysis using the apparatus of probability theory and mathematical statistics [17-19]. On the basis of the obtained knowledge, methods of controlling acoustic and vibration fields are developed, as well as recommendations for reducing the intensity of the infrasound acoustic field and vibrations are determined and implemented. In particular, passive and active methods of damping acoustic load and vibration levels are used, as well as increasing the frequency range of radiation and vibrations, which have a greater degree of attenuation in space relative to infrasound oscillations.

Conclusions.

The problem of the influence of infrasound radiation on living organisms is one of the important ones during the construction and operation of modern industrial complexes and structures with equipment that emits acoustic waves and vibration loads in this frequency range. Infrasound energy sources significantly worsen the ecological situation, the living conditions of living organisms and people in particular and also reduce the term of use of building structures and technical means. Features of the infrasound field, its physical mechanisms and sources of radiation are given. The impact of infrasound on the sensitive organs of the human body, its limit loads and threatening resonance frequencies are shown. According to the above results, it is recommended to avoid threatening infrasound parameters during the design and construction of modern industrial complexes and equipment that emit infrasound, or to reduce its intensity and increase the frequency range.

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property values

Whitman County Commissioners, Planner, Public Works Director, Denis Tracy, and Planning Commission members

From: Carol Black – October 21, 2025

Personal Property – Impacts on Neighbors and the Need for Adequate Setbacks

The existing County setbacks will lead to lower property values. The decrease in real estate values is due to viewshed, noise, flicker, and other nuisances, which are worsened by several nearby turbines. The rural community affected is used to a peaceful, quiet lifestyle with little to no road noise. People pay premium prices for the few homes in rural areas. If property values fall, the project applicant or county must legally compensate the affected landowner for the difference, as determined by a licensed appraiser.

My June 4 communication stated the 5th Amendment of the US Constitution prohibits the government's taking of private property without just compensation. This includes the extent to which the act interferes with the reasonable expectations of the property owner.

The current County code does not address **decreases in property values or other financial impacts** related to using one's own residential or agricultural property. Alan Thompson, County Planner, noted, the property line setback is primarily for safety reasons, such as preventing injury if a turbine falls. Setbacks need to protect more than health and safety.

Harvest Hills shared a map of a proposed Corridor for 45 turbines in the spring of 2025. Using their map, I added approximate locations of homes near or within the corridor and county roads (Page 4). There are 111 homes within a one-mile radius of the proposed Harvest Hills Corridor (Page 4 map is missing five additional homes). In comparison, there are three homes within one mile of the Palouse Wind project, excluding the one home sold to the project. More than 25 of the 111 homes are owned by senior citizens (over 65), who will rely on their property investment to help finance their final years when they require care; this population should be classified as "overburdened". With the density of homes in the Colfax-Palouse-Albion-Kamiak Butte area, would you characterize it as "low-density rural"? Since the Palouse Wind project was built, no new homes have been built nearby, but homes have been built in the proposed Kamiak corridor. Note: 15 family entities leased land to Harvest Hills; however, there are 111 families who live in homes within one mile of the corridor.

Washington regulations guide EFSEC (RCW 80.50.010), and the regulations state: It is the intent to seek courses of action that will balance the increasing demands for energy facility location and operation in conjunction with the broad interests of the public. Such action will be based on these premises: One stipulated premise is "**to preserve and protect the quality of the environment**; **to enhance the public's opportunity to enjoy the aesthetic and recreational benefits of the air, water, and land resources**; to promote air cleanliness; to pursue beneficial changes in the environment; and **to promote environmental justice for overburdened communities."** Whitman County, likewise, must balance the broad interests of the public and not cause harm to neighbors.

Harvest Hills Wind Project has publicly stated that real estate values are not affected and cites only academic studies, not those performed by real estate appraisers. To challenge their claim, I provide two testimonies from wind projects and three recent peer-reviewed publications. Property value depreciation should warrant a minimum of a one-mile setback from property lines, and perhaps further for ultra-tall turbines.

#1 - Tri-Cities C.A.R.E.S

During the adjudication with EFSEC, property appraisal experts testified that real estate prices may decrease by 20 to 30 percent, and properties near the turbines might never sell.

E-4

#2 - Real Estate Consulting Report for Niyol Wind Farm in Logan County, CO (June 2020)
by Kurt C. Kielisch, Forensic Appraisal Group. Real Estate Appraiser with 36 years of experience in the appraisal field, completed over 8,100 valuations totaling $13.1+ billion.

Wind industry and government-supported studies found little to no evidence of an impact. However, independent studies found a significant impact using a variety of valuation methods, from paired sales analysis to multiple regression analysis.

- Properties within the wind farm footprint= –35% impact on property value
- Properties 1-mile outside of the wind farm footprint = –22% impact on property value
- Agricultural Properties within the wind farm footprint= –8.5% impact on property value
- The Landsink (Ontario, CA) study found a loss range of -8.85%to -50%, with a loss average of -39% for residential homes within 664 ft to 2,531 ft of a wind farm.
- The Appraisal Group One Wisconsin Study found a typical loss of 1-10 acre residential lots within 6-mile of wind turbines to be -19% to -40%.
- The Clarkson University, upstate New York, study of both residential and agricultural properties found a loss ranging from -15.6% to -31% within 1-3 miles of a wind farm.
- The Forensic Appraisal Coral Springs (WY) study of large residential lots (35 acres), which would be abutting a proposed wind farm, suffered a value impact of -25% to -44%.
- The McCann study (IL) of residential properties found an average impact of -25% within 2-miles of a wind farm.
- The Forensic Appraisal Big Sky (IL) study found a loss range of -12% to -25% of residences within 0.31mi to 1.72mi of a wind turbine, with an average impact of -19% at an average distance of 0.65 miles to a wind turbine.
- The Twin Grove II Wind Farm (McLean County, IL) study of a 198MW wind farm comprised of 120 turbines being 397ft in height over an 11,000 acres area. A paired sales analysis of residential property within the influence of the wind farm found the improved property is negatively impacted by the presence of wind turbines. The impact measured ranged from -46.6% to -7.7%, with the higher impact closest to the wind turbines and the impact diminishing as the distance is increased. The distances measured ranged 1,483ft to 5,481ft away from a residence. The Twin Grove II Wind Farm also found an overall impact of -6.63% to -8.5% for vacant agricultural properties within the wind farm zone.

The Niyol proposal has turbines being **495ft to 505ft in height**. This is at least 25% greater in height and breadth than the study turbines. Therefore, it would be logical and reasonable to conclude that this **size difference would cause the predictive impacts to be conservative.** With that in consideration, it would be reasonable to conclude the following impacts:

Properties Within the Wind Farm Footprint
The graph indicates that a -28% loss in value would be found from a distance of 1,500ft from a wind turbine. However, as we noted, those studies used smaller wind turbines. It is estimated that the proposed turbines are at least 25% greater in size. Though a direct correlation of size and impact has not been established, it would be reasonable to estimate the impact would increase by a factor of 1.25. Hence, we conclude the impact to be -35%.

Properties 1-Mile outside of the Wind Farm Footprint
The graph suggests that the impact would be less the further the distance from a wind turbine. The analysis indicates that at 2-mile distance from a turbine the impact would be -18%. Considering that the turbines were smaller in the studies it would be reasonable to increase this impact by a factor of 1.25 to conclude a -22% impact.

H-9

Agricultural Properties

Agricultural properties within the footprint, but not participating in the wind lease, will be have a -8.5% impact on property value.

#3 – Commercial wind turbines and residential home values: New evidence from the universe for land-based wind projects in the United States. Brunner, E.J., et al. 2024. Energy Policy Vol. 185

- Homes within one mile decline in value by approximately 11% after the announcement of a wind project; those one to two miles have a smaller impact
- Based primarily on projects in urban counties.
- European studies show values fall 5-10% for homes located within 2 km.

#4 – Wind turbines, solar farms, and house prices. Droes, M.J. and H. Koster. 2021. Wind Policy Volume 155

- Turbine height is a significant factor; turbines 50-150m have an effect of -3.4%, whereas the effect is -8.3% for turbines over 150m in height (but the sample size is very small for taller turbines).
- Findings imply turbines have higher effects on house prices and the effect reaches just beyond 2 km, up to 2250m, but not beyond 2.5 km. Moreover, we show that low turbines (<50m) have a small impact on house prices that is confined to about 1 km

#5 - The visual effect of wind turbines on property values is small and diminishing in space and time. Gou. W, et.al. PNAS Vol 121 No 13, 2024

- Abstract: Robust evidence of a 1% drop in home values within a wind turbine's viewshed. The effect is larger for homes closer to more wind turbines, but is no longer detectable by the end of the 10-year period covered by the data."
- Conclusion: On average across the whole sample, house prices decrease by up to 8% after the construction within the viewshed and the close-range neighborhood of the property.
- The visible effects of wind turbines negatively impact home values in an economically and statistically significant way when located in close proximity (< 5 miles/8 km).
- The average effect falls to 1% reduction for houses within 10 km of visible wind turbines
- *Carol Black notes on this paper, which is widely quoted by the wind industry*
    - One of the visual illustrations was based on a turbine with a hub height under 100 feet.
    - Norris Wilson, B.A., AACI, P.App. Wrote an Opinion on this study
        - The findings are a sleight of hand since based solely on "visual effect."
        - The sample size is 250,000 homes within 1.5 km and 8.5 million within 10 km, which does not truly focus on the homes close to the turbines; the further distances dilute the findings.
        - The study also did not address noise/infrasound concerns.

Carol Black map Page 4.

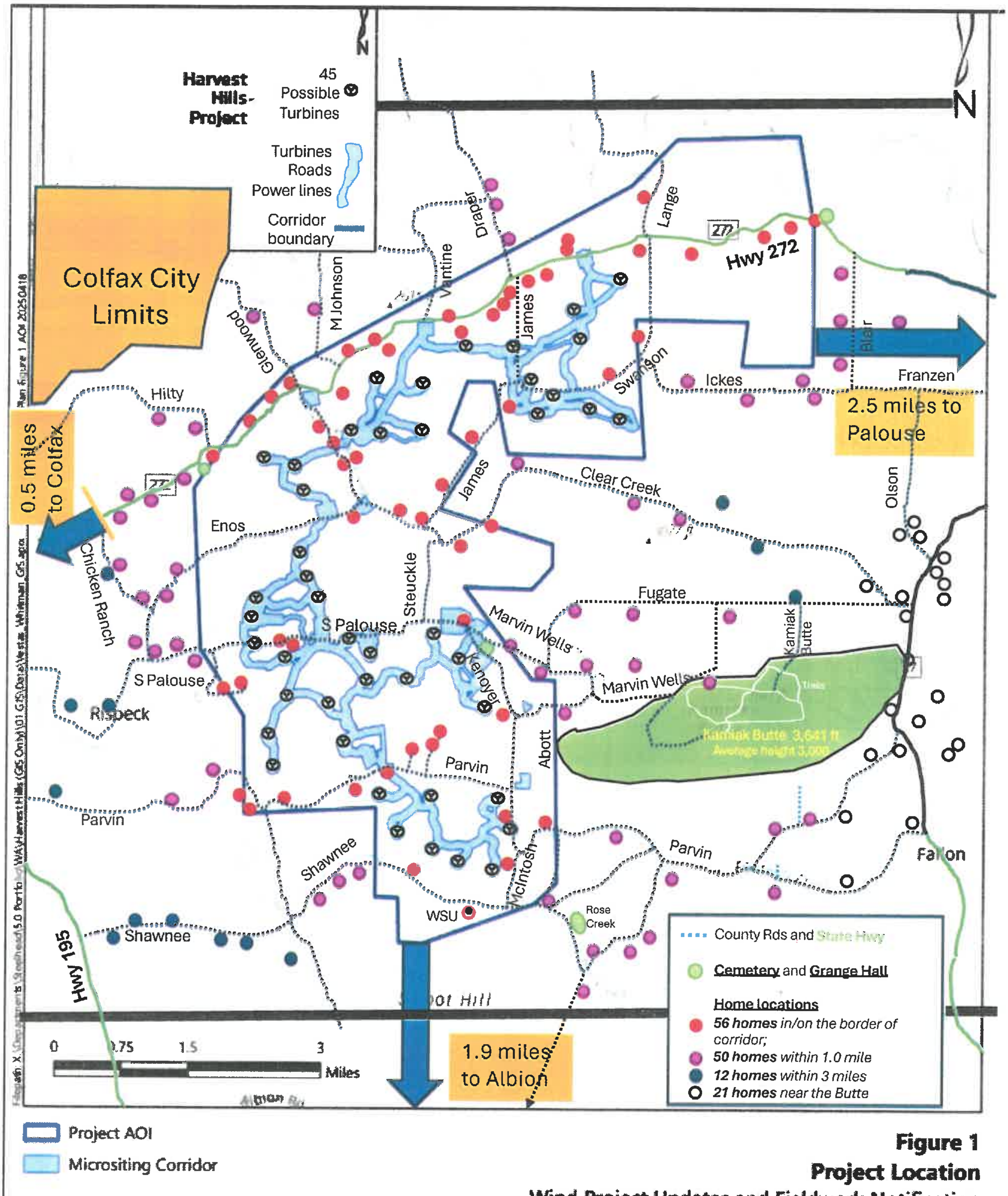


Figure 1
Project Location
Wind Project Updates and Fieldwork Notification
Harvest Hills Wind
Whitman County, WA

Version 5. Homes and county roads added by C. Black using All Trails and onX maps
Source map: PDF map from Vestas/Steelhead on April 18, 2025, correspondence with four Tribes - not to scale.

Setback Recommendations Per Various Studies

Name of Study	Date of Study	Author(s)	Link to Study	Advised Setbacks	Notes
Wind Turbine Syndrome: A report on a natural experiment	2009	Dr. Nina Pierpont	https://www.amazon.ca/Wind-Turbine-Syndrome-Natural-Experiment/dp/0984182705	Minimum 2 kilometers or 1.24 miles, but 2-3 miles in hilly terrain	Hard Copy and PDF available from Tom Thompson
Your Guide to Wind Turboine Syndrome...a road map to a complicated subject	July 2010	Calvin Luther Martin, Phd	n/a	Minimum 2 kilometers or 1.24 miles, but 2-3 miles in hilly terrain	Summary of Dr. Pierpont's book, hard copy and PDF available from Tom Thompson
Health Effects of Wind Turbines: Testimony of Ben Johnson versus MidAmerican Energy (Madison County, Iowa)	August 2019	Dr. Ben Johnson, M.D.	Hard copy provided	No recommendation given for a specific distance in this hearing	The Madison County Board of Health passed a resolution recommending that any future turbines be built at least 1.5 miles from non-participating home
Wind Turbine Noise and Human Health: A Four-Decade History of Evidence that Wind Turbines Pose Risks	May 2020	Professor Jerry L Punch and Professor Richard R James	https://www.scirp.org/journal/paperinformation?paperid=100240	.5 miles to 2.5 miles, 1.25 miles is most favored	Hard copy and PDF available
Infrasound from technical installations: Scientific basis for an assessment of health risks	July 2021	Dr. Werner Roos and Dr. Christian Vahl	PDF provided, was translated from German to English	Minimum 10 X turbine height	
Assessing Adverse Health Effects-(Confirmed and Potential) from Industrial Wind Turbine Noise Emissions	2022	Dr. Ben Johnson, M.D.	https://www.kslegislature.gov/li_2022/b2021_22/committees/ctte_s_utils_1/documents/testimony/20220207_01.pdf	1.25 miles	Power point slides of presentation before the Kansas State Legislature
Wind Turbines: Vacated/abandoned homes - Exploring participants' descriptions of their personal views, effects on safety, security, trust and social justice	Dec 2023	Carmen Marie Krogh, Robert Y McMurty, W Ben Johson, Jerry L Punch, Anne Dumbrille, Mariana Alves-Pereira, Debra Hughes, Linda Rogers, Robert W Rand, Lorrie Gillis	https://journals.lww.com/endi/fulltext/2023/08040/wind_turbines__vacated_abandoned_homes___exploring.2.aspx	10 kilometers or greater / 6.21 miles or greater	
A fundamental basis for all living creatures, mechanotransduction, is significantly endangered by periodic exposure to impulsive infrasound and vibration from technical emitters - in particular	June 2025	Dr. Ursula Bellut-Staeck	https://www.scirea.org/journal/PaperInformation?PaperID=12440	10 kilometers / 6.21 miles	NOTE: The link shows the abstract and allows you to download the PDF
Separating Myth from Fact on Wind Turbine Noise	October 2025	Prof Ken Mattsson	https://www.youtube.com/watch?v=nDwsd32SDEY	5 to 10 kilometers at least	Hard copy of transcript provided
Efficient finite difference modeling of infrasound propagation in realistic 3D domains: Validation with wind turbine measurements	Feb 2026	Ken Mattsson, Gustav Eriksson, Leif Persson, Jose Chilo, Kourosh Tatar	https://pdf.sciencedirectassets.com/271440/1-s2.0-	No specific distance given, see notes for conclusion of study	Conclusion of study: This study also shows that modern, large-scale wind turbines gener- ate infrasound levels substantially higher than those reported for older, smaller turbines. These findings enhance the understanding of the acous- tic characteristics of contemporary wind turbines and provide valuable guidance for environmental

Tom Thompson

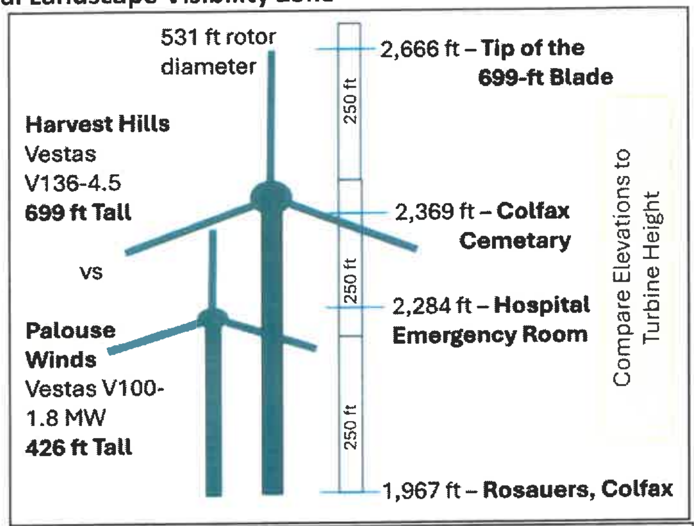
E-5

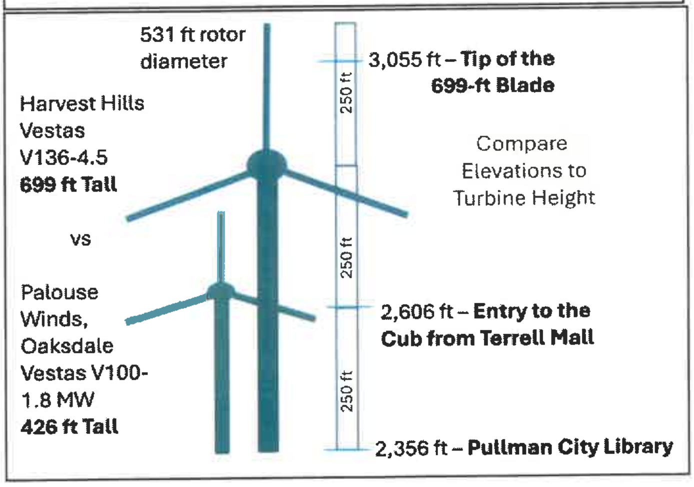
Setbacks from Buildings, etc - Findings of Facts Carol Black

Sent 12/1

Sections:

Rural Landscape Visibility Zone





Codes from Around the Country that meet or exceed the draft revised language for 6x tip height. Open Energy Data Initiative (OEDI). U.S. Wind Siting Regulation and Zoning Ordinances (2025) https://data.openei.org/submissions/8519

- 4 or 5 miles – Wheeler, NE, Sully, SD and Tooele, UT;
- 3 miles – Dawson, NE, Jefferson Davis, LA;
- 1.5-2 miles - Baker, OR, Burke, ND, Cedar, NE, Center, PA, Stark, ND, Umatilla, OR, Vermillion, IN, Walworth, SD;

E-6

    iv. A facility with a battery energy storage system of certain design and consolidate configuration is closer than 1.5 miles from noise-sensitive land uses
  b. Additionally, in recognition that existing ambient noise levels are commonly quiet in rural areas where siting of energy facilities would likely occur, an increase of 5 dBA over ambient would correspond to a readily perceptible increase in noise for permanent operations (FHWA 2017). In quiet rural areas, an increase of 5 dBA over ambient noise could potentially result when turbines generate a noise level of 40 dBA at a receptor. Based on two-dimensional geometric spreading equations, this increase is estimated to have potential to occur within approximately 5,000 feet from the turbines. Consequently, siting of wind turbines closer than 5,000 feet from a noise-sensitive land use in a quiet rural area would have a potentially significant adverse impact.

2. A couple of Michigan counties' wind codes require the applicant to measure Ambient Noise levels prior to construction. "Shall not exceed ambient sound plus 3-5 dBa or dBc." Rural ambient noise is usually around 35 dBa; an increase of 5 dBa would warrant a limitation to be set at 40 dBa in the wind code for rural areas.
    a. Carol Black Note. Since we are not addressing a rural noise standard in the Noise section of the code, it is rolled into the Setback section. A noise standard would require pre-construction noise measurement for all sensitive receptors and then limit noise to 5 dBa above that level.

  a. **Energy Policy.** February 2024Understanding subjective and situational factors of wind turbine noise annoyance. Muller, F.J.Y, et. Al.
      i. Using the single-item annoyance measure, 17.2% of participants reported not being at all annoyed by the sounds. 16.1% were slightly annoyed, 19.4% somewhat annoyed, 21.5% moderately annoyed, and 25.8% very annoyed; note: distance was not provided
      ii. three WTs with a power of 2.78 MW and total height of 199 m each (GE 2.75–120)
      iii. Michaud et al. (2016c) found that highly annoyed residents were more likely to have triple pane windows, and more likely to close their bedroom windows due to WT noise than less annoyed residents, corroborating that noise was relevant in situations associated with sleep.
  b. Sound modeling by the company does not address non-laboratory settings

Infrasound and Vibrations

Separating Myth from Fact on Wind Turbine Noise. 2025. Ken Mattson – Uppsala University, Copenhagen
Computer Scientist. Conference Presentation. Transcript PDF
https://www.youtube.com/watch?v=gpHDJPcqCQY – an amazing presentation at a conference

- Generational Sound versus Propagational Sound
- 105 dBa is not a constant and can vary during the day, often exceeded
- Vestas uses a simplified model to show sound movement and degradation
- Discusses how much sound is generated, and how is it propagated (shock wave)
- Every time the blade passes the tower, it creates a pressure pulse in a rhythmic pattern
- Infrasound infiltrates walls

- Every time the blade passes the tower, large air volumes are compressed and sheared, referred to as blade pass harmonics. They emerge from the background noise with a distinctly higher acoustic presser level, in other words, more energy.
- Modeling shows that a 5 MW turbine would possibly generate detectable infrasound signal even from a distance of 20 km. Data summary is flattened which makes the peaks disappear, making it appear similar to background noise.
- Wind turbines also generate structure-borne sound.
- Measured vibrations and infrasound measured in nearby home. – Gov't measurements would have calculated resulting in flattened out peaks.
- Professor Alec Salt, Washington University. Inner ear hairs react with electrical responses that stimulate other pathways – at a frequency of 5 Hz. Bias and money discount his findings.
- Prof. Ximena Kuhn - Infrasound affects the brain, which deals with managing stress, but the reason is unclear. Theory is that you cannot ignore the subliminal sound, like you can normal sound.
- Prototype infrasound weapons were developed, but they did not affect all people equally, so they were abandoned.
- Professor Christian, Mainz University Medical Center, laboratory experiment measuring acute effects on heart muscle. It has an effect on heart muscle strength.
- Infrasound is particularly dangerous because it is not audible to the human ear. The government is responsible for protecting its citizens from harmful environmental influences.

A fundamental basis for all living creatures, mechanotransduction, is significantly endangered by periodic exposure to impulsive infrasound and vibration from technical emitters - in particular cardiovascular and
embryological functions. Bellut-Staeck, U. SCIREA Journal of Clinical Medicine. Vol. 10.

- Mechanotransduction is the common basis for all organisms for converting physical forces into biochemical and biological information. Ongoing PIEZO channel research confirms PIEZO-I and II channels in numerous other tissues including outside the endothelium. The prerequisite for a inflammatory transformation of the endothelium is chronic oxidative and oscillatory stress, as vital regulatory processes depend on an uninterrupted laminar flow in the capillary system and the integrity of the endothelium. Vascular health, in turn, is closely linked to demand-driven NO bioavailability and its homeostasis.
- The latest findings on a growing environmental factor show clear signs of an incompatibility between chronic and impulsive low frequencies and a fundamental information pathway of all organisms. The potentially serious consequences of an interaction, e.g., loss of endothelial integrity, increased blood pressure, and tissue remodeling of the heart, reduced fertility, strandings and death of whales, decline in animal species and insects, and reduction in plant biomass, have a common basis, which is discussed in this article: mechanotransduction. A force that is not demand-oriented can lead to irregular information.
- There is an urgent need to reassess the far-reaching effects and consequences of infrasound and vibrations from technical installations such as biogas plants, heat pumps and in particular, large (250 m+) industrial wind turbines (IWT). 'If you want to discover the secrets of the universe, think in terms of energy, frequencies and vibrations' (quote from Tesla). Mechanotransduction is a common basis for all life and must be preserved.

symptoms seem to be quite common: sleeplessness, fatigue, pain, dizziness, nausea, mood disorders, cognitive difficulties, skin irritations, and tinnitus. To help alleviate symptoms in areas where wind turbines have been erected, remediation is necessary to reduce or eliminate both sound waves and electromagnetic waves. Further research is needed to better understand the relative importance of the various factors contributing to poor health. This information will enable a healthy coexistence between wind turbines and the people living nearby.

New observations on cardiac morphological changes induced by low-frequency noise and infrasound in rats. Pereira Alves, A.M, L. Kahlbau. 2019. Thesis.

- Noise is an important environmental and occupational risk factor, and human exposure to this stressor can cause systemic damage. The specific contribution of noise characteristics—such as intensity, frequency content, mean and peak decibel levels, pattern, or duration of exposure—that may lead to such damage has not been established. Previous studies suggest that high-intensity noise across a broad spectrum of wavelengths, from industrial noise (IN) to low-frequency noise (LFN) and infrasound (IFS), can act as a physical stressor. The main morphological change caused by this type of noise is a systemic abnormal proliferation of connective tissue affecting various organs and tissues, including gastric mucosa, lung parenchyma, tracheal epithelium, adrenal cortex, parotid gland, lymphatic and arterial vessels, and the heart
- Conclusions: Exposure to IN increases the perivascular tissue of rat small coronary arteries, with significant development of periarterial fibrosis. Chronic exposure also causes thickening of the small coronary vessel wall. High-pressure level IFS exposure induces coronary perivascular fibrosis in rats, and the existence of an underlying inflammatory mechanism should be considered. Infrasound exposure affects the atria of rat hearts, leading to an increase in interstitial fibrosis and a decrease in Cx43. The effects of exposure to LFN and IFS seem to be independent of their pattern, but chronic exposure can elicit additional structural changes not observed in the acute setting. We propose that both sound frequency and pressure level are key factors in explaining the toxicological effects induced by noise and should be considered in future research.

Environmental Noise Pollution: Has Public Health Become too Utilitarian? Evans. Alun. 2017. Open Journal of Social Sciences. 5. 80-109.

- The effect of the entire range of noise produced is interference with sleep and sleep deprivation. Sleep, far from being a luxury, is vitally important to health, and insufficient sleep, in the long term, is associated with a spectrum of diseases, particularly cardiovascular.
- The physiological benefits of sleep are reviewed, as is the range of diseases to which the sleep-deprived are predisposed. Governments, anxious to meet Green targets and often receiving most of their health advice from the wind industry, must commission independent studies so that the Health and Human Rights of their rural citizens are not infringed. Public Health, in particular, must remember its roots in Utilitarianism, which condoned some collateral damage provided that the greatest happiness of the greatest number was ensured.
- The level of collateral damage caused by wind farms should be totally unacceptable to Public Health, which must, like good government, fully exercise the Precautionary Principle. The types of studies that should be considered are discussed. Indeed, the father of Utilitarian philosophy, Jeremy Bentham, urged that government policy should be fully evaluated.

forest returned alone instead of returning with chicks as in previous years. The family's adult son lives 3 kilometers from the new wind industry and also keeps free-range chickens, mostly of the Blomme breed. From 2009 to 2023, the hatching success rate has been at least 90%. In 2022, the son moved three of these hens and a rooster to his parents' chicken yard, 950 meters from the nearest wind turbine. These hens also stopped incubating after 16 days, leaving dead eggs.

Property Value Decline

1. **Proceedings of the National Academy of Sciences.** 2024. The visual effect of wind turbines on property values is small and diminishing in space and time. Guo, W. et al.
    a. Estimates a reduction in nearby property value of 11% for residences located **within one mile;** *and in Carol Black's professional opinion of reviewing scientific literature, these findings are based on turbine heights under 500 feet tall, which were more common at the time of data collection.*
    b. Economically and statistically significant value reductions in close proximity (< 5 miles)
    c. Also, their sample size was small for those at one mile, and significantly more data came from further distances.
    d. *Opinion Piece* - Recent study proves property value loss results from proximity of industrial wind turbines. Norris Wilson, B.A., AACI, P.App.
        i. Caution has been advised against focusing on data from farther distances. The rebutter noted by using their data, the losses would be about 25% of property value on average.

2. **Energy Policy.** February 2024 Volume 185. Commercial wind turbines and residential home values: New evidence from the universe of land-based wind projects in the United States. Eric J. Brunner, Ben Hoen, Joe Rand , David Schwegman
    i. Note: results are from projects in urban counties greater than 250,000; more home sales
    ii. We find that homes located within one mile of a commercial wind turbine experience on average approximately an 11% decline in value following the announcement of a new commercial wind energy project, relative to counterfactual homes located 3 to 5 miles away. This impact is dynamic —it is largely driven by declines in sale prices following the announcement and during the construction of a wind project.
    iii. The value of homes within one mile declines in value after the announcement of the wind project
    iv. Homes within 1-2 miles experience smaller impacts
    v. Those greater than 2 miles are unaffected
    vi. Distance to Nearest Turbine for the Average House in the United States, 2005-2020. The average distance in 2005 was 148.6 miles (standard deviation of 367.4 miles). By 2020, the average distance was 37.1 miles (standard deviation of 25.65 miles).

  b. **Land Economics.** 2012 Tuttle, CM. Values in the wind: a hedonic analysis of wind power facilities
    i. Data from 11,331 property transactions over nine years in northern New York State were used to explore the effects of new wind facilities on property values. We use a fixed-effects framework to control for omitted variables and endogeneity biases. We find that nearby wind facilities significantly reduce property values in two of the three

be conservative. With that in consideration, it would be reasonable to conclude the following impacts:

xii. **Properties Within the Wind Farm Footprint** - The graph indicates that a -28% loss in value would be found from a distance of 1,500ft from a wind turbine. However, as we noted, those studies used smaller wind turbines. It is estimated that the proposed turbines are at least 25% greater in size. Though a direct correlation of size and impact has not been established, it would be reasonable to estimate the impact would increase by a factor of 1.25. Hence, we conclude the impact to be -35%.

xiii. **Properties 1-Mile outside of the Wind Farm Footprint** - The graph suggests that the impact would be less the further the distance from a wind turbine. The analysis indicates that at 2-mile distance from a turbine the impact would be -18%. Considering that the turbines were smaller in the studies it would be reasonable to increase this impact by a factor of 1.25 to conclude a -22% impact.

xiv. **Agricultural Properties -** Agricultural properties within the footprint, but not participating in the wind lease, will be have a -8.5% impact on property value.

f. **Commercial wind turbines and residential home values:** New evidence from the universe for land-based wind projects in the United States. Brunner, E.J., et al. 2024. Energy Policy Vol. 185

   i. Homes within one mile decline in value by approximately 11% after the announcement of a wind project; those one to two miles have a smaller impact
   ii. Based primarily on projects in urban counties.
   iii. European studies show values fall 5-10% for homes located within 2 km.

g. **Wind turbines, solar farms, and house prices**. Droes, M.J. and H. Koster. 2021. Wind Policy Volume 155

   i. Turbine height is a significant factor; turbines 50-150m have an effect of -3.4%, whereas the effect is -8.3% for turbines over 150m in height (but the sample size is very small for taller turbines).
   ii. Findings imply turbines have higher effects on house prices and the effect reaches just beyond 2 km, up to 2250m, but not beyond 2.5 km. Moreover, we show that low turbines (<50m) have a small impact on house prices that is confined to about 1 km

h. **"Regulatory Takings"** involve the court's balancing of government actions and their effects on the property's economic value or the extent to which the act interferes with the reasonable expectations of the property owner. Inverse condemnation arises when the government's actions negatively impact property rights or value without proper compensation. This occurs when government activities or regulations reduce a property's market value. Diminished property value as a result of government action is a critical aspect of inverse condemnation claims, including reduced property values.

   i. Renewable energy companies have the ability to gain waivers from neighboring property owners. Community buy-in is necessary.

critical areas code Landmarks + Houses

From Carol Black, Citizen of Whitman County

April 23, 2025

Rec'd 12/11

Whitman County Commissioners
Whitman County Planning Commission
Whitman County Planner

Attached is a downloaded and formatted County Code 9.05 Critical Areas. This is the county governance that I referenced in my earlier written communications and public testimony.

During a recent Planning Commission meeting, County Planner Alan Thomson stated that 9.05 Critical Areas "only affected" certain critical areas; reference the minutes for specifics.

I recognize that Section 9.05.060 addresses areas "regulated" by the code. **However,** the code addresses "aesthetic value protection" in section 9.05.030. I quote from section 9.05.030 C: "The County finds that critical areas provide a variety of valuable and beneficial biological and physical functions that benefit the County and its residents, and/or may pose a threat to human safety or to public and private property. The beneficial functions and values provided by critical areas include, but are not limited to, water quality protection and enhancement, fish and wildlife habitat, food chain support, flood storage, conveyance and attenuation of flood waters, ground water recharge and discharge, erosion control, protection from hazards, historical, archaeological, and aesthetic value protection, and recreation."

The aesthetic importance of the **Palouse Rolling Hills** is well known to many citizens in Whitman County, as well as to WSU alumni and photographers who visit and spend significant dollars supporting our local businesses. Kamiak Butte is a **National Natural Landmark**. The Planning Commission and Commissioners must make sure that Chapter 19.61 includes reference to these stated 9.05.030 protections because the viewshed is "valuable and a significant benefit to the County and its residents." Other areas within Whitman County do not have the same viewshed impacts as those around the cities of Colfax, Pullman, and Palouse, where the majority of county citizens live, drive, and recreate. There may be other locations in the county close to dams and power infrastructure that are more appropriate to consider for alternate energy.

The county, over the years, has maintained codes to protect the viewshed of skylines/ridgelines. The County Planner has enforced these codes over the years; thus, we do not have houses located on ridgelines in the rural, agricultural area. Rural houses have to provide viewshed protections from other houses – on a horizontal plane – not even a vertical plane. This whole vertical obstruction is not well covered in the code and must be.
Examples of codes addressing views:

- 19.40.010 **Declaration of Intent**. The purpose and intent of the RCR district is to provide a single-family residential zone for the unincorporated rural communities of the County. The intent of this district is the preservation of a rural agriculturally-oriented life style including the keeping of animals for pleasure or profit, retaining low to medium density development, and providing for a mixture of residential uses with buildings necessary to farming operations.
- 19.40.010 and 19.12.050 **Height of Buildings**
- 19.10.060 B1b – **Viewshed Site - Rural Residential Use**

E-7

Appendix H: Noise and Vibration Resource Report

For Programmatic Environmental Impact Statement on Utility-Scale Onshore Wind Energy Facilities in Washington State

By

Environmental Science Associates

For the

Shorelands and Environmental Assistance Program

Washington State Department of Ecology

Olympia, Washington

September 2024

DEPARTMENT OF ECOLOGY
State of Washington

E-8

Table of Contents

List of Figures and Tables

Figures

Tables

Acronyms and Abbreviations List

BESS	battery energy storage system
dB	decibel
dBA	A-weighted decibel
EDNA	Environmental Designation for Noise Abatement
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
gen-tie line	generation-tie transmission line
Hz	hertz
in/sec	inches per second
kV	kilovolt
lb	pound
L_{dn}	average A-weighted noise level during a 24-hour day
L_{eq}	equivalent-continuous sound level
L_{max}	maximum, instantaneous noise level
LNTE	low noise trailing edge
MRI	magnetic resonance imaging
MW	megawatt
PEIS	Programmatic Environmental Impact Statement
PPV	peak particle velocity
RCNM	Roadway Construction Noise Model
RMS	root mean square
VdB	decibel notation
WAC	Washington Administrative Code

Executive Summary

This resource report describes the noise and vibration conditions in the study area. It also describes the regulatory context, outlines methods for assessing potential noise and vibration impacts from types of onshore wind energy facilities, presents current noise levels in the study area, and identifies sensitive receptors for noise and vibration. It also assesses the potential impacts of the alternatives and actions that could avoid or reduce impacts. This technical memorandum focuses on the noise and vibration impacts on people and the vibration impacts on structures. Potential impacts of noise and vibration on terrestrial and aquatic species and habitats are described in the *Biological Resources Report* (Anchor QEA 2024a).

Findings for noise and vibration impacts described in this resource report are summarized below.

Through compliance with laws, permits, and with implementation of actions that could avoid and reduce impacts, most construction, operation, and decommissioning activities would likely result in **less than significant impacts** on noise and vibration.

Potentially significant adverse impacts related to noise would occur if:

- Construction or decommissioning activities occur within 2,500 feet of noise-sensitive receptors in a quiet rural area
- During operations, wind turbines for small to medium facilities are closer than 1,000 feet from a noise-sensitive land use or closer than 3,000 feet from a noise-sensitive land use in a quiet rural area, or turbines for large facilities are sited closer than 2,400 feet from a noise-sensitive land use or closer than 5,000 feet from a noise-sensitive receptor in a quiet rural area
- During operations, substations for small to medium facilities are closer than 110 feet from a noise-sensitive land use or closer than 350 feet from a noise-sensitive land use in quiet rural areas, or substations for large facilities are closer than 650 feet from a noise-sensitive receptor or 2,000 feet from a noise-sensitive receptor in quiet rural areas
- A facility with a battery energy storage system of certain design and consolidated configuration is closer than 1.5 miles from noise-sensitive land uses

Potentially significant adverse impacts related to vibration would occur if:

- Pile driving during construction and decommissioning activities occur closer than 350 feet from residential land uses or in close proximity to modern or historic structures
- Blasting is conducted within 2,000 feet of historic structures

No significant and unavoidable adverse impacts related to noise and vibration would occur.

Crosswalk with Noise and Vibration Resource Report for Utility-Scale Solar Energy

Two Programmatic Environmental Impact Statements (PEISs) are being released at the same time, one for utility-scale solar energy facilities and one for utility-scale onshore wind energy facilities. This crosswalk identifies the areas with substantial differences between the noise and vibration resource reports for each PEIS.

Utility-Scale Solar Energy PEIS	Utility-Scale Onshore Wind Energy PEIS (this document)
• Differences in the types of facility noise- and vibration-generating activities • Some differences in actions to avoid and reduce impacts	• Differences in the types of facility noise- and vibration-generating activities • Larger distance at which potential impacts from facilities could occur • Some differences in actions to avoid and reduce impacts

1 Introduction

This resource report describes potential noise and vibration environments within the study area and assesses probable impacts associated with types of facilities (alternatives), including a No Action Alternative. Chapter 2 of the State Environmental Policy Act Programmatic Environmental Impact Statement (PEIS) provides a description of the types of facilities evaluated (alternatives).

1.1 Resource description

1.1.1 Fundamentals of noise

Noise is generally defined as unwanted sound. Sound, traveling in the form of waves from a source, exerts a sound pressure level that is measured in decibels (dB). The dB scale is a logarithmic scale that describes the physical intensity of the pressure vibrations that make up any sound, with 0 dB corresponding roughly to the threshold of human hearing and 120 to 140 dB corresponding to the threshold of pain.

Sound pressure fluctuations can be measured in units of hertz (Hz), which correspond to the frequency of a particular sound. Typically, sound does not consist of a single frequency, but rather a broad band of frequencies varying in levels of magnitude spanning 20 to 20,000 Hz.

The typical human ear is not equally sensitive to all frequencies of the audible sound spectrum. As a consequence, when assessing potential noise impacts, sound is measured using an electronic filter that de-emphasizes the frequencies below 1,000 Hz and above 5,000 Hz in a manner corresponding to the human ear's decreased sensitivity to extremely low and extremely high frequencies. This method of frequency weighting is referred to as A-weighting and is expressed in units of A-weighted decibels (dBA). Some representative noise sources and their corresponding A-weighted noise levels are shown in Figure 1. All noise levels presented in this technical memorandum are A-weighted unless otherwise stated.

Some land uses are considered more sensitive to noise than others due to the amount of noise exposure and the types of activities typically involved. Residences, motels and hotels, schools, libraries, churches, hospitals, nursing homes, and auditoriums generally are more sensitive to noise than are commercial and industrial land uses. Section 3.2 provides more detail on noise-sensitive receptors.

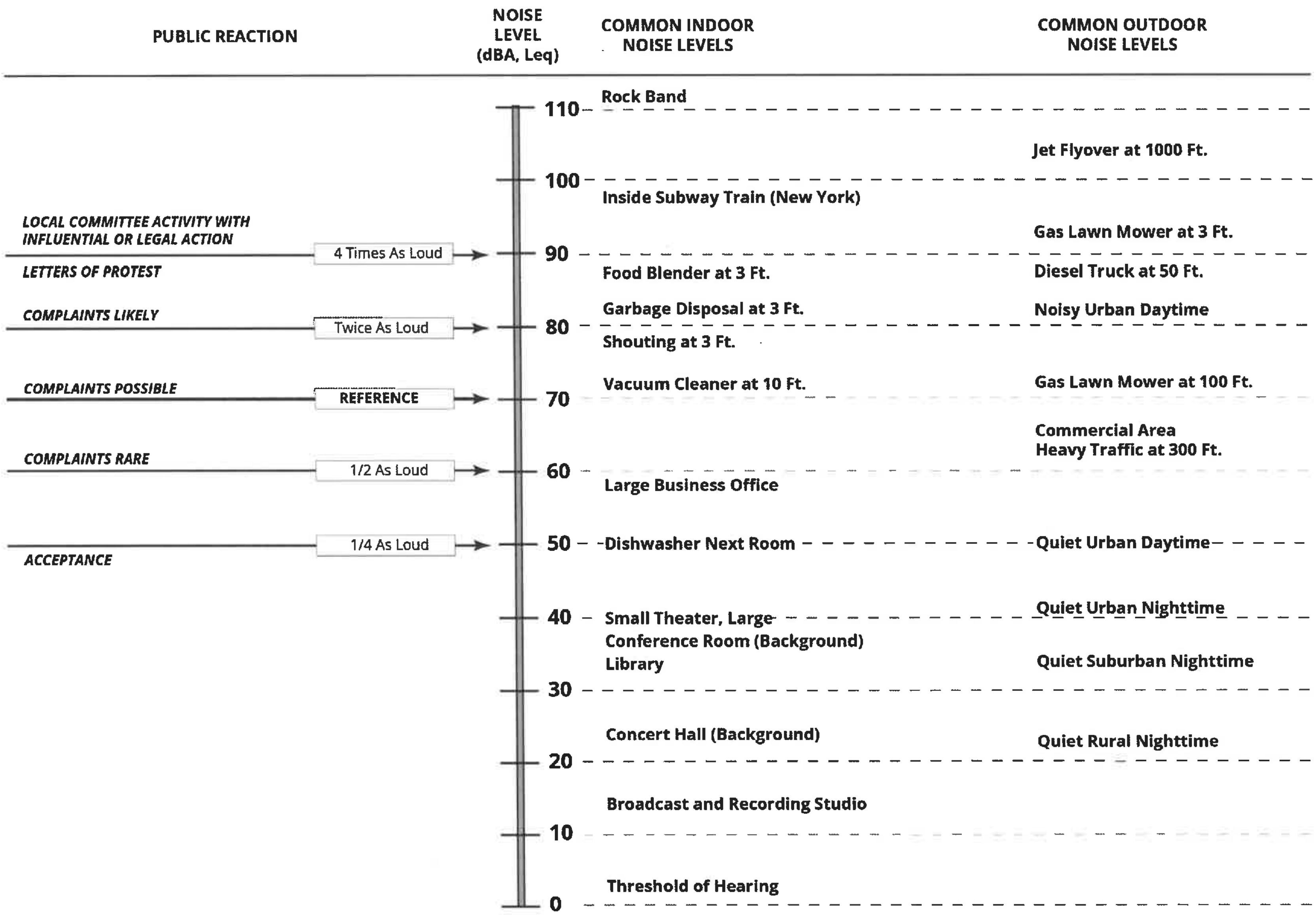


Figure 1. Common range of noise levels

Data source: Caltrans 2013; and modification by ESA

1.1.2 Fundamentals of vibration

The generally accepted source document for assessment of vibration impacts is the Federal Transit Administration's (FTA's) Transit Noise and Vibration Impact Assessment (FTA 2018). It is unusual for vibration from sources such as trucks to be perceptible, even in locations close to major roads. Some common sources of human-induced groundborne vibration are trains; loaded haul trucks on rough roads; and construction activities, such as blasting, pile driving, and operation of heavy earth-moving equipment. Vibrations from naturally occurring phenomena, such as earthquakes, are addressed in the *Earth Resource Report* (Anchor QEA 2024b).

Several different methods are used to quantify vibration. The peak particle velocity (PPV) is defined as the maximum instantaneous peak of the vibration signal. The PPV is most frequently used to describe vibration impacts on buildings. The root mean square (RMS) amplitude is most frequently used to describe the effect of vibration on the human body. The RMS amplitude is defined as the average of the squared amplitude of the signal. Decibel notation (VdB) is commonly used to measure RMS. Typically, groundborne vibration generated by man-made activities attenuates rapidly with distance from the source of the vibration.

The effects of groundborne vibration include movement of building floors, rattling of windows, shaking of items on shelves or hanging on walls, and rumbling sounds. In extreme cases, vibration can damage buildings. Building damage is not a factor for most projects, with the occasional exception of blasting and pile driving during construction. The FTA measure of the threshold of architectural damage for historic structures[1] is 0.12 inch/second (in/sec) PPV (FTA 2018).

In residential areas, the background vibration velocity level is usually around 50 VdB (approximately 0.0013 in/sec PPV). This level is well below the vibration velocity level threshold of perception for humans, which is approximately 65 VdB. A vibration velocity level of 75 VdB is considered to be the approximate dividing line between barely perceptible and distinctly perceptible levels for many people (FTA 2018). Annoyance from vibration often occurs when the vibration levels exceed the threshold of perception by only a small margin. A vibration level that causes annoyance would be well below the damage threshold for modern buildings.

Sensitive receptors for vibration include structures that may be damaged by vibration, residential uses during nighttime hours, and vibration-sensitive equipment, such as magnetic resonance imaging (MRI) machines. Section 3.2 provides more detail on vibration-sensitive receptors.

[1] FTA applies this criterion for buildings extremely susceptible to vibration damage.

1.2 Regulatory context

Potentially applicable federal, state, and local laws and regulations are listed in Table 1, which will contribute to the evaluation of potential noise and vibration impacts.

Table 1. Applicable laws, plans, and policies

Regulation, statute, guideline	Description
Federal	
Noise Control Act of 1972 (42 *United States Code* 4910)	Protects the health and welfare of U.S. citizens from the growing risk of noise pollution, primarily from transportation vehicles, machinery, and other commerce products. Increases coordination between federal researchers and noise-control activities; establishes noise emissions standards; and presents noise emissions and reduction information to the public.
Federal Transit Administration Construction Noise Impact Criteria for General Assessment; Transit Noise and Vibration Impact Assessment Manual (FTA 2018)	This document provides procedures and guidance for analyzing the level of noise and vibration, assessing the resulting impacts, and determining possible mitigation for most federally funded transit projects.
State	
Washington State Noise Control Act of 1974 (Chapter 70.107 Revised Code of Washington)	This act establishes maximum environmental noise levels. The regulations (Chapter 173-60 Washington Administrative Code) apply to a variety of land uses, activities, and facilities, including general construction activities and maintenance facilities. Exemptions include electrical substations, mobile noise sources, vehicles traveling in public right-of-way, and safety warning devices, such as bells. Many cities and counties in Washington have adopted the state provisions.
Local	
County and City Municipal Codes	Based on the scale of the study area, it is infeasible to review the county and municipal code of each local government within the scale of the Programmatic Environmental Impact Statement. However, it is noted that many counties and cities in Washington defer to the Washington Administrative Code regulations.

2 Methodology

2.1 Study area

The study area for noise and vibration includes the overall wind geographic study area (Figure 2). The programmatic study area for assessment of noise and vibration impacts associated with site characterization, construction, operation, and decommissioning of the potential utility-scale onshore wind energy facilities includes consideration of potential sensitive human receptor locations surrounding onshore wind facility sites and along access roads associated with truck hauling of materials and supplies.

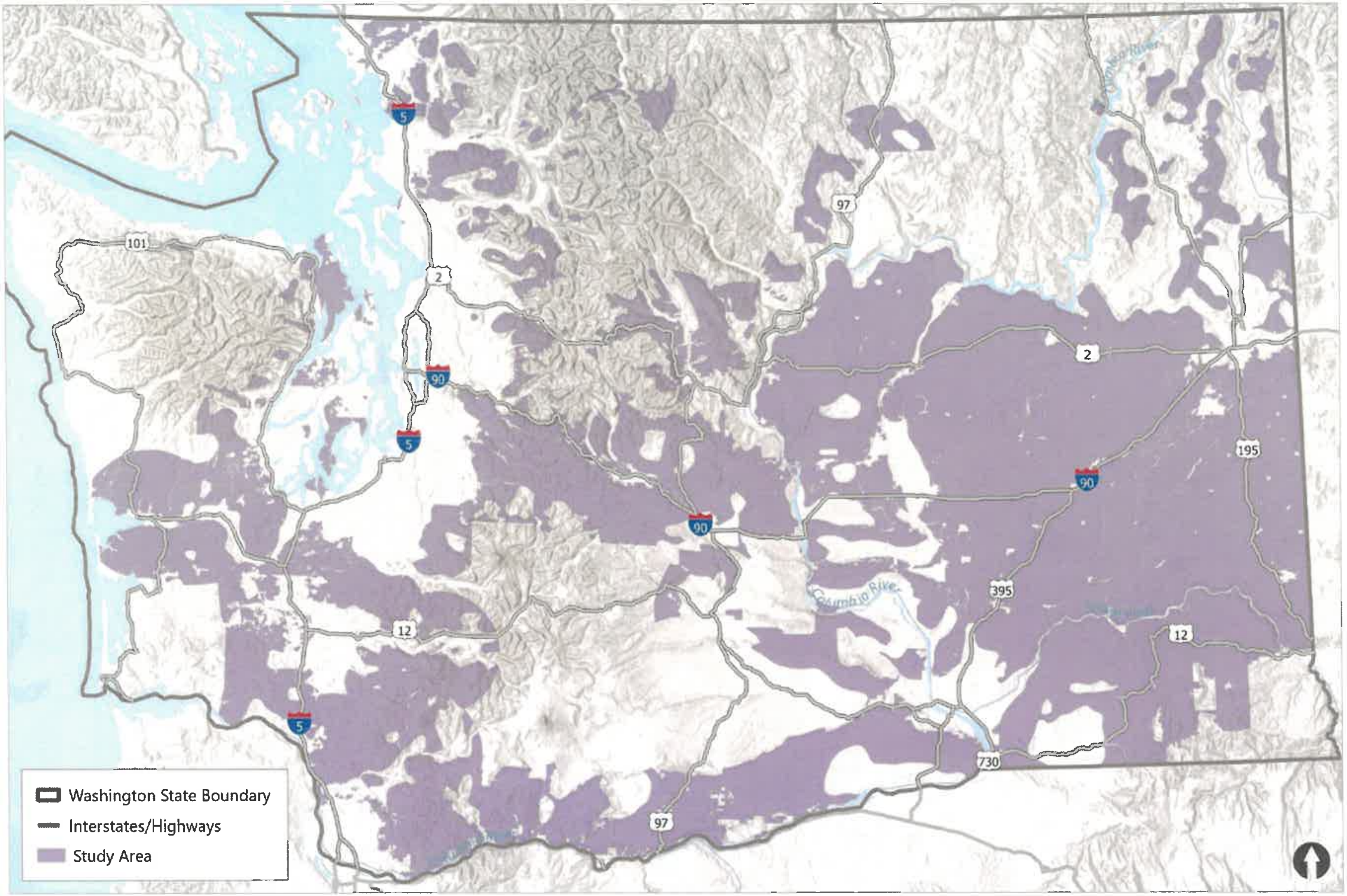


Figure 2. Onshore Wind Energy Facilities PEIS – geographic scope of study

2.2 Technical approach

The approach for assessing construction-related noise impacts utilizes the General Assessment methodology of the FTA's Noise and Vibration Impact Assessment Manual (FTA 2018). Based on an equipment list commonly used for construction of wind facilities, a tabular range of construction noise was generated with respect to distance from the outermost equipment for a typical construction site. The Federal Highway Administration's (FHWA's) Roadway Construction Noise Model (RCNM) was used to calculate noise levels at certain distances for comparison to FTA's published construction noise criteria (FHWA 2006). A separate analysis was provided for conditions where blasting or pile driving would be a necessary method of construction. This analysis can also be applied to linear construction work for generation-tie transmission lines (gen-tie lines).

Similarly, the approach for construction-related vibration impact assessment used a tabular estimate of vibration generation with distance from specific construction equipment known to generate vibration. Reference vibration levels published by FTA were used to develop impact distances to modern structures of standard construction, as well as to historic structures.

For operational impacts from utility-scale wind energy facilities, reference noise levels from sources associated with these facilities were researched from existing project-level analysis (proxy projects) that included three-dimensional noise modeling of noise generation. Using the existing analysis from proxy projects that fall within the scale of the facilities considered for the PEIS, a conservative estimate of noise generation with distance was developed for distances at which potential impacts of operational noise may occur from the extent of an onshore wind energy facility footprint.

2.3 Impact assessment

The impact analysis for noise and vibration considered the following:

- Site characterization activities of utility-scale onshore wind energy development would result in noise and vibration associated with construction of meteorological towers and soil coring.
- Construction and ultimate decommissioning of onshore wind energy facilities will result in noise and vibration associated with construction-related activities typically employed for such facilities. These would include operation of off-road equipment, pile driving for wind turbine foundations, the potential on-site operation of a concrete batch plant, and operation of haul trucks to bring in equipment and materials and remove soil or demolition debris. Blasting, if required, would also generate noise and vibration impacts.
- Construction for gen-tie lines for facilities could include noise and vibration from off-road equipment along alignments for power poles and line stringing, cut and cover trenching, and potentially sheet pile installation for jack-and-bore pits, where necessary.
- Operational noise sources may include intermittent noise from substation operations, battery storage liquid cooling units, battery storage inverters, potential corona noise

from overhead connector and gen-tie lines during wet weather conditions, and intermittent noise from operations and maintenance activities of employees during daytime hours.

Of particular note, operational noise associated with wind farms would include noise generated by wind turbines 24 hours a day, which would include the noise-sensitive nighttime hours for which more stringent noise standards apply under the Washington Administrative Code (WAC) Chapter 173-60. Wind turbines also generate a component of low-frequency infrasonic noise, which is not necessarily captured by metrics in terms of A-weighted decibels.

Site characterization, construction, and decommissioning related noise impacts were evaluated for likely conflicts with local ordinances or potential exposure of noise-sensitive land uses in excess of the FTA criteria. Additionally, in recognition that existing noise levels are commonly quiet in rural areas where siting of energy facilities would likely occur, an increase of 10 dBA over ambient was applied to the assessment, which corresponds to a perceived doubling loudness for temporary construction activities (FHWA 2017). Chapter 173-60 WAC exempts sounds originating from blasting and from temporary construction sites as a result of construction activity between the hours of 7:00 a.m. and 10:00 p.m.

Operational noise impacts were evaluated for likely conflicts with local ordinances or potential to exceed the maximum permissible environmental noise levels specific to land use as codified in Chapter 173-60 WAC. For residential uses, an Environmental Designation for Noise Abatement (EDNA) of 50 dBA would apply during nighttime hours. Additionally, in recognition that existing noise levels are commonly quiet in rural areas where siting of energy facilities would likely occur, an increase of 5 dBA over ambient is applied, which corresponds to a readily perceptible increase in noise for permanent operations (FHWA 2017).

Construction vibration impacts were evaluated for the potential to expose nearby land uses and structures to PPV levels that would meet or exceed FTA criteria of 0.5 in/sec for modern structures or 0.12 in/sec for historic structures.

3 Technical Analysis and Results

3.1 Overview

This section describes the potentially significant adverse noise and vibration impacts that might occur for a given utility-scale onshore wind facility analyzed in the PEIS. The extent of the impact area would depend on the size and design of the specific facility and the relative quiet (low ambient noise levels) of a given location. This section also evaluates actions that could avoid, minimize, or reduce the identified impacts, and potential unavoidable significant adverse impacts.

3.2 Affected environment

3.2.1 Ambient noise levels

The affected environment represents the conditions before any construction begins. Given the substantial geographic extent of the onshore wind study area, the affected environment, in terms of existing ambient noise levels, would vary considerably based on the specific facility siting conditions. Noise levels continuously vary with location and time. In general, noise levels are high around major transportation corridors (highways and railways), airports, industrial facilities, and construction activities. To characterize noise levels associated with general community activities over the study area, countywide background L_{dn}[2] (i.e., average A-weighted noise level during a 24-hour day) levels may be estimated based on population density. More densely populated counties, such as King County and Pierce County, have generalized background L_{dn} values of between 45 and 55 dBA, while more remote, sparsely populated counties, such as Columbia County, have background L_{dn} values of less than 35 dBA (BLM 2024). These are geographically averaged estimates, and localized values, particularly in urban areas, can be as high as 70 L_{dn} adjacent to freeways.

Utility-scale onshore wind energy facilities would often likely be located in rural areas with low population density. These areas are expected to have low ambient sound levels, given the lack of industrial and commercial sound sources. Noise may be sporadically elevated in localized areas due to roadway noise or periods of human activity. The existing acoustic environment in these areas could include existing wind turbines; motor vehicle traffic; mobile farming equipment; farming activities, such as plowing and irrigation; all-terrain vehicles; local roadways; periodic aircraft flyovers; and natural sounds. Rural areas can be exposed to natural

[2] The L_{dn} metric is the energy average of the A-weighted sound levels occurring during a 24-hour period, with a 10 dB penalty added to sound levels between 10 p.m. and 7 a.m. It is commonly used for land use compatibility assessment.

wind noise that can generate noise levels of up to 85 dBA at high windspeeds. Sound levels in non-industrial and rural areas are typically quieter during the night than during the daytime.

Sound propagating through the air is affected by air temperature, humidity, wind and temperature gradients, vicinity and type of ground surface, obstacles, and terrain features. Natural terrain features, such as hills, and constructed features, such as buildings and walls, can significantly alter noise levels. Rural areas can commonly possess a range of topographical features that can serve to reduce the propagation of noise.

It is uncommon for trees and vegetation to result in a noticeable reduction in noise. A vegetative strip must be very dense and wide for there to be any meaningful shielding effect. However, a heavily vegetated ground surface may increase ground absorption of noise, which can increase attenuation over distance.

3.2.2 Noise-sensitive receptors

Some land uses are considered more sensitive to noise than others due to the amount of noise exposure (in terms of both exposure duration and insulation from noise) and the types of activities typically involved. Residences, motels and hotels, schools, libraries, churches, hospitals, nursing homes, and auditoriums generally are more sensitive to noise than are commercial and industrial land uses. Recreational uses are also sensitive to noises; refer to the *Recreation Resource Report* (Anchor QEA 2024c) for an analysis of noise impacts on recreationists.

Sensitive wildlife and habitats, including the habitat of rare, threatened, or endangered species, can also be impacted by noise. For noise impacts on wildlife, including airborne noise effects on terrestrial wildlife and waterborne noise effects on fish and marine mammals, please refer to the *Biological Resources Report*.

3.2.3 Vibration-sensitive land uses and structures

Sensitive receptors for vibration include structures (especially older masonry structures), people (particularly residential uses during nighttime hours), and vibration-sensitive equipment (such as recording studios or MRI). There are separate criteria for evaluating the potential for structural damage depending on whether the structure is considered to be of modern construction versus older historic structures that are more sensitive to vibration.

3.3 Potentially required permits

With the exception of unique circumstances, there would be no specific permit requirements related to noise or vibration. If blasting were needed for construction, then a blasting permit would be required. Permits are typically administered by the city or county in which the work is conducted. Blasting with explosives requires a Washington State explosives license to abate potential hazards, including noise and vibration.

Additionally, local jurisdictions may require a permit or variance to conduct nighttime construction work.

3.4 Small to medium utility-scale facilities of 10 MW to 250 MW (Alternative 1)

3.4.1 Impacts from construction

3.4.1.1 Construction noise

Construction of a small to medium utility-scale facility (Alternative 1) would generate noise from multiple sources, including the following:

- Off-road equipment used for site preparation and construction
- Blasting
- On-road truck trips to bring materials to work sites, including sand, fly ash, and cement to a concrete batch plant
- Noise generated by rock processing at a concrete batch plant

Off-road equipment noise for site preparation and construction

An example inventory of equipment needed to construct a small to medium onshore wind facility (EFSEC 2022) is provided in Table 2. The table summarizes equipment that may be used and estimates of noise levels at a reference distance of 50 feet, as well as at 100, 1,000, and 2,500 feet from each piece of equipment, as well as from the combined contribution of all equipment. The combined noise levels in Table 2 include construction blasting, which is further addressed in the next section.

In addition to the equipment listed in Table 2, generators may be used for temporary power over the turbine commissioning period. Commissioning includes the testing and startup of the wind turbines after they are installed but before they begin normal operations. Generators for construction are estimated to generate a noise level of 78 dBA, equivalent-continuous sound level (L_{eq}) at 50 feet, which could be further reduced with an acoustical enclosure.

Table 2. Maximum and modeled equivalent noise levels from construction equipment associated with onshore wind facility construction

Equipment	L_{max} equipment sound level at 50 feet (dBA)[1]	Usage factor (%)[2]	Equipment sound level (L_{eq}) at 50 feet (dBA)	Equipment sound level (L_{eq}) at 100 feet (dBA)	Equipment sound level (L_{eq}) at 1,000 feet (dBA)	Equipment sound level (L_{eq}) at 2,500 feet (dBA)
Crane	85	16	77	71	51	43
Forklift	83	40	79	73	53	45
Backhoe	78	40	74	68	48	40
Grader	85	40	81	75	55	38

Equipment	L_{max} equipment sound level at 50 feet (dBA)[1]	Usage factor (%)[2]	Equipment sound level (L_{eq}) at 50 feet (dBA)	Equipment sound level (L_{eq}) at 100 feet (dBA)	Equipment sound level (L_{eq}) at 1,000 feet (dBA)	Equipment sound level (L_{eq}) at 2,500 feet (dBA)
Man Lift	75	20	68	62	42	47
Dozer	82	40	78	72	52	44
Loader	79	40	75	69	49	41
Scissor Lift	75	20	68	62	42	34
Truck	77	40	73	67	47	39
Welder	74	40	70	64	44	36
Compressor	78	40	74	68	48	40
Concrete Batch Plant	83	15	75	69	49	41
Pile Driver	101	20	94	88	68	60
Blasting	94	1	74	68	48	40
Combined	NA	NA	95	89	69	61

Source: FHWA 2006
Notes:

1. These are maximum field-measured values at 50 feet as reported from multiple samples. Where sufficient data are unavailable, the reference noise level is a manufacturer-specified level.
2. The usage factor is the percentage of time during operation that a piece of construction equipment is operating at full power.

As shown in Table 2, FTA's daytime criterion of 90 dBA would be exceeded if pile-driving activities were conducted within 85 feet of noise-sensitive receptors. For an onshore wind facility located in a rural environment, this would be an unlikely scenario.

However, in recognition that existing noise levels are commonly low in rural areas where siting of energy facilities would likely occur, potentially 35 to 40 dBA or lower, a prolonged noise contribution of 45 to 50 dBA could also result in a noise impact at noise-sensitive receptors located closer than 2,500 feet, particularly during nighttime hours. The extent of a construction noise impact would depend on the existing ambient noise level at any given receptor.

As shown in Table 2, at a distance of 2,500 feet, all construction activities except pile driving, forklifts, and manlifts would be below 45 to 50 dBA, as well as the composite noise level, which conservatively assumes simultaneous operation of all equipment. If required for turbine foundations, pile driving may only exceed noise criterion during construction of a small number of turbine locations and, hence, may not constitute a prolonged noise increase at a distance of 2,500 feet.

Blasting noise

Blasting may be needed for construction of facilities (e.g., wind turbine foundations) and may occur depending on subsurface conditions. Noise from blasting activities was estimated using reference noise levels from RCNM and assuming one blast per hour; the associated noise levels are presented in Table 2. Blasting mats are usually used to control noise. Blasting would typically be a part of site preparation and, therefore, not occur simultaneously with pile driving or other construction building activities. As shown in Table 2, noise generated by blasting is similar in magnitude to that of other construction activities, based on the reference noise levels for RCNM. The combined noise levels in Table 2 include construction blasting. Vibration impacts from blasting are addressed in Section 3.4.1.2.

Noise from on-road trucks

Noise from trucks bringing materials from off-site locations to a facility construction site and exporting excavated materials from the facility site would potentially increase noise levels along roadways used to access a given onshore wind facility. Generally, these truck trips would be distributed throughout the day and, except in cases where substantial volumes of material would be hauled, the increase in noise levels would not be sufficient to result in a noticeable increase in traffic noise.

Concrete batch plant noise

Noise from a concrete batch plant during facility construction was estimated using reference noise levels from RCNM, and the associated noise levels are presented in Table 2. Concrete batch plants may be used to provide material for construction of foundations and would occur simultaneously with pile driving or other construction activities. As shown in Table 2, noise generated by batch plant operations is similar in magnitude to that of other construction activities, based on the reference noise levels for RCNM. The combined noise levels in Table 2 include operation of a batch plant.

Construction noise impact summary

Heavy equipment use would vary during the site preparation and construction phases for facilities. Site characterization activities would include noise generation during soil coring and the construction of meteorological towers. Typically, noise levels are highest during site preparation when land clearing, grading, and road construction would occur.

Most local jurisdictions and the noise standards in Chapter 173-60 WAC exempt temporary construction site noise between the hours of 7:00 a.m. and 10:00 p.m. Outside of these times, construction activities would be required to meet noise limits. In addition, construction activities would be temporary and of short duration.

Potential construction noise impacts would depend on the activities, terrain, vegetation, and local weather conditions, as well as distance to the nearest sensitive receptors. Through compliance with laws, permits, and with implementation of actions that could avoid and reduce impacts, most construction, operation, and decommissioning activities would likely result in **less than significant impacts** from noise. If construction activities occur within 2,500 feet of noise-sensitive receptors in quiet rural areas, this would result in a **potentially significant adverse impact**.

3.4.1.2 *Construction vibration*

Construction may involve blasting and the use of equipment, such as impact pile drivers and vibratory rollers, that can generate substantial vibration.

Vibration impacts and human annoyance

Vibration impact criteria related to human disturbance published by FTA are established in terms of the VdB metric. Vibration levels from various construction activities known to generate vibration were estimated in Table 3 using reference vibration levels published by FTA (2018) and attenuating that vibration at a range of distances encompassing impact criteria. Bold cells in Table 3 indicate the distances at which vibration levels would exceed the applicable FTA criterion. As seen from the table, vibration from pile driving would exceed the applicable FTA criterion at distances closer than 350 feet, while vibration from vibratory rollers would exceed FTA criterion at distances closer than 50 feet. All other construction equipment could be 25 feet or closer without exceeding FTA criteria. Therefore, vibration from specific construction activities occurring at distances closer than 350 feet from residential land uses could be a potential impact with respect to human annoyance.

Table 3. Predicted vibration levels (VdB) from construction activities at distance

Equipment/ activity	Predicted VdB					
	At 25 feet (Reference)	At 50 feet	At 100 feet	At 200 feet	At 350 feet	FTA Criteria for Residential Uses (Human Response)
Jack Hammer	79	70	61	52	45	80
Loaded Trucks	**86**	77	68	59	52	80
Large Bulldozer	**87**	78	69	60	53	80
Caisson Drilling	**87**	78	69	60	53	80
Vibratory Roller	**94**	**85**	76	66	60	80
Impact Pile Driver	**104**	**65**	**86**	**77**	70	72[a]

Source: FTA 2018
Notes:
Shaded cells indicate exceedance of the applicable FTA criterion.
a. Residential criterion for frequent events applies to pile driving.

Vibration impacts and structural damage

Construction-related vibration also has the potential to result in architectural damage to nearby structures. For historic structures, including buildings that are structurally weakened, a continuous vibration limit of 0.12 in/sec PPV is the standard applied to minimize the potential for structural or cosmetic damage (e.g., minor cracking in plastered walls). A continuous vibration limit of 0.50 in/sec PPV is applied to minimize the potential for cosmetic damage at buildings of modern construction.

Table 4 presents the analysis of vibration from typical construction activities with distances to structures. In Table 4, distances at which vibration levels would exceed the criterion for conventional structures are indicated with a superscript "a." Distances at which the criterion would be exceeded for historic structures or structurally weakened buildings are marked with a superscript "b." As shown in Table 4, cosmetic damage could result from pile driving closer than 30 feet to a conventionally constructed building, or closer than 80 feet to a historic building. Given the distances at which most off-site structures and sensitive receptors are assumed to be located from potential utility-scale facilities and with appropriate control measures and monitoring programs in place and as required by permits, temporary construction-related vibration effects for the construction of small to medium utility-scale onshore wind energy facilities would be less than significant.

Table 4. Vibration levels (PPV) for construction activity

Equipment	Estimated PPV (inches per second)			
	At 25 feet	At 30 feet	At 40 feet	At 80 feet
Jackhammer	0.035	0.027	0.01710	0.00610
Loaded Trucks	0.076	0.058	0.038	0.013
Caisson Drilling	0.089	0.068	0.044	0.016
Large Bulldozer	0.089	0.068	0.044	0.016
Vibratory Roller	0.20[b]	0.160[b]	0.104	0.037
Impact Pile Driver	0.65[a]	0.494[b]	0.321[b]	0.113

Source: FTA 2018
Notes:

a. Indicates distances where vibration levels would exceed the criterion for conventional structures.
b. Indicates the distances at which the criterion for historic structure or buildings that are documented to be structurally weakened would be exceeded.

Vibration generated by blasting

Blasting may occur as part of site preparation activities, depending on subsurface conditions. When blasting occurs at greater distances from sensitive structures, the primary concern is the potential for cosmetic damage. Cosmetic damage can occur as a result of groundborne vibration or acoustic overpressures. Vibration levels that may be generated by blasting events were calculated using methods established by the former U.S. Bureau of Mines (USDI 2000) and are presented in Table 5. Calculated ground vibration levels are summarized in Table 5 for a variety of charge weights and distances. Receptors located farther from blasting activities would experience lower vibration levels.

Table 5. Ground vibration levels generated by blasting

Distance (feet)	Blasting level (in/sec PPV) for various explosive charge weights per delay[1] (lbs)		
	175 lbs	350 lbs	700 lbs
2,000	0.098	0.170	0.296
3,000	0.051	0.089	0.155
4,000	0.032	0.056	0.098

Note:

1. The maximum quantity of explosive charge detonated on one interval (delay) within a blast.

As shown in Table 5, blasting, using a charge weight of 700 lbs/delay[3] within 2,000 feet of sensitive structures could generate groundborne vibration levels as high as 0.296 in/sec PPV, which would be below the 0.5 in/sec PPV threshold for modern structures, but would exceed the 0.12 in/sec PPV threshold for historic structures. Consequently, use of charge weights in excess of approximately 250 pounds per delay could result in vibration impacts if historic structures are located within 2,000 feet.

Construction vibration impact summary

Potential construction vibration impacts would depend on the equipment, methods, and distance to sensitive receptors or structures. Through compliance with laws, permits, and with implementation of actions that could avoid and reduce impacts, most construction and decommissioning activities would likely result in **less than significant impacts** related to vibration.

Vibration from specific construction activities occurring at distances closer than 350 feet from residential land uses, or in close proximity to conventional or historic structures, would be a **potentially significant adverse impact** with respect to human annoyance or building damage. If some types of blasting are conducted within 2,000 feet of historic structures, it would result in a **potentially significant adverse impact.**

3.4.2 Impacts from operation

Operation activities would not be expected to generate vibration.

Wind turbine noise

Noise impacts from turbines will vary based on the type of model, configuration of towers, wind environment, distance to nearest sensitive receptors, and presence of intervening structures or geographic features. The major noise sources for small to medium facilities that could be operated under Alternative 1 are wind turbines and substations. Generally, these sources are likely to operate 24-hours a day and hence would generate noise during the more noise-sensitive nighttime hours. While there are different operational cycles whereby some

[3] The maximum quantity of explosive charge detonated on one interval (delay) within a blast.

equipment will be operating while other equipment will be cycling on and off, given the programmatic approach of this analysis, all sources are conservatively assumed to operate at all times.

For the small to medium facilities, a project-level noise assessment for a proxy project was used to estimate the noise generation potential. Project-level analysis for onshore wind energy facilities generally requires modeling with a three-dimensional noise propagation program, such as CadnaA, that develops noise contours around facilities to determine the spatial extent of noise levels from turbines and transformers. The proxy project analysis used for the small to medium facilities was for a proposed 216-megawatt (MW) wind facility with up to 72 turbines rated from 3 to 7.5 MW each (Fountain Wind in Shasta County, California).

Noise modeling developed for the proxy project shows that while turbines may be clumped into groups of three or more on a given project footprint, the 50 dBA, L_{eq} noise contour consistently extends approximately 1,000 feet from each turbine (I&R 2019).

In Washington state, the maximum permissible environmental noise levels specific to land use are codified in Chapter 173-60 WAC. For residential uses, an EDNA of 50 dBA would apply during nighttime hours.

Additionally, in recognition that existing ambient noise levels are commonly quiet in rural areas where siting of energy facilities would likely occur, an increase of 5 dBA over ambient conditions could also result in a noise impact at noise-sensitive receptors located in such an area. An increase of 5 dBA corresponds to a readily perceptible increase in noise for permanent operations (FHWA 2017). As discussed in Section 3.2.1, remote, sparsely populated counties, such as Columbia County, can have background L_{dn} values of 35 dBA or lower (BLM 2024). In such rural areas, an increase of 5 dBA over ambient noise could result when turbines generate a noise level of 40 dBA at such a receptor. Based on two-dimensional geometric spreading equations, it is estimated that this noise increase would have the potential to occur within approximately 3,000 feet of the nearest turbine.

Substation noise
An on-site collector substation and switching station (substation) would increase the voltage of the electricity from the collection system's rated voltage to match the voltage of the existing or proposed power transmission line.

A typical substation transformer is estimated to generate a noise level of 72 dBA at a distance of 6 feet during full load with fans and pumps running (I&R 2019). With two transformers running simultaneously, the noise level would be 3 dBA higher. Equipment-generated noise levels drop off at a rate of about 6 dBA per doubling of the distance between the source and receptor. Shielding by buildings or terrain can provide an additional 5 to 10 dBA or more noise reduction at distant receptors. At a distance of 110 feet, noise would be attenuated to below the 50 dBA EDNA that would apply during nighttime hours.

Similarly, at a distance of 350 feet, noise would be attenuated to below 40 dBA, which is the working assumption for a 5 dBA increase over ambient conditions in a rural area.

Corona noise

Onshore wind facilities would require overhead gen-tie lines ranging from 69 kilovolts (kV) to 345 kV to match the voltage of existing transmission lines. Collector lines would range from 34.5 kV to 230 kV. Higher-voltage overhead lines of 100 kV or more may be used if the distance to the electrical substation is long. The localized electric field near an energized conductor can be sufficiently concentrated to produce a small electric discharge, which can ionize air close to the conductors. This effect is called corona and is associated with all energized electric power lines. Corona can produce small amounts of sound. Corona noise is typically characterized as a hissing or crackling sound, which may be accompanied by a 120-Hz hum. Slight irregularities or water droplets on the conductor and/or insulator surface accentuate the electric field strength near the conductor surface, making corona discharge and the associated audible noise more likely. Therefore, audible noise levels from gen-tie lines are generally higher during wet weather.

Computer modeling software developed by the Bonneville Power Administration (BPA 1977) indicates that, during wet weather conditions, audible noise levels of up to 46 dBA can occur within the gen-tie right-of-way corridor for a 230-kV line. The study assumed an 80-foot-wide right-of-way, and the gen-tie right-of-way for onshore wind facilities is assumed to be wider than this. The 34.5-kV lines would likely be inaudible outside the right-of-way assumed for onshore wind facilities. Noise from lower voltage lines and/or during dry conditions would be lower. Such a noise level would be below the 50 dBA EDNA applicable to residential uses within the State of Washington.

Operational noise impact summary

Through compliance with laws, permits, and with implementation of actions that could avoid and reduce impacts, most operations activities would likely result in **less than significant impacts** related to noise and vibration.

Wind turbines located closer than 1,000 feet from a noise-sensitive land use, or closer than 3,000 feet from noise-sensitive land uses within a quiet rural setting, could have a **potentially significant adverse impact**. Facility substations located closer than 110 feet from a noise-sensitive land use or closer than 350 feet from a noise-sensitive land use located in a rural area would also have a **potentially significant adverse impact.**

3.4.3 Impacts from decommissioning

For the purposes of this analysis, it is assumed that facility decommissioning or repowering of wind facilities would result in similar noise levels and vibration as construction, with the exception of pile driving and blasting activities, which would not occur for decommissioning. Therefore, noise impacts from decommissioning activities would be similar or less than those described for construction and would range from **less than significant impact** to **potentially significant adverse impact** depending on the distance from sensitive receptors.

3.4.4 Actions to avoid and reduce impacts

Because this a programmatic environmental review of utility-scale onshore wind facilities, site-specific mitigation actions would be developed during project-specific reviews and permitting for each facility proposed in the future. Potential actions that could avoid or reduce impacts from construction, operation, or decommissioning of facilities are outlined below.

Recommended siting distances identified in this programmatic analysis are based on proxy projects and unspecified existing noise conditions and locations of sensitive receptors. Each individual facility would need to conduct facility- and site-specific modeling to determine the applicable distances necessary to avoid a significant noise or vibration impact.

3.4.4.1 Siting and design considerations

Careful site selection and layout for a utility-scale onshore wind facility represents the best tool available to reduce the potential for noise and vibration impacts. For the potentially significant adverse noise and vibration impacts identified previously, the following site selection considerations could be used to reduce these potential impacts to a less than significant level.

Construction and decommissioning noise
As discussed above, FTA's daytime noise criterion for construction would likely not be exceeded if the construction footprint was located more than 100 feet from noise-sensitive receptors. For facility construction in quiet rural areas, a distance of at least 2,500 feet to noise-sensitive receptors should be provided. Provision of a buffer distance from noise-sensitive receptors would reduce the need for additional mitigation measures.

Operational noise
As discussed above, siting of wind turbines closer than 1,000 feet from a noise-sensitive land use would have the potential for a significant adverse impact with respect to the State of Washington nighttime EDNA of 50 dBA for residential uses, and facility-specific modeling would be required to substantiate the need for mitigation. Consequently, siting of utility-scale wind turbines 1,000 feet or farther from the closest noise-sensitive land use could preclude a significant adverse operational impact.

For facilities in quiet rural areas, a turbine distance of at least 3,000 feet from noise-sensitive receptors should be provided for siting the closest turbines.

Construction vibration
Siting utility-scale wind facilities such that the construction zone would be at least 80 feet from the closest structure would avoid a significant adverse construction-related vibration impact.

3.4.4.2 Permits, plans, and best management practices

The only permit, plan, or best management practice related to noise or vibration associated with construction of a utility-scale onshore wind facility would be a blasting permit, if blasting were needed for site preparation. Blasting with explosives requires a Washington State explosives license to abate potential hazards, including noise and vibration.

3.4.4.3 *Additional mitigation measures*

Construction noise

If the construction area of a proposed utility-scale onshore wind facility is closer than 2,500 feet from a noise-sensitive receptor, then a Construction Noise Management Plan should be developed and implemented to minimize localized noise increases from prolonged construction activity. Elements of the Construction Noise Management Plan include the following:

- Install cast-in-place concrete piles, as feasible. Noise from auger drilling is 17 dBA less than an impact pile driver.
- Vibrate piles into place and install shrouds around the pile-driving hammer where feasible.
- Site immobile construction equipment (e.g., compressors and generators) and permanent sound-generating facilities away from nearby residences and other sensitive receptors.
- Incorporate low-noise systems (e.g., for pumps, generators, compressors, and fans) and select equipment with low noise emissions and/or without prominent discrete tones, as indicated by the manufacturer.
- Use noise-reduction measures, such as siting noise sources to take advantage of existing topography and distances and constructing engineered sound barriers and/or berms to reduce potential noise impacts at the locations of nearby sensitive receptors.
- Establish a noise complaint resolution process and hotline to address any noise complaints received.
- Enclose noisy equipment when located near sensitive receptors.
- Notify nearby residents in advance of noisy activities, such as blasting or pile driving, before and during the construction period.
- Post warning signs at high-noise areas and implement a hearing protection program for work areas with noise in excess of 85 dBA.
- Maintain tools and equipment in good operating order according to manufacturers' specifications.
- Schedule construction activity during normal working hours on weekdays to reduce noise impacts.
- Limit possible evening shift work to low-noise activities, such as welding, wire pulling, and other similar activities.
- Equip any internal combustion engine used for any purpose on the job or related to the job with a properly operating muffler that is free from rust, holes, and leaks.
- For construction devices that use internal combustion engines, ensure the engine's housing doors are kept closed and install noise-insulating material mounted on the engine housing consistent with manufacturers' guidelines, if possible.
- Limit noise-producing signals, such as horns, whistles, or alarms, to safety warning purposes only.
- Locate construction vehicle routes at the most distant point feasible from noise-sensitive receptors.

- Ensure all heavy trucks are properly maintained and equipped with noise-control (e.g., muffler) devices, in accordance with manufacturers' specifications, at each work site during facility construction, decommissioning, and site reclamation to minimize heavy truck traffic noise effects on sensitive receptors.
- Limit construction operations located within 2,500 feet of residences to daytime hours.
- Prohibit nighttime (10 p.m. to 7 a.m.) blasting.

Operational noise

Because of the height of wind turbines, acoustical barriers do not represent a feasible mitigation strategy for reducing potential noise impacts.

Equipment selection could reduce operational noise impacts. Some turbines are designed to operate in noise-reduced operation mode. Manufacturer-provided options include the use of low noise trailing edge (LNTE) technology and noise-reduced operation modes. LNTE consists of the addition of plastic or metal sawtooth serrations that can be affixed to the blade's rear edge to reduce blade trailing edge noise. Application of noise-reduced operation modes limits the rotational speed of the turbines to reduce their sound emissions. However, available data on the potential degree of noise reduction would depend on manufacturer design and are not specified for this programmatic analysis. The need for manufacturer-provided options to reduce noise levels would not be required over an entire wind farm but only to the extent needed to address impacts to affected noise-sensitive receptors.

Construction vibration

Blast vibrations are a function of several variables besides distance, primarily the weight of explosives per delay. This variable can be controlled by the blasting contractor to ensure that blasting activities do not result in either structural damage or human annoyance. The Oregon Department of Transportation estimates that if a structure is 1,320 feet away (1/4 of a mile) and the PPV at that receptor is limited to 0.5 in/sec to avoid structural damage, then the maximum weight of explosives that can be detonated is approximately 2,300 pounds per delay period (ODOT 2000). Therefore, blasting contractors should calculate and maintain the weight of explosives necessary to ensure that vibrations from blasting do not exceed a performance standard of 0.5 PPV in/sec for conventional construction and 0.12 PPV in/sec for historic structures.

If the construction area of a proposed utility-scale onshore wind facility is closer than 80 feet from an existing structure, a Construction Vibration Management Plan should be developed and implemented to reduce the potential for building damage. Measures and controls should be identified based on facility-specific design and may include, but are not limited to, the following:

- Use nonvibratory excavator-mounted compaction wheels and small, smooth drum rollers for final compaction of asphalt base and asphalt concrete. If needed to meet compaction requirements, use smaller vibratory rollers to minimize vibration levels during repaving activities to meet vibration standards.
- Implement buffers and use specific types of equipment to minimize vibration impacts during construction at nearby receptors.

- Implement a vibration, crack, and line and grade monitoring program for identified historic buildings located within 80 feet of construction activities, in coordination with a geotechnical engineer and qualified architectural historian.

3.4.5 Unavoidable significant adverse impacts

Through compliance with laws, permits, and with implementation of actions to avoid and mitigate significant impacts, small to medium utility-scale wind facilities would have **no significant and unavoidable adverse impacts** from noise from construction, operation, or decommissioning.

3.5 Large utility-scale facilities of 751 MW to 1,500 MW (Alternative 2)

3.5.1 Impacts from construction

Site characterization and construction of a large utility-scale onshore wind facility would include the same equipment and activities generating construction noise and vibration as those analyzed for small to medium utility-scale facilities, but likely across a larger facility footprint and over a greater construction period. Noise and vibration from multiple sources, including off-road equipment, blasting, vendor and haul truck trips, and a concrete batch plant, could all increase noise levels at receptors in the vicinity of the construction area footprint. Construction equipment and methods for large facilities would be the same as those for small to medium facilities. Therefore, construction noise and vibration impacts would be the same as those identified for small to medium facilities and would range from **less than significant impact** to **potentially significant adverse impact** depending on the distance from sensitive receptors.

3.5.2 Impacts from operation

Larger facilities would likely require a larger, and potentially louder, substation transformer. For the large-scale facilities, a project-level noise assessment for a proxy project was used to estimate the noise generation potential. The proxy project analysis used for the large facility was for a proposed 1,150-MW wind facility with 244 turbines rated from 2.8 to 5.5 MW each (Horse Heaven in Benton County, Washington).

Noise modeling for the proxy project was developed for operation of the turbines, as well as for the contributions from substations. The contours show that turbines are the predominant source of noise (EFSEC 2022).

Wind turbine noise

While turbines may be clumped into groups of three or more on a given project footprint, the 55 dBA, L_{eq} noise contour consistently extends approximately 1,260 feet from each turbine (EFSEC 2022).

For residential uses, an EDNA of 50 dBA would apply during nighttime hours. Based on two-dimensional geometric spreading equations, it is estimated that this noise level would occur at approximately 2,400 feet. Therefore, siting of wind turbines closer than 2,400 feet from a noise-sensitive land use could have a **potentially significant adverse impact**.

Additionally, in recognition that existing ambient noise levels are commonly quiet in rural areas where siting of energy facilities would likely occur, an increase of 5 dBA over ambient would correspond to a readily perceptible increase in noise for permanent operations (FHWA 2017). In quiet rural areas, an increase of 5 dBA over ambient noise could potentially result when turbines generate a noise level of 40 dBA at a receptor. Based on two-dimensional geometric spreading equations, this increase is estimated to have potential to occur within approximately 5,000 feet from the turbines. Consequently, siting of wind turbines closer than 5,000 feet from a noise-sensitive land use in a quiet rural area would have a **potentially significant adverse impact**.

Substation Noise

Modeling from the proxy project, in which the substations are surrounded by wind turbines, indicates that the contributions of substation noise would be negligible in the presence of wind turbine operations for large facilities (EFSEC 2022). Substation noise modeling for another proxy project indicated that the 40 dBA noise contour extends approximately 2,000 feet from substations (BLM and Tetra Tech 2011). Based on 2D geometric spreading equations, it is estimated that the 50 dBA contour would occur at 650 feet. Consequently, siting of substations for large facilities closer than 650 feet from a noise-sensitive receptor or 2,000 feet from a noise-sensitive land use in a quiet rural area would have a **potentially significant adverse impact.**

Corona noise

Analysis of corona noise for overhead lines of 34.5 kV is included in Section 3.4.2 and would be the same for large facilities. Noise estimates would be negligible (EFSEC 2022) and would result in a **less than significant impact**.

3.5.3 Impacts from decommissioning

Decommissioning or repowering noise and vibration impacts for large facilities would be the same as those identified in Section 3.4.3 and would range from **less than significant impact** to **potentially significant adverse impact** depending on the distance from sensitive receptors.

3.5.4 Actions to avoid and reduce impacts

Available means of reducing noise and vibration-related impacts for large facilities are the same as those identified in Section 3.4.4.

3.5.5 Unavoidable significant adverse impacts

Through compliance with laws, permits, and with implementation of actions to avoid and mitigate significant impacts, large utility-scale wind facilities would have **no significant and unavoidable adverse impacts** from noise from construction, operation, or decommissioning.

3.6 Wind facility and co-located battery energy storage system (Alternative 3)

3.6.1 Impacts from construction

Site characterization and construction of a utility-scale onshore wind facility and a co-located battery energy storage system (BESS) would generate the same construction noise levels and vibrations as those analyzed for small to medium facilities and large facilities, with the minor addition of construction of the BESS using the same construction equipment and methods. Therefore, construction noise and vibration impacts for wind energy facilities and co-located BESSs would be the same as those identified for small to medium and large facilities and would range from **less than significant impact** to **potentially significant adverse impact** depending on the distance from sensitive receptors.

3.6.2 Impacts from operation

The major noise sources for wind facilities and co-located BESSs are wind turbines and substations.

Noise from a BESS would be generated by battery storage liquid cooling units, as well as inverters specific to the BESS. BESSs would not be expected to generate operational vibration. In general, these sources would likely operate 24-hours a day and, hence, would generate noise during the more noise-sensitive nighttime hours.

For the utility-scale wind facilities with co-located BESSs, a project-level noise assessment for a proxy project—the 470-MW Wautoma Solar Energy Project in Benton County, Washington—was used to estimate the noise generation potential. Large-scale consolidated direct current-coupled BESSs generate higher noise levels when concentrated in a single area. Such systems can result in a noise level of approximately 65 dBA at a distance of one-half mile (2,600 feet) as compared to approximately 700 feet from each of a single distributed unit (Tetra Tech 2022). The analysis for another proxy project—the 1,150-MW Horse Heaven Wind Farm Project in Benton County, Washington—indicates that three consolidated BESS facilities, one in each solar array area, generate noise levels below 65 dBA within 1,000 feet (Tetra Tech 2022), substantially less than the consolidated BESS for Wautoma. These proxy project analyses indicate that there is a wide range of variability in predicted noise levels based on BESS design and configuration, particularly when comparing distributed and consolidated BESS. The potential exists for some consolidated BESS operations to exceed the Chapter 173-60 WAC EDNA of 50 dBA at distances ranging up to 1.5 miles from consolidated BESS equipment, depending on the design layout of the BESS.

The addition of BESSs could change the operational noise impacts identified for small to medium facilities and large facilities, and the operational noise impact would range from **less than significant impact** to **potentially significant adverse impact** depending on the design and layout of the BESS and distance of sensitive receptors from the facility.

Noise contours for the proxy project indicate that while turbines may be clumped into groups of three or more on a given project footprint, the 55 dBA, L_{eq} noise contour consistently extends approximately 1,260 feet from each turbine (EFSEC 2022).

In Washington state, maximum permissible environmental noise levels specific to land use are codified in Chapter 173-60 WAC. For residential uses, an EDNA of 50 dBA would apply during nighttime hours. Based on two-dimensional geometric spreading equations, it is estimated that this noise level would occur at approximately 2,400 feet. Therefore, siting of wind turbines closer than 2,400 feet from a noise-sensitive land use could have a **potentially significant adverse impact**.

Additionally, in recognition that existing ambient noise levels are commonly quiet in rural areas where siting of energy facilities would likely occur, an increase of 5 dBA over ambient would correspond to a readily perceptible increase in noise for permanent operations (FHWA 2017). As discussed in Section 3.2.1, remote, sparsely populated counties, such as Columbia County, can have background L_{dn} values of 35 dBA or lower (BLM 2024). In such rural areas, an increase of 5 dBA over ambient noise could potentially result when turbines generate a noise level of 40 dBA at such a receptor. Using two-dimensional geometric spreading equations, this increase is estimated to have potential to occur within approximately 5,000 feet from the turbines or substations. Consequently, siting of wind turbines closer than 5,000 feet from a noise-sensitive land use within a quiet rural setting could have a **potentially significant adverse impact**.

Corona noise
Analysis of corona noise for overhead lines of 34.5 kV is included in Section 3.4.2 and would be the same for facilities with co-located BESS. Noise estimates would be negligible (EFSEC 2022) and result in a **less than significant impact**.

Vibration
The BESS would not be expected to generate operational vibration.

3.6.3 Impacts from decommissioning

Decommissioning or repowering noise and vibration impacts for wind facilities with co-located BESSs would be the same as those identified for small to medium facilities and large facilities and would range from **less than significant impact** to **potentially significant adverse impact** depending on the distance from sensitive receptors.

3.6.4 Actions to avoid and reduce impacts

Available means of reducing noise and vibration-related impacts for wind energy facilities with co-located BESSs are the same as those identified in Section 3.4.4, including additional mitigation measures. Additionally, noise generated by BESSs may need to be controlled to maintain operational noise exposure to within the noise standards of Chapter 173-60 WAC. Additional potential actions that could avoid or reduce impacts are outlined below.

3.6.4.1 Siting and design considerations

- Include acoustical enclosures or barriers for BESS containers to reduce potential operational noise impacts.
- Utilize a dispersed or distributed layout of BESSs.

3.6.5 Unavoidable significant adverse impacts

Through compliance with laws, permits, and with implementation of actions to avoid and mitigate significant impacts, utility-scale wind facilities with co-located BESSs would have **no significant and unavoidable adverse impacts** from noise from construction, operation, or decommissioning.

3.7 Wind facility combined with agricultural land use (Alternative 4)

3.7.1 Impacts from construction

A utility-scale onshore wind facility combined with agricultural use may be located on land that already had existing agricultural uses or the facility could add a new agricultural use where the facility is located. Site characterization and construction would generate the same construction noise and vibration levels as those analyzed for small to medium facilities and large facilities without combined agriculture land use. Therefore, construction noise and vibration impacts for facilities combined with agricultural use would be the same as those identified for small to medium and large facilities and would range from **less than significant impact** to **potentially significant adverse impact** depending on the distance from sensitive receptors.

3.7.2 Impacts from operation

For a facility that includes agricultural land uses, any existing agricultural lands would be maintained, or new agricultural use could be co-located with the utility-scale wind facility, including rangeland or farmland. Activities at these facilities may include maintenance of existing or addition of new infrastructure, roads, fences, gates, and operation of farming machinery. If the agricultural uses exist prior to facility construction, any noise contribution from these existing activities would reduce the increase over ambient that is assumed to occur (as analyzed in Sections 3.4.2 and 3.5.2). If a new agricultural use is also introduced as part of this alternative, it would result in seasonal operations of farm equipment (tractors, tillers, and reapers) that would generate noise levels similar to those identified in Table 2. While mobile equipment operations of agricultural equipment under this alternative could represent a new additional noise source, the seasonality of such operations and temporary duration of any additional noise generation would be a **less than significant** noise contribution. Overall operational noise impact would range from **less than significant impact** to a **potentially significant adverse impact** depending on the distance of the receptor from the facility

3.7.3 Impacts from decommissioning

Decommissioning or repowering noise and vibration impacts for a facility that includes agricultural land uses would be the same as those identified for small to medium and large facilities and would range from **less than significant impact** to **potentially significant adverse impact** depending on the distance from sensitive receptors.

3.7.4 Actions to avoid and reduce impacts

Available means of reducing noise and vibration-related impacts for a facility that includes agricultural land uses are the same as those identified in Section 3.4.4.

3.7.5 Unavoidable significant adverse impacts

Through compliance with laws, permits, and with implementation of actions to avoid and mitigate significant impacts, utility-scale wind facilities with agricultural uses would have **no significant and unavoidable adverse impacts** from noise from construction, operation, or decommissioning.

3.8 No Action Alternative

Under the No Action Alternative, the city, county, and state agencies would continue to conduct environmental review and permitting for utility-scale wind energy development under existing state and local laws on a project-by-project basis. The potential impacts from facilities developed under the No Action Alternative would be similar to the impacts for the types of facilities described previously for construction, operations, and decommissioning, depending on facility size and design, and would range from **less than significant impacts** to **potentially significant adverse impacts.**

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Wind Turbines, Amenities and Disamenities: A Study of Home Value Impacts in Densely Populated Massachusetts

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E-9

DISCLAIMER

Wind Turbines, Amenities and Disamenities: A Study of Home Value Impacts in Densely Populated Massachusetts

Authors Ben Hoen and Carol Atkinson-Palombo

Abstract In this study, we investigate the effect of planned or operating wind turbines on urban home values. Previous studies, which largely produced non-significant findings, focused on rural settings. We analyzed more than 122,000 home sales, between 1998 and 2012, that occurred near 41 turbines in densely populated Massachusetts communities. Although we found the effects from various negative features (such as electricity transmission lines) and positive features (such as open space) generally accorded with previous studies, we found no net effects due to turbines in these communities. We also found no unique impact on the rate of home sales near wind turbines.

Wind energy offers several advantages over other low-emission alternatives such as nuclear power and large-scale hydropower projects but has met with opposition in the United States and many other countries (Firestone and Kempton, 2007; Moragues-Faus and Ortiz-Miranda, 2010; Nadai and van der Horst, 2010). One common concern is that wind turbines constitute a disamenity, which reduces the desirability and hence the price of nearby properties. In the U.S., large-scale wind installations have tended to be built in sparsely populated locations in the Plains and West, so existing studies of the effect of wind turbines on the price of residential properties have tended to focus on large-scale installations located in rural settings. Rural residents have expressed concern about the way in which industrialized large-scale wind farms have transformed the rural sense of place through the creation of "landscapes of power" (Pasqualetti, Gipe, and Righter, 2002, p. 3).

Smaller-scale distributed renewable energy technologies located in and around urbanized areas where energy is being consumed provide an opportunity to reduce transmission costs. However, locating wind turbines in more densely populated areas potentially means that more homes may be affected if the facilities were to constitute a disamenity. Nuisances from turbine noise and shadow flicker might be especially relevant in urban settings where other negative features, such as landfills or high-voltage utility lines, have been shown to reduce home prices. Alternatively, people residing in more urbanized settings may have different perceptions about the built and natural environment from those living in rural environments. Despite the growing popularity of smaller-scale energy facilities being built in more urbanized settings, no comprehensive studies have yet been undertaken to identify whether or not wind turbines constitute a disamenity in these locations.

Massachusetts has been especially progressive in its adoption of renewable energies and as of October 2015 had almost 107 MW of installed capacity distributed across 129 separate wind projects. Turbines have been located in a variety of settings including the mountainous Berkshire East Ski Resort, heavily urbanized Charlestown, and coastal Cape Cod. The average gross population density surrounding the Massachusetts turbines of approximately 416 persons per square mile (based on 2005 population levels and turbines as of 2012) far exceeds the national average of approximately 11 persons per square mile around turbines.

Accordingly, in this study we analyze the effect of Massachusetts' wind turbines larger than 600 kilowatts (kW) of rated capacity on nearby home prices to inform the debate about the siting and operation of smaller-scale wind projects across a broad range of land use types in more densely populated areas of the U.S. Our study makes five major unique contributions to the wind energy property value literature: (1) We use the largest and most comprehensive dataset ever assembled for a study linking wind facilities to nearby home prices in North America. (2) Our study includes the largest range of home sale prices ever examined. (3) We examine wind facilities in areas across a range of land use and zoning types from rural to urban/industrial (with relatively high-priced homes), whereas previous analyses have focused on rural areas (with relatively low-priced homes). (4) We largely focus on wind facilities that contain fewer than three turbines, while previous studies have focused on large-scale wind facilities. (5) Our modeling approach controls for seven environmental amenities and disamenities in the study area, allowing the effect of wind facilities to be compared directly to the effects of these other factors.

The remainder of this paper is organized as follows. We begin with a literature review and identification of gaps in the literature that inform our empirical analysis. We then discuss our empirical analysis, including descriptions of the data, methods, and results. We next present the results, and close with a discussion of the findings, conclusions, and suggestions for future research.

Literature

Wind energy is one of the fastest growing sources of power generation in the world, and public and political support for it are generally strong (e.g., Graham, Stephenson, and Smith, 2009). Despite this strong support, the construction of wind projects provokes concerns about local impacts (e.g., Devine-Wright, 2012), specifically, turbine-related impacts on homes located a short distance away (Hoen et al., 2011). If wind turbines create such a disamenity, then house prices closer to the turbine would be expected to decline (all else being equal). Therefore, their impact can be examined by investigating nearby house prices after the facility has been erected compared to their values before the turbine was installed, while taking into account the prices of houses farther away that sold during the same period.

The peer-reviewed, published studies that have used hedonic modeling have generally found non-significant post-construction effects (Sims, Dent, and Oskrochi, 2008; Hoen et al., 2011; Hoen et al., 2013; Lang, Opaluch, and Sfinarolakis, 2014; Vyn and McCullough, 2014), or relatively small impacts (Jensen, Panduro, and Lundhede, 2014), implying that average impacts in their study areas were either relatively small or sporadic near existing turbines. Three academic studies found similarly non-significant results (Hoen, 2006; Hinman, 2010; Carter, 2011) while two found relatively small effects (Dröes and Koster, 2015; Gibbons, 2015), and one found a substantial effect (Grieser, Sunak and Madlener, 2015). The geographic extent of the North American studies varied from single county (Hoen, 2006; Hinman, 2010; Carter, 2011; Vyn and McCullough, 2014), to three counties in New York (Heintzelman and Tuttle, 2012), to eight (Hoen et al., 2011) or nine states (Hoen et al., 2013), showing that results have been robust to geographic scale and sample selection. Some studies have found evidence of pre-construction yet post-announcement impacts (Hinman, 2010; Hoen et al., 2011; Heintzelman and Tuttle, 2012).[1] This "anticipation effect" (Hinman, 2010) correlates with surveys of residents living near wind facilities finding that residents are more supportive of the facilities after they have been built than they were when the construction of that facility was announced (Wolsink, 2007; Sims, Dent, and Oskrochi, 2008). This effect is consistent with analyses of home prices related to other disamenities (e.g., incinerators), which have also shown anticipation effects and post-construction rebounds in prices (Kiel and McClain, 1995).

Wind turbines are typically limited to high-wind-resource areas but disamenities such as highways, overhead electricity transmission lines, power plants, and landfills are ubiquitous in urban and semi-rural areas, and have been well studied. This more established "disamenity literature" (e.g., Boyle and Kiel, 2001; Jackson, 2001; Simons and Saginor, 2006) helps both to frame the expected level of impact around turbines and validate whether the coefficients for the amenities and disamenities included in our model are reasonable. For example, adverse home-price effects near electricity transmission lines, a largely visual disturbance, have ranged from 5% to 20%, fading quickly with distance and disappearing beyond 200 to 500 feet (Colwell, 1990; Delaney and Timmons, 1992; Kinnard and Dickey, 2000; Pitts and Jackson, 2007). Landfills, which present smell and truck activity nuisances and potential health risks from groundwater contamination, have been found to decrease adjacent property values by 13.7% on average, decreasing by 5.9% for each mile a home is further away for large-volume operations.[2] Lower-volume operations decreased adjacent property values by 2.7% on average, decreasing by 1.3% per mile (Ready, 2010). Finally, studies on the impact of road noise on house prices found price decreases of 0.4% to 4% for houses adjacent to a busy road compared to those on a quiet street [e.g., Bateman, Day, and Lake (2001) and the references therein, and Andersson, Jonsson, and Ogren (2010); Day, Bateman, and Lake (2007); and Kim, Park, and Kweon (2007)].

Community amenities also have been well studied. Open space (i.e., publicly accessible areas that are available for recreational purposes) has been found to increase surrounding prices (Irwin, 2002; Anderson and West, 2006); Anderson and West (2006) estimated those premiums to be 0.1% to 5%, with an average of 2.6% for every mile that a home is closer to the open space. Proximity to (and access to and views of) water, especially oceans, has been found to increase values (e.g., Benson, Hansen, and Schwartz, 2000; Bond, Seiler, and Seiler, 2002); for example, being on the waterfront increased values by almost 90% (Bond, Seiler, and Seiler, 2002). Although many researchers of the community perceptions of wind turbines suggest that local residents may see turbines as a disamenity, this is not always the case. Some suggest that wind turbines could be considered amenities (i.e., a positive addition to the community), particularly if benefits accrue to the local community (Loomis and Aldeman, 2011; Loomis, Hayden, and Noll, 2012) and therefore might decrease the tax burden for local residents.

The evidence discussed above for other disamenities and for other studies of turbines suggests that any turbine-related disamenity impact likely would be relatively small, for example, less than 10% if it exists at all. If this is the case, tests to discover this impact would require correspondingly small margins of error and hence large amounts of data. Yet much of the North American studies have used relatively small numbers of transactions near turbines. For example, the largest dataset studied to date had only 376 post-construction sales within 1 mile of the turbines (Hoen et al., 2013), while others contained far fewer post-construction transactions within 1 mile: Hoen et al. (2009, 2011) (n = 125); Hinman (2010) ($n \sim 11$); Carter (2011) ($n \sim 41$); Heintzelman and Tuttle (2012) ($n \sim 35$); and Vyn and McCullough (2014) ($n \sim 22$). Although these numbers of observations might be adequate to examine large impacts (e.g., greater than 10%), they are less likely to discover smaller effects because of the size of the corresponding margins of error. Larger datasets of transactions would allow smaller effects to be discovered. Using results from Hoen et al. (2009) and the confidence intervals for the various fixed effect variables in that study, we estimated the numbers of transactions needed to find effects of various sizes. Approximately 50 transactions are needed to find an effect of 10% or greater, 200 to find an effect of 5%, 500 to find an effect of 3.5%, and approximately 1,000 to find a 2.5% effect.

Additionally, research has identified that wind facilities are sited in areas where property prices are lower than in surrounding areas—hereafter referred to as a "preexisting price differential." For example, Hoen et al. (2009) found significantly lower prices (−13%) for homes that sold more than two years prior to the wind facilities' announcements and were located within one mile of where the turbines were eventually located, as compared to homes that sold in the same period and were located outside of 1 mile. Hinman (2010) found a similar phenomenon that she termed a "location effect." Thus, further investigation of whether wind facilities are located in areas with lower home values than surrounding areas is warranted. Finally, there have been claims that the home sales rate (i.e., sales volume) near existing wind turbines is far lower than the rate in the same location before the turbines' construction and the rate farther away from the turbines, because homeowners near turbines cannot find buyers [see sales volume discussion in Hoen et al. (2009)].

Empirical Study

Research Questions

We address the following questions informed by gaps in the literature: (Q1) Have wind facilities in Massachusetts been located in areas where average home prices were lower than prices in surrounding areas (i.e., a "preexisting price differential")?[3] (Q2) Are post-construction (i.e., after wind-facility construction) home price impacts evident in Massachusetts, and how do Massachusetts' results compare to previous results estimated for more rural settings? (Q3) Is there evidence of a post-announcement/pre-construction effect (i.e., an "anticipation effect")? (Q4) How do impacts near turbines compare to the impacts of amenities and disamenities also located in the study area, and how do they compare to previous findings? (Q5) Is there evidence that houses near turbines that sold during the post-announcement and post-construction periods do so at lower relative rates (i.e., frequencies) than during the pre-announcement period?

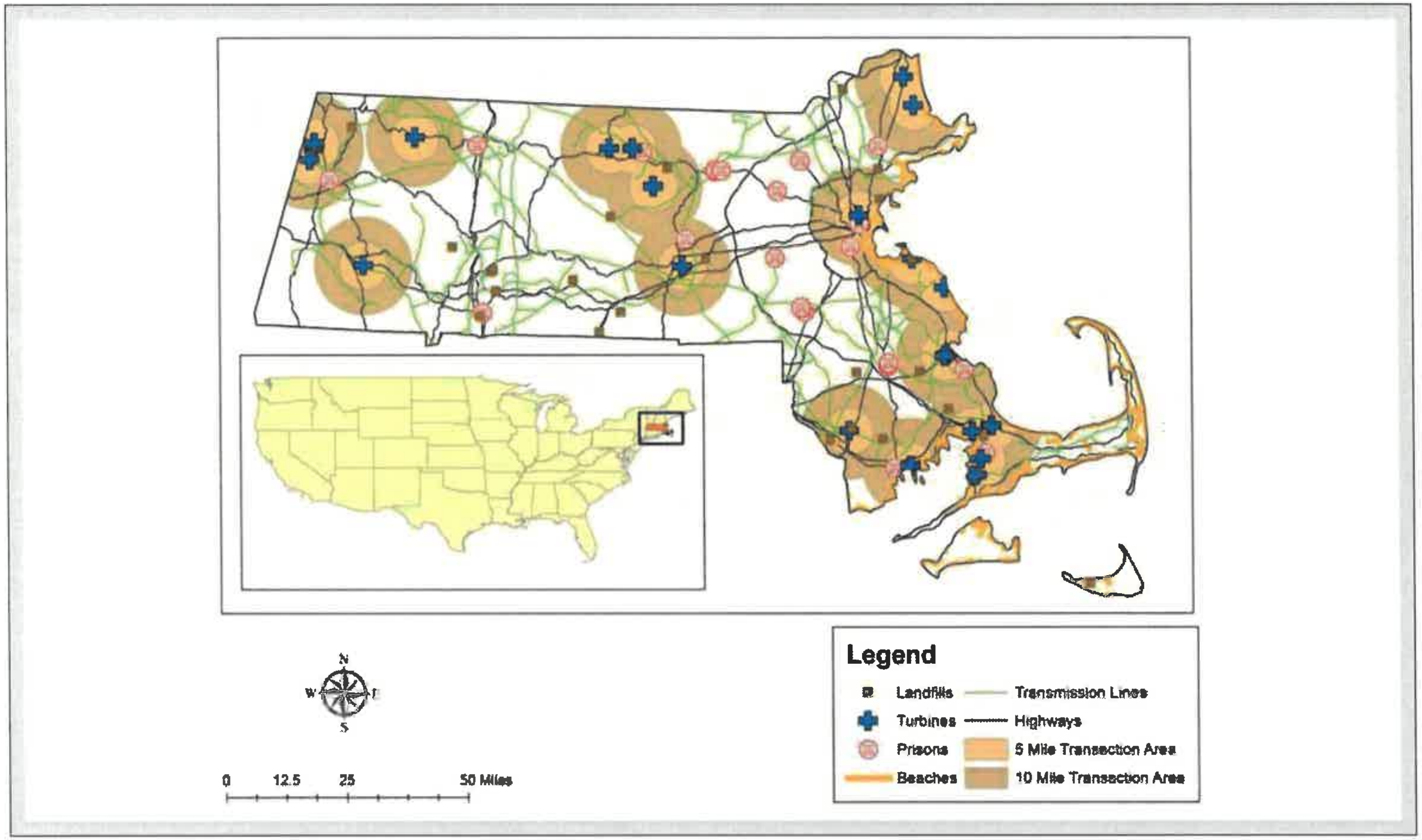
Data

The study uses data from the Massachusetts Clean Energy Center (MassCEC) for 41 wind turbines in Massachusetts that had been commissioned as of November 2012 with a capacity of at least 600 kW.[4] The location of the wind turbines along with other features included in the analysis is shown in Exhibit 1. Data on homes were purchased from the Warren Group[5] and a geographic information system (GIS) was used to calculate the distance of each home to the nearest turbine. Transactions inside five miles were used for the base model, while those outside of five miles were retained for the robustness tests.

Summary Statistics

The base model dataset includes all home sales within five miles of a wind turbine, which are summarized in Exhibit 2.[6] The average home in the dataset of 122,198

Exhibit 1 | Location of Wind Turbines and Amenities and Disamenities in Massachusetts



Sample location detail showing turbines, five- and ten-mile sample areas, and multiple overlapping locations of various amenities and disamenities.

Exhibit 2 | Summary of Characteristics of Base Model Dataset

Variable	Description	Mean	Std. Dev.	Min.	Median	Max.
sp	Sale price	$322,948	$238,389	$40,200	$265,000	$2,495,000
lsp	Log of sale price	12.49	0.60	10.6	12	14.72
sd	Sale date	10/19/2004	1522	3/3/1998	2/6/2005	11/23/2012
sy	Sale year	2004	4	1998	2004	2012
syq	Sale Year and Quarter (e.g., 20042 = 2004, 2nd Quarter)	20042	42	19981	20043	20124
sfla1000	Square Feet Of Living Area (1,000s of Square Feet)	1.72	0.78	0.41	1.6	9.9
acre[a]	Number of acres	0.51	1.1	0.005	0.23	25
acrelt1[a]	The number of acres less than one	−0.65	0.31	−0.99	−0.77	0
age	Age of home at time of sale	54	42	−1	47	359
agesq	Age of home squared	4671	4764	0	3474	68347
bath[b]	The number of bathrooms	1.90	0.79	0.5	1.5	10.5
wtdis	Distance to nearest turbine (miles)	3.10	1.20	0.1	3.2	5
fdp	Wind facility development period	1.95	1.18	1	1	4
annacre	Average nearest neighbor's acres	0.51	0.93	0.015	0.25	32
annage	Average nearest neighbor's age	53.71	30.00	−0.8	52	232
annagesq	Average nearest neighbor's agesq	4672	4766	0	3474	68347
annsfla1000	Average nearest neighbor's sfla1000	1.72	0.53	0.45	1.6	6.8

Notes: Summary statistics of base model dataset showing a wide range in prices, sizes, ages and distances from turbines of homes in the sample. Sample size for the full dataset is 122,198.

[a]Together *acrelt1* and acre are entered into the model as a spline function with acrelt1 applying to values from 0 to 1 acres (being entered as values from −1 to 0, respectively) and acre applying to values from 1 to 25 acres.

[b]Bath is calculated as follows: number of bathrooms + (number of half bathrooms *0.5).

Exhibit 3 | Distribution of Transaction Data Across Distance and Period Bins

	prioranc	*preanc*	*postanc-precon*	*postcon*	All Periods
0–0.25 mile	60 0.04%	9 0.02%	14 0.03%	38 0.06%	121 0.04%
0.25–0.5 mile	434 0.25%	150 0.39%	210 0.47%	192 0.33%	986 0.32%
0.5–1 mile	3,190 1.9%	805 2.1%	813 1.8%	1,273 2.2%	6,081 1.9%
1–5 mile	62,967 37%	14,652 38%	17,086 38%	20,305 34%	115,010 37%
5–10 mile	104,188 61%	22,491 59%	26,544 59%	37,256 63%	190,479 61%
Total	170,839 100%	38,107 100%	44,667 100%	59,064 100%	312,677 100%

Note: Count of transactions across distance and wind facility development periods showing over 1,000 transactions within a half mile and stable numbers of transactions near turbines over time.

sales from 1998 to 2012 has a sale price of $322,948, sold in 2004, in the second quarter, has 1,728 square feet of living area, is on a parcel with a lot size of 0.51 acres, is 54 years old, has 1.9 bathrooms, and is 3.1 miles from the nearest turbine. As summarized in Exhibit 3, of the 122,198 sales within five miles of a turbine, 7,188 (5.9%) are within one mile of a turbine, 1,107 (approximately 0.9%) are within a half mile, and 121 (0.1%) are within a quarter mile. In the post-construction period, 1,503 sales occurred within one mile of a turbine, and 230 occurred within a half mile. It is worth noting that although the land area within a quarter mile ($\sim$0.2 mile^2) is one-third of that between a quarter mile and a half mile ($\sim$0.6 mile^2), the number of transactions (and homes) is approximately one-tenth (121/986 = 0.12). This makes sense because there are regulatory and business practices that, respectively, require and/or encourage utility scale turbines to be set back from homes. Often these setbacks are 1,000 feet or so (NARUC, 2012). Therefore a significant percentage of the usable land around all wind facilities will contain only a few or no homes. That notwithstanding, this sample represents the most densely populated sample studied to date in North America and its density is similar to other "urban" utility scale wind installations elsewhere in the U.S. (in Connecticut, Ohio, and New Jersey). Moreover, the sample of homes studied immediately near the turbines is sufficient to gauge if an effect existed that might be relatively small, as is hypothesized, and especially so if an effect is larger (say, greater than 10%). The mean values for each of the distance bins and development periods for sale price, square feet, age, and acres are provided in Exhibit 4.

Exhibit 4 | Mean Values of Key Variables by Distance and Period Bins

	prioranc	*preanc*	*postanc-precon*	*postcon*	*prioranc*	*preanc*	*postanc-precon*	*postcon*
	Sale Price				Square Feet (in 1000s)			
0–0.5 mile	$256,378	$309,149	$314,337	$332,708	1.784	1.577	1.622	1.582
0.5–1 mile	$288,536	$377,842	$359,003	$385,499	1.744	1.700	1.737	1.715
1–5 mile	$292,258	$361,352	$346,581	$370,096	1.737	1.716	1.719	1.718
	Acre				Age			
0–0.5 mile	0.45	0.40	0.42	0.35	46	46	49	53
0.5–1 mile	0.35	0.36	0.48	0.32	55	57	55	65
1–5 mile	0.51	0.52	0.60	0.47	51	53	54	61

Note: Summary statistics of sale price, square feet, acres, and age of homes that sold across the various wind facility development periods and distance bins showing consistently lower prices of homes near the turbines across all periods and varying levels of acres, square feet and age.

Hedonic Base Model Specification

We estimate the following customarily used (e.g., Sirmans, Lynn, Macpherson, and Zietz, 2005) semi-log base model to which the set of robustness models are compared.

$$\ln(P) = \beta_0 + \sum \beta_1 LD + \beta_2 N + \sum \beta_3 AD + \sum \beta_4 ED + \sum B_5 T + \varepsilon', \quad (1)$$

where the dependent variable is the log of sales price (P), and L is the vector of characteristics of the property including living area (in thousands of square feet); lot size (in acres); lot size less than one acre (in acres if the lot size is less than 1, otherwise 1);[7] effective age (sale year minus either the year built or, if available, the most recent renovation date); effective age squared; and number of bathrooms (the number of full bathrooms plus the number of half bathrooms multiplied by 0.5). D is the development period in which the sale occurred for the nearest wind turbine (e.g., if the sale occurred more than two years before the nearest turbine's development was announced, less than two years before announcement, after announcement but before construction, or after construction). N is the U.S. census tract in which the sale occurred.[8] A is the vector of amenity/disamenity variables for the home, including the amenities: if the home is within a half mile from open space; is within 500 feet or is within a half mile but outside 500 feet of a beach; and disamenities: is within a half mile of a landfill, and/or prison; and is within 500 feet of an electricity transmission line, highway, and/or major road.[9] T is the vector of time variables, including the year in which the sale occurred and the quarter in which the sale occurred.[10] E is a binary variable representing if the home is within a half mile from a turbine, and ε is the error term. β_0, β_1, β_2, β_3, β_4, and β_5 are coefficients for the variables.

The vectors of lot-specific and amenity/disamenity variables are interacted with the development period. This is done for three reasons: (1) to allow the covariates to vary over the study period, which will, for example, allow the relation of living area and sale price to be different earlier in the study period, such as more than two years before announcement, than it is later in the study period, such as after construction of the nearest turbine;[11] (2) to ensure that the variables of interest do not absorb any of this variation and therefore bias the coefficients; and (3) to allow the examination of the amenity/disamenity variables for subsets of the data.[12] The distance-to-the-nearest-turbine variable specified in the base model is binary: one if the home is within a half mile of a turbine and zero if not. Further, we used a binary variable as opposed to other forms used to capture distance. For example, other researchers investigating wind turbine effects have commonly used continuous variables to measure distance such as linear distance (Sims, Dent, and Oskrochi, 2008; Hoen et al., 2009), inverse distance (Heintzelman and Tuttle, 2012; Vyn and McCullough, 2014; Grieser, Sunak, and Madlener, 2015), or mutually exclusive non-continuous distance variables (Hoen et al., 2009; Hinman, 2010; Carter, 2011; Hoen et al., 2011; Heintzelman and Tuttle, 2012; Hoen et al., 2013; Vyn and McCullough, 2014; Grieser, Sunak, and Madlener, 2015). We preferred the binary variable because we believe the other forms have limitations (although we explore a continuous specification as a robustness test). For example, using the linear or inverse continuous forms necessarily forces the model to estimate effects at the mean distance. In some of these cases, those means can be quite far from the area of expected impact (Heintzelman and Tuttle, 2012; Grieser, Sunak, and Madlener, 2015). More importantly, this method encourages researchers to extrapolate their findings to the ends of the distance curve, near the turbines, despite having few data in this distance band (Heintzelman and Tuttle, 2012; Grieser, Sunak, and Madlener, 2015).

One method to avoid using a single continuous function is to use a spline model, which breaks the distances into continuous groups (Hoen et al., 2011), but this still imposes some structure on the data that might not actually exist. By far the most transparent method is to use binary variables for discrete distances that therefore impose only slight structure on the data (Hoen et al., 2009; Hinman, 2010; Hoen et al., 2011; Heintzelman and Tuttle, 2012; Hoen et al., 2013; Vyn and McCullough, 2014). Although this method has been used in existing studies, because of a paucity of data, margins of error for the estimates were large (e.g., 7% to 10% in Hoen et al., 2011). However, as discussed above, the extensive dataset for Massachusetts allows this approach to be taken while maintaining relatively small margins of error. Moreover, although others have estimated effects for multiple distance bins out to five or ten miles, we focus our estimates on the group of homes that are within a half mile of a turbine, although other groups, such as those within a quarter of a mile and between one half and one mile, are explored in the robustness tests. The homes within a half mile of turbines are most likely to be impacted and are, therefore, the first and best place to look for impacts. Further, we use the entire group of homes outside of a half mile as the reference category, which gives us a large heterogeneous comparison group and therefore one that is likely *not* correlated with omitted variables, although we also explore other comparison groups in the robustness tests.

Robustness Tests

A suite of robustness tests explored changes in: (1) the spatial extent at which both the effect and the comparable data are specified; (2) an alternative representation of distance to turbine as a "distance decay" function; (3) the variables used to describe fixed effects; (4) the screens that are used to select the final dataset, as well as outliers and influencers; (5) a series of tests associated with the suite of disamenity variables; and (6) the inclusion of spatially and temporally lagged variables to account for the presence of spatial autocorrelation. Each is described below and indicates the appropriate model in the results in Exhibit 6.

Varying the Distance to Turbine. In the base model, we test for effects on homes sold within a half mile of a turbine (and compare the sales to homes located outside of a half mile and inside five miles of a turbine). Conceivably, effects are stronger the nearer homes are to turbines and weaker the further they are away because that roughly corresponds to the nuisance effects (e.g., noise and shadow flicker) that we are measuring, but we do not explore this in the base model. Therefore, this set of robustness models investigates effects within a quarter mile (robustness model a), as well as between a half and one mile (model b). It is assumed that effects will be larger within a quarter mile and smaller outside of a half mile.

Additionally, the basis of comparison could be modulated as well. In the base model, we compare homes within a half mile to those outside of a half mile and inside of five miles, most of which are between three and five miles. Conceivably, homes immediately outside of a half mile are also affected by the presence of the turbines, which might bias down the comparison group and therefore bias down the differences between it and the target group inside of a half mile. Therefore, two additional comparison groups are explored: (1) those outside of a half mile and inside of ten miles (model c), and (2) those outside of five miles and inside of ten miles (model d). It is assumed that effects from turbines are not experienced outside of five miles from the nearest turbine.

Using a "Distance Decay" Effect. The aim of the paper is to specifically examine if effects within a half mile of turbines are apparent, while also examining effects for homes proximate to other amenities and disamenities within the same dataset using the same methods. We have enough data to allow us to do so with a reasonably small margin of error (3%–5%). As a robustness test, we also estimate a model with a distance decay function (1/distance) to capture a decrease in effects with increased distance to the turbines (model e).

Fixed Effects. The base model uses census tract boundaries as the geographic extent of fixed effects, aiming to capture "neighborhood" effects throughout the sample area. Because this delineation is both arbitrary (a census tract does not necessarily describe a neighborhood) and potentially too broad (multiple neighborhoods might be contained in one census tract), the census block group is used in a robustness test (model f). This is expected to allow a finer adjustment to the effects of individual areas of the sample and therefore be a more accurate control for neighborhood effects. The drawback is that the variables of interest (e.g., within a half mile and the development period variables) might vary less within the block group, and therefore the block group will absorb the effects of the turbines, biasing the results for the variables of interest.

Screens, Outliers, and Influencers. As described below, to ensure that the data used for the analysis are representative of the sample in Massachusetts and do not contain exceptionally high- or low-priced homes or homes with incorrect characteristics, a number of screens are applied for the dataset. To explore what effect these screens have on the results, they are relaxed for this set of robustness tests (model g). Additionally, a selection of outliers (based on the 1st and 99th

percentiles of sale price) and influencers (based on a Cook's distance of greater than 1), (Cook, 1977) might bias the results, and therefore a model is estimated with them removed (model h).

Disamenity Variables. The base model includes a series a binary variables to represent the various disamenities and amenities located near the homes in our dataset, and assumes that any potential disamenity associated with wind turbines would be "over and above" that for the existing disamenities. To account for the possibility that the combined effect of multiple disamenities may not necessarily be additive, and that the disamenity associated with wind turbines may be small compared to other negative externalities, we conducted three separate robustness tests with respect to our disamenity variables. In the first test, we exclude observations where the negative externalities (other than the wind turbines) are present, focusing on a sample that only includes houses close to wind turbines but not close to any other negative externalities (model i). In the second test, we use factor analysis on all of our disamenity variables to create indices of disamenity that are then used in a regression in place of the individual binary variables representing disamenities (model j). In the third analysis, to test for the possibility that there are latent effects that are not being captured with the regression, or that the results are over or understating the effects of the wind turbines, we conduct two separate tests utilizing 2010 census data on household income, education, and employment level and percentage owner-occupied for all of the block groups in the sample area: (1) using *t*-tests, we examine whether census characteristics for block groups close to the turbines are statistically significantly different from those outside of five miles; we find they were not in terms of employment, household income, and education (results not shown); and (2) we include the census variables in our regression model (model k).[13]

Spatially and Temporally Lagged Nearest-Neighbor Data. The value of a given house is likely impacted by the characteristics of neighboring houses (i.e., local spatial spillovers, defined empirically as W_x) or the neighborhood itself. For example, a house in a neighborhood with larger parcels (e.g., five-acre lots) might be priced higher than an otherwise identical home in a neighborhood with smaller parcels (e.g., one-acre lots).

If statistical models do not adequately account for these spatial spillovers, the effects are relegated to the unexplained component of the results contained in the error term, and therefore the other coefficients could be biased. If this occurs, then the error terms exhibit spatial autocorrelation (i.e., similarity on the basis of proximity). Often, in the hedonic literature, concern is paid to unobserved (and spatially correlated) neighborhood factors in the model.[14]

A common approach for controlling for the unobserved neighborhood factors is to include neighborhood fixed effects (e.g., Bourassa, Cantoni, and Hoesli, 2010; Zabel and Guignet, 2012), which is the approach we took in the base model. To additionally control for the characteristics of neighboring houses, a model can be estimated that includes spatial lags of their characteristics as covariates in the hedonic model, as is done for this robustness test. Neighboring houses are determined by a set of *k*-nearest neighbors (*k*, in this case, equals 5), although alternative methods could have been used (Anselin, 2002). Using the data obtained from the Warren Group for the home and site characteristics, x/y coordinates, and the sale date, a set of spatially and temporally lagged nearest-neighbor variables are derived for use in a robustness test. For each transaction, the five nearest neighbors were selected that transacted within the preceding six months and were the closest in terms of Euclidian distance. Using those five transactions, average 1,000s of square feet of living space (*annsfla1000*), average acres (*annacre*), average age (*annage*), and age squared (*annagesq*) of the neighbors were created for each home. These four variables were used in the robustness test (model l).

Results

Base Model Results

The base model results for the turbine, amenity, and disamenity variables are presented in Exhibit 5. The base model has a high degree of explanatory power, with an adjusted R^2 of 0.80, while the controlling variables are all highly significant and conform to the a priori assumption as far as sign and magnitude (e.g., Sirmans, Lynn, Macpherson, and Zietz, 2005).[15] In the model, we interact the four wind-facility periods with each of the controlling variables to test the stability of the controlling variables across the periods (and the subsamples they represent) and to ensure that the coefficients for the wind turbine distance variables, which are also interacted with the periods, do not absorb any differences in the controlling variables across the periods.[16] The controlling variables do vary across the periods, although they are relatively stable. For example, each additional 1,000 square feet of living area adds 21%–24% to a home's value in each of the four periods; the first acre adds 14%–22% to home value, while each additional acre adds 1%–2%; each year a home ages reduces the home's value by approximately 0.2%, and each bathroom adds 6%–11% to the value. Additionally, the sale years are highly statistically significant compared to the reference year of 2012; prices in 1998 are approximately 52% lower, and prices in 2005 and 2006 are approximately 31% and 28% higher, after which prices decline to 2012 levels. Finally, there is considerable seasonality in the transaction values. Compared to the reference third quarter, prices in the first quarter are approximately 7% lower, while prices in the second and fourth are about 1%–2% lower (see the Appendix for full results).

Similar to the controlling variables, the coefficients for the amenity and disamenity parameters are, for the most part, of the correct sign and within the range of findings from previous studies. For example, being within 500 feet of a beach increases a home's value by 21%–30%, while being outside of 500 feet but within a half mile of a beach increases a home's value by 5%–13%. Being within 500 feet of a highway reduces value by 5%–7%, and being within 500 feet of a major

Exhibit 5 | Selected Results from Base Model: Wind Facility Development Period

Variables	Description	*prioranc* Coeff.	*preanc* Coeff.	*postanc-precon* Coeff.	*postcon* Coeff.
halfmile	Within a half mile of a wind turbine	−5.1%*** (0.000)	−7.1%*** (0.002)	−7.4%*** (0.000)	−4.6%* (0.081)
	Net Difference Compared to *prioranc* Period			−2.3% (0.264)	0.5% (0.853)
beach500ft	Within 500 feet of a beach	20.8%*** (0.000)	30.4%*** (0.000)	25.3%*** (0.000)	25.9%*** (0.000)
beachhalf	Within a half mile and outside of 500 feet of a beach	5.3%*** (0.000)	8.8%*** (0.000)	8.7%*** (0.000)	13.5%*** (0.000)
openhalf	Within a half mile of open space	0.6%** (0.021)	0.1% (0.729)	0.1% (0.903)	0.9%* (0.062)
line500ft	Within 500 feet of a electricity transmission line	−3.0%*** (0.001)	−0.9% (0.556)	−0.9% (0.522)	−9.3%*** (0.000)
prisonhalf	Within a half mile of a prison	−5.9%*** (0.001)	2.6% (0.291)	2.8% (0.100)	−2.3% (0.829)
hwy500ft	Within 500 feet of a highway	−7.3%*** (0.000)	−5.2%*** (0.000)	−3.7%*** (0.000)	−5.3%*** (0.000)
major500ft	Within 500 feet of a major road	−2.8%*** (0.000)	−2.3%*** (0.000)	−2.5%*** (0.000)	−2.0%*** (0.000)
fillhalf	Within a half mile of a landfill	1.8% (0.239)	−0.9% (0.780)	1.0% (0.756)	−12.2%*** (0.002)

Exhibit 5 | (continued)

Selected Results from Base Model: Wind Facility Development Period

Variables	Description	*prioranc* Coeff.	*preanc* Coeff.	*postanc-precon* Coeff.	*postcon* Coeff.
sfla1000	Living area in thousands of square feet	22.9%*** (0.000)	21.4%*** (0.000)	22.6%*** (0.000)	23.5%*** (0.000)
acre	Lot size in acres	1.1%*** (0.000)	1.9%*** (0.000)	1.3%*** (0.000)	−0.02% (0.863)
acrelt1	Lot size less than 1 acre	21.7%*** (0.000)	17.2%*** (0.000)	14.7%*** (0.000)	22.1%*** (0.000)
age	Age of the home at time of sale	−0.2%*** (0.000)	−0.2%*** (0.000)	−0.2%*** (0.000)	−0.2%*** (0.000)
agesq†	Age of the home at time of sale squared	0.6%*** (0.000)	0.5%*** (0.000)	0.6%*** (0.000)	0.8%*** (0.000)
bath	Number of bathrooms	6.4%*** (0.001)	7.9%*** (0.556)	8.4%*** (0.522)	11.1%*** (0.000)

Notes: Results from the base model showing consistently statistically significant differences in home prices for those located within a half mile of a turbine's current or eventual location, yet no significance difference in price when comparing across periods. For simplicity, coefficient values are reported as percentages, although the actual conversion is 100*(exp(b) − 1)% (Halvorsen and Palmquist, 1980). In most cases, the differences between the two are de minimis, though, larger coefficient values would be slightly larger after conversion. The model adjusted R^2 is 0.80; $f < 0.001$; $n = 122{,}198$. *p*-values are in parentheses.

† Coefficient values are multiplied by 1,000 for reporting purposes only.

*Significant at 0.10.

**Significant at 0.05.

***Significant at 0.01.

Exhibit 6 | Robustness Results

				Prior Announcement Turbine Effect			"Net" Post-Announcement Pre-Construction Turbine Effect			"Net" Post-Construction Turbine Effect		
				Inside 1/4 Mile	Inside 1/2 Mile	Between 1/2 and 1 Mile	Inside 1/4 Mile	Inside 1/2 Mile	Between 1/2 and 1 Mile	Inside 1/4 Mile	Inside 1/2 Mile	Between 1/2 and 1 Mile
#	Model Name	*n*	Adj. R^2	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
	Base Model	122,198	0.80		−5.1%*** (0.000)			−2.3% (0.264)			0.5% (0.853)	
a	Inside 1/4 mile	122,198	0.80	−5.3% (0.260)			12.7% (0.118)			0.7% (0.916)		
b	Between 1/2 and 1 Mile	122,198	0.80		−5.0%*** (0.000)	−0.4% (0.536)		−2.0% (0.336)	1.4% (0.225)		1.0% (0.715)	1.3% (0.288)
c	All Sales Out to 10 Miles	312,677	0.82		−5.8%*** (0.000)			−3.0% (0.886)			1.0% (0.724)	
d	Using Outside of 5 Miles as Reference	312,677	0.82		−7.6%*** (0.000)			1.6% (0.435)			1.1% (0.695)	
e	Distance Decay	122,198	0.80		−2.0%*** (0.000)			0.5% (0.458)			0.003% (0.997)	
f	Using Block Group	122,198	0.81		−3.1%*** (0.024)			−1.3% (0.554)			−2.6% (0.324)	
g	No Screens	123,555	0.73		−4.0%*** (0.003)			−4.6%* (0.072)			−0.8% (0.800)	
h	Removing Outliers and Influencers	119,623	0.79		−4.3%*** (0.001)			−2.6% (0.205)			0.04% (0.989)	

Exhibit 6 | (continued)

Robustness Results

				Prior Announcement Turbine Effect			"Net" Post-Announcement Pre-Construction Turbine Effect			"Net" Post-Construction Turbine Effect		
				Inside 1/4 Mile	Inside 1/2 Mile	Between 1/2 and 1 Mile	Inside 1/4 Mile	Inside 1/2 Mile	Between 1/2 and 1 Mile	Inside 1/4 Mile	Inside 1/2 Mile	Between 1/2 and 1 Mile
#	Model Name	*n*	Adj. R^2	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
i	No Homes Near Negative Externalities	121,676	0.80		−2.4%*** (0.000)			−4.6% (0.101)			−1.3% (0.714)	
j	Using Indices of Disamenities	122,198	0.80		−6.4%*** (0.000)			0.3% (0.884)			−0.9% (0.730)	
k	Including Census Variables	122,198	0.80		−3.7%*** (0.000)			−2.8% (0.168)			0.2% (0.945)	
l	Including Spatial Variables	122,198	0.80		−5.3%*** (0.000)			−1.5% (0.467)			1.4% (0.621)	

Notes: An extensive set of robustness tests results in similar findings as the main base model: there is not a statistically significant difference in price of homes near turbines that sold before the turbines were erected as compared to those that sold after the turbines we built and operational. For simplicity, coefficient values are reported as percentages, although the actual conversion is 100*(exp(b) − 1)% (Halvorsen and Palmquist, 1980). In most cases, the differences between the two are de minimis, though, larger coefficient values would be slightly larger after conversion. *p*-values are in parentheses.

† Coefficient values are multiplied by 1,000 for reporting purposes only.

* Significant at 0.10.

** Significant at 0.05.

*** Significant at 0.01.

road reduces value by 2%–3%. Being within a half mile of a prison reduces value by 6%, but this result is only apparent in one of the periods. Similarly, being within a half mile of a landfill reduces value by 12% in only one of the periods, and being within a half mile of open space increases value by approximately 1% in two of the periods. Finally, being within 500 feet of an electricity transmission line reduces value by 3%–9% in two of the four periods. As noted above, the wind development periods are not meaningful as related to the amenity/disamenity variables, because they all likely existed well before this sample period—and therefore the turbine's operation—began. That said, they do represent different data groups across the dataset (one for each wind development period) and therefore are illustrative of the consistency of findings for these variables, with beaches, highways, and major roads showing very consistent results, while electricity transmission lines, open space, landfills, and prisons show more sporadic results.

Turning now to the variables that capture the effects in our sample, for being within a half mile of a turbine, we find interesting results (Exhibit 5). The coefficients for the *halfmile* variable over the four periods are as follows: *prioranc* (sale more than two years before the nearest wind turbine was announced) −5.1%, *preanc* (less than two years before announcement) −7.1%, *postancprecon* (after announcement but before the nearest turbine construction commenced) −7.4%, and *postcon* (after construction commenced) −4.6%.[17] Importantly, we estimate that home values within a half mile of a future turbine were lower than in the surrounding area even before wind-facility announcement. In other words, wind facilities in Massachusetts are associated with areas with relatively low home values, at least compared to the average values of homes more than a half mile but less than five miles away from the turbines. Moreover, when we determine if there has been a "net" effect from the arrival of the turbines, we must account for this preexisting *prioranc* difference. The net *postancprecon* effect is −2.3% ([−7.4%] − [−5.1%] = −2.3%; *p*-value 0.26). The net *postcon* effect is 0.5% ([−4.6%] − [−5.1%] = 0.5%: *p*-value 0.85).[18] Therefore, after accounting for the "preexisting price differential" that predates a turbine's development, there is no evidence of an additional impact from a turbine's announcement or eventual construction.

Robustness Test Results

To test and possibly bound the results from the base model, several robustness tests were explored. Exhibit 6 shows the robustness test results and the base model results for comparison. For brevity, only the "net" differences in value for the *postancprecon* and *postcon* periods are shown that quantify the *postancprecon* and *postcon* effects after deducting the difference that existed in the *prioranc* period.[19] Throughout the rest of this section, those effects will be referred to as net *postancprecon* and net *postcon*.

A number of key points arise from the results that have implications for stakeholders involved in wind turbine siting. For example, the effects for both the net *postancprecon* and net *postcon* periods for sales within a quarter mile of a turbine are positive and non-significant (which is believed to be a circumstance of the small dataset in that distance range, see Exhibit 3), providing no evidence of a large negative effect near the turbines (model a). Further, there are weakly significant net *postancprecon* impacts for relaxing the screens (−4.6%), indicating a possible effect associated with turbine announcement that disappears after turbine construction (model g). Finally, and most importantly, no model specification uncovers a statistically significant net *postcon* impact, bolstering the base model results. Moreover, all net *postcon* estimates for homes within a half mile of a turbine fall within a relatively narrow band that spans from zero (−2.6% to 1.4%), further reinforcing the non-significant results from the base model. Importantly, using an alternative representation of distance to turbine as a "distance decay" function as a robustness test (model e), and the set of three robustness tests used to test the way in which the disamenity variables were specified (models i, j, and k) did not change our results.

Discussion

In this study, we estimate a base hedonic model along with a large set of robustness models to test and bound the results. These results are now applied to our research questions.

Question 1: Have wind facilities in Massachusetts been located in areas where average home prices were lower than prices in surrounding areas (i.e., a preexisting price differential)?

To test for this effect, we examine the coefficient in the *prioranc* period, in which sales occurred more than two years before a nearby wind facility was announced. The −5.1% coefficient for the *prioranc* period (for home sales within a half mile of a turbine compared to the average prices of all homes between a half and five miles) is highly statistically significant (p-value < 0.000). This clearly indicates that houses near where turbines eventually are located are depressed in value relative to comparable houses further away. Other studies have also uncovered this phenomenon (Hoen et al., 2009; Hinman, 2010; Hoen et al., 2011). If the wind development is not responsible for these lower values, what is?

Examination of turbine locations reveals possible explanations for the lower home prices. Six of the turbines are located at wastewater treatment plants, and another eight are located on industrial sites. Some of these locations (e.g., Charlestown) have facilities that generate large amounts of hazardous waste regulated by Massachusetts and/or the U.S. Environmental Protection Agency and use large amounts of toxic substances that must be reported to the Massachusetts Department of Environmental Protection.[20] It is possible that the choice of these locations for wind development was driven, in part, by the preexisting land use. This is echoed by other researchers; Sims and Dent (2007, p. 5), after their examination of three locations in Cornwall, United Kingdom, commented that "wind farm developers are...locating their developments in places where the impact on prices is minimized, carefully choosing their sites to avoid any negative impact on the locality." Regardless of the reason for this preexisting price differential in Massachusetts, the effect must be factored into estimates of impacts due to the turbines' eventual announcement and construction—as this analysis does—if one is to accurately measure the incremental impact of turbines.

Question 2: Are post-construction (i.e., after wind-facility construction) home price impacts evident in Massachusetts, and how do Massachusetts results contrast with previous results estimated for more rural settings?

To test for these effects, we examine the "net" *postcon* effects (*postcon* effects minus *prioranc* effects), which account for the preexisting price differential. In the base model, with a *prioranc* effect of −5.0% and a *postcon* effect of −3.7%, the net effect is 1.2% and not statistically significant. Similarly, none of the robustness models reveal a statistically significant net effect, and the range of estimates from those models is −1.8% to 3.3%, effectively bounding the results from the base model. Therefore, in our sample of more than 122,000 sales, of which more than 21,808 occurred after nearby wind facility construction began (with 230 sales within a half mile), no evidence emerges of a *postcon* impact. This collection of *postcon* data within a half mile (and that within 1 mile: n = 1,501) is orders of magnitude larger than had been collected in previous North American studies and is large enough to find effects of the magnitude others have claimed to have found (e.g., Heintzelman and Tuttle, 2012; Grieser, Sunak, and Madlener, 2015).[21] Therefore, if effects are captured in our data, they are either too small or too sporadic to be identified.

These *postcon* results conform to previous analyses (Hoen, 2006; Sims, Dent, and Oskrochi, 2008; Hoen et al., 2009; Hinman, 2010; Carter, 2011; Hoen et al., 2011). Our study differs from previous analyses because we examine sales near turbines in more urban settings than had been studied previously. Contrary to what one might expect, there do not seem to be substantive differences between our results and those found by others in more rural settings. Thus it seems possible that turbines, on average, are viewed similarly (i.e., with only small differences) across these urban and rural settings.

Question 3: Is there evidence of a post-announcement/pre-construction effect (i.e., an "anticipation effect")?

To answer this question, we examine the "net" *postancprecon* effect (*postancprecon* effect of −7.4% minus *prioranc* effect of −5.1%), which is −2.3% and not statistically significant. This base model result is bounded by robustness-model *postancprecon* effects ranging from −4.6% to 1.6%. One of the robustness models reveals a weakly statistically significant effect of −4.6% (p-value 0.07) when the set of data screens is relaxed. It is unclear, however, whether these statistically significant findings result from spurious data or multicollinearity parameters, examination of which is outside the scope of this research. Still, it is reasonable to say that these *postancprecon* results, which find some effects, *might* conform to effects found by others (Hinman, 2010), and, to that extent, they *might* lend credence to the anticipation effect put forward by Hinman and others (e.g., Wolsink, 2007; Sims, Dent, and Oskrochi, 2008; Hoen et al., 2011), especially if future studies also find such an effect. For now, we can only conclude that there is weak and sporadic evidence of a *postancprecon* effect in our sample.

Question 4: How do impacts near turbines compare to the impacts of amenities and disamenities also located in the study area, and how do they compare with previous findings?

The effects on house prices of our amenity and disamenity variables are remarkably consistent with a priori expectations and stable throughout our various specifications. The results clearly show that home buyers and sellers account for the surrounding environment when establishing home prices. Beaches (adding 20%–30% to price when within 500 feet, and adding 5%–13% to price when within a half mile), highways (reducing price 4%–8% when within 500 feet), and major roads (reducing price 2%–3% when within 500 feet) affected home prices consistently in all models. Open space (adding 0.6%–0.9% to price when within a half mile), prisons (reducing price 6% when within a half mile), landfills (reducing price 13% when within a half mile), and electricity transmission lines (reducing price 3%–9% when within 500 feet) affected home prices in some models.

Our disamenity findings are in the range of findings in previous studies. For example, Des Rosiers (2002) found price reduction impacts ranging from 5% to 20% near electricity transmission lines, although those impacts faded quickly with distance. Similarly, the price reduction impacts we found near highways and major roads appear to be reasonable, with others finding impacts of 0.4%–4% for homes near "noisy" roads (Andersson, Jonsson, and Ogre, 2010; Bateman, Day, and Lake, 2001; Blanco and Flindell, 2011). Further, although sporadic, the large price reduction impact we find for homes near a landfill is within the range of impacts in the literature (Ready, 2010), although this range is categorized by volume: an approximately 14% home price reduction effect for large-volume landfills and a 3% effect for small-volume landfills. One potential explanation for the sporadic nature of the coefficients is the small number of observations. The sample of landfills in our study does not include information on volume, thus we cannot compare the results directly.

Our amenity results are also consistent with previous findings. For example, Anderson and West (2006) found that proximity to open space increased home values by 2.6% per mile and ranged from 0.1% to 5%. Others have found effects from being on the waterfront, often with large value increases, but none have estimated effects for being within 500 feet or outside of 500 feet and within a half mile of a beach, as we did, and therefore we cannot compare results directly.

Clearly, home buyers and sellers are sensitive to the home's environment in our sample, consistently seeing more value where beaches and open space are near and less where highways and major roads are near, with sporadic value distinctions where landfills, prisons, and electricity line corridors are near. This observation not only supports inclusion of these variables in the model because they control for potentially collinear aspects of the environment, but it also strengthens the claim that the market represented by our sample does account for surrounding amenities and disamenities that are reflected in home prices. Therefore, buyers and sellers in the sample should also have accounted for the presence of wind turbines when valuing homes.

Question 5: Is there evidence that houses that sold during the post-announcement and post-construction periods did so at lower relative rates than during the pre-announcement period?

To test for this sales-volume effect, we examine the differences in sales rate in fixed distances from the turbines over the various development periods (see Exhibit 3). Approximately 0.29% of all homes in our sample (i.e., inside of ten miles from a turbine) that sold in the *prioranc* period are within a half mile of a turbine. That percentage increases to 0.50% in the *postancprecon* period and then drops to 0.39% in the *postcon* period for homes within a half mile of a turbine. Similarly, homes located between a half mile and 1 mile sold, as a percentage of all sales out to ten miles, at 1.9% in the *prioranc* period, 1.8% in the *postancprecon* period, and 2.2% in the *postcon* period (and similar results are apparent for those few homes within a quarter mile). Neither of these observations indicates that the rate of sales near the turbines is affected by the announcement and eventual construction of the turbines, thus we can conclude that there is an absence of evidence to support the claim that sales rate was affected by the turbines.[22]

Conclusion

In this study, we investigate a common concern of people who live near planned or operating wind developments: How might a home's value be affected by the turbines? Previous studies on this topic, which have largely coalesced around non-significant or relatively small findings, focused on rural settings. Wind facilities in urban locations could produce markedly different results. Nuisances from turbine noise and shadow flicker might be especially relevant in urban settings where other negative features, such as landfills or high-voltage utility lines, have been shown to reduce home prices. To determine whether wind turbines have a negative impact on property values in urban settings, we analyze more than 122,000 home sales, between 1998 and 2012, that occurred near the current or future location of 41 turbines in densely populated Massachusetts. Over 1,100 transactions were within a half mile of the turbines, an amount ample enough to gauge relatively small effects.

The results of this study do not support the claim that wind turbines affect nearby home prices. Although we found the effects on home prices from a variety of negative features (such as electricity transmission lines, landfills, prisons, and major roads) and positive features (such as open space and beaches) that accorded with previous studies, we found no net effects due to the arrival of turbines in the sample's communities. Weak evidence suggests that the announcement of the wind facilities had an adverse impact on home prices, but those effects were no longer apparent after turbine construction and eventual operation commenced. The analysis also showed no unique impact on the rate of home sales near wind turbines. These conclusions were the result of a variety of model and sample specifications.

We identify a number of areas for future work. Because much of the existing work on wind turbines has focused on rural areas, which is where most wind facilities have been built, there is no clear understanding of how residents would view the introduction of wind turbines in landscapes that are already more industrialized. Therefore, investigating residents' perceptions, through survey instruments, of wind turbines in more urbanized settings may be helpful. Policy-makers may also be interested in understanding the environmental attitudes and perceptions towards wind turbines of people who purchase houses near wind turbines after they have been constructed. Also, we aggregate the effects of wind turbines on the price of single-family houses for the study area as a whole. Although the data span an enormous range of sales prices, and contain the highest mean value of homes yet studied, it might be fruitful to analyze impacts partitioned by sales price or neighborhood to discover whether the effects vary with changes in these factors. One additional characteristic of home sales that may be worth investigating in future research is whether or not the amount of time that a house is on the market (TOM) is affected by the announcement or construction of a wind turbine.

Appendix
Full Set of Results

	Coeff.	SE	*t*-stat.	*p*-value
Intercept	12.15	0.01	1133.88	0.000
Within a half mile of a wind turbine				
prioranc	−0.051	0.01	−3.95	0.000
preanc	−0.071	0.02	−3.08	0.002
postancprecon	−0.074	0.02	−4.34	0.000
postcon	−0.046	0.03	−1.74	0.081
Net difference compared to *prioranc* period within a half mile of a wind turbine				
postancprecon	−0.023	0.02	−1.12	0.264
postcon	0.005	0.03	0.19	0.853

Appendix (continued)

Full Set of Results

	Coeff.	SE	*t*-stat.	*p*-value
Within 500 feet of a electricity transmission line				
prioranc	−0.030	0.01	−3.41	0.001
preanc	−0.009	0.02	−0.59	0.556
postancprecon	−0.009	0.01	−0.64	0.522
postcon	−0.093	0.02	−4.79	0.000
Within 500 feet of a highway				
prioranc	−0.073	0.01	−14.28	0.000
preanc	−0.052	0.01	−4.57	0.000
postancprecon	−0.037	0.01	−4.16	0.000
postcon	−0.053	0.01	−3.95	0.000
Within 500 feet of a major road				
prioranc	−0.028	0.00	−12.18	0.000
preanc	−0.023	0.00	−5.05	0.000
postancprecon	−0.025	0.00	−5.43	0.000
postcon	−0.020	0.00	−4.01	0.000
Within a half mile of a landfill				
prioranc	0.018	0.02	1.18	0.239
preanc	−0.009	0.03	−0.28	0.780
postancprecon	0.010	0.03	0.31	0.756
postcon	−0.122	0.04	−3.08	0.002
Within a half mile of a prison				
prioranc	−0.059	0.02	−3.38	0.001
preanc	0.024	0.02	1.05	0.291
postancprecon	0.028	0.02	1.64	0.100
postcon	−0.020	0.09	−0.22	0.829
Within 500 feet of a beach				
prioranc	0.208	0.02	12.71	0.000
preanc	0.304	0.03	12.09	0.000
postancprecon	0.253	0.02	12.72	0.000
postcon	0.259	0.02	16.95	0.000
Within a half mile and outside of 500 feet of a beach				
prioranc	0.053	0.01	10.07	0.000
preanc	0.088	0.01	10.52	0.000
postancprecon	0.087	0.01	11.99	0.000
postcon	0.135	0.01	17.30	0.000
Within a half mile of open space				
prioranc	0.006	0.00	2.31	0.021
preanc	0.001	0.00	0.35	0.729
postancprecon	0.001	0.00	0.12	0.903
postcon	0.009	0.00	1.87	0.062

Appendix (continued)
Full Set of Results

	Coeff.	SE	*t*-stat.	*p*-value
Living area in thousands of square feet				
prioranc	0.229	0.00	86.37	0.000
preanc	0.214	0.01	41.62	0.000
postancprecon	0.226	0.00	48.41	0.000
postcon	0.235	0.01	46.58	0.000
Lot size in acres				
prioranc	0.011	0.00	6.67	0.000
preanc	0.019	0.00	6.51	0.000
postancprecon	0.013	0.00	4.17	0.000
postcon	−0.001	0.00	−0.17	0.863
Lot size less than 1 acre				
prioranc	0.217	0.01	34.79	0.000
preanc	0.172	0.01	18.45	0.000
postancprecon	0.147	0.01	16.03	0.000
postcon	0.221	0.01	21.71	0.000
Age of the home at time of sale				
prioranc	−0.002	0.00	−21.87	0.000
preanc	−0.002	0.00	−11.33	0.000
postancprecon	−0.002	0.00	−13.99	0.000
postcon	−0.003	0.00	−16.47	0.000
Age of the home at time of sale squared				
prioranc	0.00001	0.00	28.55	0.000
preanc	0.00001	0.00	17.03	0.000
postancprecon	0.00001	0.00	20.01	0.000
postcon	0.00001	0.00	26.40	0.000
Number of bathrooms				
prioranc	0.064	0.00	29.22	0.000
preanc	0.079	0.00	17.98	0.000
postancprecon	0.084	0.00	20.31	0.000
postcon	0.111	0.00	25.54	0.000
Sale year				
1998	−0.52	0.007	−73.48	0.000
1999	−0.41	0.007	−58.44	0.000
2000	−0.26	0.007	−37.59	0.000
2001	−0.13	0.007	−18.03	0.000
2002	0.02	0.007	2.33	0.020
2003	0.14	0.007	21.26	0.000
2004	0.24	0.007	37.05	0.000
2005	0.31	0.006	49.32	0.000
2006	0.28	0.006	43.94	0.000

Appendix (continued)

Full Set of Results

	Coeff.	SE	t-stat.	p-value
2007	0.23	0.006	37.58	0.000
2008	0.12	0.006	18.43	0.000
2009	0.04	0.006	7.29	0.000
2010	0.04	0.006	6.15	0.000
2011	−0.02	0.006	−3.74	0.000
2012	Omitted			
Sale quarter				
1	−0.07	0.002	−28.05	0.000
2	−0.02	0.002	−9.56	0.000
3	Omitted			
4	−0.01	0.002	−3.03	0.002

Notes: n = 122,198; $R^2 = 0.80$; Adj. $R^2 = 0.80$; and F = 2,418.

Endnotes

1 Heintzelman and Tuttle (2012) do not appear convinced that the effect they found is related to the post-announcement period, yet the two counties in which they found an effect (Clinton and Franklin Counties, New York) had transaction data produced almost entirely in that period.

2 Defined as accepting more than 500 tons per day.

3 Any preexisting price differential, by definition, does not exist because of the turbines, but instead is likely the result of the fact that wind turbines may be located in areas of relative disamenity. There are some known possible explanations for these possible latent effects, such as being co-located with a wastewater treatment facility or an industrial facility, as is the case for some wind facilities in Massachusetts. Further, there might be unknown effects. We were not able to obtain reliable data on the wastewater and industrial facilities, and any other unknown effects, and therefore estimated the DID model to control for those. We did include seven different amenities and disamenities in our model to account for many of these latent effects.

4 We used this cut-off point because installations smaller than this built on individual properties would theoretically not have spatial spillover effects.

5 We purchased the data for these variables from the Warren Group. Any duplicate observations, cases where key information is missing, or observations where the data appeared to be erroneous are removed from the dataset. Screens are used to remove sales prices lower than \$40,000 and over \$2,500,000; properties with more than 12 bathrooms or bedrooms; lot size greater than 25 acres; and sale price per square foot less than \$30 or more than \$1,250. These screens are relaxed for a robustness test, creating no significant change to the results.

[6] Although not shown in the exhibit, homes nearest the turbines are consistently lower in value in all development periods than homes further away, but also have less living area, are on slightly smaller parcels, and are a bit younger in age. Homes outside of a half mile but inside of five miles are relatively similar in terms of price, age, size, and parcel size, but homes outside of five miles are higher in value, larger, younger, and are on slightly larger parcels. Full summary statistics are available from the authors upon request.

[7] An anonymous reviewer suggested we consider not using the spline function but instead the natural log of lot size. Our results are robust to this alternative specification.

[8] A binary variable is used to represent whether a property is located in a particular Census Tract or not.

[9] Each of the amenity/disamenity variables are expressed as a binary variable: 1 if "yes," 0 if "no," giving a total of seven individual binary variables. In addition, we use factor analysis to generate three indices of disamenity based on these individual variables, which are subsequently used in the regression in place of the individual binary variables as a robustness check. We assume that all disamenities existed prior to the wind facilities' development.

[10] We use separate yearly and quarterly binary variables and assume that seasonality is constant over time. We did, however, conduct a robustness test using separate binary variables for each year and quarter, and because the results are unchanged, opted to use the more parsimonious specification.

[11] Our results for the wind turbine variables are robust to alternative specifications without these interactions.

[12] While the coefficients associated with the amenity/disamenity variables interacted with the facility development periods are not particularly meaningful, creating the subsets enables examination of the data represented by the different wind turbine development periods and shows how stable the amenity/disamenity variables are with these subsets of data.

[13] One anonymous reviewer suggested we estimate a two-step Heckman model, but because the form of the model used for this analysis utilized a large set of fixed effect and dummy variables, which are not acceptable when estimating a Heckman model in Stata, we were not able to explore this method.

[14] LeSage and Pace (2009) argue that including an expression of neighboring observations (i.e., a spatial lag, known as Wy) of the dependent variable (i.e., sale price) in the model is appropriate for dealing with these omitted variables. They show that spatially dependent omitted variables generate a model that contains spatial lags of the dependent and exogenous variables, known as the spatial Durbin model (Anselin, 1988). Ideally, we would have estimated these models, but this was not possible because of computing limitations.

[15] All models are estimated using the .areg procedure in Stata MP 12.1 with robust estimates, which corrects for heteroscedasticity. The effects of the census tracts are absorbed. Results are robust to an estimation using the .reg procedure.

[16] The results are robust to the exclusion of these interactions, but theoretically we believe this model is the most appropriate, so it is presented here.

[17] Although a post-construction effect is shown here and for all other models, a post-operation (after the turbine was commissioned and began operation) effect is also estimated and is no different than this post-construction effect.

[18] These linear combinations are estimated using the post-estimation .lincom test in Stata MP 12.1.

[19] The full set of robustness results is available upon request.

[20] See, e.g., http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/dep-bwp-major-facilities-.html.

[21] However, as discussed earlier, their findings might be the result of their continuous distance specification and not the result of the data; moreover, although Heintzelman and Tuttle (2012) claim to have found a *postcon* effect, their data primarily occurs prior to construction.

[22] This conclusion is confirmed with Friedman's two-way analysis of variance for related samples using period as the ranking factor, which confirms that the distributions of the frequencies across periods is statistically the same.

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This work was supported in part by the Massachusetts Clean Energy Center and 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. We thank the anonymous reviewers for their insightful comments. A previous version of this paper received the Marc Louargand Award for the Best Research Paper by a Practicing Real Estate Professional presented at the 2014 ARES Annual Meeting.

Ben Hoen, Lawrence Berkeley National Laboratory, Berkeley, CA 94720-8136 or bhoen@lbl.gov.

Carol Atkinson-Palombo, University of Connecticut, Storrs, CT 06269-4148 or carol.atkinson-palombo@uconn.edu.

Megan Zumbuhl

From: Denis Tracy
Sent: Tuesday, December 16, 2025 2:14 PM
To: Megan Zumbuhl
Subject: FW: Wind Code Public Hearing Comment
Attachments: Sample Real Value Protection Plan.docx

From: Julie Clarkson <jclark766@hotmail.com>
Sent: Tuesday, December 16, 2025 2:03 PM
To: Alan Thomson <Alan.Thomson@whitmancounty.gov>; Grace Di Biase <Grace.DiBiase@whitmancounty.gov>; Commissioners <commissioners@whitmancounty.gov>
Cc: Denis Tracy <DenisT@whitmancounty.gov>
Subject: Wind Code Public Hearing Comment

Whitman County Commissioners
Whitman County Planning Commission
Whitman County Planner

Thank you for your work on updating the Wind Energy Code for Whitman County. Improvements from the prior version have been made including adding exclusion zones, underground cabling, fire mitigation requirements and a section covering decommissioning. While the increase in setbacks is an improvement, they are insufficient to address the health safety concerns caused by these industrial towers or allow adequate space for air access such as crop dusting for the local terrain, life-flight, or air fire mitigation should the need occur. Pilots have testified that the current setback of 6x height is insufficient. Who is liable should someone die because a medevac helicopter could not get close enough to someone needing medical care due to the massive turbine on a neighbor's property? Especially if pilots and community members are stating that the setbacks are insufficient but a shorter distance is approved by the Commissioners anyway.

In addition to insufficient setbacks, my major area of concern that has not been addressed is a property value guarantee / real value protection plan. Neighbors should not have to assume the risk and pay the price of reduced land values so a handful of other landowners, most who no longer actually live here, can make a profit. The attached sample was pulled from Carteret County North Carolina: https://library.municode.com/nc/carteret_county/codes/code_of_ordinances?nodeId=COOR_APXFTAST_ART3WIENFA

There are certainly other areas that need improvements such as a requirement for noise studies and limits, erosion control, addressing water needs for construction, agDRIFT (drift of chemicals caused by the rotating

E-10

blades), height limits, and general cleanup of grammatical issues throughout the document which reflect poorly on our county. I'm sure other citizens have provided feedback on items I have missed.

I understand the urgency in recording some updates to the Whitman County Wind Ordinance Code and am supportive of approving the submitted draft with amendments to the setbacks to the greater of 1.5 miles or 10 times the height of the turbine, then extending the moratorium for a couple more months to finish the remaining updates.

Thank you.

Julie Clarkson-Gulick

Sent from Outlook

Sample **Real Value Protection Plan**. This might help address concerns from citizens of the county. The below is from Carteret County, North Carolina https://library.municode.com/nc/carteret_county/codes/code_of_ordinances?nodeId=COOR_APXFTAST_ART3WIENFA

Sec. 3-13. - Real property value protection plan.

The WEF Owner(s) ("Applicant") shall assure the County that there will be no loss in real property value within two miles of each wind turbine within their WEF. To legally support this claim, the Applicant shall consent in writing to a Real Property Value Protection Agreement ("Agreement") as a condition of approval for the WEF. This Agreement shall provide assurance to non-participating real property owners (i.e. those with no turbines on their property) near the WEF, that they have some protection from WEF-related real property values losses.

The Applicant shall agree to guarantee the property values of all real property partially or fully within two miles of the WEF. Any real property owner(s) included in that area who believe that their property may have been devalued due to the WEF, may elect to exercise the following option:

3-13.1. All appraiser costs are paid by the Applicant, from the Escrow Account. Applicant and the property owner shall each select a licensed appraiser. Each appraiser shall provide a detailed written explanation of the reduction, if any, in value to the real property ("Diminution Value"), caused by the proximity to the WEF. This shall be determined by calculating the difference between the current Fair Market Value (FMV) of the real property and what the FMV would have been at the time of exercising this option, assuming no WEF was proposed or constructed.

A. If the higher of the Diminution Valuations submitted is equal to or less than 25 percent more than the other, the two values shall be averaged ("Average Diminution Value": ADV).

B. If the higher of the Diminution Valuations submitted is more than 25 percent higher than the other, then the two appraisers will select a third licensed appraiser, who shall present to Applicant and property owner a written appraisal report as to the Diminution Value for the real property. The parties agree that the resulting average of the two highest Diminution Valuations shall constitute the ADV.

C. In either case, the property owner may elect to receive payment from Applicant of the ADV. Applicant is required to make this payment within 60 days of receiving said written election from property owner, to have such payment made.

3-13.2. Other Agreement Conditions:

A. If a property owner wants to exercise this option, they must do so within ten years of the WEF receiving final approval from the County.

B. A property owner may elect to exercise this option only once.

C. The Applicant and the property owner may accept mutually agreeable modifications of this Agreement, although the Applicant is not allowed to put other conditions on a financial settlement (e.g. confidentiality). If the property owner accepts some payment for property value loss, based on an alternative method that is considered an exercise of this option.

E-11

D. This Agreement applies to the property owner of record as of the date of the WEF application, and is not transferrable to subsequent owners.

E. The property owner of record as of the date of the WEF application must reasonably maintain the property from that time, until they choose to elect this option.

F. The property owner must permit full access to the property by the appraisers, as needed to perform the appraisals.

G. The property owner must inform the appraisers of all known defects of the property as may be required by law, as well as all consequential modifications or changes to the property subsequent to the date of the WEF application.

H. This Agreement will be guaranteed by the Applicant (and all its successors and assigns), for ten years following the WEF receiving final approval from the County, by providing a bond (or other surety), in an amount determined to be acceptable by the County.

I. Payment by the Applicant not made within 60 days will accrue an interest penalty. This will be 12 percent annually, from the date of the written election from property owner.

J. For any litigation regarding this matter, all reasonable legal fees and court costs will be paid by the Applicant.

K. Upon application, Applicant shall provide a performance bond (or equivalent) in an amount determined by the County and held by the County. This surety account will ensure execution of all aspects of this Agreement (including compensation of eligible property owners in the case of default by Applicant). Failure to maintain this surety account shall be cause for revocation (or denial of renewal) of the WEF Permit.

From Carol Black, Citizen of Whitman County

April 23, 2025

Whitman County Commissioners
Whitman County Planning Commission
Whitman County Planner

Attached is a downloaded and formatted County Code 9.05 Critical Areas. This is the county governance that I referenced in my earlier written communications and public testimony.

During a recent Planning Commission meeting, County Planner Alan Thomson stated that 9.05 Critical Areas "only affected" certain critical areas; reference the minutes for specifics.

I recognize that Section 9.05.060 addresses areas "regulated" by the code. **However,** the code addresses "aesthetic value protection" in section 9.05.030. I quote from section 9.05.030 C: "The County finds that critical areas provide a variety of valuable and beneficial biological and physical functions that benefit the County and its residents, and/or may pose a threat to human safety or to public and private property. The beneficial functions and values provided by critical areas include, but are not limited to, water quality protection and enhancement, fish and wildlife habitat, food chain support, flood storage, conveyance and attenuation of flood waters, ground water recharge and discharge, erosion control, protection from hazards, historical, archaeological, and aesthetic value protection, and recreation."

The aesthetic importance of the **Palouse Rolling Hills** is well known to many citizens in Whitman County, as well as to WSU alumni and photographers who visit and spend significant dollars supporting our local businesses. Kamiak Butte is a **National Natural Landmark**. The Planning Commission and Commissioners must make sure that Chapter 19.61 includes reference to these stated 9.05.030 protections because the viewshed is "valuable and a significant benefit to the County and its residents." Other areas within Whitman County do not have the same viewshed impacts as those around the cities of Colfax, Pullman, and Palouse, where the majority of county citizens live, drive, and recreate. There may be other locations in the county close to dams and power infrastructure that are more appropriate to consider for alternate energy.

The county, over the years, has maintained codes to protect the viewshed of skylines/ridgelines. The County Planner has enforced these codes over the years; thus, we do not have houses located on ridgelines in the rural, agricultural area. Rural houses have to provide viewshed protections from other houses – on a horizontal plane – not even a vertical plane. This whole vertical obstruction is not well covered in the code and must be.
Examples of codes addressing views:

- 19.40.010 **Declaration of Intent.** The purpose and intent of the RCR district is to provide a single-family residential zone for the unincorporated rural communities of the County. The intent of this district is the preservation of a rural agriculturally-oriented life style including the keeping of animals for pleasure or profit, retaining low to medium density development, and providing for a mixture of residential uses with buildings necessary to farming operations.
- 19.40.010 and 19.12.050 **Height of Buildings**
- 19.10.060 B1b – **Viewshed Site - Rural Residential Use**

E-12

Placing towering monoliths in the Palouse Hills viewshed between Colfax, Albion, Palouse, and Kamiak Butte is not protecting what the citizens consider valuable and important to their quality of life in a rural county.

Respectfully,

Carol Black

TCC
Pre-Filed Testimony
Kurt Kielisch
EXH-5812_R

Key Report

Real Estate Consulting Report

Impact Analysis of the Niyol Wind Farm on Surrounding Rural Residential and Agricultural land Values in Logan County Colorado

Property value

Appraiser assessment ~ critique

FORENSIC APPRAISAL GROUP

E-13

PREPARED FOR:

Concerned Citizens for a Safe Logan County
c/o Lauren Gerk
1321 W. Main Street #28
Sterling, CO 80751

DATE OF REPORT:

June 11, 2020

CONSULTING REPORT PREPARED BY:

FORENSIC APPRAISAL GROUP
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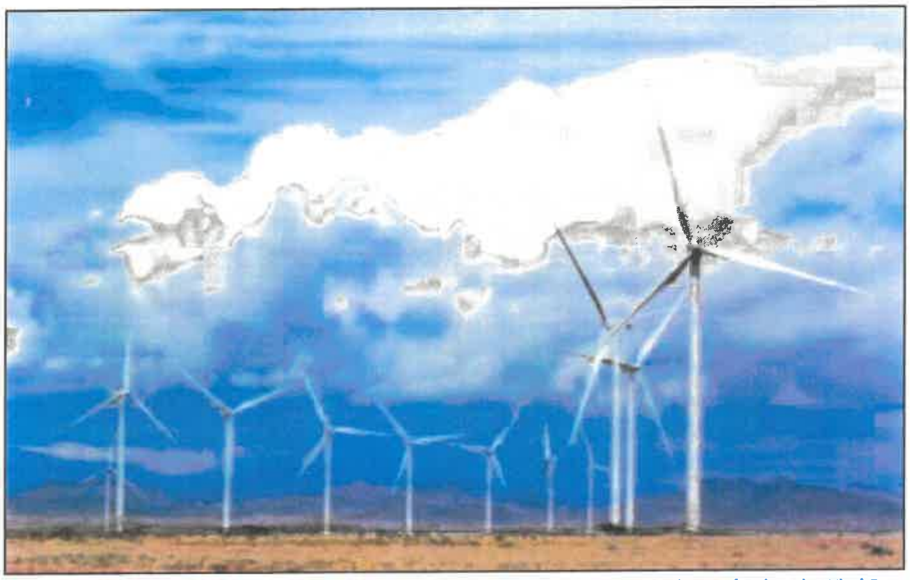
Table of Contents


Stock photo of Colorado Wind Farm

Impact Analysis of the Niyol Wind Farm on Surrounding Rural Residential and Agricultural land Values in Logan County Colorado

Report Summary

This report was contracted by Concerned Citizens for a Safe Logan County for our opinion on how the Niyol Wind LLC will impact rural residential and agricultural farm values within the wind farm footprint and 1-mile outside of this zone of this proposed wind farm.

Proposed Wind Farm

The proposed 200.8MW wind farm is called the Niyol Wind LLC. The developer is Niyol Wind, LLC, which is a wholly owned subsidiary of NextEra Energy, a Delaware Corporation (700 Universe Boulevard, Juno Beach, Florida). The wind farm is located in the Fleming area, Logan County, Colorado. The conditional use permit submitted by Niyol states that the wind farm will occupy 39,314 acres of area. The development will have 89 wind turbines, having a height (including the tower and blades at 12 o'clock position) of 495ft -505ft. The project will include graveled access roads over private land to the wind turbines, a maintenance area of approximately 4-acres, a substation of 10-acres graveled with a chain-link security fence and outside yard lighting, two meteorological towers being 275ft in height, underground and above ground electrical supply lines and a thirty-one mile 230kV high voltage transmission line that is to link up with an existing high voltage transmission line for transmission of the produced energy.

The three-blade wind turbines will be one of two models: the GE 2.5MW turbine or the GE 2.8MW

Turbine. Their designs follow.

Figure 1 GE 2.5 MW Turbine Diagram

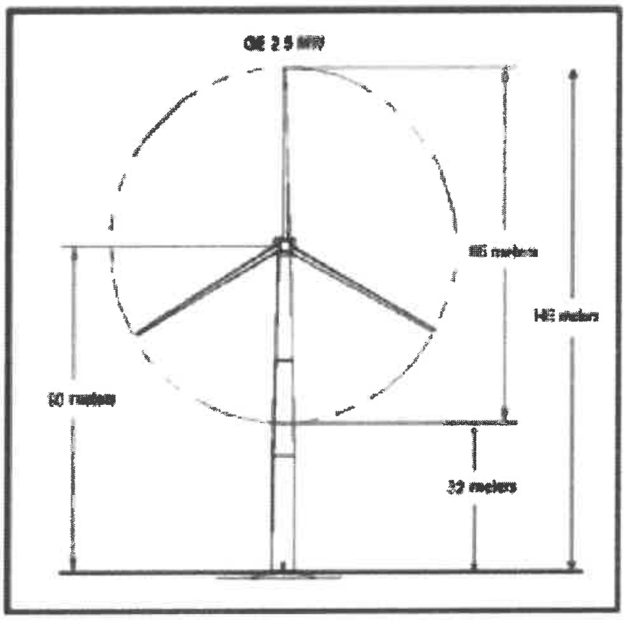
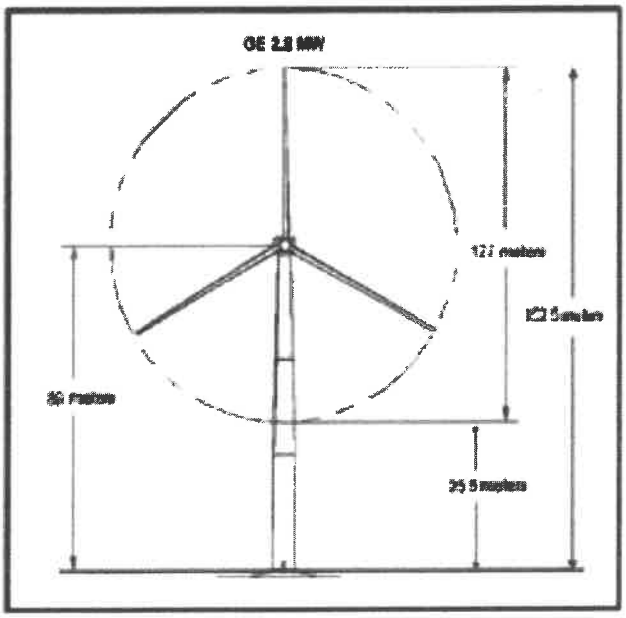
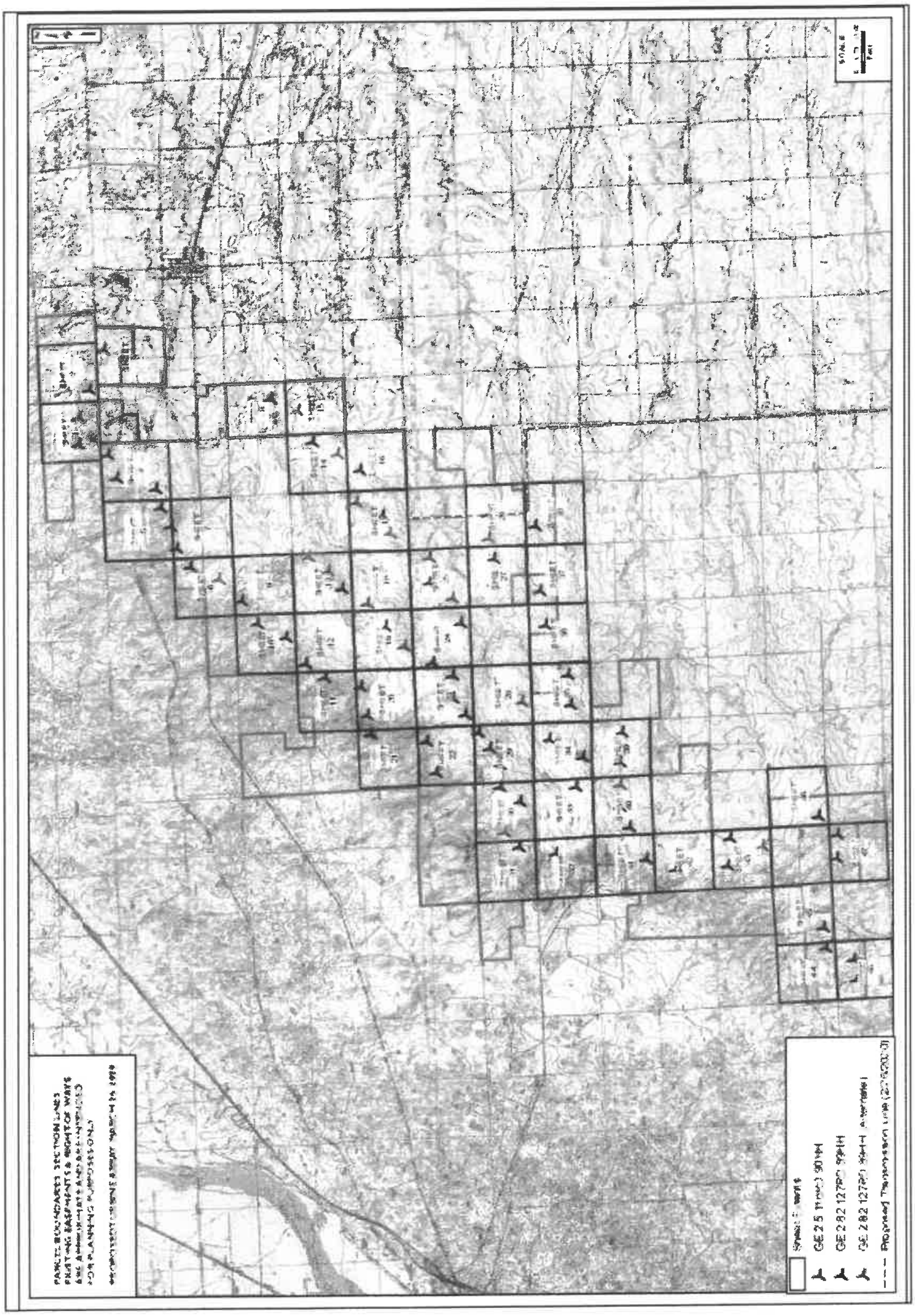


Figure 2. GE 2.8 MW Turbine Diagram



The electrical collector lines are to be buried, the collector substation is above ground and connected to an overhead 230kV high voltage transmission line. The map on the next page illustrates the wind farm project.



Format of Study

The format of the study is in three parts. The first part is a qualitative analysis. The second is a quantitative analysis. The third is to apply the qualitative and quantitative conclusions to the subject properties.

A *qualitative* analysis is an analysis that is focused on non-empirical data to guide a conclusion of value. An example would be an observation that a home has better landscaping than another. Another example would be opinion surveys. Application of this type of analysis is helpful in forming a "yes/no" answer to the question "Does proximity to wind turbines negatively impact property value?"

A *quantitative* analysis is an analysis that is focused on empirical or measurable data to guide a conclusion of value. An example would be a matched pair comparison of a sale of a property influenced by a wind turbine as compared to one that is not. The difference in value is measurable. Another example would be a regression analysis whereas the sale price of several "influenced" properties would be compared to the several "non-influenced" properties. Again, a measurable event.

The advantage of using both methods is that they have a symbiotic relationship and help give a full picture of both the motivations and results of such motivations by the buying public to a particular issue. In this case, the presence of a wind farm.

The first part is a literature study to discover what the buying public is reading, viewing and learning through various communication platforms regarding wind farms and land use which would impact their opinion of value. This is a *qualitative* analysis of the impact on property value. The literature study was broad in scope focusing mostly on North America but including other developed nations. We did this for two reasons. First, the typical buyer of properties that would be impacted by wind farms develop their perception of property value and its use from not only their own observations but observations of others. Though these buyers will be from the United States they are sophisticated to understand that the impacts of wind farms are not a locale geographic issue. Second, these same buyers understand the wind turbines being utilized in other developed countries are the same or similar to the ones utilized in the United States, therefore the impacts would be similar.

The second part is a summary of wind farm value impact studies that are applicable to this analysis. This is a quantitative analysis of the impact on property value. The impact studies that were reviewed include both published and unpublished studies, large and small in scope. These studies tend to counter the utility corporate sponsored studies and need to be included as they give insight to the potential impacts that wind farms have on property value.

The third part is to apply the qualitative and quantitative studies to the rural residential and agricultural property values within the Niyol wind farm footprint and also a 1-mile perimeter outside of the wind farm.

Results of Study

The study results are summarized as follows.

Literature Study	The media generally portrays the impact of wind turbines on residential properties as negative, bringing up fear factors and conflicting benefit, or no benefit issues. Overall, the qualitative factor is centered along the lines of health, noise, flicker, and viewshed. With regard to the question, "Do wind turbines affect property value?" the two Centerville Township (Michigan) officials summed it up with this statement: "It is totally counter-intuitive to suggest anything else."
Impact Studies	Wind industry and government supported studies found little to no evidence of an impact. However, independent studies found a significant impact using a variety of valuation methods from paired sales analysis to multi-regression analysis. The Landsink (Ontario, CA) study found a loss range of -8.85% to -50%, with a loss average of -39% for residential homes within 664ft to 2,531ft of a wind farm. The Appraisal Group One Wisconsin Study found a typical loss of 1-10 acre residential lots within ½-mile of wind turbines to be -19% to -40%. The Clarkson University upstate New York study of both residential and agricultural properties found a loss ranging from -15.6% to -31% within 1-3 miles of a wind farm. The Forensic Appraisal Coral Springs (WY) study of large residential lots (35 acres) which would be abutting a proposed wind farm suffered a value impact of -25% to -44%. The McCann study (IL) of residential properties found an average impact of -25% within 2-miles of a wind farm. The Forensic Appraisal Big Sky (IL) study found a loss range of -12% to -25% of residences within 0.31mi to 1.72mi of a wind turbine, with an average impact of -19% at an average distance of 0.65 miles to a wind turbine. The Twin Grove II Wind Farm (McLean County, IL) study of a 198MW wind farm comprised of 120 turbines being 397ft in height over an 11,000 acres area. A paired sales analysis of residential property within the influence of the wind farm found the improved property is negatively impacted by the presence

	of wind turbines. The impact measured ranged from -46.6% to -7.7%, with the higher impact closest to the wind turbines and the impact diminishing as the distance is increased. The distances measured ranged 1,483ft to 5,481ft away from a residence. The Twin Grove II Wind Farm also found an overall impact of -6.63% to -8.5% for vacant agricultural properties within the wind farm zone.

Application of Studies to the Niyol Wind Farm

The quantitative analysis provided by the studies and qualitative analysis provided by the literature review submitted in this report show two different stories.

One story is that there is no impact on property value due to the presence of wind turbines regardless of the distance to the property. The authors of this position tend to be academicians using statistical analysis. This story is difficult to accept for if we were to take it at face value, we would have to conclude that viewsheds do not matter (Hoen et al refutes that position in their discussion of viewsheds) and no distance to a wind turbine is too close. Comments from Realtors through surveys, testimony, and letters refute that notion. Logic would also question that position. A survey of experienced appraisers who attended the Appraisal Institute webinar Wind Turbine Effects on Value (March 2015, Hoen & Jackson) [1] overwhelmingly stated that they believe wind turbines negatively impact property value. To add to the disbelief of the "no impact" position is that the wind farm developers consistently refuse to "guarantee" that there will be no property loss or purchase the properties from property owners who desire to leave the area due to the development. If the wind developers believed these studies, there would be no risk in taking such a position and it would effectively negate opposition. (As a side note, electrical transmission line developers in Minnesota must buy any property that is encumbered with a new electric transmission if the property owner claims the "buy the farm" provision. So, though rare, there is a precedent of energy developers buying properties that are impacted, or thought to be impacted, by their development.)

The other story is that there is a measurable negative impact on property value due to the presence of wind turbines and that this impact is in direct relation to the distance and viewshed of the turbines. The authors of this position are dominated by real estate appraisers and realtors, often utilizing comparative sales analysis as their method of study. The results of these studies (and others completed by some academicians) have cited losses from 10% to over 50% depending on the distance and viewshed factors. Additionally, they have concluded that these losses are found to begin at the wind farm announcement stage leading to the post-construction stage.

Agricultural land also is impacted by the presence of a wind farm losing -6.3% to -8.5% of its overall value if located within a wind farm.

It is concluded that the qualitative and quantitative evidence supports the position that the presence of

1 *Wind Turbine Effects on Value*. Appraisal Institute, Chicago. March 5, 2015. Ben Hoen and Thomas Jackson, Ph.D., were the presenters.

wind turbines in close proximity to properties will have a negative impact on property value and this impact is permanent. And, the closer the properties are the wind turbines the greater the impact.

We conclude that the following impacts will be experienced by the Niyol wind farm on the client's properties:

Properties within the Wind Farm Footprint= -35% impact on property value
Properties 1-Mile outside of the Wind Farm Footprint = -22% impact on property value
Agricultural Properties within the Wind Farm Footprint= -8.5% impact on property value

Application of these estimated losses to the client's property value is:

Niyol Wind Farm Loss to Property Value Estimate			
	total assessed value	impact	value loss
Properties within the Footprint	$4,014,430	-35%	-$1,405,051
Properties 1-mile outside of the Footprint	$6,948,960	-22%	-$1,528,771
Total			**-$2,933,822**

Sincerely,

Kurt C. Kielisch, ASA, SR/WA, R/W-AC
President/Senior Appraiser

Literature Study

Literature Study

Perception=Value

It is important to remember "perception drives value." This may appear to be an overly simplistic statement, but what a buyer believes a property is worth and how a buyer acts based on that belief, are truly the core elements of market value. Therefore, to understand market value, appraisers need to examine its driving element – perception. Perception is strongly influenced by the media which is no longer limited to the traditional print, radio, and television venues, but also includes the Internet. The Internet brings opinions, facts, and stories from all over the nation and the world, influencing one's perception. This perception need not be based on fact; it simply has to be believed and then acted upon to result in an impact

Some argue that perception is simply revealed by comparable sales. It is true that the resultant action of perception is quantified in the sale, but it may not be true that the underlying perception driving that action is defined by the sale. In appraisal, we call this the *qualitative factor*. Often this factor is identified in appraisal analysis as a judgment call based on perception such as "fair" in a quality description or "undesirable" as to a view. To achieve this perception, the appraiser needs to look deeper into the driving force of the action by reviewing what is being said in the media regarding the question: "Do wind turbines affect property value?" Such a study may be useful to an appraiser to put a qualitative value on this perception when estimating the impact that a Wind Farm may have on property value.

Following is a summary of our findings from published sources outside of the trade industry to get a measure of the public's perception of wind turbines and their potential impact on property value.

Health Issues

Many people living near operating wind turbines are reporting neurological and physiological disorders that are only resolved when the turbines are off, or when they leave the area. Common symptoms include sleep problems, headaches, dizziness, unsteadiness and nausea, exhaustion, anxiety, anger, irritability and depression, problems concentrating and learning, and Tinnitus (ringing in the ears).[2] Symptoms can be experienced up to 1.2 miles away in rolling terrain; 1.5 miles away in valleys; and 1.9 miles away in mountainous regions.[3] These symptoms are commonly being referred to as "Wind Tower Syndrome"[4] in the U.S., but they are the same symptoms of a proven ailment, Vibroacoustic Disease (VAD).[5]

In 2007, two Portuguese scientists found that the amount of infrasound and low-frequency noise (LFN)

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2 Nina Pierpont, MD, PhD, *Wind Turbine Syndrome: Testimony Before the New York State Legislature Energy Committee*. March 7, 2006.
3 Ibid.
4 Ibid.
5 Mariana Alves-Pereira, Nuno A. A. Castelo Branco, *Second International Meeting on Wind Turbine Noise*. Lyon, France – September 20-21, 2007.

generated by wind turbines is conducive to VAD.[6] Symptoms include slight mood swings, indigestion, heartburn, mouth/throat infections, bronchitis, chest pain, definite mood swings, back pain, fatigue, skin infections (fungal, viral, and parasitic), inflammation of stomach lining, pain and blood in the urine, conjunctivitis, allergies, psychiatric disturbances, hemorrhages (nasal, digestive, conjunctive mucosa) varicose veins, hemorrhoids, duodenal ulcers, spastic colitis, decrease in visual acuity, headaches, severe joint pain, intense muscular pain, and neurological disturbances.[7]

Besides noise, wind farms can electrically pollute their surroundings.[8] A study of before-and-after sound waveforms demonstrates how overexposure to high frequencies can cause symptoms such as ringing in the ears, headaches, sleeplessness, dangerously high blood pressure, heart palpitations, itching in the ears, eye-watering, earaches, and chest pressure. All are symptoms of Radio Wave Sickness – a proven phenomenon that predates Wind Tower Syndrome. It takes very little exposure to start experiencing these symptoms.[9]

The symptoms became so bad that four families had to abandon their homes near the wind farms – prompting the wind company to bury the collector line for turbines near the worst-hit homes. They also put an insulator between the neutral line and the grounding grid. It reduced the high frequencies but didn't completely resolve the situation.[10]

In 2009, Minnesota's Department of Health released a study on the public health impact of wind turbines. They found that wind turbines generate a broad spectrum of low-intensity (frequency) noise. Though homes typically block most high-frequency noise, they do little to weaken low-frequency noise. Sleeplessness and headaches are the most common health complaints associated with proximity to turbines and are highly correlated with annoyance complaints. Most available evidence suggests that reported health effects are related to audible low-frequency noise. LFN is typically a non-issue at more than a half mile. However, differences in terrain or different wind conditions could cause the sound to reach further. Unlike LFN, shadow flicker can affect people outdoors and indoors. They recommend the following: further testing to determine the LFN impact; evaluating potential impacts from shadow flicker and visibility; estimating the cumulative noise impacts of all wind turbines.[11]

Although acousticians and engineers working for the wind energy industry conclude that audible noise and low-frequency noise from wind turbines are unlikely to cause health effects, experts in biomedical research have drawn different conclusions.[12]

Industry advocates commonly quote the WHO Community Noise Paper of 1995 which says, "There is no reliable evidence that infrasound below the hearing threshold produces physiological or psychological

6 Ibid.
7 Ibid.
8 Catherine Klieber, *Modern Wind Turbines Generate Dangerously "Dirty" Electricity*. Dirtyelectricity.ca. April 28, 2009.
9 Ibid.
10 Ibid.
11 *Public Health Impacts of Wind Turbines*. Minnesota Department of Health Environmental Health Division. May 22, 2009.
12 Barbara J. Frey, BA, MA and Peter J. Hadden, BSc, FRICS, *Noise Radiation from Wind Turbines Installed Near Homes: Effects On Health – With an annotated review of the research and related issues*. February 2007, June 2007.

effects." However, the final WHO document of 1999 reversed that statement: "The evidence on low-frequency noise is sufficiently strong to warrant immediate concern."[13]

A British study surveyed 39 residents already known to be suffering from problems they felt were due to their close proximity to the turbines. On average, 75% of them reported fatigue, lack of sleep, and headaches. Half reported stress and anxiety, and a quarter reported migraines, depression, and tinnitus.[14]

It is clearly evident that there are people living near turbines who are genuinely suffering from health effects from the noise produced by wind turbines[15] – despite developers' and some acousticians' claims to the contrary.

Field studies performed among people living in the vicinity of wind turbines showed that there is a correlation between sound pressure levels and annoyance, but that annoyance is also influenced by other factors such as attitude to wind turbines and the landscape. However, noise annoyance from wind turbines was found at lower sound pressure levels than in studies of annoyance from road traffic noise. This is because the absolute noise level is less important than the character of the noise produced.[16]

People are "in an extremely delicate state of equilibrium with the sonic environment and any profound disturbance of this system will have profound ramification to the individual." Our auditory and cerebral systems are extremely complex. Thus, issues surrounding noise annoyance/disturbance and associated health effects are not simple. The noise produced from wind turbines is extremely complex...and it is the complexity of the noise and vibration which causes the disturbance.[17]

Low-frequency noise is also produced by wind turbines. It's mainly the result of the displacement of air by a blade and of turbulence at the blade surface. LFNs contribute to the overall audible noise but also produce a seismic characteristic which is why people can say they can "feel" the noise.[18]

Body vibration exposure at seemingly low frequencies from 1-20 Hz can have the following effects:[19]

- General feeling of discomfort	4-9 Hz
- Head symptoms	13-20 Hz
- Influence on speech	13-20 Hz
- Lump in throat	12-16 Hz
- Chest pains	5-7 Hz
- Abdominal pains	4-10 Hz
- Urge to urinate	10-18 Hz
- Influence on breathing	4-8 Hz

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13 Ibid.
14 Dr. Amanda Harry M.B.Ch.B., P.G. Dip.E.N.T., *Wind Turbines, Noise and Health.* February 2007.
15 Ibid.
16 Ibid.
17 Ibid.
18 Ibid.
19 Ibid.

Over time, symptoms from LFN can have serious adverse physiological effects.[20]

- After 1-4 years: slight mood swings, indigestion, heartburn, mouth/throat infections, and bronchitis.
- After 4-10 years: chest pain, definite mood swings, back pain, fatigue, skin infections, inflammation of stomach lining, pain and blood in urine, conjunctivitis, and allergies.
- After 10 years: psychiatric disturbances, hemorrhages, varicose veins, hemorrhoids, duodenal ulcers, spastic colitis, blindness, headaches, severe joint pain, intense muscular pain, and neurological disturbances.

LFN intensity is subject to the sudden variation in air flow. LFN also modulates well-audible, higher frequency sounds and thus can create periodic sound. The effect is stronger at night – sometimes up to 15-18dBs higher – because of atmospheric differences. Multiple turbines can interact with each other to multiply the effect – which will be greater for larger, more modern turbines.[21]

Because the wind is inconsistent, so too will be the noise (and thus health effects) caused by wind turbines.[22]

Noise and "flicker" at nearby residences often affect the occupant's health.[23]

One particular case has generated substantial press. The d'Entermont family home is in the midst of a 17-turbine wind farm. Soon after the turbines began operating, they started feeling irritation that caused noticeable shifts in their six children's behavior. They started hearing ringing in the ears, loss of concentration, and high blood pressure. They had to move 30 miles away to resolve the health issues, and no one will buy their home.[24]

However, these symptoms don't affect everyone. As a result, the wind energy industry ignores such health claims by leaning on acoustics consultants who base their conclusions on engineering principles instead of on audiologists and physicians who study the effect of sound and vibration on people.[25]

Likewise, many environmentalists dismiss any health effects – claiming they're fictitious beliefs fueled by not-in-my-backyard-ism.[26]

The French National Academy of Medicine has warned that the harmful effects of sound related to wind turbines are insufficiently assessed. They consider wind turbines to be industrial installations and to comply by that fact to specific regulations that take account of the harmful effects of sound as particularly

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20 Ibid.
21 Ibid.
22 Ibid.
23 Gleen Schleede, *Investment in Wind Yields Negligible Environmental Benefits*. Energy Market & Policy Analysis, Inc. Date Unknown.
24 David Rodenhiser, *N.S. Goes Green, but at What Cost? In remedying one problem, we shouldn't ignore signs we're creating another.* The Daily News, September 23, 2007.
25 Ibid.
26 Ibid.

produced by these structures.[27]

Health Solutions

The international community recommends generous setbacks be given to property owners from wind farms in order to mitigate any potential health effects and loss of property values. The setbacks range from a minimal 1,500-foot setback[28] to 1.5 miles away from any home, school, or business.[29] Because symptoms can be suffered up to a mile from the wind farm, one study suggests that turbines should be no closer than 1.5 miles from a residence.[30] Some recommend an immediate and mandatory minimum buffer of 2km between a dwelling and an industrial wind turbine and with greater separation from a dwelling for a wind turbine with greater than 2MW installed capacity.[31]

One solution is to filter inverters at each turbine; bury all collector lines; filter the power at the substation before going to the grid, and install a proper neutral system to handle the high-frequency return current.[32]

Local governments are advised to establish beyond reasonable doubt that the families' right to respect for their homes and their private lives is not violated. If the State decides that the public interest in building wind turbines is greater than the individual private interest, then the violation is not proportionate without compensation for the individual.[33]

Wind Turbine Hazards

Turbines, like all machines, have weaknesses and are subject to accidents and failure. Inclement weather and strong gusts can snap off wind tower blades;[34] ice can build up on the blades, break, and throw large ice chunks[35] and fling ice shards onto nearby homes,[36,37] potentially harming nearby residents;[38]

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27 Keith Sterling, MA, MNIMH, Dip. Phyt., MCPP, *Calculating the Real Cost of Industrial Wind Power: An Information Update for Ontario Electricity Consumers.* Friends of Arran Lake Wind Action Group, November 2007.
28 *Report from the Bethany Wind Turbine Study Committee.* January 25, 2007.
29 Nina Pierpont, MD, PhD, *Wind Turbine Syndrome: Testimony before the New York State Legislature Energy Committee.*
30 Dr. Amanda Harry M.B.Ch.B., P.G. Dip.E.N.T., *Wind Turbines, Noise and Health.* February 2007.
31 Barbara J. Frey, BA, MA and Peter J. Hadden, BSc, FRICS, *Noise Radiation from Wind Turbines Installed Near Homes: Effects on Health – With an annotated review of the research and related issues.* February 2007, June 2007.
32 Catherine Klieber, *Modern Wind Turbines Generate Dangerously "Dirty" Electricity.* Dirtyelectricity.ca. April 28, 2009.
33 Barbara J. Frey, BA, MA and Peter J. Hadden, BSc, FRICS, *Noise Radiation from Wind Turbines Installed Near Homes: Effects on Health – With an annotated review of the research and related issues.* February 2007, June 2007.
34 Alastair Taylor, *Wind Turbine Smashed...By Wind.* The Sun (UK). June 28, 2008.
35 *Report from the Bethany Wind Turbine Study Committee.* January 25, 2007.
36 Kirsten Beacock, *Wind Turbine's Deadly Ice Shower.* The Evening Telegraph (UK). December 2, 2008.
37 Tom Hewson, *Wind Power Siting Issues Overview.* Presented to the National Association of Attorney Generals Wind Energy Facility Siting Issue Panel. April 21, 2008.
38 Eleanor Tillinghast, *Wind Turbines Don't Make Good Neighbors: Some Problems of Wind Power in the Berkshires.* Study presented by Green Berkshires, Inc. May 14, 2004.

turbulent wind can accelerate a blade's deterioration, weakening it to the point of breaking off and crashing into nearby homes;[39] high winds can also overpower its automatic braking system and result in structural failure; [40] automatic shut-down systems can malfunction, damaging the turbine to the point of collapse;[41] and gale force winds can shut down turbines and make them a safety concern. In one such case, British police cordoned off a 1,500-foot area around the wind farm for "safety precautions."[42] Other common problems include fires and blade disintegration caused by mechanical failures and lightning.[43]

In Europe, which has long had wind farms, turbines are seeing a spike in accidents, defects, and needed repairs. A turbine's gearbox is expected to last 5 years and often quits before then. Due to the huge demand for turbines, manufacturers have no time to test their product before sending it into the field. This demand has so strained manufacturing capabilities that the waiting list for replacement parts can sometimes top 18 months – leaving the turbine motionless the whole time.[44]

Wind farms interfere with weather radar by sending false storm signals,[45] thus limiting the ability of surrounding areas to know if they should seek shelter or not. They also interfere with military radar, affecting military readiness.[46] And they may interfere with civilian radar,[47] making it very dangerous to site turbines near airports or military installations.[48]

Despite the constant warning lights on top of each turbine, wind farms are dangerous to planes. A distance of 1,200 feet is still too close to an airport or landing strip because it's impossible for aircraft to turn fast enough to avoid the turbines. Also, turbines create a downdraft – additional turbulence that pilots have to overcome in takeoffs and landing.[49]

Wind farms can also constitute a nuisance to nearby landowners. Even though the State Public Service Commission approved the facility, such approval did not overrule the common law of nuisance. Accepted causes of nuisance include noise, eyesore, flicker, and strobe effect of light reflecting from blades, potential danger from broken blades, ice throws, and reduced property values.[50]

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39 Michael Connellan, *Spinning to Destruction*. The Guardian (UK). September 4, 2008.

40 *Report from the Bethany Wind Turbine Study Committee.* January 25, 2007.

41 Jason Lehmann, *Faulty Wiring Likely Caused Wind Turbine Collapse at Altona Wind Farm*. SNL Interactive. March 10, 2009.

42 Natalie Chapples, *Exclusion Zone around Wind Farm after Gales*. North West Evening Mail (UK). March 12, 2008.

43 Gleen Schleede, *Investment in Wind yields Negligible Environmental Benefits.* Energy Market & Policy Analysis, Inc., Date Unknown.

44 Simone Kaiser and Michael Frohlingsdorf, *The Dangers of Wind Power.* BusinessWeek, August 24, 2007.

45 Scott Williams, *Wind Turbines Complicate Wind Monitoring*. The Journal Sentinel, April 11, 2009.

46 Author Unknown, *Energy Law Alert: Department of Defense Issues Report on Effects of Windmills on Radar*. Stoel Rivers, LLP – Attorneys at Law, October 19, 2006.

47 *Wind Power Siting Issues Overview*. Tom Hewson. Presented to the National Association of Attorney Generals Wind Energy Facility Siting Issue Panel, April 21, 2008.

48 Eleanor Tillinghast, *Wind Turbines Don't Make Good Neighbors: Some Problems of Wind Power in the Berkshires.*

49 Chris Luxemburger, *Living with the Impact of Windmills*. Date appx. between 2008 & 2009.

50 *Contracting Legal Issues*. Erin C. Herbold, staff attorney, ISU Center for Agricultural Law and Taxation. North Central Risk Management Education Center, May 14, 2009.

Conservation Concerns

Even conservation groups are divided on Wind Energy. In North Carolina, environmentalists are fighting over siting issues. Some environmentalists and the wind companies want to place turbines on mountain ridges for optimal winds. But other environmentalists want them off the ridges in order to protect the mountains' natural beauty.[51]

Conservation groups are concerned about the impact of wind farms on birds. Poor siting has led to bird and bat fatalities.[52] According to the American Bird Conservancy, wind towers kill 10,000 to 40,000 birds every year. However, this is still much lower than the 100 million window-related bird deaths each year.[53] Bats, however, are killed three times as much as birds by wind turbines.[54] And many bats killed by turbines are most likely migrating for mating rituals. If such bats are killed then certain bat species are in danger of failing to repopulate.[55] According to industry advocates, the most damage to wildlife and plant-life happens during construction. After construction, collision consequences are insignificant compared to the effects of other man-made structures, vehicles, and pollution.[56]

Promoters routinely ignore wind development environmental damage. Electricity from the wind is not environmentally benign. Wind plants adversely affect a wide variety of environmental, ecological, and scenic values including bird kills and interference with migration patterns.[57] And construction disruptions are extensive and turbine installation can significantly affect natural drainage and groundwater.[58]

Property Values and Land Use

Industry advocates say little about a turbine's aesthetic impact. When they do mention property values, they deny that wind farms negatively impact property values. They say property value fears are exaggerated and if they do admit impact, they say the only effect would be more time on the market for sales to be completed.[59] One utility president went so far as to claim that those who claim property

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51 Jack Betts, *Wind Farms on Ocracoke? Nope.* This Old State (blog), July 15, 2009.
52 Tom Hewson, *Wind Power Siting Issues Overview.* Presented to the National Association of Attorney Generals Wind Energy Facility Siting Issue Panel, April 21, 2008.
53 Caleb Hale, *Wind Turbines and Migratory Birds: A serious problem?* The Southern (IL), May 23, 2009.
54 Ibid.
55 Paul Cryan, *Bat Fatalities at Wind Turbines: Investigating the Causes and Consequences.* United States Geological Survey Fort Collins Science Center. Date unknown.
56 *Permitting of Wind Energy Facilities: A Handbook (Revised 2002).* National Wind Coordinating Committee, August 2002.
57 Gleen Schleede, *Investment in Wind Yields Negligible Environmental Benefits.* Energy Market & Policy Analysis, Inc. Date Unknown.
58 *Report from the Bethany Wind Turbine Study Committee,* January 25, 2007.
59 Bob Shaw, *Developers Balking at Proposed Woodbury Wind Turbine.* Pioneer Press, September 24, 2008.

value diminutions "pull myths out of thin air and persist in wild accusations despite being debunked."[60] To prove this point, industry advocates frequently refer to the following studies:

- Relationship between Wind Turbines and Residential Property Values in Massachusetts: A Joint Report of University of Connecticut and Lawrence Berkeley National Laboratory by Carol Atkinson-Palombo and Ben Hoen (2014)
- The Windy City: Property Value Impacts of Wind Turbines in an Urban Setting by Corey Lang, James J. Opaluch, and George Sfinarolakis (2014)
- The Effects of Wind Turbines on Property Values in Ontario: Does Public Perception Match Empirical Evidence? by Richard Vyn and Ryan McCullough (2014)
- The Effect of Wind Development on Local Property Values by the Renewable Energy Policy Project (REPP) (2004)

The 2014 Ben Hoen study analyzed more than 122,000 home sales, between 1998 and 2012, that occurred near the current or future location of 41 turbines in densely populated Massachusetts' communities. The study determined that wind turbines do not have a negative impact on property values in urban settings. It was an update of his 2009 study. Funding for the study was provided by the Massachusetts Clean Energy Center and the U.S. Department of Energy Wind & Water Power Program within the Office of Energy Efficiency and Renewable Energy.[61]

The 2014 Rhode Island study analyzed 48,554 single-family, owner-occupied transactions within five miles of a turbine site, including 3,254 within one mile. The authors concluded that wind turbines have no statistically significant negative impacts on house prices. Funding for the study was provided by Rhode Island's Office of Energy Resources, University of Rhode Island's Coastal Institute, and Rhode Island Agricultural Experiment Station.62

In the 2014 study from Vyn and McCullough, the authors analyzed 7,000 home and farm sales in and around Melancthon Township – home to one of Ontario's first and largest wind farms (113 turbines). They concluded that wind turbine developments have no effect on property values.63

The 2004 study was performed by the Renewable Energy Policy Project (REPP) – an organization dedicated to accelerating the use of renewable energy, reviewed assessed values of property sales within 5 miles of wind projects from 1998-2001 to determine if there was a negative effect on property values within the viewshed of the wind farm projects. In 9 out of their 10 case studies, they found either no change in value or even an increase in value resulting from being in the turbines' view shed than those outside of it.[64]

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60 Mike Sagrillo, *Residential Wind Turbines and Property Values*. Sagrillo Power & Light Co. American Wind Energy Association website, 2004.

61 Carol Atkinson-Palombo and Ben Hoen, *Relationship between Wind Turbines and Residential Property Values in Massachusetts: A Joint Report of University of Connecticut and Lawrence Berkeley National Laboratory*. January 9, 2014.

62 Corey Lang, James J. Opaluch, George Sfinarolakis, *The Windy City: Property Value Impacts of Wind Turbines in an Urban Setting*. Energy Economics. Volume 44, July 2014.

63 Richard Vyn and Ryan McCullough of The University of Guelph, *Wind farms to do not affect property values, study finds*. Canadian Journal of Agricultural Economics, December 8, 2014.

64 George Sterzinger (REPP Exec. Dir.), Fredric Beck (REPP Research Manager), Damian Kostiuk (REPP Research & Communications Specialist), *The Effect of Wind Development on Local Property Values*. Prepared for the Renewable Energy Policy Project (REPP), May 2003.

However, the remarkable conclusion that property values increased isn't verified.[65] They did not follow up with the property purchasers, thus invalidating their conclusion.[66] The REPP findings surprisingly omit many necessary variables for analysis such as adjustments for a rising or falling market, number of days from listing to sale, residential property vs. rural property, effect of noise, flickering and shadows, distances of the homes from the turbines, and possible change in highest and best use due to the presence of the turbines.[67] And anyone who has ever owned a home or property knows that assessed values rarely reflect a property's market value.

The study also fails to analyze whether or not the properties had a direct line to the turbines, and they also failed to incorporate distance from the wind farms as a variable. Curiously, the number of property transactions decreases the closer one approaches the wind farm. By only examining change in comparable property values over a three-year period, the study weakens itself because, in most cases, the projects had been announced and debated long before the three-year window opened. As a result, any depressive effect on property values would have occurred prior to the start of the study. The REPP study also did not look at other indices of real estate value, such as rising or falling inventory values, or the number of days from listing to sale.[68]

In reality, close proximity to wind turbines can devalue a property 20-30%.[69] And even townships widely disregard the REPP study for its wind energy bias, its incomplete data, and its deeply flawed methodology.[70] [71]

Shortly after the University of Guelph study was published, real estate professionals strongly criticized its findings that wind turbines do not impact nearby property values.72 Interviewed professionals shared how wind turbines impact property values:

- "I have had several deals fall apart in this area because, in the appraisal report, it has been mentioned that there are windmills visible or adjacent to the property."73
- "Turbines complicate your property enjoyment, period. That alone spells depreciated value(s)."74

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65 Richard Light & Molly Hyde, *Introduction to Research on Property Value Impacts.* Centerville Township, Michigan, August 2006.
66 Ibid.
67 Derry T. Gardner, *Impact of Wind Turbines on Market Value of Texas Rural Land.* Gardner Appraisal Group, Inc. February 13, 2009.
68 Richard Light & Molly Hyde, *Introduction to Research on Property Value Impacts.* Centerville Township, Michigan. August 2006.
69 Kevin Sampler, *Wind Farm Opponents Air Concerns; Experts say Rail Splitter project will create noise, affect property values.* Journal Star, May 2, 2008.
70 Richard Light & Molly Hyde, *Introduction to Research on Property Value Impacts*. Centerville Township, Michigan. August 2006.
71 Ibid.
72 *Industry criticizes wind turbine report*. Jennifer Paterson. Canadian Real Estate Wealth. December 18, 2014.
73 Ibid.
74 Ibid.

- "If you were to buy your future home, given the choice, would you buy where you would have noise, shadow flicker, an industrial view, potential health issues caused by the turbines, and the possibility of a very difficult resale, or would you spend your money elsewhere?"75

Other university-led studies, such as these three published within one year of each other, found different results:

- A 2010 study by Illinois State University used 3,851 residential transactions from January 1, 2001, through December 1, 2009, from McLean and Ford Counties, Illinois to see whether proximity to a 240-turbine wind farm impacts nearby residential property values. They found "some evidence that supports wind farm anticipation stigma theory, and the results strongly reject the existence of wind farm area stigma theory."76
- A 2011 study by Illinois State University looked at sales across a 13-year period to see if the Mendota Hills Wind Farm in Lee County, Illinois impacted the average selling price of nearby residential real estate. The study's author concludes that it does not. Further, he states that the wind farm significantly increased the selling values of nearby residential properties.77
- A 2011 study by Clarkson University looked at 11,369 property transactions over 9 years in Northern New York to see if new wind facilities affected property values. The author found that "nearby wind facilities significantly reduce property values. Decreasing the distance to the nearest turbine to 1-mile results in a decline in price of between 7.73% and 14.87%."78

Industry advocates often liken wind turbines to other man-made structures like water towers.[79] But water towers don't move.[80] If they had no effect, then people would want to live near them. However, developers are balking at even building near wind turbines lest potential buyers of high-end homes be "spooked by the noise and visual distraction of the huge whirling fan blades."[81]

In reality, value comes down to location, location, and location. If an individual is given two identical homes, but one has a wind turbine and the other does not, common sense (and research) shows the house without the turbine will be purchased first. In many cases, there is a complete lack of interest in any homes near existing or planned wind farms. And when they do sell, they usually sell at less than current market value.[82]

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75 Ibid.
76 Jennifer L. Hinman, *Wind Farm Proximity and Property Values: A Pooled Hedonic Regression Analysis of Property Values in Central Illinois*. Illinois State University, May 2010.
77 Jason Carter, *The Effect of Wind Farms on Residential Property Values in Lee County, Illinois*. Illinois State University, Spring 2011.
78 Martin D. Heintzelman and Carrie M. Tuttle, *Values in the Wind: A Hedonic Analysis of Wind Power Facilities*. Economics and Financial Studies School of Business at Clarkson University, March 3, 2011.
79 Mike Sagrillo, *Residential Wind Turbines and Property Values*.
80 Bob Shaw, *Developers Balking at Proposed Woodbury Wind Turbine.*
81 Ibid.
82 Julian Davis BSc & Jane Davis M.A., *Property Values and House Prices: Appendix 1 of the Report to the Select Committee on Economic Affairs,* June 2008.

Devaluation also affects what people are willing to pay to rent vacation property near wind farms. In 2017, a choice-experiment was conducted with people who had recently rented a vacation property along the North Carolina coastline to assess the impacts of a utility-scale wind farm on their rental decisions. Visualizations were presented to survey respondents that varied both the number of turbines and their proximity to shore. They found the following:

- No respondents would be willing to pay more to rent a home with turbines in view.
- Many said they would change their vacation destination if wind farms were placed within view.
- A discount of 5% or more was required to attract respondents most amenable to viewing a utility-scale wind farm within eight miles of shore.83

Even when turbines are offshore, seeing them can impact property values. In Henderson, New York, a study of a proposed 31-turbine, 102.3-megawatt project found that the project's 575-foot turbines would be visible from a 15-mile radius, negatively impacting the value of waterfront properties from $11,300 (low estimate), $33,200 (central estimate) and $53,900 (high estimate). The estimates were based on the 15% value depreciation of properties with a view of the nearby Wolfe Island turbines in Ontario, Canada.84

When another wind farm was announced in addition to the one at Wolfe Island, waterfront property values started to slide. By the time the additional project was scrapped five years after being announced, waterfront homes were selling up to $300,000 less than they were before the project. Though buying has started to rebound, properties are being sold for hundreds of thousands below asking price, and properties take years to sell instead of months.85

The wind company proposing the Henderson wind farm contested the town's study that estimated a loss of $40 million in property values. They claim the study used flawed methodology – specifically regarding the distance of the project from the mainland.86 If these properties' values dropped, their assessments would too, and homes without a view of the turbines "would probably see an increase in property taxes to make up for the overall drop in property values."87

As the Principal of JTC Energy Research Associates wrote for Forbes, "A piece of property, after all, is just what someone is willing to pay for it. Markets are about supply and demand, and all things being equal, why would somebody choose to buy a home with an industrial wind farm nearby? And simply put, it seems impossible to believe that wind turbines would actually add to a property's value."88

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83 Sanja Lutzeyer, Daniel J. Phaneuf, Laura O. Taylor, *The Amenity Costs of Offshore Wind Farms: Evidence from a Choice Experiment*. Center for Environmental and Resource Economic Policy – NC State University, August 2017.
84 Ted Booker, *Clarkson study: Henderson could lose $40 million in property value from Galloo Island wind project*. Watertown Daily Times, April 5, 2016.
85 Ted Booker, *Realtors say Wolfe Island wind turbines caused waterfront home prices to plummet*. Watertown Daily Times, June 1, 2014.
86 Ted Booker, *Wind developer: Study erroneously predicted turbine impact on Henderson*. Watertown Daily Times, April 17, 2016.
87 Ted Booker, *Clarkson study: Henderson could lose $40 million in property value from Galloo Island wind project*. Watertown Daily Times, April 5, 2016.
88 Jude Clemente, *Do Wind Turbines Hurt Property Values?* Forbes.com, September 23, 2015.

Assessors are starting to devalue homes that are at least 1,500 feet away from the nearest turbine. In one case, several residents near an industrial wind farm received up to a 10% lower property value due to their proximity to turbines. The assessors considered the turbine space an industrial area and devalued nearby properties accordingly.[89]

In another case, Vermont homeowners living near four wind turbines appealed their assessment due to excessive noise. The local Board of Civil Authority agreed and lowered the assessed value on the $400,000 home by more than $50,000.90 91

In Ontario, property assessments near a wind farm were reduced from -$101,000 on the low end, to -$143,000 on the high end.92

In New York, a homeowner appealed his 25-acre property assessment due to neighboring wind turbines. The assessor lowered the assessment by 60%.93

In Vermont, contention arose between landowners and assessors. Landowners said nearby turbines' noise devalued their land, but the assessors rejected their claims. The wind farm developers also resisted their claims on the basis of academic and government studies that showed no impact on property values. However, the Board of Civil Authority reconsidered the claims and reduced the assessments by 8-15%.94

Wind farm developers like to promote the idea that while their wind farms may cover a very large area, they only physically occupy 3-5% of the total land area for the towers, associated structures, and access roads. They claim the rest of the land is left largely undisturbed and "available for continued use by the landowner."[95]

However, turbines come with many use restrictions.

Even though a minority may find windmills to be a nuisance, property values can still drop $2,900 per turbine up to $16,000 for a property abutting 12 turbines.[96]

In testimony before the Livingston County Zoning Board of Appeals (Illinois) regarding a wind farm, Appraiser Michael McCann shared that properties within 3 miles of wind turbines sell at 25% less

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89 *Wind Farms Lower Property Assessments in Western P.E.I.* CBC News, December 23, 2008.

90 Alexei Rubenstein, *Vermont wind farm blows down home values*. WCAX.com. October 15, 2013 (Updated October 17, 2013).

91 Terri Hallenbeck, *Town listers become next arbiter in Vermont's debate over wind*. Burlington Free Press, October 26, 2013.

92 *Wolfe Island property assessment reductions of over $3 million*. Ontario Wind Resistance. September 19, 2012.

93 John Servo, *Tax Assessment Lowered 60% due to Adjacent Wind Turbine Site*. Cohocton Wind Watch, August 31, 2009.

94 Matthew Preedom, *Wind Turbines: Do property values fall?* St. Albany Messenger, August 17, 2015.

95 *Permitting of Wind Energy Facilities: A Handbook (Revised 2002)*. National Wind Coordinating Committee, August 2002.

96 David C. Maturen of Maturen & Associates, Inc., *RE: Impact of Wind Turbine Generators on Property Values*. September 9, 2004 (e-mailed letter). Study referenced within text: Social Assessment of Windpower – Visual Effect and Noise from Windmills – Quantifying and Evaluation.

compared to control sales more than 3 miles away.97

As with other easements, some claim that the impact from windmills will diminish over time. However, studies from Europe show otherwise. In Germany, which has long had windmills, real estate agents report property value losses between 20-30% for properties in sight of wind farms.[98]

Likewise, Scottish real estate agents found that a 41-turbine wind farm would result in $1 million in property value losses.[99]

Further, hundreds of homeowners in Scotland fear they have lost vast sums of property value due to nearby turbines. In one example, a cottage lost 50,000 pounds of value because of a planned wind farm half a mile away. Real estate agents are advising sellers to automatically lower their asking price by 30%, but some still can't sell.100

Another Scottish homeowner put her home on the market after learning of a proposed wind farm less than 500 years from her residence. After two years, she was unable to find a buyer. One potential buyer withdrew her offer, citing a conversation with the town's planning council that told her the turbines will cause "a whooshing noise and flicker." Her cottage was originally valued at 130,000 pounds before the wind farm, but then the valuation was lowered to 100,000 pounds after it was built. She eventually sold the cottage for 85,000 pounds.101

In the UK, property experts say wind farms can reduce the value of homes by up to 8%.102

In England and Wales, a study found that large wind farms (20+ turbines) reduce prices by 12% within 2km. Averaging wind farms of all sizes, the study found the price reduction from wind turbines to be 5-6% within 2km, less than 2% between 2 and 4km. There are small (~2%) increases in neighboring prices where the wind farms are not visible, although these are only statistically significant in the 4-8km area. The author suggests, "These offsetting price effects in neighboring places where wind farms are visible and where they are not may explain, in part, why previous studies that focus only on distance to wind farms fail to find significant effects."103

The author further explains, "These findings are comparable to the effects of coal power plants in the US found in Davis (2011) who finds up to 7% reduction within 2 miles (3.2 km). It takes many geographically dispersed wind farms to generate the same power as a single coal (or nuclear) plant, so the aggregate effects of wind farms and the number of households affected by their visual impact is likely to be

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97 Cynthia Grau, *Experts offers insight to wind farm questions*. Pontiac Daily Leader, February 11, 2015.

98 David C. Maturen of Maturen & Associates, Inc., *RE: Impact of Wind Turbine Generators on Property Values.* September 9, 2004. (e-mailed letter.) Study referenced within text: Strutt & Parker study of the Edinbane Windfarm on the Isle of Skye.

99 Ibid.

100 *Wind farm misery for property owners*. The Sunday Post, September 29, 2013.

101 Ben Borland, *Proof windfarms will cut Scots house prices*. Express, September 8, 2013.

102 Alice Philipson, *Wind farms knock eight per cent off average home value, property experts reveal*. The Telegraph. October 31, 2013.

103 Stephen Gibbons, *Gone with the wind: valuing the visual impacts of wind turbines through house prices*. Journal of Environmental Economics and Management. March 2015.

considerably larger."104

In the UK, a couple successfully sued their conveyancer for "a substantial compensation settlement" for not disclosing plans that a wind farm was to be constructed less than a mile away and that the turbines would be visible from the property. The couple said, had they known about the wind farm, "they would have reconsidered their offer."105

In a landmark case, a UK court agreed with a couple that argued that ten 360-foot-tall wind turbines ruined their quality of life. The company responsible for the turbines has to remove them at their expense and pay large fines and legal expenses.106

The effect of wind farms on property values ultimately "forced" the UK's Valuation Office Agency to rebrand homes near wind farms into lower tax categories. In one case, a property owner saw the value of their home fall 25% because it is 650 yards from a turbine.107

In Denmark, so many landowners were concerned about lost property valued due to neighboring wind turbines that a "loss-of-value" clause was passed by their parliament in 2008. It allowed landowners to seek financial compensation for lost property values. Those applicants who received compensation (average of 57,000 kroner per household (~$7,000) said it "did not come close to reflecting the actual value." Further, "Estate agents say the amount is often far below the actual property value loss, which in some cases is up to 20 percent."108

Property value concerns due to neighboring wind farms are so widespread that property value guarantee agreements are being included in government ordinances nationwide from New York to North Carolina, Illinois, Maine, New Hampshire, and Michigan. For example, voters in the Newfound region of New Hampshire passed wind-related articles by as much as five to one. One of them would require wind developers to guarantee the property value of any home within a 3-mile radius of a wind farm. It deterred the developer of a small 3-turbine operation.109

The Board of Zoning Appeals in Tipton County (Indiana) approved a conditional use permit for a proposed wind farm with conditions requiring a 1,500-foot setback from property lines and a property value guarantee to "protect non-participating property owners in the project area." The wind farm company submitted a plan that limited their liability to $1 million. However, the company is planning on contesting the property value guarantee as a condition.110

Other wind energy companies are resisting such guarantees. For example, the Town of Hammond, New

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104 Ibid.

105 Joanne Atkin, *Compensation for couple after conveyancer fails to find wind farm*. Mortgage Finance Gazette. March 9, 2015.

106 Peter Allen, *Couple win landmark battle to have 10 wind turbines taken down because they spoil the view from their dream home in France*. The Daily Mail, November 7, 2013.

107 Gerri Peev, *Wind farms DO hit house prices: Government agency finally admits that thousands can be wiped off value of homes*. The Daily Mail, July 22, 2012.

108 *Wind turbine compensation stirring discontent*. The Copenhagen Post. November 12, 2012.

109 Sam Evans-Brown, *Newfound Area Voters Again Show Distaste For Wind Power At Town Meeting*. New Hampshire Public Radio, March 12, 2014.

110 Ken de la Bastide, *Prairie Breeze Wind Farm fight headed to court*. Kokomo Tribune, August 30, 2013.

York, proposed a wind law that requires a wind farm company to compensate property owners who cannot get the appraised value of their home at sale because of the presence of wind turbines. If passed, the company says it will scrap plans to build a proposed wind farm.111

In Ontario, Canada, a high court determined that landowners living near "industrial wind turbine projects" do lose property value. The court further accepted that 22% to 55% loss of property values is occurring.112 In a case study of two areas in Ontario with wind turbines, the author concludes, "Real or perceived nuisances resulting from wind turbines produce buyer resistance that results in price diminution" of 22.47% on the low end to 55.18% on the high end.113 In another case, a member of the Multi-Municipal Wind Turbine group said an assessment of property values confirmed a 25% devaluation due to industrial wind turbines.114 Elsewhere in Canada, landowners in Alberta are opposing plans to build 83 turbines near their properties. To protect their property values, they want the county to implement a 1.5 km setback instead of the proposed 500 meters.115

The effect of wind farms on property values is also a concern in Australia. Rural landholders are worried they may face fewer buyers and devaluations of up to 60% because of neighboring wind farms.116 Elsewhere in Australia, a resident in a community selected for a proposed wind farm said he will sue any of his neighbors who host a turbine on their property because doing so would diminish his property. Lawyers said there was extensive precedent backing his claim of right to damages from turbine noise nuisance.117

The township of Lincoln in Kewaunee, WI performed its own study and found that sales within one mile of the wind farm prior to installation were 104% of the assessed values. Properties selling after the wind farm installation in the same area were at 78% of the assessed value.[118] The UK has reported similar impacts up to a 20% loss in value from the presence of four 360-foot tall turbines 550 yards from a new home.[119]

In some coastal areas with turbines, affluent properties have lost up to a third of their value. However, in rural farming areas, prices remained steady or even increased from the associated income stream from the turbines.[120]

Wisconsin residents fear the impact large wind farms can have on lowered property values. Their fear is justified by a plethora of independent studies and reports that all find the same thing: Wind farms have a

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111 Matt McAllister, *Iberdola Threatens To Leave*. The Journal, December 8, 2010.

112 Amanda Brodhagen, *Ontario court says wind turbines reduce property values*. Farms.com, April 24, 2013.

113 Ben Lansink, *Diminution in Price, Melancthon & Clear Creek Conclusions*. February 2013.

114 Janice Mackay, *Wind Turbine Group Told of Falling Property Values*. BlackburnNews.com, October 13, 2015.

115 Lisa Joy, *Wind turbines affect property values*. The Stettler Independent, April 29, 2018.

116 Matthew Cranston, *Wind farms win few fans*. The Australian Financial Review, October 14, 2013.

117 Hamish Boland-Rudder, *Threat of legal action against wind farm hosts*. The Canberra Times, October 29, 2013.

118 David C. Maturen of Maturen & Associates, Inc., *RE: Impact of Wind Turbine Generators on Property Values.* September 9, 2004. (e-mailed letter.) Study referenced within text: Strutt & Parker study of the Edinbane Windfarm on the Isle of Skye.

119 Ibid.

120 Marius Cuming and Lucy Skuthorp, *Wind Farms Change Land Values.* National Rural News (Australia), November 11, 2008.

negative effect on property values.[121]

Properties within wind farm areas may experience longer days on market. One study of 600 sales over 3 years within proximity of a windmill found that the days on market were more than double for properties within the windmill zone. The selling price was an average of $48,000 lower inside the zone than outside. And 11% of homes within the zone did not sell vs. 3% of homes outside the zone.[122]

At a wind forum held in Grafton, VT, concerned residents discussed the environmental and residential impacts of a proposed wind farm. A representative of a company that specializes in high-end homes and country estates said it was difficult to sell a 40-acre, 5,500 sq. ft. home once the wind project was announced. The property was valued at $2.2 million but sold for $1.25 million. The representative said, "People don't come to Vermont to look at wind farms and they don't come to Vermont to hear a lot of noise. So, these are direct impacts on the values."123

Even residents in desert regions are concerned about property values. Residents in a desert region of Nevada popular with retirees and tourists are worried that the installation of 428-feet-tall wind turbines will diminish property values. Residents are familiar with value studies and sound assessments that highlight unforeseen impacts arising from wind turbines near residences.124

Wind farms are normally built in rural locations. Therefore, apart from accommodation size, important influences on value will often be the view, the peace and serenity, and a rural environment. In many rural locations, a wind farm will reduce the value of properties located nearby. But as the distance between wind turbines and dwellings increases, the valuation impact is lessened, and the prospect of consequent health problems is reduced. A part of the loss in value will be attributable to the loss of a quality view. However, a substantial apportionment of the loss in value flows directly from the environmental noise pollution and the consequent health impact. A smaller part of the loss will be due to the rotation of the turbine blades, which in certain circumstances will cause strobing light/shadow flicker (which can have health repercussions). In a high-value area of the country, the potential valuation impact is likely to be higher.[125]

In most cases, environmental noise pollution will influence the bulk of property damages. In a well-populated rural area, the cumulative financial damage (the loss imposed on the community) will substantially exceed the public interest that will be served from the wind farm.[126]

Wind farms have significant adverse impacts on environmental, ecological, scenic and property values. The drop in real estate values of neighboring homes is an unfair burden to those who have chosen to live or retire to the country. The value of a farmhouse may be affected by as much as 30% if it is in close

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121 Richard Mertens, *In Wisconsin, Tilting at Windmills Is a Serious Matter*. The Christian Science Monitor, April 25, 2005.
122 Chris Luxemburger, *Living with the Impact of Windmills.* Date appx. between 2008 & 2009.
123 Brandon Canevari, *Wind concerns addressed at Grafton forum*. Manchester Journal, February 24, 2014.
124 Kyle Gillis, *Searchlight wind farm could reduce property values by 25-60 percent, suggest studies.* Nevada Journal, April 2, 2013.
125 Barbara J. Frey, BA, MA and Peter J. Hadden, BSc, FRICS, *Noise Radiation From Wind Turbines Installed Near Homes: Effects On Health – With an annotated review of the research and related issues,* February 2007, June 2007.
126 Ibid.

proximity to a wind turbine.[127]

One British study of 919 home sales within 5 miles of a wind farm found no impact from wind turbines on property value.[128] However, the turbines were small. Their maximum height was just over a third (48m) of turbines being currently built. No account was taken of whether the properties concerned had views of the turbines. They lumped all distance zones and rural and town properties into one big pot without differentiating them. There was no before-and-after analysis of sale prices. [129] Curiously, when interviewing general agents, they found 60% said that proximate wind farms would decrease property values in the viewshed, 67% believe depreciation starts at the planning stages and lessen with time.[130]

The "threat" of a wind farm may have a more significant impact than the actual presence of one. Wind farm developers in the UK are purposely avoiding populated areas in order to mitigate property value-based opposition.[131]

Concerned about the impact wind turbines may have on local property values, two members of the Centerville Township in Michigan conducted a literature review of four available studies on the subject. The township committee found that it is reasonable to conclude that the presence of wind turbine generators near residential houses causes property values to decline and further impact on property values depends on location. "This is common sense, and there are no serious scholarly studies that support an opposite conclusion." Large wind turbines can affect neighboring property values due to noise, health effects, and visual impacts on residents. Some homes have been reported as "not salable" because of WTG proximity. These adverse impacts on property values may not exist in agricultural areas that have huge farms. If the land is being sold as fertile farmland then the presence or absence of a nearby wind turbine is probably irrelevant. If there is a chance that a future wind turbine might be placed on the farmland, a potential buyer might think the land was slightly more valuable. However, though the lessee may slightly benefit, large wind turbines can also affect neighboring property owners who receive nothing because the turbine isn't on their land. A town real estate agent lost a large vineyard sale within the township because the proposed wind farm was seen as a detriment to potential buyers.[132]

"The locating of a WTG near a residential house can, at best, have no effect on the value and salability of the house. But logically, as wind turbines are larger and larger, in some cases 400 feet tall, and as they produce constant audible noise over a large area, as they intrude on the viewshed, the only valid conclusion is that nearby residences are less valuable than they would be if there was no turbine nearby. Why would a buyer choose a house within sight and sound of a turbine, if a comparable house at the same

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127 Keith Sterling, MA, MNIMH, Dip. Phyt., MCPP, *Calculating the Real Cost of Industrial Wind Power: An Information Update for Ontario Electricity Consumers*. Friends of Arran Lake Wind Action Group, November 2007.
128 Peter Dent and Dr. Sally Sims, *What Is the Impact of Wind Farms on House Prices?* Department of Real Estate and Construction, Oxford Brookes University, UK. Paid for by the Royal Institution of Chartered Surveyors Education Trust, March 2007.
129 *What is the Impact of Wind Farms on House Prices? An assessment of the study done in March 2007 for RICS.* I.C. Eperon, June 2008.
130 Peter Dent and Dr. Sally Sims, *What Is the Impact of Wind Farms on House Prices?* Department of Real Estate and Construction, Oxford Brookes University, UK. Paid for by the Royal Institution of Chartered Surveyors Education Trust, March 2007.
131 Ibid.
132 Richard Light & Molly Hyde, *Introduction to Research on Property Value Impacts.* Centerville Township, Michigan, August, 2006.

price were available elsewhere, beyond the sight and sound of the turbine? It is totally counter-intuitive to suggest anything else."[133]

While some may think a windmill lease on their property boosts their land value, the reality is that they also incur a higher property tax. Their property's appreciation is offset by their neighbors' depreciation. The WTG lessee incurs a higher property tax and receives annual rent for signing the lease/easement. The other landholders find their property values decreased, and they receive nothing.[134]

Though wind energy development may create an income stream, and thus increase a property's production value, that increased production value does not necessarily result in increased market value.

Real Estate brokers in rural areas confirm that property values in wind farm areas are 10-30% less than similar properties outside of wind farm areas.[135]

View adds value to rural property. That's just common sense. Take away the view, and you take away the value.[136]

Homes with a turbine within 300 feet can suffer reduced property values of up to 10%. Noise, blinking lights, glare from the blades, and vibrations all played a role in the devaluation.[137]

In Kewaunee, Wisconsin, a study paid for by a wind farm developer found no measurable differences in home values in the target areas close to the wind farms and the control areas outside of the wind farm vicinity. It found the same for a case study in Mendota, Illinois.[138]

Three years later, The Wisconsin Public Service Commission proposed new regulations that worried Realtors because the setbacks were too small from residences, noise standards were insufficient, and shadow flicker limits were inadequate.139 Five years after the PSC's proposal, The Wisconsin Realtors Association asked the state Supreme Court to invalidate a 2009 rule establishing setback requirements for building wind turbines near residential housing. The WRA said 1,250-foot setbacks aren't enough to protect housing values.140

Vermont's government wants green energy, even if it has to sacrifice its natural beauty to attain it.[141] But wind farms negatively impact pastoral beauty, driving tourists away and severely damaging their main

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133 Ibid.
134 Ibid.
135 Derry T. Gardner, *Impact of Wind Turbines on Market Value of Texas Rural Land*. Gardner Appraisal Group, Inc., February 13, 2009.
136 Ibid.
137 Erin C. Herbold, staff attorney, ISU Center for Agricultural Law and Taxation, *Contracting Legal Issues*. North Central Risk Management Education Center, May 14, 2009.
138 Peter J. Poletti, *A Real Estate Study of the Proposed White Oak Energy Center McLean and Woodford Counties, Illinois*. For Invenergy Wind LLC, January 2007.
139 Tom Larson, *New Wind Farm Regulations Could Decrease Property Values*. Wisconsin Realtors Association, September 2, 2010.
140 Gilman Halsted, *Realtors Argue For Bigger Wind Turbine Setbacks*. Wisconsin Public Radio, February 6, 2015.
141 Eleanor Tillinghast, *Wind Turbines Don't Make Good Neighbors: Some Problems of Wind Power in the Berkshires*. Study presented by Green Berkshires, Inc., May 14, 2004.

industry. [142] Supporters claim the turbines themselves will become an attraction. [143] However, empirical evidence worldwide agrees that wind farms tarnish local beauty and damage tourism. [144] Property values will also suffer up to 20% for a turbine 550 meters away. [145] "It is an incursion into the countryside. It ruins the peace." [146] Real estate agents agree. It's common sense that an industrial structure will damage what was before a naturally beautiful area. [147] Agents in Britain and Australia and the U.S.A. have found it nearly impossible to sell properties next to wind farms unless they discount it 20-30%.[148] A realtor study around Nantucket Sound found that 49% of realtors expect property values to fall in proximity to a wind farm. [149]

Two studies conducted in Nantucket, Massachusetts found that a 130-turbine offshore wind farm would drive enough visitors away to see a loss of up to 2,500 tourism-related jobs. They also found that inland property values would decline 4.6% while the waterfront properties suffer nearly 11% diminution for a total loss of $8 million in yearly tax revenue.[150]

Combining an area of natural beauty with industrial development like a wind farm will have an adverse impact on its desirability. It is not only devalued, but the property may also be rendered unsaleable. Turbines not only have a visual impact, but they also impact the quality of life. People who buy rural land typically do so to enjoy the natural views, but a wind farm within their viewshed ruins the horizon and heritage views.[151]

The scenic impact of wind plants is significant, and as valued natural landscapes disappear, more concern is apparent.[152]

Another attraction of rural land is the quiet. Buyers want someplace to get away from the noise and sounds of industry and the city. Closing the door [on a wind farm] eliminates the view, but it does not eliminate the sound. The constant drone cannot be escaped. It takes away the enjoyment of their property. It doesn't allow them to sleep at night.[153]

Their greatest concern is the substantial loss of value of their property. They do not believe they can sell

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142 Ibid.
143 Ibid.
144 Ibid.
145 Ibid.
146 Ibid.
147 Ibid.
148 Ibid.
149 Ibid.
150 David C. Maturen of Maturen & Associates, Inc., *RE: Impact of Wind Turbine Generators on Property Values*. September 9, 2004. (e-mailed letter.) Studies referenced within text: Blowing in the Wind: Offshore Wind and Cape Cod Economy (October 2003) and Free but Costly: An Economic Analysis of a Wind Farm in Nantucket Sound (March 2004).
151 *Testimony of Russell Bounds, Realtor in the State of Maryland, before the Maryland Public Service Commission on windplants affecting property values,* 2005.
152 Gleen Schleede, *Investment in Wind yields negligible Environmental Benefits*. Energy Market & Policy Analysis, Inc, Date Unknown.
153 *Testimony of Russell Bounds, Realtor in the State of Maryland, before the Maryland Public Service Commission on Windplants Affecting Property Values,* 2005.

without substantial loss and cannot afford to sustain the loss and move.[154]

Wind farms destroy property value; they take a property of substantial value and take away all of the characteristics that are the strengths of that property. The visual impact takes away value. The noise takes away value. The property owners complain that the wind turbines take away value and there is no way for them to escape.[155]

In Maryland, a wind farm developer accidentally proved the diminution of value when he bought two abutting properties to his wind farm and was unable to sell them for their purchase price. He bought one property for $104,447.50 and sold it for $65,000. He bought another property for $101,049.00 and shortly thereafter sold it for only $20,000.[156]

A similar thing happened to a wind farm developer in New York, as explained by the landowner who sold the property to the wind farm company: "In Apex's glossy brochure, the Wyoming County property that's listed as having sold for $245,000 happens to have been mine. Apex conveniently left out the most important facts about the property: It was a 93-acre farm, sold for $245,000 on June 11, 2013, prior to completion of the 58-turbine Orangeville wind factory that was being constructed. The new owner subsequently broke up the property into three parcels, two of which were sold off after the turbines went up, in July and August 2014. The combined assessed value of the three parcels is now $205,000. That's a $40,000 or nearly 20 percent loss of value after the Orangeville wind factory was built."157

Values of the natural and scenic properties within one-half mile and probably within a mile of the wind turbines will be negatively impacted. The visual impact and the noise impact will substantially diminish special attributes of property including scenic view, natural setting and peace, and quiet. Undeveloped properties will be rendered undevelopable. Some parcels may be rendered unsaleable. The visual impact beyond a mile will likely adversely impact value. The sound impact will apparently vary outside one mile, but some properties outside one mile will be adversely impacted by the noise.[158]

Studies have shown that fear of wind farms can negatively affect purchase prices even if the project is a mile or more away. In one case study, 350 acres of premium ranch land was put on the market for $2.1 million. A prospective buyer agreed to the sale price but backed out when the seller disclosed a 27-turbine wind farm within a 1½ mile radius from the property. The seller discounted the land by 25%, but the buyer still declined to purchase. After two years, there has been little interest in the property despite its other positive characteristics.[159]

Independent studies have shown an average diminution of value up to -37% when the turbine is on the property; up to -26% average diminution for properties within .2 – .4 miles of a turbine; and up to -25% average diminution for properties within 1.8 miles of turbines. Properties can also suffer an additional 15-

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154 Ibid.
155 Ibid.
156 Ibid.
157 Cathi Orr, *Apex's land value impact claims are deceiving*. Lockport Union-Sun & Journal, October 15, 2015.
158 *Testimony of Russell Bounds, Realtor in the State of Maryland, before the Maryland Public Service Commission on Windplants Affecting Property Values*, 2005.
159 Derry T. Gardner, *Impact of Wind Turbines on Market Value of Texas Rural Land*. Gardner Appraisal Group, Inc, February 13, 2009.

25% diminution in value due to infrastructure construction (clearing, blasting, digging, etc.), HVTLs to transport generated electricity, substations, additional traffic for servicing turbines and HVTLs, and additional roads.[160]

Wind farms have the potential to impact local property values.[161]

To calm property owners, one township recommended that the wind farm developer provide property value assurances that are transferable to subsequent owners of the wind facility.[162]

Noise

Industry advocates say that the windy nature of rural locations often masks the quiet nature of modern turbines, even for "the very few individuals" located close enough to hear it.[163] However, turbine noise greatly affects people even a mile away, and low-frequency noise makes people quite irritable.[164] Industry advocates say little, if anything, about infrasound or low-frequency noise.

The environmental noise pollution from wind turbines built too close to dwellings causes serious discomfort, and often health injury, to families. Oftentimes those affected did not object to the construction, accepting the developer's assurances that noise would not be problematic.[165]

Turbines interact and placement can influence noise emission. Other factors include the constantly changing atmosphere and wind speed, temperature, and terrain. Noise, particularly low-frequency noise, travels not only seismically but also airborne over the terrain. Local geography can sometimes act like a giant microphone.[166]

Shadow flicker and noise are detriments. Noise at the turbine hub can range from 100-105 dBA. It can be noticeable for long distances in more remote areas with existing low ambient levels (Humans can differentiate sounds up to 3 dBA above background levels).[167]

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160 Ibid.
161 Tom Hewson, *Wind Power Siting Issues Overview.* Presented to the National Association of Attorney Generals Wind Energy Facility Siting Issue Panel, April 21, 2008.
162 *Report from the Bethany Wind Turbine Study Committee,* January 25, 2007.
163 *Permitting of Wind Energy Facilities: A Handbook (Revised 2002).* National Wind Coordinating Committee, August 2002.
164 Eleanor Tillinghast, *Wind Turbines Don't Make Good Neighbors: Some Problems of Wind Power in the Berkshires.* Study presented by Green Berkshires, Inc, May 14, 2004.
165 Barbara J. Frey, BA, MA and Peter J. Hadden, BSc, FRICS, *Noise Radiation From Wind Turbines Installed Near Homes: Effects On Health – With an annotated review of the research and related issues.* February 2007, June 2007.
166 Ibid.
167 Tom Hewson, *Wind Power Siting Issues Overview.* Presented to the National Association of Attorney Generals Wind Energy Facility Siting Issue Panel, April 21, 2008.

Quality of Life

Turbine-generated noise has an adverse impact on quality of life and may adversely impact the health of those living nearby. Research links noise to adverse health effects such as sleep deprivation and headaches. Sleep deprivation may lead to physiological effects such as a rise in cortisol levels – a sign of physiologic stress – as well as headaches, mood changes, and inability to concentrate. Initial research into the health impact of wind turbine noise (including the 'visual noise' of shadow flicker) reveals similar findings.[168]

Even proximity to small wind farms can have a serious impact on nearby residents. One Illinois Township, concerned about the potential effects of a 22-turbine wind farm, surveyed its residents and found that, on average, 42% were bothered by blade flicker and noise, had been awakened by turbine sound, and had TV reception problems. Nearby property owners also cited increased lightning activity, increased traffic hazard, annoyance at the tower's blinking lights, the emergence of strange symptoms, and fears of EMFs. These tangible and intangible issues had a marked impact on the market value of nearby real estate. Reluctance to live near the turbines dramatically increased with proximity. For example, 41% of residents would not build or buy a home within 2 miles of the turbines. Within a half mile, 61% would not build or buy a home. And a quarter mile away from the turbines, 74% would not build or buy a home.[169]

In Oklahoma, a couple is trying to move away from wind turbines because they "can't get accustomed to the sounds because it's constantly changing." Their home near the turbines has sat on the market for two years and has received one offer that was 30% below the appraised value.170

In Vermont, landowners reported persistent noise from the turbines that "penetrated the house", causing sleep problems, difficulty with their ears, a pounding sensation in their home, and bothering their children. They abandoned their home but have been unable to sell it, citing disruption from the turbines as the primary reason.171

In Maryland, residents living near wind turbines have filed suits, alleging that the wind farm has interfered with their use, enjoyment, and value of their property. Residents also say that the wind farm has caused mental and physical health problems.172

Wind farm developers said property values wouldn't suffer. But the town zoning administrator did his own empirical research and found that sales within 1 mile of the windmills prior to their construction were 104% the assessed value, and properties selling in the same area after construction were at 78%. Sales more than a mile away were at 105% the assessed value before and 87% after. They also found several properties have taken much longer than normal to sell, and some are still on the market.[173]

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168 Barbara J. Frey, BA, MA and Peter J. Hadden, BSc, FRICS, *Noise Radiation From Wind Turbines Installed Near Homes: Effects On Health – With an Annotated Review of the Research and Related Issues.* February 2007, June 2007.

169 *Excerpts from the Final Report of the Township of Lincoln Wind Turbine Moratorium Committee.* Prepared by Elise Bittner-Macking for presentation to the Bureau County, Illinois, Zoning Board of Appeals, July 2, 2001.

170 Karl Torp, *Caddo County Couple Fighting Against Wind Turbines.* News 9, April 26, 2017.

171 Matthew Preedom, *Wind Turbines: Do property values fall?* St. Albany Messenger (VT). August 17, 2015.

172 *32 lawsuits filed against Pinnacle Wind Farm.* Cumberland Times-News, November 14, 2013.

173 *Excerpts from the Final Report of the Township of Lincoln Wind Turbine Moratorium Committee.* Prepared by

A New York landowner has a turbine on his property 2,000 feet from his house and says the turbine rattles his windows, and he can hear some turbines a mile away in his house. The wind company said the sound wouldn't exceed the sound of a refrigerator 900 feet away. He was joined by two other neighbors with similar complaints and who also said neighbors to the turbines started experiencing seizures, anxiety attacks, learning disorders, and other ailments once the turbines started running. Neither he nor the other leaseholders, nor the town has received any promised compensation because the turbines are not selling into the grid. They were told the lights would be the softest available but instead were much brighter than any anticipated.[174]

Wind turbines produce no constant tonality, making the creation of a noise standard challenging.[175]

Audible noise isn't the issue; it's the low-frequency sound waves. 2-3Hz can cause vomiting and other serious health issues. 12Hz can cause hallucinations.[176]

Hills and valleys can create a megaphone effect that can focus the direction, combine, and intensify the sounds of multiple turbines.[177]

Because of the deep foundations necessary to stabilize large wind turbines, LFN is transmitted down and throughout the contours of the land, often following bedrock, and even accelerates to immerge randomly miles from its origin.[178]

500' setbacks are "woefully inadequate...Anything less than a half mile is a recipe for disaster."[179]

Audible noises and LFN vibrations should be considered plus the potential noise of a failed bearing.[180]

In one case this year, two families in Ontario had to move due to adverse health effects from nearby wind turbines. One of the displaced landowners said he started suffering from very high blood pressure, sore feet, and irritability once the farm was online. Once he leaves the farm, he quickly recovers. The wind company is paying for one of them to stay in a hotel while tests are being done on their property.[181]

An industry spokesperson said such complaints are "few and far between" and "there's no cause and effect relationship between audible sound produced by turbines and adverse health effects." He even went so far as to claim, "...all research to date indicates that turbines do not produce infrasound at levels near enough to have impacts on humans."[182]

Elise Bittner-Macking for presentation to the Bureau County, Illinois, Zoning Board of Appeals, July 2, 2001.

174 Nancy Madsen, *New York Wind Farm Foes Say Noise Is Almost Unbearable.* Watertown Daily Times, July 20, 2009.

175 Arnold C. Palmer, *Expert: It's Difficult to Write Noise Ordinance*, July 19, 2009.

176 Ibid.

177 Ibid.

178 Ibid.

179 Ibid.

180 Ibid.

181 Don Crosby, *Wind Farm Neighbours Say They Had to Move.* Owen Sound Sun Times, July 4, 2009.

182 Ibid.

Industry advocates often say health concerns are exaggerations, and those who complain "are just worried about their real estate values."[183]

Elizabeth May, the former Executive Director of Sierra Club of Canada, vehemently defends wind energy but admits that literature studies show that wind towers negatively affect human health. She makes a concession for better project siting – away from impacted citizens.[184]

Strobe lights and shadows destroy any feeling of peace and solitude.[185]

The only potential health effect the wind industry acknowledges is toxic or hazardous materials in the form of relatively small amounts of leaking lubricating oils and hydraulic and insulating fluids.[186] However, even small leakages of such materials can negatively impact groundwater if left unchecked over time.[187] Fluid leaks not only drip directly downward, but they also fly off the tips of the spinning blades, thus spreading the contamination over a wider area.[188] On-site storage of new and used lubricants and cleaning fluids also constitutes a hazard.[189] Even the National Wind Coordinating Committee recommends setback requirements to provide "an adequate buffer" between wind generators and consistent public exposure and access.[190]

Several case studies by industry advocates show little to no concern for proximity landowners. In Oregon's Stateline Project, a 127-turbine farm covering 15 square miles in 2001 only sparked concerns over wildlife protection.[191]

Southwest MN has been building wind farms since 1995 ranging from 17 turbines to 143. Very few issues were raised during the review and permitting process and only after being built have issues emerged regarding poor television reception in proximity to the farms, additional noise generated by loose pieces of material within the blade at low speeds; cleanup of materials associated with turbine or blade modifications. Neighbors have also been complaining of their aesthetic detriment. Bird health is also an issue.[192]

As the number of houses near to, or with a view of the installation increases, the likelihood of aesthetic or economic objections seems to increase.[193]

New homeowners were attracted by the area's rural character and do not view their land as a source of

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183 Ibid.

184 Daniel & Carolyn d'Entermont, *Letter by Elizabeth May: Wind Power Flaps*. www.dangerwind.org/main.htm, March 13, 2009. Nova Scotia, Canada.

185 Eleanor Tillinghast, *Wind Turbines Don't Make Good Neighbors: Some Problems of Wind Power in the Berkshires*. Study presented by Green Berkshires, Inc., May 14, 2004.

186 *Permitting of Wind Energy Facilities: A Handbook (Revised 2002)*. National Wind Coordinating Committee, August 2002.

187 Ibid.

188 Ibid.

189 Ibid.

190 Ibid.

191 Ibid.

192 Ibid.

193 Ibid.

livelihood, nor identify with the farmers in the area who earn their living working their land. These "commuter" households are less likely to support a proposed wind project because they do not understand the economic situation of resident farmers and the extent to which wind energy revenues may act as a buffer against the fluctuations of the farm economy. Suburban development pressure may not be a fatal problem if the remaining farmers still control the local government.[194]

Developers may wish to consider compensating the community in some fashion that benefits even non-participants, such as impact payments to the township. Resulting benefits, such as reduced property taxes, may help to address concerns about inequities.[195]

A rural mountain community in Virginia fears that a proposed 19-turbine, 400-feet-tall-each project will blight their rural landscape and destroy the area's scenic beauty. The wind farm developer claims the turbines can power 20k homes. Community response has been very negative. Residents are afraid the turbines will kill tourism—their only industry—and negatively impact property values.[196]

A proposed 67-tower wind farm in Illinois sparked strong opinions among its affected community. Supporters say it will bring additional property tax revenue, jobs, and clean energy. Its opponents say it will be an eyesore, a dangerous obstacle to crop dusters, and would lower property values. An acoustical engineer from Michigan testified that the turbines would create noise that could affect nearby residents.[197]

Turbines are visually distracting, out of place, and threaten residents' peace and quality of life.[198]

Turbines create infrasound, low-frequency noise, flicker effect, loss of TV reception, cell phone, local networking reception disruptions, and electronic/electromagnetic interference. Careful placement might lessen the effects, but it's doubtful.[199]

Strobe lighting from the towers is a source of electrical pollution.[200]

Turbines generate flicker and shadows that can distract nearby motorists.[201]

They also interfere with television signals, thus affecting the quality of life for nearby residents.[202]

In addition to landscape blight, landowners are furious when the wind farm developers bring new transmission lines to transmit the wind energy to metro areas. But utilities are generally dismissive of such

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194 Ibid.
195 Ibid.
196 Adam Hochberg, *Wind Farms Draw Mixed Response in Appalachia*. Npr.com., July 23, 2009.
197 Kevin Sampler, *Wind Farm Opponents Air Concerns; Experts say Rail Splitter project will create noise, affect property values.* Journal Star, May 2, 2008.
198 *Report from the Bethany Wind Turbine Study Committee*, January 25, 2007.
199 Ibid.
200 *Report from the Bethany Wind Turbine Study Committee*, January 25, 2007.
201 Ibid.
202 Eleanor Tillinghast, *Wind Turbines Don't Make Good Neighbors: Some Problems of Wind Power in the Berkshires*. Study presented by Green Berkshires, Inc., May 14, 2004.

concerns, usually saying that "the importance of the lines outweighs the aesthetic worries."[203]

In pursuing alternative energy sources, it is imperative not to strip property rights to streamline green energy projects as the Ontario Minister of Energy proposes; he wants to invalidate municipal zoning laws preventing industrial wind farms and severely restrict what citizens can appeal. [204]

Tall structures are highly visible.[205]

In Europe, where wind farms have existed and operated for many years, people are loath to be near them, especially in scenic areas.[206]

Economic Impact

Some townships prefer to look at the projected tax revenues from proposed wind farms. One township in Ohio estimated that a 100MW wind farm would yearly generate the tax dollar equivalent of 449 homes, and they estimate a 300MW farm would generate the tax dollar equivalent of 1,347 homes. Due to conflicting studies on the impact of turbines on property values, they chose to disregard the issue completely. They anticipate significant positive local property tax impacts are possible assuming they can tax and collect at local levels. They expect local spending, job creation, lease payments, and earnings and outputs to increase regardless of the turbines' tax status. And they expect to maintain a "healthy, equitable and sustainable tax base" by balancing residential development with commercial development and conserving open/farmlands to prevent the county from continuing to become a "bedroom community."[207]

Wind farm projects have little to no significant job impact.[208] In Ireland, wind energy promoters' claims of job creation were rebutted by Britain's environment secretary who said that wind farms had "significant impacts on the rural economy and the rural environment."209

Wind farms contribute little to county property taxes. In some states, energy producing equipment is exempt from property taxes; taxable items may be limited to foundation and tower structure. Some developers also apply for additional local tax relief.[210]

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203 Amanda Casnova, *Transmission Line Debates: Wind here, towers somewhere else.* Abilne Reporter-News, July 18, 2009.
204 Sven Hombach, *Guest Article: Ontario Set to Become a Wind Power-house.* National Renewable Energy Group of the Fraser Milner Casgrain, LLP. Windpowerlaw.info, June 16, 2009.
205 Tom Hewson, *Wind Power Siting Issues Overview.* Presented to the National Association of Attorney Generals Wind Energy Facility Siting Issue Panel, April 21, 2008.
206 Candida Whitmill, *UK Energy Policy: The Small Business Perspective & The Impact on the Rural Economy.* Small Business Council, February 2006.
207 Dave Faulkner, Exec. Director of Community Improvement Corporation of Champaign County, Ohio, *Economic Impact Study of Wind Farm Development in Champaign County, Ohio.* Prepared for Champaign County Wind Tower Study Group, November 13, 2007.
208 *Report from the Bethany Wind Turbine Study Committee*, January 25, 2007.
209 Frank McDonald, *Jobs claim by wind farm lobby dismissed.* The Irish Times, October 16, 2012.
210 Tom Hewson, *Wind Power Siting Issues Overview.* Presented to the National Association of Attorney Generals Wind Energy Facility Siting Issue Panel, April 21, 2008.

A public policy research group studied a proposed wind farm in Nantucket Sound and found it failed the cost-benefit test recommended by the U.S. government for assessing large-scale projects. The wind farm developer stressed the value of wind power as a source of clean, renewable energy. But the study found that the overall economic costs of the project would exceed benefits by $211.8 million. Without $241 million from state and federal subsidies, the project would not be financially viable. And while the farm may generate some wind energy jobs, the impact on tourism would result in a net loss of 1,000 local jobs.[211]

Industry advocates frequently cite additional tax revenues as a positive reason to build wind farms. General Electric, the wind turbine manufacturer that's currently backlogged $12 billion in turbine orders, claims that over the long-term wind farms will add $250 million to the US Treasury. However, they also acknowledge they will only begin to "pump money into the US Treasury" once the Production Tax Credits expire. PTCs are good for the first 10 years of a wind farm's production. They also project creating thousands of short-term construction jobs with long-term employment of 1,600 over 20 years or more of operation. They also project 10 million metric tons per year of CO2 emissions avoided.[212]

Rural tourism is big business in the UK (worth approximately $26.7 billion) and supports up to 800,000 jobs. 75% of visitors say the quality of the landscape and countryside is the most important factor in choosing a destination. Between 47% and 75% of visitors felt that wind turbines damage landscape quality. Of the three areas they studied, they found that 11% of visitors would avoid Case #1, resulting in a loss of $48.5 million and the loss of 800 jobs. Approximately 7% of visitors would not return to the second case, resulting in a loss of $117 million and 1,753 jobs. In the third case, just 5% would stay away, but its affluence would result in $668.5 million lost along with 15,000 jobs. In some areas, 49% of all sectors of rural businesses experienced a negative impact.[213]

The success of rural enterprises is inextricably linked to the maintenance and conservation of a healthy and attractive and irreplaceable rural appeal.[214]

In a tourist area of the UK, five wind farms are proposed totaling 71 turbines along 18 miles. In a pilot survey of 1,500 visitors, approximately 95% of the visitors said wind turbines would spoil their enjoyment of the landscape. And this spoiling directly translates into less business from tourism and thus, lost jobs.[215]

In another tourist area in the UK, two-thirds of local businesses said turbines are visually intrusive. While 54% thought wind turbines would increase their 'green' credentials, 27% believed it would still have a negative impact on the tourism industry by reducing visitor numbers. After the details of the tower heights were revealed the next year, the 27% grew to 39% who felt the 400-foot-high turbines would make visitors stop visiting completely.[216]

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211 *Beacon Hill Institute Study: Cape Wind proposal fails cost benefits test.* The Beacon Hill Institute for Public Policy Research, March 16, 2004.
212 Steve Taub (Senior VP of GE Energy Financial Services), *GE Energy Financial Services Study: Impact of 2007 Wind Farms on US Treasury.* GE Energy Financial Services, Date Unknown.
213 Candida Whitmill, *UK Energy Policy: The Small Business Perspective & The Impact on the Rural Economy.* Small Business Council, February 2006.
214 Ibid.
215 Ibid.
216 Ibid.

In North Devon, an area renowned for its beauty, a before-and-after survey was conducted to gauge visitors' feelings toward possible wind farms. Before details of their 300' height were revealed, 34% were generally favorable and 66% unfavorable towards turbines. After the size and location of the turbine proposals were revealed, the number of 'unfavorable' visitors rose to 84%. When asked if wind farms would affect their choice of holiday destination, just less than 50% claimed that they would still choose North Devon. A further 39% said they would choose North Devon, but subject to the size and location of the wind farms. Eleven percent would stay away from North Devon altogether. Visitors claimed that if they found wind turbines on their arrival and had not been previously informed, 15% would complain to their tour or holiday operator and around 28% stated they would never return.[217]

Scotland is also proposing wind farms, but a visitor survey found that 15% of visitors would not return if wind turbines are built, resulting in a potential loss of $133.7 million and 3,750 jobs.[218]

Wind energy advocates claim their wind farms would actually boost tourism. They tried it in the UK, and both utterly failed, proving that visitors do not accept wind farms as tourist attractions. In 1999, a visitor's center was built in Norfolk, UK – then home to one of the largest turbines in the world. It ran out of money and closed in 2002. Then in 2001, a $9.1 million visitor center was built with hopes of attracting 150,000 annual visitors to its wind farm. Despite opening with much publicity, it attracted less than a tenth of projected visitors, and it went bankrupt. Its CEO debunked advocates' mindset when he said, "Sadly, just like many eco-attractions, they're not sustainable; there's just not enough interest."[219]
They recommend micro-generation as an acceptable alternative.[220]

In summary, the media generally portrays the impact of wind turbines on residential properties as negative, bringing up fear factors and conflicting benefit, or no benefit issues. Overall, the qualitative factor is centered along the lines of health, noise, flicker, and viewshed. With regard to the question, "Do wind turbines affect property value?" the two Centerville Township (Michigan) officials summed it up with this statement: "It is totally counter-intuitive to suggest anything else."

217 Ibid.
218 Ibid.
219 Ibid.
220 Ibid.

Review of Impact Studies

Review of Impact Studies

Introduction

Though not an exhaustive listing, the following studies, and articles were utilized to develop an opinion as to what impact a wind farm will have on property value.

- *The Impact of Wind Power Projects on Residential Property Values in the United States: A Multi-Site Hedonic Analysis (2009 updated in 2013)* by Berkeley National Laboratory (California).

- *Impact of Industrial Wind Turbines on Residential Property Assessment in Ontario, 2012 Assessment Base Year Summary* by Municipal Property Assessment Corporation (MPAC).

- *Case Study Diminution in Value Wind Turbine Analysis (2012)* by Ben Lansink, AACI, P.Appr, MRCS, real estate appraiser (Ontario, Canada).

- A market study by Glen Taylor on the Chevron Wind Tower Development in Wyoming.

- *Wind Turbine Impact Study (2009)* completed by Kurt C. Kielisch, Appraisal Group One (Wisconsin).

- *Values in the Wind: A Hedonic Analysis of Wind Power Facilities (2011)* completed by Heintzelman and Tuttle, Clarkson University (New York).

- *Coral Springs Development Study (2007)* completed by Kurt C. Kielisch, Appraisal Group One (Wisconsin).

- *Mendota Hills Residential Property Impact Study (2011) completed by Michael S. McCann (Illinois).*

- *Big Sky Wind Farm Matched Pair Analysis Study (2015)*, completed by Kurt C. Kielisch, Forensic Appraisal Group (Wisconsin).

The following is a review and critique of each study.

Berkeley National Laboratory Study

In the fall of 2009, the Berkeley National Laboratory (California) released their study, "The Impact of Wind Power Projects on Residential Property Values in the United States: A Multi-Site Hedonic Analysis." This study was sponsored by the Department of Energy. In summary, this study found no relationship between the presence of wind turbines and residential property value. A review of this study brings out several observations that the reader should be cognitive of when considering applying these findings to a wind farm in Illinois.

No Real Estate Value Experts

The first problem with this study is the use of hedonic modeling to isolate variables in value. Though this is a recognized methodology in the statistical world; it is still young in its application to the real estate appraisal field. This modeling technique is considered a tool in the appraiser's toolbox which can assist him in making valuation decisions; but it is not the sole source of determining value in real estate. The appraiser must also apply his expertise and, some would say, "art," to the understanding of the valuation process to arrive at a realistic interpretation of the results of the study. This fact is recognized in the study where it states, "It should be emphasized that the hedonic model is not typically designed to appraise properties..."221 One of the leading real estate appraisal texts adds, "Appraisers should recognize the differences between statistical processes in the collection and description of data and should be able to distinguish between descriptive and inferential statistics. Without an understanding of the issues, any use of statistical calculations is dangerous or ill-advised." 222 It is here where we take issue with the foundation of the study and its authors.

Through correspondence with Ben Hoen, the primary author of the Berkeley Labs study, it was learned that no one involved in the study was an expert in real estate valuation, nor had any practical experience as a real estate appraiser, a real estate broker, or as a real estate developer. Ben Hoen is trained in applied statistics, having a master's degree in that field. The other signature authors are Thayer, Ph.D. in economics (i.e. how things work, not their value); Sethi, Ph.D. in agriculture and resource economics (again, how it works, not its value); Wiser, Ph.D. in energy and resources; and Cappers, masters in applied economics. In review, one can see that these authors are well-schooled in economics, but not in the practical valuation of real estate. This academic approach most likely led to an error in the selection of the database for the model—the use of improved residential properties.

Use of Improved Residential Properties

The use of improved residential properties in large-scale statistical analysis can be problematic. Appraisers know that the easiest real estate to use in statistical analysis is vacant land. This is due to a number of variables which may impact the value. When valuing land, there are approximately 12 value factors commonly used by appraisers to represent how the market (buyer) would react.223 The value factors that are specific to land are:

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221 Berkeley study, page x.

222 *The Appraisal of Real Estate* – 12th Edition (Chicago: Appraisal Institute), 440.

223 This number may vary between property types and appraisers, but the noted variables are typical.

- Size
- Location
- Shape
- Topography (woods, open area, soils, physical limitations)
- Water features (ponds, creeks, streams, rivers, lakes, oceans)
- Wetlands and flood zones
- Terrain (level, rolling or severe)
- Zoning
- Utilities (private or municipal water and sewage, natural gas, electrical and telephone)
- Road frontage (town, county, highway or interstate roads)
- Access (direct off-road, indirect via a long driveway, access easement, no access)
- View (including positive and negative environmental factors)224

When you add residential improvements to the equation you not only have the 12 value factors of land, but you add another 25 variables which typically include:225

- Location of improvements
- View
- Physical age
- Condition
- Quality of construction
- Style/design/number of stories
- Exterior siding
- Roof cover/gutters/downspouts
- Gross living area above grade
- Basement (full, partial, crawl, exposed/hillside)
- Finished area in basement
- Garage/carport (size, # car storage)
- Finished area in or above garage
- Room count (total rooms/bedrooms/bathrooms)
- Patios (concrete, brick)
- Porches (open, covered, screened)
- Decks (type of wood, size, levels)
- Air conditioning (central, zoned, through wall)
- Type of furnace (forced air, hot water, steam, gas, in floor, fuel oil, electric)
- Energy efficiency items
- Functional utility (layout of interior rooms, functional problems, outdated items)
- Extra buildings (sheds, barns, workshops)

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224 These factors are mentioned in *The Appraisal of Real Estate* - 12th Edition (Chicago: Appraisal Institute), 333.
225 This number may vary between property types and appraisers but are typical for most properties.

- Fireplace (wood, gas, stoves)
- Landscaping (including paved/concrete/brick driveways and walks, shrubbery, and gardens)
- Special features (Jacuzzi, hot tubs, built-in appliances, stone countertops, wood or tiled floors, built-in entertainment centers, theater rooms, swimming pools, ponds, fencing, etc)226

Factors that were not mentioned in this list, but have an influence on value, are street appeal, interior decorating and availability of financing.

As you may imagine, when you add these value factors to the land value factors you have an exponential number of potential match-ups and adjustments. For this reason, an experienced appraiser would know that to compare 7,500 improved properties of all sizes, styles, ages, conditions, gross living areas, amenities, and different localities would be a nearly impossible task without the ability to appraise each sale independently, assessing all the factors of value.

The list of variables considered in the hedonic analysis appears on page 21 of the Berkeley study. You will notice there are only three variables in relation to land, that being size in acres, cul-de-sac, and waterfront (yes/no question with no consideration to quality, type, amount, etc.). In relation to the actual improvements, there are 9 variables. These variables are:

- Age
- Gross living area above grade
- Number of bathrooms
- Exterior siding (only variable is stone, brick or stucco – not vinyl, steel, wood or log)
- Air conditioning (central air only, yes/no)
- Finished basement (only includes finished if it is greater than 50% of area)
- Waterfront (the only factor is fronting on water with no reference to type, size, amount, etc.)
- Condition
- Vista (view)

This list is missing 26 other distinct and important variables of value for a residence. To ignore these is an error and could result in an inaccurate comparison of the sales used in the analysis.
Due to the sheer size of this study and the logistics of obtaining the data on the improved properties, the authors of the study chose to collect their data via government records. These records included assessor records, which can be problematic. Few assessment records are considered up-to-date on the condition of the property and other improvements which give value, such as fencing, landscaping, room layout, and decoration. Most assessment records are only updated on a periodic basis and contain the base information about the residence. This base is what undoubtedly limited the selection of the valuation variables utilized in the hedonic models.

Location of Sales – Urban vs. Rural

An appraiser or real estate professional recognizes that location is of primary importance. In most cases,

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226 Note: This is not an inclusive list of the variables present with residential improvements. Many of the items listed are found on the Fannie Mae form 1004/Freddie Mac form 70.

it simply cannot be adequately factored in to get a true representation of how the market would react. For instance, there is a distinct difference between the typical buyer of a rural property, who desires to get away from the noise and congestion of the urban environment and is willing to be inconvenienced to obtain this escape, as compared to that of an urban buyer who will accept the noise, congestion, and other urban settings for the convenience factor. Therefore, it would be unwise to compare residential sales of these separate and distinct environments to each other. However, the Berkeley study does just that.

An example of this may be found on page 84. This page shows a map of the wind towers and the residential sales utilized in the study. The red '+' marks denote the placement of the wind turbines and the maroon dots denote the sales used in the study. This map shows nearly all the sales utilized were in an urban area, either in Kennewick (9 miles to 20 miles away) or Milton-Freewater (approximately 9 miles away). Only a few sales are located outside of these urban areas. An extreme example of this would be found on page 90, whereas nearly all the sales are located in the City of Weatherford. This pattern is repeated in most of the study locations (pages 93, 99, 102, 108, and 111). The best study, having the most non-urban sales, can be found on page 96, whereas only a small portion of sales is found in the cities of Paw and Compton. Unfortunately, this study had only 2 sales that were less than 1.00 mile from a wind turbine out of a total of 412 sales utilized.

Of particular interest was the study found on page 99. This study area is located in the Kewaunee and Door County area of Wisconsin. This author is very familiar with this area, having appraised a number of properties along State Highway 57, which runs through these two counties. In this study; you can see that most of the sales were from the urban centers of Luxemburg, Casco, Brussels, and Algoma. In addition, the Algoma area fronts on Lake Michigan with dynamic views of the lake and is known for tourism due to its location on the water. Opposite, and on the other side of the land mass, is the Green Bay area which is a large bay of Lake Michigan between Door County and the city of Green Bay. These sales are all aligned along the lake shore which has high bluffs with dynamic lake views. Any residence found in either area would be oriented toward the lake vista and not inwards toward the wind turbines. In addition, Algoma is over 5 miles to the east of the nearest wind turbines, which are not visible. The same is true of the other urban areas and the Green Bay shoreline. This opinion is supported on the chart found on page 101 which lists only 5 sales with either a substantial or extreme view of the wind turbines. Lastly, it was this same area that homes were purchased by the wind farm developer who then either razed the buildings or resold the property at a substantial loss. This information appears not to be included in the study.

Few Sales in Close Proximity to Wind Turbines

The study utilized approximately 7,500 residential, improved sales. Of this number, only 67 sales (<1%) were within 0.57 miles of a wind turbine and 63 sales (<1%) had a substantial or extreme view of the wind turbines. Conversely, 98% of all the sales were a mile or greater in distance away, with the greatest number being over 3 miles away (57%).[227] The author correctly states that view or vista is a significant factor in value. The study has a chart showing that a poor vista results in a -21% loss of value and a below average vista results in a -8% loss.[228] However, when this vista measurement was applied to substantial and extreme views of the wind turbines it found the opposite to be true, indicating a +2.1% increase in value by having an extreme view. This result is counter-intuitive: Common sense and experts in the real

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227 Berkeley study, xiii, xiv.
228 Ibid, 29, Figure 5.

estate field would agree that a wind turbine meets the definition of a poor vista. Surely, a wind turbine does not enhance the vista. When the study compared proximity to the wind turbines (which may overlap the Vista factor) it found a -5.3% to -5.5% loss in value.229 It would appear that the problem lies in the number of samples in close proximity with a clear view of the wind turbines as suggested by the author regarding the proximity factor not being significant in statistical terms: "Even though the differences are not found to be statistically significant, they might point to effects that exist but are too small for the model to deem statistically significant due to the relatively small number of homes in the sample within 1 mile of the nearest turbine."230 Though a -5.5% loss in value may not be substantial in the field of statistics, it is substantial in the valuation of real estate as any appraiser or property owner would know. This type of loss would equate to a $13,750 loss for a $250,000 home.

Other Studies Have Found a Negative Impact

Though the Berkeley study found no loss of value for an improved residential property due to proximity to a wind farm, other studies have suggested otherwise. The study's author acknowledges this very point, listing the studies he found in his literature research regarding the impact of wind turbines on real estate values. In the chart found on page 9, the author notes that 3 out of 4 (75%) of the homeowner surveys found a loss; 3 out of 5 (60%) of the expert surveys found a loss; 2 out of 10 (20%) of the transaction analysis-simple statistics found losses; and 3 out of 4 (75%) of the transaction analysis-hedonic model found losses. As a matter of fact, the only two studies authored by certified real estate appraisers (McCann, Kielisch) both found significant losses and the only hedonic model study listed in this chart that did not find a loss was the Berkeley (Hoen) study.

It would appear that the Berkeley study is only one of a few that have resulted in finding no impact on property value due to the presence of wind turbines. One reason for this could go back to the very base of the model, the selection of improved residential properties and their limitation to extract values due to the complexity and sheer number of the variables to value that interplay with the final market value. Another reason is cited by Heintzelman stating, "However, they limit themselves to discontinuous measures of proximity based on having turbines within 1 mile, between 1 and 5 miles, or outside of 5 miles, or a similar set of measures of the impact on scenic view, and they again find no adverse impacts from wind turbines. In addition, by including so many disparate regions within one sample they may be missing effects that would be significant in one region or another."231

Another potential reason for their finding of no impact could be the lack of adequate numbers of sales within close proximity to the wind turbines for their statistical study to work properly. The author identified this as problematic, saying, "Unfortunately for the study, most wind power projects are not located near densely populated areas. As a result, finding a single wind project site with enough transaction data to rigorously analyze was not possible."232 This, of course, is a prejudice of many academic statisticians, but it is not shared with the appraisal profession as indicated by this statement from a guide to statistical analysis by the Appraisal Institute, "Based on the experience of the authors, the

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229 Ibid, 31.
230 Ibid, 31.
231 Martin D. Heintzelman, Ph.D. & Carrie M. Tuttle, *Values in the Wind: A Hedonic Analysis of Wind Power Facilities* (Clarkson University, 2011), 8-9.
232 Berkeley Study, 10.

ideal number of sale properties usually ranges between 18 and 32."233 Indeed, a smaller, localized study may be a much better analysis to isolate the impact on property value of a wind turbine than a combination of 10 different studies in nine states.

Conclusion

This brief review touched on several major points to consider when looking at the Berkeley study. It showed that the base of the study (that is, to use improved residential sales) has a great potential to result in flawed conclusions due to the great number of value variables present in such properties. A vacant land analysis would have been better and more accurate. The selection of sales combining both urban (city) and rural sales is flawed on the onset since these two buyer groups are very different from each other and have different motivations for their purchases. Of course, the reason the two were combined was due to the lack of a large number of sales in and around the wind turbines themselves. This could suggest to the authors that: (a) possibly this lack of sales activity is due to the presence of the wind turbines themselves; or (b) the sales sample set and model should be smaller, potentially resulting in a more accurate measure of the effects. The desire for a large database caused the authors to combine ten different studies located in nine different states, states that were decidedly different from each other, which resulted in a larger database pool. However, on the practical side of real estate valuation, such a large database is not representative of greater accuracy. It could be that these basic errors in judgment were a result of the lack of professional and practical experience in the real estate valuation field.

This is a study of improved residential properties, which overwhelmingly were located in urban centers, not the rural countryside. This study did not measure impacts to agricultural land, recreational, or rural residential land. Therefore, its direct application to such properties is cautioned.

233 *A Guide to Appraisal Valuation Modeling* (Chicago: Appraisal Institute), 61.

Impact of Industrial Wind Turbines on Residential Property Assessment in Ontario, 2012 Assessment Base Year Summary

The Municipal Property Assessment Corporation (MPAC) completed this study to review their assessment practices with regard to the potential negative impact to property value caused by the presence of wind turbines. MPAC is a governmental agency responsible for the assessment of millions of properties in the Ontario, Canada, region. This agency is both political and governmental. Political since the directors are politically appointed and governmental in that a finding of a negative value impact due to the wind turbines would require the local assessors to revalue such impacted properties and the governmental agencies that are dependent upon tax revenue from property assessments would be negatively impacted. With this responsibility, the MPAC went about testing the null hypothesis that there is "no difference between properties in close proximity to wind turbines to those that are not." (A null hypothesis in statistics basically assumes no difference between two sets.) MPAC chose to test this hypothesis through the use of checking the accuracy of their assessments by comparing the two sets and then using statistical analysis of selling prices to test if there is a valuation impact.

The first test examined the accuracy of the assessments in the two data sets, one being less than 2km proximity to a wind turbine and the other outside of that distance (>2km). Using Canadian government assessment standards of accuracy, which state that an assessment is considered accurate if the assessment-to-sale price (ASR) lies within 0.95 to 1.05 of the assessment. An ASR ratio is calculated by assessment ÷ sale price. As an example, if a property was assessed at $100,000 and sold for $105,000 the ASR would be 0.952 or 95% of the assessed value and the assessment would be considered accurate. If the property sold for $90,000 the ASR would be 1.11 or 111% of the assessed value and the assessment would fail the accuracy test.

The geographic area of this study was fifteen market areas in Ontario, Canada. These areas were identified as potential study markets since wind turbine farms were in their vicinity. MPAC tested the assessment ratios pre-construction of the wind farms (but after their announcement) and after the construction of the wind farms. The hypothesis was if the ratios were within the acceptable range, i.e. 0.95 to 1.05, for both data sets and in both conditions, then there was no relationship between the presence of wind turbines and value.

The test of the ASR showed those properties within the 2km distance of wind turbines had a -4.2% to -4.5% loss factor. Since this was within the 5%± acceptable range of value, MPAC concluded wind turbines do not impact property value. It should be noted that the overall property values that were <2km were consistently less than those values >2km (MPAC report, figure 2, p.18) and their ASRs were higher, typically over 1.034 as compared with the >2km properties which were in the 0.992 range.

The second test was a sales analysis using multiple regression analysis. This study indicated that only two market areas had sufficient pre-construction and post-construction sales to derive a variable for this comparison. One of these areas, market area 26RR010-Chatham, indicated a loss of $6,451 per property if <1km of a wind turbine and a loss of $3,686 if within the 1km-2km distance. Both statistics were considered not statistically significant since they were at the 10% significance level.

Overall, the study concluded that distance to a wind turbine was not a factor influencing property value.

Critique

The first test of the study had little to do with measuring the impact on property value due to the presence of a wind turbine and everything to do with measuring the accuracy of assessments. There is nothing said in the report to investigate if the local assessors had already considered the locational factor in their assessment. So, if a home that was located outside of the zone of influence and would have a value of $125,000 and assessed accordingly, and a similar home that laid within the zone of influence would have a value of $100,000 and assessed accordingly, the ASR for both subsets would be 1.00. Accordingly, if you applied the MPAC test of ASRs you could conclude there is no influence due to the wind turbines. Hence, this first test was simply an exercise in measuring their accuracy of assessment and not to extract an impact factor.

The second test had some issues as the charts illustrated. For instance, in only two out of the fifteen market test areas did they have sufficient sales to measure both the pre-construction and after-construction values, which was the stated purpose of this exercise. Additionally, one of the two areas indicated a measurable (though not deemed significant) negative effect. Of course, the problem here, as with the Berkeley study, is that there were few variables measured for the improved properties. Limiting these value-influencing variables is a mistake that will skewer the results of any study. The study itself did not provide any insight into the other variables to be considered and why or why they were not included. It can be said with consistency that this study indicated properties within close proximity of the wind turbines had overstated assessments and lower valued properties.

Case Study Diminution in Value Wind Turbine Analysis (2012)

Real estate appraiser Ben Lansink, AACI, P.Appr, MRCS, real estate appraiser (Ontario, Canada) completed a comparative sales analysis study of five properties located within a wind farm area. These properties were selected because they were purchased by the Canadian Hydro Developers, Inc (Hydro) who was the developer of the Melancthon Wind Facility (MWF) located in Shelburne, Ontario, Canada. MWF is a 200-megawatt development comprised of one hundred and thirty-three General Electric 1.5mw wind turbines having 262ft± tall towers and a 147ft± blade wingspan. The wind farm was developed in two phases, with the first phase coming online in 2005 and the second in 2008. Hydro purchased these five properties at the property owners' request and paid full market value for each property according to Lansink. The purchases were completed between 2005-2007, and the resale of the properties took place between 2009-2012. Lansink inspected all the properties in 2012, compared the results of the personal inspection with the MLS listings at the time of purchase and resale to note any changes that may have taken place. The five properties consisted of four single-family residences and one farm.

Lansink used a comparative analysis of twenty comparable properties sold in 2005-2007 to measure the validity of the initial purchase price concluding that the properties were purchased at market value without consideration given to the value influence of the wind farm. He then proceeded to do a market trend study in the area to establish a measurable and reasonable adjustment for time. He then applied this market trend adjustment to predict the market value of the properties sold at a later date and compared that estimate to the actual sale price. The difference, if any, was applied to the wind farm influence having all other factors being equal. He concluded the following:

Sale 1- This property was a 1.5-story Cape Cod design residence on 1.88 acres. Its room count was 6 total rooms, 3 bedrooms and 2 bathrooms (6/3/2). The closest wind turbine was 1,902ft away. The home was purchased in November 2007 for $500,000 and sold two years later in December 2009 for $288,400. The condition of the home was considered the same in both sale dates. When the market trend adjustment was factored the estimated resale price was $557,509 representing a -48.27% loss due to the wind turbine. If no market trend adjustment was applied, the loss would be -42.32%.

Sale 2- This property was a 2-story farmhouse residence on 100± acres. Its room count was (13/4/2) with 3,500sf of gross living area. It had a large Quonset agricultural building. The closest wind turbine was 1,902ft away. The home was purchased in October 2007 for $350,000 and sold about three years later in November 2010 for $175,000. The condition of the home was considered the same in both sale dates. When the market trend adjustment was factored, the estimated resale price was $422,272 representing a -58.56% loss due to the wind turbine. If no market trend adjustment was applied the loss would be -50.00%.

It should be noted that Hydro chose to market the property as "vacant land," however Lansink inspected the property and found the buildings viable and considered the sale "as improved."

Sale 3- This property was a 2-story contemporary design residence on 10± acres. Its room count was (6/3/1) and included a 2-car garage and raised wood decks. The closest wind turbine was 664ft away. The home was purchased in January 2007 for $305,000 and sold two and a half years later in August 2009 for $278,000. The condition of the home was considered the same in both sale dates. When the market trend adjustment was factored, the estimated resale price was $362,153 representing a -23.24% loss due to the wind turbine. If no market trend adjustment was applied the loss would be -8.85%.

Sale 4- This property was a split-level design residence on 1± acre. Its room count was 10/5/2 and had a 1-car attached garage. The closest wind turbine was 1,136ft away. The home was purchased in August 2007 for $302,670 and sold two years and nine months later in April 2010 for $215,000. The condition of the home was considered the same in both sale dates. When the market trend adjustment was factored the estimated resale price was $293,172 representing a -26.66% loss due to the wind turbine. If no market trend adjustment was applied the loss would be -28.97%.

Sale 5- This property was a bi-level design residence on 2± acre and had a 2-car attached garage. The closest wind turbine was 1,213ft away. The home was purchased in June 2005 for $299,000 and sold seven years later in June 2012 for $250,000. The condition of the home was considered the same in both sale dates. When the market trend adjustment was factored the estimated resale price was $398,723 representing a -37.3% loss due to the wind turbine. If no market trend adjustment was applied the loss would be -16.39%.

Depending on how you calculated the losses, either from the estimated market value at the date of resale or the difference between the purchase and resale price with no consideration for the time lapse, the analysis found the following losses:

Market trend method:

Median loss	-37.30%
Average loss	-38.81%

The difference between purchase and resale method:

Average loss	-29.31%

If you isolate the impact on only rural residences having less than 10 acres (excluding Sale 2), then the losses change slightly.

Market trend method:

Average loss	-33.87%

The difference between purchase and resale:

Average loss	-24.13%

In summary, the study indicated that the presence of a wind turbine in close proximately (664ft to 2,531ft) resulted in significant value losses ranging from an average of -24% to -39%.

Glen Taylor Chevron Wind Tower Market Study - Wyoming

In 2010, realtor Glen Taylor (Equity Brokers, Casper, Wyoming) completed an informal market study of the residential properties in close proximity to the Chevron Wind Tower Development. The area of study was in Evansville, Wyoming just outside of Casper. The wind farm had 11 wind turbines. Mr. Taylor based his study on observations of market activity both in near proximity to the wind farm and out of the wind farm influence. His study concluded:

> "My determination was that the presence of the large Wind Towers has had a detrimental effect on property values, not only residential property values, but also unimproved and presently uninhabited properties as well. Keep in mind; these now uninhabited properties may someday be candidates for development of residential or small ranchette type of locations. The report also indicates that those properties closest to the development are the most affected by the huge towers close to adjacent property lines and my 20 years of experience in the real estate marketing business tells me that the further away the towers are from adjacent property lines, the less affected the property values would be. The term "further" may be the key word here as it can be a very subjective term."234

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234 Letter to Converse County Commissioners, November 2, 2010, from Glen Taylor.

Appraisal Group One Study - Wisconsin


Figure 1: This is a view of the Blue Sky Green Field wind farm.

In the fall of 2009, Appraisal Group One (now, Forensic Appraisal Group, Ltd, Wisconsin) completed a study entitled "Wind Turbine Impact Study – 2009" for the Calumet County Citizens for Responsible Energy, a group of property owners united to prevent wind farms from being located in their county. The study examined the impact that wind turbines have on rural residential property value. The wind turbines that were the focus of this study are approximately 389ft tall and produce 1.0+ megawatts each. This study was based in Dodge and Fond du Lac Counties, Wisconsin. It was broken down into three parts: A literature study, a realtor opinion survey, and sales studies. Overall, the study concluded that the presence of a wind farm had a negative impact on rural residential property value 5 to 10 acres in size, and farmettes up to 20 acres in size. The impacts according to the realtor survey suggested losses ranging from 24% to 43%; the literature study indicated losses averaging 20.7%, and the sales study indicated losses ranging from 19% to 74% – with the most likely range of loss being 19% to 40%. Some observations of this study and its conclusions follow.

Realtor Survey

The purpose of the realtor survey was to learn from the people who are on the first tier of the buying and selling of real estate what they thought of wind turbines and their impact on residential property value. This survey was designed to measure what type of impact (positive, negative, or no impact) that wind turbines have on vacant residential land and improved property. The questions were designed to measure three different visual field proximity situations to wind turbines. These three were *bordering* proximity (defined as 600ft from the turbine), *close* proximity (defined as 1,000ft from the turbine) and *near* proximity (defined as one-half mile from the wind turbines). In all situations, the wind turbines were visible from the property.

Graphics and photographs were utilized to illustrate each question so that the survey taker would have the same or similar understanding as others on each question. In addition to asking the realtors about the type of impact they expected in each situation, the survey then asked them to estimate the percentage of the impact. Though it is understood that realtors are salespeople and not appraisers, it is also true that they often have to estimate asking prices for their clients or act in the capacity of a buying agent for a client. Both situations demand an estimate of value and recognition of those factors that both benefit and detract from value.

The geographic area for the selection of the survey participants was defined by the wind farm projects. These projects were in Fond du Lac and Dodge Counties, Wisconsin.

A total of 36 realtors were surveyed, indicating an average of 13.4 years of experience.

The survey indicated that, in all but two scenarios, over 60% of the participants thought that the presence of the wind turbines had a negative impact on property value. This was true of both vacant land and improved land. Where the group diverted from that opinion is when they were presented with a 10-20 acre hobby farm being in *close* and *near* proximity. In these cases, 47% (close proximity) and 44% (near proximity) of the participants thought that the wind turbines caused a negative impact on property value. The answers showed that *bordering* proximity showed the greatest loss of value at -43% for 1-5 acre vacant land and -39% for improved properties. Next in line was the *close* proximity, showing a -36% value loss for 1-5 acre vacant land and -33% for improved property. Last in line was the *near* proximity, showing a -29% loss of value for a 1-5 acre vacant parcel and -24% loss in value for improved parcels. These losses show a close relationship between vacant land and improved land. This pattern was replicated regarding the *bordering* proximity for a hobby farm, whereas 70% believed it would be negatively impacted. Lastly, the opinions regarding the impact of the wind turbines due to placement (that being in front of the residence or behind the residence) showed that in both situations most participants believed there would be a negative impact (74% said negative to the front placement and 71% said negative to the rear placement).

In conclusion, it was observed that: (a) In all cases with a 1-5 acre residential property, whether vacant or improved, there will be a negative impact on property value; (b) with 1-5 acre properties, the negative impact on property value in *bordering* proximity ranged from -39% to -43%; (c) with 1-5 acre properties, the negative impact on property value in *close* proximity ranged from -33% to -36%; (d) with 1-5 acre properties, the negative impact on property value in *near* proximity ranged from -24% to -29%; (e) in all cases the estimated loss of value between the vacant land and improved property was close. However, the vacant land estimates were always higher by a few percentage points; (f) it appears that hobby farm use on larger parcels would have lesser sensitivity to the proximity of wind turbines than single-family land use; and (g) placement either in front or at the rear of a residence has similar negative impacts.

Literature Study

This study looked at the recent articles and studies published related to the impact of wind turbines on residential property values. The review broke down the articles into several categories including health issues, health solutions, wind turbine hazards, conservation concerns, property values and land use, noise, quality of life, wind energy production, wind farms as tax havens, and economic impact.

Below is a brief summary of the findings:

- Articles and studies show wind turbines:
    - Intrude on the viewshed
    - Make noise
    - Cause flicker and strobe light irritants
    - Limit development
    - Affect highest & best use
    - Increase time on the market
    - Lower property values

- Wind industry cites a 2004 study by the Renewable Energy Policy Project to support their position that there is no impact on property value. REPP is an organization dedicated to advancing renewable energy.
- European countries report property losses from 10% to 30%.
- Realtors overwhelmingly consider wind turbines to have a negative impact on property value.
- Independent appraisers usually find a diminution of land value due to the presence of wind turbines.
- Regarding rural properties, articles indicated that land values are affected by the turbines due to:
  - Incursion into peaceful countryside,
  - Turns farms and land into industrial zones,
  - Flicker, noise and nighttime strobes.
- Adjacent properties are impacted the same as the host landowner but receive none of the compensation.
- Sometimes land values remain the same or increase for the host landowners.
- Value impact decreases with distance from the turbine.

After reviewing the articles and studies on wind energy, the study concluded that wind turbines appear to have a negative impact on the property values, health, and quality of life of residents in close proximity. Of the studies that found no impact on property value, nearly all were funded by wind farm developers or renewable energy advocacy groups. Of the studies and reports showing property loss, the average negative effect is -20.7%.

Additionally, the research shows it is equally reasonable to conclude that some residents in close proximity to wind turbines experience genuine negative health effects from Low-Frequency Noise, infrasound and blade flicker. Of the studies and reports cited, an average setback of little over a mile should significantly lessen detrimental health effects. In addition to noise and flicker issues, disrupted TV and cell phone receptions contribute to a negative impact on the quality of life for residents living in close proximity to wind turbines.

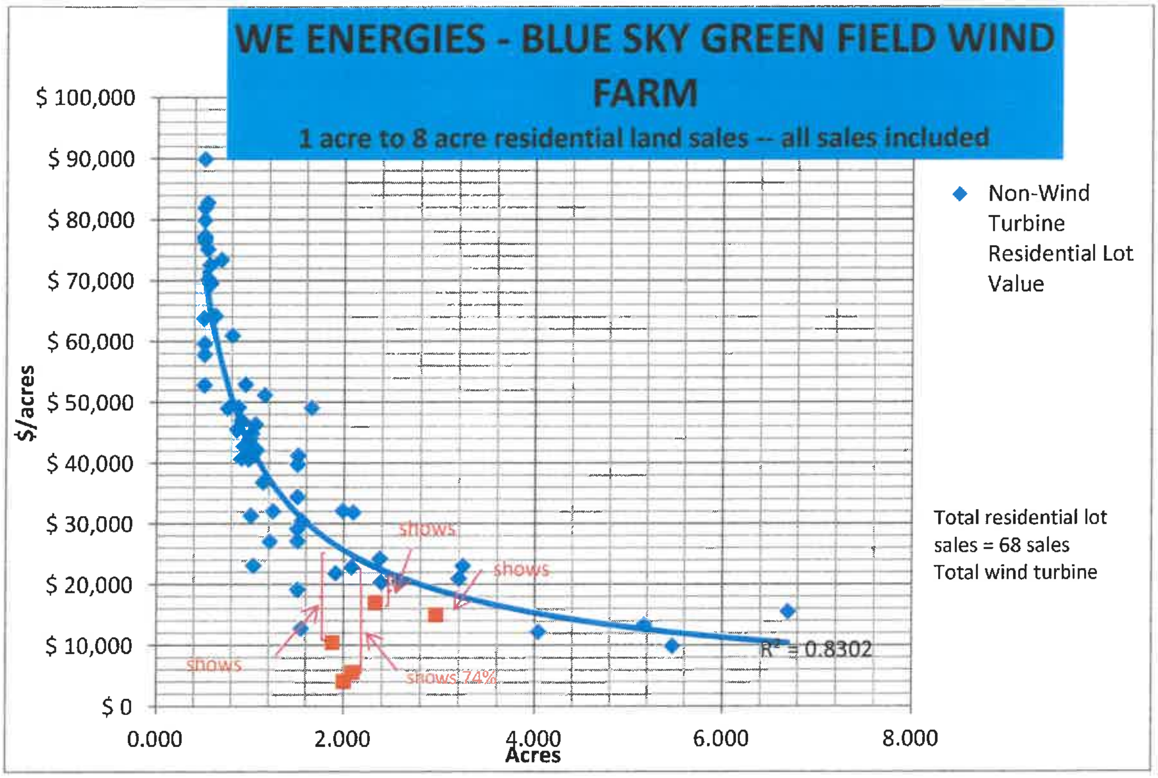
Sales Study

The purpose of the wind turbine impact sales studies was to compare the residential land sales of properties located within the wind turbine farm area to comparable land sales located outside of the influence area of the wind turbines. Being located outside of the influence area meant that the wind turbines could not be seen from the property.

The areas of study include the WE Energies – Blue Sky Green Field wind farm located in the northeast section of Fond du Lac County and the Invenergy – Forward wind farm located in southwest Fond du Lac County and northeast Dodge County, all in the State of Wisconsin. The sales studies and their conclusions follow.

WE Energies – Blue Sky Green Field Wind Farm Sales Study

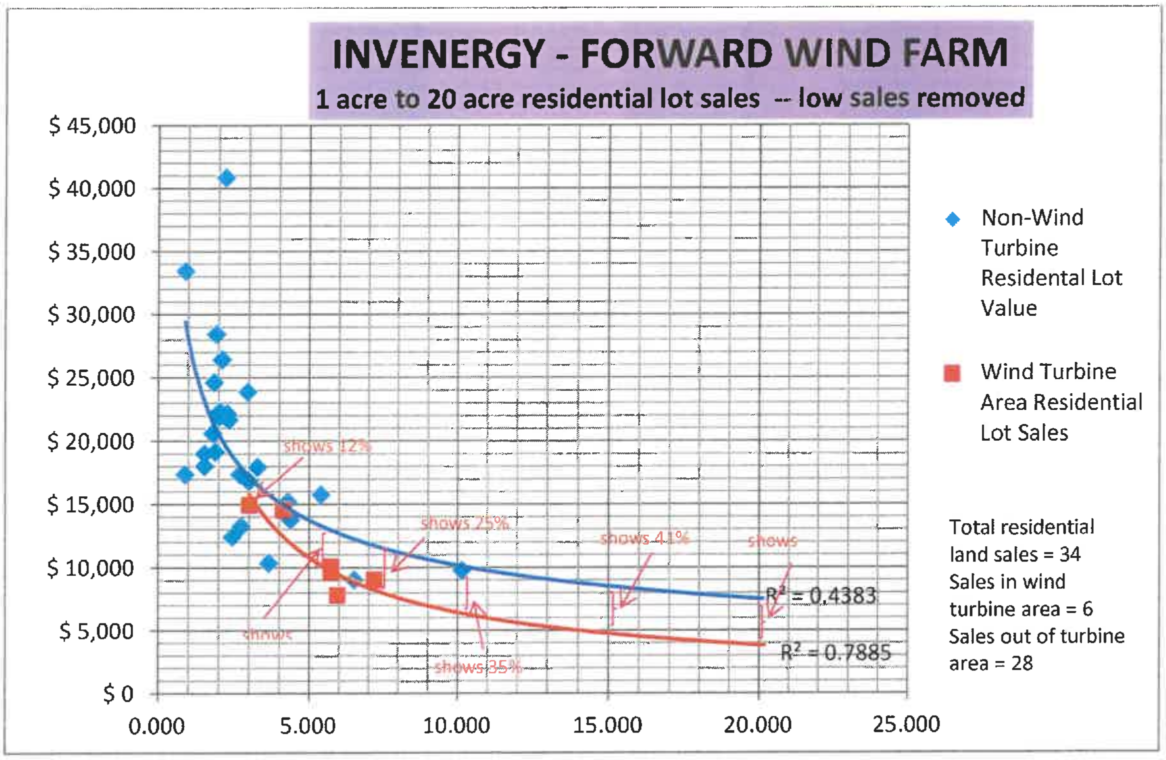
The area of study was the northeast section of Fond du Lac County bordered by Calumet County to the north, Lake Winnebago to the west and Sheboygan County to the east. The study included the townships of Calumet, Taycheedah, and Marshfield. A total of 68 vacant residential land sales were utilized for this study. From that total, 6 land sales were within the influence of the wind turbines (within the wind farm parameters), and 62 sales were located outside of that sphere of influence. The simple regression analysis graph is found below.



The sales study indicated three factors: (1) Sales within the wind turbine influence area sold for less than those outside of this area; (2) there were substantially fewer sales available within the turbine influence area as compared to those sales outside of the influence area; and (3) the impact of the wind turbines decreased the land values from -19% to -74%, with an average of -40%. Additionally, it can be said with a high rate of confidence that the impact of wind turbines on residential land sales is negative and creates a loss greater than -19%, averaging -40%. It is logical to conclude that the factors that created the negative influence on vacant land are the same factors that will impact the improved property values. Therefore, it is not a leap of logic to conclude that the impact of wind turbines on improved property value would also be negative, most likely following the same pattern as the vacant land sales, that being greater than -19%, averaging -40%.

Invenergy – Forward Wind Farm Sales Study

The area of study was the southwest section of Fond du Lac County and the northeast section of Dodge County being bordered by US Highway 41 to the east and Horicon Marsh to the west. The study included the townships of Oakfield and Byron in Fond du Lac County and Leroy and Lomira in Dodge County. A total of 34 vacant residential land sales was utilized for this study. From that total, 6 land sales were in the influence of the wind turbines (within the wind farm parameters) and 28 sales were located outside of that sphere of influence. The simple regression analysis graph is found below.



The sales study indicated three factors: (1) Sales within the wind turbine influence area sold for less than those outside of this area; (2) there were substantially fewer sales available within the turbine influence area as compared to those sales outside of the influence area; and (3) the impact of the wind turbines decreased the land values from -12% to -47%, with the average being -30%. Additionally, it can be said with a high rate of confidence that the impact of wind turbines on residential land sales is negative and creates a loss greater than -12%, averaging -30%. It is logical to conclude that the factors that created the negative influence on vacant land are the same factors that will impact the improved property values. Therefore, it is not a leap of logic to conclude that the impact of wind turbines on improved property value would also be negative, most likely following the same pattern as the vacant land sales, that being greater than -12%, averaging -30%.

Conclusion

The sales study indicated that there was a loss in value of rural residential properties from a low of -12% to a high of -74%. The most typical range of loss could be concluded to be in the range of -19% to -40%. This study was for rural residential large acreage properties ranging from 1 to 10 acres. The properties impacted by the wind turbines all had a view of the turbines and were less than one-half mile from any wind turbine. This study did not measure impacts to agricultural land or recreational; therefore, its direct application to such properties is cautioned.

Clarkson University Study (Heintzelman & Tuttle)

On March 3rd, 2011, Assistant Professor Martin D. Heintzelman, Ph.D., and Carrie M. Tuttle, a Ph.D. candidate in Environmental Science and Engineering, Clarkson University, published their study entitled "Values in the Wind: A Hedonic Analysis of Wind Power Facilities." This study used 11,369 arm's length transactions of residential and agricultural properties between 2000 and 2009 in Northern New York State to extract the impact of wind farms on property value. They found that the nearby wind facilities significantly reduced property values. Specifically, they found that "Decreasing the distance to the nearest turbine to 1-mile results in a decline in price of between 7.73% and 14.87% on the average."235 At the block-group level, the existence of a wind turbine between 1 and 3 miles away impacted property values between -15.6% and -31%.236

Study area

The study area included three counties in Northern New York State, Clinton, Franklin and Lewis Counties. This area is located in the northeast corner of New York bordering Vermont to the east, Canada to the north and has within the area, Adirondack Park, and Lake Champlain. The area of the study is primarily rural, lightly populated, with small towns and villages. The area of study includes six wind farms which are not within the borders of the Park but are in close proximity. The per capita income analysis for the area indicates that it is less affluent than the rest of New York State. The typical property value in the study was $106,864.

Conclusions from the Study

The study indicated several factors. First, the impact of a wind farm on property values was significantly negative. Second, distance is a direct factor in the negative influence, and the further the distance the lesser the impact. Last, when measured with properties outside the influence area of the wind farms, the impact can be as great as -32.06% (being within 0.10 miles of a turbine) to -13.79% (being 3 miles away from a wind turbine) when measured as a block-group with fixed effects factored in. A more conservative conclusion, using the repeat sales method, results in an impact of -24.12% (being within 0.10 mile of a wind turbine) to -10.06% (when 3 miles away).237 Other results showed at the block-group level that the existence of a wind turbine between 1 and 3 miles away impacted property values between -15.6% and -31%.238

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235 *Values in the Wind*, 2.
236 Ibid, 21.
237 *Values in the Wind*, 39, Table 12.
238 Ibid, 21.

Coral Springs Development Study (Forensic Appraisal Group, Ltd)

The Coral Springs development is located on Boulder Ridge Road across the road from Fish Creek, in Section 34, T13N, R73W, of Albany County, Wyoming. This development is comprised of 7 lots being 35.1 acres to 35.3 acres in size, having a mix of vegetation from spruce and fir trees to grassland and sagebrush. It is in the foothills, having a view of the grassland valley to the east and north. Currently, there are no residences in this development, however, there are some storage buildings built on Lot A. It is improved with private gravel/dirt roads and underground utilities. The development has protective covenants which require stick-built homes - no modular or mobile homes. It has direct access to Boulder Ridge Road which connects with Cherokee Park Road one mile to the east. It is being marketed by Duane Toro Real Estate, Laramie, Wyoming; Duane Toro and Bob Davis, agents. One parcel was marketed by Dean Smith a private property owner. The original development owners are Grant L. Lindstrom and Shane M. Cox.

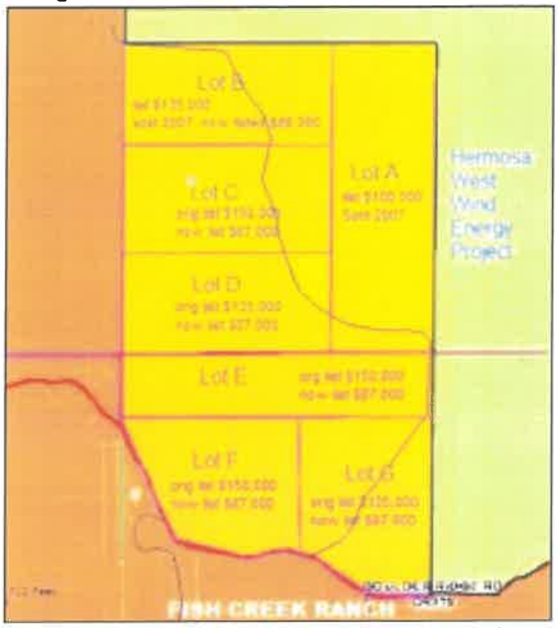


Figure 2: The Coral Springs development is highlighted in yellow with the original and new listing prices noted per lot. The Hermosa West project is highlighted in light green. Fish Creek is located just south of the development.

Sales and Listing History

Since the development began, there have been three lots sold: two lots before the Hermosa West Project was announced and one lot after.

Lot A sold for $100,000 on July 13th, 2007 to Stanley P. Hobbs as a custodian for Morganna E. & Alexandra L. Hobbs. Lot B sold for $100,000 on December 12th, 2007 to Dean P. Smith and Diane Smith-Conroy. The listing price on Lot A was $100,000 and on Lot B $135,000. These sales were completed before the Hermosa West project was announced. The remaining lots were listed between $125,000 to $150,000.[239]

Since the Hermosa West project was announced and is known in the area, the owner of Lot B has placed his lot up for sale, asking $79,000 and sold for $75,000, June 13, 2010.[240] This sale shows a $25,000 (25%) deduction from its original sold price in 2007. The remaining unsold lots have all been reduced to $87,000 since November 15, 2010. This reduction ranges from -30% for the lowest lot listed at $125,000, and -42% for the ones listed at $150,000.

It would appear that the Smith sale is an indicator of how the market is responding to the proposed wind farm and the remaining listed parcels will sell for much less than the new asking price. Investigating the reason for the decrease in unsold lot prices, two factors were uncovered that played a part: The sluggish economy and the Hermosa West project. According to the seller, the Smith property was put up for sale

239 Information confirmed with listing broker, Bob Davis.

240 Information confirmed with Bob Davis, Michelle White, and court records.

due entirely to the Hermosa West project which is proposed to abut the Coral Springs development to the east and north.241

Observations and conclusions

It is apparent that, though the sluggish economy in the Wyoming real estate market can be attributed to some of the declines in property value, the Hermosa West project appears to be the dominating factor, indicating a negative impact on value with a potential range of -25% to -44%, showing an average of -35%.

241 Information confirmed with Dean Smith.

McCann Value Impact Study

Michael S. McCann, CRA, a state licensed Certified General Appraiser (Illinois), completed a study of improved residential properties in the Mendota Hills wind farm area (Lee County, Illinois). This study was completed for property owners who were disputing the claims of another wind farm developer that wind farms do not have an impact on residential property value.

Mendota Hills wind farm is located near the village of Paw, Lee County, Illinois, and operated 63 wind turbines at the time of the study. Each wind turbine stands 214ft from ground to the bub and has three 85ft long blades. It was constructed in June-November 2003. It was the first utility-scale wind farm in the state.

Mr. McCann compared the average sale price $/GLA of fifteen residences located within two miles of the Mendota wind farm to the average sale price $/GLA of thirty-eight residences located greater than two miles from the Mendota wind farm. The time period of this study was 2003-2005 when the residential market was very robust in the Lee County area.

The study indicated the following values:

STUDY GROUP	LOCATION	VALUES
GROUP 1	Within 2-miles of Mendota wind farm	$ 78.84 sf
GROUP 2	Greater than 2-miles of the Mendota wind farm	$104.72/sf
	Difference in sale price per GLA	$ 25.89/sf
	Average diminution of value of residences within 2-miles of the wind farm	-25%

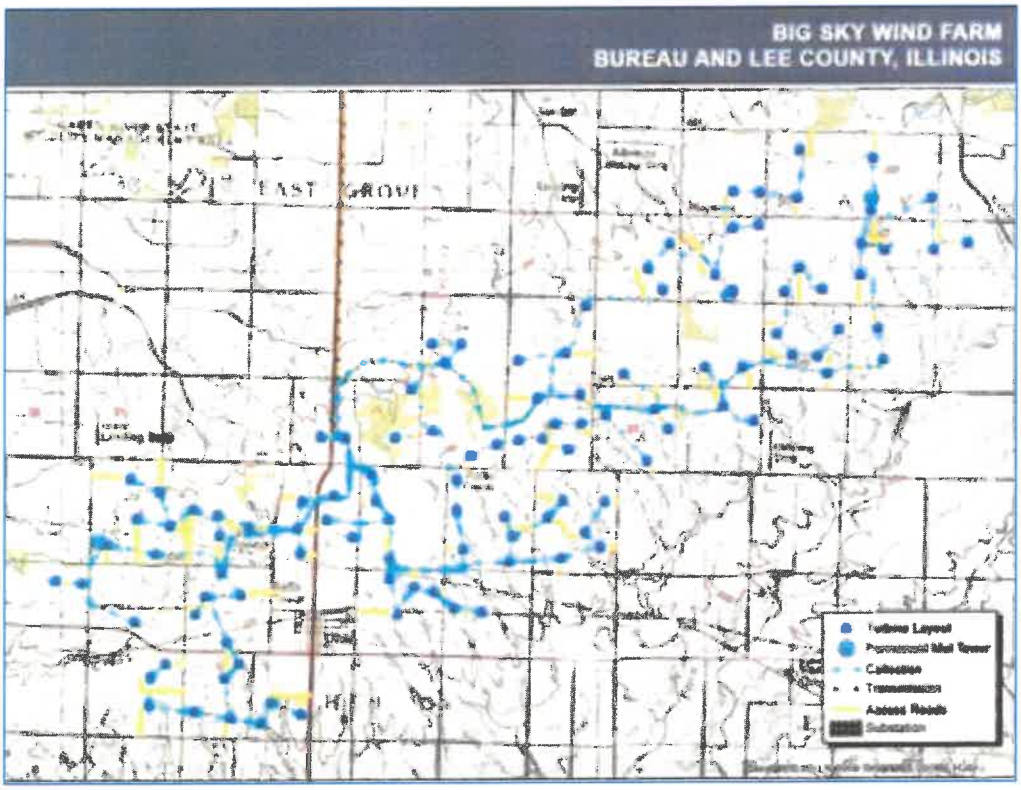
Mr. McCann concluded that the presence of the Mendota wind farm had a -25% impact on residential improved properties that were located within two miles of the wind farm.

Figure 3: Mendota Hills wind farm west of I-39. (Wikipedia)

Big Sky Wind Farm (IL) Matched Pair Analysis (Paired Data Analysis)

A matched pair analysis study using residential sales outside of the Big Sky Windfarm was completed in July 2015, by Kurt C. Kielisch (Forensic Appraisal Group, Ltd, Wisconsin). A matched pair analysis (a.k.a. paired data sales analysis) is defined as "a procedure used in the direct sales comparison approach to estimate values of specific property characteristics in order to find a value of the subject property. Property sales are paired with similar property characteristics."242 The Appraisal Institute's text further defines paired data analysis as: "A quantitative technique used to identify and measure adjustments to the sales prices . . . of comparable properties . . . to isolate the single characteristic's effect on value . . ."243 The isolated variable, in this case, was the impact that wind farms, i.e. wind turbines, have on residential property value.

This wind farm is located in Lee and Bureau Counties centered around Ohio, Illinois. Big Sky is a 22,400-acre project area generating 240MW through one-hundred and fourteen 80-meter tall wind turbines of 2.1MW each.



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242 The Language of Real Estate (1991). Jeffrey D. Fisher, Robert S. Martin and Paige Mosbaugh. Real Estate Education Company. Chicago. Pg 137.

243 The Appraisal of Real Estate 14th Edition (2013). Appraisal Institute. Chicago. Pg 399.

The scope of work (SoW) followed for this analysis was:

1. Collect all topographical and aerial maps of Big Sky which show the placement of the wind turbines.
2. From the Big Sky wind turbine placement map, create a study map indicating three zones: zero zone which is within the confines of the wind farm, 1-mile zone which is a band approximately one mile wide generating from the perimeter of the zero zone and 3-mile zone which is a band approximately 3-miles wide generating from the edge of the zero zone.
3. Search for all residential sales found within the three zones from January 1st, 2011 to present to make certain all sales took place right before or after Big Sky was in operation.
4. Utilize MRED (MLS), Zillow, and assessment records as our research tools for finding sales.
5. Once sales were discovered confirm the sale was not a foreclosure, short sale or non-arms- length transaction. Remove all non-sales from the study.
6. Using the remaining sales search for comparable sales within the non-impact zone (greater than 5-miles from the edge of the zero zone, or sales less than this distance that cannot see the wind turbines). Keep the parameters narrow as to the dates of sale, gross living area (GLA), size of parcel, style of residence, number of outbuildings, and location.
7. Confirm that the comparable sales discovered are all arms-length transactions. Remove the sales that did not fit this category.
8. Pair up the "wind farm zone" sales with comparable non-wind farm sales. Remove all wind farm zone sales that did not have adequate comparable sales.
9. Locate all sales on a study map.
10. View all sales confirming the data description from our sources, take pictures and note location and view of wind turbines. Remove wind farm zone sales that do not have a view of wind turbines.
11. Confirm all wind farm zone and comparable sales with either the buyer, seller or broker of the transaction, check assessor's records and get a copy of the transaction deed.
12. Create sales sheets for all sales.
13. Create a sales map of all sales.
14. Complete matched pair analysis of selected wind farm zone sales and their corresponding comparable sale.
15. Utilize Marshall & Swift Cost services, extracted values from sales and other acceptable methods to support adjustments for known variables in the analysis.

The following pages include five matched pair analyses, sales map locating the sales utilized and data sheets of each sale.

Matched Pair 1						
Item Sale ID	Sale 1-WF Subitte-IR-001	adj	Comparable 1-A Leecter-IR-003	adj	difference	notes
distance to WT	1.72 miles (cluster)		none visible (see note)			wind turbines 0.875 miles from comparable but cannot see them due to the wooded area and ravines, can see them as you exit and enter subdivision.
address	408 LaMoilee Road		1939 Ole Hickory Rd			
city/county	Sublette/Lee		Amboy/Lee			
sales price	$ 250,000.00		$ 272,000.00			
terms	arms length		arms length			
terms adj	typical	0%	typical	0%		
date of sale	January 9, 2015		June 19, 2015			
difference in months	base		-5			
time adj			none needed	0%		
adj sales price	$ 250,000.00		$ 272,000.00			
GLA (above grade)	2,271		2,008			
$/GLA	$ 110.08		$ 135.46		-23%	comparing GLAs only with no other adjustments

neighborhood	rural		rural- subdivision	$ -		subdivision has superior appeal is factored in land
lot size in acres	3.01		2.2	$ 13,500.00		based on $15,000/ac
lot description	open with few trees		good landscaping, mature trees	$ (10,000.00)		superior landscaping
home style	1 sty- traditional		1 story- traditional	$ -		
exterior siding	vinyl/brick		vinyl	$ 5,000.00		brick 3% adjustment based on cost
home built/eff age	2004/10yrs		2000/14yrs	$ 13,000.00		total economic life used = 55 yrs
condition	very good		very good	$ -		
room count	7 total/4 br/3.5bth		6 total/3 br/2.5 baths	$ 6,000.00		bathroom contribution value = $6,000
GLA in sf	2,271		2,008	$ 21,000.00		contribution value = $80/sf
basement	partly finished		finished 924±sf, br, fam, kit, fair quality	$ (4,000.00)		finished bsmt at $20/sf contribution value includes extra br, family rm, bath less the partial finish of WT sale
patio/deck/porch	patio		deck	$ -		similar
fireplace	yes- 2 sided		yes	$ -		similar
central air	yes		yes	$ -		
garage	attached 3-car		attached 3-car	$ -		similar size
outbuildings	none		2 car garage w/loft	$ (15,000.00)		garage = $15,000 contribution value
other	gravel drive, garden tub, central vac, in ground pool		paved driveway, whirlpool	$ 7,000.00		paved vs gravel= $5,000, whirlpool= garden tub, central vac = $2,000, pool= $10,000
total adjusted $				$ 36,500.00		
total adjusted value (adj + adj sales price)		$ 250,000.00		$ 308,500.00		
difference in value in $					$ (58,500.00)	
difference in value in %					-23%	overall impact due to presence of wind turbines/farm

Matched Pair 2-A						
Item Sale ID	Sale 2-WF Ohio-IR-001	adj	Comparable 2-A Wyanet-IR-001	adj	difference	notes
distance to WT	0.32 miles		none			no wind turbine was visible from property, closest turbine was 5.58 miles away
address	29813 2010 E. Street		16025 Wyanet-Walnut Rd			
city/county	Ohio/Bureau		Wyanet/Bureau			
sales price	$ 231,000.00		$ 275,000.00			
terms	arms length		arms length			
terms adj	typical	0%	typical	0%		
date of sale	June 2, 2015		April 3, 2015			
difference in months	base		2			
time adj			none needed	0%		
adj sales price	$ 231,000.00		$ 275,000.00			
GLA (above grade)	2,316		1,936			
$/GLA	$ 99.74		$ 142.05		-42%	comparing GLAs only with no other adjustments
						notes
neighborhood	rural- near Ohio		rural- near Wyanet	$ -		
lot size in acres	6.07		6.95	$ -		similar in size
lot description	mature landscaping, trees & stream		mature landscaping, young trees	$ 5,000.00		stream typically adds +10% of land value
home style	1.5 sty - traditional		1.5 sty- traditional	$ -		
exterior siding	vinyl		vinyl	$ -		
home built/eff age	2001/eff 12yrs		1998/eff 12 yrs	$ -		similar in condition and effective age
condition	good		good	$ -		
room count	7 total/4 br/2.5bth		6 total/3 br/2.5 baths	$ -		
GLA in sf	2,316		1,936	$ 29,000.00		based on $ 78/sf contribution value
basement	full - unfinished		full- partly finished	$ (12,000.00)		estimated @ $12,000
patio/deck/porch	deck, screened porch		covered porch	$ 2,500.00		deck = cov porch, screened porch = $2,500
fireplace	yes		yes	$ -		
central air	yes		yes	$ -		
garage	2 car attached		2 car attached	$ -		
outbuildings	refurbished barn - ave condition		large steel pole barn with truck & reg overhead doors	$ (20,000.00)		refurbished barn = $10,000 contrib value, pole barn with concrete floor, storage, ave qlty = $30,000
other	concrete drive, hot tub, heated garage		concrete circular drive	$ -		comparable concrete drive was larger $2,000, hot tub $1,000 and heated garage $1,000
total adjusted $				$ 4,500.00		
total adjusted value (adj + adj sales price)		$ 231,000.00		$ 279,500.00		
difference in value in $					$(48,500.00)	
difference in value in %					-21%	overall impact due to presence of wind turbines/farm

Matched Pair 2-B						
Item Sale ID	Sale 2-WF Ohio-IR-001	adj	Comparable 2-B Marion-IR-001	adj	difference	notes
distance to WT	0.32 miles		none			no wind turbines visible, closest one is 9.42 miles.
address	29813 2010 E. Street		1033 Pump Factory Rd			
city/county	Ohio/Bureau		Dixon/Lee			
sales price	$ 231,000.00		$ 225,000.00			
terms	arms length		arms length			
terms adj	typical	0%	typical	0%		
date of sale	June 2, 2015		June 24, 2014			
difference in months	base		11			
time adj			none needed	0%		
adj sales price	$ 231,000.00		$ 225,000.00			
GLA (above grade)	2,316		2,900			
$/GLA	$ 99.74		$ 77.59		22%	comparing GLAs only with no other adjustments
neighborhood	rural- near Ohio		rural- near Wyanet	$ -		
lot size in acres	6.07		1.08	$ 40,000.00		estimated 1 acre value at $20,000, 6 acre= $60,000
lot description	mature landscaping, trees & stream		mature landscaping, trees	$ -		
home style	1.5 sty - traditional		1.5 sty- traditional	$ -		
exterior siding	vinyl		vinyl	$ -		
home built/eff age	2001/eff 12yrs		1999/eff 12 yrs	$ -		similar in condition and effective age
condition	good		good	$ -		
room count	7 total/4 br/2.5bth		8 total/4 br/1.5 baths	$ 5,000.00		adj based on one bath
GLA in sf	2,316		2,900	$ (45,500.00)		based on $ 78/sf contribution value
basement	full - unfinished		none (crawl space)	$ 21,000.00		estimated @ $20/sf x 1,038sf due to no basement
patio/deck/porch	deck, screened porch		lg cov porch, lg deck	$ -		deck = deck, screened porch = lg cov porch
fireplace	yes		yes	$ -		
central air	yes		yes	$ -		
garage	2 car attached		2 car attached	$ -		
outbuildings	refurbished barn - ave condition		none	$ 10,000.00		refurbished barn = $10,000 contribution value
other	concrete drive, hot tub, heated garage		gravel drive, hot tub	$ 6,000.00		concrete $5,000, hot tub $1,000, heated garage $1,000, comparable had an above ground pool treated as personal property
total adjusted $				$ 36,500.00		
total adjusted value (adj + adj sales price)		$ 231,000.00		$ 261,500.00		
difference in value in $					$(30,500.00)	
difference in value in %					-13%	overall impact due to presence of wind turbines/farm

Matched Pair 3

Item / Sale ID	Sale 3-WF / Eastove-IR-001	adj	Comparable 3-A / Walnut-IR-001	adj	difference	notes
distance to WT	0.34 miles to nearest one		none visible			closest wind turbine to comparable sale is 5.2 miles
address	31 Peoria Road		27531 1250 E. Street			
city/county	Ohio/Lee		Walnut/Bureau			
sales price	$ 125,000.00		$ 139,700.00			
terms	arms length		arms length			
terms adj	typical	0%	typical	0%		
date of sale	December 8, 2012		February 4, 2014			
diffence in months	base		-14			
time adj			none needed	0%		
adj sales price	$ 125,000.00		$ 139,700.00			
GLA (above grade)	1,420		1,864			
$/GLA	$ 88.03		$ 74.95		15%	comparing GLAs only with no other adjustments
neighborhood	rural- close to Ohio		rural - close to Walnut	$ -		
lot size in acres	2.45		2.5	$ -		similar
lot description	mature landscaping some trees		mature landscaping some trees	$ -		
home style	ranch		ranch	$ -		
exterior siding	vinyl		wood press board, brick wainscoting in front	$ 3,600.00		5% of cost per sf contribution value of residence for press board vs vinyl
home built/eff age	1978/24 yrs		1977/24 yrs	$ -		similar condition and effective age
condition	average		average	$ -		
room count	7 total/3 br/2bth		7 total/4 br/3.5 baths	$ (5,000.00)		adj is for 1.5 baths @$3,000 per bath & $2,000 half
GLA in sf	1,420		1,864	$ (22,200.00)		based on $50/sf contribution value
basement	no basement- slab		full- partly finished	$ (14,000.00)		estimated @ $10/sf x 1420sf due to no basement
patio/deck/porch	brick paver patio		none	$ 2,000.00		
fireplace	yes		yes	$ -		
central air	yes		yes	$ -		
garage	3 car detached		2 car attached	$ 8,000.00		$8,000 per car bay beyond two
outbuildings	32x40 pole shed- newer		none	$ 22,000.00		pole shed estimated at $39,000 new, $22,000 contribution value
other	concrete drive, new greenhouse, fence		concrete drive, none	$ 6,000.00		greenhouse estimated at $5,000 contribution value, fence=$1,000
total adjusted $				$ 400.00		
total adjusted value (adj + adj sales price)		$ 125,000.00		$ 140,100.00		
difference in value in $					$(15,100.00)	
difference in value in %					-12%	overall impact due to presence of wind turbines/farm

Matched Pair 4						
Item Sale ID	Sale 4-WF May-IR-001	adj	Comparable 4-A Bradord-IR-001	adj	difference	notes
distance to WT	0.53 mi to closest one		none			no wind turbines in view, closest one is 7.89 miles
address	341 Rockyford Road		2369 McGirr Road			
city/county	Amboy/Lee		Ashton/Lee			
sales price	$ 132,000.00		$ 183,000.00			
terms	arms length/divorce		arms length			
terms adj	typical	10%	typical	0%		Realtor stated thought sold under market due to divorce, 10% adjustment was made to represent this based on comments & appraiser's experience
date of sale	February 6, 2015		October 6, 2014			
difference in months	base		4			
time adj			none needed	0%		
adj sales price	$ 145,200.00		$ 183,000.00			
GLA (above grade)	2,000		1,936			
$/GLA	$ 72.60		$ 94.52		-30%	comparing GLAs only with no other adjustments

neighborhood	rural		rural	$ -		
lot size in acres	5.00		3.92	$ 8,000.00		at $8,000/ac
lot description	mature lot, some trees		mature lot, some trees	$ -		
home style	2 sty- farmhouse		2 sty- farmhouse	$ -		
exterior siding	vinyl		vinyl	$ -		
home built/eff age	1901/30 yrs		1901/25 yrs	$ (12,900.00)		used total economic life = 55 yrs
condition	average		average	$ -		
room count	8 total/4 br/2bth		7 total/3 br/1 bath	$ 3,000.00		$3,000 for full bath
GLA in sf	2,000		1,936	$ -		no adjustment needed, very similar in size
basement	full- unfinished		partial- unfinished	$ -		no adjustment needed, similar in use, old basement
patio/deck/porch	cov porch		wood deck	$ -		wood deck = covered porch
fireplace	none		heatilator system	$ (2,000.00)		
central air	none		none	$ -		
garage	none		2 car detached w/game room	$ (12,000.00)		$12,000 contribution value for garage w/14x21 game room
outbuildings	36x120 metal sided shed with heat and bathroom, 36x140 metal sided shed, 50x55 metal sided barn, 28x33 corn crib		40x50 metal sided machine shed	$ 14,000.00		36x140 building old chicken coop= $3,000, 36x120 building has work shop w/bathroom = $18,000, 50x55 barn = $5,000, corn crib is Quonset hut for storage= $3,000, 40x50 machine shed= $15,000
other	gravel drive		gravel drive	$ -		
total adjusted $				$ (1,900.00)		
total adjusted value (adj + adj sales price)		$ 145,200.00		$ 181,100.00		
difference in value in $					$(35,900.00)	
difference in value in %					-25%	overall impact due to presence of wind turbines/farm

No Sales within the Zero Zone

It was interesting to note that there were no residential sales (outside of the Village of Ohio) from January 1, 2011, to July 1, 2015, that was located in the Zero Zone (that zone within the perimeter of the wind farm). Traveling through this area indicated that there were plenty of residential homes, some on larger farm plots and some on smaller residential lots less than 10 acres. It appeared the density of these residential properties were similar to the outside zones (1-mile Zone, 3-mile Zone) yet there were no sales. There appears to be no explanation for this lack of sales activity in an area of 22,400 acres. The lack of sales is interesting and possibly instructive to the impact that wind turbines have on property value. It may suggest that when a property is inside the wind farm it is either not marketable or the property is receiving an income due to the wind turbines that the owner does not want to relinquish. It should be noted that since we have no sales nor did not engage in an in-depth study as to the cause of the lack of sales, any statement on our part the reason is a theory.

Summary of Findings

This analysis through five match pairs indicated that the impact of wind turbines on residential property value is negative ranging from -12% to -25% of the whole property value. The average loss indicated was -19%. The distance of the wind turbines ranged from 0.32 miles to 1.72 miles with the average being 0.65 miles. It was also indicated that often when the wind turbines are not clearly seen from the property that they have little impact on the property value. Now, this conclusion may run counter to the noise, vibration and health concerns, but it may also be true that those issues are only discovered after the sale and hence do not play a part of it.

It was also discovered that there were no sales found within the perimeters of the Big Sky Wind Farm using MRED and Zillow sources, which may indicate that such properties have suffered substantial value loss that it is not viable to sell them (possibly hold and rent).

Twin Groves II Wind Farm –Residential Paired Sales Analysis

Introduction

We completed an impact study to isolate the impact that a wind farm has on improved residential property value located in within and outside of the Twin Groves II wind farm. We attempted to include vacant residential land, however, we found only one land sale in the wind farm, so we excluded this type from the analysis.

The Farm

The wind farm that was selected was the Twin Groves II wind farm located in McLean County, Illinois. This wind farm was selected due to its size, contemporary wind turbines and an adequate number of sales within the identified wind farm.

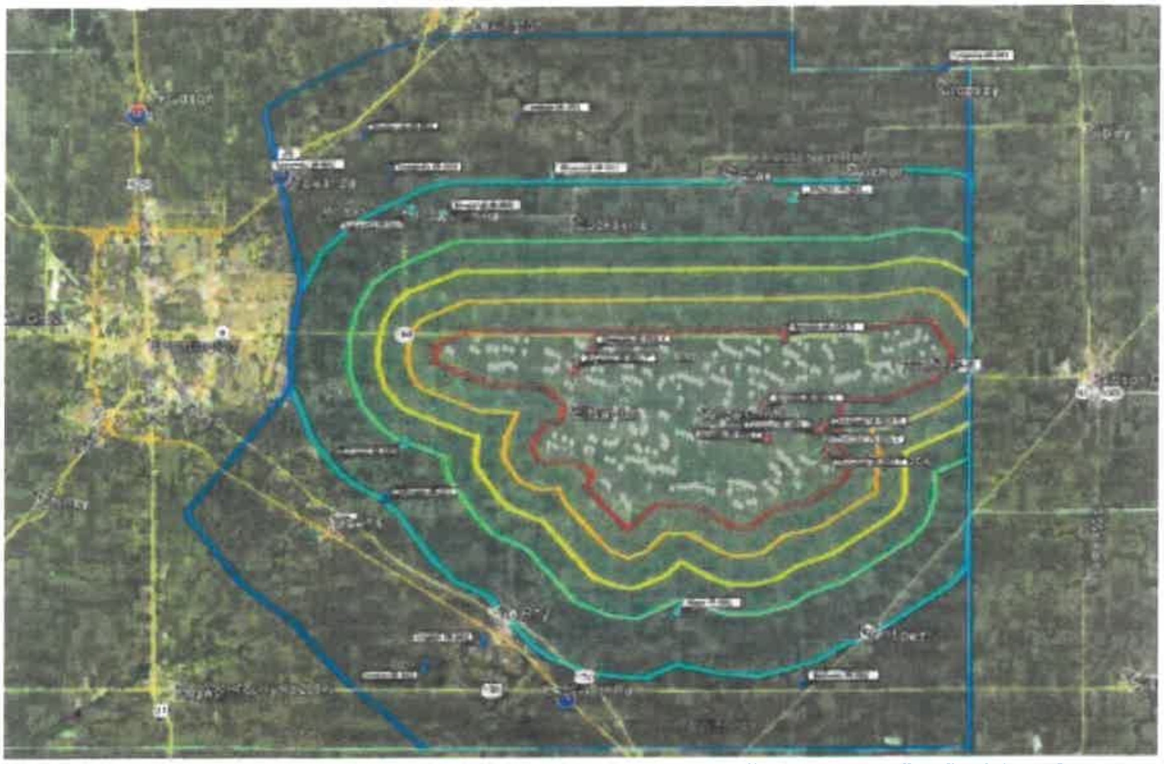
The details of the Twin Grove II wind farm are found in the chart below:

Name	Twin Groves II
Location	McLean County, Illinois, Townships of Arrowsmith, Cheney's Grove and Dawson.
Land area	11,000 acres (approximately half of the two wind farms Twin Groves I & II)
Date of operation	2008
Number of wind turbines	120 wind turbines
Type of wind turbines	Vestas V82 1.65 MW Wind Turbines *(picture on next page)*
Size in kW of wind turbines	1.65MW each x 120 turbines = 198MW
Hub height of wind turbines	80m (280ft±)
Diameter of Turbine	82.0m (269ft±)
Turbine height	Hub ht + ½ diameter of rotors = 80m + ½ (82m)= 121m (397ft±)
Maximum MW output	Approximately 198MW

Scope of Work

The scope of work to complete this study included:

- Research, collect data and confirm information regarding the Twin Groves II wind farm.
- Locating the wind farm on Google Pro mapping software, locate all the wind turbines within the wind farm and create the wind farm zone and concentric 1-mile zones radiating out from the farm to locate comparable sales as indicated on the map *(see next page for working map)*.
- Research and collect sales of improved residential properties within the wind farm, Zone 0.
- Research and collect sales of comparable improved residential sales in Zones 1-5.
- Collect sales data, property data and assessor's data on all sales.



Visit each sale Figure 4: the red line outlines the wind farm Zone-0, orange line is Zone-1, yellow line is Zone-2, green line is Zone 3, light blue line is Zone 4 which has a two-mile width and the dark blue line is Zone 5 which has a five-mile width.

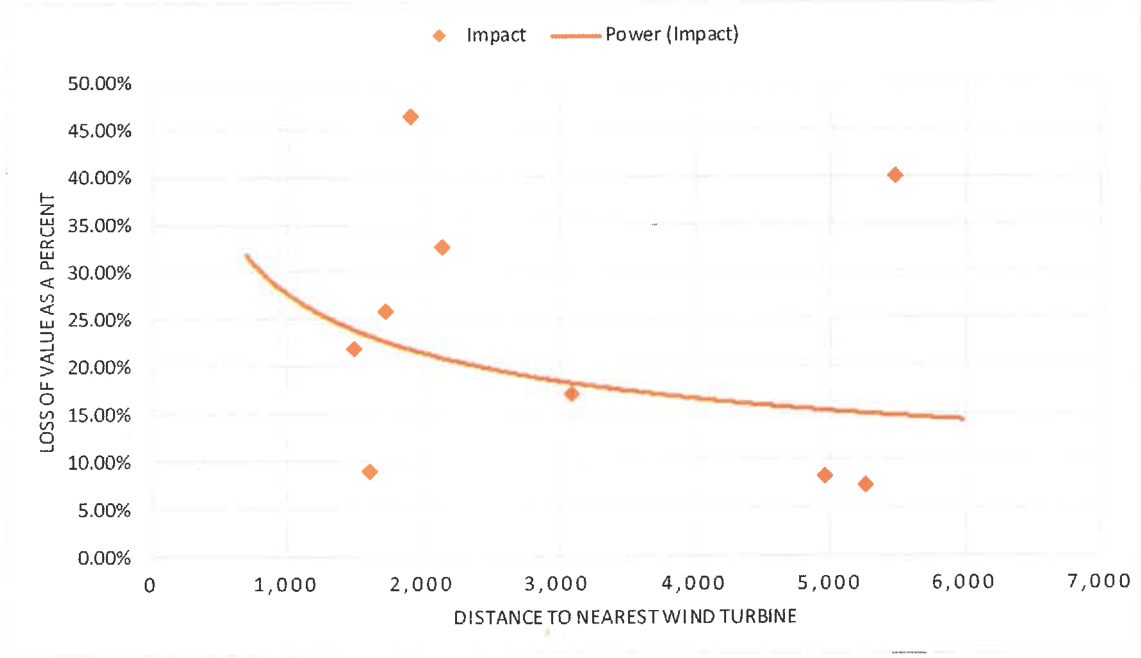
- on-site, take photographs, make field notes and try to confirm sale with the current property owner.
- Send confirmation requests to those sales not confirm in the field.
- Collect sales and support data from the McLean County Court House.
- Complete sales information data sheets.
- Complete a cost approach for each sale using the Marshall & Swift Cost Handbook and Valuation Service.
- Extract Effective Age of each sale using the Cost Approach.
- Complete Paired Sales analysis for each comparable Zone 0 sale.
- Extract the impact of the wind farm from the Paired Sales analysis.
- Using mapping services, locate the nearest wind turbines to each Zone 0 sale, map them and measure the distance from the turbine to the residence.
- Complete a sales map for each Zone 0 Paired Sales analysis.

Conclusions

The conclusions of the nine paired sales are found in the following table:

Pairing	Impact	Type of Residence	Gross Living Area	Age (year built)	Distance to nearest wind turbine
C	-22.0%	Ranch	1,858 sf	1987	1,483 ft
D	-7.7%	One story	2,290 sf	1992	5,259 ft
E	-46.6%	One story	2,089 sf	2008	1,896 ft
F	-25.9%	1.5 story	1,100 sf	1909	1,722 ft
G	-8.5%	Two story	2,271 sf	2001	4,950 ft
H	-40.2%	Tri-level	1,901 sf	1977	5,481 ft
I	-32.8%	Two story	1,728 sf	1880	2,129 ft
J	-17.2%	Two story	2,016 sf	1911	3,094 ft
K	-9.2%	Two story	2,054 sf	1920	1,591 ft

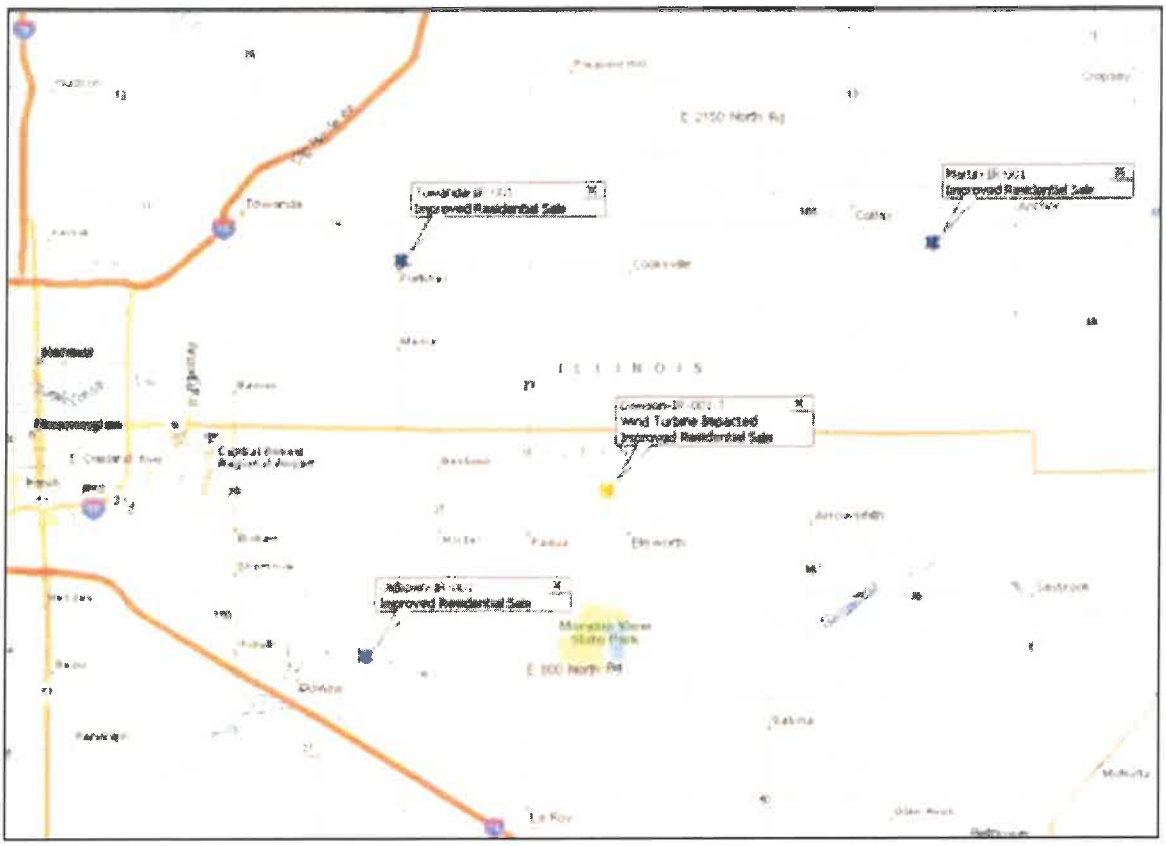
This table was put into the following graph to test if distance had a factor in the impact:



This chart clearly indicates that there is a relationship between distance from a wind turbine and impact to value that a wind turbine causes. It can be said with confidence, that the closer a wind turbine is to a residence the greater negative impact it has on value.

The location map, the analysis, corresponding cost approach and sales sheets for each Paired Analysis follows.

Paired Sale Group C



Paired Sales Analysis- Group C		Dawson-IR-001-T	Oldtown-IR-001	Martin-IR-001	Towanda-IR-001
address		12348N 2800 East Road	22286 Ridgewood Drive	18368 N 3600 East Road	17797 N2300 East Road
Municipality/County		Dawson Township	Old Town Township	Martin Township	Towanda Township
Sale Price		$219,000.00	$304,500.00	$312,000.00	$285,000.00
Sale Date		May 15, 2017	August 31, 2016	August 31, 2017	November 3, 2017
time in months		Base	9	-4	-6
time adj per year		0.0%	0.00%	0.00%	0.00%
Adj Sales Price			$304,500.00	$312,000.00	$285,000.00
lot size description	acres	2.12	5.86	3.21	7.59
	land=	$44,500.00	$99,600.00	$64,200.00	$91,100.00
adjustment			($55,100.00)	($19,700.00)	($46,600.00)
neighborhood location		Wind Farm- Zone 0	Non-wind farm	Non-wind farm	Non-wind farm
adjustment			$0.00	$0.00	$0.00
style		ranch	ranch	1-sty	1-sty
age		1987	1974	1993	1991
effective age		24	25	24	24
percent adj of residence			2%	0%	0%
adjustment			$3,600.00	$0.00	$0.00
exterior siding		vinyl	wood/brick	brick & vinyl	brick
quality of construction		average	average	average	average
room count	total	unknown	8	unknown	unknown
	BRs	3	4	4	3
	baths	2	3	2.5	2.5
GLA	in sq.ft	1,858	2,304	2,458	1,911
contribution value $/sf			$62.34	$60.85	$66.26
adjustment	$/sf base		($27,800.00)	($36,500.00)	($3,500.00)
basement		1858	2304	2458	1911
portion finished in sf		500	1728	1980	0
contribution value $/sf			$7.00	$7.00	$7.00
adjustment			($8,600.00)	($10,400.00)	$3,500.00
garage		725	576	576	600
contribution value		$15,000.00	$9,000.00	$9,000.00	$10,000.00
adjustment			$ 6,000.00	$ 6,000.00	$ 5,000.00
porches, decks		wd deck, encl porch	encl por, porch, wd deck	wd deck, porch	wd deck, porch
contribution value		$10,000.00	$8,000.00	$7,000.00	$3,000.00
adjustment			$ 2,000.00	$ 3,000.00	$ 7,000.00
Other		concrete & gravel drive	gravel drive	gravel drive	gravel drive
		hot tub	shed	pole building	detached garage
		1,380sf lean to			machine shed
		2,208 pole building			grain bins
		3,500 machine shed			
		fire pit			
		18ft dia pool			
		fencing			
contribution value		$49,900.00	$6,400.00	$39,400.00	$31,700.00
			$ 43,500.00	$ 10,500.00	$ 18,200.00
Total Adjustments			($36,400)	($47,100)	($16,400)
Indicated value if Not in Wind Farm			$268,100	$264,900	$268,600
Concluded Value of Subject if Not in Wind Farm Zone		$267,200			
Sale Price of Subject		$219,000			
Difference in dollars		($48,200)			
Difference as precentage		-22.0%			
distance to nearest wind turbine		1,483 ft			
number of turbines in group sight		5			
furtherst wind turbine in grouping		2,849 ft			

Sale #	Dawson-IR-001-T		
Description	**area**	**$/area**	**$ sub-total**
GLA	1,858 sf	$ 109.78 /sf	$ 203,978.11
basement	1858 sf	$ 24.72 /sf	$ 45,927.12
garage	725 sf	$ 35.50 /sf	$ 25,737.02
wood deck	320 sf	$ 14.56 /sf	$ 4,658.41
enclosed porch	252 sf	$ 53.51 /sf	$ 13,483.58
	sf	$ - /sf	$ -
Total Cost New			$ 293,784.24

Less Depreciation:			
Physical Depreciation		44%	$ 128,196.76
Effective Age:	*24*	*years*	
Total Economic Life:	*55*	*years*	
Depreciated value of structures:			$ 165,587.48
Functional Obsolescence		0%	$ -
Reason: none			
Economic Obsolescence		14%	$ 41,487.48
Reason: within windfarm			

Contribution (depreciated) value of building:	$ 124,100.00
Contribution (depreciated) value of outbuildings	$ 39,900.00
Plus, contribution value of site improvements	$ 10,500.00
Land value	$ 44,500.00
TOTAL (rounded)	$ 219,000.00

Sale #	Oldtown-IR-001		
Description	**area**	**$/area**	**$ sub-total**
GLA	2,304 sf	$ 114.72 /sf	$ 264,310.41
basement	2,304 sf	$ 30.41 /sf	$ 70,071.49
garage	576 sf	$ 28.36 /sf	$ 16,332.50
enclosed porch	160 sf	$ 63.87 /sf	$ 10,218.57
open porch	56 sf	$ 20.75 /sf	$ 1,162.26
wood deck	144 sf	$ 22.16 /sf	$ 3,190.73
Total Cost New			$ 365,285.97

Less Depreciation:			
Physical Depreciation		46%	$ 166,785.97
Effective Age:	*25*	*years*	
Total Economic Life:	*55*	*years*	
Depreciated value of structures:			$ 198,500.00
Functional Obsolescence		0%	$ -
Reason: none			
Economic Obsolescence		0%	$ -
Reason: none			

Contribution (depreciated) value of building:	$ 198,500.00
Contribution (depreciated) value of outbuildings	$ 1,400.00
Plus, contribution value of site improvements	$ 5,000.00
Land value	$ 99,600.00
TOTAL (rounded)	$ 304,500.00

Sale #	Martin-IR-001		
Description	**area**	**$/area**	**$ sub-total**
GLA	2,458 sf	$ 108.40 /sf	$ 266,456.91
basement	2,458 sf	$ 31.13 /sf	$ 76,508.28
garage	576 sf	$ 28.12 /sf	$ 16,197.80
wood deck	288 sf	$ 14.56 /sf	$ 4,192.57
Covered porch	288 sf	$ 27.36 /sf	$ 7,880.01
	sf	/sf	$ -
Total Cost New			$ 371,235.57
Less Depreciation:			
Physical Depreciation		44%	$ 162,835.57
Effective Age:	24	*years*	
Total Economic Life:	55	*years*	
Depreciated value of structures:			$ 208,400.00
Functional Obsolescence		0%	$ -
Reason: none			
Economic Obsolescence		0%	$ -
Reason: none			

Contribution (depreciated) value of building:	$ 208,400.00
Contribution (depreciated) value of outbuildings	$ 33,400.00
Plus, contribution value of site improvements	$ 6,000.00
Land value	$ 64,200.00
TOTAL (rounded)	$ 312,000.00

Sale #	Towanda-IR-001		
Description	**area**	**$/area**	**$ sub-total**
GLA	1,911 sf	$ 118.62 /sf	$ 226,689.42
basement	1,911 sf	$ 20.40 /sf	$ 38,991.92
garage	600 sf	$ 30.99 /sf	$ 18,591.55
wood deck	192 sf	$ 19.64 /sf	$ 3,771.63
porch - open	72 sf	$ 32.74 /sf	$ 2,357.27
	sf	/sf	$ -
Total Cost New			$ 290,401.80
Less Depreciation:			
Physical Depreciation		44%	$ 128,201.80
Effective Age:	24	*years*	
Total Economic Life:	55	*years*	
Depreciated value of structures:			$ 162,200.00
Functional Obsolescence		0%	$ -
Reason: none			
Economic Obsolescence		0%	$ -
Reason: none			

Contribution (depreciated) value of building:	$ 162,200.00
Contribution (depreciated) value of outbuildings	$ 25,700.00
Plus, contribution value of site improvements	$ 6,000.00
Land value	$ 91,100.00
TOTAL (rounded)	$ 285,000.00

Sale Date	Sale Price
May 15, 2017	$219,000
Gross Living Area (sf)	GLA Price per sf
1,858	$117.87
Lot Size (acre)	Lot Price per acre
2.120	$103,302

SALE: Dawson-IR-001-T

Located at:	12348 N 2800 East Road
Municipality:	Dawson Township
County:	McLean, IL
Parcel No.:	23-10-400-002
Grantor:	Brian & Melinda Kagel
Grantee:	Ryan Root
Recording Doc:	2017-00008863
Document type:	Warranty Deed
Zoning:	A - Agriculture
Use:	Agricultural

Land	Topography:	open: 83%	wooded: 17%	wetlands: 0%	FEMA/FIRM Floodplain: 0%		
Land	Terrain:	Level	Type of land use present in area:	Agricultural, rural residential	Water Feature:	None	
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes			
Improvements	Style/story:	1 story	Exterior siding:	Vinyl	Year Built:	1987	
Improvements	Construction Quality:	Average	Basement Type:	Full w/crawl space	FBLA (sf):	500sf±	
Improvements	# Garage spaces:	2	Garage Type:	725sf attached & insulated	Driveway type:	Concrete & gravel	
Improvements	Room Count:	N/A / 3 / 2	Fireplace:	Natural fireplace	Porches/ Patios/Decks	320sf deck, 252sf enclosed porch	
Improvements	Central Air:	Yes	Heating:	LP gas FHA & Corn Burner Stove	Road Frontage	County road	
Improvements	# of Outbuildings:	3	Outbuilding Descriptions:	1,380sf lean-to, 2,208sf pole building with 2 insulated stalls, 3,500sf machine shed with 30'x30' heated concrete floor	Overall Condition:	Average	

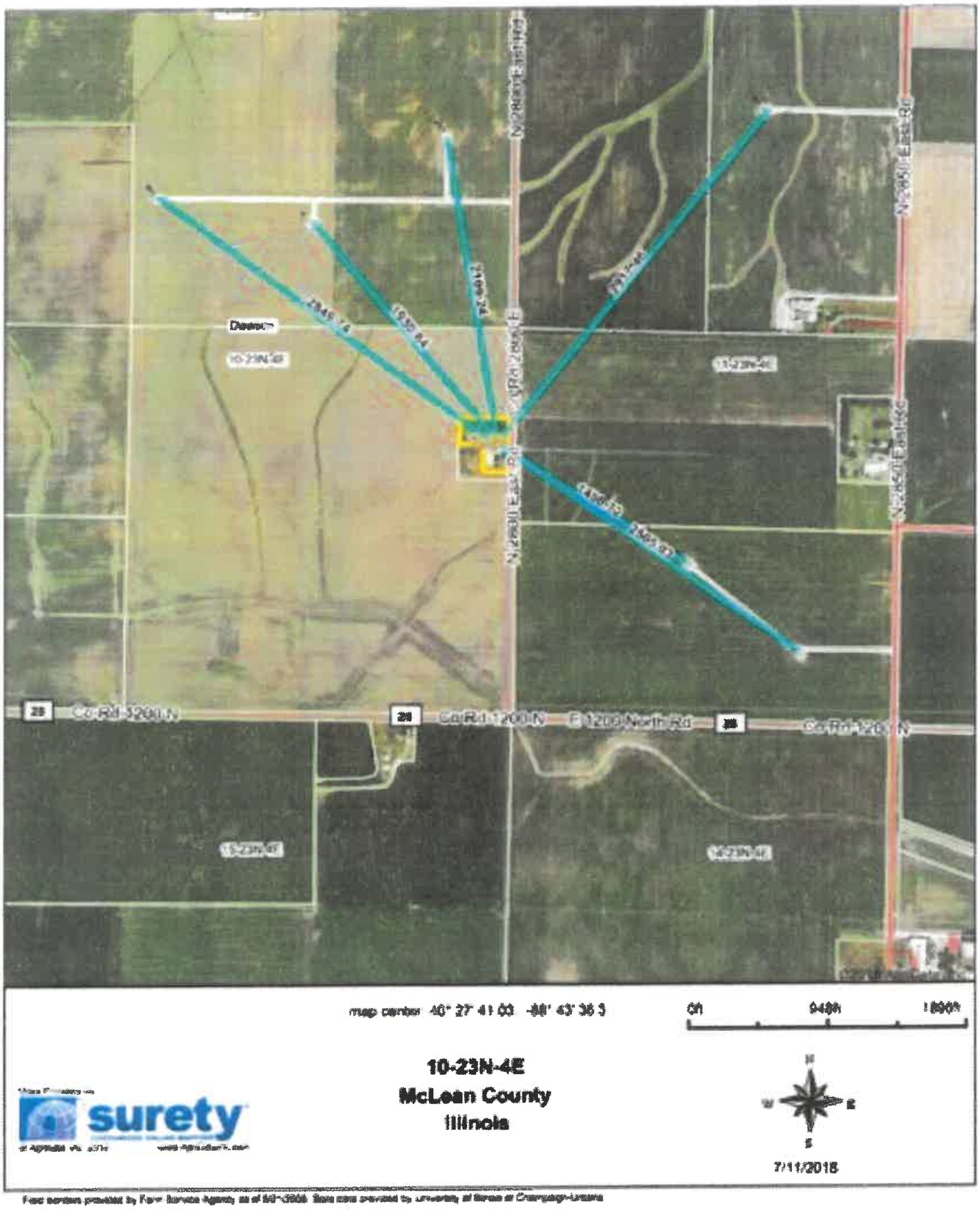
Additional Observations:	**Land:** The property has a level contour. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0575E, effective 07-16-2008. **Improvements:** 18' swimming pool, hot tub hook up, fire pit, well septic system/private well. **Verification Comments:** The buyer Ryan Root, stated by questionnaire that he did not know the previous owner, the sale price was fair, and that the sale price was negotiated down from the asking price. The seller, Brian Kagel stated by questionnaire that the sale price was fair, and the buyer approached with an offer. The closest wind turbine that is in the view from this property is approximately 1,490.72 linear feet to the southeast.

Site Inspected by:	James Marske	Date of Inspection:	May 17, 2018

Figure 5: View of residence with Wind Turbine figuring prominently, looking northwesterly from across 2800 East Road.

Figure 6: View of Wind Turbines located across N 2800 East Road looking southeasterly from the driveway.

Proximity to closest Wind Turbine - 1,490.72 linear feet



SALE: Martin-IR-001

Sale Date	Sale Price
July 29, 2016	$312,000
Gross Living Area (sf)	**GLA Price per sf**
2,458	$126.93
Lot Size (acre)	**Lot Price per acre**
3.210	$97,196

Located at:	18368 N 3600 East Road
Municipality:	Martin Township
County:	McLean, IL
Parcel No.:	17-12-400-012
Grantor:	Curt B. & Sue Ann Heimer
Grantee:	Reed & Lindsey Rinkenberger
Recording Doc:	2016-00014717
Document type:	Warranty Deed
Zoning:	A – Agriculture
Use:	Residential

Land	Topography:	Open: 93%	Wooded: 7%	Wetlands: 0%	FEMA/FIRM Floodplain: 0%	
Land	Terrain:	Gently Rolling	Type of land use present in area:	Rural Residential, Agricultural	Water Feature:	None
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes		
Improvements	Style/story:	1 story	Exterior siding:	Brick & Vinyl	Year Built:	1993
Improvements	Construction Quality:	Average	Basement Type:	Full	FBLA (sf):	1980sf
Improvements	# Garage spaces:	2	Garage Type:	576sf attached	Driveway type:	Gravel with concrete apron
Improvements	Room Count:	4 / 2.5	Fireplace:	Natural fireplace with stone hearth	Porches/ Patios/Decks	288sf deck, 288sf open porch
Improvements	Central Air:	Yes	Heating: LP gas FHA	Road Type: County road		
Improvements	# of Outbuildings:	1	Outbuilding Descriptions:	4,320sf pole building	Overall Condition:	Average

Additional Observations:	**Land:** The property has a gently rolling contour. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0390E, effective 07-16-2008. **Improvements:** Private well/septic system, newer kitchen updates, main floor carpet and paint recently updated. Circular gravel driveway. **Verification Comments:** Owner not present at the time of inspection, questionnaires returned unanswered.

Site Inspected by:	James Marske	Date of Inspection:	May 17, 2018

Sale Date	Sale Price
August 31, 2016	$304,500
Gross Living Area (sf)	GLA Price per sf
2,304	$132.16
Lot Size (acre)	Lot Price per acre
5.860	$51,962

SALE: Oldtown-IR-001

Located at:	22286 Ridgewood Drive
Municipality:	Old Town Township
County:	McLean, IL
Parcel No.:	22-35-300-012
Grantor:	Jason W. Proehl
Grantee:	Paul J. & Jill M. Messamore
Recording Doc:	2016-00016839
Document type:	Warranty Deed
Zoning:	A – Agriculture
Use:	Residential

Land	Topography:	open: 54%	wooded: 46%	wetlands: 0%	FEMA/FIRM Floodplain: 0%		
Land	Terrain:	Gently Rolling	Type of land use present in area:	Rural Residential, Agricultural	Water Feature:	None	
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes, landscaping site improvements, mulch beds			
Improvements	Style/story:	1 story w/walkout	Exterior siding:	Wood & Brick	Year Built:	1974	
Improvements	Construction Quality:	Average	Basement Type:	Full w/crawl space	FBLA (sf):	1,728sf	
Improvements	# Garage Spaces:	2.5	Garage Type:	576sf attached	Driveway type:	Gravel	
Improvements	Room Count:	8 / 4 / 3	Fireplace:	2 natural fireplaces	Porches/ Patios/Decks	160sf enclosed porch, 56sf open porch, 144sf deck	
Improvements	Central Air:	Yes	Heating: Forced air, 2 fireplaces	Road Frontage: Town Road			
Improvements	# of Outbuildings:	1	Outbuilding Descriptions: 280sf shed		Overall Condition:	Average	

Additional Observations:	**Land:** The property lies at 840ft to 862ft above sea level. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0550E, effective 07-16-2008. Property located at the end of a rural cul-de-sac. **Improvements:** Private well/septic system, New 50-year roof installed in 2015. Vaulted ceilings, hardwood floors. Basement is mostly finished with a full bathroom. **Verification Comments:** The seller Jason W. Proehl, stated by questionnaire that he knew the buyer as a friendly acquaintance, the sale price was fair, and that the sale price was the asking price.
Site Inspected by:	James Marske — Date of Inspection: May 17, 2018

Sale Date	Sale Price
November 3, 2017	$285,000
Gross Living Area (sf)	**GLA Price per sf**
1,911	$149.14
Lot Size (acre)	**Lot Price per acre**
7.590	$37,549

SALE: Towanda-IR-001

Located at:	17797 N 2300 East Road
Municipality:	Towanda Township
County:	McLean, IL
Parcel No.:	15-13-100-005
Grantor:	Armstrong Construction Co.
Grantee:	Joseph D. Snodgrass
Recording Doc:	2017-00020701
Document type:	Warranty Deed
Zoning:	A - Agriculture
Use:	Agricultural

Land	Topography:	open: 87%	wooded: 13%	wetlands: 0%	FEMA/FIRM Floodplain: 0%	
Land	Terrain:	Level to Gently Rolling	Type of land use present in area:	Agricultural	Water Feature:	None
Land	Landscaping:	Average	Landscaping Observations:	45+ tree apple orchard, Lawn, mature trees, shade trees		
Improvements	Style/story:	1 story	Exterior siding:	Brick	Year Built:	1991
Improvements	Construction Quality:	Average	Basement Type:	Full	FBLA (sf):	0
Improvements	# Garage spaces:	2	Garage Type:	600sf attached	Driveway type:	Gravel
Improvements	Room Count:	N/A · 3 · 2.5	Fireplace:	Wood burning stove	Porches/ Patios/Decks	192sf deck, 72sf open porch
Improvements	Central Air:	Yes	Heating: Forced Air	Road Frontage: US Highway		
Improvements	# of Outbuildings:	2	Outbuilding Descriptions:	704sf garage, 1,536sf metal shed, 2 4,000 BU Bins	Overall Condition:	Average

Additional Observations:

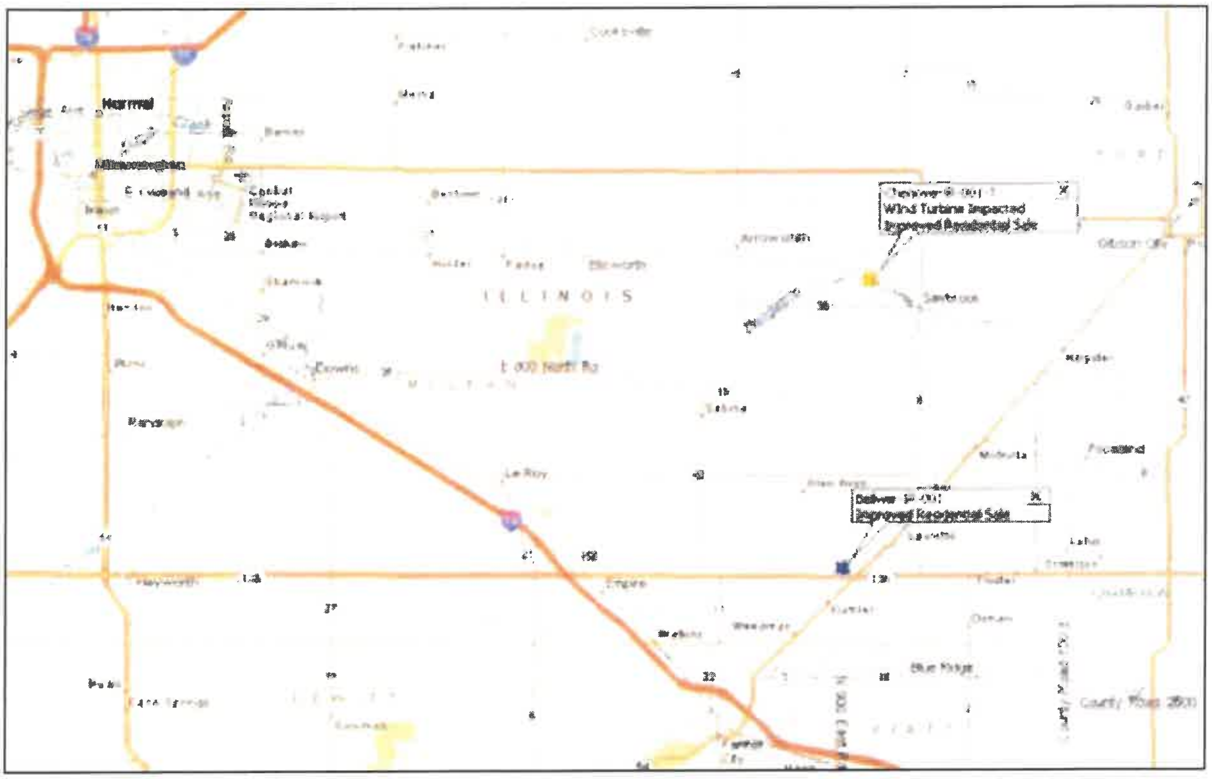
Land: The property lies at 804ft to 816t above sea level. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0350E, effective 07-16-2008.

Improvements: Private well/septic system. Above ground pool.

Verification Comments: Owner not present at the time of inspection, questionnaires returned unanswered.

Site Inspected by:	James Marske	Date of Inspection:	May 17, 2018

Paired Sale Group D



Paired Sales Analysis- Group D			
		Chenove-IR-001-T	Bellwer-IR-001
address		10402 Feather Lane	22286 Ridgewood Drive
Municipality/County		Cheneys Grove Township	Bellflower Township
Sale Price		$162,000.00	$150,000.00
Sale Date		August 18, 2017	July 20, 2016
time in months		Base	13
time adj per year		0.0%	0.00%
Adj Sales Price			$150,000.00
lot size description	acres	1.01	2.32
	land=	$40,400.00	$60,300.00
adjustment			($19,900.00)
neighborhood location		Wind Farm- Zone 0	Non-wind farm
adjustment			$0.00
style		one story	one story
age		1992	1976
effective age		25	41
percent adj of residence			29%
adjustment			$24,000.00
exterior siding		vinyl	brick
quality of construction		average	average
room count	total	unknown	unknown
	BRs	3	3
	baths	2.5	2
GLA	in sq.ft.	2,290	2,212
contribution value $/sf			$29.02
adjustment			$2,300.00
basement		2290	2212
portion finished in sf		390	0
contribution value $/sf			$0.00
adjustment			$3,900.00
garage size in sf		565	780
contribution value		$9,000.00	$6,000.00
adjustment			$ 3,000.00
porches, decks		cov porch, open porch	wood deck
contribution value		$10,000.00	$1,000.00
adjustment			$ 9,000.00
Other		blacktop paved drive	asphalt & concrete drive
		storage shed (80sf)	storage shed (100sf)
		average landscaping	average landscaping
contribution value		$9,400.00	$7,300.00
			$ 2,100.00
Total Adjustments			$24,400
Indicated value if Not in Wind Farm			$174,400
Concluded Value of Subject if Not in Wind Farm Zone		$174,400	
Sale Price of Subject		$162,000	
Difference in dollars		($12,400)	
Difference as percentage		-7.7%	
distance to nearest wind turbine		5,259 ft	
number of turbines in group sig		1	
furthest wind turbine in groupi		5,259 ft	

Sale #	Chenove-IR-001-T			
Description	**area**		**$/area**	**$ sub-total**
GLA	2,290	sf	$ 106.66 /sf	$ 244,255.34
basement	2290	sf	$ 23.96 /sf	$ 54,865.07
garage	565	sf	$ 28.12 /sf	$ 15,888.47
covered porch	510	sf	$ 27.36 /sf	$ 13,954.19
porch	230	sf	$ 15.55 /sf	$ 3,576.83
		sf	$ - /sf	$ -
Total Cost New				$ 332,539.90
Less Depreciation:				
Physical Depreciation			45%	$ 151,154.50
Effective Age:	*25*		*years*	
Total Economic Life:	*55*		*years*	
Depreciated value of structures:				$ 181,385.40
Functional Obsolescence			0%	$ -
Reason: none				
Economic Obsolescence			21%	$ 69,185.40
Reason: within windfarm				

Contribution (depreciated) value of building:	$ 112,200.00
Contribution (depreciated) value of outbuildings	$ 400.00
Plus, contribution value of site improvements	$ 9,000.00
Land value	$ 40,400.00
TOTAL (rounded)	$ 162,000.00

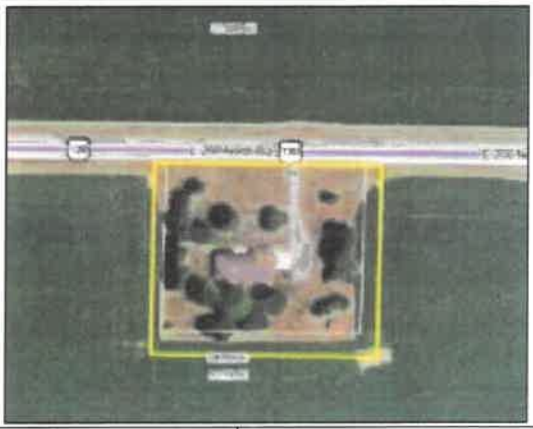
Sale #	Bellwer-IR-001		
Description	**area**	**$/area**	**$ sub-total**
GLA	2,212 sf	$ 112.74 /sf	$ 249,385.25
basement	2,212 sf	$ 20.09 /sf	$ 44,435.17
garage	780 sf	$ 29.23 /sf	$ 22,800.96
wood deck	160 sf	$ 22.16 /sf	$ 3,545.26
	sf	/sf	$ -
	sf	/sf	$ -
Total Cost New			$ 320,166.64

Less Depreciation:			
Physical Depreciation		74%	$ 237,766.64
Effective Age: 41 *years*			
Total Economic Life: 55 *years*			
Depreciated value of structures:			$ 82,400.00
Functional Obsolescence		0%	$ -
Reason: none			
Economic Obsolescence		0%	$ -
Reason: none			

Contribution (depreciated) value of building:	$ 82,400.00
Contribution (depreciated) value of outbuildings	$ 300.00
Plus, contribution value of site improvements	$ 7,000.00
Land value	$ 60,300.00
TOTAL (rounded)	$ 150,000.00

SALE: Bellwer-IR-001

Sale Date	Sale Price
July 20, 2016	$150,000
Gross Living Area (sf)	**GLA Price per sf**
2,212	$67.81
Lot Size (acre)	**Lot Price per acre**
2.320	$64,655



Located at:	36215 E 200 North Road
Municipality:	Bellflower Township
County:	McLean, IL
Parcel No.:	39-06-100-004
Grantor:	D. Darwin Builta & Rebecca Builta
Grantee:	Eric A. Sommer
Recording Doc:	2016-00013649
Document type:	Warranty Deed
Zoning:	A – Agriculture
Use:	Rural Residential

Land	Topography:	open: 88%	wooded: 12%	wetlands: 0%	FEMA/FIRM Floodplain: 0%	
Land	Terrain:	Level	Type of land use present in area:	Rural Residential/Agricultural	Water Feature:	None
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes		
Improvements	Style/story:	1 story	Exterior siding:	Brick	Year Built:	1976
Improvements	Construction Quality:	Average	Basement Type:	Full	FBLA (sf):	0
Improvements	# Garage spaces:	2.5	Garage Type:	780sf attached	Driveway type:	Asphalt and concrete
Improvements	Room Count:	N/A N/A 2	Fireplace:	None	Porches/ Patios/Decks	160sf deck
Improvements	Central Air:	Yes	Heating: LP gas FHA	Road Frontage: US Highway		
Improvements	# of Outbuildings:	1	Outbuilding Descriptions:	Utility shed (100sf)	Overall Condition:	Average

Additional Observations:	**Land:** The property lies at 695ft to 705ft above sea level. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17147C0025E, effective 06-16-2011. **Improvements:** well/septic system. **Verification Comments:** Owner not present at time of inspection, questionnaires returned unanswered.

Site Inspected by:	James Marske	Date of Inspection:	May 17, 2018

FORENSIC APPRAISAL GROUP

Sale Date	Sale Price
August 18, 2017	$162,000
Gross Living Area (sf)	**GLA Price per sf**
2,290	$70.74
Lot Size (acre)	**Lot Price per acre**
1.010	$160,396

SALE: Chenove-IR-001-T

Located at:	10402 Feather Lane
Municipality:	Cheneys Grove Township
County:	McLean, IL
Parcel No.:	25-19-280-007
Grantor:	Donald E. & Mildred I. Alexander
Grantee:	Brian Huang & Stacey Johnson
Recording Doc:	2017-00015564
Document type:	Warranty Deed
Zoning:	R-1 - Residential
Use:	Residential

Land	Topography:	open: 90%	wooded: 10%	wetlands: 0%	FEMA/FIRM Floodplain: 0%	
Land	Terrain:	Level to Gently Rolling	Type of land use present in area:	Rural Residential & Agricultural	Water Feature:	Creek/stream
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes		
Improvements	Style/story:	1 story	Exterior siding:	Vinyl	Year Built:	1992
Improvements	Construction Quality:	Average	Basement Type:	Full	FBLA (sf):	390sf
Improvements	# Garage Spaces:	2	Garage Type:	656sf attached	Driveway type:	Asphalt
Improvements	Room Count:	N/A | 3 | 2.5	Fireplace:	Natural fireplace	Porches/ Patios/Decks	230sf open porch, 510sf covered porch
Improvements	Central Air:	Yes	Heating: LP gas FHA	Road Frontage: Town street		
Improvements	# of Outbuildings:	1	Outbuilding Descriptions:	Storage shed (80sf)	Overall Condition:	Average

Additional Observations:	**Land:** The property has a level to gently rolling contour. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0600E, effective 07-16-2008. The property lies at the end of a cul-de-sac. **Improvements:** Septic system/private well. Un-obstructed view of wind turbines from the back yard of a residence. **Verification Comments:** The buyer Brian Huang, stated by questionnaire and in person that he did not know the previous owner, the sale price was fair, and that the sale price was accepted after the seller approached with an offer. Mr. Huang stated that the view of wind turbines from his property did not impact property value in his opinion. The closest wind turbine that is in the view from this property is approximately 5,298.53ft± to the southwest.

Site Inspected by:	James Marske	Date of Inspection:	May 17, 2018

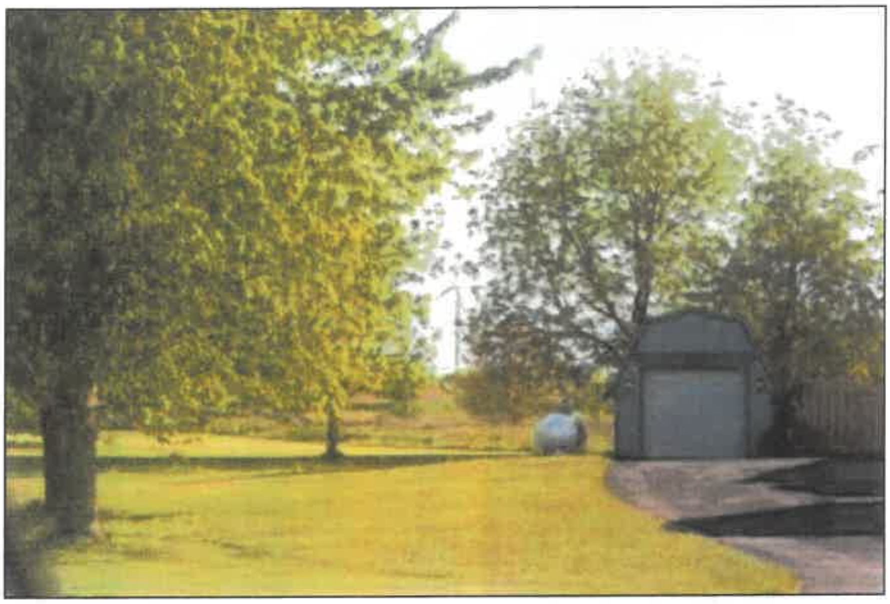
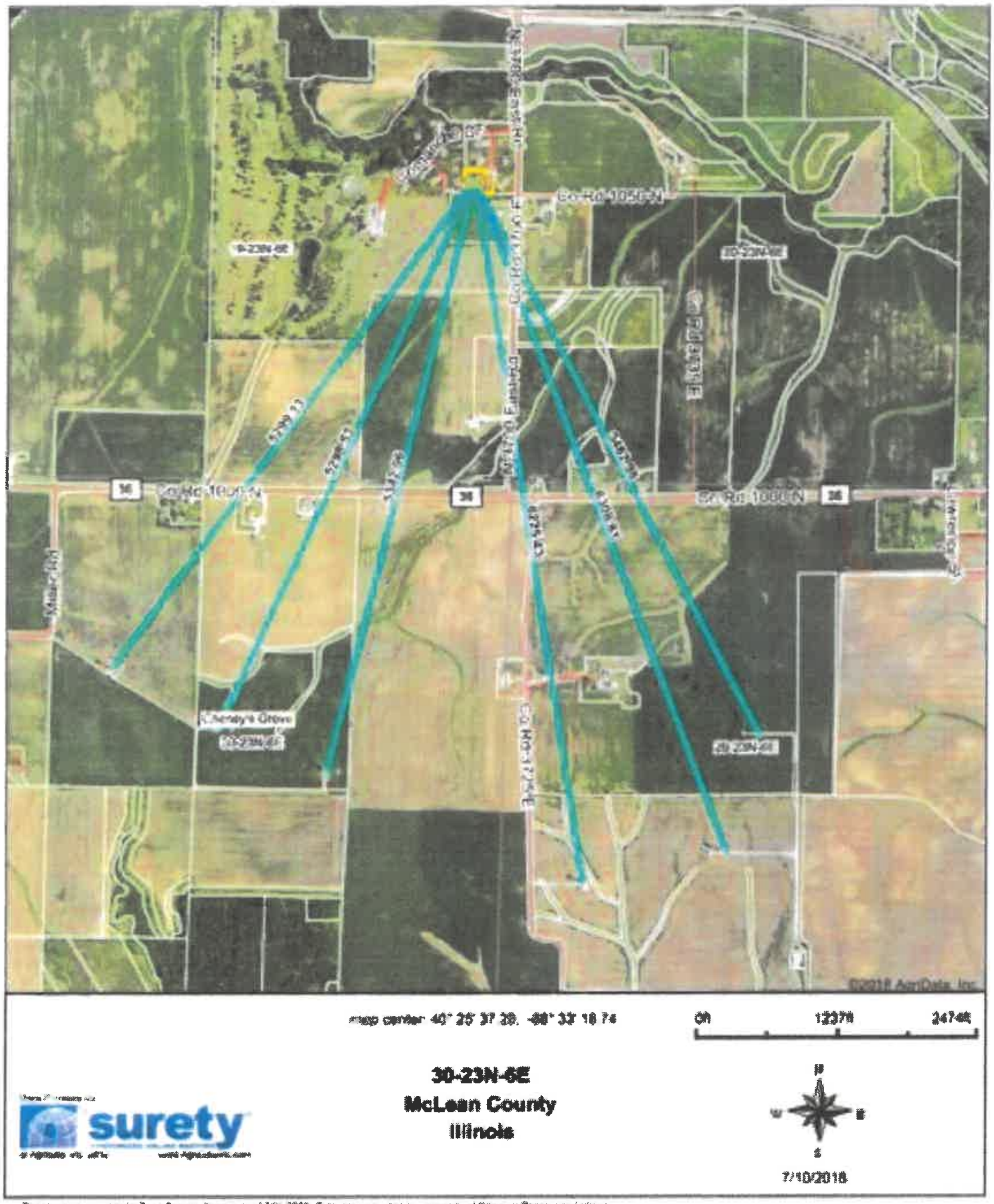


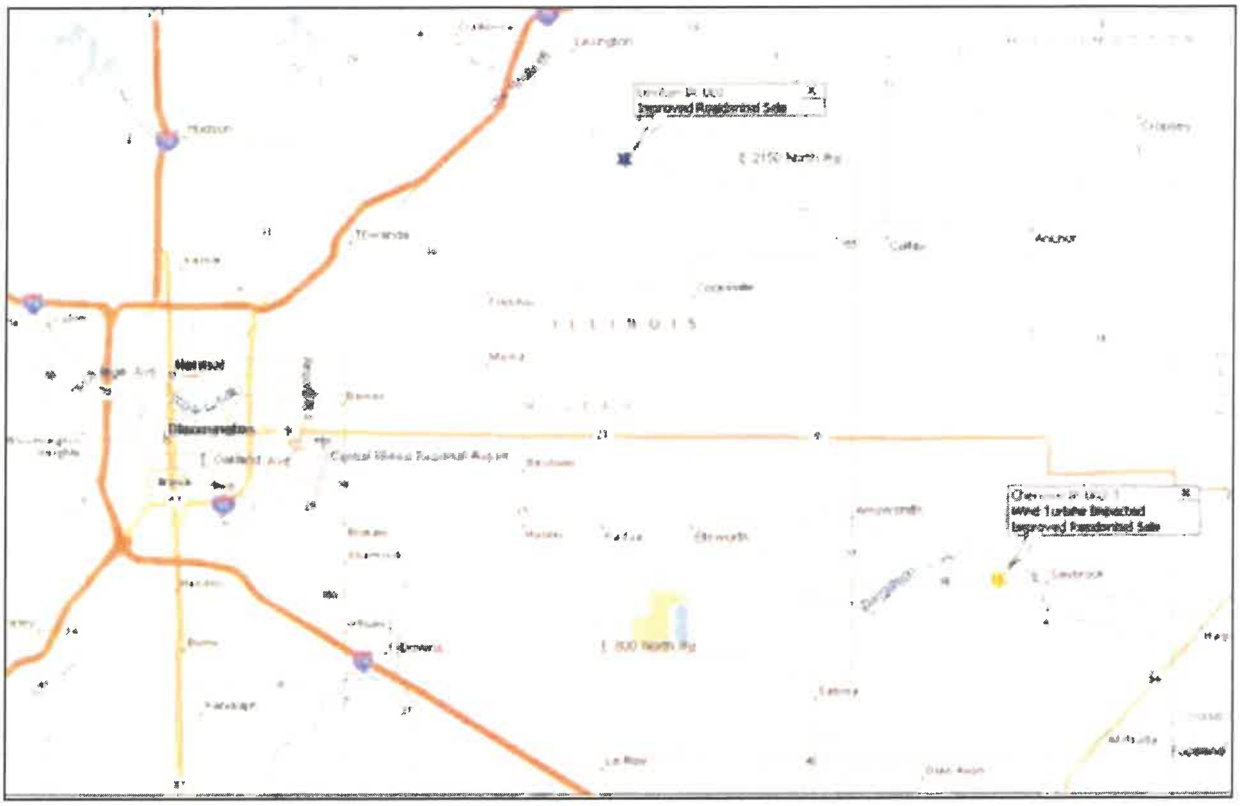
Figure 7: View of wind turbine looking southwesterly from the edge of the driveway.

Figure 8: View of residence looking southwesterly from the edge of the driveway.

Proximity to closest Wind Turbine - 5,288.53 linear feet



Paired Sale Group E



Paired Sales Analysis- Group E			
		Chenove-IR-002-T	**Lexiton-IR-001**
address		9697 N 3725 East Road	21213 N 2650 East
Municipality/County		Cheneys Grove Township	Lexington Township
Sale Price		$199,900.00	$267,500.00
Sale Date		September 28, 2017	June 28, 2016
time in months		Base	15
time adj per year		0.0%	0.00%
Adj Sales Price			$267,500.00
lot size description	acres	1.12	4.15
	land=	$44,800.00	$66,400.00
adjustment			($21,600.00)
neighborhood location		Wind Farm- Zone 0	Non-wind farm
adjustment			$0.00
style		one story	one story
age		2008	2001
effective age		9	17
percent adj of residence			15%
adjustment			$28,300.00
exterior siding		vinyl	vinyl/brick face
quality of construction		average	average
room count	total	unknown	unknown
	BRs	4	3
	baths	2	2
GLA	in sq ft.	2,089	1,929
contribution value $/sf			$78.80
adjustment			$12,600.00
basement		2089	1929
portion finished in sf		0	0
contribution value $/sf			$0.00
adjustment			$0.00
garage		672	465
contribution value		$15,000.00	$10,000.00
adjustment			$5,000.00
porches, decks		covered porch (299sf)	2 open porches, wood deck
contribution value		$7,000.00	$6,000.00
adjustment			$1,000.00
Other		concrete & gravel	concrete & gravel drive
		storage shed (100sf)	storage shed (120sf)
		average landscaping	average landscaping
contribution value		$6,600.00	$6,400.00
			$200.00
Total Adjustments			$25,500
Indicated value if Not in Wind Farm			$293,000
Concluded Value of Subject if Not in Wind Farm Zone		$293,000	
Sale Price of Subject		$199,900	
Difference in dollars		($93,100)	
Difference as percentage		-46.6%	

Sale #	Chenove-IR-002-T				
Description	**area**		**$/area**	**$ sub-total**	
GLA	2,089	sf	$ 106.76 /sf	$ 223,011.75	
basement	2089	sf	$ 20.40 /sf	$ 42,623.82	
garage	672	sf	$ 27.36 /sf	$ 18,386.69	
covered porch	299	sf	$ 27.36 /sf	$ 8,180.98	
		sf	/sf	$ -	
		sf	$ - /sf	$ -	
Total Cost New				$ 292,203.25	
Less Depreciation:					
Physical Depreciation			16%	$ 46,752.52	
Effective Age:	9	*years*			
Total Economic Life:	55	*years*			
Depreciated value of structures:				$ 245,450.73	
Functional Obsolescence			0%	$ -	
Reason: none					
Economic Obsolescence			33%	$ 96,950.73	
Reason: within windfarm					
Contribution (depreciated) value of building:					$ 148,500.00
Contribution (depreciated) value of outbuildings					$ 600.00
Plus, contribution value of site improvements					$ 6,000.00
Land value					$ 44,800.00
TOTAL (rounded)					$ 199,900.00

Sale #	Lexiton-IR-001		
Description	**area**	**$/area**	**$ sub-total**
GLA	1,929 sf	$ 114.79 /sf	$ 221,426.47
basement	1,929 sf	$ 20.40 /sf	$ 39,359.19
garage	465 sf	$ 29.84 /sf	$ 13,875.61
open porch	55 sf	$ 20.75 /sf	$ 1,141.51
open porch	72 sf	$ 19.06 /sf	$ 1,372.27
wood deck	550 sf	$ 11.69 /sf	$ 6,431.04
Total Cost New			$ 283,606.09
Less Depreciation:			
Physical Depreciation		31%	$ 88,906.09
Effective Age:	*17*	*years*	
Total Economic Life:	*55*	*years*	
Depreciated value of structures:			$ 194,700.00
Functional Obsolescence		0%	$ -
Reason: none			
Economic Obsolescence		0%	$ -
Reason: none			

Contribution (depreciated) value of building:	$ 194,700.00
Contribution (depreciated) value of outbuildings	$ 400.00
Plus, contribution value of site improvements	$ 6,000.00
Land value	$ 66,400.00
TOTAL (rounded)	$ 267,500.00

Sale Date	Sale Price
September 28, 2017	$199,900
Gross Living Area (sf)	**GLA Price per sf**
2,089	$95.69
Lot Size (acre)	**Lot Price per acre**
1.120	$178,482

SALE: Chenove-IR-002-T

Located at:	9697 N 3725 East Road
Municipality:	Cheneys Grove Township
County:	McLean, IL
Parcel No.:	25-29-100-007
Grantor:	Jody Hall a/k/a Jodi Hall
Grantee:	Gary Kiel
Recording Doc:	2017-00018325
Document type:	Warranty Deed
Zoning:	A - Agriculture
Use:	Rural Residential

Land	Topography:	open: 100%	wooded: 0%	wetlands: 0%	FEMA/FIRM Floodplain: 0%	
Land	Terrain:	Level to Gently Rolling	Type of land use present in area:	Rural Residential & Agricultural	Water Feature:	None
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes		
Improvements	Style/story:	1 story	Exterior siding:	Vinyl	Year Built:	2008
Improvements	Construction Quality:	Average	Basement Type:	Full	FBLA (sf):	0
Improvements	# Garage Spaces:	2	Garage Type:	672sf attached	Driveway type:	Concrete and gravel
Improvements	Room Count:	N/A 4 2	Fireplace:	-	Porches/ Patios/Decks	299.3sf covered porch
Improvements	Central Air:	Yes	Heating: LP gas FHA	Road Frontage: County road		
Improvements	# of Outbuildings:	1	Outbuilding Descriptions:	Storage shed (100sf±)	Overall Condition:	Average

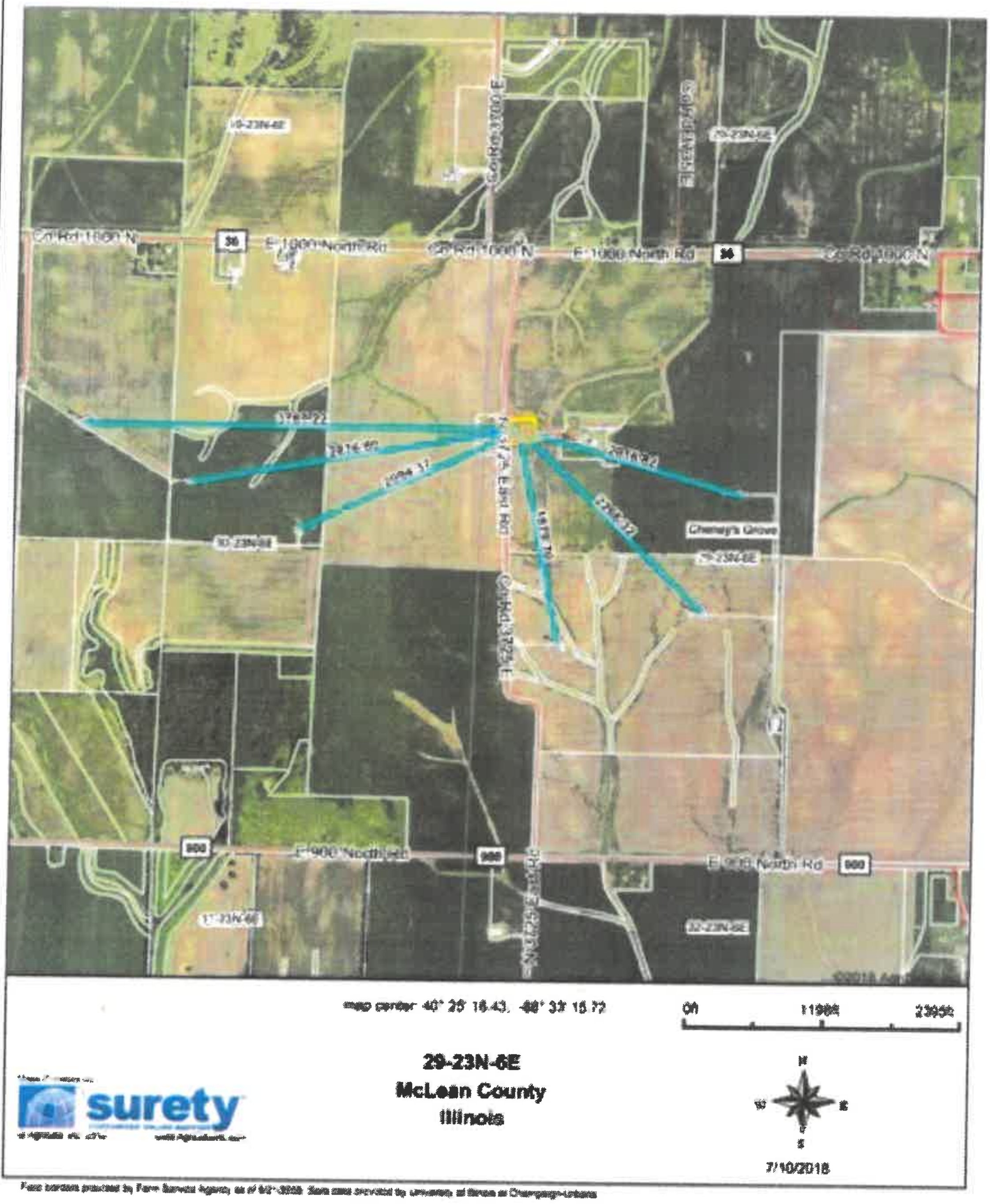
Additional Observations:	**Land:** The property has a level to gently rolling contour. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0600E, effective 07-16-2008. **Improvements:** private well/septic system, partial fencing, new steel roof, newer air conditioner, and furnace. **Verification Comments:** The buyer Gary Kiel, stated in person that he did not know the previous owner, the sale price was fair, and that the sale price was negotiated down from the asking price. He also stated that he did not believe that wind turbines had an impact on property value. The closest wind turbine that is in the view from this property is approximately 1,879.70ft± to the southeast.

Site Inspected by:	James Marske	Date of Inspection:	May 17, 2018

Figure 9: View of residence looking southeasterly from northern driveway entrance.

Figure 10: View of residence looking easterly from northern driveway entrance.

Proximity to closest Wind Turbine - 1,879.70 linear feet



SALE: Martin-IR-001

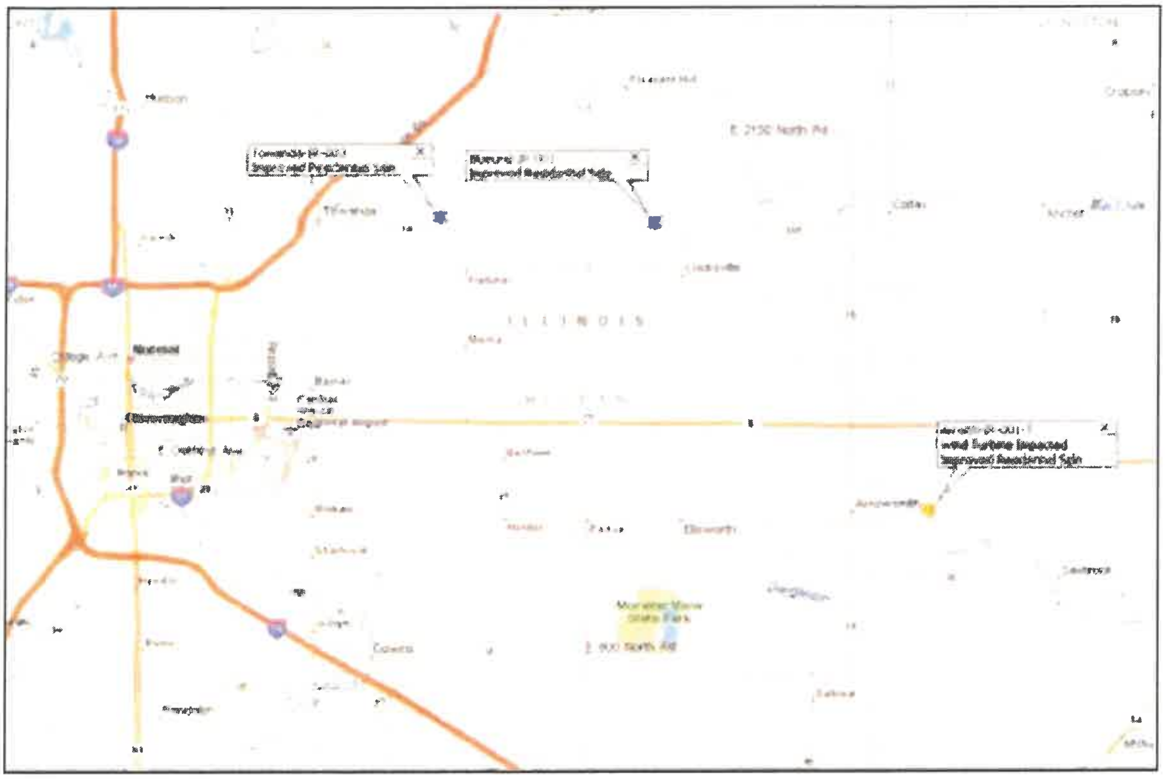
Sale Date	Sale Price
July 29, 2016	$312,000
Gross Living Area (sf)	**GLA Price per sf**
2,458	$126.93
Lot Size (acre)	**Lot Price per acre**
3.210	$97,196

Located at:	18368 N 3600 East Road
Municipality:	Martin Township
County:	McLean, IL
Parcel No.:	17-12-400-012
Grantor:	Curt B. & Sue Ann Heimer
Grantee:	Reed & Lindsey Rinkenberger
Recording Doc:	2016-00014717
Document type:	Warranty Deed
Zoning:	A – Agriculture
Use:	Residential

Land	Topography:	Open: 93%	Wooded: 7%	Wetlands: 0%	FEMA/FIRM Floodplain: 0%	
Land	Terrain:	Gently Rolling	Type of land use present in area:	Rural Residential, Agricultural	Water Feature:	None
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes		
Improvements	Style/story:	1 story	Exterior siding:	Brick & Vinyl	Year Built:	1993
Improvements	Construction Quality:	Average	Basement Type:	Full	FBLA (sf):	1980sf
Improvements	# Garage spaces:	2	Garage Type:	576sf attached	Driveway type:	Gravel with concrete apron
Improvements	Room Count:	4 / 2.5	Fireplace:	Natural fireplace with stone hearth	Porches/ Patios/Decks	288sf deck, 288sf open porch
Improvements	Central Air:	Yes	Heating: LP gas FHA	Road Type: County road		
Improvements	# of Outbuildings:	1	Outbuilding Descriptions:	4,320sf pole building	Overall Condition:	Average

Additional Observations:	**Land:** The property has a gently rolling contour. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0390E, effective 07-16-2008. **Improvements:** Private well/septic system, newer kitchen updates, main floor carpet and paint recently updated. Circular gravel driveway. **Verification Comments:** Owner not present at the time of inspection, questionnaires returned unanswered.
Site Inspected by:	James Marske — Date of Inspection: May 17, 2018

Paired Sale Group F



Paired Sales Analysis- Group F				
		Arroith-IR-001-T	Blueund-IR-001	Towanda-IR-003
address		11365 N 3500 East Road	27607 E 1900 North Road	22416 E1900 North Road
Municipality/County		Arrowsmith Township	Blue Mound Township	Towanda Township
Sale Price		$107,900.00	$172,000.00	$150,000.00
Sale Date		May 30, 2017	April 26, 2017	March 31, 2017
time in months		Base	1	2
time adj per year		0.0%	0.00%	0.00%
Adj Sales Price			$172,000.00	$150,000.00
lot size description	acres	0	1.81	1.23
	land=	$54,100.00	$36,200.00	$39,400.00
adjustment			$17,900.00	$14,700.00
neighborhood location		Wind Farm- Zone 0	Non-wind farm	Non-wind farm
adjustment			$0.00	$0.00
style		1.5 sty	1.5 sty	1.5 sty
age		1909	1909	1911
effective age		28	28	29
percent adj of residence			0%	2%
adjustment			$0.00	$1,900.00
exterior siding		vinyl	vinyl	wood
quality of construction		average	average	average
room count	total	unknown	unknown	unknown
	BRs	3	unknown	3
	baths	1	1	1
GLA	in sq.ft.	1,100	1,748	1,928
contribution value $/sf			$49.46	$47.83
adjustment	$/sf base		($32,100.00)	($39,600.00)
basement		748	952	0
portion finished in sf		0	0	0
contribution value $/sf			$0.00	$0.00
adjustment			$0.00	$0.00
garage		576	468	360
contribution value		$10,000.00	$8,000.00	$7,000.00
adjustment			$2,000.00	$3,000.00
porches, decks		wd deck, encl porch	cov porch, open porch, deck	wd deck, porch
contribution value		$6,000.00	$5,000.00	$5,000.00
adjustment			$1,000.00	$1,000.00
Other		gravel drive	gravel drive	depreciated asphalt drive
		landscaping	landscaping	landscaping
			pole shed 3,024sf	fencing
				pole shed 846sf
contribution value		$5,500.00	$24,400.00	$6,600.00
			($18,900.00)	($1,100.00)
Total Adjustments			($30,100)	($20,100)
Indicated value if Not in Wind Farm			**$141,900**	**$129,900**
Concluded Value of Subject if Not in Wind Farm Zone		$135,900		
Sale Price of Subject		$107,900		
Difference in dollars		($28,000)		
Difference as percentage		**-25.9%**		

FORENSIC APPRAISAL GROUP

Sale #	Arroith-IR-001-T		
Description	**area**	**$/area**	**$ sub-total**
GLA	1,100 sf	$ 102.31 /sf	$ 112,543.20
basement	748 sf	$ 25.20 /sf	$ 18,848.09
garage	576 sf	$ 34.20 /sf	$ 19,700.03
wood deck	168 sf	$ 22.16 /sf	$ 3,722.52
covered porch	264 sf	$ 29.88 /sf	$ 7,887.03
	sf	$ - /sf	$ -
Total Cost New			$ 162,700.87
Less Depreciation:			
Physical Depreciation		51%	$ 82,829.53
Effective Age:	28 years		
Total Economic Life:	55 years		
Depreciated value of structures:			$ 79,871.34
Functional Obsolescence		0%	$ -
Reason: none			
Economic Obsolescence		19%	$ 31,571.34
Reason: within windfarm			

Contribution (depreciated) value of building:	$ 48,300.00
Contribution (depreciated) value of outbuildings	$ -
Plus, contribution value of site improvements	$ 5,500.00
Land value	$ 54,100.00
TOTAL (rounded)	$ 107,900.00

FORENSIC APPRAISAL GROUP

Sale #	Blueund-IR-001

Description	area	$/area	$ sub-total
GLA	1,748 sf	$ 100.15 /sf	$ 175,060.16
basement	952 sf	$ 23.79 /sf	$ 22,652.70
garage	468 sf	$ 36.54 /sf	$ 17,100.72
covered porch	144 sf	$ 32.04 /sf	$ 4,613.51
open porch	220 sf	$ 15.55 /sf	$ 3,421.31
wood deck	110 sf	$ 24.67 /sf	$ 2,713.90
Total Cost New			$ 225,562.30

Less Depreciation:			
Physical Depreciation		51%	$ 114,162.30
Effective Age: 28 *years*			
Total Economic Life: 55 *years*			
Depreciated value of structures:			$ 111,400.00
Functional Obsolescence		0%	$ -
Reason: none			
Economic Obsolescence		0%	$ -
Reason: none			

Contribution (depreciated) value of building:	$ 111,400.00
Contribution (depreciated) value of outbuildings	$ 18,400.00
Plus, contribution value of site improvements	$ 6,000.00
Land value	$ 36,200.00
TOTAL (rounded)	$ 172,000.00

FORENSIC APPRAISAL GROUP

Sale #	Towanda-IR-003		
Description	**area**	**$/area**	**$ sub-total**
GLA	1,928 sf	$ 101.48 /sf	$ 195,656.93
basement	- sf	$ - /sf	$ -
garage	360 sf	$ 39.76 /sf	$ 14,311.99
enclosed porch	128 sf	$ 83.53 /sf	$ 10,692.27
	- sf	$ - /sf	$ -
	sf	/sf	$ -
Total Cost New			$ 220,661.19
Less Depreciation:			
Physical Depreciation		53%	$ 116,661.19
Effective Age:	*29*	*years*	
Total Economic Life:	*55*	*years*	
Depreciated value of structures:			$ 104,000.00
Functional Obsolescence		0%	$ -
Reason: none			
Economic Obsolescence		0%	$ -
Reason: none			

Contribution (depreciated) value of building:	$ 104,000.00
Contribution (depreciated) value of outbuildings	$ 2,600.00
Plus, contribution value of site improvements	$ 4,000.00
Land value	$ 39,400.00
TOTAL (rounded)	$ 150,000.00

Sale Date	Sale Price
May 30, 2017	$107,900
Gross Living Area (sf)	**GLA Price per sf**
1,100	$98.09
Lot Size (acre)	**Lot Price per acre**
2.080	$51,875

SALE: Arroith-IR-001-T

Located at:	11365 N 3500 East Road
Municipality:	Arrowsmith Township
County:	McLean, IL
Parcel No.:	24-13-300-008 & 24-13-300-010
Grantor:	Dane M. & Andrea Murray
Grantee:	Raymond F. Loftus
Recording Doc:	2017-00009650
Document type:	Warranty Deed
Zoning:	A – Agriculture
Use:	Rural Residential

Land	Topography:	open: 91%	wooded: 9%	wetlands: 0%	FEMA/FIRM Floodplain: 0%	
Land	Terrain:	Gently Rolling	Type of land use present in area:	Rural Residential, Agricultural	Water Feature:	None
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes		
Improvements	Style/story:	1.5 story	Exterior siding:	Vinyl	Year Built:	1880
Improvements	Construction Quality:	Average	Basement Type:	Crawl space	FBLA (sf):	0
Improvements	# Garage Spaces:	2.5	Garage Type:	576sf detached	Driveway type:	Gravel
Improvements	Room Count:	N/A 3 1	Fireplace:	-	Porches/ Patios/Decks	264sf covered porch, 168sf deck
Improvements	Central Air:	No	Heating: LP gas FHA	Road Frontage: County road		
Improvements	# of Outbuildings:	0	Outbuilding Descriptions: --		Overall Condition:	Average

Additional Observations:	**Land:** The property has a gently rolling contour. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0600E, effective 07-16-2008. **Improvements:** Private well/septic system, hardwood floors throughout, newer roof, windows, and garage. **Verification Comments:** The buyer Raymond Loftus, stated in person that he did not know the previous owner, the sale price was fair, and that the sale price was negotiated down from the asking price. He also stated that he did not believe that wind turbines had an impact on property value. The closest wind turbine that is in the view from this property is approximately 1,721.21ft± to the west.
Site Inspected by:	James Marske — Date of Inspection: May 17, 2018

Figure 11: View of Wind Turbines located across N 3500 East Road, looking westerly from residence driveway.

Figure 12: View of Wind Turbines looking northeasterly from the southern end of the property.

Aerial Map

13-23N-5E
McLean County
Illinois

7/11/2016

SALE: Blueund-IR-001

FORENSIC APPRAISAL GROUP

Sale Date	Sale Price
April 26, 2017	$172,000
Gross Living Area (sf)	**GLA Price per sf**
1,748	$98.40
Lot Size (acre)	**Lot Price per acre**
1.810	$95,028

Located at:	27607 E 1900 North Road
Municipality:	Blue Mound Township
County:	McLean, IL
Parcel No.:	16-10-200-004
Grantor:	Scott A. & Pamela L. Hardman
Grantee:	Ryan Thedens & Patricia Billingsley
Recording Doc:	2017-00008512
Document type:	Warranty Deed
Zoning:	A – Agriculture
Use:	Rural Residential

Land	Topography:	open: 77%	wooded: 23%	wetlands: 0%	FEMA/FIRM Floodplain: 0%		
Land	Terrain:	Level	Type of land use present in area:	Rural Residential, Agricultural	Water Feature:	None	
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes			
Improvements	Style/story:	2 story	Exterior siding:	Vinyl	Year Built:	1909	
Improvements	Construction Quality:	Average	Basement Type:	Full	FBLA (sf):	0	
Improvements	# Garage Spaces:	2	Garage Type:	468sf detached	Driveway type:	Gravel	
Improvements	Room Count:	N/A | N/A | 1	Fireplace:	No	Porches/ Patios/Decks	144sf covered porch, 220sf open porch, 110sf deck	
Improvements	Central Air:	No	Heating: LP gas FHA	Road Type: County road			
Improvements	# of Outbuildings:	1	Outbuilding Descriptions:	3,024sf pole frame building	Overall Condition:	Average	
Additional Observations:	**Land:** The property has a level contour. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0375E, effective 07-16-2008. **Improvements:** Well/septic system, oak wood cabinetry throughout the kitchen. 2 separate gravel driveways leading onto the property. **Verification Comments:** The buyer Patricia Billingsley, stated by a questionnaire that she knew the previous owner, that the final sale price was arrived at by prior contract and that the sale price was fair.						
Site Inspected by:	James Marske	Date of Inspection:	May 17, 2018				

SALE: Towanda-IR-003

Sale Date	Sale Price
March 31, 2017	$150,000
Gross Living Area (sf)	**GLA Price per sf**
1,928	$77.80
Lot Size (acre)	**Lot Price per acre**
1.230	$121,951

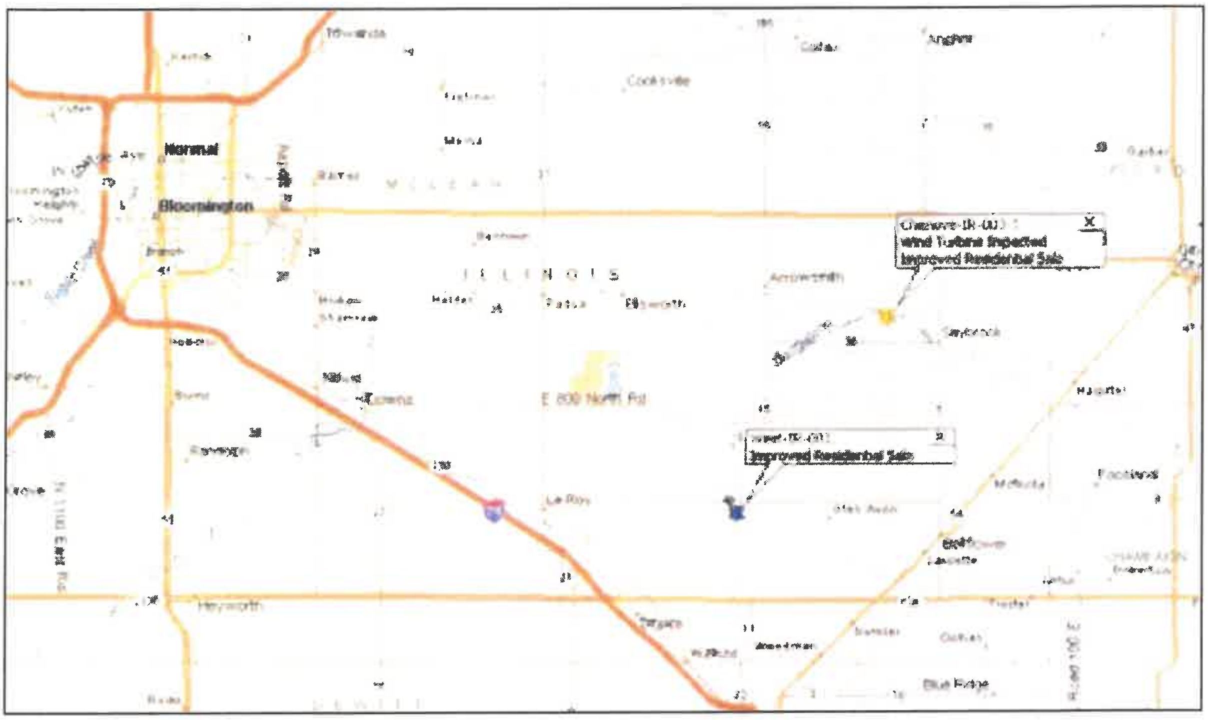
Located at:	22416 E 1900 North Road
Municipality:	Towanda Township
County:	McLean, IL
Parcel No.:	15-02-300-004
Grantor:	Peter D. & Patricia A. Cuoco
Grantee:	Lyle D. Gordon
Recording Doc:	2017-00005755
Document type:	Warranty Deed
Zoning:	A – Agriculture
Use:	Rural Residential

Land	Topography:	open: 93%	wooded: 7%	wetlands: 0%	FEMA/FIRM Floodplain: 0%		
Land	Terrain:	Level	Type of land use present in area:	Rural Residential/Agricultural	Water Feature:	None	
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes			
Improvements	Style/story:	1 story	Exterior siding:	Wood	Year Built:	1911	
Improvements	Construction Quality:	Average	Basement Type:	Crawl space	FBLA (sf):	None	
Improvements	# Garage spaces:	1	Garage Type:	360sf detached	Driveway type:	Asphalt (old and cracked)	
Improvements	Room Count:	N/A / 3 / 1	Fireplace:	Wood burning stove	Porches/ Patios/Decks	128sf enclosed porch	
Improvements	Central Air:	No	Heating:	LP gas FHA	Road Frontage	State Highway	
Improvements	# of Outbuildings:	1	Outbuilding Descriptions:	4-sided metal 864sf shed (24' X 36')	Overall Condition:	Average	

Additional Observations:	**Land:** The property lies at 788ft to 792ft above sea level. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0350E, effective 07-16-2008. **Improvements:** Septic system/private well, ceiling fan with lighting throughout the residence. Partially fenced yard. **Verification Comments:** The seller Peter Cuoco, stated by a questionnaire that he did not know the buyer, the sale price was fair, and that the sale price was negotiated down from the asking price.

Site Inspected by:	James Marske	Date of Inspection:	May 17, 2018

Paired Sale Group G



Paired Sales Analysis- Group G		
	Chenove-IR-003-T	West-IR-001
address	37253 Comache Drive	4397 N 3200 East Road
Municipality/County	Cheneys Grove Township	West Township
Sale Price	$172,000.00	$143,500.00
Sale Date	May 18, 2017	September 27, 2017
time in months	Base	-4
time adj per year	0.0%	0.00%
Adj Sales Price		$143,500.00
lot size description — acres	0.72	1.50
land=	$34,600.00	$48,000.00
adjustment		($13,400.00)
neighborhood location	Wind Farm- Zone 0	Non-wind farm
adjustment		$0.00
style	2 sty	2 sty
age	2001	1999
effective age	16	38
percent adj of residence		40%
adjustment		$31,600.00
exterior siding	vinyl	vinyl
quality of construction	average	average
room count — total	unknown	unknown
BRs	3	4
baths	2.5	2.5
GLA — in sq.ft.	2,271	2,058
contribution value $/sf		$30.49
adjustment — $/sf base		$6,500.00
basement	1489	1176
portion finished in sf	782	0
contribution value $/sf	$19.00	$0.00
adjustment		$14,900.00
garage	809	768
contribution value	$15,000.00	$6,000.00
adjustment		$9,000.00
porches, decks	wood deck	cov porch, open porch, deck
contribution value	$4,000.00	$2,000.00
adjustment		$2,000.00
Other	concrete driveway	gravel drive
	landscaping	landscaping
	outdoor cooking setup	pole shed 3,024sf
contribution value	$9,000.00	$16,400.00
		($7,400.00)
Total Adjustments		$43,200
Indicated value if Not in Wind Farm		**$186,700**
Concluded Value of Subject if Not in Wind Farm Zone	$186,700	
Sale Price of Subject	$172,000	
Difference in dollars	($14,700)	
Difference as percentage	-8.5%	

Sale #	Chenove-IR-003-T			
Description	**area**		**$/area**	**$ sub-total**
GLA	2,271	sf	$ 101.70 /sf	$ 230,969.73
basement (partly	1489	sf	$ 38.26 /sf	$ 56,967.42
garage	809	sf	$ 26.60 /sf	$ 21,520.31
wood deck	465	sf	$ 12.86 /sf	$ 5,980.87
	0	sf	$ - /sf	$ -
		sf	$ - /sf	$ -
Total Cost New				$ 315,438.31

Less Depreciation:			
Physical Depreciation		29%	$ 91,763.87
Effective Age:	*16*	*years*	
Total Economic Life:	*55*	*years*	
Depreciated value of structures:			$ 223,674.44
Functional Obsolescence		0%	$ -
Reason: none			
Economic Obsolescence		30%	$ 95,274.44
Reason: within windfarm			

Contribution (depreciated) value of building:	$ 128,400.00
Contribution (depreciated) value of outbuildings	$ -
Plus, contribution value of site improvements	$ 9,000.00
Land value	$ 34,600.00
TOTAL (rounded)	$ 172,000.00

Sale #	West-IR-001		
Description	**area**	**$/area**	**$ sub-total**
GLA	2,058 sf	$ 100.48 /sf	$ 206,780.08
basement	1,176 sf	$ 22.39 /sf	$ 26,332.65
garage	768 sf	$ 26.60 /sf	$ 20,429.66
concrete patio	480 sf	$ 6.31 /sf	$ 3,030.77
wood deck	240 sf	$ 17.09 /sf	$ 4,102.77
	- sf	$ - /sf	$ -
Total Cost New			$ 260,675.94
Less Depreciation:			
Physical Depreciation		70%	$ 181,575.94
Effective Age:	*38*	*years*	
Total Economic Life:	*55*	*years*	
Depreciated value of structures:			$ 79,100.00
Functional Obsolescence		0%	$ -
Reason: none			
Economic Obsolescence		0%	$ -
Reason: none			

Contribution (depreciated) value of building:	$ 79,100.00
Contribution (depreciated) value of outbuildings	$ 12,400.00
Plus, contribution value of site improvements	$ 4,000.00
Land value	$ 48,000.00
TOTAL (rounded)	$ 143,500.00

FORENSIC APPRAISAL GROUP

Sale Date	Sale Price
May 18, 2017	$172,000
Gross Living Area (sf)	**GLA Price per sf**
2,271	$75.74
Lot Size (acre)	**Lot Price per acre**
0.720	$238,889

SALE: Chenove-IR-003-T

Located at:	37253 Comanche Drive
Municipality:	Cheneys Grove Township
County:	McLean, IL
Parcel No.:	25-19-279-001
Grantor:	Marty & Teresa A. Benningfield
Grantee:	Daniel & Kelsey Kaeb
Recording Doc:	2017-00009122
Document type:	Warranty Deed
Zoning:	R-1 - Residential
Use:	Rural Residential

Land	Topography:	open: 98%	wooded: 2%	wetlands: 0%	FEMA/FIRM Floodplain: 0%	
Land	Terrain:	Level	Type of land use present in area:	Rural Residential & Agricultural	Water Feature:	None
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes, stone beds, garden area		
Improvements	Style/story:	2 story	Exterior siding:	Vinyl	Year Built:	2001
Improvements	Construction Quality:	Average	Basement Type:	Full	FBLA (sf):	782sf (est.)
Improvements	# Garage spaces:	3	Garage Type:	809sf attached	Driveway type:	Concrete
Improvements	Room Count:	N/A / 3 / 2.5	Fireplace:	Gas fireplace	Porches/ Patios/Decks	465sf wood deck
Improvements	Central Air:	Yes	Heating: LP gas FHA	Road Frontage: Town street		
Improvements	# of Outbuildings:	-	Outbuilding Descriptions:	-	Overall Condition:	Average

Additional Observations:	**Land:** The property has a level contour. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0600E, effective 07-16-2008. The property is located across the street from Indian Springs Golf Course, which attracts significant traffic. **Improvements:** Septic system/shared well, vaulted ceilings, unobstructed view of wind turbines from the backyard of the residence. **Verification Comments:** Owner not present at the time of inspection, questionnaires returned unanswered. The closest wind turbine that is in the view from this property is approximately 4,924.86ft± to the southwest.
Site Inspected by:	James Marske — Date of Inspection: May 17, 2018

Figure 13: View of Wind Turbine looking southeasterly from the driveway entrance of the residence.

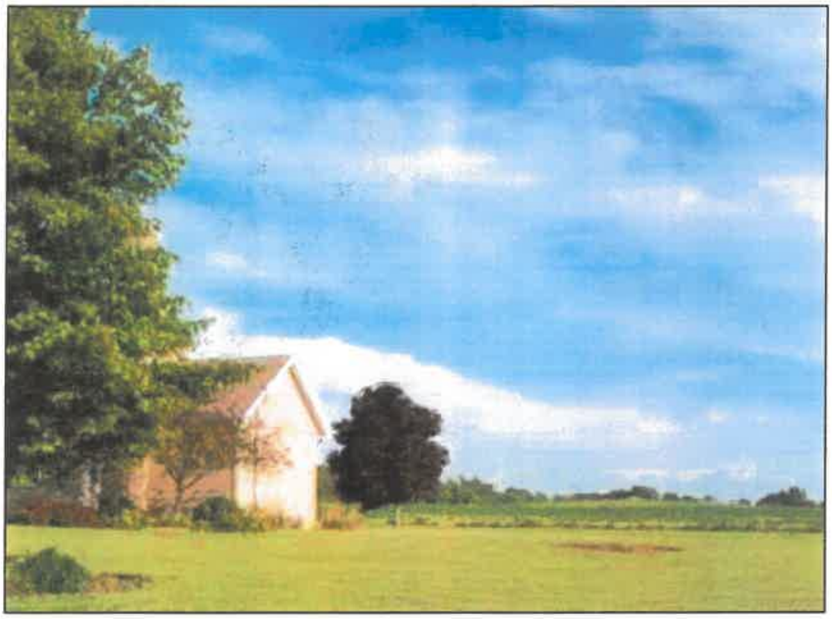
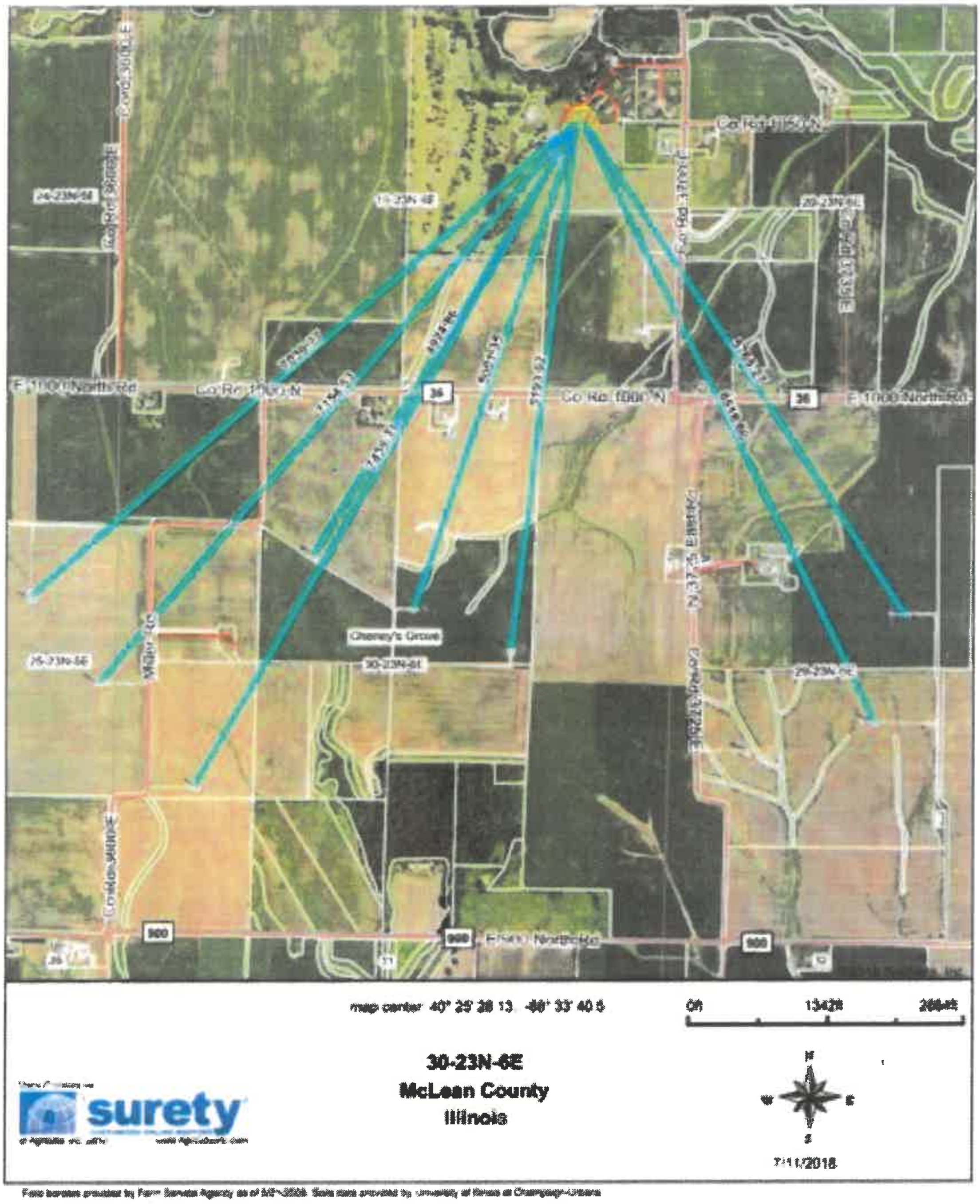


Figure 14: View of Wind Turbines looking southeasterly from NW corner of the property.

Proximity to closest Wind Turbine - 4,924.86 linear feet



SALE: West-IR-001

Sale Date	Sale Price
September 27, 2017	$143,500
Gross Living Area (sf)	**GLA Price per sf**
2,058	$69.73
Lot Size (acre)	**Lot Price per acre**
1.500	$95,667

Located at:	4397 N 3200 East Road
Municipality:	West Township
County:	McLean, IL
Parcel No.:	31-21-301-007
Grantor:	Michael R. & Ruth Ann Martens
Grantee:	Megan Maher
Recording Doc:	2017-00017946
Document type:	Warranty Deed
Zoning:	A – Agriculture
Use:	Rural Residential

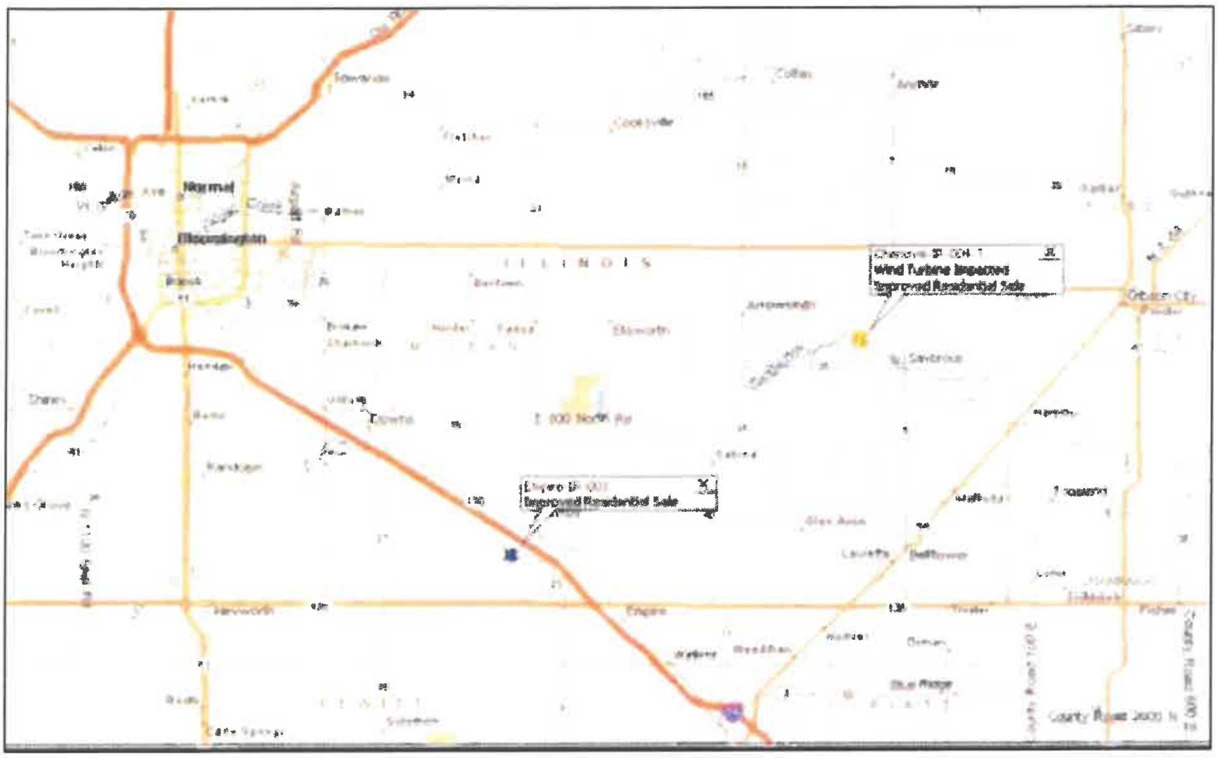
Land						
Topography:	open: 67%	wooded: 33%	wetlands: 0%	FEMA/FIRM Floodplain: 0%		
Terrain:	Level to Gently Rolling	Type of land use present in area:	Rural Residential/Agricultural	Water Feature:	None	
Landscaping:	Fair	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes			

Improvements								
Style/story:	2 story			Exterior siding:	Vinyl		Year Built:	1999
Construction Quality:	Average			Basement Type:	Full		FBLA (sf):	0
# Garage Spaces:	3			Garage Type:	768sf attached		Driveway type:	Gravel driveway
Room Count:	N/A	4	2.5	Fireplace:	No		Porches/ Patios/Decks	240sf deck, 480sf concrete patio
Central Air:	Yes	Heating:	LP gas FHA		Road Frontage	State Highway		
# of Outbuildings:	2	Outbuilding Descriptions:	4-sided metal shed (616sf), detached garage (500sf)				Overall Condition:	Average

Additional Observations:	**Land:** The property lies at 720ft to 730ft above sea level. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0350E, effective 07-16-2008. **Improvements:** well/septic system, hardwood flooring. **Verification Comments:** Owner not present at the time of inspection, questionnaires returned unanswered.

Site Inspected by:	James Marske	Date of Inspection:	May 17, 2018

Paired Sales Group H



Paired Sales Analysis- Group H			
		Chenove-IR-004-T	Empire-IR-001
address		37367 Comache Drive	25288 Chestnut Drive
Municipality/County		Cheneys Grove Township	Empire Township
Sale Price		$136,500.00	$220,000.00
Sale Date		April 1, 2016	June 7, 2017
time in months		Base	-14
time adj per year		0.0%	0.00%
Adj Sales Price			$220,000.00
lot size description	acres	0.62	1.75
	land=	$37,200.00	$49,000.00
adjustment			($11,800.00)
neighborhood location		Wind Farm- Zone 0	Non-wind farm
adjustment			$0.00
style		tri-level	tri-level
age		1977	1968
effective age		22	22
percent adj of residence			0%
adjustment			$0.00
exterior siding		vinyl & brick	vinyl & brick
quality of construction		average	average
room count	total	8	unknown
	BRs	4	4
	baths	2	3
GLA	in sq.ft.	1,901	1,938
contribution value $/sf			$65.68
adjustment	$/sf base		($2,400.00)
basement		529	650
portion finished in sf		0	0
contribution value $/sf		$0.00	$0.00
adjustment			$0.00
garage		576	621
contribution value		$10,000.00	$10,000.00
adjustment			$0.00
porches, decks		patio	cov porch, open porch, deck
contribution value		$1,000.00	$10,000.00
adjustment			($9,000.00)
Other		asphalt driveay	gravel drive
		lanscaping	landscaping
		utility shed	shed 784sf
contribution value		$6,900.00	$12,300.00
			($5,400.00)
Total Adjustments			($28,600)
Indicated value if Not in Wind Farm			$191,400
Concluded Value of Subject if Not in Wind Farm Zone		$191,400	
Sale Price of Subject		$136,500	
Difference in dollars		($54,900)	
Difference as precentage		**-40.2%**	

Sale #	Chenove-IR-004-T			
Description	**area**		**$/area**	**$ sub-total**
GLA	1,901	sf	$ 106.85 /sf	$ 203,119.58
basement	529	sf	$ 28.24 /sf	$ 14,937.96
garage	576	sf	$ 28.12 /sf	$ 16,197.80
patio	286	sf	$ 7.68 /sf	$ 2,197.10
	0	sf	$ - /sf	$ -
		sf	$ - /sf	$ -
Total Cost New				$ 236,452.44
Less Depreciation:				
Physical Depreciation			40%	$ 94,580.98
Effective Age:	22	*years*		
Total Economic Life:	55	*years*		
Depreciated value of structures:				$ 141,871.47
Functional Obsolescence			0%	$ -
Reason: none				
Economic Obsolescence			21%	$ 49,471.47
Reason: within windfarm				

Contribution (depreciated) value of building:	$ 92,400.00
Contribution (depreciated) value of outbuildings	$ 400.00
Plus, contribution value of site improvements	$ 6,500.00
Land value	$ 37,200.00
TOTAL (rounded)	$ 136,500.00

Sale #	Empire-IR-001		
Description	**area**	**$/area**	**$ sub-total**
GLA	1,938 sf	$ 109.40 /sf	$ 212,013.01
basement	650 sf	$ 28.24 /sf	$ 18,354.77
garage	621 sf	$ 28.12 /sf	$ 17,463.26
concrete patio	441 sf	$ 6.31 /sf	$ 2,784.52
wood deck	160 sf	$ 22.16 /sf	$ 3,545.26
screened porch	260 sf	$ 39.18 /sf	$ 10,187.47
Total Cost New			$ 264,348.29
Less Depreciation:			
Physical Depreciation		40%	$ 105,648.29
Effective Age:	22	*years*	
Total Economic Life:	55	*years*	
Depreciated value of structures:			$ 158,700.00
Functional Obsolescence		0%	$ -
Reason: none			
Economic Obsolescence		0%	$ -
Reason: none			

Contribution (depreciated) value of building:	$ 158,700.00
Contribution (depreciated) value of outbuildings	$ 5,800.00
Plus, contribution value of site improvements	$ 6,500.00
Land value	$ 49,000.00
TOTAL (rounded)	$ 220,000.00

Sale Date	Sale Price
April 1, 2016	$136,500
Gross Living Area (sf)	**GLA Price per sf**
1,901	$71.80
Lot Size (acre)	**Lot Price per acre**
0.620	$220,161

SALE: Chenove-IR-004-T

Located at:	37367 Comanche Drive
Municipality:	Cheneys Grove Township
County:	McLean, IL
Parcel No.:	25-19-280-002
Grantor:	Cheryl L. Burke
Grantee:	John E. Knerr II
Recording Doc:	2016-00005626
Document type:	Warranty Deed
Zoning:	R-1 - Residential
Use:	Rural Residential

Land	Topography:	open: 71%	wooded: 29%	wetlands: 0%	FEMA/FIRM Floodplain: 0%	
Land	Terrain:	Level to Gently Rolling	Type of land use present in area:	Rural Residential & Agricultural	Water Feature:	Creek/stream
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes		
Improvements	Style/story:	Tri-level	Exterior siding:	Brick/vinyl	Year Built:	1977
Improvements	Construction Quality:	Average	Basement Type:	Full w/crawl space	FBLA (sf):	0
Improvements	# Garage Spaces:	2	Garage Type:	576sf attached	Driveway type:	Asphalt
Improvements	Room Count:	8 / 4 / 2	Fireplace:	Natural fireplace (lower level)	Porches/ Patios/Decks	286sf concrete patio
Improvements	Central Air:	Yes	Heating: LP gas FHA	Road Frontage: Town street		
Improvements	# of Outbuildings:	1	Outbuilding Descriptions:	Utility shed (80sf)	Overall Condition:	Average

Additional Observations:	**Land:** The property has a level to gently rolling contour. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0600E, effective 07-16-2008. **Improvements:** Septic system/shared well, split level, basement has walkout doors to concrete patio, kitchen completely updated, newer roof and siding. Un-obstructed view of wind turbines from the backyard of residence. **Verification Comments:** Owner not present at the time of inspection, questionnaires returned unanswered. The closest wind turbine that is in the view from this property is approximately 5,533.37ft± to the southwest.
Site Inspected by:	James Marske — Date of Inspection: May 17, 2018

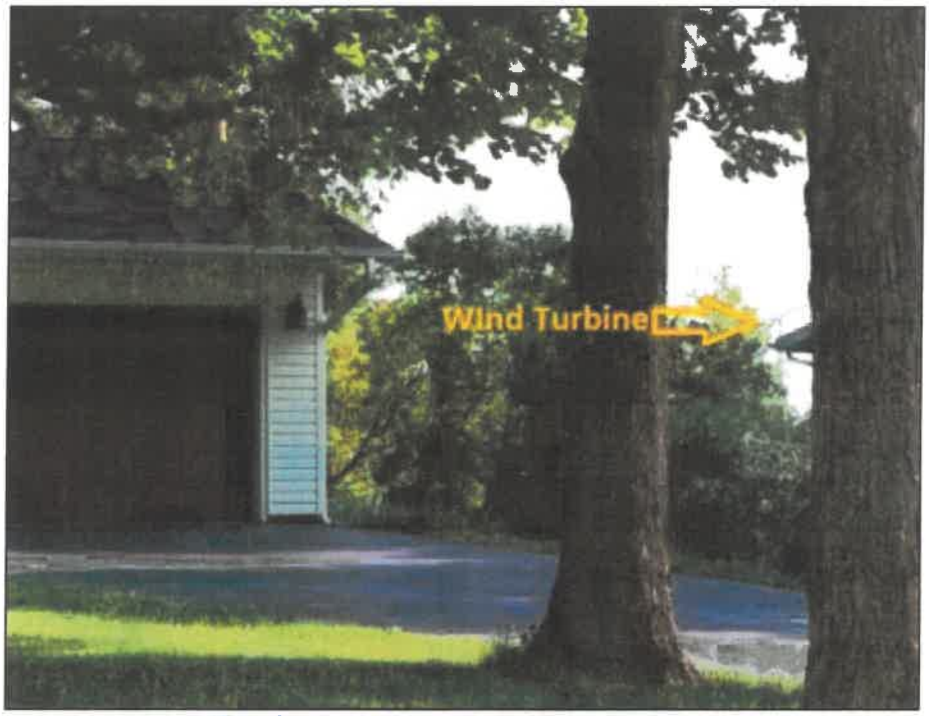
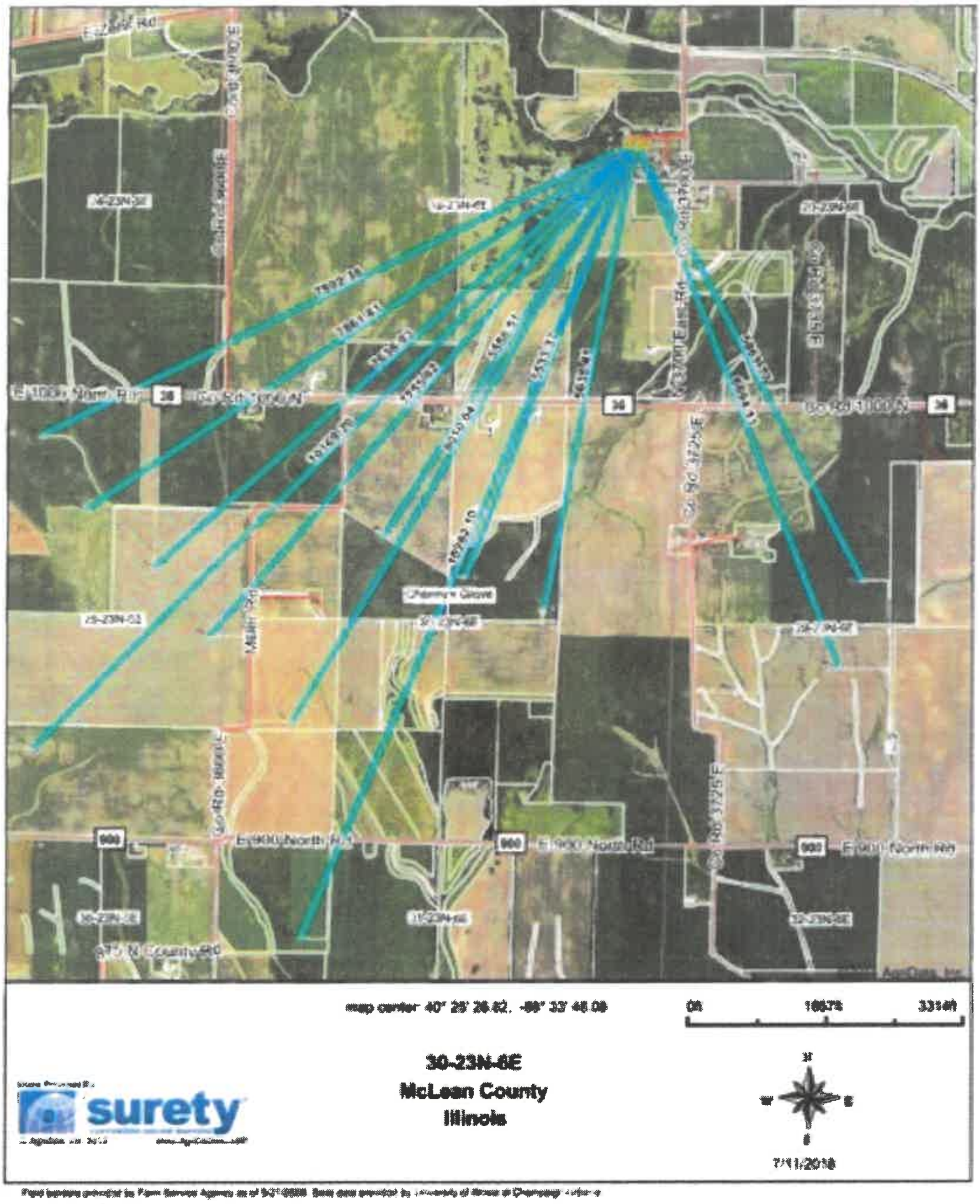


Figure 15: View of Wind Turbine looking southerly from driveway entrance.

Figure 16: View of residence looking southerly from Indian Spring Road.

Proximity to closest Wind Turbine - 5,533.37 linear feet



Sale Date	Sale Price
June 7, 2017	$220,000
Gross Living Area (sf)	GLA Price per sf
1,938	$113.52
Lot Size (acre)	Lot Price per acre
1.750	$125,714

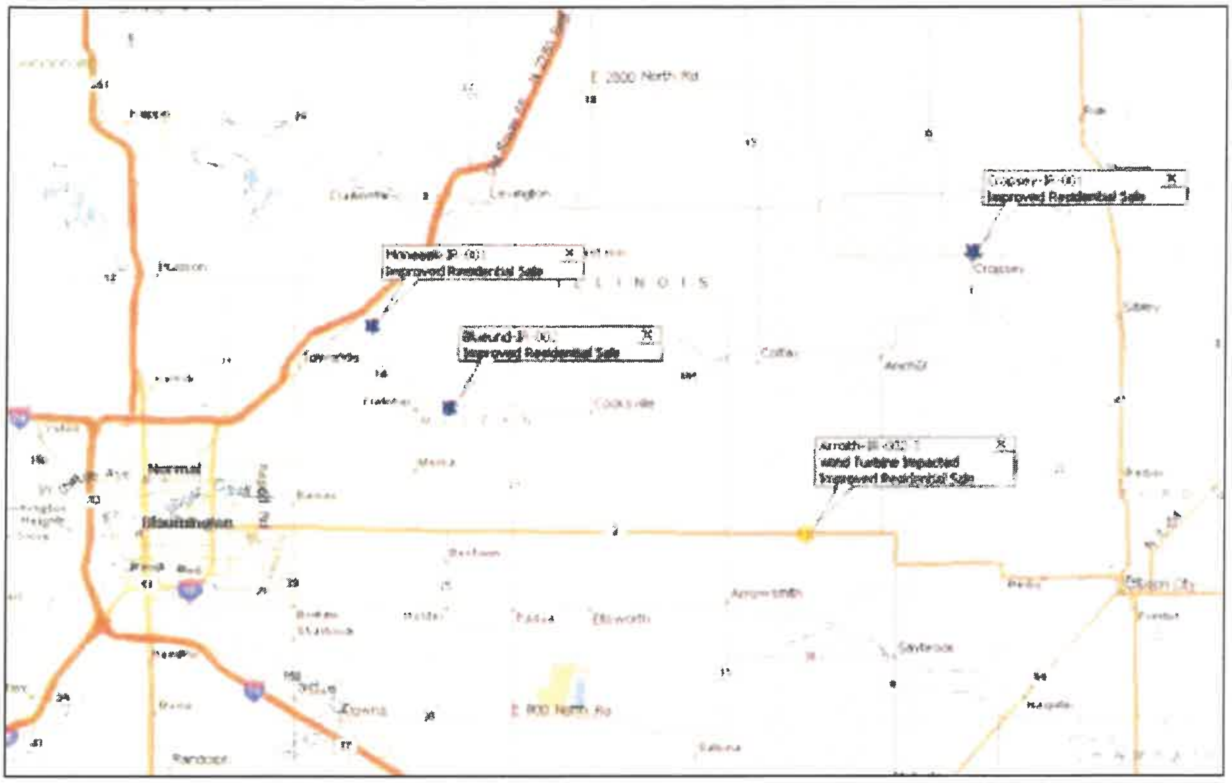
SALE: Empire-IR-001

Located at:	25288 Chestnut Drive
Municipality:	Empire Township
County:	McLean, IL
Parcel No.:	30-29-300-004
Grantor:	Paul R. Belyea, Trustee
Grantee:	Christian W. Gallion
Recording Doc:	2017-00010396
Document type:	Warranty Deed
Zoning:	A – Agriculture
Use:	Rural Residential

Land	Topography:	open: 31%	wooded: 69%	wetlands: 10%	FEMA/FIRM Floodplain: 0%		
Land	Terrain:	Gently Rolling to Rolling	Type of land use present in area:	Rural Residential/Agricultural	Water Feature:	Salt Creek	
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes			
Improvements	Style/story:	Tri-level	Exterior siding:	Wood/brick	Year Built:	1968	
Improvements	Construction Quality:	Average	Basement Type:	Full w/crawlspace	FBLA (sf):	0	
Improvements	# Garage Spaces:	2	Garage Type:	621sf attached	Driveway type:	Asphalt and concrete	
Improvements	Room Count:	N/A 4 3	Fireplace:	Natural fireplace with brick hearth	Porches/ Patios/Decks	Raised wood deck (160sf±), concrete patio (441sf±), enclosed screen porch (260sf±)	
Improvements	Central Air:	Yes	Heating: LP FHA	Road Frontage: Town Road			
Improvements	# of Outbuildings:	1	Outbuilding Descriptions:	784sf 4-sided metal shed	Overall Condition:	Average	

Additional Observations:	**Land:** The property lies at 745ft to 780ft above sea level. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0350E, effective 07-16-2008. There are freshwater forested/shrub wetlands areas located on the property. **Improvements:** well/septic system, basement has a walkout, concrete patio is located beneath an enclosed screen porch. **Verification Comments:** The seller Paul R. Belyea, stated by questionnaire that he did not know the buyer, the sale price was fair, and that the sale price was negotiated down from the asking price. The buyer Christian W. Gallion, stated by interview, that he did not know the seller, the sale price was fair, and that the sale price was negotiated down from the asking price. Mr. Gallion stated that he did not mind wind turbines. His wife stated that she hated the sound of wind turbines and would not live by them.
Site Inspected by:	James Marske — Date of Inspection: May 17, 2018

Paired Sales Group I



Paired Sales Analysis- Group I					
		Arroith-IR-002-T	Blueund-IR-002	Cropsey-IR-001	Moneeek-IR-001
address		13691 N 3550 East Road	17669 N 2400 East Road	22747 N 4100 East Road	20393 N 2150 East Road
Municipality/County		Arrowsmith Township	Blue Mound Township	Cropsey Township	Money Creek Township
Sale Price		$155,000.00	$174,000.00	$100,915.00	$160,000.00
Sale Date		October 10, 2017	July 20, 2016	August 19, 2016	February 8, 2017
time in months		Base	15	14	8
time adj per year		0.0%	0.00%	0.00%	0.00%
Adj Sales Price			$174,000.00	$100,915.00	$160,000.00
lot size description	acres	2.57	1.44	1.56	1.36
	land=	$59,100.00	$46,100.00	$49,900.00	$43,500.00
adjustment			$13,000.00	$9,200.00	$15,600.00
neighborhood location		Wind Farm- Zone 0	Non-wind farm	Non-wind farm	Non-wind farm
adjustment			$0.00	$0.00	$0.00
style		2 sty	2 sty	1.50 sty	1.5 sty
age		1880	1899	1901	1920
effective age		30	29	40	26
percent adj of residence			-2%	18%	-7%
adjustment			($2,000.00)	$8,400.00	($8,100.00)
exterior siding		metal	vinyl	vinyl	vinyl
quality of construction		average	average	average	average
room count	total	unknown	unknown	unknown	unknown
	BRs	3	4	3	3
	baths	2	1	2	1.5
GLA	in sq.ft.	1,728	1,658	1,408	1,815
contribution value $/sf			$46.86	$28.03	$49.75
adjustment	$/sf base		$3,300.00	$9,000.00	($4,100.00)
basement		1056	1074	1024	1112
portion finished in sf		0	256	0	0
contribution value $/sf			$7.00	$0.00	$0.00
adjustment			($1,800.00)	$0.00	$0.00
garage		888	704	0	360
contribution value		$10,000.00	$9,000.00	$0.00	$7,000.00
adjustment			$1,000.00	$10,000.00	$3,000.00
porches, decks		porch, cov porch, (2) encl por	enclosed porch	wood deck	(2) porches
contribution value		$14,000.00	$7,000.00	$1,000.00	$1,000.00
adjustment			$7,000.00	$13,000.00	$13,000.00
Other		gravel	gravel drive	gravel drive	gravel drive
		lanscaping	landscaping	landscaping (min)	landscaping
		detached garage (840sf)	pole barn (2,240sf)	utility shed (80sf)	
		machine shed (1,152sf)	chicken coop	utility shed 120sf)	
		barn (1,088sf)			
		barn (864sf)			
contribution value		$40,800.00	$20,000.00	$4,700.00	$4,500.00
			$20,800.00	$36,100.00	$36,300.00
Total Adjustments			$41,300	$85,700	$55,500
Indicated value if Not in Wind Farm			$215,300	$186,615	$215,500
Concluded Value of Subject if Not in Wind Farm Zone		$205,800			
Sale Price of Subject		$155,000			
Difference in dollars		($50,800)			
Difference as precentage		-32.8%			

Sale #	Arroith-IR-002-T		
Description	**area**	**$/area**	**$ sub-total**
GLA	1,728 sf	$ 100.27 /sf	$ 173,259.23
basement	1056 sf	$ 23.79 /sf	$ 25,127.36
garage	888 sf	$ 25.98 /sf	$ 23,071.48
covered porch	144 sf	$ 37.71 /sf	$ 5,430.14
enclosed porch	270 sf	$ 48.12 /sf	$ 12,991.29
enclosed porch	240 sf	$ 48.12 /sf	$ 11,547.81
Total Cost New			$ 251,427.31

Less Depreciation:		
Physical Depreciation	55%	$ 137,142.17
Effective Age: 30 *years*		
Total Economic Life: 55 *years*		
Depreciated value of structures:		$ 114,285.14
Functional Obsolescence	0%	$ -
Reason: none		
Economic Obsolescence	24%	$ 59,185.14
Reason: within windfarm		

Contribution (depreciated) value of building:	$ 55,100.00
Contribution (depreciated) value of outbuildings	$ 34,800.00
Plus, contribution value of site improvements	$ 6,000.00
Land value	$ 59,100.00
TOTAL (rounded)	$ 155,000.00

Sale #	Blueund-IR-002		
Description	**area**	**$/area**	**$ sub-total**
GLA	1,658 sf	$ 98.56 /sf	$ 163,410.18
basement	1,074 sf	$ 27.84 /sf	$ 29,900.76
garage	704 sf	$ 28.12 /sf	$ 19,797.31
enclosed porch	240 sf	$ 57.60 /sf	$ 13,823.70
	sf	$ - /sf	$ -
	sf	$ - /sf	$ -
Total Cost New			$ 226,931.94
Less Depreciation:			
Physical Depreciation		52%	$ 119,031.94
Effective Age:	29	*years*	
Total Economic Life:	55	*years*	
Depreciated value of structures:			$ 107,900.00
Functional Obsolescence		0%	$ -
Reason: none			
Economic Obsolescence		0%	$ -
Reason: none			

Contribution (depreciated) value of building:	$ 107,900.00
Contribution (depreciated) value of outbuildings	$ 14,000.00
Plus, contribution value of site improvements	$ 6,000.00
Land value	$ 46,100.00
TOTAL (rounded)	$ 174,000.00

Sale #	Cropsey-IR-001		
Description	**area**	**$/area**	**$ sub-total**
GLA	1,408 sf	$ 102.98 /sf	$ 144,993.71
basement	1,024 sf	$ 23.79 /sf	$ 24,365.92
garage	- sf	$ - /sf	$ -
wood deck	128 sf	$ 23.42 /sf	$ 2,997.85
	sf	$ - /sf	$ -
	sf	/sf	$ -
Total Cost New			$ 172,357.48

Less Depreciation:		
Physical Depreciation	73%	$ 125,442.48
Effective Age: 40 *years*		
Total Economic Life: 55 *years*		
Depreciated value of structures:		$ 46,915.00
Functional Obsolescence	0%	$ -
Reason: none		
Economic Obsolescence	0%	$ -
Reason: none		

Contribution (depreciated) value of building:	$ 46,915.00
Contribution (depreciated) value of outbuildings	$ 1,100.00
Plus, contribution value of site improvements	$ 3,000.00
Land value	$ 49,900.00
TOTAL (rounded)	$ 100,915.00

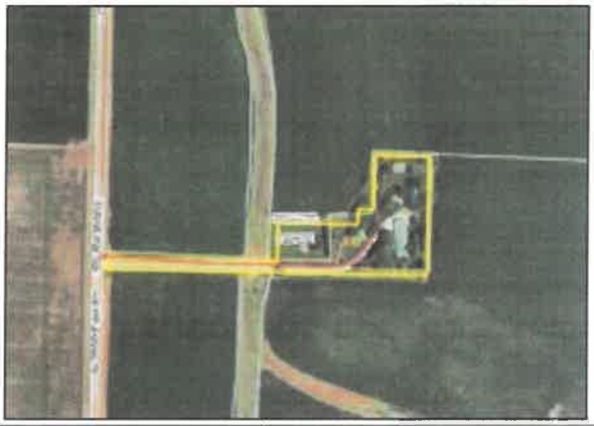
Sale #	Moneeek-IR-001		
Description	**area**	**$/area**	**$ sub-total**
GLA	1,815 sf	$ 95.44 /sf	$ 173,217.49
basement	1,112 sf	$ 22.39 /sf	$ 24,899.58
garage	360 sf	$ 38.88 /sf	$ 13,996.28
porch	84 sf	$ 19.06 /sf	$ 1,600.98
porch	54 sf	$ 20.75 /sf	$ 1,120.75
	sf	/sf	$ -
Total Cost New			$ 214,835.09

Less Depreciation:		
Physical Depreciation	48%	$ 102,835.09
Effective Age: 26 *years*		
Total Economic Life: 55 *years*		
Depreciated value of structures:		$ 112,000.00
Functional Obsolescence	0%	$ -
Reason: none		
Economic Obsolescence	0%	$ -
Reason: none		

Contribution (depreciated) value of building:	$ 112,000.00
Contribution (depreciated) value of outbuildings	$ -
Plus, contribution value of site improvements	$ 4,500.00
Land value	$ 43,500.00
TOTAL (rounded)	$ 160,000.00

Sale Date	Sale Price
October 10, 2017	$155,000
Gross Living Area (sf)	GLA Price per sf
1,728	$89.70
Lot Size (acre)	Lot Price per acre
2.570	$60,311

SALE: Arroith-IR-002-T



Located at:	13691 N 3550 East Road
Municipality:	Arrowsmith Township
County:	McLean, IL
Parcel No.:	24-01-200-002
Grantor:	Barbara N. Kline
Grantee:	John C. Schmidtt
Recording Doc:	2017-00019062
Document type:	Warranty Deed
Zoning:	A – Agriculture
Use:	Agricultural

Land	Topography:	open: 36%		wooded: 64%	wetlands: 0%		FEMA/FIRM Floodplain: 0%	
Land	Terrain:	Gently Rolling		Type of land use present in area:	Rural Residential, Agricultural		Water Feature:	Creek/stream
Land	Landscaping:	Average		Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes			
Improvements	Style/story:	2 story		Exterior siding:	Metal		Year Built:	1880
Improvements	Construction Quality:	Average		Basement Type:	Full		FBLA (sf):	0
Improvements	# Garage Spaces:	3		Garage Type:	888sf attached		Driveway type:	Gravel
Improvements	Room Count:	N/A	3	2	Fireplace:	Wood burning stove	Porches/ Patios/Decks	128sf open porch, 144sf covered porch, 270sf enclosed porch, 240sf enclosed porch
Improvements	Central Air:	No	Heating:	Forced air	Road Frontage	County road		
Improvements	# of Outbuildings:	4	Outbuilding Descriptions:	3 car detached garage (840sf), 1,152sf shed, 1,088sf barn, 864sf barn			Overall Condition:	Average

Additional Observations:	**Land:** The property has a level to gently rolling contour. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0600E, effective 07-16-2008. **Improvements:** Private well/septic system, window air conditioning units, hardwood floors. **Verification Comments:** Owner not present at the time of inspection, questionnaires returned unanswered. The closest wind turbine that is in the view from this property is approximately 2,199.85ft± to the southeast.

Site Inspected by:	James Marske	Date of Inspection:	May 17, 2018

Figure 17: View of property with Wind Turbines figuring prominently in the picture looking easterly from N 3550 East Road.

Figure 18: View of residence (Picture used from Trulia due to landowner not being present).

Proximity to closest Wind Turbines - 2,199.85 linear feet

1-23N-5E
McLean County
Illinois

7/11/2018

SALE: Blueund-IR-002

Sale Date	Sale Price
July 20, 2016	$174,000
Gross Living Area (sf)	**GLA Price per sf**
1,658	$104.95
Lot Size (acre)	**Lot Price per acre**
1.440	$120,833

Located at:	17669 N 2400 East Road
Municipality:	Blue Mound Township
County:	McLean, IL
Parcel No.:	16-18-100-011
Grantor:	Kim C. & Beth A. Schwab
Grantee:	Corey Owens & Ryan Windle
Recording Doc:	2016-00013908
Document type:	Warranty Deed
Zoning:	A – Agriculture
Use:	Rural Residential

Land	Topography:	open: 90%		wooded: 10%	wetlands: 0%	FEMA/FIRM Floodplain: 0%	
Land	Terrain:	Gently Rolling	Type of land use present in area:	Rural Residential, Agricultural	Water Feature:	None	
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes, garden area			
Improvements	Style/story:	2 story	Exterior siding:	Vinyl	Year Built:	1899	
Improvements	Construction Quality:	Average	Basement Type:	Full	FBLA (sf):	256sf±	
Improvements	# Garage spaces:	2.5	Garage Type:	704sf detached	Driveway type:	Gravel	
Improvements	Room Count:	N/A / 4 / 1	Fireplace:	No	Porches/ Patios/Decks	240sf enclosed porch	
Improvements	Central Air:	Yes	Heating:	LP gas FHA	Road Type	County road	
Improvements	# of Outbuildings:	2	Outbuilding Descriptions:	2,240sf pole frame building, chicken coop	Overall Condition:	Average	

Additional Observations:	**Land:** The property lies at 790ft to 805ft above sea level. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0350E, effective 07-16-2008. There is an ingress-egress easement and a well/septic maintenance easement upon the lane that connects the property to N 2400 East Road over the adjacent property to the west. **Improvements:** Septic system/private well, newer roof and newer electrical throughout residence and metal shed. **Verification Comments:** Owner not present at the time of inspection, questionnaires returned unanswered.

Site Inspected by:	James Marske	Date of Inspection:	May 17, 2018

Sale Date	Sale Price
August 19, 2016	$100,915
Gross Living Area (sf)	**GLA Price per sf**
1,408	$71.67
Lot Size (acre)	**Lot Price per acre**
1.560	$64,689

SALE: Cropsey-IR-001

Located at:	22747 N 4100 East Road
Municipality:	Cropsey Township
County:	McLean, IL
Parcel No.:	11-24-101-011
Grantor:	Benjamin T. & Stephanie Gunther
Grantee:	Tyler W. & Cassandra L. McMurray
Recording Doc:	2016-00016072
Document type:	Warranty Deed
Zoning:	A – Agriculture
Use:	Rural Residential

Land	Topography:	open: 60%	wooded: 40%	wetlands: 0%	FEMA/FIRM Floodplain: 0%	
Land	Terrain:	Level to Gently Rolling	Type of land use present in area:	Rural Residential, Agricultural	Water Feature:	None
Land	Landscaping:	Fair	Landscaping Observations:	Lawn, scattered semi-mature and mature trees		
Improvements	Style/story:	1.5 story	Exterior siding:	Vinyl	Year Built:	1901
Improvements	Construction Quality:	Average	Basement Type:	Full	FBLA (sf):	0
Improvements	# Garage spaces:	-	Garage Type:	-	Driveway type:	Gravel
Improvements	Room Count:	N/A | 3 | 2	Fireplace:	No	Porches/ Patios/Decks	128sf deck
Improvements	Central Air:	Yes	Heating: LP gas FHA	Road Frontage: County Road		
Improvements	# of Outbuildings:	2	Outbuilding Descriptions:	Utility shed (80sf±), Utility shed (120sf±)	Overall Condition:	Average

Additional Observations:	**Land:** The property lies at 745ft to 755ft above sea level. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0425E, effective 07-16-2008. **Improvements:** Private well/septic system. Updates include roof, insulation, siding, gutters, plumbing, electrical, drywall, and flooring. **Verification Comments:** The buyer, Cassandra McMurray, stated by questionnaire that she did not know the seller, the sale price was fair, and that the sale price was negotiated from the asking price.

Site Inspected by:	James Marske	Date of Inspection:	May 17, 2018

FORENSIC APPRAISAL GROUP

Sale Date	Sale Price
February 8, 2017	$160,000
Gross Living Area (sf)	**GLA Price per sf**
1,815	$88.15
Lot Size (acre)	**Lot Price per acre**
1.360	$117,647

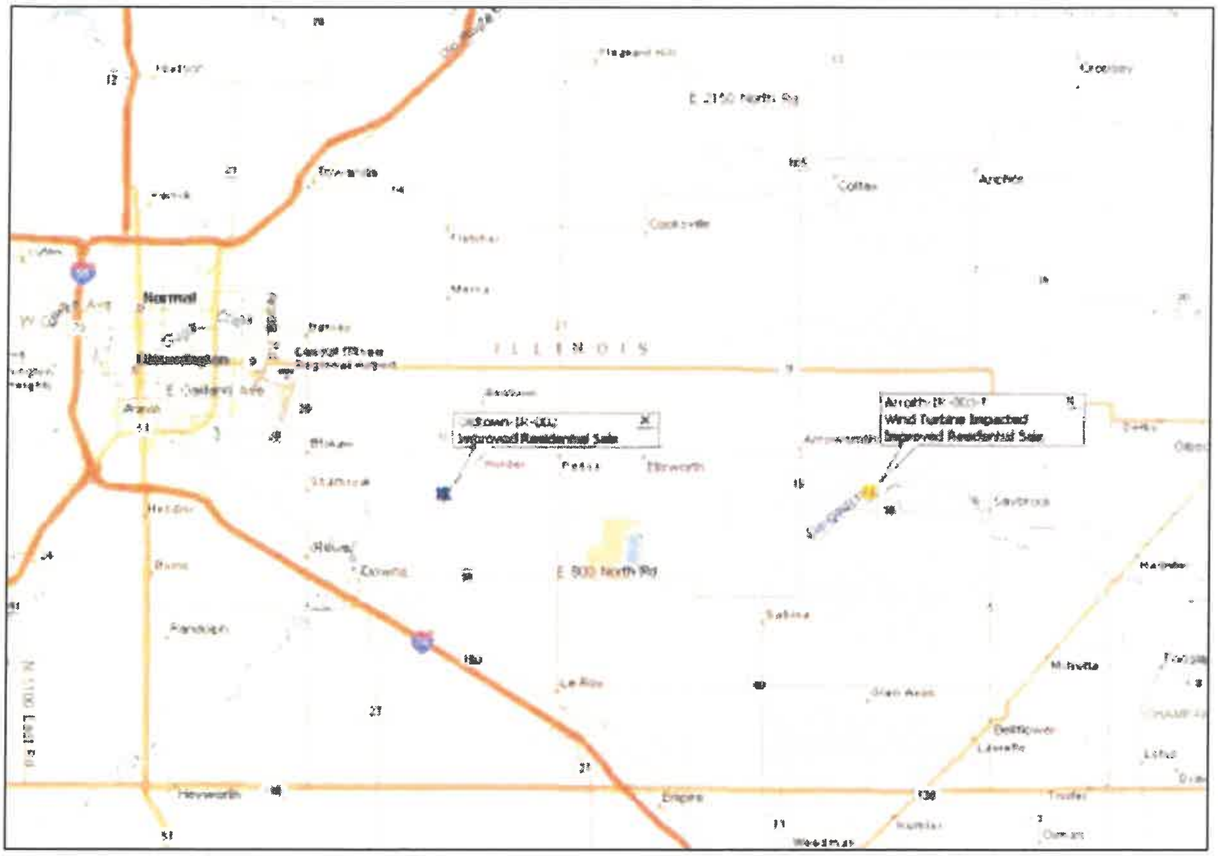
SALE: Moneeek-IR-001

Located at:	20393 N 2150 East Road
Municipality:	Money Creek Township
County:	McLean, IL
Parcel No.:	08-34-400-019
Grantor:	Sara E. Standish
Grantee:	Joanna M. Kitchens
Recording Doc:	2017-00002830
Document type:	Warranty Deed
Zoning:	A – Agriculture
Use:	Rural Residential

Land	Topography:	open: 74%	wooded: 26%	wetlands: 0%	FEMA/FIRM Floodplain: 0%	
Land	Terrain:	Level	Type of land use present in area:	Rural Residential, Agricultural	Water Feature:	None
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes		
Improvements	Style/story:	1.5 story	Exterior siding:	Vinyl	Year Built:	1920
Improvements	Construction Quality:	Average	Basement Type:	Full w/crawl space	FBLA (sf):	None
Improvements	# Garage spaces:	2	Garage Type:	360sf detached	Driveway type:	Gravel
Improvements	Room Count:	N/A | 3 | 1.5	Fireplace:	None	Porches/ Patios/Decks	84sf open porch, 54sf open porch
Improvements	Central Air:	No	Heating: Forced air	Road Frontage: County Road		
Improvements	# of Outbuildings:	-	Outbuilding Descriptions: -		Overall Condition:	Average

Additional Observations:	**Land:** The property lies at 790ft to 792ft above sea level. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0350E, effective 07-16-2008. **Improvements:** Well and septic system on the property, above ground pool, unfinished attic in the house (703sf). **Verification Comments:** The buyer Joanna Kitchens, stated by questionnaire that she did not know the previous owner, the sale price was fair, and that the sale price was negotiated down from the asking price.
Site Inspected by:	James Marske — Date of Inspection: May 17, 2018

Paired Sales Group J



Paired Sales Analysis- Group J				
		Arroith-IR-003-T	Oldtown-IR-002	Moneeek-IR-001
address		10197 N 3500 East Rpad	22792 E 1000 North Road	20393 N 2150 East Road
Municipality/County		Arrowsmith Township	Old Town Township	Money Creek Township
Sale Price		$261,900.00	$207,000.00	$160,000.00
Sale Date		June 4, 2016	December 16, 2016	February 8, 2017
time in months		Base	-7	-8
time adj per year		0.0%	0.00%	0.00%
Adj Sales Price			$207,000.00	$160,000.00
lot size description	acres	9.6	3.21	1.36
	land=	$124,800.00	$64,200.00	$43,500.00
adjustment			$60,600.00	$81,300.00
neighborhood location		Wind Farm- Zone 0	Non-wind farm	Non-wind farm
adjustment			$0.00	$0.00
style		2 sty	1.5 sty	1.5 sty
age		1911	1901	1920
effective age		26	30	26
percent adj of residence			7%	0%
adjustment			$9,100.00	$0.00
exterior siding		metal w/brick trim	brick	vinyl
quality of construction		average	average	average
room count	total	unknown	unknown	unknown
	BRs	3	3	3
	baths	2.5	3	1.5
GLA	in sq.ft.	2,016	1,990	1,815
contribution value $/sf			$50.09	$49.75
adjustment	$/sf base		$1,300.00	$10,000.00
basement		1176	1654	1112
portion finished in sf		0	0	0
contribution value $/sf			$0.00	$0.00
adjustment			$0.00	$0.00
garage		624	320	360
contribution value		$12,000.00	$6,000.00	$7,000.00
adjustment			$6,000.00	$5,000.00
porches, decks		enclosed por, deck, patio	(2) covered porches, patio	cov porch, porch
contribution value		$7,000.00	$4,000.00	$1,000.00
adjustment			$3,000.00	$6,000.00
Other		gravel	gravel drive & concrete	gravel drive
		landscaping	landscaping (min)	landscaping (min)
		riding arena + stalls + shop (6,264sf)	loafing shed (192sf)	
			Pole barn/garage (1,800sf)	
contribution value		$43,100.00	$17,100.00	$4,500.00
			$26,000.00	$38,600.00
Total Adjustments			$106,000	$140,900
Indicated value if Not in Wind Farm			$313,000	$300,900
Concluded Value of Subject if Not in Wind Farm Zone		$307,000		
Sale Price of Subject		$261,900		
Difference in dollars		($45,100)		
Difference as precentage		-17.2%		

Sale #	Arroith-IR-003-T			
Description	**area**	**$/area**	**$ sub-total**	
GLA	2,016 sf	$ 102.42 /sf	$ 206,473.15	
basement	1176 sf	$ 22.39 /sf	$ 26,332.65	
garage (heated)	624 sf	$ 37.88 /sf	$ 23,640.04	
enclosed porch	196 sf	$ 53.51 /sf	$ 10,487.23	
wood deck	144 sf	$ 22.16 /sf	$ 3,190.73	
patio	248 sf	$ 7.42 /sf	$ 1,841.38	
	sf	$ - /sf	$ -	
Total Cost New			$ 271,965.17	
Less Depreciation:				
Physical Depreciation		47%	$ 128,565.35	
Effective Age:	26	*years*		
Total Economic Life:	55	*years*		
Depreciated value of structures:			$ 143,399.82	
Functional Obsolescence		0%	$ -	
Reason: none				
Economic Obsolescence		34%	$ 49,399.82	
Reason: within windfarm				
Contribution (depreciated) value of building:				$ 94,000.00
Contribution (depreciated) value of outbuildings				$ 36,100.00
Plus, contribution value of site improvements				$ 7,000.00
Land value				$ 124,800.00
TOTAL (rounded)				$ 261,900.00

Sale #	Oldtown-IR-002		
Description	**area**	**$/area**	**$ sub-total**
GLA	1,990 sf	$ 109.36 /sf	$ 217,631.89
basement	1,654 sf	$ 20.99 /sf	$ 34,715.10
garage	320 sf	$ 38.88 /sf	$ 12,441.14
covered porch	120 sf	$ 40.87 /sf	$ 4,903.96
covered porch	60 sf	$ 52.85 /sf	$ 3,171.09
patio	204 sf	$ 7.68 /sf	$ 1,567.16
Total Cost New			$ 274,430.34

Less Depreciation:			
Physical Depreciation		54%	$ 148,730.34
Effective Age:	30	*years*	
Total Economic Life:	55	*years*	
Depreciated value of structures:			$ 125,700.00
Functional Obsolescence		0%	$ -
Reason: none			
Economic Obsolescence		0%	$ -
Reason: none			

Contribution (depreciated) value of building:	$ 125,700.00
Contribution (depreciated) value of outbuildings	$ 12,100.00
Plus, contribution value of site improvements	$ 5,000.00
Land value	$ 64,200.00
TOTAL (rounded)	$ 207,000.00

Sale #	Moneeek-IR-001		
Description	**area**	**$/area**	**$ sub-total**
GLA	1,815 sf	$ 95.44 /sf	$ 173,217.49
basement	1,112 sf	$ 22.39 /sf	$ 24,899.58
garage	360 sf	$ 38.88 /sf	$ 13,996.28
covered porch	84 sf	$ 19.06 /sf	$ 1,600.98
porch	54 sf	$ 20.75 /sf	$ 1,120.75
	sf	/sf	$ -
Total Cost New			$ 214,835.09
Less Depreciation:			
Physical Depreciation		48%	$ 102,835.09
Effective Age:	*26*	*years*	
Total Economic Life:	*55*	*years*	
Depreciated value of structures:			$ 112,000.00
Functional Obsolescence		0%	$ -
Reason: none			
Economic Obsolescence		0%	$ -
Reason: none			

Contribution (depreciated) value of building:	$ 112,000.00
Contribution (depreciated) value of outbuildings	$ -
Plus, contribution value of site improvements	$ 4,500.00
Land value	$ 43,500.00
TOTAL (rounded)	$ 160,000.00

Sale Date	Sale Price
June 4, 2016	$261,900
Gross Living Area (sf)	**GLA Price per sf**
2,016	$129.91
Lot Size (acre)	**Lot Price per acre**
9.600	$27,281

SALE: Arroith-IR-003-T

Located at:	10197 N 3500 East Road
Municipality:	Arrowsmith Township
County:	McLean, IL
Parcel No.:	24-24-300-003
Grantor:	Brandon A. & Amanda R. Clark
Grantee:	Geoff & Andrea Skinner
Recording Doc:	2016-00011578
Document type:	Warranty Deed
Zoning:	A – Agriculture
Use:	Agricultural

Land	Topography:	open: 94%	wooded: 6%	wetlands: 0%	FEMA/FIRM Floodplain: 50%	
Land	Terrain:	Gently Rolling	Type of land use present in area:	Rural Residential, Agricultural	Water Feature:	Sangamon River
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes, orchard trees		
Improvements	Style/story:	2 story	Exterior siding:	Brick/metal	Year Built:	1911
Improvements	Construction Quality:	Average	Basement Type:	Full	FBLA (sf):	0
Improvements	# Garage Spaces:	2	Garage Type:	624sf attached	Driveway type:	Gravel
Improvements	Room Count:	N/A 3 2.5	Fireplace:	Natural fireplace	Porches/ Patios/Decks	196sf enclosed porch, 144sf deck, 248sf patio
Improvements	Central Air:	Yes	Heating: LP gas FHA	Road Type: County road		
Improvements	# of Outbuildings:	1	Outbuilding Descriptions:	6,264sf 4-sided metal shed with 4 stalls and riding area with concrete floor and insulation in the workshop area	Overall Condition:	Average

Additional Observations:	**Land:** The property has a gently rolling contour. A large part of the property surrounding the Sangamon River lies in Flood Zone A, a floodplain, within FIRM Panel #17113C0600E, effective 07-16-2008. The remainder of the property lies in Flood Zone X, an area of minimal flood hazard. **Improvements:** Well/septic system, new roof, and new high-efficiency furnace, updated cabinetry throughout. **Verification Comments:** Owner not present at the time of inspection, questionnaires returned unanswered. The closest wind turbine that is in the view from this property is approximately 3,144.74ft± to the southeast.

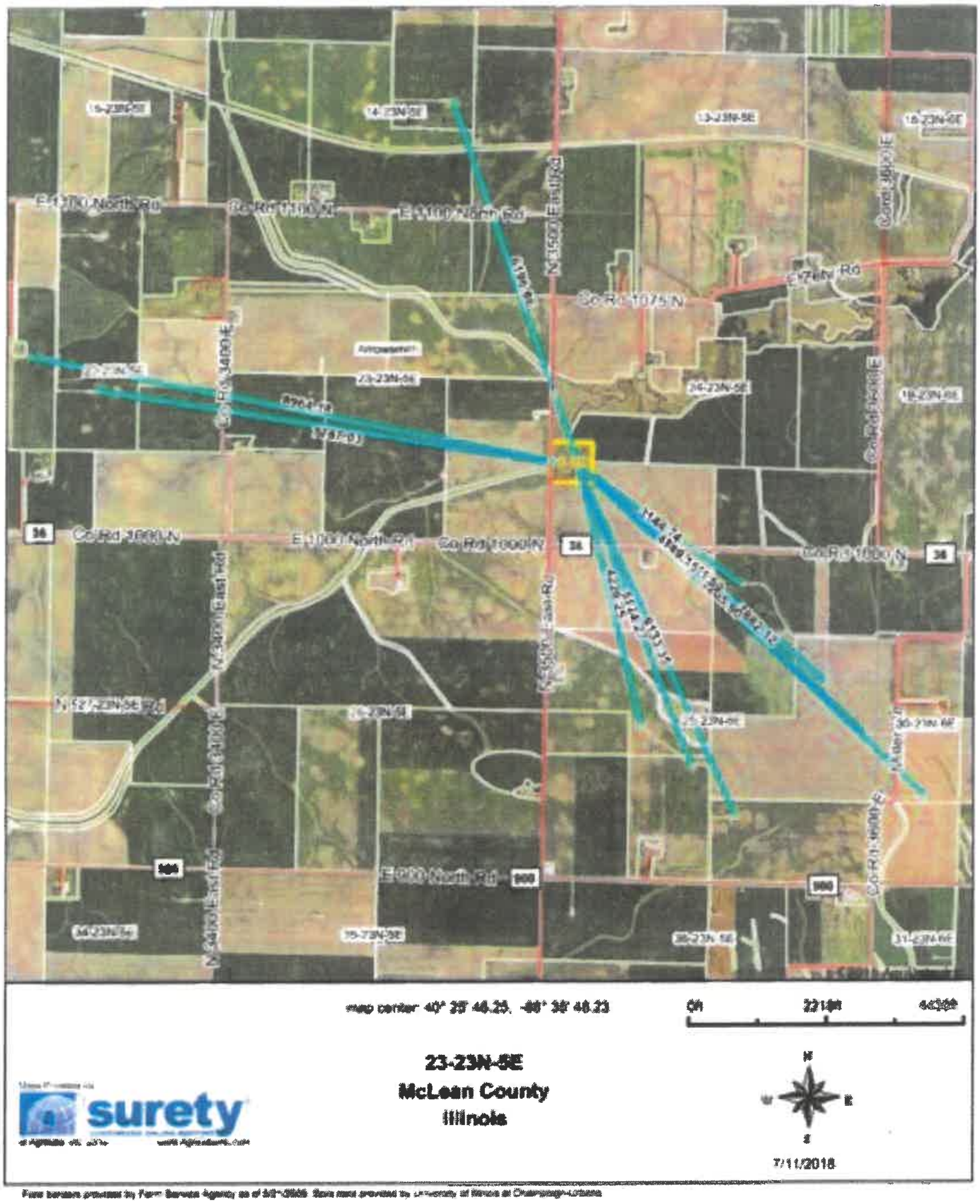
Site Inspected by:	James Marske	Date of Inspection:	May 17, 2018

FORENSIC APPRAISAL GROUP

Figure 19: View of Wind Turbines looking southerly from a driveway in front of the residence.

Figure 20: View of Wind Turbines looking southeasterly from a driveway in front of the residence.

Proximity to closest Wind Turbines - 3,144.74 linear feet



SALE: Moneeek-IR-001

Sale Date	Sale Price
February 8, 2017	$160,000
Gross Living Area (sf)	**GLA Price per sf**
1,815	$88.15
Lot Size (acre)	**Lot Price per acre**
1.360	$117,647

Located at:	20393 N 2150 East Road
Municipality:	Money Creek Township
County:	McLean, IL
Parcel No.:	08-34-400-019
Grantor:	Sara E. Standish
Grantee:	Joanna M. Kitchens
Recording Doc:	2017-00002830
Document type:	Warranty Deed
Zoning:	A – Agriculture
Use:	Rural Residential

Land	Topography:	open: 74%	wooded: 26%	wetlands: 0%	FEMA/FIRM Floodplain: 0%		
Land	Terrain:	Level	Type of land use present in area:	Rural Residential, Agricultural	Water Feature:	None	
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes			
Improvements	Style/story:	1.5 story	Exterior siding:	Vinyl	Year Built:	1920	
Improvements	Construction Quality:	Average	Basement Type:	Full w/crawl space	FBLA (sf):	None	
Improvements	# Garage spaces:	2	Garage Type:	360sf detached	Driveway type:	Gravel	
Improvements	Room Count:	N/A, 3, 1.5	Fireplace:	None	Porches/ Patios/Decks	84sf open porch, 54sf open porch	
Improvements	Central Air:	No	Heating:	Forced air	Road Frontage	County Road	
Improvements	# of Outbuildings:	-	Outbuilding Descriptions:	-	Overall Condition:	Average	

Additional Observations:	**Land:** The property lies at 790ft to 792ft above sea level. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0350E, effective 07-16-2008. **Improvements:** Well and septic system on the property, above ground pool, unfinished attic in the house (703sf). **Verification Comments:** The buyer Joanna Kitchens, stated by questionnaire that she did not know the previous owner, the sale price was fair, and that the sale price was negotiated down from the asking price.
Site Inspected by:	James Marske — **Date of Inspection:** May 17, 2018

Sale Date	Sale Price
December 16, 2016	$207,000
Gross Living Area (sf)	GLA Price per sf
1,990	$104.02
Lot Size (acre)	Lot Price per acre
3.210	$64,486

SALE: Oldtown-IR-002

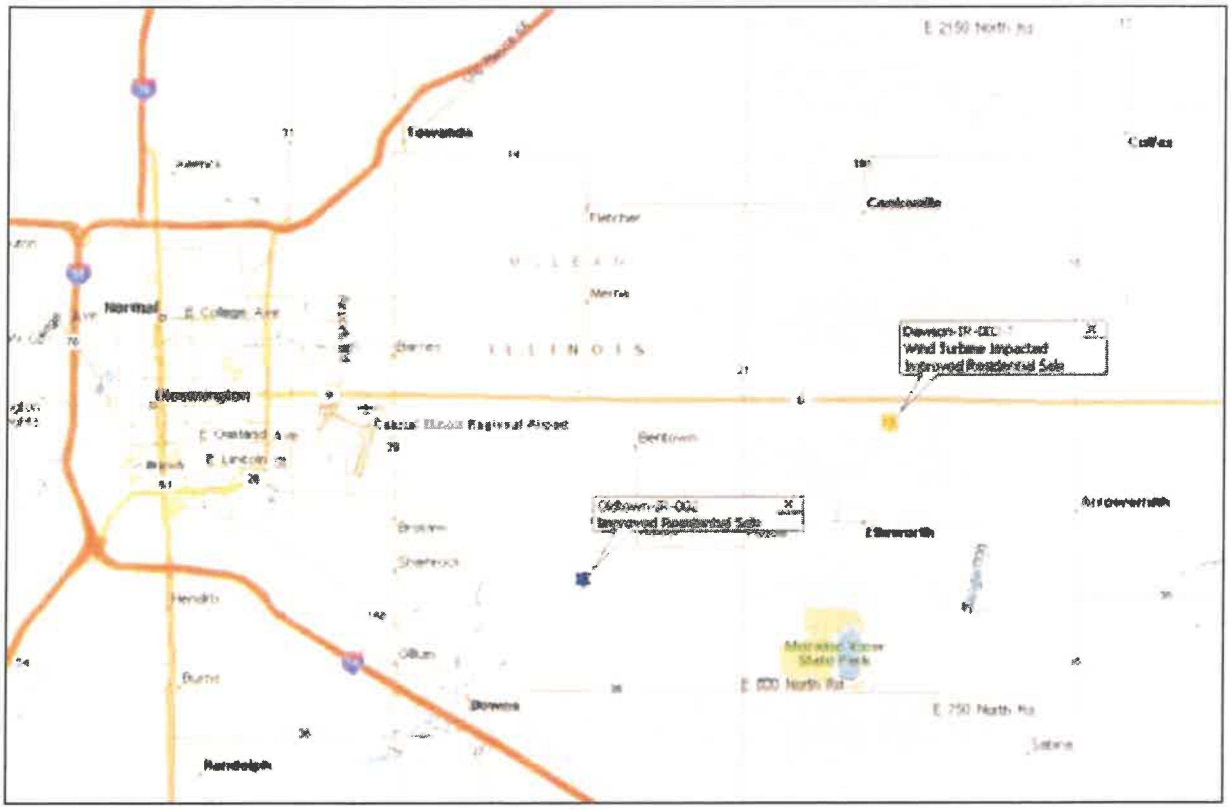
Located at:	22792 E 1000 North Road
Municipality:	Old Town Township
County:	McLean, IL
Parcel No.:	22-23-400-006
Grantor:	Ronald & Rebecca Wheeler
Grantee:	Joseph J. & Karla S. T. Jenkins
Recording Doc:	2016-00024490
Document type:	Warranty Deed
Zoning:	A – Agriculture
Use:	Residential

Land	Topography:	open: 82%	wooded: 18%	wetlands: 0%	FEMA/FIRM Floodplain: 0%	
Land	Terrain:	Level	Type of land use present in area:	Rural Residential, Agricultural	Water Feature:	Drainage ditch
Land	Landscaping:	Average	Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes		
Improvements	Style/story:	1.5 story	Exterior siding:	Vinyl	Year Built:	1884
Improvements	Construction Quality:	Average	Basement Type:	Full	FBLA (sf):	0
Improvements	# Garage Spaces:	1	Garage Type:	320sf detached	Driveway type:	Gravel and concrete
Improvements	Room Count:	N/A / 3 / 3	Fireplace:	Wood burning stove	Porches/ Patios/Decks	120sf covered porch, 60sf covered porch, 204sf concrete patio
Improvements	Central Air:	Yes	Heating: LP FHA	Road Frontage: County Road		
Improvements	# of Outbuildings:	2	Outbuilding Descriptions:	192sf shed, 1,800sf pole barn/garage	Overall Condition:	Average

Additional Observations:	**Land:** The property lies at 865ft to 875ft above sea level. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0550E, effective 07-16-2008. **Improvements:** Well/septic system, new roof, new hardwood floors, new foundation. **Verification Comments:** The buyer Joseph Jenkins, stated by questionnaire that he did know the seller as a family acquaintance, the sale price was fair and that the sale price was negotiated down from the asking price.

Site Inspected by:	James Marske	Date of Inspection:	May 17, 2018

Paired Sales Group K



Paired Sales Analysis- Group K			
		Dawson-IR-002-T	Oldtown-IR-002
address		13321 N 2900 East Road	22792 E 1000 North Road
Municipality/County		Dawson Township	Old Town Township
Sale Price		$275,000.00	$207,000.00
Sale Date		May 15, 2017	December 16, 2016
time in months		Base	5
time adj per year		0.0%	0.00%
Adj Sales Price			$207,000.00
lot size description	acres	5.16	3.21
	land=	$82,600.00	$64,200.00
adjustment			$18,400.00
neighborhood location		Wind Farm- Zone 0	Non-wind farm
adjustment			$0.00
style		2 sty	1.5 sty
age		1920	1901
effective age		20	30
percent adj of residence			18%
adjustment			$22,900.00
exterior siding		brick	brick
quality of construction		average	average
room count	total	unknown	unknown
	BRs	4	3
	baths	2	3
GLA	in sq.ft.	2,054	1,990
contribution value $/sf			$50.09
adjustment	$/sf base		$3,200.00
basement		1294	1654
portion finished in sf		0	0
contribution value $/sf			$0.00
adjustment			$0.00
garage		480	320
contribution value		$11,000.00	$6,000.00
adjustment			$5,000.00
porches, decks		deck, porch	(2) covered porches, patio
contribution value		$4,000.00	$4,000.00
adjustment			$0.00
Other		gravel	gravel drive & concrete
		landscaping	landscaping (min)
		shed (800sf)	loafing shed (192sf)
		barn with lean-to (2,720sf)	Pole barn/garage (1,800sf)
		pole barn (1,560sf)	
contribution value		$60,900.00	$17,100.00
			$43,800.00
Total Adjustments			$93,300
Indicated value if Not in Wind Farm			**$300,300**
Concluded Value of Subject if Not in Wind Farm Zone		$300,300	
Sale Price of Subject		$275,000	
Difference in dollars		($25,300)	
Difference as precentage		-9.2%	

Sale #	Dawson-IR-002-T		
Description	**area**	**$/area**	**$ sub-total**
GLA	2,054 sf	$ 110.60 /sf	$ 227,176.91
basement	1,294 sf	$ 21.69 /sf	$ 28,067.05
garage	480 sf	$ 36.54 /sf	$ 17,539.20
wood deck	144 sf	$ 22.16 /sf	$ 3,190.73
porch	180 sf	$ 19.64 /sf	$ 3,535.90
	sf	$ - /sf	$ -
Total Cost New			$ 279,509.79
Less Depreciation:			
Dawson-IR-002-T		36%	$ 101,639.92
Effective Age:	20	*years*	
Total Economic Life:	55	*years*	
Depreciated value of structures:			$ 177,869.87
Functional Obsolescence		0%	$ -
Reason: none			
Economic Obsolescence		26%	$ 46,369.87
Reason: none			

Contribution (depreciated) value of building:	$ 131,500.00
Contribution (depreciated) value of outbuildings	$ 53,900.00
Plus, contribution value of site improvements	$ 7,000.00
Land value	$ 82,600.00
TOTAL (rounded)	$ 275,000.00

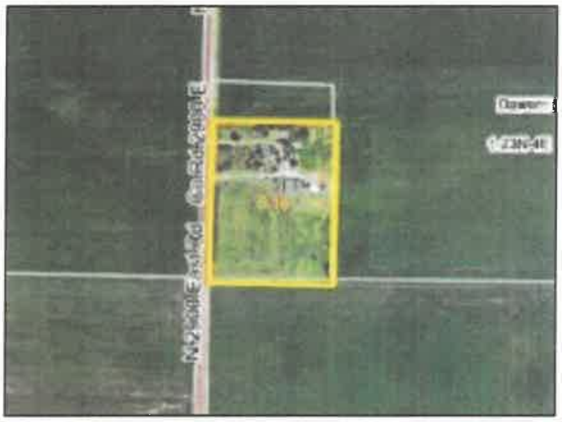
Sale #	Oldtown-IR-002		
Description	**area**	**$/area**	**$ sub-total**
GLA	1,990 sf	$ 109.36 /sf	$ 217,631.89
basement	1,654 sf	$ 20.99 /sf	$ 34,715.10
garage	320 sf	$ 38.88 /sf	$ 12,441.14
covered porch	120 sf	$ 40.87 /sf	$ 4,903.96
covered porch	60 sf	$ 52.85 /sf	$ 3,171.09
patio	204 sf	$ 7.68 /sf	$ 1,567.16
Total Cost New			$ 274,430.34

Less Depreciation:			
Physical Depreciation		54%	$ 148,730.34
Effective Age:	30	*years*	
Total Economic Life:	55	*years*	
Depreciated value of structures:			$ 125,700.00
Functional Obsolescence		0%	$ -
Reason: none			
Economic Obsolescence		0%	$ -
Reason: none			

Contribution (depreciated) value of building:	$ 125,700.00
Contribution (depreciated) value of outbuildings	$ 12,100.00
Plus, contribution value of site improvements	$ 5,000.00
Land value	$ 64,200.00
TOTAL (rounded)	$ 207,000.00

Sale Date	Sale Price
May 15, 2017	$275,000
Gross Living Area (sf)	**GLA Price per sf**
2,054	$133.89
Lot Size (acre)	**Lot Price per acre**
5.160	$53,295

SALE: Dawson-IR-002-T



Located at:	13321 N 2900 East Road
Municipality:	Dawson Township
County:	McLean, IL
Parcel No.:	23-01-300-006
Grantor:	James M. & Debbie L. Wheeler
Grantee:	Bethany M. Presutti
Recording Doc:	2016-00006469
Document type:	Warranty Deed
Zoning:	A - Agriculture
Use:	Agricultural

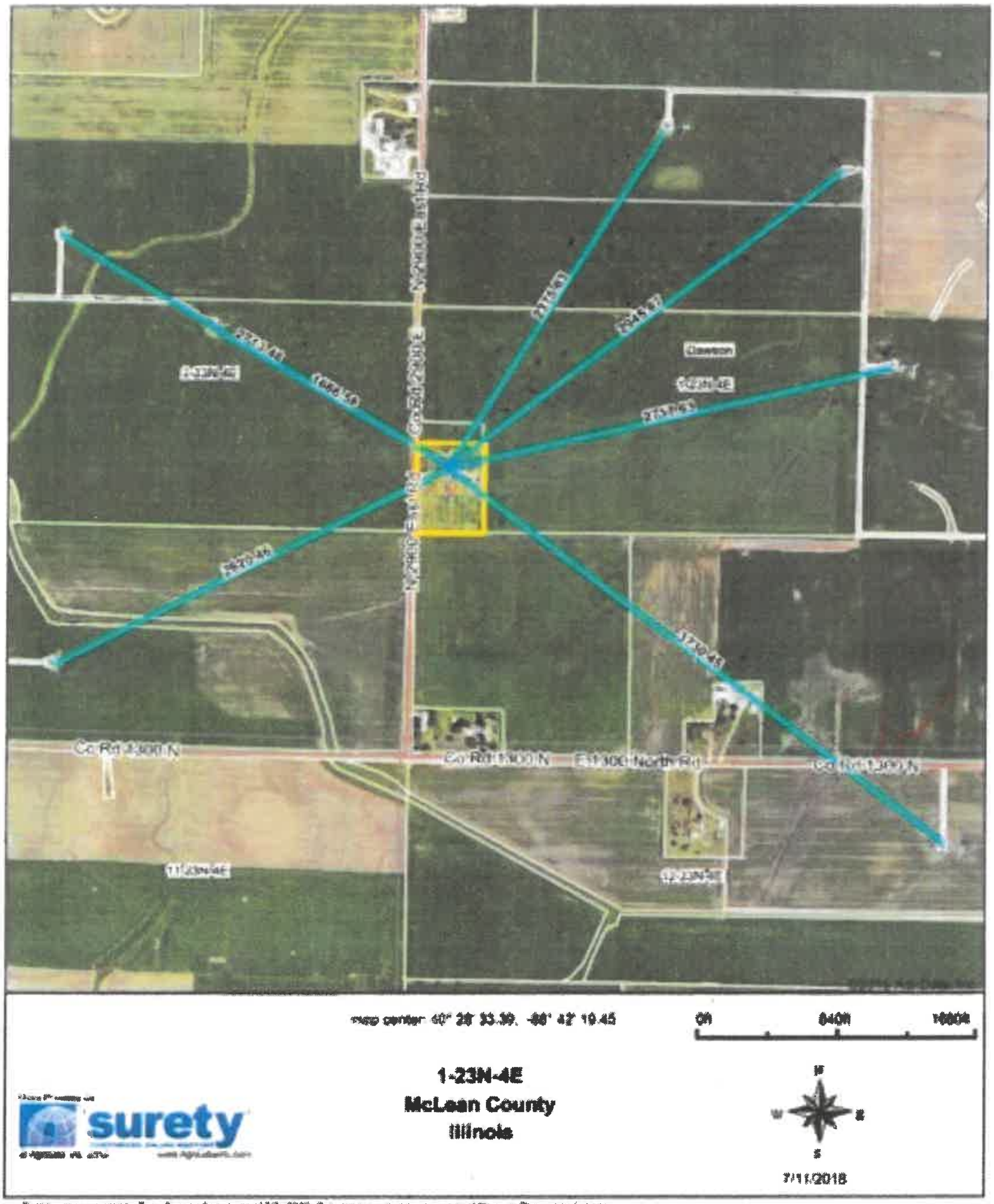
Land	Topography:	open: 98%		wooded: 2%	wetlands: 0%	FEMA/FIRM Floodplain: 0%	
Land	Terrain:	Level		Type of land use present in area:	Agricultural	Water Feature:	None
Land	Landscaping:	Average		Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes, stone landscaping improvements with flower beds		
Improvements	Style/story:	2 story		Exterior siding:	Brick/Wood	Year Built:	1920
Improvements	Construction Quality:	Average		Basement Type:	Full w/crawl space	FBLA (sf):	0
Improvements	# Garage Spaces:	2.5		Garage Type:	480sf detached	Driveway type:	Gravel
Improvements	Room Count:	N/A	4	2	Fireplace:	Wood burning stove	Porches/ Patios/Decks: 144sf deck, 180sf open porch
Improvements	Central Air:	Yes	Heating:	LP gas FHA	Road Frontage:	County road	
Improvements	# of Outbuildings:	3	Outbuilding Descriptions:	800sf shed, 2,720'sf barn & lean-to (barn-864sf/lean-to-864'sf), 1,560sf shed		Overall Condition:	Average

Additional Observations:	**Land:** The property has a level contour. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0575E, effective 07-16-2008. **Improvements:** Private well/septic system, fenced pastures with a double cross hotwired fence, newer roof, central air, furnace, wood burning stove, and windows, above ground pool. **Verification Comments:** Owner not present at the time of inspection, questionnaires returned unanswered. The closest wind turbine that is in the view from this property is approximately 1,666.58± to the northwest.
Site Inspected by:	James Marske — Date of Inspection: May 17, 2018

Figure 21: View of Wind Turbines across N 2900 East Road looking westerly from driveway entrance.

Figure 22: View of Wind Turbines looking easterly from the detached garage entrance at the eastern end of the property.

Proximity to closest Wind Turbines - 1,666.58 linear feet



SALE: Oldtown-IR-002

Sale Date	Sale Price
December 16, 2016	$207,000
Gross Living Area (sf)	**GLA Price per sf**
1,990	$104.02
Lot Size (acre)	**Lot Price per acre**
3.210	$64,486

Located at:	22792 E 1000 North Road
Municipality:	Old Town Township
County:	McLean, IL
Parcel No.:	22-23-400-006
Grantor:	Ronald & Rebecca Wheeler
Grantee:	Joseph J. & Karla S. T. Jenkins
Recording Doc:	2016-00024490
Document type:	Warranty Deed
Zoning:	A – Agriculture
Use:	Residential

Land	Topography:	open: 82%			wooded: 18%	wetlands: 0%	FEMA/FIRM Floodplain: 0%	
Land	Terrain:	Level			Type of land use present in area:	Rural Residential, Agricultural	Water Feature:	Drainage ditch
Land	Landscaping:	Average			Landscaping Observations:	Lawn, mature trees, shade trees; ornamental bushes		
Improvements	Style/story:	1.5 story			Exterior siding:	Vinyl	Year Built:	1884
Improvements	Construction Quality:	Average			Basement Type:	Full	FBLA (sf):	0
Improvements	# Garage Spaces:	1			Garage Type:	320sf detached	Driveway type:	Gravel and concrete
Improvements	Room Count:	N/A	3	3	Fireplace:	Wood burning stove	Porches/ Patios/Decks	120sf covered porch, 60sf covered porch, 204sf concrete patio
Improvements	Central Air:	Yes	Heating:		LP FHA / Road Frontage: County Road			
Improvements	# of Outbuildings:	2	Outbuilding Descriptions:		192sf shed, 1,800sf pole barn/garage		Overall Condition:	Average

Additional Observations:	**Land:** The property lies at 865ft to 875ft above sea level. The property lies in Flood Zone X, an area of minimal flood hazard, within FIRM Panel #17113C0550E, effective 07-16-2008. **Improvements:** Well/septic system, new roof, new hardwood floors, new foundation. **Verification Comments:** The buyer Joseph Jenkins, stated by questionnaire that he did know the seller as a family acquaintance, the sale price was fair, and that the sale price was negotiated down from the asking price.
Site Inspected by:	James Marske — Date of Inspection: May 17, 2018

Twin Groves II Wind Farm – Regression Analysis of Agricultural Vacant Land

Introduction

We completed a regression analysis study to isolate the impact that a wind farm has vacant agricultural property value located within and outside of the Twin Groves II wind farm. Since we had a high level of homogeneity of sales and an adequate number of sales, we were able to utilize the valuation methodology of multiple-regression analysis.

The Farm

The wind farm that was selected was the Twin Groves II wind farm located in McLean County, Illinois. This wind farm was selected due to its size, contemporary wind turbines and an adequate number of sales within the identified wind farm.

The details of the Twin Grove II wind farm are found in the chart below:

Name	Twin Groves II
Location	McLean County, Illinois, Townships of Arrowsmith, Cheney's Grove and Dawson.
Land area	11,000 acres (approximately half of the two wind farms Twin Groves I & II)
Date of operation	2008
Number of wind turbines	120 wind turbines
Type of wind turbines	Vestas V82 1.65 MW Wind Turbines *(picture on next page)*
Size in kW of wind turbines	1.65MW each x 120 turbines = 198MW
Hub height of wind turbines	80m (280ft±)
Diameter of Turbine	82.0m (269ft±)
Turbine height	Hub ht + ½ diameter of rotors = 80m + ½ (82m)= 121m (397ft±)
Maximum MW output	Approximately 198MW

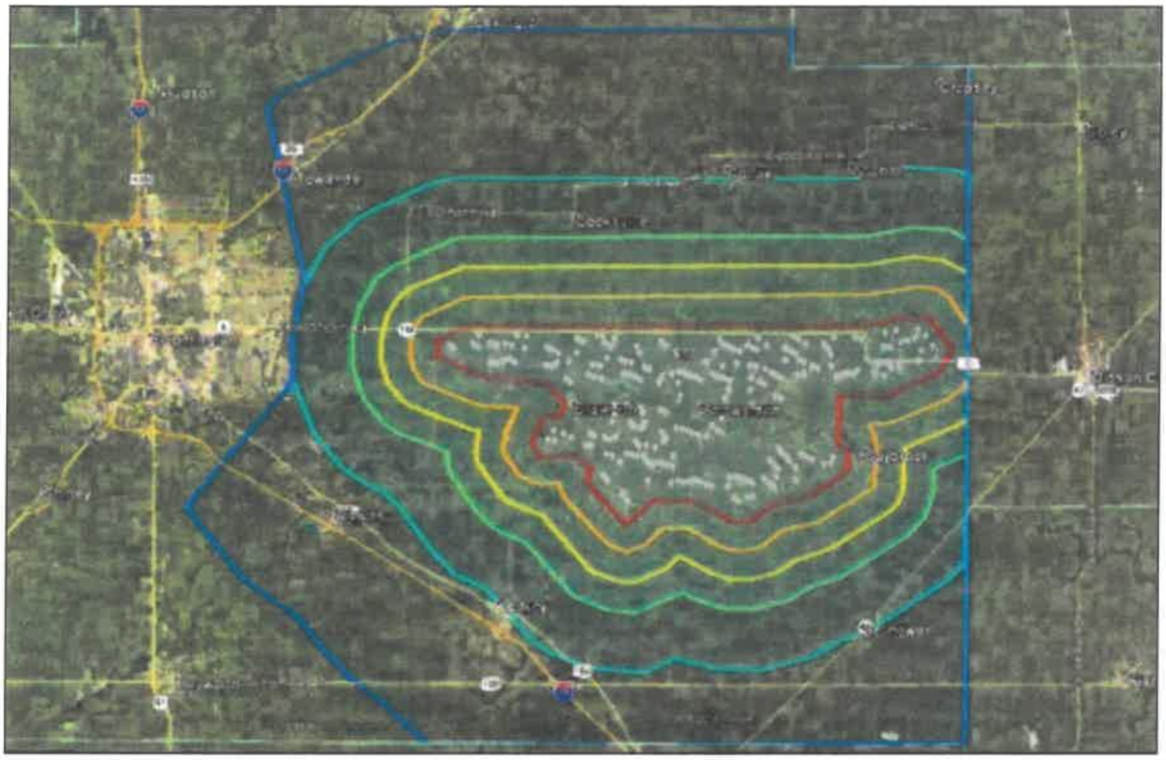


Figure 23: the red line outlines the wind farm Zone-0, orange line is Zone-1, yellow line is Zone-2, green line is Zone 3, light blue line is Zone 4 which has a two-mile width and the dark blue line is Zone 5 which has a five-mile width.

Scope of Work

The scope of work to complete this study included:

- Research, collect data and confirm information regarding the Twin Groves II wind farm.
- Locating the wind farm on Google Pro mapping software, locate all the wind turbines within the wind farm and create the wind farm zone and concentric 1-mile zones radiating out from the farm to locate comparable sales as indicated on the map *(see next page for working map)*.
- Research and collect sales of agricultural land sales within the wind farm, Zone 0.
- Research and collect sales of comparable agricultural land sales in Zones 1-5.
- Collect sales data, property data and assessor's data on all sales.
- Visit each sale on-site, take photographs, make field notes and try to confirm sale with the current property owner.
- Send confirmation requests to those sales not confirm in the field.
- Collect sales and support data from the McLean County Court House.
- Complete sales information data sheets.
- Income stream due to wind turbine lease payments of all sales located within the wind farm.

- The income stream was capitalized and then that amount was extracted from the sales price to leave the vacant land value which was then compared to comparable land sales outside of the wind farm.
- Contract the services of Jim Sanders (appraiser and statistician) with REAL LLC, Tucson, Arizona, to complete the regression analysis and write the summary of the analysis.

The Study

The study utilized a total of 38 agricultural land sales all located within and around the wind farm. Of the total sales, 8 sales were found within the wind farm and 30 were located outside of the wind farm in zones 1-5. The following variables were found and recorded for each sale:

1. Location of sale being either within or outside of the wind farm Zone 0.
2. Sale amount.
3. Date of sale.
4. Acres.
5. Productivity index of the land.
6. Ground cover.

All the sales were selected to have the highest level of comparability to the wind farm land sales. All sales had 100% open ground cover being all open cropland without any wooded areas. The variables of value then became the date of sale and productivity index of the soils.

Study Conclusion

The regression analysis extracted a -8.5% impact on the overall land value due to the presence of the wind farm. Therefore, it is projected that agricultural land located within the wind farm Zone 0 will experience an overall property loss of -8.5% net of the value generated by the wind turbine lease income stream.

Regression Analysis

Regression Analysis: AdjSP versus Productivity, XSDAC, ...

```
The regression equation is
AdjSP = 2949523 + 10135 Productivity + 10783 XSDAC - 101 Date of Sale - 843 ac zone
```

Predictor	Coef	SE Coef	T	P	VIF
Constant	2949523	2806081	1.05	0.301	
Productivity	10135	2206	4.59	0.000	1.085
XSDAC	10782.8	148.0	72.83	0.000	1.630
Date of Sale	-101.36	64.15	-1.58	0.124	1.048
ac zone	-843.0	162.3	-5.19	0.000	1.617

S = 65296.1   R-Sq = 99.6%   R-Sq(adj) = 99.5%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	4	3.31308E+13	8.28270E+12	1942.66	0.000
Residual Error	33	1.40698E+11	4263581461		
Total	37	3.32715E+13			

Durbin-Watson statistic = 1.97573

No evidence of lack of fit (P >= 0.1).

This is the XLOF test checking for lack of fit (LOF). This is a test to make sure there are no violations of linearity between the predicted variable of Adjsp and the predicted variables

Explanation of the Predictors

Adjsp: This is the adjusted sales price for those sales located within the wind farm zone that are receiving cash payments. This is the variable that is being predicted in the model. Thus, the sales prices of the farms are being predicted by the variables described below. Note that this model explains 99.5% of the variance in the mean sales price. This is essentially a perfect fit.

Constant: Since the regression analysis is actually multi-linear regression analysis, a straight-line function is estimated. A straight line function takes the form of $y = a + bx_i$, where "y" is the predicted variable, "a" is the constant which represents where the straight line crosses the x-axis in a Cartesian coordinate graph. The "b" represents the coefficients of the explanatory variables.

Productivity: This is a measure of the farm's soil quality stated as crop productivity index (CPI). The coefficient of 10135 means that for every integer increase in the productivity scale results in an increase, on average, of $10,135 to the sales price. The SE Coef means the standard error of the coefficient which is an indication of variance in this estimate. The "P" value for this coefficient is 0.000 which means a rejection of the null hypothesis that this variable does not impact sales price. To put into practical terms, one CPI unit equals 0.36% increase(decrease) in land value.

XSDAC: This is what is called an interaction variable between SD (sales date) and AC (the number of acres. This variable indicates that on average over time the size of the farms purchased increased. Again, the P value indicates a rejection of the null hypothesis.

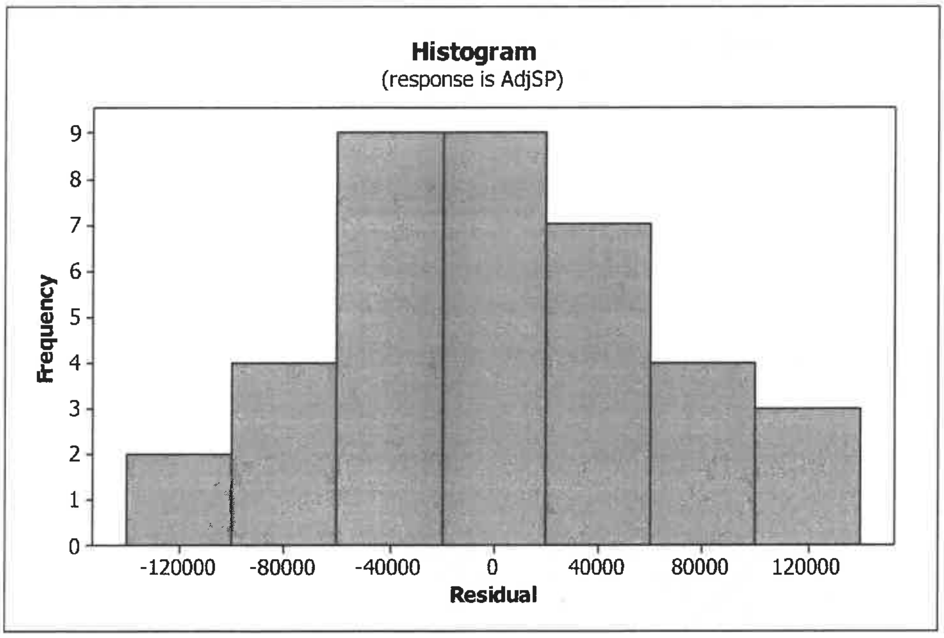
Date of Sale: This is the date of sale for each property. Each date is transformed into a number that is created by starting with the first day in January in year 0, assigning the number 1 and increases monotonically with each new day. The -101.36 the negative sign does not mean prices are going down over time because this a correcting adjustment term needed because sales date is part of the interaction variable above.

ac zone: This is the variable of interest. This is an interaction term of the number of acres interacting with only those sales located within the wind farm zone. Thus, the -$843.0 indicates a decrease in value of $843 per acre on average for the sales located within the wind farm zone. Using the median value of the non-windfarm properties (not adjusted for any variables) of $9,942 per acre, you have a -8.5% impact due to being within the wind farm.

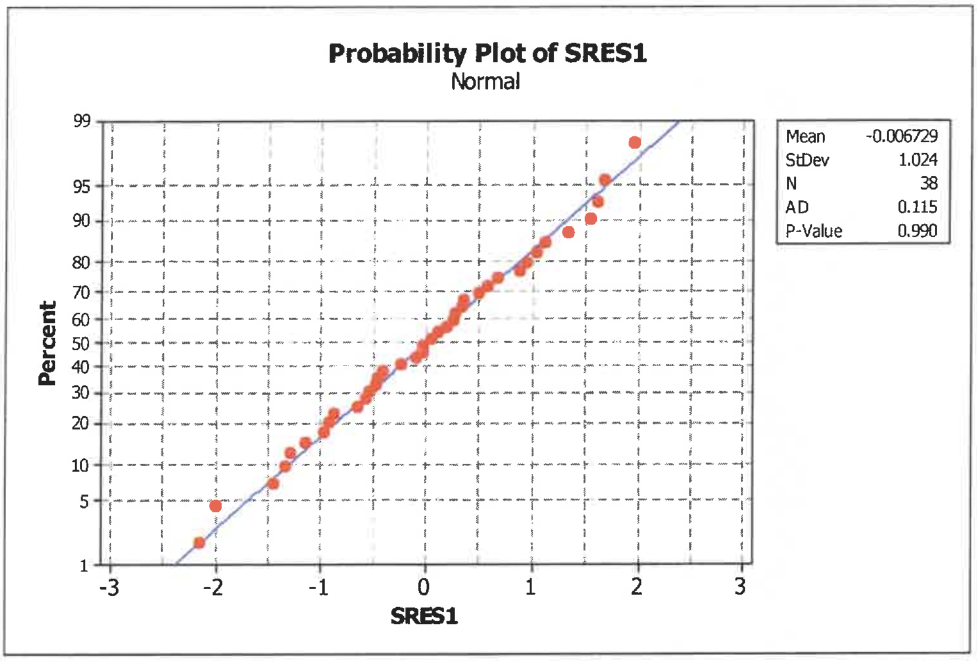
This model was checked to make sure there were no significant violations of the assumptions for regression analysis that are:

1. The regression model is linear in parameters. This means that the relationship between the predicted variable) adjusted sales price) has a linear or straight-line relationship with each predictor variable.
2. The mean of residuals is zero. This means the set actual sales prices for each farm less the model prediction of sales price in normally distributed. This is automatic by how the regression analysis is calculated, that is minimizing the square of this error over the model.
3. Homoscedasticity of residuals or equal variance. This means that the variance of the residuals does not show any patterns that either increases or decreases creating more or less error in the prediction of sales price over the range of each prediction variable. This was tested using the Anderson-Darling test indicating no issues with the distribution of the residuals.
4. No autocorrelation of residuals meaning that the terms in each prediction variable are not correlated with each other. This is tested above by the Durbin-Watson statistic where a score of 2.0 means absolutely no autocorrelation. A perfect score never happens with a real date.

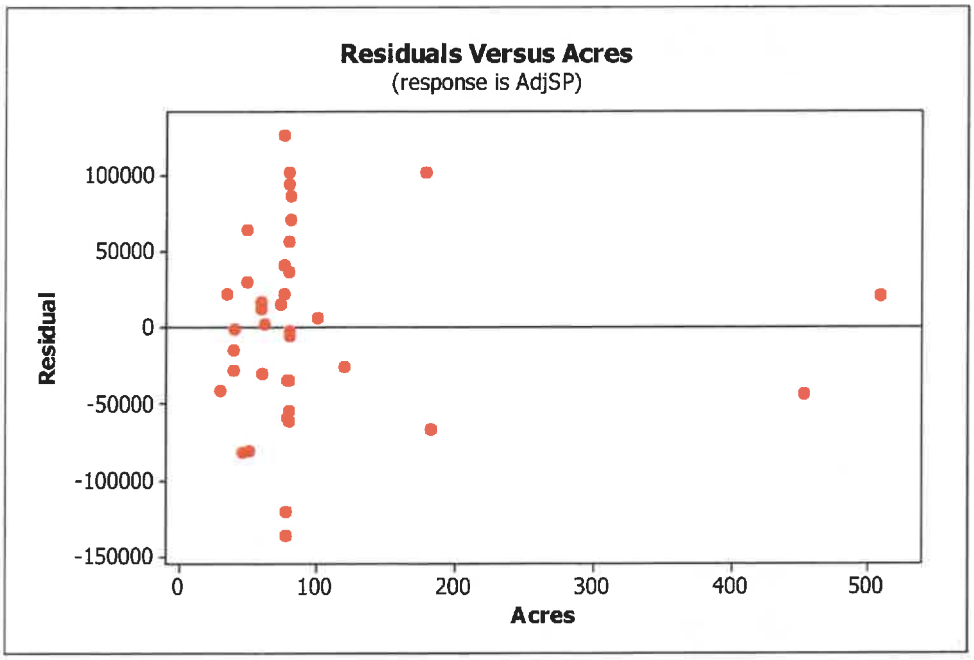
The following pages are some graphics examined looking for issues:



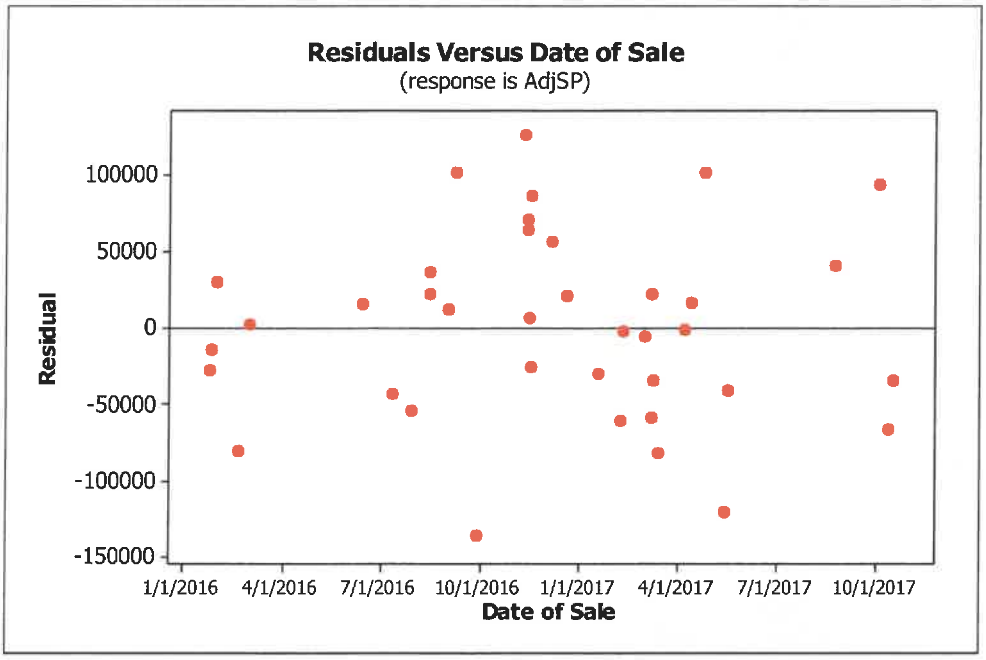
This chart shows a normal distribution of residuals.



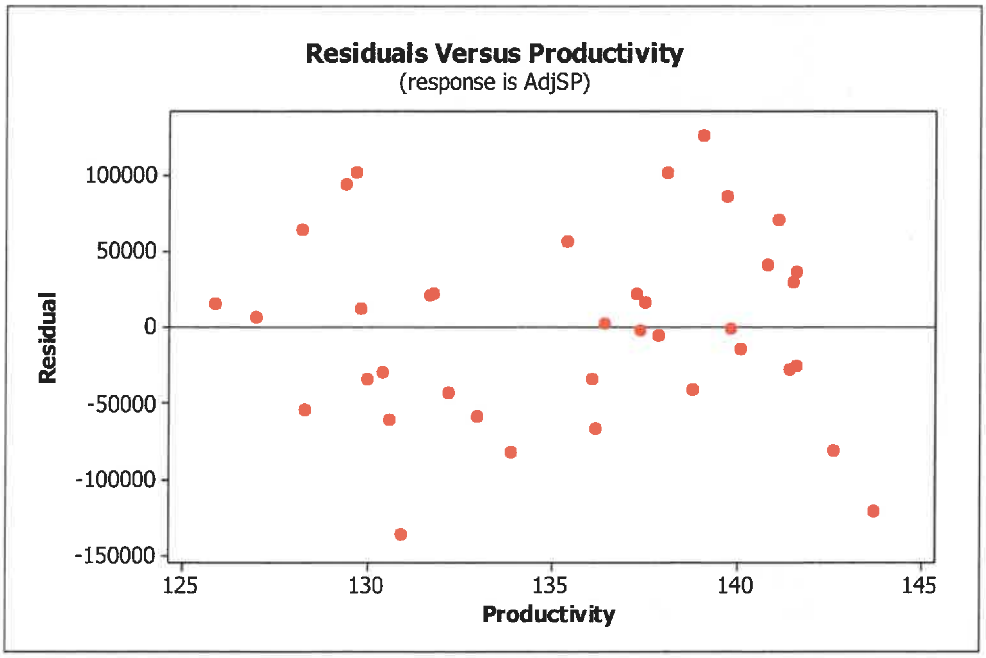
This shows the Anderson-Darling normal probability of the residuals test



This shows the residuals plotted against the number of acres in the dataset. I note that the data has two sales much larger than the rest of the data and two sales larger than the balance of the data. In this model, this is not an issue. In addition, the economics of farm sales and the numerous farm sale data examined over many cases typically show a linear relationship between price per acre and the number of acres where the acres vary functional obsolescence 20 to over 600.



This plot of residuals over time does not indicate any problems. However, it does show that more sales would be needed to have more points in the year 2016.



This last plot of residuals shows no issues.

The following section has the sales data that was used for this analysis.

LAND SALES DATA FOR TWIN GROVES II WIND FARM

Doc File #	Parcel #	Township	Date of Sale	Sold $	Acres	$/acre	Zone	Productivity	soil rating	grd cover	WF income	Wind Farm Income Details	PV	Adj $/acre
		Wind Farm												
2016-13825	24-28-300-002;	Arrowsmith	7/12/2016	$4,494,600	454.56	$9,888	0	132.2	good	100% open	yes	$6,200/year + 2% minimum annual increase, 3 total WT, 20.5yrs	($310,303)	$9,205.16
2017-19419	24-21-400-004	Arrowsmith	10/18/2017	$715,100	78.74	$9,082	0	130.0	good	100% open	yes	$6,200/year + 2% minimum annual increase, 1 total WT, 19.2yrs	($98,048)	$7,836.58
2017-20557;	24-04-300-002	Arrowsmith	10/4/2017	$752,032	80	$9,400	0	129.4	good	100% open	no			$9,400.40
2017-21007	24-32-100-002;	Arrowsmith	10/13/2017	$1,637,592	183.33	$8,932	0	136.2	excellent	100% open	no			$8,932.48
2017-6359	24-28-100-005	Arrowsmith	4/7/2017	$400,000	40	$10,000	0	139.8	excellent	100% open	no			$10,000.00
2017-6665	24-30-300-010	Arrowsmith	4/14/2017	$677,096	59.43	$11,393	0	137.5	excellent	100% open	yes	$6,200/year + 2% minimum annual increase, 1 total WT, 19.67yrs	($100,011)	$9,710.33
2017-7913	24-02-100-003;	Arrowsmith &	4/26/2017	$1,720,641	180.22	$9,547	0	129.7	good	100% open	no			$9,547.45
2016-17858	23-22-100-004;	Dawson	9/8/2016	$880,000	80	$11,000	0	138.1	excellent	100% open	no			$11,000.00
8														
		AVERAGE			144.535	$9,905	0	134.1					AVERAGE	$9,454
		MEDIAN			80	$9,718	0	134.2					MEDIAN	$9,474
		Non-Wind Farm												
2017-1983	18-24-300-005	Anchor	1/20/2017	$524,784	60.32	$8,700		130.4	good	100% open	no			$8,700
2016-24521	32-02-100-001;	Bellflower	12/20/2016	$5,204,448	510.24	$10,200		131.7	good	100% open	no	Outbuildings - Assessed value = $6,720.00	($6,700)	$10,187
2016-24580	32-18-100-002	Bellflower	12/7/2016	$868,000	80	$10,850		135.4	excellent	100% open	no			$10,850
2016-5078	39-12-176-002	Bellflower	3/2/2016	$664,020	62	$10,710		136.4	excellent	100% open	no	Railroad abuts property		$10,710
2017-9547	32-06-300-002	Bellflower	5/15/2017	$741,000	78	$9,500		143.7	excellent	100% open	no			$9,500
2017-9230	16-13-300-002	Blue Mound	5/18/2017	$277,500	30	$7,583		138.8	excellent	100% open	no			$9,250
2016-11882	11-22-400-007	Cropsey	6/15/2016	$680,000	73.62	$9,237		125.9	good	100% open	no			$9,237
2016-4313	23-20-100-002	Dawson	2/21/2016	$528,320	50.6	$10,441		142.6	excellent	100% open	no			$10,441
2016-19420	29-26-100-003	Downs	9/29/2016	$606,550	77.24	$7,853		130.9	good	100% open	no			$7,853
2017-16275	29-34-200-004	Downs	8/24/2017	$850,704	76.64	$11,100		140.8	excellent	100% open	no			$11,100
2017-4809	29-18-200-006	Downs	3/15/2017	$363,168	46.59	$7,795		133.9	excellent	100% open	no			$7,795
2016-24275	30-01-400-008	Empire	11/15/2016	$495,000	49.79	$9,942		128.2	good	100% open	no			$9,942
2016-14845	10-06-300-002	Lawndale	7/29/2016	$696,000	80	$8,700		128.3	good	100% open	no			$8,700
2016-23072	10-02-100-002	Lawndale	11/16/2016	$947,144	100.76	$9,400		127.0	good	100% open	no			$9,400
2017-4678	10-10-400-001	Lawndale	2/8/2017	$696,000	80	$8,700		130.6	good	100% open	no			$8,700
2016-17049	09-02-200-005	Lexington	9/2/2016	$570,000	60	$9,500		129.8	good	100% open	no			$9,500
2017-4700	09-15-100-001	Lexington	3/10/2017	$776,000	80	$9,700		136.1	excellent	100% open	no			$9,700
2017-5322	09-27-200-004	Lexington	3/9/2017	$715,644	79.54	$8,997		133.0	excellent	94% open	no			$8,997
2017-4596	17-33-100-005	Martin	3/9/2017	$750,275	76.17	$9,850		131.8	good	100% open	no			$9,850
2017-4830	17-14-200-006	Martin	3/2/2017	$824,515	80.05	$10,300		137.9	excellent	100% open	no			$10,300
2017-5115	17-24-400-001	Martin	2/10/2017	$824,000	80	$10,300		137.4	excellent	100% open	no			$10,300
2017-16635	08-30-400-002;	Money Creek	8/16/2016	$920,000	80	$11,500		141.6	excellent	100% open	no			$11,500
2016-16246	08-21-300-002	Money Creek	8/16/2016	$401,005	34.87	$11,500		137.3	excellent	100% open	no			$11,500
2016-4209	22-08-100-008;	Old Town	2/1/2016	$617,763	49.45	$12,493		141.5	excellent	100% open	no			$12,493
2016-22490	15-17-100-004;	Towanda	11/12/2016	$936,156	76.03	$12,313		139.1	excellent	100% open	no			$12,313
2016-22491	15-17-300-002;	Towanda	11/18/2016	$1,258,318	119.93	$10,492		141.6	excellent	100% open	no			$10,492
2016-22492	15-17-200-003	Towanda	11/18/2016	$952,141	80.97	$11,759		139.7	excellent	100% open	no			$11,759
2016-22493	15-17-100-005	Towanda	11/14/2016	$952,141	81.01	$11,753		141.1	excellent	100% open	no			$11,753
2016-2292	38-09-100-003	West	1/26/2016	$464,000	40	$11,600		141.4	excellent	100% open	no			$11,600
2016-2293	38-09-100-004	West	1/27/2016	$464,000	40	$11,600		140.1	excellent	100% open	no			$11,600
30														
		AVERAGE			84	$10,146		136					AVERAGE	$10,201
		MEDIAN			77	$10,250		137					MEDIAN	$10,243
												Difference before adjustments for time and soil quality		-7.32%

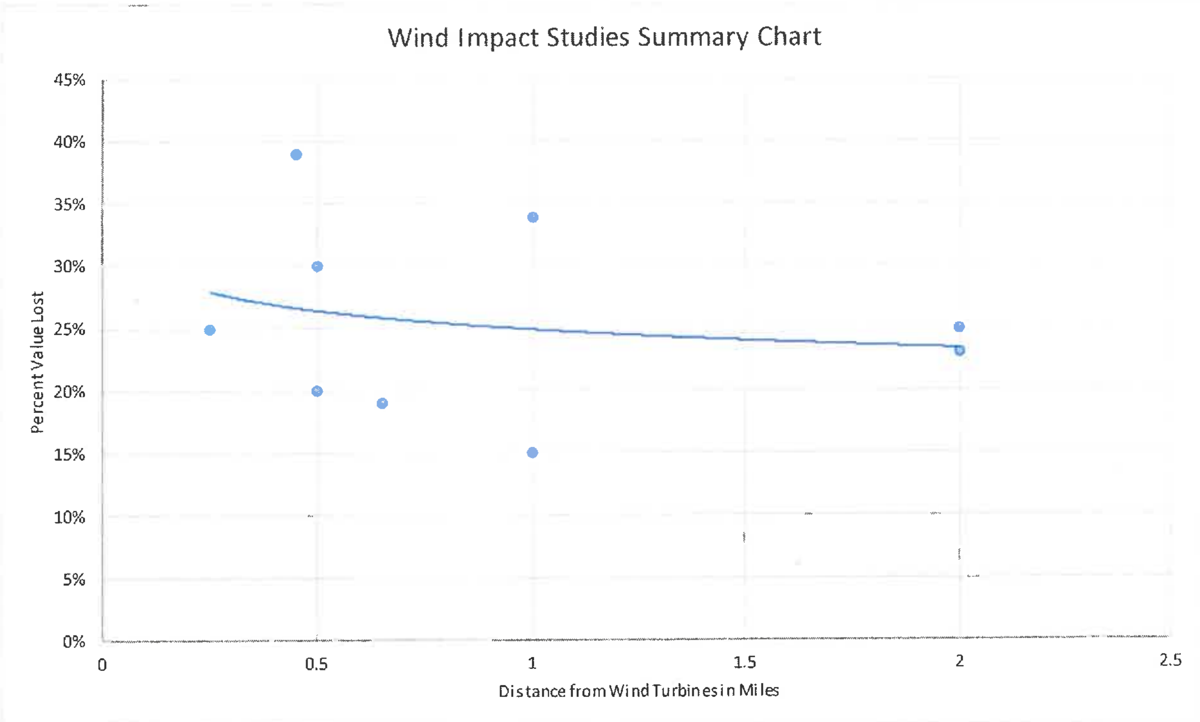
Niyol Wind LLC Property Impact Analysis

Analysis

The literature study answered the question of whether wind farms in proximity to residential homes and agricultural land negatively impact property value with an affirmative. Next, is estimating what that impact would be. To assist in that analysis we will chart out a summary of those studies and their respective impacts by distance from the wind turbines.

Summary of Wind Farm Impact Studies

study	distance from wind turbine in miles	negative impace to value
Twin Grove II	0.25	25%
Landsink	0.45	39%
AGO Wis	0.5	30%
Twin Grove II	0.5	20%
Big Sky	0.65	19%
Coral Springs	1	34%
Twin Grove II	1	15%
Clarkson University	2	23%
McCann	2	25%



From this chart and graph we have a better understanding on how the distance factor impacts property value. As expected, the closer the wind turbines are to the property the greater the impact.

It should be noted that in all of these studies the wind turbines in place were the older, smaller diameter and of lesser height that what is being proposed for the Niyol wind farm. The Niyol proposal has turbines being 495ft to 505ft in height. This is at least 25% greater in height and breadth than the study turbines. Therefore, it would be logical and reasonable to conclude that this size difference would cause the predictive impacts to be conservative. With that in consideration it would be reasonable to conclude the following impacts:

Properties Within the Wind Farm Footprint

The graph indicates that a -28% loss in value would be found from a distance of 1,500ft from a wind turbine. However, as we noted, those studies used smaller wind turbines. It is estimated that the proposed turbines are at least 25% greater in size. Though a direct correlation of size and impact has not been established, it would be reasonable to estimate the impact would increase by a factor of 1.25. Hence, we conclude the impact to be -35%.

Properties 1-Mile outside of the Wind Farm Footprint

The graph suggests that the impact would be less the further the distance from a wind turbine. The analysis indicates that at 2-mile distance from a turbine the impact would be -18%. Considering that the turbines were smaller in the studies it would be reasonable to increase this impact by a factor of 1.25 to conclude a -22% impact.

Agricultural Properties

Agricultural properties within the footprint, but not participating in the wind lease, will be have a -8.5% impact on property value.

Application to the Loss Estimate

Our client provided us with the residential properties located within the footprint of the Niyol wind farm and those located within 1-mile from the foot print for analysis. They are listed in the following charts along with their assessed value. We will apply the assessed value to the predicted loss to arrive at a total loss estimate due to the Niyol wind farm.

NIYOL WIND PROJECT					
AREA	SHEET	LAST NAME	ADDRESS	TOWN	ASSESSED VALUE
FOOTPRINT	2	NAB	37423 COUNTY ROAD 38	FLEMING	$110,610
FOOTPRINT	3	CHRISTOPHER	36705 COUNTY ROAD 36.5	FLEMING	$80,770
FOOTPRINT	4	BROWNELL	32600 US HIGHWAY 6	FLEMING	$93,200
FOOTPRINT	7	BOCK	34943 US HWY 6	FLEMING	$95,760
FOOTPRINT	7	BROWNELL	34403 COUNTY ROAD 34	FLEMING	$162,550
FOOTPRINT	7	LIND	35260 COUNTY ROAD 34	FLEMING	$2,510
FOOTPRINT	9	SALYARDS	15979 COUNTY ROAD 73	FLEMING	$224,030
FOOTPRINT	14	ETL	15083 COUNTY ROAD 71	FLEMING	$127,510
FOOTPRINT	14	HARRIS	35009 COUNTY ROAD 32	FLEMING	$61,180
FOOTPRINT	15	LARSON	36369 COUNTY ROAD 30	FLEMING	$144,190
FOOTPRINT	17	DONNELSON	12939 COUNTY ROAD 71	FLEMING	$161,700
FOOTPRINT	18	MCCRACKEN	13189 COUNTY ROAD 69	FLEMING	$251,150
FOOTPRINT	19	ABBOTT	32969 COUNTY ROAD 28	FLEMING	$66,040
FOOTPRINT	26	UNREIN	11751 COUNTY ROAD 71	FLEMING	$155,170
FOOTPRINT	27	PHIPPS	11150 COUNTY ROAD 67	FLEMING	no data
FOOTPRINT	28	HERICKS	32017 COUNTY ROAD 24	FLEMING	$70,390
FOOTPRINT	34	HICKERSON	10878 COUNTY ROAD 61	STERLING	$62,560
FOOTPRINT	35	KUNTZ	10257 COUNTY ROAD 63	STERLING	$97,170
FOOTPRINT	35	STEWARD	10814 COUNTY ROAD 63	STERLING	$221,360
FOOTPRINT	40	ALFLEN	9002 COUNTY ROAD 59	STERLING	$408,480
FOOTPRINT	40	NORELL	9127 HIGHWAY 61	STERLING	$140,640
FOOTPRINT	40	SCHNEIDER	9100 COUNTY ROAD 59	STERLING	$388,740
FOOTPRINT	40	WAITLEY	8963 HIGHWAY 61	STERLING	$58,550
FOOTPRINT	42	GERBITZ	28342 COUNTY ROAD 18	STERLING	$204,730
FOOTPRINT	42	VANHORN	8945 COUNTY ROD 59	STERLING	$60,200

FOOTPRINT	43	FRYE	28240 COUNTY ROAD 18	STERLING	$204,460
FOOTPRINT	45	SCHNEIDER	28486 COUNTY ROAD 16	STERLING	$58,820
FOOTPRINT	NONE	GLARDON	35510 HIGHWAY 6	FLEMING	$56,280
FOOTPRINT	NONE	MONROE	34745 COUNTY ROAD 26	FLEMING	$39,860
FOOTPRINT	NONE	PARKS	16061 COUNTY ROAD 73	FLEMING	$205,820
			Total Appraised Value of Properties within Footprint		$4,014,430
BORDER	3	KINZIE	17243 COUNTY ROAD 75	FLEMING	$145,340
BORDER	5	GERK	17249 COUNTY ROAD 69	FLEMING	$111,880
BORDER	15	STRINGHAM	13945 COUNTY ROAD 75	FLEMING	$98,650
BORDER	16	GABLE	12957 COUNTY ROAD 73	FLEMING	$126,900
BORDER	26	CANNON	35033 COUNTY ROAD 26	FLEMING	$48,820
BORDER	26	UNREIN	11149 COUNTY ROAD 71	FLEMING	$24,000
BORDER	27	HUTT	33051 COUNTY ROAD 24	FLEMING	$223,550
BORDER	35	GOOD	10991 COUNTY ROAD 65	STERLING	$198,110
BORDER	37	SCHMIDT	10301 COUNTY ROAD 69	FLEMING	$193,440
BORDER	46	DAVIDSON	6057 HIGHWAY 61	STERLING	$275,740
BORDER	48	FELZIEN & NORMAN	26765 COUNTY ROAD 12	STERLING	$139,190
BORDER	48	RINGLEIN	5462 COUNTY ROAD 55	STERLING	$258,060
BORDER		BAUDER	5245 COUNTY ROAD 63	STERLING	$166,550
BORDER		BOERNER	9198 COUNTY ROAD 71	FLEMING	$291,540
BORDER		CHAMP	36517 HIGHWAY 6	FLEMING	$165,770
BORDER		COAKLEY	10529 HIGHWAY 61	STERLING	$859,580
BORDER		CONYERS	37333 HIGHWAY 6	FLEMING	$28,690
BORDER		COOK	3917 County Road 65	STERLING	$404,770
BORDER		DAVIS	37773 HIGHWAY 6	FLEMING	$256,200
BORDER		DAY	34473 COUNTY ROAD 8	FLEMING	$59,480
BORDER		DOBBINS	35501 COUNTY ROAD 24	FLEMING	$48,020
BORDER		FISCUS	25867 COUNTY ROAD 12	STERLING	$136,580

BORDER		FRANTZ	14385 COUNTY ROAD 77	FLEMING	no data
BORDER		HERSKIND & WORKMAN	2721 COUNTY ROAD 73	FLEMING	$145,440
BORDER		JAPP	36400 COUNTY ROAD 22	FLEMING	$111,880
BORDER		LOUSBERG	10235 COUNTY ROAD 79	FLEMING	$474,670
BORDER		MARSHALL	13313 COUNTY ROAD 75	FLEMING	$241,890
BORDER		MUNSON	12340 COUNTY ROAD 71	FLEMING	$123,990
BORDER		PALSER	41924 COUNTY ROAD 41	OTIS	??
BORDER		RAY	16413 COUNTY ROAD 75	FLEMING	$137,560
BORDER		SERRATO	37299 HIGHWAY 6	FLEMING	$154,570
BORDER		SCHMIDT	9571 COUNTY ROAD 71	FLEMING	$438,920
BORDER		SMITH	4296 COUNTY ROAD 53	STERLING	$96,300
BORDER		SONNENBERG	27189 COUNTY ROAD 24	STERLING	$260,660
BORDER		SWINDELL	5083 HIGHWAY 61	STERLING	$168,740
BORDER		UNREIN	9501 COUNTY ROAD 69	FLEMING	$82,870
BORDER		VANDENBARK	14450 COUNTY ROAD 75	FLEMING	$250,240
BORDER		VANDENBARK	COUNTY ROAD 75	FLEMING	$370
			Total assessed value of Border Homes		$6,948,960

BORDER are homes located 1-mile outside of footprint

Applying the assessed values to the estimated impacts we have the following conclusions:

Niyol Wind Farm Loss to Property Value Estimate			
	total assessed value	impact	value loss
Properties within the Footprint	$4,014,430	-35%	-$1,405,051
Properties 1-mile outside of the Footprint	$6,948,960	-22%	-$1,528,771
Total			**-$2,933,822**

Addendum

Curriculum Vitae of Kurt C. Kielisch

Work Experience

As of January 2020, I have 36 years of experience in the appraisal field. During this tenure I have completed over 8,100 valuations totaling $13.1+ billion dollars.

As a practitioner, I entered the appraisal industry in 1984 employed by ValuPruf Valuation Service, Milwaukee, Wisconsin. Appraisal assignments through the years have included the following: single-family residential, multi-family residential, dairy farms, crop farms, horse ranches, cattle ranches, commercial properties, special use properties, tax assessment, ocean-front properties and islands, stigmatized properties, eminent domain, utility easements, valuation consulting, litigation support work and impact studies. I have provided appraisal services for properties located in Alaska, Colorado, Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Mexico, North Dakota, Ohio, Pennsylvania, South Dakota, South Carolina, Virginia, Wisconsin, and Wyoming.

As a communicator, I have authored the book: *The Listing Appraisal Program* (ATI press, 1996) and three magazine articles: *Dead Body Appraisers* (The Appraisal Buzz, October 3, 2002), *Expert Testimony and Reports: Is Change Good?* (Working R.E. Magazine, February 2002), and *Rails to Trails Property Rights* (Right of Way Magazine, Nov/Dec 2012). I have been engaged in valuation related research projects on the impacts of high voltage transmission lines, natural gas pipelines, oil pipelines, wind farms and solar farms on property value. Related to the impact on property value of utility projects, wind and solar farms, I have given testimony before the Wisconsin Senate Committee, Wisconsin Public Service Commission, Wisconsin Wind Farm Siting Council, Illinois Wind Farm Siting Councils, Missouri Public Service Commission and the Wyoming Industrial Committee. Our research has been utilized by other appraisers, experts and property owners when arguing before government committees, public service counsels, courts and in reports.

As an expert witness, I have been an approved expert in Wisconsin, Kansas, North Dakota, South Dakota and Virginia state courts, commissioner hearings in Wisconsin and Minnesota, mediation in Indiana and Illinois, and Federal Courts in Wisconsin, Kansas and Ohio. In the Wisconsin Supreme Court case of Spiegelberg vs. State of Wisconsin DOT (2004AP3384), I was the principle appraiser for Ms. Spiegelberg. This hearing resulted in a majority decision in favor of my client making a landmark decision relating to the proper valuation methodology when appraising property involved in eminent domain to obtain just compensation. In the Wisconsin Supreme Court decision of Waller vs. American Transmission Corporation, LLC (2012AP805 & 2012AP840) the high court overwhelming found in favor of my client and made a landmark decision involving relocation rights and an uneconomic remnant. I was the principle appraiser and expert witness for the Wallers.

As an educator, I taught appraisal pre-licensing and continuing education courses throughout a multi-state area from 1994 to 2000. During this time, I authored course curriculum for seven pre-licensing courses and twelve continuing education courses as well as the creation of a two-year professional appraiser training program. Since 2000, I have given presentations for professional continuing education (IRWA – Badger Chapter, The American Law Institute and CLE Annual Eminent Domain Conferences (2013, 2014, 2016), IRWA Annual Conference (2013) and for general information at many public meetings.

Academics

M.A. Education. Regent University, Virginia Beach, Virginia. This degree concentrated on the adult learner and state-of-the-art communication technology to enhance learning. The focus was on the adult learner.

B.A. Business Administration (Economics Minor). Lakeland College, Sheboygan, Wisconsin.

B.A. Biology (Natural Sciences Minor). Silver Lake College, Manitowoc, Wisconsin.

Certifications/Designations/Organizations

Certified General Real Property Appraiser State of Illinois. License #553.002453 (Expires 9/30/2021)
Certified General Real Property Appraiser State on Indiana. License #CG41500059 (Expires 6/30/2020)
Certified General Real Property Appraiser State of Nebraska. License #CG2020016R (Expires 12/31/20)
Certified General Appraiser State of South Dakota. License #1443CG (Expires 9/30/2020).
Certified General Appraiser State Pennsylvania. License #GA004389 (Expires 6/30/2021).
Certified General Appraiser State of Virginia. License #016559 (Expires 3/31/2021).
Certified General Appraiser State of Wisconsin. License #1097-010 (Expires 12/14/2021).
Temporary Certified General Licenses. Colorado, Illinois, Indiana, Iowa, Kansas, Nebraska, New Mexico, Mississippi, Missouri, Ohio, and Wyoming.
Past Certified General Appraisal Licenses. Iowa, Kansas, Michigan, Minnesota, North Dakota, Ohio, and Wyoming.
ASA (real property) Urban Designated Member. American Society of Appraisers (ASA).
SR/WA (Senior Member) Designated Member. International Right-of-Way Association.
R/W-AC (Appraisal Certified Member) Designated Member. International Right-of-Way Association.
IFAS (Senior Member) Designated Member (designation now retired). National Association of Independent Fee Appraisers (now merged with the ASA).
Review Appraiser (past). Department of Regulation and Licensing, State of Wisconsin (contract position).
Associate Member. Appraisal Institute (AI).
Approved Contract Appraiser. Wisconsin Department of Natural Resources (DNR).
REALTOR member. Realtors Association of Northeast Wisconsin and National Association of Realtors.
Approved R.E. Appraisal Instructor (past). Virginia, Maryland, Indiana, Illinois, Minnesota, and Wisconsin.
Assistant Editor. ASA-Real Property quarterly newsletter (2012-2014).
Faculty. Eminent Domain and Land Valuation Litigation, The American Law Institute – CLE: Miami Beach, FL (January 2013) and New Orleans, LA (January 2014). Eminent Domain Impact of Political & Economic Forces, Eminent Domain Institute CLE International (September 2013), Cleveland, Ohio. Eminent Domain: Current & Emerging Issues, Eminent Domain Institute-CLE International (September 2016), Las Vegas, NV.
Seminar Instructor. International Right-of-Way Annual Conference (2013), Charleston, West Virginia (topic Valuation of Rails to Trails Corridors); International Right-of-Way Appraisal Day Seminar (May 13, 2014) Ohio IRWA Chapter 13 (topic Valuation of Utility Corridors).

Appraisal/Real Estate Courses (29 courses, 572hrs)

Fundamentals of Real Property Appraisal (40hrs). IAAO, University of Virginia, Charlottesville, VA.
Income Approach to Valuation (40hrs). IAAO. University of Virginia, Charlottesville, VA.
Real Estate Appraisal (45hrs). Alpha College of Real Estate [Instructor].
Uniform Standards of Professional Appraisal Practice (15hrs). Alpha College of Real Estate [Instructor].
Appraising the Small Income Residential Property (15hrs). Alpha College of Real Estate [Instructor].
Advanced Income Appraisal I (30hrs). Alpha College of Real Estate [Instructor].
Advanced Income Appraisal II (30hrs). Alpha College of Real Estate [Instructor].
Residential Construction, Design & Systems (20hrs). Appraisal Training Institute [Instructor].

Residential Cost Approach & Depreciation Methods (20hrs). Appraisal Training Institute [Instructor].
Residential Market Approach & Extraction Methods (20hrs). Appraisal Training Institute [Instructor].
Computer Applications in Appraisal Report Writing (15hrs). Appraisal Training Institute [Instructor].
Completing the URAR in Compliance with FNMA Guidelines (15hrs). Appraisal Training Institute [Instructor].
The Residential Appraisal Process (20hrs). Appraisal Training Institute [Instructor].
Residential Appraisal Practicum (40hrs). Appraisal Training Institute [Instructor].
Pipeline ROW Agent's Development Program: Course 215 (16hrs). International Right-of-Way Association.
Eminent Domain Law Basics for Right-of-Way Professionals: Course 803 (16hrs). International Right-of-Way.
Financial Analysis of Income Properties (16hrs). National Association of Independent Fee Appraisers (NAIFA).
Appraisal of Partial Acquisition: Course 401 (40hrs). International Right-of-Way Association.
National Uniform Standards of Professional Appraisal Practice (USPAP): Course 2005 (15hrs). NAIFA.
Easement Valuation: Course 403 (8hrs). International Right-of-Way Association.
Principles of Real Estate Negotiation: Course 200 (16hrs). International Right-of-Way Association.
Bargaining Negotiations: Course 205 (16hrs). International Right-of-Way Association.
Principles of Real Estate Appraisal: Course 400 (exam). International Right-of-Way Association.
Principles of Real Estate Law: Course 800 (exam). International Right-of-Way Association.
Principles of Real Estate Engineering: Course 900 (exam). International Right-of-Way Association.
SR/WA Comprehensive Exam: International Right-of-Way Association.
Course 420: Business Practices & Ethics (8hrs). Appraisal Institute.
United States Land Titles (16hrs). International Right-of-Way Association.
Quantitative Analysis (40hrs). Appraisal Institute.

Appraisal/Real Estate Seminars (59 courses, 304.9hrs)

Real Estate Taxation (7hrs). University of Wisconsin: Continuing Education Division.
Review Appraising as the Supervising Appraiser (3hrs). Appraisal Training Institute [Instructor].
Legal Ramifications of Environmental Laws (3hrs). International Association of Assessing Officers (IAAO).
Virginia State Mandatory Continuing Education (4hrs). Appraisal Training Institute [Instructor].
Appraising the Small Income Property (8hrs). Appraisal Training Institute [Instructor].
Listing Appraisals (7hrs). Appraisal Training Institute [Instructor].
Marshall & Swift Residential Cost Approach: Sq. Ft. Method, (7hrs). Western Illinois University [Instructor].
Marshall & Swift Residential Cost Approach: Segregated Method, (7hrs). Western Illinois University [instars].
Residential Construction, Design and Systems (7hrs). Appraisal Training Institute [Instructor].
EMF and Its Impact on Real Estate (4hrs). Appraisal Training Institute [Instructor].
Easements and Their Effect on Real Estate Value (7hrs). Appraisal Training Institute [Instructor].
Exploratory Data Analysis: A Practical Guide for Appraisers (3hrs). Appraisal Institute.
Residential Statistical Modeling (3hrs). Appraisal Institute.
Valuation Modeling: A Case Study (3hrs). Appraisal Institute.
Real Estate Valuation Cycles (3hrs). Appraisal Institute.
Subdivision Analysis (3hrs). Appraisal Institute.
Appraisal of Nursing Facilities (7hrs). Appraisal Institute.
National Standards of Professional Appraisal Practice: Course 400 (7hrs). Appraisal Institute.
Land Valuation Adjustment Procedures (7hrs). Appraisal Institute.
Valuation of Detrimental Conditions in Real Estate (7hrs). Appraisal Institute.
Appraising Conservation Easements (7hrs). Gathering Waters Conservancy.
ROW Acquisition in an Environment of Power Demand Growth & Legislative Mandates (12hrs). IRWA - Minnesota.
Analyzing Distressed Real Estate (4hrs). Appraisal Institute.
7 Hour National USPAP Course for 2008-2009 (7hrs). International Right-of-Way Association.
6th Annual Condemnation Appraisal Symposium (6hrs). Appraisal Institute.
Contemporary Issues in Condemnation Appraisal (4hrs). Appraisal Institute.
7-Hour National USPAP course for 2010 (7hrs). International Right-of-Way Association.

Real Estate Finance Statistics and Valuation Modeling (14hrs). Appraisal Institute.
Michigan Law Update (2hrs): McKissock.
Local Public Agency Real Estate Seminar 2010 (6hrs). Wisconsin Department of Transportation.
8th Annual Condemnation Appraisal Symposium (6hrs). Appraisal Institute.
Golf & Hotel Valuation (3.4hrs). International Right-of-Way Association.
7-Hour National USPAP course for 2012 (7hrs). International Right-of-Way Association.
Statistics, Modeling, and Finance (14hrs). McKissock.
Eminent Domain Issues in the Pipeline Industry: IRWA 2013 Conference (1.5hrs).
Pipelines: Abandoned vs. Idle/Consequences of Not Maintaining Your Easements or ROW. IRWA 2013 Conference (1.5hrs).
The Right of Reversion, "Who's on First." IRWA 2013 Conference (1.5hrs).
Ad Valorem Tax Consultation (2hrs). McKissock.
Appraisal Applications of Regression Analysis (7hrs). McKissock.
Valuation of Avigation Easements (3hrs). ASA Wisconsin Chapter (Instructor)
11th Annual Condemnation Symposium. Appraisal Institute – Wisconsin Chapter. (6hrs)
7-Hour National USPAP course for 2014-2015 (7hrs). Appraisal Institute
Uniform Standards for Federal Land Acquisitions – Appraisal Institute – Florida Chapter (16hrs)
A Review of Disciplinary Cases: How to Avoid a Visit with the Licensing Board (3hrs), McKissock.
Eminent Domain Current & Emerging Issues- Eminent Domain Institute (2016), CLE International – Las Vegas (12hrs)
13th Annual Condemnation Symposium. Appraisal Institute – Wisconsin Chapter. (6hrs)
Marcellus Shale: Effects of Energy Resource Operations on Residential Property Value (3hrs). McKissock.
7-Hour National USPAP course for 2016-2017 (7hrs). McKissock.
IRWA Aviation Easements Seminar (2hrs). International Right-of-Way Association.
Review of Disciplinary Cases (3hrs). McKissock.
The Dirty Dozen (3hrs). McKissock
Attacking & Defending While Staying out of Trouble (2hrs). American Society of Appraisers.
Introduction to Expert Witness Testimony for Appraisers (4hrs). McKissock.
Pennsylvania State Mandated Law for Appraisers (2hrs). State Board of Certified Real Estate Appraisers.
15th Annual Condemnation Symposium. Appraisal Institute – Wisconsin Chapter. (6hrs)
Evaluations, Desktops and other Limited Scope Appraisals (4hrs). McKissock.
7-Hour National USPAP course for 2018-2019 (7hrs). McKissock.
16th Annual Condemnation Symposium. Appraisal Institute – Wisconsin Chapter. (6hrs)
REALTOR Code of Ethics (0hrs). The National Association of Realtors.

EXPLANATION OF DESIGNATIONS

ASA-Urban Real Property: The ASA designation is the senior designation granted by the American Society of Appraisers, which is the only multi-discipline international appraisal association in America. The ASA-Urban designation requires the passing of five advanced level commercial appraisal courses, the passing of a comprehensive exam, a passing grade on a demonstration narrative report, 5 years full-time appraisal experience, a Certified General appraisal license and the recommendation of the local and national membership committee. All ASA designated members must adhere to the Code of Ethics of the Association and keep up-to-date with continuing education (Source: www.appraisers.org).

IFAS (now retired): For this senior level designation from the International Fee Appraisal Association the appraiser must meet the requirements for the Member [IFA], successfully pass the Senior Member Examination, score a passing grade on a narrative demonstration report on an income-producing property conforming to prescribed guidelines and meet educational and experience requirements as outlined by the Association. In addition, the designation requires a minimum of 4 years appraisal experience in commercial type properties, a State Certified General Appraisal license, successful completion of over 200-hours of appraisal course work, completion of the current USPAP course, a college degree and the recommendation of the appraiser's peers and local chapter (Source: www.naifa.com). All IFAS members must adhere to the Code of Ethics of the Association and keep up-to-date with continuing education.

Senior Right of Way (SR/WA): This is the most prestigious professional designation granted by the International Right-of-Way Association to members who have achieved professional status through experience, education, and examination. The SR/WA designation requires training and examination in seven major right-of-way disciplines. The SR/WA designation says, "I have more than five years of right-of-way experience, plus I have had formal training in a wide variety of right-of-way areas." The SR/WA professional may be a specialist in one area such as appraisal, engineering, or law, but also must be familiar with the other seven disciplines associated with the right-of-way profession. Additional requirements for the SR/WA designation include: a bachelor's degree, 5 years right-of-way experience, successful completion of four core courses and four elective courses, passing the all-day comprehensive exam and recommendation from the designee's peers and local chapter. The SR/WA designation is the only designation reflecting evidence of professional attainment in the right-of-way field (Source: www.irwaonline.org). All SR/WA members must adhere to the Code of Ethics of the Association and keep up-to-date with continuing education.

Right of Way Appraisal Certified (R/W-AC): The Right of Way (R/W) Certification is an esteemed professional designation granted to members who have achieved professional status through experience, education, and examination in a specific discipline. Earning this certification demonstrates an unparalleled achievement in a single discipline and reinforces a standard of excellence in services provided to the public (Source: www.irwaonline.org). All R/W-AC members must adhere to the Code of Ethics of the Association and keep up-to-date with continuing education.

Appraiser's Certification

I certify that to the best of my knowledge and belief:

- The statements of fact contained in this report are true and correct.

- The reported analyses, opinions, and conclusions are limited only by the reported assumptions and limiting conditions and are my personal, impartial and unbiased professional analyses, opinions, and conclusions.

- I have no present or prospective interests in the property that is the subject of this report and no personal interest with respect to the parties involved.

- I have no bias with respect to the property that is the subject of this report or to the parties involved with this assignment.

- My engagement in this assignment was not contingent upon developing or reporting predetermined results.

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

- My analyses, opinions, and conclusions were developed, and this report has been prepared, in conformity with the Uniform Standards of Professional Appraisal Practice.

- I have made a personal inspection of the property that is the subject of this report.

- No one provided significant real property appraisal assistance other than staff members employed by Forensic Appraisal Group for research and comparable sales confirmation. That individual was Appraisal data technician, Stacy Martin, and staff appraiser James D. Marske.

Signed on June 12, 2020.

Kurt C. Kielisch, ASA, SR/WA, R/W-AC
President/Senior Appraiser

Property value ·
small sample
500ft turbines
11% decline w/in 1 mile

PNAS

RESEARCH ARTICLE | ENVIRONMENTAL SCIENCES

The visual effect of wind turbines on property values diminishing in space and time

Wei Guo[a,b], Leonie Wenz[c,d], and Maximilian Auffhammer[e,f,1]

Edited by Geoffrey Heal, Columbia University, New York, NY; received June 3, 2023; accepted January 10, 2024

Renewable power generation is the key to decarbonizing the electricity system. Wind power is the fastest-growing renewable source of electricity in the United States. However, expanding wind capacity often faces local opposition, partly due to a perceived visual disamenity from large wind turbines. Here, we provide a US-wide assessment of the externality costs of wind power generation through the visibility impact on property values. To this end, we create a database on wind turbine visibility, combining information on the site and height of each utility-scale turbine having fed power into the U.S. grid, with a high-resolution elevation map to account for the underlying topography of the landscape. Building on hedonic valuation theory, we statistically estimate the impact of wind turbine visibility on home values, informed by data from the majority of home sales in the United States since 1997. We find that on average, wind turbine visibility negatively affects home values in an economically and statistically significant way in close proximity (<5 miles/8 km). However, the effect diminishes over time and in distance and is indistinguishable from zero for larger distances and toward the end of our sample.

renewable energy | economic valuation | statistical analysis | climate change mitigation

Investment in renewable power generation capacity has gained significant momentum in the United States and globally in recent years (1). This is driven by massive drops in the cost of wind and solar and by concerns over the negative local and global externalities stemming from a fossil fuel–based energy system. While renewable technologies address the issue of pollution externalities, their rollout poses different challenges (e.g., intermittency) (2, 3). Wind power is the fastest-growing source of renewable electricity in the United States. In 2020, wind power accounted for more than 7% of total electricity generation, and it is projected to continue to grow in the coming years (4).

Wind turbines, in particular, have also been a source of controversy as they may create low-frequency noise, cast shadows, create flickering, and visually degrade the landscape (5–8). Understanding the visual disamenity value of wind turbines is becoming increasingly policy relevant as already large wind turbines are growing in height and are often located on high-elevation areas with extensive visibility (9, 10). They are widely perceived as unattractive and disruptive to the landscape, with some polls suggesting that 8 to 25% of respondents strongly dislike seeing wind turbines (11, 12). Homeowners and developers may be negatively affected by the proximity of wind turbines through depressed home values (13–15). These "NIMBY" (Not In My BackYard) concerns, which in many places have manifested in vocal local public opposition to new projects, can have an impact on the siting decision of wind power infrastructure (16–18).

This paper presents a comprehensive national-level analysis to causally estimate the visual externality costs of wind power generating capacity in the United States. We utilize the universe of re-geocoded home transactions listed in the ZTRAX database for the years 1997 to 2020 and match these to the installation of wind turbines nearby (Fig. 1).

We rely on the broadly applied theory of hedonic valuation to reveal local residents' preferences for views of wind turbines (19, 20). Previous studies have either focused on wind facilities outside of cities in Europe or on selected areas across the United States, making their results difficult to generalize to the entire USA (18, 21–27). Further, unlike previous studies, we do not only consider mere proximity of a wind turbine to a home, but compute whether a wind turbine can actually be seen from each home (visibility). To this end, we combine digital elevation models of the landscape with the location and height information of turbines, utilizing advanced geospatial tools from geomorphometry and computer science (28–30). We can thus create a geospatial database on wind turbine visibility, comprising a high-resolution viewshed for every single wind facility in the USA (see *Data & Methods* for detail). This database allows us to characterize whether and

Significance

A substantial expansion of renewable energy generation is necessary for decarbonizing the U.S. economy. Wind power is the fastest-growing renewable source of electricity in the United States. It has been argued that wind turbines are a visual disamenity. We statistically estimate the impact of having at least one wind turbine within sight on home values, using data from more than 300 million home sales and 60,000 wind turbines in the United States from 1997 to 2020. We find robust evidence of a 1% drop of home values within a wind turbine's viewshed. The effect is larger for homes closer to more wind turbines, but is no longer detectable by the end of the 20-y period covered by our data.

Author affiliations: [a]CMCC Foundation - Euro-Mediterranean Center on Climate Change, Leece 73100, Italy; [b]RFF-CMCC European Institute on Economics and the Environment, Centro Euro-Mediterraneo sui Cambiamenti Climatici, Milan 20144, Italy; [c]Department of Complexity Science, Potsdam Institute for Climate Impact Research, Potsdam 14412, Germany; [d]Mercator Research Institute on Global Commons and Climate Change, Berlin 10829, Germany; [e]Department of Agricultural and Resource Economics, University of California, Berkeley, CA 94720; and [f]National Bureau of Economic Research, Cambridge, MA 02138-5398

Author contributions: M.A. developed the research concept; W.G., L.W., and M.A. designed the study; W.G. analyzed data; M.A., L.W., and W.G. edited the paper; and W.G. wrote the paper.

The authors declare no competing interest.

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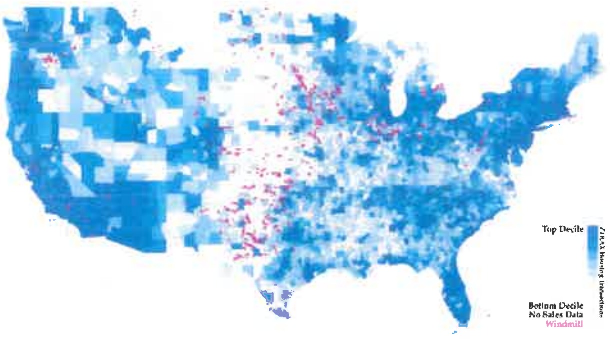

Fig. 1. Map of property transactions and wind turbine locations. Blue shading indicates the number of property transactions between 1990 and 2020 by decile, aggregated to the county level. Areas without sales data are white. Magenta dots show the locations of wind turbines installed in that period.

Table 1. Baseline regression results of wind turbine visibility on property value

Log(Property Value)	(1)	(2)	(3)	(4)
Treated x Post	−0.0112**	−0.0090**		−0.0103**
	(0.0043)	(0.0042)		(0.00415)
x # Turbines (x10)		−0.0021***		
		(0.0005)		
x # Turbines (<20)			−0.0102**	
			(0.0042)	
x # Turbines (>20)			−0.0248**	
			(0.0096)	
x Installation Year				0.00169**
				(0.000683)
Post-treatment	0.0090	0.0102*	0.0098*	0.0104*
	(0.0059)	(0.0058)	(0.0058)	(0.00563)
Treated	-0.0101**	−0.0101**	−0.0101**	−0.0101**
	(0.0044)	(0.0044)	(0.0044)	(0.0044)
N	5,705,597	5,705,597	5,705,597	5,492,914
Adj. R^2	0.516	0.516	0.516	0.515
Property Char.	X	X	X	X
Census tract x year	X	X	X	X
County x month	X	X	X	X

Column (1) shows the effect of wind turbine visibility on average property values within 10 km. The control group includes properties that are within 10 km but cannot see any wind turbine. Coefficients on property characteristics are reported in column (1) of *SI Appendix*, Table S1. Column (2) differentiates between the effect of the first wind turbine in view and that of every additional 10 wind turbines (second row). Column (3) distinguishes between the effect of less than or more than 20 wind turbines, respectively. Column (4) incorporates the trend interaction of the DiD indicators with the demeaned installation year of wind turbine (mean is 2011).

when a location can actually see a wind turbine or whether it is hidden from view by the natural landscape.

To investigate the causal effect of wind turbines on housing prices, we employ a spatial difference-in-difference (DiD) design that takes advantage of both temporal variation in turbine installations and spatial variation in visibility induced by the underlying topography of the landscape. Our analysis estimates the average change in housing prices for homes with a wind turbine in their viewshed when it becomes operational, relative to the average change in housing prices for homes not visible to the same facility, within a 10-km (6.2-mile) range from the wind facility. The high-resolution housing transaction data, which include precise property locations, allow us to relax the statistical identification assumption, as the exact location and installation of wind turbines is assumed to be exogenous to the evolution of nearby housing markets. This is because the visibility of wind turbines is primarily determined by the underlying landscape topology, which is exogenous to changes in property values over time. Our examination of the parallel property value trends assumption pre-installation supports this statement. We also control for other confounding variables, such as location, general economic trends, and housing quality (see *Data & Methods* for detail).

Results

Property Value Impacts. We find that having at least one wind turbine in a home's viewshed (10 km radius) reduces the sales price of such a property on average by 1.12%, which is statistically different from zero Table 1, column (1). To put this in perspective, this amounts to a US $24.5 billion reduction in the property value for all houses affected by the visibility disamenity effect nationwide, which is small when compared to the total value of US homes (≈ US$45 trillion).

Additionally, we estimate that prior to the installation of a wind facility, there is a significant gap of 1.01% in the average property value between those areas that will later have a wind turbine in their viewshed (treated areas) and those that will not (control areas). This gap cannot be explained by differences in observed property characteristics or disparities in neighborhood factors and housing market changes. Our best explanation for this gap is that wind turbines are more likely to be sited in areas where their visual disamenity affects communities with lower housing values. Since the visibility of wind turbines is primarily determined by the nearby geographic landscape, this cross-sectional gap reflects only subtle decisions on wind turbine location within a small area rather than across entire neighborhoods.

The finding regarding the disamenity effect remains robust across multiple ways of specifying the regression model. These include limiting the sample to only properties that have experienced repeated sales over the research period, excluding nondisclosure states on property transactions, incorporating interaction terms between property characteristics and yearly indicators, as well as interacting treatment with state indicators. These checks are reported in *SI Appendix*, Table S1.

We investigate whether the visual impact of wind turbines varies with the intensity of visibility using two measures: The number of wind turbines in view and the intensity classified by whether there are more than 20 turbines in sight. We find that the capitalization of the visual disamenity increases with the treatment intensity, with every additional 10 wind turbines in view reducing the property value by an additional 0.2% [Table 1, column (2)]. Furthermore, wind farms with more than 20 turbines reduce the property value in visible areas by an average of 2.48%, whereas those with less than 20 turbines have a reduction effect of only 1.02% on visible areas [Table 1, column (3)]. These findings suggest that the density of wind turbines in view plays a role in driving the magnitude of the visual disamenity valuation.

The impact of visual disamenity created by wind turbines may also vary depending on the distance from the nearest visible turbine. To test how the effect varies by distance, we re-run the baseline specification with the indicators of interest interacted with 500-m (∼ 0.3-mile) distance bin indicators for the proximity of the closest wind turbine. The effect of wind turbine visibility decreases as distance increases (Fig. 2). The effect is largest in immediate proximity of wind turbines—with the

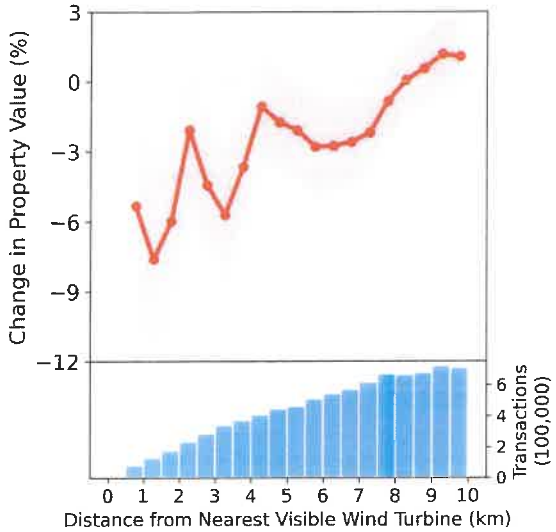

Fig. 2. Effect of wind turbine visibility on property value by distance. The effect of wind turbine visibility on property values for different distance bins. Each distance bin represents a 500-m range, determined by the distance from the nearest visible wind turbine. Red dots indicate estimated coefficients, as obtained by interacting the coefficient of interest from the difference-in-difference model (interaction between post-treatment status and treatment assignment) with distance bin indicators. Shaded areas represent 95% CIs constructed using two-way clustered SEs at the census tract and year level. Bars in the *Lower* panel show the number of transactions within each distance bin, corresponding to the right y-axis.

visual disamenity reducing property values by up to 8% within a neighborhood range of 1.5 km (∼ 0.9 miles). Even though this number is economically large, there are two noteworthy caveats. First, the CI is sizable including reductions in property value between 3 and 13%. Second, the number of properties within this distance bin is small. Nationally, there are fewer than 250,000 transactions within 1.5 km of the nearest wind turbine, as opposed to approximately 8.5 million transactions within 10 km. The effect for the full sample is statistically indistinguishable from zero 8 km (5 miles) away from the nearest wind turbine. To put this in perspective, if one stretched out an average-sized arm and held up an aspirin tablet, this would equate the perceived size of an average wind turbine five miles away. Were the same wind turbine one mile away, it would appear to be roughly the size of a golf ball.

To further test the robustness of our results to model setting, we modify the baseline DiD specification in various ways, using single, triple, and quadruple difference frameworks, respectively (*SI Appendix*, Table S2). First, we conduct a spatial difference by visibility and by proximity (within 10 km) only, without using the installation timing (columns 1 and 2). Second, we expand the sample to 50-km distance and identify the treatment coefficient by a 10-km proximity interaction (column 4). Finally, within this last framework, we also allow for effects of proximity to interact with installation timing (column 5). The results are almost identical to the effect of visibility to wind turbines on property value found in the baseline model (column 3). Moreover, we find that properties within 10 km from wind turbines are 1.16 to 1.7% lower in sales price than those 10 to 50 km away. These gaps are not driven by differences in the housing characteristics of properties located in different communities. Therefore, the cross-sectional difference in property value between visible and nonvisible areas as well as between proximate and distant areas indicates a potential selection effect that is consistent with the siting of wind turbines in places with lower property values.

As our visibility metric only considers features of the landscape and not buildings, we restrict the sample to areas with low building heights (*SI Appendix*, Fig S1). The results from this analysis are given in *SI Appendix*, Table S3. The results are almost identical to those in our main specification, with a point estimate of −1.2% for urban areas with low building heights.

We further investigate whether the visual disamenity effect varies across various dimensions, as shown in Fig. 3. We find that the negative impact of wind turbines on property values is primarily observed among urban properties, with negative but noisy effects in rural areas. Our analysis based on geographical altitude suggests that the negative impact of wind turbine visibility is particularly pronounced in nonmountainous regions. We also observe a strong correlation between local political leanings and disamenity effects, with right-leaning communities experiencing a significantly greater impact compared to left-leaning areas. Last, the visual disamenity is more accentuated in high-income locales as opposed to low-income areas.

The impact of wind turbine visibility may not manifest immediately, as it could require time for people to perceive and adapt to the visual disamenity (14). We explore the durability and dynamics of this effect in three ways. First, we investigate the impact trajectory following a wind turbine installation (Fig. 4). We find that the disamenity impact emerges instantly upon the installation, leading to a decline of more than 3% in nearby property values over the following 3 y. The effect diminishes and eventually disappears within the next 7 y. This is consistent with the idea that people initially dislike wind turbine installations but gradually become accustomed to them over time. Consistent with that, we find in a second analysis that wind turbines installed in earlier periods have a significantly more pronounced visual disamenity effect than more recent installations (column 4 of

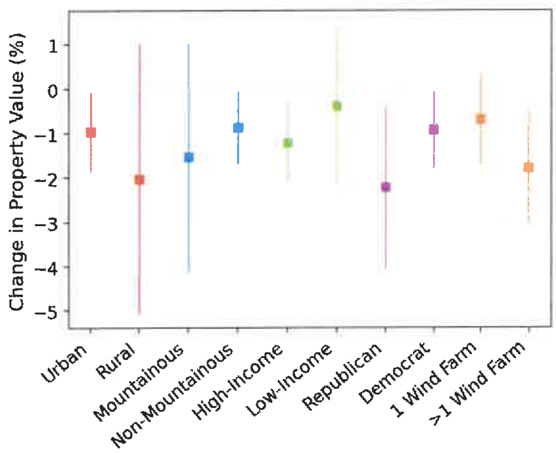

Fig. 3. Visual disamenity effect of wind turbine visibility by different county characteristics. Squares are the point estimates of the effect of wind turbine visibility on property values when partitioning the data based on different county characteristics. These estimates stem from a regression model, which adjusts the baseline model in Column (1) of Table 1, incorporating an interaction between the treated-post-treatment indicator with the categorical indicator of interest. Results for urban and rural counties, respectively, are shown in red. Blue indicates a segmentation into mountainous and nonmountainous groups, having compared the county's average elevation with 1,000 m. Green gives results having split counties by whether the median household income is above the nation's average level, using the 2015 American Community Survey. Purple divides counties between right-wing and left-wing using the presidential election results from the 2016 election. Orange breaks counties down by whether there is only one wind farm or multiple farms. The 95% CIs of the estimates are shown as bars, having clustered SEs at the census tract and year level. The zero effect line is illustrated by a gray line for reference.

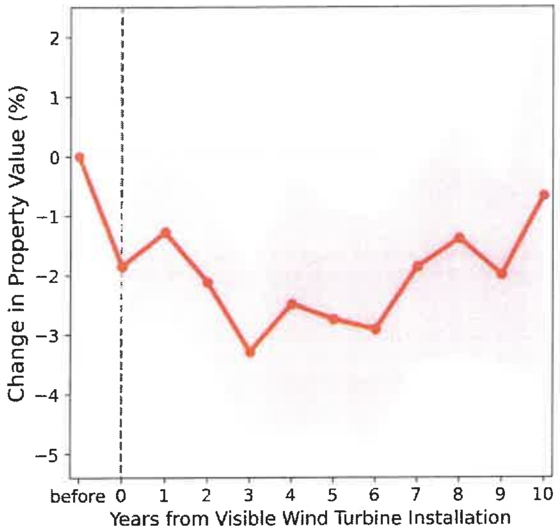

Fig. 4. The effect of wind turbine visibility on property values for different year bins, relative to the year when the wind turbine was installed. Each bin represents 1 y, determined by the year of property transaction relative to the year of the first installation of a wind turbine in visibility. Black dots are the estimated coefficients, as obtained by interacting the coefficient of interest from the difference-in-difference model (interaction between post-treatment status and treatment assignment) with the year indicators. The coefficients for pre-installation periods are normalized to zero. Shaded areas represent 95% CIs constructed using two-way clustered standard errors at the census tract and year level.

Table 1). We arrive at this finding by incorporating interaction terms between a trend of installation year and our DiD indicators (*Methods*). This is a significant finding, suggesting that the average effect we estimate above is larger than the effect one would expect for recent and future installations. Specifically, while an average wind turbine (installed in 2011) has a negative effect on nearby property values, the effect becomes indistinguishable from zero for turbines installed after 2017. Our third analysis differentiates the disamenity effect between initial and subsequent wind turbine installations. We segment the data based on years and counties that have seen a county's first wind farm installation and conduct the baseline regression separately for the two groups (orange squares in Fig. 3). We find that the introduction of the first wind farm results in an insignificant, minor effect, whereas subsequent installations lead to a more substantial, noticeable decrease in property values.

Discussion

This paper provides a national-level plausibly causal evaluation of the externality costs of wind power generation through the visibility impact on property values in the United States. We take advantage of the densely populated geographic setting across the nation, with rich geological features such as undulating terrain and prominent elevations on the surface, and numerous wind farms developed within sight of residential properties. We use advanced geospatial tools from geomorphometry and computer science to overcome computational difficulties and construct a comprehensive database on wind turbine visibility throughout the nation. Our analysis relies on the universe of housing transactions in the ZTRAX database spanning a 20-y period across the country and employs a spatial difference-in-difference design based on a quasi-experimental setting that compares the effect of wind power installation on property values in areas visible to the turbines with the value change of properties within the same area—but not visible to the same facility.

The findings indicate that wind turbines have a negative effect on property value in locations where they are visible. On average, across the whole sample, house prices decrease by up to 8% after the construction of a wind turbine within viewshed and close neighborhood range from the property, with the effect decaying as the distance increases. The average effect falls to a 1% reduction for houses within 10 km of visible wind turbines. It also diminishes over time—both in terms of more recent installations having a smaller disamenity effect and in the sense that the reduction in value a property experiences peaks 3 y after the installation and then becomes smaller the more years pass. These findings are consistent with a cognitive model where people get used to new structures in their environment over time.

The reduction in property values resulting from wind turbine installations raises questions about how this might affect siting decisions for future wind farms. This paper highlights the externality of wind power developments as they are capitalized in the housing markets. These estimates could also serve as a future basis for calculating compensation to local homeowners for placing a new wind turbine within their viewshed.

Data & Methods. The analysis primarily utilizes data from three sources: the wind turbine installation panel, the real estate transaction records, and the digital elevation models.

Wind turbine operation. We obtain the full sample of wind turbine installations from the United States Wind Turbine Database (2022 Version) of the United States Geological Survey (USGS), which has collected and compiled comprehensive records of wind turbines from various public and private sources on a quarterly basis. The data consist of all land-based and offshore utility-scale turbines that have ever generated and fed power into the grid to supply utilities with energy, including both newly installed as well as dismantled ones across the nation. For each facility, the data provide geo-referenced information of longitude and latitude, dates of announcement, construction, and operation, along with technical specifications on turbine make and model such as nameplate capacity, hub height, rotor diameter, and facility size.

We limit the sample to wind turbines that have started installation or have been in operation anytime since 1997. This includes 68,649 facilities in the continental United States, with their summary statistics presented in *SI Appendix*, Table S4.

Housing transactions. Data on the universe of property transactions are obtained from the ZTRAX database (2021 version). The data are created by combining transaction observations from multiple sources, including records from the buyer's, seller's, and county assessor's points of view, along with records from county assessments on an annual basis. This results in a rich dataset that allows us to observe the date and sale price of each transaction, as well as key characteristics of the transacted property, such as the property type, year of construction and renovation, building area, number of bedrooms and bathrooms, and other amenity features included in assessments. Each property or parcel point is geographically identified by its street address, and we conduct geocoding using the USA Local Composite locator of ArcGis to obtain the exact geo-referenced location. The data cover records of housing transactions from 1997 to 2020.

To conduct hedonic valuation, we limit our analysis to residential properties within the continental US, and exclude non-arm's-length transactions (below \$10,000) or outlier properties (above \$4,000,000), which account for 3.1% of the total data. We also exclude transactions that occurred on the same parcel within 3 mo of the previous sale to avoid duplicate observations. To examine the impact of visibility disamenity on property values, we further limit our sample to properties within 10 km of wind turbines, as discussed below. The final data comprise 180,682,544 transactions, and their summary statistics are presented in *SI Appendix*, Table S5. The shares of treated properties and treated properties post treatment by state are presented in *SI Appendix*, Fig. S4.

Data for heterogeneity analysis. We utilized data from the 2015 American Community Survey to obtain median household incomes at the county level. Counties were classified into high-income and low-income groups by comparing their median income with the national average.

Political leanings of counties were determined using the 2016 presidential election outcomes sourced from the MIT Election Data and Science Lab (31). Counties were categorized as right-leaning or left-leaning based on whether the majority of their voters chose the Republican or Democratic Parties, respectively, in the 2016 presidential election.

We acquired average elevation data at the county level through calculations based on Environmental Systems Research Institute data from the USGS. Counties were classified into mountainous and nonmountainous categories based on whether their average elevation exceeded 1,000 m. For context, the least elevated mountainous U.S. state, Montana, has an average elevation of 1,036 m. This categorization yielded 403 mountainous counties, representing 12.8% of all U.S. counties.

Digital elevation models. Digital elevation models (DEMs) provide crucial information on the ground topography of the study area. The DEMs we utilize are based on the Shuttle Radar Topographic Mission produced by NASA, which employs remote sensing technology to gather laser light measurements of the earth's surface. The resulting height (x), width (y), and depth (z) measurements are then used to create a comprehensive and accurate map of elevation for the entire globe. In particular, we use the most recent version of the DEMs data (2018), which are available at a resolution of 90 m for the entire continental US (32). The high level of accuracy and resolution of the DEMs is essential to our analysis, as it allows us to capture subtle variations in elevation and terrain that could have a significant impact on the sight of view.

Viewshed analysis. One of the key contributions of our analysis is the creation of a comprehensive database that measures the visibility of wind turbines across the United States. This is achieved by generating and aggregating viewsheds from the location point of each wind turbine. Viewshed is a term used in geography and cartography that refers to the area visible from a specific observation point or vantage point, based on the topography of the surrounding terrain and any obstructions that may block the view. Unlike typical viewshed analyses that calculate the viewshed to each property, we compute the viewshed from the site of wind turbines thanks to the duality of vision, which requires less computational effort since the number of wind turbines is much smaller than the number of housing properties. This approach greatly increases computational efficiency.

Our analysis of viewshed generation involves combining the site and height data of each turbine with information on the underlying topography of the landscape and the curvature of the earth. By utilizing the viewshed module in GRASS GIS, we are able to differentiate neighboring residential properties based on their ability to view the facility. The module relies on the line of sight and its geographical intersection with the terrain, which offers considerable advantages in terms of accuracy, reliability, and efficiency.

The visual significance of an object decreases as its distance from the observer increases, and increases as the observer's location elevates or as their height increases. To account for air quality conditions across the nation, we assume a maximum visible range of 10 km. Given that the horizontal distance of observation and the hub height of wind turbines are significantly greater than the height of a representative person, the observer's height is unlikely to have a significant effect on the visibility analysis. Therefore, we assume a representative observer's height of 1.75 m.

To visually illustrate the visibility analysis, we present an example of viewshed generation for a wind turbine in Fig. 5. This is a wind facility of the Patterson Pass Wind in Altamont, California, which became operational and began providing power in 1985, has the turbine capacity of 65 kw, the hub height of 24 m, and rotor diameter of 16 m. This is a fairly typical wind farm development in the full sample. Panel *A* illustrates the topographic features of the neighboring surface to the facility, which is represented by the blue point of center. Located in an approximately 50,000-acre area that extends across the northeastern hills of Alameda County and into a small portion of Contra Costa County to the north, the facility finds the visibility sight to itself largely void by the mountain ridges at high elevations in the north and remains visible from the south side only. This can be seen in Panel *B*, where the dark shaded areas represent places from which the view to the facility is obscured by geographical elevations, and the light yellow shading indicates lands where the hub of turbine blades is visible. Empirical results presented above rely on comparisons of outcomes occurring with the start of wind farm operation in the areas where the turbines are visible, and those occurring where they are nonvisible.

As of the end of 2020, wind power facilities have led to visual disamenity across more than a quarter of the continental US (*SI Appendix*, Fig. S2), resulting in exposure for approximately 37.2 million homes, which account for 30.6% of all households in the nation. A significant proportion of the affected populations are "treated" by multiple wind power facilities, with more than 75% of the affected lands exposed to the visibility of more than 10 wind turbines.

Statistics: Property value model. We start by utilizing a standard difference-in-differences (DiD) framework to compare the effects of wind farm development on the property value of homes in visible areas after the wind turbines become operational, relative to places within the same area (i.e., within a radius of 10 km of the wind turbine in question) where the turbines are not visible. Our examination of pre-installation property value trends supports the assumption for paralleling pre-treatment trends, as shown in *SI Appendix*, Fig. S1. The specification is as follows:

$$\log(P_{it}) = \beta_1 \text{Treat}_i \times \text{Post}_{it} + \beta_2 \text{Treat}_i + \beta_3 \text{Post}_{it} + \beta_4 X_{it} + \alpha_{ny} + \alpha_{cm} + \epsilon_{it}. \quad [1]$$

Here, each observation corresponds to a transaction for property i that occurred on date t, with the outcome variable being the log of sales price P_{it}. Treat_i is an indicator that denotes whether a property was assigned to the "treated" group, which refers to whether the property is located in areas with any wind turbine in view either currently or in the future. Note that the division between treatment and control group depends only on the location of property i, rather than on the transaction date or wind turbine installation status. Post_{it} is the indicator that denotes whether a property was transacted after the wind turbine in view became operational. Thus, the coefficient β_1 for the interaction term between Treat_i and Post_{it} captures the effect of wind turbine installation on the value of visible properties. To account for potential changes in building

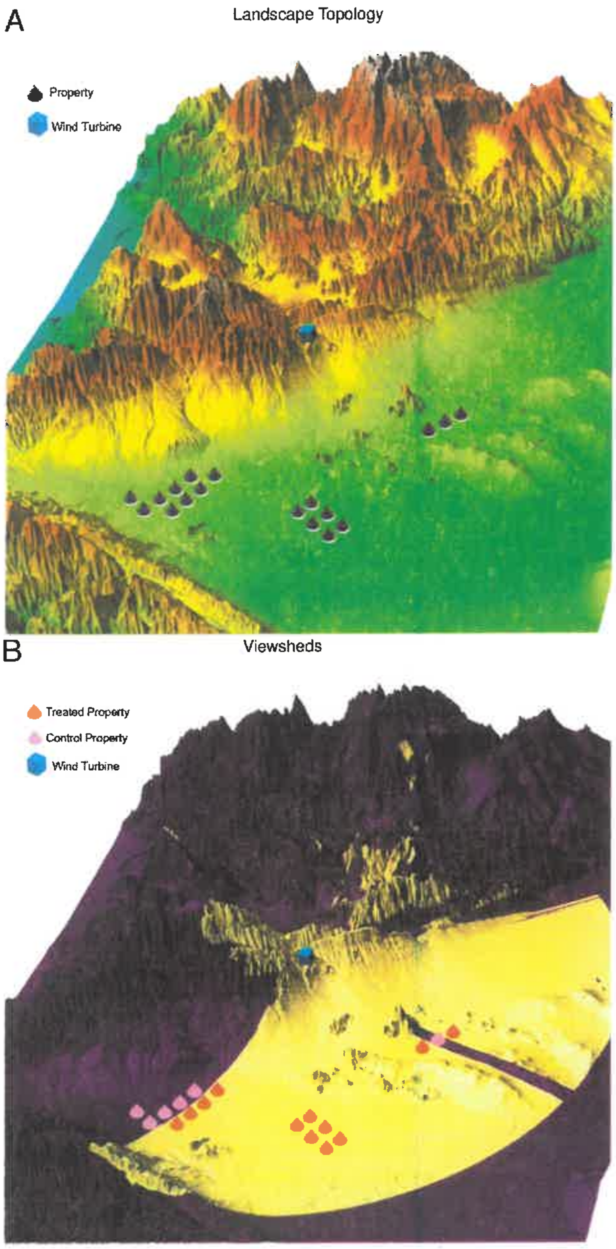

Fig. 5. Surface and viewshed of patterson pass wind in Altamont of California. Panels (*A* and *B*) depict the landscape topology and viewshed, respectively, of a wind turbine located in the Patterson Pass Wind facility in Altamont, California. It has a hub height of 24 m, and rotor diameter of 16 m. The blue point located at the *Center* of both figures represents the wind turbine, and the gray cones represent housing properties. In Panel (*B*), light-colored areas indicate locations from which the turbine is visible, while dark-colored areas indicate areas where the turbine is not visible. Accordingly, orange cones are properties in the treatment group whereas pink cones are housing properties in the control group.

characteristics that could affect property values, we include several property characteristics X_{it} that could vary over time, including the most recent year the property was built or renovated, the number of bedrooms and bathrooms, and the lot size in acres.

Crucially, there might exist time-varying location-specific factors that correlate with the visual disamenity created by wind farms. For instance, the spatial distribution of pre-existing wind turbines may influence the siting decisions for future wind turbines, potentially due to the participation of local communities in policy making. This correlation might also exist when wind farms are not randomly assigned across space, or if areas close to wind farms where turbines are visible may not be comparable to those further away in terms of other amenities affecting housing prices. To address this, we assume that each community has its own time trend, fully capturing any community-specific factors that impacted the siting of wind turbines. We include these trends in the analysis by incorporating fixed effects on census tract by year level, denoted as α_{ny} for census tract n and year y. Moreover, to control for seasonal trends in housing markets that might be specific to each county, we include fixed effects on the county by month level, denoted as α_{cm} for county c and sales month m. This way, we can ensure the DiD estimator of interest, β_1, is not contaminated by correlation with the time effects driven by the endogenous selection of wind farm siting and the general trends in property value over time. It is worth noting that while we acknowledge that the siting decision of windmills might be correlated with the post-treatment trends in housing markets, our control for the census-tract-by-year and county-by-month trends will ensure the DiD coefficients to capture only nuanced location variations within a community, rather than pronounced variations across neighborhoods.

Data, Materials, and Software Availability. Windmill data have been deposited in Github (33). Some study data available (Zillow's Transaction and Assessment Database (ZTRAX) data: ZTRAX data are offered by Zillow's research team through their website https://www.zillow.com/research/ztrax/ (34). To access ZTRAX data, the user will need to first review and agree to the ZTRAX Data License Agreement, then complete the registration online. Once logged in, the user can request access to specific ZTRAX datasets. For acquisition, the user will need to be prepared to provide details on the intended use of the data. To replicate of our study, we recommend applying for comprehensive access to ZTRAX's housing transaction data, covering all U.S. states from 1995 to the most recent available data. If that fails, alternative housing data are provided by Corelogic, which can be purchased. Windmill data: Windmill data can be accessed from the United States Wind Turbine Database produced by United States Geological Survey (USGS), available at https://doi.org/10.5066/F7TX3DN0 (35). We have consolidated key data and saved it as windmill.dta in the replicate kit. Digital Elevation Models Digital Elevation Models are produced by NASA's Shuttle Radar Topographic Mission and available at https://srtm.csi.cgiar.org/ (36). These are crucial for viewshed computations in the replication. Due to size constraints, the original Digital Elevation Models (DEMs) are not included as part of our replication kit. The user will need to download and extract the data to /data/DEMs/ under the replication directory. Other Data: Data for heterogeneity analysis are drawn from multiple sources. The county-level median household income records come from the 2015 American Community Survey. Presidential election data is sourced from the Massachusetts Institute of Technology (MIT) Election Data and Science Lab (37). Additionally, the county-level average elevation data is derived from the Environmental Systems Research Institute. All these data are either acquired through public access in our code or included in the replication kit.

ACKNOWLEDGMENTS. Data were provided by Zillow through the Zillow Transaction and Assessment Dataset (ZTRAX). More information on accessing the data can be found at http://www.zillow.com/ztrax. The results and opinions are those of the author(s) and do not reflect the position of Zillow Group. We gratefully acknowledge financial support from the Fisher Center for Real Estate and Urban Economics, the VW Foundation (Europe and Global Challenges), and the Giannini Foundation. An earlier version of this paper appeared in Wei Guo's 2022 dissertation.

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Commercial wind turbines and residential home values: New e... the universe of land-based wind projects in the United S...

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Property value
428 diff. wind facilities
no height given
11% decline w/ 1 mile

ARTICLE INFO

We augment the USWTDB database with additional information on the date of the "announcement" that a wind energy project was being developed and seeking permit approval. Data on announcement date comes from Hitachi Velocity Suite, which often corresponds to the date a transmission interconnection application is filed and necessarily would follow or be coincident with a period in which land agents are securing local landowner leases, the development company sets up a local office, and other development activity occurs, such as the erection of a meteorological tower to collect local wind speeds. Any of these could incite local conversations about the possible arrival of the project in future years. We observe non-missing announcement dates for 60% of the wind energy projects in our sample. Given that most announcement dates occur approximately four years prior to a wind energy project becoming operational, we set the announcement date equal to four years prior to the operation date in cases where we are missing the actual announcement date.

JEL classification:
R31
R21
Q53

Keywords:
Wind turbines
House price capitalization
Externalities
Property values
Hedonic

ABSTRACT

We examine the impact of proximity to land-based co... ...urbines on residential home values in the United States using data on the universe of commercial w... ...bines and residential property transactions from 2005 to 2020. Using event study and difference-in-differences identification strategies we find that, on average, homes located within 1 mile of a commercial wind turbine experience approximately an 11% decline in value following the announcement of a new commercial wind energy project, relative to counterfactual homes located 3 to 5 miles away. Event study estimates also reveal important dynamics in the evolution of home values, with property values first declining following project announcement, and then recovering post project construction, with property value impacts becoming relatively small (~2%) and statistically insignificant 9 years or more after project announcement (roughly 5 years after operation began). Homes located within 1–2 miles of a commercial wind turbine experience much smaller impacts and homes located farther than 2 miles away are unaffected. Our results are primarily driven by wind projects located in urban counties with populations greater than 250,000.

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E-15

1. Introduction

Over the past decade, wind energy has become one of the fastest growing energy sources in the United States, accounting for approximately 32% of U.S. electric capacity growth in 2021 (Wiser et al., 2023). Commercial wind energy generation has grown from approximately 6 billion kWh in 2000 to 380 billion kWh in 2021, with more than 70,000 turbines now accounting for 9.2% of total U.S. utility-scale electricity generation (Hoen et al., 2018; United States Energy Information Administration, 2022). The rapid growth in wind energy production has been accompanied by a large expansion in the number of counties hosting commercial wind energy projects and the number of homes located in close proximity to such projects.

The growth of commercial wind energy installations has led to opposition to the siting of new projects, particularly as those projects have moved closer to more densely populated areas. One primary concern among residents within close distances of commercial wind turbines is the potential negative impact on home values due to the noise and shadow flicker associated with turbine rotation as well as the change to the surrounding landscape (Hoen et al., 2019). A relatively large body of literature has examined how proximity to wind turbines impacts residential home values. Within the U.S. context, the evidence is mixed but the majority of studies find insignificant effects of wind turbines on home values (see reviews Brinkley and Leach, 2019; Rand and Hoen, 2017, Parsons and Heintzelman, 2022). In contrast, studies from Europe generally find that close proximity to wind turbines has a negative effect on home values with home values falling by approximately 5–10% for homes located within 2 km (~1.2 miles) of a wind turbine.

The purpose of this paper is to provide new evidence on how proximity to commercial wind turbines affects residential housing values within the U.S. context. Our analysis is based on the most comprehensive and nationally representative sample of wind energy projects and housing value transactions in the United States to date. We combine data from the U.S. Wind Turbine Database (USWTDB, Hoen et al., 2018) on the timing and exact location of the universe of wind turbine installations in the U.S. from 2005 to 2020 with data on the universe of residential housing transactions from CoreLogic including the location, attributes, and sales data from 2005 to 2020. Our final sample consists of 428 unique wind energy projects located across the United States and nearly 500,000 housing sale transactions located within five miles of a wind energy project.

To isolate the causal effect of wind turbines on residential property values, we use difference-in-differences (DiD) and event study models that allow us to examine the evolution of housing prices for homes within [0, 1], [1, 2], and [2, 3] miles from a turbine four years prior to the announcement of a new commercial wind energy project to 10 years after the announcement. Our identification strategy has several key advantages for isolating the causal impact of proximity to a wind turbine on residential home values. First, as described in more detail below, our comparison group, which consists of homes 3 to 5 miles from the nearest turbine, and our fixed effect structure enables us to use only within project variation in sale prices and distance from a wind turbine. Thus, we avoid inter-housing market (or across-jurisdiction) comparisons that may bias our estimates. Second, we control for wind project-specific nonparametric trends in housing prices over time allowing us to better model generalized housing trends in specific markets. Finally, our identification strategy directly addresses the potential biases that can arise in standard DiD and event study models in the presence of staggered timing of treatment with heterogeneous treatment effects (Callaway and Sant'Anna, 2021; Goodman-Bacon, 2021; Sun and Abraham, 2021).

We find that the average home located within 1 mile of a commercial wind turbine experienced approximately an 11% decline in value following the announcement of a new commercial wind energy project, relative to homes 3 to 5 miles away from the project. Event study estimates also reveal important dynamics in the evolution of home values, with property values first declining following project announcement, and then recovering post project construction, with property value impacts becoming relatively small (~2%) and statistically insignificant 9 years or more after project announcement. Homes located within 1–2 miles of a commercial wind turbine experience much smaller impacts and homes located farther than 2 miles away are unaffected. Furthermore, we find that our results are driven by wind projects and housing markets located in populated, urban metro areas with populations of 250,000 or more.

Our paper extends the existing literature in several important ways. First, much of the existing literature is focused on specific states or regions (e.g., Dong et al., 2023). In contrast, our study is based on the full universe of housing transactions and wind turbines in the United States. Second, all but one of the existing studies within the United States rely on housing transactions that occurred prior to 2014–2015 at the latest (Hoen et al., 2015). In contrast, we examine the impact of turbines constructed in the past 15 years. Lastly, we specifically examine the impact of turbines constructed in urban areas. This second contribution is particularly policy-relevant given we find that wind projects built in urban areas (counties with populations greater than 250,000) have negative impacts on property values compared to wind projects built in more rural communities (where we find no impact on property values). We discuss potential mechanisms for this difference below.

2. Background & existing literature

Since the early 1980's when the first commercial wind turbines went into operation, wind energy has become an increasingly important energy source in the United States, accounting for over 32% of U.S. electric capacity growth in 2021 and 9.2% of total U.S. utility-scale electricity generation. Appendix Figure A1 presents the distribution of county-level wind energy capacity in 2005 and 2022. As of 2005, there were 123 counties with commercial wind energy installations that were concentrated in the southeastern part of California and the Southwest and Midwest. By 2022, the number of counties with wind energy installations had grown six-fold to 687, with wind energy installations spread across the Western, Southwestern, and Central United States and to a lesser extent the Northeast. As shown in Fig. 1, the rapid growth of wind energy projects has also resulted in a steep decrease in average distance to the nearest turbine for all transactions in our data. In 2005, the average parcel in our data was located 148.6 miles (238.2 km) away

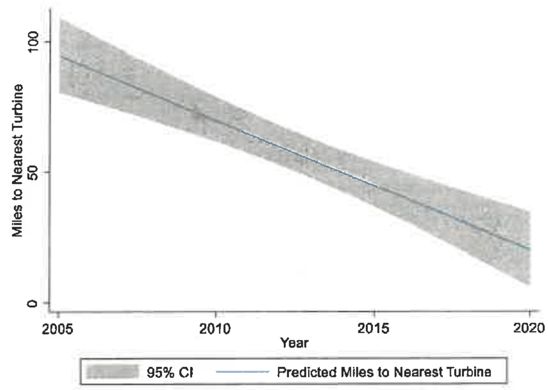

Fig. 1. Distance to Nearest Turbine for the Average House in the United States, 2005-2020

Notes: The figure represents the average distance to the nearest turbine for the average parcel in our transaction from 2005 to 2020. The average distance in 2005 was 148.6 miles (standard deviation of 367.4 miles). By 2020, the average distance was 37.1 miles (standard deviation of 25.65 miles).

from the nearest turbine. This distance decreased to 54.1 miles (86.9 km) by 2010, and then further to 37.1 miles (59.7 km) by 2020.

Despite public opinion polls showing the majority of the U.S. population supports the expansion of alternative energy sources, such as wind energy, the rapid expansion of wind energy projects, accompanied by the increase in the number of projects located in closer proximity to more densely populated areas, has led to controversy regarding the siting of wind energy projects.[1] Much of this controversy revolves around concerns over the potential impact of wind projects on residential property values. As noted by Hoen et al. (2011) and Krekel and Zerrahn (2017), concerns about the potential negative impact of wind turbines on residential property values can be categorized into three general areas: 1) the potential impact of direct views of wind turbines on property values; 2) perceptions that wind turbines will make an area appear more developed and reduce the aesthetic appeal of the areas surrounding a wind project regardless of whether wind turbines can be directly seen from residential properties; and 3) concerns over noise and shadow flicker impacts from the rotating blades of a wind turbine along with annoyance associated with aviation obstruction lights installed on top of turbines.[2]

Over the last decade a relatively large body of literature has emerged that examines the impact of wind turbines on residential property values, primarily using data from the United States and Europe. Within the U.S. context, the evidence is mixed but the majority of studies have found insignificant effects of wind turbines on residential property values. For example, using data on over 50,000 homes, including 1198 homes within 1 mile of a turbine, Hoen et al. (2015) find negative, but small and insignificant, effects of turbines on homes located in close proximity to operating turbines, and slightly larger but still insignificant effects in the period after announcement but before operation. Lang et al. (2014) and Hoen and Atkinson-Palombo (2016), examine the impact of wind turbines on residential home values in more urban settings in Rhode Island and Massachusetts, respectively, and these studies find little evidence that close proximity to turbines lowers property values. While Hoen et al. (2015) and Hoen and Atkinson-Palombo (2016) both find small and insignificant impacts on average, both studies also find that estimates in the post-announcement-pre-operation period being slightly more negative, though still insignificant. In contrast, using data on approximately 11,000 residential property transactions in three upstate New York counties, Heintzelman and Tuttle (2012) find that close proximity to wind turbines (within 0.5 miles) reduces property values in 2 of the 3 counties by between 6 and 10%.[3] Most recently, using data on wind turbines and home values in Massachusetts and Rhode Island, Dong, Gaur and Lang (2023) find that properties within 1 km of a wind turbine decrease in value by approximately 2.5%–4.6% after construction relative to properties 3–10 km away.

While the majority of U.S. studies have found small negative and insignificant effects of proximity to wind turbines on property values, the evidence from studies that use data from European countries typically finds that proximity to wind turbines reduces residential property values. For example, using data from Denmark, Jensen et al. (2014) estimate that homes where residents can see a turbine decline in value by 3%, and these homes decline by an additional 2% if residents can hear the turbines when compared to those properties outside of visible or auditory range. They also find effects fade as distance increases. Gibbons (2015) finds that English and Welsh homes with a visible wind energy project within 2 km experience approximately a 5%–6% decline in value relative to homes without a view and those located farther away. From the Netherlands and using a difference-in-differences identification strategy, Dröes and Koster (2016) find a 1.4% reduction in home prices for homes located within 2 km of a wind turbine with the effects being larger for homes located near turbines in urban areas and for larger turbines. Similarly, using data from Germany, Sunak and Madlener (2016) and Sunak and Madlener (2017) find that turbine visibility and close proximity to wind turbines reduces residential home values by approximately 9%–20% respectively. More recently, Jensen et al. (2018), Dröes and Koster (2021) and Eichholtz et al. (2023), using data from Denmark, the Netherlands, respectively, find that close proximity to wind turbines reduces residential property values by between 3%, 6% and 7%.[4]

A number of studies have found evidence of negative anticipatory effects on housing values, which begin after the announcement of the wind project and continue through operation rather than manifesting when construction begins (e.g., Dröes and Koster, 2016; Jarvis, 2021; Dong et al., 2023). Furthermore, some studies find that post project construction, housing values rebound to levels existing prior to the project's announcement (Dong et al., 2023).[5]

The stark difference in findings between studies conducted in the U.S. and those conducted in Europe raises an important question: why do European studies nearly universally find that wind turbines reduce residential property values (and in many cases by a considerable magnitude), while studies from the U.S. typically find small and statistically insignificant effects? While the existing literature provides no definitive answer to that question, there are several possibilities. First, the population density of Europe is approximately 3.5 times higher than that of the U.S. Furthermore, that figure represents average population density and most wind turbines in the U.S. are located in the less densely populated areas of the Midwest and Southwest. Thus, it is simply harder to site wind turbines farther away from residential locations in Europe than in the U.S. Second, and relatedly, European studies tend to have significantly more residential sale transactions in close proximity to a wind turbine. For example, Dröes and Koster (2016) observe 149,939 transactions within 2 km of a wind turbine while in the largest U.S. study to date, Hoen et al. (2015) observe approximately 1200 homes within 1 mile of a turbine.

As noted above, previous U.S. studies of the impact of wind turbines on residential property values contained a relatively small number of residential sales transactions within close proximity to turbines. That is not surprising given that most U.S. studies were published between 2012 and 2016. These studies tended to use data on residential housing transactions from the mid-1990s through, at most, 2015. For example,

[1] For example, a January 2022 poll by the Pew Research Center, finds that 69% of U.S. adults support the expansion of renewable energy installations such as wind and solar.

[2] Numerous studies have examined the potential health effects associated with living in close proximity to wind turbines, such as annoyance, sleep disturbance, anxiety, or depression. The consensus from the more rigorous studies (e.g., Bakker et al., 2012; Michaud et al., 2016, van Kamp and van den Berg, 2021) find links to annoyance but not health outcomes (also reviews by Knopper and Ollson, 2011; Guski et al., 2017; Freiberg et al., 2019). Annoyance has also been found to be correlated with perceptions of the planning process (Hübner et al., 2019; van Kamp and van den Berg, 2021).

[3] In related work, Heintzelman et al. (2017), examine the impact of wind turbines located on Wolfe Island, which straddles the border between New York and Canada, on property values. They find evidence of a negative effect of wind turbines on property values for homes located on the New York side of the border but no effect (and in some specification positive but insignificant effects) of wind turbines on property values for homes located on the Canadian side of the border.

[4] Appendix Table A1 provides a complete list of peer-reviewed studies examining the impact of wind turbines on residential property values along with whether those studies were conducted in the U.S. or Europe and their main finding.

[5] Although differences were not statistically significant, several studies find evidence of more negative effects on housing values in the post-announcement pre-construction period than that in the post-operation period (Hoen et al., 2011, 2015; Lang et al., 2014; Vyn and McCullough, 2014; Hoen and Atkinson-Palombo, 2016).

Hoen et al. (2015), which represents perhaps the most extensive U.S. study to date, utilizes data on residential sale transactions from 1996 to 2011, which, as shown in Fig. 1 predates the time period when wind turbines increasingly began to be sited closer to more densely populated areas. Further, over the last decade commercial wind turbines have grown in size, which likely has increased the visual impacts associated with turbines.[6] Given the trend in the U.S. toward larger wind turbines located closer to areas with great population and more active housing markets over the last 10 years, the purpose of this paper is to revisit the relationship between residential property values and proximity to commercial wind turbines using data on the universe of commercial turbines and residential home transactions in the U.S. between 2005 and 2020. Relative to existing U.S. studies, we observe over 20,000 residential sales transactions within 1 mile of a wind turbine, compared to the approximately 1200 transactions observed by Hoen et al. (2015).

3. Empirical framework

To examine the relationship between proximity to wind turbines and residential property values we utilize a difference-in-differences (DiD) identification strategy that relates the timing of treatment (being close to a wind turbine post the announcement of a wind project) to home prices for homes located [0 to 1], [1 to 2], and [2 to 3] miles away from the closest turbine within a given wind energy project. Specifically, we first created 428 unique datasets, each representing a unique commercial wind project and the residential home transactions that occurred within 5 miles of the project and transacted within 4 years prior to project announcement and 10 years post project announcement. We call each of these unique datasets a "project." We then stacked the 428 projects to create our final analytic dataset and specify a stacked difference-in-differences specification of the following form:

$$ln(P_{icdjt}) = \beta \boldsymbol{D}_{idt} + \boldsymbol{X}_i\alpha + \delta_{dc} + \lambda_{tc} + \varphi_{jc} + \varepsilon_{icdjt}, \tag{1}$$

where $ln(P_{icdjt})$ is the natural log of the sales price of residential home transaction i that belongs to project c within distance bin d and census block group j, that transacted in quarter and year t. D_{idt} is a vector consisting of 3 distance bin indicators for homes located [0 to1], [1 to 2] and [2 to 3] miles from the closest turbine in the wind energy project and where each distance bin is interacted with an indicator for whether the home sale occurred after the announcement of the wind project. The omitted category for the distance bin indicators is homes located 3 to 5 miles from the closest wind turbine in the project. δ_{dc}, λ_{tc} and φ_{jc} are, respectively, distance bin-by-project fixed effects (FEs), transaction quarter-by-year-by-project FEs and census block group-by-project FEs, and ε_{icdjt} is a random disturbance term. Finally, $\boldsymbol{X}_i$ is the vector of individual home characteristics including: parcel size building living area square feet, the age of the building at the time of sale, age squared, the number of stories, bedrooms, and full and half bathrooms, . The standard errors in equation (1) are clustered at the project level, and we use STATA/MP v17 to estimate the regressions and event studies.

The coefficients of primary interest in (1) are the β s which represent the DiD estimates of the effect of treatment (being close to a wind turbine post announcement of the project) on home prices for homes located [0 to1], [1 to 2], and [2 to 3] miles away from the closest wind turbine in a project, respectively. Note that each of the 428 projects represents a unique quasi-experiment where the DiD treatment group is homes located within [0 to1], [1 to 2], and [2 to 3] miles from the closest turbine in a wind project, which is compared to the control group, homes located 3 to 5 miles away, both before and after announcement of the wind project.

The inclusion of distance bin-by-project FEs, δ_{dc} and transaction quarter-by-year-by-project FEs, λ_{tc}, imply that our estimates are identified based only on within project variation in sale prices and distance from a wind turbine. Thus, our coefficients of primary interest, β s, represent the average treatment effect over the 428 quasi-experiments for homes located within each of our specified distance bins. Furthermore, note that the inclusion of quarter-by-year-by-project FEs allows for very localized (project-specific) nonparametric trends in housing prices over time. Finally, our stacked DiD framework avoids the potential biases that can arise in standard DiD and event study models in the presence of staggered timing of treatment with heterogeneous treatment effects. Specifically, several recent studies have shown that DiD specifications relying on the staggered timing of treatment for identification may be biased in the presence of heterogeneous treatment effects due to the contamination of treatment effects from early versus later adopters from other relative time periods (Callaway and Sant'Anna, 2021; Goodman-Bacon, 2021; Sun and Abraham, 2021). As discussed by Cengiz et al. (2019) and Goodman-Bacon (2021) our stacked DiD model avoids this potential source of bias by ensuring that treatment effects are based only on within project comparisons.

To examine the evolution of property values over time, we complement the DiD model with an event-study model of the following form:

$$ln(P_{icdjt}) = \sum_{k=-4}^{10} \boldsymbol{T}_{k,idt}\gamma_k + \boldsymbol{X}_i\alpha + \delta_{dc} + \lambda_{tc} + \varphi_{jc} + \eta_{icdjt}, \tag{2}$$

where $\boldsymbol{T}_{k,idt}$ represents a series of lead and lag indicators for when a wind energy project is announced for each of the three distance bins, η_{icdjt} is a random disturbance term and all other terms are as defined in equation (1). We re-centered $T_{k,idt}$ so that $T_{0,idt}$ always equals one in the year a project was announced. We included a series of indicators from 2 to 4 years prior to a project being announced ($T_{-4,idt}$ to $T_{-2,idt}$), and a series of indicators for the year the project was announced and 1–10 years after announcement ($T_{0,idt}$ to $T_{10,idt}$). Note that $\boldsymbol{T}_{k,idt}$ is a vector consisting of 14 indicators for the four years prior to a wind project being announced and the ten years after announcement for each of the three distance bins outlined in equation (1). Thus, $\boldsymbol{T}_{k,idt}$ includes 42 indicators all together (14 temporal indicators for each of the three distance bins). The omitted category for our treatment indicators (i.e., the reference year for all estimates) is the year prior to the announcement of a project ($T_{-1,idt}$).

The coefficients of primary interest in equation (2) are the γ_k's. The estimated coefficients on the lead treatment indicators (γ_{-4} to γ_{-2}) indicate whether the parallel trends assumption appears to hold. Specifically, if wind turbines induce exogenous changes in home values, these lead treatment indicators should be small in magnitude and statistically insignificant, implying that the price of homes located close to a turbine (within 1, 2 or 3 miles) were trending in a similar way to homes located farther away (3–5 miles) prior to the announcement of a wind energy project. The lagged treatment indicators ($\gamma_1, \ldots, \gamma_{10}$) allow the effect of distance to a wind turbine on home prices to evolve nonparametrically over time in the post treatment period.

4. Data

We construct an original dataset that combines data on the universe of residential property transactions from CoreLogic with data from the U.S. Wind Turbine Database (USWTDB) on the timing and exact location of the universe of wind energy installations and turbines in the U.S. from 2005 to 2020. The complete CoreLogic housing transaction data consists of over 260 million residential property transactions in the United States from January 2005 to December 2020 and contains property-level characteristics including address, latitude-longitude coordinates, property type, and many property characteristics (e.g., living area, number of

[6] According to the U.S. Office of Energy Efficiency & Renewable Energy, the hub height of commercial wind turbines has increased 66% since 2000 from approximately 190 feet–322 feet in 2021. Furthermore, the diameter of turbine rotor blades has also increased substantially, up 104% since 1999 to 432 feet (Wiser et al., 2023).

bedrooms, baths, etc.), as well as transaction-specific data, including sale amount and sale date for each transaction.

The USWTDB provides information on the universe of land-based and offshore wind turbines in the United States including the year each wind turbine became operational, the installed capacity of each turbine measured in kilowatts (kW), turbine technical specifications, and the latitude and longitude of each turbine which we use to geocode each property transaction to the nearest utility-scale wind turbine.

We restrict the property transaction data in several ways. First, we restrict the sample to property transactions within 5 miles of the nearest utility-scale turbine (i.e., greater than 600 kW). We further restrict the sample to arm's length transactions of residential properties that had complete information on their sale date and sale amount along with several other restrictions that are detailed in Appendix Table A2. Finally, we restrict the sample by removing transactions that do not contribute to our identification strategy due to insufficient observations within our distance bins. Our final analytic sample consists of 428 unique wind projects, across 34 states, and 496,054 transactions that occurred within 5 miles of a utility-scale turbine.

Fig. 2 illustrates the density of housing transactions in each of our pre-specified distance bins. The majority of these transactions are in our control group—homes located greater than 3 miles but within 5 miles of a turbine. We have approximately 20,000 transactions within 1 mile of a turbine, 61,000 transactions greater than 1 mile but within 2 miles of the nearest turbine, and over 90,000 transactions greater than 2 miles but within 3 miles of the nearest turbine. As noted above, we treat each of our 428 wind projects in our sample as unique quasi-experiments. Appendix Figure A2, provides an example of one such project in Herkimer County, New York.

In Table 1, we provide descriptive statistics on the full sample (Column 1), transactions within 3 miles (Column 2), and the control group (Column 3), and, in Table 2, we conduct a series of balancing tests that compare the characteristics of homes located within three miles of a utility-scale turbine to homes located 3 to 5 miles from the nearest turbine. Specifically, we regress the pre-determined characteristics of homes on an indicator that takes the value one if the transaction occurred within 3 miles of a turbine, and we include census block group, transaction quarter-by-year, and project fixed effects. We cluster standard errors at the project level. As shown in Table 2 the treatment and control sample display remarkable balance: none of the property characteristics of homes located within 3 miles of the nearest turbine (treatment group) are statistically different from the characteristics of homes located 3 to 5 miles from the nearest turbine (control group).

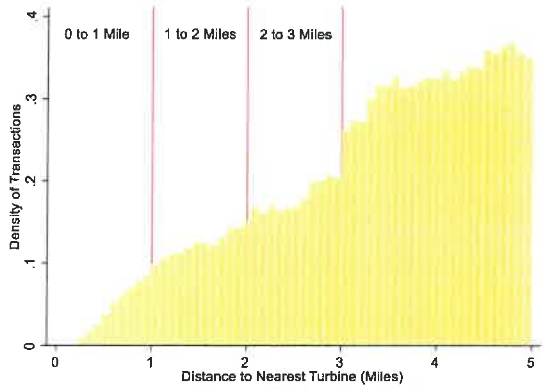

Fig. 2. Density of Transactions within 5 miles of a Turbine
Notes: Figure presents the density of housing transactions within our three main distance bins of [0, 1], [1, 2] and [2, 3] miles from the nearest wind turbine and transactions in our control group consisting of homes located [3, 5] miles from the nearest turbine.

Table 1
Descriptive statistics.

	Full Sample	Within 3 Miles	Greater than 3
Parcel Size (Acres)	0.43	0.44	0.43
	[1.32]	[1.25]	[1.35]
Building Square Feet	1817.56	1792.96	1830.67
	[1171.48]	[1012.17]	[1247.88]
Age of Building	54.72	59.81	52.01
	[37.53]	[39.71]	[36.02]
Number of Stories	1.54	1.58	1.52
	[0.58]	[0.57]	[0.58]
Number of Bedrooms	3.39	3.40	3.39
	[1.43]	[1.44]	[1.43]
Number of Full Baths	1.82	1.79	1.84
	[0.99]	[0.97]	[1.00]
Number of Half Baths	1.08	1.08	1.07
	[0.69]	[0.39]	[0.80]
Adjusted Sale Price ($)	186,050	178,774	189,927
	[169,734]	[167,709]	[170,677]
Total Transactions	496,054	172,423	323,631

Notes: Table presents summary statistics for housing transactions where Column 1 presents summary statistics for the full sample, column 2 presents summary statistics for homes located within 3 miles (being close to a wind turbine), and column 3 presents summary statistics for the control sample of homes located 3 to 5 miles from the nearest turbine.

In Table 3, we present results similar to those reported in Table 2 except we now include separate indicators for homes within 1 mile, homes located greater than 1 but within 2 miles, and homes located greater than 2 but within 3 miles of the nearest turbine. We find that 3 of these balancing tests (out of 24) are statistically significant at the 10%-level or less. Two of these tests (on the number of half baths) are small in magnitude (−0.1 fewer half-baths), and 2 of the 3 tests are on the "1 to 2 miles" indicator. Overall, based on the results in Tables 2 and 3, we find relatively little evidence of meaningful differences between transactions within 3 miles of the nearest turbine (treatment group) and those between 3 and 5 miles of the nearest turbine (control group), which provides us with further confidence that our identification strategy can isolate the causal impact of proximity to a wind turbine on housing values.

5. Results

5.1. Event study estimates

We begin by presenting the impact of proximity to a utility-scale wind turbine on property values by plotting the estimated $\gamma_k's$ and associated 90% and 95% confidence intervals from our event study specification given by Equation (2). For ease of presentation, and to clearly visualize the dynamic treatment effects for home sales in each respective distance bin, we present separate event study estimates for each of our three treatment distance bins ([0 to1], [1 to 2] and [2 to 3] miles from the closest turbine) in Figs. 3–5 respectively. We note however, that the estimates reported in Figs. 3–5 are all from the same regression model given by Equation (2).

Fig. 3 presents event study estimates for homes within 1 mile of the closest turbine and reveals important dynamics in the effect of wind turbines on home values. Immediately following the announcement of a wind energy project, property values begin to decline, falling by approximately 15% two years after the announcement and remaining depressed until project construction is generally complete (approximately 4 years after announcement). Following the beginning of operation of a wind project, property values begin to stabilize and then rise. Nine years or more after the announcement of the project (i.e., 5 years after the project begins operating), any impact of wind turbines on property values becomes relatively small (~2%) and statistically insignificant. Thus overall, Fig. 3 reveals a measurable, but ephemeral,

Table 2
Balance tests on unit-level characteristics with fixed effects.

	Adjusted Sale Price ($)	Parcel Size (Acres)	Building Square Feet	Age of Building	Number of Stories	Number of Bedrooms	Number of Full Baths	Number of Half Baths
Within Distance (=1 if < 3 miles)	-5162	0.0539	-21.0369	0.0639	0.0005	0.0096	0.0104	-0.0179
	(4948)	(0.057)	(29.75)	(1.242)	(0.022)	(0.031)	(0.032)	(0.017)
Control Mean	$189,927	0.425	1830.67	52.01	1.52	3.40	1.84	1.72

Notes: This table presents balancing tests for housing transaction attributes. Each column represents a separate regression where the listed housing attribute is regressed on an indicator that equals one if the housing unit is within 3 miles of the nearest wind turbine. All specifications include census block group fixed effects, sale year-quarter fixed effects, and project fixed effects. Robust standard errors in parentheses, clustered at the project level.

Table 3
Balance tests within distance bins.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Adjusted Sale Price ($)	Parcel Size (Acres)	Building Square Feet	Age of Building	Number of Stories	Number of Bedrooms	Number of Full Baths	Number of Half Baths
0 to 1 Mile	3086	-0.0820	-46.9664	2.0015	0.0258	-0.0006	0.0027	-0.0948*
(tx1)	(8891)	(0.2700)	(60.1986)	(4.2381)	(0.0371)	(0.0732)	(0.0739)	(0.0488)
1 to 2 Miles	-5782	0.4324*	-49.9998	-2.3200	-0.0202	-0.0666	-0.0057	-0.1034**
(tx2)	(5676)	(0.2580)	(45.9568)	(2.9173)	(0.0300)	(0.0488)	(0.0456)	(0.0424)
2 to 3 Miles	-5376	-0.0033	-14.7521	0.5499	0.0049	0.0302	0.0111	0.0043
(tx3)	(5343)	(0.0465)	(32.7739)	(1.2786)	(0.0223)	(0.0345)	(0.0357)	(0.0167)
Control Mean	$189,927	0.425	1830.67	52.01	1.52	3.40	1.84	1.72

Notes: Table presents balancing tests for housing transaction attributes. Each column and row represents a separate regression where the listed housing attribute is regressed on an indicator that equals one if the housing unit is within 1 mile (Panel 1), 1 to 2 miles (Panel B) or 2 to 3 miles (Panel C) of the nearest wind turbine. All specifications include census block group fixed effects, sale year-quarter fixed effects, and project fixed effects. Robust standard errors in parentheses, clustered at the project level. ***p < 0.01, **p < 0.05, *p < 0.1.

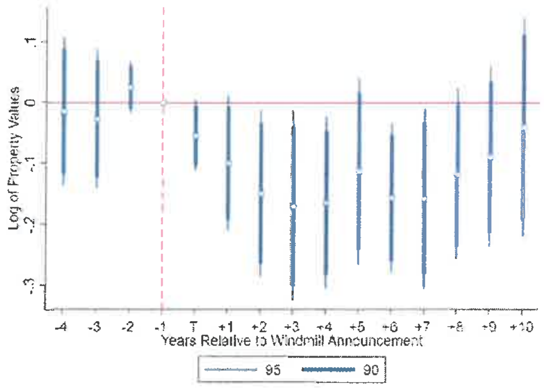

Fig. 3. Stacked Event Study Estimates for Homes located within 0–1 Miles of a Turbine
Notes: Figure presents estimated coefficients from the stacked event study specification given by Equation (2). Estimates are for home located within 1 mile of the nearest wind turbine. Specification includes distance-bin-by-project, census-block-group-by-project, and quarter-by-year-by-project fixed effects. Dotted red line denotes year prior to the announcement of a wind project. The thin vertical blue lines denote the 95% confidence intervals, whereas the thicker vertical blue lines denote the 90% confidence intervals. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

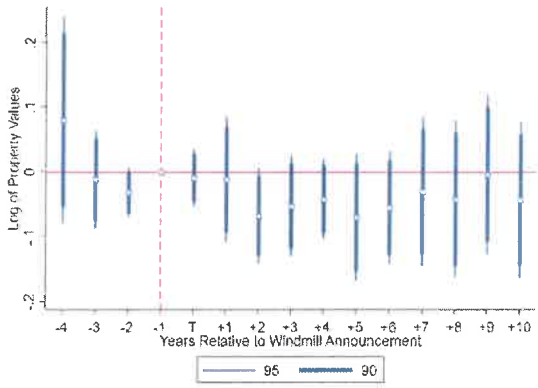

Fig. 4. Stacked Event Study Estimates for homes located within 1–2 Miles of a Turbine
Notes: Figure presents estimated coefficients from the stacked event study specification given by Equation (2). Estimates are for home located within 1–2 miles of the nearest wind turbine. Specification includes distance-bin-by-project, census-block-group-by-project, and quarter-by-year-by-project fixed effects. Dotted red line denotes year prior to the announcement of a wind project. The thin vertical blue lines denote the 95% confidence intervals, whereas the thicker vertical blue lines denote the 90% confidence intervals. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

negative impact of wind turbines on property values following announcement of a wind project for properties within a mile of the turbine. Importantly, Fig. 3 provides little evidence that property values within 1 mile of a turbine were trending either higher or lower relative to property values 3 to 5 miles from a turbine prior to the announcement of a wind project: the estimated coefficients on two, three, or four years prior to announcement indicators are small in magnitude and close to zero.

Figs. 4 and 5 present event study estimates for homes located more than 1 mile but within 2 miles of a turbine and homes located more than

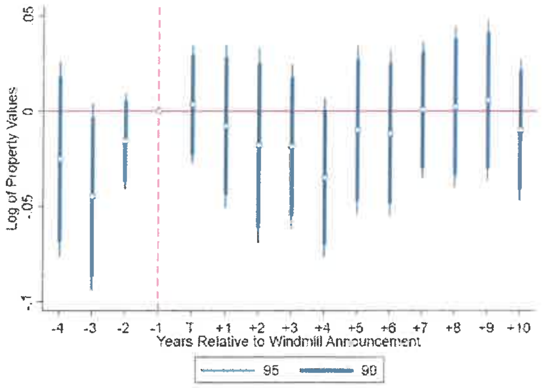

Fig. 5. Stacked Event Study Estimate for homes located 2 to 3 Miles of a Turbine

Notes: Figure presents estimated coefficients from the stacked event study specification given by Equation (2). Estimates are for home located within 2–3 mile of the nearest wind turbine. Specification includes distance-bin-by-project, census-block-group-by-project, and quarter-by-year-by-project fixed effects. Dotted red line denotes year prior to the announcement of a wind project. The thin vertical blue lines denote the 95% confidence intervals, whereas the thicker vertical blue lines denote the 90% confidence intervals. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

2 miles but within 3 miles of a turbine, respectively. For homes located within 1–2 miles of a turbine (Fig. 4), the estimated treatment effects follow a similar pattern to those shown in Fig. 3, except the estimated treatment effects post project announcement are much smaller in magnitude and noisier. Specifically, 2–5 years post project announcement, property values decline by approximately 6 percent but then begin to rebound 6–10 years post announcement. Furthermore, we once again find no evidence of pre-trending prior to the announcement of a wind project. In contrast, for homes located 2 to 3 miles from the nearest turbine (Fig. 5), there is some evidence of a small decline in property values (~3%) 2–4 years post project announcement but in general we see no meaningful pattern in the estimated treatment effects and very few of the coefficients are economically meaningful (coefficients are between −0.04 and 0.00) or statistically significantly different from zero.

We test the robustness of all our stacked DiD event study estimates using an alternative event study estimator developed by Sun and Abraham (2021), which is also free from contamination and bias that may arise in event study models with staggered timing of treatment and heterogeneous treatment effects. We report these event studies in Appendix Figure A3 through A5, and they are substantively and economically similar to our main event studies.

5.2. Difference-in-differences estimates

In Table 4, we present DiD estimates based on Equation (1). All specifications in Table 4 include our core fixed effect structure, namely distance-bin-by-project fixed effects and transaction quarter-by-year-by-project fixed effects. The estimates represent the average treatment effect after project announcement, through construction and into project operation. Columns 1–8 then present estimated treatment effects based on specifications with and without controls and with different locational fixed effects. Specifically, columns 1 and 2 present estimated treatment effects with and without controls from specifications that include census-tract fixed effects. Columns 3 and 4 replace the census tract fixed effects with census-tract-by-project fixed effects. Finally, columns 5 and 6 replace the census tract fixed effects in columns 1 and 2 with census block group fixed effects while columns 7 and 8 report results from our preferred specification which replaces the block group fixed effects with block-group-by-project fixed effects.

We begin by noting that the estimated treatment effects reported in Table 4 are remarkably robust regardless of the locational fixed effects we employ or whether or not we include controls: none of the estimated coefficients for each distance bin are statistically different from one another across each specification. While the coefficient on the "1–2 mile" indicator oscillates between being marginally statistically significant (in Columns 1–5 and 7) and statistically insignificant (in Columns 6 and 8), the magnitudes of the coefficients are all similar, i.e., varying between 3.06% and 4.36%. The "0–1 mile" indicator remains highly statistically significant and large in magnitude regardless of the specification. Moreover, the fact that the estimates reported in Table 4 are insensitive to the inclusion or exclusion of a host of controls for the physical characteristics of homes, provides further evidence that our event study and DiD estimates have a causal interpretation and that our identification strategy mimics a randomized control trial. Nevertheless, given the potential precision gains from including controls, our preferred specification includes the full set of controls for the attributes of transacted properties.

We present the results of our preferred specification from Equation (1) in Column 8. On average the announcement, construction and operation of a wind project causes a 10.91% decline in property values for homes that are within one mile of the nearest turbine. This is a meaningful, though as noted above, ephemeral, decline following project announcement. For homes located within 1–2 miles from the nearest turbine, we find a statistically insignificant 3.06% decline in sales price, which is approximately one-third the size of the impact on homes within one mile of the turbine. This suggests that the negative effects of proximity to turbines on home values dissipates rather quickly with distance. Consistent with that notion, for homes located 2 to 3 miles from the nearest turbine, we consistently find no negative impacts on home values—all the estimated coefficients are positive in sign but small in magnitude and statistically insignificant.[7]

Using our preferred specification, rather than using a somewhat arbitrary bandwidth of one mile, we estimate the impact of a wind turbines on home values using quarter-mile distance bins, and we plot these coefficients in Fig. 6.[8] Consistent with Table 4, we find that the impact of wind turbines on home values decays quickly with distance. In fact, we find no statistically significant impacts after 1.25 miles. In this figure, the comparison group is properties more than 3.25 miles from the nearest turbine. However, these results are robust to altering the comparison group to properties at least 2.5 miles from a turbine or those greater than 4 miles from a turbine. Note that the estimated coefficient on the [0 to 0.5) mile indicator bin is negative but statistically insignificant, likely because there are very few transactions within 0.5 miles of a turbine (hence the large standard errors).

5.3. Falsification tests, Robustness Checks, and heterogeneity analysis

To provide further evidence that our core results have a causal interpretation, we conduct a falsification test in which we randomly assign placebo wind energy projects to the centroid of census tracts located in counties *without* wind energy projects but with wind speeds

[7] Although not included in this paper for reasons of brevity we estimated effects within 1 mile of homes in four separate U.S. Census designated regions—the Northeast, Midwest, South, and West, finding similar temporal trends as the full sample but insignificant differences between the regions. These results are available upon request.

[8] Given the relatively few observations between 0 and 0.25 miles that are not properties that directly host wind turbines, we aggregate 0 to 0.5 miles together. The remaining indicators are quarter-mile bins.

Table 4
Main effects.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Log of Sale Price	Log of Sale Price	Log of Sale Price	Log of Sale Price	Log of Sale Price	Log of Sale Price	Log of Sale Price	Log of Sale Price
0 to 1 Mile (tx1)	-0.1288***	-0.1267***	-0.1283***	-0.1270***	-0.1120***	-0.1101***	-0.1102***	-0.1091***
	(0.0389)	(0.0406)	(0.0368)	(0.0383)	(0.0367)	(0.0390)	(0.0367)	(0.0388)
1 to 2 Miles (tx2)	-0.0436*	-0.0400*	-0.0423*	-0.0400*	-0.0382**	-0.0305	-0.0383**	-0.0306
	(0.0233)	(0.0241)	(0.0224)	(0.0231)	(0.0192)	(0.0204)	(0.0191)	(0.0203)
2 to 3 Miles (tx3)	0.0187	0.0152	0.0173	0.0134	0.0180	0.0141	0.0177	0.0138
	(0.0232)	(0.0223)	(0.0220)	(0.0211)	(0.0197)	(0.0180)	(0.0196)	(0.0179)
Observations	479,841	479,841	475,607	475,607	496,215	496,215	496,054	496,054
R-squared	0.7952	0.8255	0.8072	0.8337	0.7188	0.7781	0.7193	0.7784
Distance Bin-Project FE	Y	Y	Y	Y	Y	Y	Y	Y
Tract FE	Y	Y	N	N	N	N	N	N
Tract-by-Project FE	N	N	Y	Y	N	N	N	N
Block Group FE	N	N	N	N	Y	Y	N	N
Block Group-by-Project FE	N	N	N	N	N	N	Y	Y
Year-Quarter-by-Project FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	N	Y	N	Y	N	Y	N	Y

Notes: Table presents estimates or the impact of proximity to wind turbines on housing values based on Equation (1). All specifications include distance-bin-by-project fixed effects and year-by-quarter-by-project fixed effects. Specifications with controls include the full list of housing attributes reported in Table 1. Robust standard errors in parentheses, clustered at the project level. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

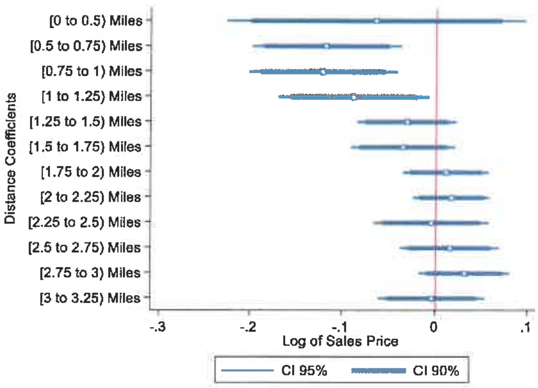

Fig. 6. Differences in Treatment Effect by Bin Distance
Notes: Figure presents estimated coefficients from a version of Equation (1) where we include indicator terms by the half-mile rather than the one-mile indicators presented in Equation (1). The specification includes distance-bin-by-project, census-block-group-by-project, quarter-by-year-by-project fixed effects, and control. The thin part of the blue lines denotes the 95% confidence interval, and the thicker part of the blue lines denotes the 90% confidence interval. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

and other characteristics that resemble counties with wind energy ("the matched sample"). Specifically, we first identify a sample of comparison counties, or counties that observationally resemble counties with wind projects, measured by socio-demographics and wind capacity, using propensity score matching. We use data on county income and demographic characteristics from the 2000 U.S. Decennial Census and measures of average county wind speed to estimate a propensity score using a nearest neighbor matching algorithm without replacement. We include controls for wind speed, wind speed squared, household income, population density, percent college educated, fraction homeowner, and share non-white. We exclude counties that have installed wind projects prior to 2005 from the falsification exercise.

We randomly sample census tracts from the matched sample and randomly assign project announcement dates to these placebo wind energy projects from the probability distribution function of announcement dates we observe in our analytic sample. We then re-estimate our DiD models 1100 times and plot the estimated coefficients, as well as the lower and the upper bounds of a 95% confidence interval for each coefficient, in Fig. 7 through 9. In Fig. 7, we see that our estimated effect from Table 4 for transactions within 1 mile lies significantly to the left of the estimated coefficients from this placebo test, which are normally distributed around zero. For transactions within 1–2 miles of a turbine, the estimated treatment effect from Table 4 is once again in the left tail of the distribution of estimated coefficients, while

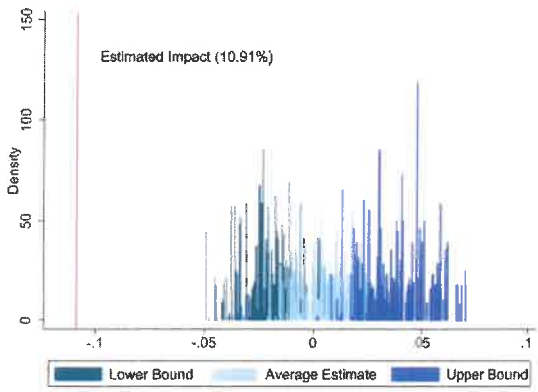

Fig. 7. Falsification Tests for within 1 Mile (N = 1100)
Notes: Figure presents estimates from falsification tests where we randomly assign pseudo wind energy projects to the centroid of census tracts located in counties without wind energy projects and randomly draw from the empirical distribution of actual project start dates. Red line depicts actual treatment effect estimate from column 8 of Table 4 for homes located within one mile of the nearest wind turbine. The lower bound is the lower bound of the 95% Confidence Interval for each of the average estimates, whereas the upper bound is the upper bound of the 95% Confidence Interval for each average estimate. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

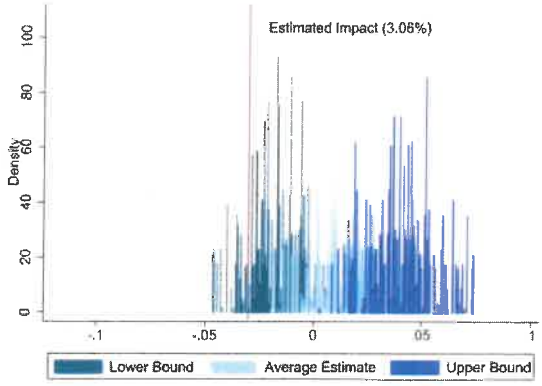

Fig. 8. Falsification Tests for homes located 1 to 2 Miles (N = 1100)
Notes: Figure presents estimates from falsification tests where we randomly assign pseudo wind energy projects to the centroid of census tracts located in counties without wind energy projects and randomly draw from the empirical distribution of actual project start dates. Red line depicts actual treatment effect estimate from column 8 of Table 4 for homes located within 1–2 miles of the nearest wind turbine. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

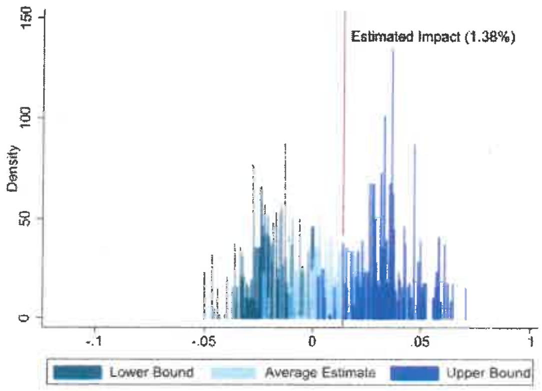

Fig. 9. Falsification Tests for homes located 2 to 3 Miles (N = 1100)
Notes: Figure presents estimates from falsification tests where we randomly assign pseudo wind energy projects to the centroid of census tracts located in counties without wind energy projects and randomly draw from the empirical distribution of actual project start dates. Red line depicts actual treatment effect estimate from column 8 of Table 4 for homes located within 2–3 miles of the nearest wind turbine. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

the estimated effect on homes between 2 and 3 miles from a turbine is within the distribution of the estimated coefficients, consistent with the results in Table 4 showing no impact of turbines on housing values for homes located 2 to 3 miles from the nearest turbine. Overall, the falsification tests provide robust evidence that our estimated impact of proximity to wind turbines on home values is not being driven by chance or idiosyncratic market factors.

As noted previously, we restrict our sample by trimming potential outliers which we define as transactions in the top and bottom percentile of sales amount, land area, or living area, as well as foreclosed properties. Trimming these potential outliers, which some studies define as the top/bottom percentile (see Hoen et al., 2011; Hoen et al., 2015) or the top/bottom 5th percentile (see Dong et al., 2023), is common in the existing literature. Moreover, foreclosed properties frequently sell for below-market rates in non-competitive or non-traditional sales, and thus we drop these observations as well (Mian et al., 2015). To ensure that these sample restrictions are not significantly affecting our analysis, Appendix Table A3 presents the results of our preferred specification (Column 8 of Table 4) for our analytic sample in Column 1, for the full sample with the bottom and top percentile observations and the foreclosed properties included in Column 2, for the sample where we drop the top/bottom percentile observations but include foreclosed properties in Column 3, and for the sample where we drop foreclosures but keep the top/bottom percentile in Column 4. The estimated coefficients are qualitatively, economically, and statistically similar across all samples.

Given results by Dröes and Koster (2016) and Dong et al. (2023), which find greater impacts of wind farms in urban areas, in Columns 1 and 2 of Table 5, we re-estimate equation [1] except we restrict our sample to projects located in counties in metro areas with populations of 250,000 or more. In column 3 and 4, we restrict our sample to projects located in metro counties with a population of less than 250,000 and non-metro counties.[9] Given that our identification strategy requires active housing markets with sufficient number of within-project housing transactions before and after the announcement of a project, 72.3% of our sample is located in highly urban counties with populations greater

Table 5
Results by urbanicity.

	Urban Sample (Counites with Pop ≥250,000)		Non-Urban Sample (Counites with Pop <250,000)	
	(1)	(2)	(3)	(4)
	Log of Sale Price	Log of Sale Price	Log of Sale Price	Log of Sale Price
0 to 1 Mile (tx1)	-0.1471***	-0.1494***	-0.0157	-0.0071
	(0.0407)	(0.0423)	(0.0432)	(0.0473)
1 to 2 Miles (tx2)	-0.0467**	-0.0427*	-0.0099	0.0059
	(0.0231)	(0.0240)	(0.0227)	(0.0185)
2 to 3 Miles (tx3)	0.0134	0.0094	0.0344	0.0324
	(0.0246)	(0.0220)	(0.0233)	(0.0229)
Observations	358,734	358,734	135,874	135,874
R-squared	0.7294	0.7801	0.6020	0.7128
Distance Bin-Project FE	Y	Y	Y	Y
Tract FE	N	N	N	N
Tract-by-Project FE	N	N	N	N
Block Group FE	N	N	N	N
Block Group-by-Project FE	Y	Y	Y	Y
Year-Quarter-by-Project FE	Y	Y	Y	Y
Controls	N	Y	N	Y

Notes: Table presents estimates or the impact of proximity to wind turbines on housing values based on Equation (1) for the sample of transactions located in counties in metro areas with population of 250,000 or more people, i.e., urban-rural continuum 2003 codes of 1 or 2. All specifications include distance-bin-by-project fixed effects and year-by-quarter-by-project fixed effects. Specifications with controls include the full list of housing attributes reported in Table 1. Robust standard errors in parentheses, clustered at the project level. ***p < 0.01, **p < 0.05, *p < 0.1.

[9] Specifically, we restrict our sample to counties with a 2003 urban-rural continuum classification of "1," which is "county in metro area with 1 million population or more" and "2", or a "county in a metro area of 250,000 to 1 million population." These urban-rural continuum codes are available from the Economic Research Services at the U.S. Department of Agriculture.

than 250,000. We find that our results are entirely driven by this urban sample. As shown in Columns 1 and 2, on average the announcement, construction, and operation of a wind project in an urban county causes a 14.94% decline in property values for homes that are within one mile of the nearest turbine. We also find a marginally statistically significant decline of 4.27% for homes located within 1–2 miles from the nearest turbine. We continue to find no impact on properties beyond 2 miles. In Fig. 10, we examine differences in treatment effects by quarter-mile distance bins, and we find statistically significant and negative effects of wind turbine announcement, construction, and operation on homes within 1.5 miles but no measurable impact beyond that distance.[10] The estimated effects of proximity to turbines in less urban and non-metro counties (Columns 3 and 4 of Table 5) are near zero and statistically insignificant. These results are similar (i.e., much smaller than the highly urban sample and statistically insignificant) if we restrict exclusively to non-metro counties that have an urban population of 20,000 people or fewer. Overall, these results suggest that the negative effects of proximity to turbines on home values dissipate quickly with distance, and most of these negative effects are driven by transactions in urban areas.

6. Conclusion and policy implications

Over the past 40 years, wind energy in the United States has grown from a relatively novel energy source in rural counties in the plains of North Dakota and the deserts of Southern California to now representing almost 40% of all new commercial energy installations in the United States (United States Energy Information Administration, 2022). This trend is expected to continue, with over 15 GW (GW) of land-based wind energy projects currently under construction, 9 GW in advanced

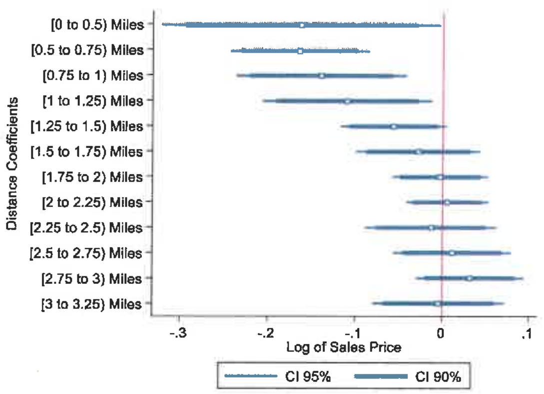

Fig. 10. Differences in Treatment Effect by Bin Distance for Urban Counties Notes: Figure presents estimates from equation [1] for transactions belonging to wind project constructed in urban counties with populations greater than 250,000. This urban classification is based on 2003 Rural-Urban Continuum Codes available from the Economic Research Services at the U.S. Department of Agriculture. The Urban restriction in this figure are counties with a "1" or "2" urban classification. The thin part of the lines is the edge of the 95% confidence interval, and the thicker part of the lines are the 90% confidence interval.

development stages, and more than 170 GW of land-based wind projects with active grid interconnection requests across the U.S at the end of 2022 (ACP, 2022; Rand et al., 2022). As wind energy has become an increasingly common energy source, wind turbines have, by extension, been sited increasingly closer to more populated areas and in proximity to more residential homes. While previous research examining the impact of wind turbines on property values in the United States has generally found small and statistically insignificant impacts of wind turbines on home prices (see Appendix Table A1), these studies have examined wind projects in relatively rural areas with comparatively fewer homes sales proximate to the wind turbines. Given the increasing encroachment of wind projects on residential areas, this study revisits this question using the most comprehensive dataset to date on wind turbines and nearby home sales.

We find that homes located within one mile of a commercial wind turbine experience on average approximately an 11% decline in value following the announcement of a new commercial wind energy project, relative to counterfactual homes located 3 to 5 miles away. This impact is dynamic —it is largely driven by declines in sale prices following the announcement and during the construction of a wind project. Once a wind project becomes operational, home prices tend to rise with property value impacts becoming small and statistically insignificant 9 years or more after the announcement of the project (about 5 years after project operation). This suggests that the housing market is reacting negatively to the expectation of likely impacts (after announcement) and the heightened activity during construction, but after operation begins, those negative perceptions and related home price impacts appear to fade. These results align with previous hedonic analysis (Dong et al., 2023) and qualitative research finding that attitudes toward wind projects are the most negative after announcement yet prior to operation (Devine-Wright, 2005; Ellis et al., 2023), which might be capitalized into home values, at least in some cases (Mills et al., 2019). It also might be explained by sorting (Tiebout, 1956), as individuals with more favorable attitudes toward the wind project move into the area, which has been found elsewhere (Hoen et al., 2019). Finally, a third possibility is that, during the pre-construction period, the actual (i.e., long-term) impacts to home prices cannot be determined because the turbines are not yet constructed and operational, so home buyers are internalizing that risk with lower offers.

We find the negative capitalization effect is localized to homes proximate to the wind projects and any negative effects decay quickly beyond 1.25 miles and these results are driven primarily by projects in highly urban counties, i.e., counties with a population greater than 250,000 people. What is unique about projects or the neighbors of those projects in counties with higher population densities? Wind projects are not located in urban areas, but, in these counties, might be nearer to then, i.e., in the urban fringe. We find in our own sample they have, on average, fewer turbines than the projects in more rural counties, indicating they have less land area to fit into. It might be the case that landowners who live in these urban fringe areas place greater value on the aesthetic qualities of the land than those who live in more rural areas, and therefore are averse to changes to those qualities (see Janhunen et al., 2014; Devine-Wright, 2009; Bessette and Mills, 2021).

We find the declines in property values induced by a wind project are borne by a geographically identifiable group of residents, suggesting policy mechanisms may exist to remedy these impacts.[11] Brunner et al. (2022) and Brunner and Schwegman (2022a), demonstrate that wind energy installations lead to significant increases in local government revenues due to the property tax payments and payments in lieu of taxes

[10] In results available upon request, we examine potential heterogeneity in our average treatment effects by size or scale of wind energy projects, the height of the turbines, and by population and housing density. We find no evidence that the impact of wind turbines on property values varies by the size of wind projects, whether measured by number of turbines or nameplate capacity, the height of the turbines, or the density of the local area.

[11] Further, property value impacts represent a potential distributive injustice, where the neighbors of a project are being disproportionately burdened as compared to homes further away from the project (Schlosberg, 2007; Jørgensen et al., 2020), though, Dong et al. (2023) theorize those impacted are more affluent.

that wind energy developers pay. One possible way to compensate homeowners located near a wind energy installation would be to provide them with a property tax abatement for a period after announcement and continuing for a period of years after operation begins, funded with the revenue generated from the wind project, that might offset any reduction in the value of their homes. Alternatively, compensation could be offered by developers directly to homeowners during this period as suggested by others (Jacquet, 2012; Walker et al., 2014; Garcia et al., 2016; Fast et al., 2016).[12]

On the other hand, because effects are found to begin prior to construction (and then fade), and therefore logically represent the pricing of future risk into the market (that is later not fully realized), possibly better efforts to describe the actual effects on communities can be employed. For example, simulations of the future views of turbines from individual homes are rarely, if ever, available. Instead, photo simulations from a relatively small set of prominent viewpoints in communities are provided, and, therefore, home buyers and sellers are left to speculate what views of turbines from their homes might look like. Similarly, the sounds of turbines, especially those at night when the background sounds dissipate (Müller et al., 2023), are not ever simulated at individual home locations, though they are often regulated at those locations (Haac et al., 2019). Providing views, both day and night, from many more viewpoints including homes throughout the community, and simulated sounds from different locations, might help to alleviate the practice of pricing in this risk. Opportunities for individuals to visit nearby projects and talk to existing homeowners near those projects might additionally help provide greater certainty of actual effects during this period. Finally, much has been written about the connection between local attitudes and perceptions of the planning process (e.g., see review by Rand and Hoen, 2017), and those perceptions and property values (Vyn, 2018). Therefore, if greater efforts are made to improve that process to give local stakeholders more say in the process, property values might be less impacted.

Further, the results of Brunner et al. (2022) and Brunner and Schwegman (2022a) suggest that local jurisdictions use the property tax revenue and PILOTS from wind energy installations to increase spending on public services, reduce property taxes, or both. A large literature starting with Oates (1969) demonstrates that reductions in local taxes and/or increases in public services are capitalized into housing values. Consistent with that notion Brunner and Schwegman (2022a) and Brunner and Schwegman (2022b) find that property values in counties with large wind energy installations tend to rise after the turbines become operational. This suggests another avenue through which wind energy installations may increase the local tax base and hence provide another stream of revenue to compensate homeowners in close proximity to turbines for any property value losses. Because this study compares values of sets of homes all within 5 miles of the same wind project, this capitalization effect, if it exists, would be experienced by all homes in the local jurisdiction. These potential positive effects are, therefore, not exhibited in our results.

Given these results, a number of areas of further research are encouraged. Conducting an analysis where views of turbines are explicitly accounted for would be valuable, building on the previous literature (e.g., Lang et al., 2014; Jensen et al., 2018; Gibbons, 2015; Sunak and Madlener, 2016; Hoen et al., 2011). Further, examining positive impacts wind energy projects might have, such as within school district and county boundaries, would be valuable. Finally, qualitative work, with an attempt to unpack housing preferences among a large set of buyers and sellers, especially those in urban areas, would provide more insight into the largely heterogenous set of findings in this literature and this paper. Combining that with longitudinal data collection would be particularly valuable to further investigate how and why sentiment toward local projects evolves over time in different locations.

CRediT authorship contribution statement

Eric J. Brunner: Conceptualization, Methodology, Validation, Formal analysis, Writing – original draft, Writing – review & editing, Supervision. **Ben Hoen:** Conceptualization, Funding acquisition, Writing – original draft, Writing – review & editing, Supervision, Project administration. **Joe Rand:** Software, Data curation. **David Schwegman:** Conceptualization, Methodology, Validation, Formal analysis, Data curation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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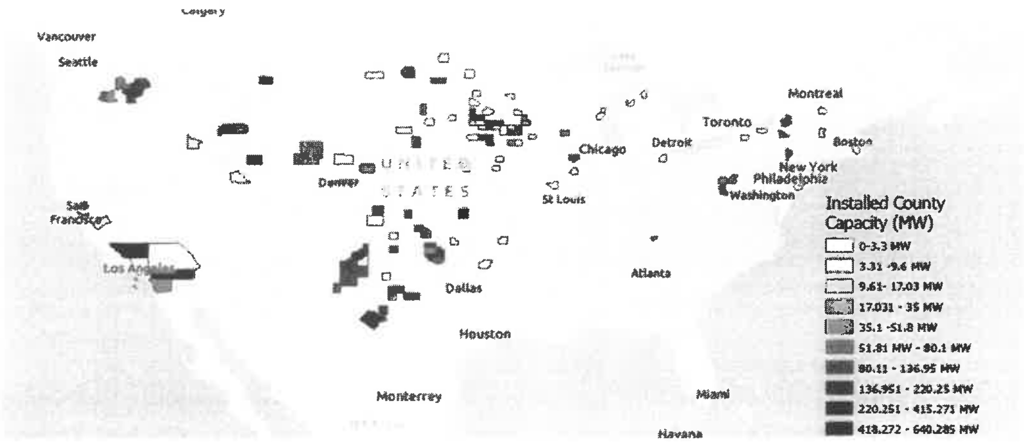
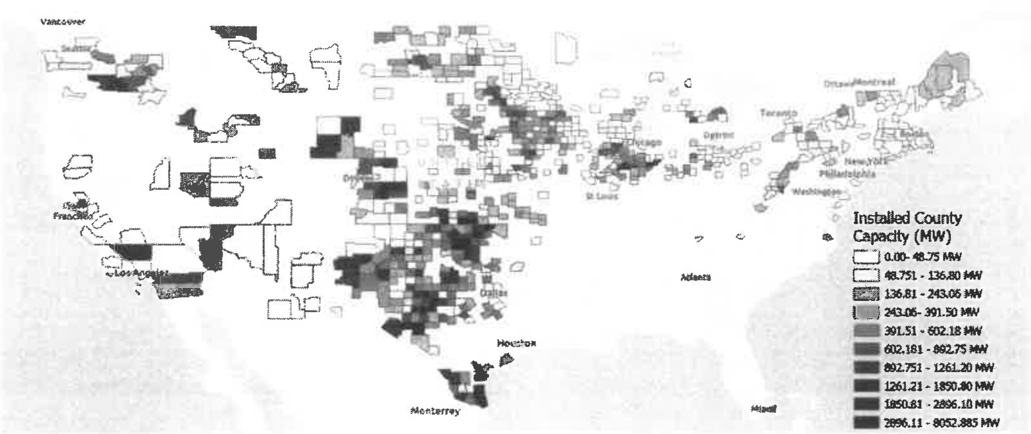
Appendix Figures and Tables

[12] One anonymous reviewer suggested a property value guarantee similar to the one offered in Denmark. Though, this approach has been criticized as not addressing key concerns (Jørgensen et al., 2020) and would require an appraisal of individual properties, which is highly susceptible to spurious results because of the small sample sizes.

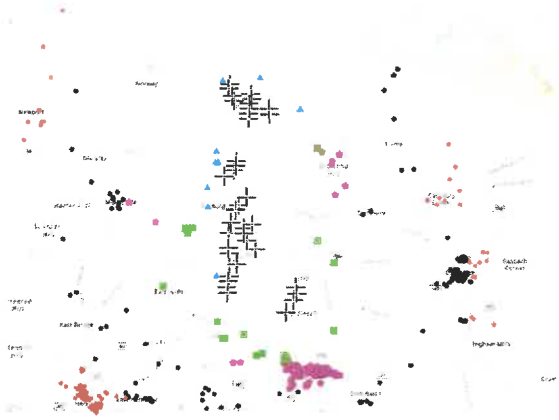
Installed Capacity by County in 2005



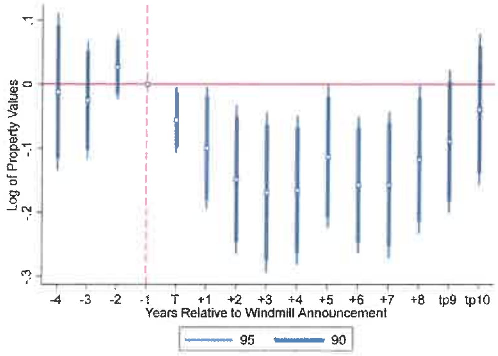
Installed Capacity by County in 2022



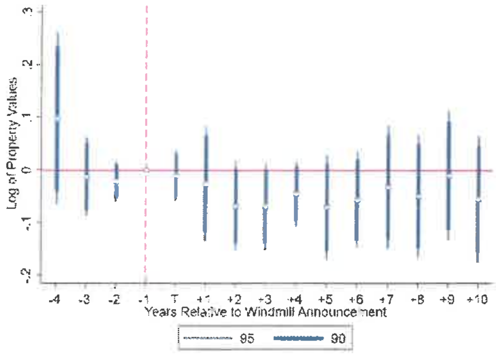
Appendix Fig. A1. County-Level Installed Wind Energy Capacity in 2005 and 2022 (MW).



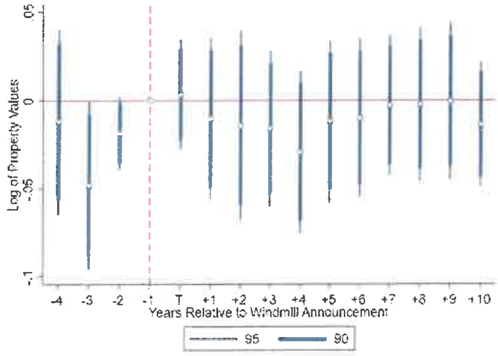
Appendix Fig. A2. Example Project (Herkimer County, New York)
Notes: Figure presents a representative wind energy project from our analytic sample. Black crosses represent wind turbines, blue triangles denote homes located within 1 mile of the nearest wind turbine, homes within 1–2 miles are depicted using green squares, and homes within 2–3 miles are depicted as purple pentagons. Our comparison homes are represented by black dots while transactions greater than 5 miles (excluded observations) are depicted as red dots.



Appendix Fig. A3. Sun and Abraham (2021) Event Study Specification, 0 to 1 Mile
Notes: Figure presents event study estimates based on the estimator developed by Sun and Abraham (2021). Estimates are for homes located within 1 mile of the nearest wind turbine. Specification includes distance bin, census block-group, and quarter-by-year fixed effects. Dotted red line denotes year prior to the announcement of a wind project. The thin vertical blue lines denote the 95% confidence intervals, whereas the thicker vertical blue lines denote the 90% confidence intervals.



Appendix Fig. A4. Sun and Abraham (2021) Event Study Specification, 1 to 2 Mile
Notes: Figure presents event study estimates based on the estimator developed by Sun and Abraham (2021). Estimates are for home located within 1–2 miles of the nearest wind turbine. Specification includes distance bin, census block-group, and quarter-by-year fixed effects. Dotted red line denotes year prior to the announcement of a wind project. The thin vertical blue lines denote the 95% confidence intervals, whereas the thicker vertical blue lines denote the 90% confidence intervals.



Appendix Fig. A5. Sun and Abraham (2021) Event Study Specification, 2 to 3 Mile

Notes: Figure presents event study estimates based on the estimator developed by Sun and Abraham (2021). Estimates are for home located within 2–3 miles of the nearest wind turbine. Specification includes distance bin, census block-group, and quarter-by-year fixed effects. Dotted red line denotes year prior to the announcement of a wind project. The thin vertical blue lines denote the 95% confidence intervals, whereas the thicker vertical blue lines denote the 90% confidence intervals.

Appendix Table A1
Wind Energy Studies

Notes: All studies citations can be found in the reference list. North American studies are in the top panel, while non-North American (primarily European) studies are in the bottom panel. All studies that find a negative impact (or association) between wind projects and home values are colored in red under the findings column. Studies that find no significant impacts or minimal impacts are colored black.

Study	Location	Sample Size (distance)	Findings
North American Studies			
Grover (2002)	USA	n/a (2-25 miles)	No impact on property assessments
Laposa and Miller (2010)	USA	2,910 (n/a)	Insignificant and minimal impacts
Hoen et al. (2011)	USA	2,500 (0-3 miles); 7,500 (0-5 miles)	No significant impact on property values
Heintzelman and Tuttle (2012)	USA	1,1659 (0-1 mile); 11,331 (0-10 miles)	Significant decline in sale price (-8% - -15% for homes within 1 mile)
Lang et al. (2014)	USA	3,254 (0-1 mile); 48,554 (0-5 miles)	No significant impact on property values
Hoen et al. (2015)	USA	1,198 (0-1 mile); 50,000 (0-10 miles)	No significant impact on property values
Castleberry and Greene (2018)	USA	23,000	No significant impact on property values
Hoen & Atkinson-Palombo (2016)	USA	1,503 (0-1 mile); 122,000 (0-5 miles)	No significant impact on property values
Dong, Gaur, & Lang (2023)	USA	369,260 (0 – 3 KM)	Significant decline in in sales prices (-2.5 to -4.6 % for homes within 2 miles)
Vyn and McCullough (2014)	Canada	32 (0-2km); 106 (0-10 km)	No significant impact on property values (2.5 to 4.6% for homes within 1km)
Vyn (2018)	Canada	Unknown	WTs have negatively impacted property values in "unwilling host" municipalities, while no significant impacts are found in unopposed municipalities.
Non-North American Studies			
Jensen et al. (2014)	Denmark	12,640 (0-2.5 km)	Significant reduction in sale price (-3% for homes with a view and -6.7% for homes with significant noise exposure)
McCarthy & Balli (2014)	New Zealand	945	No significant impact on property values
Gibbons (2015)	UK	38,000 (0-2 km)	Significant reduction in sale price (-5-6% within 2 km with larger effects for visible areas)
Droes and Koster (2016)	Netherlands	80,000 (0-2 km)	Significant reduction in sale price (-1.4% within 2 km)
Sunak and Madlener (2016)	Germany	2,141 (0-3 km)	Significant reduction in price (-9-14% if turbine visible). No impact if no or marginal view.
Jensen et al. (2018)	Denmark	4,932 (0-3 km)	Significant negative effect to a distance of 3 km.
Droes and Koster (2021)	Netherlands	171,500 (0-2 km)	Large turbines decrease house prices within 2 km by 5.4%.
Jarvis (2021)	UK	~8 million transactions; includes failed wind projects (0-5 km)	The median wind project causes a 4-5% reduction in residential property values at 2km. Effects increase at closer distances and for larger projects.
Sims and Dent (2007)	UK	1,052 (0.5-4 miles)	No significant impact on property values
Sims et al. (2008)	UK	201 (0-0.5 mile)	No significant impact on property values

Appendix Table A2
Retention criteria for transactions

Condition for retention	Rationale
Coordinate values are populated	Coordinates are needed to obtain distances between homes and wind turbines.
Land area, year built, and home square footage are populated	Land area, year built, and home square footage are essential property characteristics to control for in analysis
Coordinates appear 20 times or less	Repeated, identical coordinates for multiple properties may indicate data quality issue

(*continued on next page*)

Appendix Table A2 (*continued*)

Condition for retention	Rationale
Property type is residential (including single family residence, condominium, duplex, apartment)	Analysis only considers homes (i.e. residential properties) sold in arms-length transactions after the year 2000
Transaction is categorized as arms-length	
Year of sale between 2000 and December 2020	
Sale amount is greater than $5000 or the 1st percentile of sale price (whichever value is higher) and less than the 99th percentile of sale amount values within a given state	Removing outliers from analysis
Sale amount per unit area of living space is greater than the 1st percentile and less than the 99th percentile of sale amount per unit area of living space values within a given state	
Land area is greater than the 1st percentile and less than the 99th percentile of land area values within a given state	
Property was built before 2020, and after the 1st percentile of values for year built within a given state	
Sale amount is greater than the mortgage amount, or mortgage amount is missing	Any other relationship (between sale amount & mortgage amount, land area & living space area, sale year & year built, set of variables representing land area) may indicate data quality issues
Land area is greater than living space area	
Age of property (sale year minus year built) is non-negative	
Both variables representing land area converge within 0.01 acres	
Deed is not categorized as foreclosure	Sale amount in a foreclosure may not accurately represent the value of a home
Sale occurred over one year after last recorded sale for that property	Removes potentially "flipped" homes, or homes that undergo a rapid renovation and are re-sold, from dataset; for those homes, characteristics in CoreLogic dataset may not be representative of characteristics after renovation
Property address was not determined from mail	Address determined from mail may reflect the address of an absentee owner, not of the physical property location

Appendix Table A3
Robustness Checks to Sample Restrictions

	(1)	(2)	(3)	(4)
	Log of Sale Price	Log of Sale Price	Log of Sale Price	Log of Sale Price
0 to 1 Mile (tx1)	-0.1091***	-0.1036***	-0.1073***	-0.0978**
	(0.0388)	(0.0380)	(0.0379)	(0.0395)
1 to 2 Miles (tx2)	-0.0306	-0.0239	-0.0329*	-0.0228
	(0.0203)	(0.0226)	(0.0199)	(0.0217)
2 to 3 Miles (tx3)	0.0138	0.0154	0.0123	0.0165
	(0.0179)	(0.0180)	(0.0175)	(0.0184)
Sample	Analysis Sample	Full Sample – Including Top and Bottom 1% and Foreclosures	Dropping Top and Bottom 1% Sample	Dropping Foreclosures
Observations	496,054	537,929	516,898	515,895
R-squared	0.7784	0.7698	0.7764	0.7868

Notes: Table presents separate estimates by different sample restrictions of the impact of proximity to wind turbines on housing values based on Equation (1). All models include distance-bin project fixed effects, block-group by project fixed effects, year-quarter-by-project fixed effects, and controls (i.e., the same model as Column 8 of Table 4). Standard errors clustered at the project level. ***p < 0.01, **p < 0.05, *p < 0.1.

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Property value
Height
distance

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Wind turbines, solar farms, and house prices☆

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ABSTRACT

This paper examines the effect of wind turbines and solar farms on house prices. Using detailed data from the Netherlands between 1985 and 2019, the results show that tall wind turbines have considerably stronger effects on house prices, as compared to small turbines. For example, a tall turbine (>150m) decreases house prices within 2 km by 5.4%, while a small turbine (<50m) has an effect of maximally 2% and the effect dissipates after 1 km. Further results indicate that solar farms lead to a decrease in house prices within 1 km of about 2.6%. By comparing the overall impact on house prices, we show that the external effects of solar farms per unit of energy output are comparable to those of wind turbines. Thus, building solar farms instead of wind turbines does not seem to be a way to avoid the external effects of renewable energy production.

1. Introduction

Renewable energy is on the rise. While global demand is still strongly increasing, the demand for fossil fuels has actually strongly declined (IEA, 2020). Furthermore, the current Covid-19 crisis has made clear the downsides of fossil fuels: the effective use of fossil fuels depend heavily on storage capacity and transportation (Science, 2020). Instead, renewable energy is typically produced locally and could be a viable alternative to fossil fuels. Two important sources of renewable energy production are wind turbines and commercial solar farms.

Renewable energy production may have external effects on local residents (Meyerhoff et al., 2010; Groth and Vogt, 2014). Wind turbines make noise, cast shadows, and create flickering. Moreover, turbines can visually pollute the landscape, particularly if they are tall. Solar panels can reflect sound and sunlight and are also usually not considered to be aesthetically pleasing. In line with a large literature on hedonic pricing, we would expect that such externalities capitalize into house prices. Increasing our understanding of these external effects is policy-relevant for at least two reasons. First, it provides insight in what could be a more efficient allocation of renewable energy production facilities (Rodman and Meentemeyer, 2006). Second, because the effects of wind turbines and solar farms are local, the effect on house prices is indicative that the burden of renewable energy production is not necessarily distributed equally within society.

The aim of this paper is to examine the effect of wind turbines and solar farms on house prices. We employ a quantitative revealed-preferences approach to measure this effect. We contribute to the existing literature in several ways. First, this paper explicitly focuses on the role of turbine height on house prices. In particular, we investigate whether tall turbines have a larger effect on house prices *and* at a larger distance. Given the substantial increase in wind turbine height in the last years, we would expect heterogeneity in the effect of turbines of different heights on house prices. This is important for spatial policies regarding the placement of wind turbines.[1]

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[1] Some studies find effects of turbines up to 14%, while others do not find any effect (see Appendix A.1 for an extensive review). One potential explanation is that previous studies did not take into account that large turbines may lead to larger decreases in housing values. A notable exception is Dröes and Koster (2016), who show that in the Netherlands turbines larger than 100m lead to an additional price decline of 2.2%. However, Dröes and Koster (2016) only analyze a handful of tall turbines and it remains unclear whether the spatial extent of negative externalities for turbines of different heights is the same.

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E-16

Second, to identify a causal effect of renewable energy production facilities on house prices is not straightforward, as turbines and solar farms are mostly located in sparsely populated areas with lower house prices. That is, the placement of renewable energy production sites is not random. To mitigate endogeneity concerns many studies use a differences-in-differences design based on comparison with a local control group (Gibbons, 2015; Dröes and Koster, 2016; Jensen et al., 2018). A key identifying assumption is that there are *parallel trends* between treated and control areas. This assumption may be restrictive and is hard to test.[2] Instead, we exploit *temporal variation* in the openings of turbines and solar farms. That is, we employ a hedonic regression design that compares price changes in areas that have received a wind turbine or solar farm; to areas that will receive a turbine or solar farm in the future. By examining the causal effect on *house prices* we aim to measure the (revealed) preferences of households regarding the placement of wind turbines and solar farms.[3]

Third, to the best of our knowledge, we are among the first to investigate the impact of solar farms on house prices. For solar farms, we use essentially the same identification strategy as for wind turbines. However, the effects of solar farms are expected to be more local than those of wind turbines, as visual pollution is likely to be more localized. Additionally, we compare the results of solar farms to those of wind turbines. Many previous studies only focus on a single type of renewable energy production facility.

This paper relies on detailed housing transactions data from the Netherlands between 1985 and 2019, which we combine with data on all wind turbines and solar farms that have been placed during this period. The Netherlands is typically seen as a fairly urbanized country and thus provides an ideal study area to examine the external effects of wind turbines and solar farms on house prices.[4]

The results in this paper show that the construction of a wind turbine leads to a decrease in local house prices of 1.8%. In particular, we find that a turbine taller than 150m decreases prices within 2 km by 5.4%, while the effect of small turbines (<50m) is statistically indistinguishable from zero. Also, the effect of tall wind turbines does not extend much beyond 2 km, but we do find evidence that the impact radius is smaller (<1 km) for low wind turbines. Various additional robustness checks support the main findings. Regarding solar farms, we find that house prices decrease by about 2.6% after opening. The effect is confined to 1 km, so it is more localized than that of wind turbines.

Finally, we show that the total loss in housing values as a result of the placement of wind turbines is about €5 billion, while solar farms imply a total loss of €800 million. Yet, 1% of the turbines cause almost 50% of the total loss in housing values. These are turbines that are placed too close to residential areas. The median loss per installed megawatt-hour (MWh) is €53, with taller turbines having a much lower median loss per MWh (*i.e.* €277 for a turbine <50m versus €11 for a turbine >150m). Hence, it seems much more efficient to build taller, more powerful, turbines. We further find that the average loss per MWh for a solar farm is of the same order of magnitude as that of a wind turbine.

From a policy perspective, our results thus imply that building solar farms instead of wind turbines will not mitigate the external effects of renewable energy production. Our results further highlight the importance of avoiding the placement of wind turbines and solar farms near urban areas.

The remainder of this paper is structured as follows. Section 2 provides a discussion of the international and Dutch policy context. Section 3 discusses the data, while the methodology is discussed in Section 4. Section 5 highlights the regression results and Section 6 concludes.

2. Policy context

Wind turbines are an important source of renewable energy with 30% of its capacity located in Europe and 17% in the U.S. in 2018. Especially China has invested heavily in wind energy, overtaking the E. U. already in 2015 as being the largest producer of wind energy. Currently, 36% of worldwide capacity is located in China (GWEC, 2019). Many other Western and Asian countries have been increasing their capacity over the past decades as well. Technological change fueled by an increased demand for energy has led wind turbines to become taller over time (as taller turbines produce more energy). Where turbines in the 1980s were still around 30m, the newest generation of wind turbines is currently well above 100m.[5]

A relatively new phenomenon is the commercial production of renewable energy via solar farms, which are large fields of solar panels. The first solar farm was constructed in 1982 in California. Yet, with advances in technology, it has become attractive to commercially exploit solar farms only in the last decade or so. Many countries, like India, China, and the United States have heavily invested in very large solar farms.[6]

In 2019, the renewable energy capacity captured 27% of total electricity production with solar photovoltaics capturing only 2.8% of the total production, about half that of wind turbines. Hydropower is still one of the largest contributors. By contrast, last year's growth in solar photovoltaics capacity was about twice that of wind turbines (REN21, 2020). Whether the current surge in the construction of tall wind turbines and solar farms will continue remains to be seen, but some countries have already suggested that the economic recovery after Covid-19 should be a green one (Associated Press, 2020).

In this study, we focus on the Netherlands (which is an E.U. member state). The E.U. has extended its energy efficiency directive in 2018 posing new targets for 2030. According to the national energy and climate plans of the different member states, many European countries will rely on wind and solar energy to meet those targets. In 2013, the Dutch government reached an energy agreement with many central stakeholders in the Dutch society (*i.e.* labor unions, environmental organizations, financial institutions) to reduce CO_2 emissions by 2020–2023. An important pillar of this agreement is to construct about 1300 wind turbines on land (SER, 2013).[7]

In 2019, this ambition was extended and a National Climate Agreement was reached to reduce CO_2 emissions by 49% in 2030 compared to 1990. To achieve this goal, about 50% of renewable energy production should be realized on land (35 of the 84 TWh), while the remainder will be produced offshore. Furthermore, a large-scale subsidy program is now in operation and 30 Dutch regions are required to develop energy production plans. From this, it is clear that wind and solar energy produced on land will play a major role in reaching the renewable energy goals (National Climate Agreement, 2019). Although the Dutch government aims to ensure the participation of local residents in developing renewable energy production sites, there have been a lot of protests, particularly against tall wind turbines (Telegraaf, 2020). Our study is

[2] For a more elaborate discussion, see Bertrand et al. (2004); Abadie (2005), and Donald and Lang (2007).

[3] More specifically, house prices are a useful monetary measure of household preferences (Rosen, 1974).

[4] The Netherlands (an E.U. member state) is more than twice the size of the San Francisco Bay Area (U.S.) but has a comparable population density (430/km^2 versus 488/km^2 for San Francisco).

[5] The average power a turbine <50m generates is 0.14 MW, while it is 4.15 MW for a turbines >150m. These are large differences in potential energy output.

[6] Currently, the largest solar farm in the world is 40 km^2, located in Bhadla, India.

[7] In 2019, the Dutch government lost a major court case against the non-profit environmental organization *Urgenda* because it did not fulfill its climate goals set for 2020. This event created a precedent for other related court cases in other E.U. member states (Supreme Court, 2019), and has created a sense of urgency to increase renewable energy production more quickly.

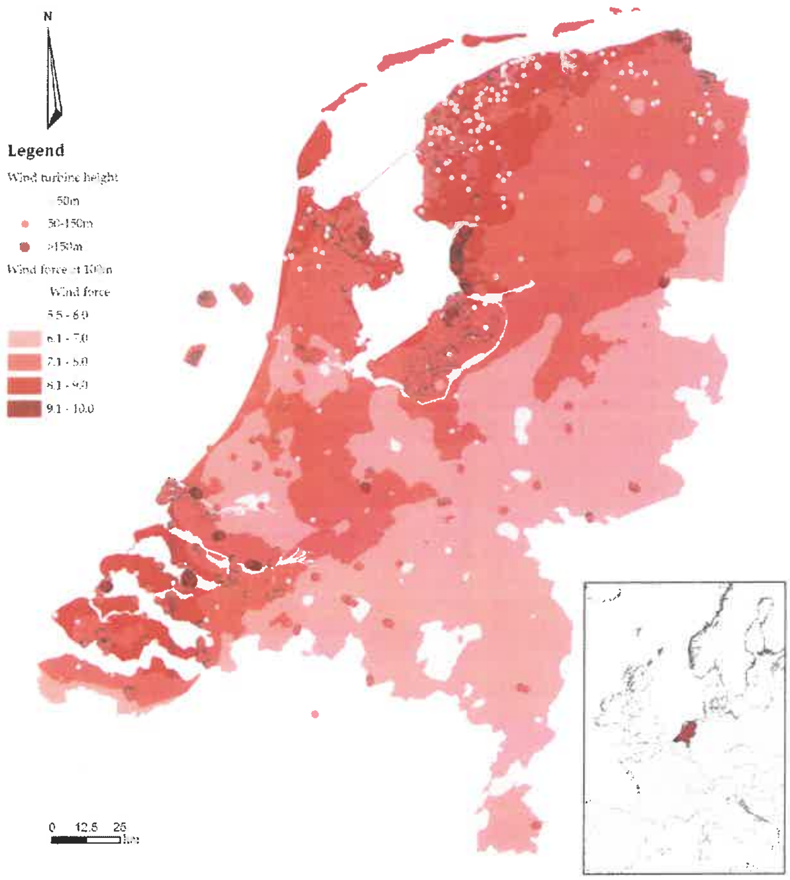

Fig. 1. The location of wind turbines
Notes: We obtain data on solar farms from windstats. Data on wind speeds is from the KNMI. The map is compiled by the authors.

therefore very societally relevant.

3. Data

3.1. Data on wind turbines and housing values

The locations of wind turbines, as well as the axis height, diameter of the blades, and the power (MW) of the turbine come from www.windstats.nl. We define *turbine height* as the axis height plus half the diameter of the rotor blades (*i.e.* the so-called tip height).[8] There is a very high correlation ($\rho = 0.918$) between height of the turbine and the power it generates. For example, a turbine of 3 MW (with a height of about 150m) produced 6.5 million kWh, while a turbine of 2 MW (115m) only provides 4.5 million kWh.

The total number of wind turbines up to and including mid-2019 is 2, 695. This study focuses on the 2, 406 turbines that have been built on land.[9] Of the turbines that have been built on land, 614 were built after 2011. Many of these new turbines are close to the locations where wind turbines have previously been installed. Fig. 1 shows the locations of wind turbines. The map highlights that wind turbines are often concentrated in coastal areas (which have a lot of wind). Fig. 2 shows that there is clearly an upward trend in the height of turbines. In 2000 the average height of new turbines was still around 80m. Towards the end of the sample period, the average height is about 140m with a maximum of 200m. Interestingly, the trend seems to stabilize as of 2016. Currently, low turbines (<50m) account for about 10% of the turbines, medium-sized (50–150m) for about 80% and tall turbines (>150) for the remaining 10%.

The dataset concerning house prices has been provided by Brainbay. The data cover approximately 70% of the market.[10] The data contain

[8] Dröes and Koster (2016) use axis height and the diameter of rotor blades separately, but the effect of these are difficult to measure as height and diameter of the blades are highly correlated (*i.e.* there are 'no high turbines' with tiny blades).

[9] The *Princess Amalia*, *Egmond aan Zee*, *Luchterduinen*, and *Gemini* offshore wind farms are therefore not included in our analysis, *Gemini* is missing from the map shown here because it is far from the coast.

[10] The sales that are not included are by real estate agents that are not a member of the NVM real estate organization, but most of them are.

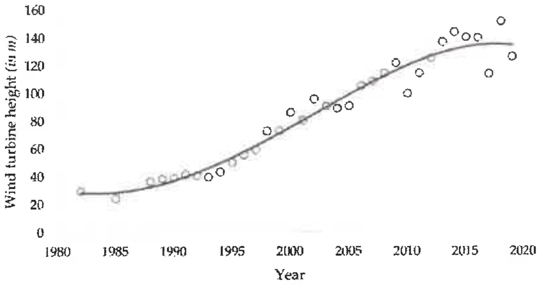

Fig. 2. Average height of new wind turbines
Notes: We obtain data on the height of wind turbines from Windstats. The solid line indicates the non-linear trend line.

sales of existing properties between 1985-(mid)2019. In addition to property prices, the dataset includes information on many different property features. Based on this, we can calculate the distance to the nearest existing wind turbine for each (transacted) home in our sample. The descriptive statistics are reported in Table 1.

The average house price between 1985 and 2019 is €214.178. This is based on more than 3 million transactions (2.7 million homes). The average house price is slightly lower (€206.658) within 2 km of an existing wind turbine, suggesting there is a slight tendency to built turbines in areas with lower prices. In Appendix A.2 we provide more details on differences between treated and control areas.

Finally, the average distance of properties to wind turbines in 2019 is 8.7 km. This distance has been decreasing for years; in 1995 for example the distance was still 26.6 km. However, for many households, wind turbines are still relatively far away. Only 5.1% of the housing transactions between 1985 and 2019 occur within 2 km wind turbines *after* they have become operational. Yet, the total number of transactions near all wind turbines present in 2019 is 290,002 (238,164 houses).

3.2. *Data on solar farms and housing values*

The data on solar farms come from Zon op Kaart, compiled by ROM3D. We have double-checked these data through OpenStreetMap. Furthermore, using OpenStreetMap, we geocode the data so that we have exact information on the size and geographic demarcation of solar farms. The number of solar farms (107) included in the analysis is much lower than the number of wind turbines.[11]

Fig. 3 shows the location and opening year of solar farms in the Netherlands until mid-2019. The first solar farm in our dataset is *Ecopark Waalwijk* (4.2 thousand panels) which opened in 2004. The locations of the solar farms are not randomly distributed in the Netherlands. As solar farms are land-intensive, many solar farms are located in areas with a low population density because of land availability.

The largest solar farm currently is located in Vlagtwedde (Groningen) and consists of 320,000 solar panels (approximately 1 km^2) with a total nominal peak power of 109 MWP.[12] It appears that new solar farms generally contain more panels, so the size of solar farms has increased over time. Using the data on property transactions, we calculate the distance of each property to the edge of the nearest solar farm.

Although the first solar farm was opened in 2004 we do not observe transactions within 1 km after the opening of this solar farm. 97 solar farms were opened in 2017, 2018, and 2019. Because almost all solar farms have been opened in recent years, we use the transactions data from the last 10 years (*i.e.* from 2009 to 2019). The descriptive statistics are reported in Table 2.

The average property price between 2009 and mid-2019 is €249, 586. The other descriptive statistics regarding housing characteristics are almost identical to those of wind turbines. The number of transactions in the Netherlands between 2009 and 2019 is about 1.5 million. Yet, there are not that many observations nearby solar farms. In particular, within 1 km there are 1,736 transactions *after* the placement of a solar farm (0.118% of the data). Fortunately, the total number of transactions within 1 km of all solar farms that are present in 2019 is 12,650 (11,843 houses).

Similarly to wind turbines, house prices within 1 km of a solar farms are lower (€226,000) than the sample average. These, and other descriptive statistics, are discussed in more detail in Appendix A.2.

Table 1
Descriptives: house prices and wind turbines.

	(1)	(2)	(3)	(4)
	Mean	St.dev.	Min	Max
Transaction price (€)	214,180	121,704	25,000	1,000,000
Wind turbine, <2 km	0.0506	0.2192	0	1
House size in m^2	117.9	37.71	26	250
Number of rooms	4.384	1.340	1	25
Terraced	0.317	0.465	0	1
Semi-detached	0.281	0.449	0	1
Detached	0.128	0.334	0	1
Garage	0.331	0.471	0	1
Garden	0.976	0.154	0	1
Maintenance state is good	0.866	0.341	0	1
Central heating	0.891	0.312	0	1
Listed building	0.00618	0.0784	0	1
Construction year 1945–1959	0.0717	0.258	0	1
Construction year 1960–1970	0.150	0.357	0	1
Construction year 1971–1981	0.169	0.374	0	1
Construction year 1981–1990	0.138	0.345	0	1
Construction year 1991–2000	0.126	0.332	0	1
Construction year >2000	0.109	0.311	0	1

Notes: The number of observations is 3,389,903. The data covers the period 1985-(mid)2019. Apartments are the reference group for the type of residence. Houses built before 1945 are the reference category for the building year.

4. Methodology

4.1. *Measuring the price effect of wind turbines*

To measure the effect of wind turbines on house prices, we employ a difference-in-differences hedonic price method in which house price developments nearby wind turbines are compared with house price developments further away. In particular, we estimate:

$$\log P_{it} = \beta w_{it-1} + \gamma X_{it} + \lambda_j + \lambda_t + \epsilon_{it}, \quad (1)$$

where P_{it} is the transaction price of property i sold in year t, w_{it-1} is an indicator that is 1 if a property is sold within 2 km in all years *after* placement of a wind turbine (for now we focus on the nearest wind turbine), X_{it} are housing characteristics, λ_j are location fixed effects at the postcode 6-digit level (containing about a half a street and on average just over 20 households, but fewer in rural areas), λ_t are month and year time dummies that control for overall price trends and seasonality, ϵ_{it} contains characteristics of properties or locations that are unobserved. These are assumed to be uncorrelated with the placement of

[11] Importantly, we disregard solar panels on roofs of industrial or agricultural buildings and only consider land-based solar farms.

[12] This solar farm produces about 0.85 × 1,000,000 × 109 = 92 million kWh per year (see Tenten Solar, 2019). For comparison purposes, an (average) wind turbine of 3 MW delivers around 8 million kWh; the park is therefore roughly equal to 14 wind turbines.

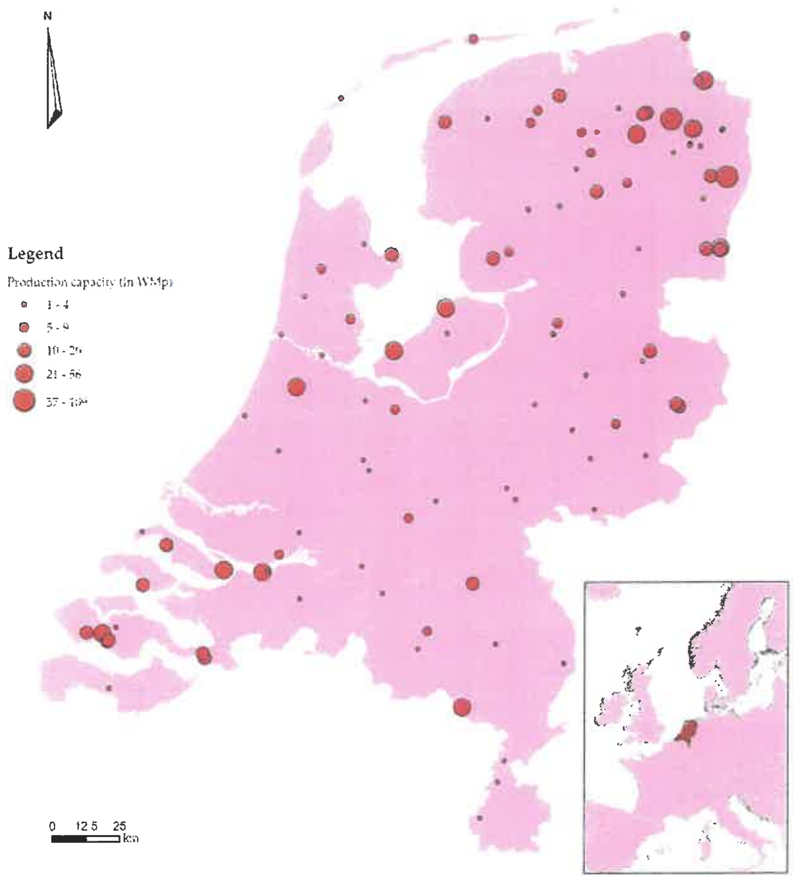

Fig. 3. The locations of solar farms (until mid-2019)
Notes: We obtain data on solar farms from ZonopKaart. The first solar farm was built in 2004. The map is compiled by the authors.

a turbine.[13]

We control for any time-constant price difference across locations. This is important as differences in prices may arise because amenities may differ between locations (for example, the presence of schools, etc.). To alleviate the concern that the location fixed effects are not detailed enough we will also show robustness using a repeat sales approach, completely absorbing time-invariant property and location characteristics. We use 2 km around turbines as treatment areas, as most of the noise (<500m), flickering (<1000m), and landscape pollution (< 2000m) typically falls within this area (Dröes and Koster, 2016). Nevertheless, we will also explicitly investigate whether the effect reaches beyond 2 km.

We are particularly interested in β, which measures *the percentage change in property value relative to a (local) control group*. We start our analysis by using transactions in the rest of the Netherlands as the control group and subsequently examine the effect using 3–5 km and 2–3 km as control group areas.

Still, one may be concerned that properties that are further away than 2 km may have different price trends. For example, they may be located closer to city centers, which are prone to relatively strong price increases due to inelastic housing supply and gentrification. Our preferred specification therefore only keeps observations within 2 km of a (future) wind turbine, implying that we only use the variation in the opening dates of wind turbines. We are then comparing the price development in areas in which wind turbines are opened to locations where they will be opened in the future. This is possible because there is variation in the opening date of wind turbines.

This approach is a version of a difference-in-differences strategy, but one in which unobserved price trends are much more likely to be very similar in treatment and control areas, and much less restrictive than the standard parallel trend assumption between spatially differentiated treatment and control groups that is usually applied in standard differences-in-differences methodologies. In particular, in Appendix A.3 we show that this is equivalent to a model with *non-parallel trends* (*i.e.* we implicitly control for differences in income, unemployment trends, etc.) between control and treatment groups.

Finally, it is important to control for housing characteristics because certain types of homes are more often located closer to wind turbines. A possible decrease in value could then mistakenly be attributed to the

[13] Note that the location fixed effects capture time-invariant price differences between control and treatment areas (*e.g.* the selection effect of wind turbines being placed in low-priced areas). The time fixed effects capture time trends, such as general economic trends affecting house prices. Time fixed effects also absorb any difference between real and nominal prices.

Table 2
Descriptives: house prices and solar farms.

	(1)	(2)	(3)	(4)
	Mean	St.dev.	Min	Max
Transaction price (€)	249,586	124,274	25,000	1,000,000
Solar farm <1 km	0.00118	0.0343	0	1
House size in m^2	116.8	37.70	26	250
Number of rooms	4.453	1.398	1	24
Terraced	0.313	0.464	0	1
Semi-detached	0.277	0.448	0	1
Detached	0.122	0.327	0	1
Garage	0.314	0.464	0	1
Garden	0.970	0.170	0	1
Maintenance state is good	0.867	0.340	0	1
Central heating	0.881	0.323	0	1
Monumental status	0.00636	0.0795	0	1
Construction year 1945–1959	0.0704	0.256	0	1
Construction year 1960–1970	0.133	0.339	0	1
Construction year 1971–1981	0.139	0.346	0	1
Construction year 1981–1990	0.114	0.317	0	1
Construction year 1991–2000	0.119	0.324	0	1
Construction year > 2000	0.203	0.402	0	1

Notes: The number of observations is 1,470,808. The data is as of 2009. Apartments are the reference group for the type of residence. Houses built before 1945 are the reference category for the building year.

placement of a wind turbine. We will show various robustness tests showing the validity of our research design.

Furthermore, we are particularly interested to examine heterogeneity in the impact of wind turbines by allowing the price effect to differ between low (<50m), medium-sized (50–150m), and tall (>150) turbines. The specification to be estimated is then:

$$\log P_{it} = \sum_{h=1}^{3} \beta_h w_{iht-1} + \gamma X_{it} + \lambda_j + \lambda_t + \varepsilon_{it}, \quad (2)$$

where w_{iht-1} is a dummy that equals one when the nearest turbine falls in height category h and is within 2 km in $t-1$, and β_h are the coefficients to be estimated for each height category. We will also examine whether the impact radius differs for turbines with different heights.

4.2. Measuring the price effect of solar farms

For solar farms we initially assume an impact radius of 1 km, which we realize is somewhat arbitrary. We will therefore also investigate the spatial extent of the effect. To measure the impact of the opening of a solar farm on property values, we use the same methodology as that for wind turbines. We estimate the following equation:

$$\log P_{it} = \zeta s_{it-1} + \gamma X_{it} + \lambda_j + \lambda_t + \eta_{it}, \quad (3)$$

where P_{it} is again the transaction price of property i sold in year t, s_{it-1} is an indicator that is 1 if a property is sold within 1 km in all years after opening of a solar farm (again we look at the nearest solar farm), X_{it} are property characteristics, λ_j are postcode fixed effects, λ_t are month dummies, and η_{it} again captures unobserved heterogeneity.

We are particularly interested in ζ. This coefficient measures the percentage change in property values due to the placement of a solar farm relative to a (local) control group. The initial control group consists of transactions from the whole of the Netherlands. We improve on this by selecting transactions within 2–5 km and 1–2 km. As there are much fewer solar farms as compared to wind turbines, we expect that just using temporal variation in the opening of solar farms (*i.e.* only using observations within 1 km of a solar farm) will lead to somewhat imprecise estimates.

5. Results

5.1. Baseline estimates: wind turbines and house prices

Table 3 shows the regression results based on equation (1). In column (1) we use the whole dataset. The results suggest that the opening of a wind turbine within 2 km of the property is associated with a house price decrease of 1.9% ($= (e^{-0.0192} - 1) \times 100\%$). This effect is statistically significant at the 1% significance level. Using the whole of the Netherlands as a control group is unlikely to yield unbiased results, as price trends between rural areas (where turbines are often placed) and urban areas are most likely different.[14]

In columns (2) and (3) we change the control group to include transactions within 3–5 km and 2–3 km of a wind turbine, respectively. The effect becomes a bit higher(2.5%) using the 3–5 km control group and -2.1% in case of the 2–3 km control group. The fact that the effect we find is relatively robust and remains statistically significant even with a substantially smaller sample and different control groups suggests that it is plausible we are capturing a causal effect of the opening of wind turbines on house prices.

Finally, we estimate a version of equation (1) that is based on the sample of transactions within 2 km of all existing wind turbines in 2019. That is, we measure the effect conditional on the placement of wind turbines in particular areas. This should capture any selection effect concerning the location of wind turbines. The regression estimate in column (4) shows that house prices within 2 km of a wind turbine decrease by 1.8% *relative* to areas in which a wind turbine has not yet been constructed. The effect is statistically significant at the one percent significance level. We consider this to be strong evidence that wind turbines affect nearby house prices.[15]

5.2. Robustness checks

In Appendix A.3, we discuss several sensitivity analyses concerning the results. First, we estimate a repeat sales model, which conditions out all time-invariant housing and location characteristics by differencing prices between pairs of consecutive transactions of the same house. The estimated coefficient is still very close to the baseline estimate suggesting that the detailed location fixed effects we have used before seem to capture unobserved housing and location characteristics well.

Second, we test whether *anticipation effects* are important. Such anticipation effects may arise because house prices already adjust before the construction of a turbine, *e.g.* because the planning phase may take several years. We show that the treatment effect *controlling for any anticipation effects* is -2.1%. The effect is still statistically significant at the one percent significance level. Prices start to decline about 3 years before the opening of a turbine.

Third, we investigate whether regional trends may be correlated with the placement of turbines. We estimate a specification with travel-to-work-area (TTWA) fixed effects interacted with time trends. The treatment effect remains very stable (*i.e.* it is -2.1%).

Fourth, we examine wind turbine removals and show that house

[14] Yet, the equation including controls and fixed effects seems to capture a considerable amount of the variation in house prices, as we can explain 93% of the variation in house prices. This high fit is mainly due to the inclusion of highly detailed PC6 fixed effects.

[15] In principle, this specification is equivalent to a difference-in-differences model that allows for non-parallel trends between the control and treatment groups. In Appendix A.3 we show that a classical difference-in-differences (DID) model based on the model estimated in column (3) (2–3 km control group), but allowing for such non-parallel trends indeed yields identical point estimates. Only the standard errors are (marginally) smaller as they are (artificially) lowered by adding the control group transactions. We, therefore, prefer the results reported in Table 3, column (4).

Table 3
Average effect of wind turbines on house prices.

(Dependent variable: the logarithm of house prices)				
	(1)	(2)	(3)	(4)
	Full sample	*Control group*	*Control group*	*Temporal*
		(3–5 km)	*(2–3 km)*	*variation only*
Wind turbine placed, <2km	−0.0192***	−0.0256***	−0.0214***	−0.0183***
	(0.0041)	(0.0045)	(0.0048)	(0.0068)
Housing characteristics	✓	✓	✓	✓
Postcode fixed effects	✓	✓	✓	✓
Year and month fixed effects	✓	✓	✓	✓
Observations	3,389,780	1,488,276	710,703	290,002
R^2	0.92	0.92	0.92	0.92

Notes: This table is based on data between 1985 and 2019. Standard errors are clustered at the neighborhood level and are in parentheses. Significance levels: ***p<0.01, **p<0.05, *p<0.10.

prices increase by 1.1% if a turbine is removed. However, due to a low number of removed turbines, the estimate is somewhat imprecise and not statistically significant at conventional levels.

Fifth, we study the effect of multiple turbines. We show that it is particularly the first turbine that has an effect on house prices. When more turbines are built within 2 km turbines, the additional turbines generally have a negative effect but the effect is less than 1% and statistically insignificant. From a policy perspective, these results imply that to reduce external effects on house prices it is best to cluster turbines in wind farms.

Finally, one may be concerned that the perception regarding wind turbines may have changed. We, therefore, test whether the willingness to pay to live nearby turbines is constant across the study period. It appears that we cannot reject the null hypothesis that the effect is constant over time.

5.3. *Demography and sorting*

One may wonder what type of households are the most affected by the placement of wind turbines. We explore this in Appendix A.4, where we gather data from Statistics Netherlands on various demographic characteristics at a very spatially disaggregated postcode 6-digit level. The results do confirm that turbines are built in sparsely populated areas with about 30% lower population densities. Interestingly, we find that the median income is only 2% lower within 2 km of a turbine. Hence, the households that are affected are not necessarily those at the lower end of the income distribution. Moreover, the share of people receiving income assistance is the same between treated and untreated areas.

Finally, we further investigate whether preference-based sorting occurs after the placement of a wind turbine. We find small changes in population density, household size, and the share of foreigners after a wind turbine is placed. Although statistically significant, these effects are economically small. Hence, we do not find evidence that the demographic composition changes considerably after turbine construction.

5.4. *Wind turbine height*

Up until now, we have ignored the effect of turbine height and assumed that the effect of turbines is confined to 2 km. As shown, turbines have become taller over time, which may, in turn, have exacerbated visual pollution, as well as the potential reach of noise pollution, flickering and shadow. We would expect that this increases the treatment effect and also affects the overall impact radius.[16] We, therefore, estimate several regression based on equation (2), using temporal variation only (see Table 3, column (4)), and show the results in several figures.[17]

In Fig. 4a we show that taller turbines indeed have a larger effect on house prices. Small turbines (<50m) on average have an effect of less than -1%. while this effect is not statistically significant. For a medium-sized turbine (50–150m) the effect is around 2% and statistically significant.[18] For turbines taller than 150m the effect is around 5% and also statistically significant, even though the confidence bands are a bit wider due to a lower number of observations.[19] The effect ranges between 3 and 7% and it is clear that the effect is considerably stronger than the effect of low turbines.

In Fig. 4b, we control for time-varying effects of turbines, as to control for any potential changes in perception over time. We find very similar effects for small, medium and tall wind turbines. The effect of a medium-sized turbine is now about − 3% and the effect of a tall turbine is also a bit larger and − 5.4%. These effects are still statistically significant, but note that the confidence bands are now somewhat wider.

5.5. *Impact area of turbines*

Distance to a wind turbine is likely an important factor in determining the possible decrease in prices. Within 5 times the axis height there is a possible effect of sound and for the average turbine up to 1 km there is also possible shadow. Up to 2 km (and beyond), there is potentially visual pollution.

In Fig. 5 we, therefore, show a specification where we interact the effect of turbines by 250m distance band dummies. Hence, we estimate the treatment effect for different distance bands. The number of observations increases as we now include housing transaction prices within 2.5 km of a (future) turbine. Fig. 5 shows that within 500m the confidence bands are large because the number of observations is low. Hence, we cannot precisely determine the effect of the opening of a wind turbine on transaction prices within short distances. Between 500 and 750m the effect is about − 3%. The effect gradually decreases until at 2500m the effect is small and indistinguishable from zero. Hence, the impact area of turbines seems to be maximally 2250m.

Although the average effect across all turbine heights is of interest, it is important to investigate whether the impact area is different for tall turbines. Therefore, we re-estimate the regression but now allow the effects to vary by wind turbine height *and* distance. Even with this large dataset, the number of observations for tall turbines is small. Hence, we aggregate the distance bins for the tallest turbines by 500m instead of 250m. The results are depicted in Fig. 6. Small turbines only have a statistically significant effect of about 2% at 1 km and the effect is essentially zero beyond 1 km. At 500m and 750m the effects are imprecisely measured.

A turbine with a height between 50 and 150m yields a statistically significant effect of -3.4% at 750m. The effect decreases over distance, but at a relatively low rate. At 2500m the effect is no longer statistically

[16] For example, at a distance of 2 km a turbine of 100m in height has a perceived height of 5cm. Instead, a 200m high turbine at that distance has already a perceived height of 10cm. The view of such a turbine might well be less obscured by features of the (urban) landscape.

[17] The underlying regression table is reported in Appendix A.3.

[18] We also considered splitting this category up even further but did not find statistically significant differences between those turbines.

[19] In the Netherlands, turbines larger than 150m also need to have a flashing light (white during the day, red during the night). This might increase the experienced nuisance and visibility of those wind turbines.

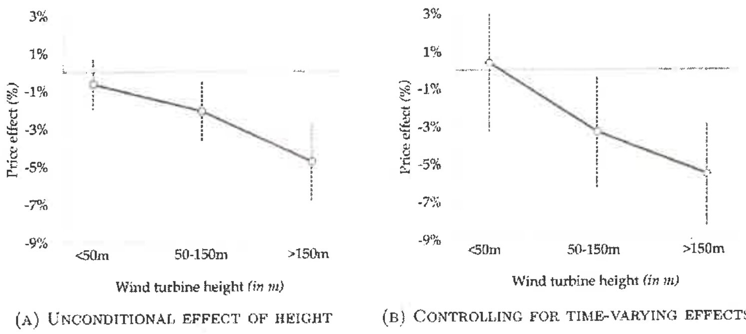

Fig. 4. Price effects for different turbine heights
Notes: The dotted lines represent the 95% confidence intervals. These regressions include observations within 2 km of a (future) turbine and control for housing characteristics, postcode fixed effects, as well as year and month fixed effects. The number of observations is 290,002 and the R^2 in both regressions is 0.92.

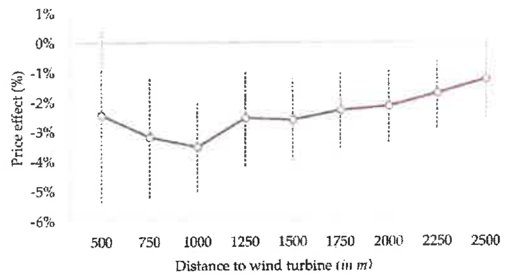

Fig. 5. Wind Turbines: Price effects at different distances (1985–2019)
Notes: The dotted lines represent the 95% confidence intervals. This regression includes observations within 2.5 km of a (future) turbine and controls for housing characteristics, postcode fixed effects, as well as year and month fixed effects. The number of observations is 491,337 and the R^2 is 0.92.

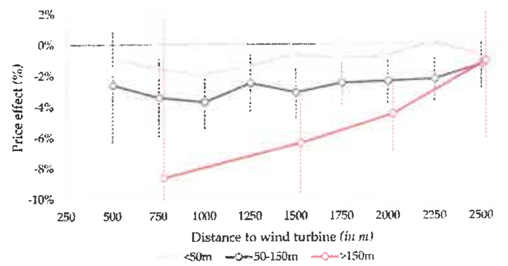

Fig. 6. Distance and wind turbine height
Notes: The dotted lines represent the 95% confidence intervals. This regression includes observations within 2.5 km of a (future) turbine and controls for housing characteristics, postcode fixed effects, as well as year and month fixed effects. The number of observations is 491,337 and the R^2 is 0.92.

significant. For the tallest wind turbines, the effect is again larger than for small turbines. At 750m the effect is -8.3%, albeit very imprecise due to the low number of observations (within 500m of a turbine exceeding 150m there are even no transactions available). The effect again decreases with distance, but more rapidly, and the effect is small and no longer statistically significant at 2500m. Note that the confidence bands for different heights are overlapping in most cases, except when comparing the largest and smallest turbines, which suggests that measuring the effect of height and distance to a turbine demands a lot from the data.

Overall, our results imply that taller turbines have higher effects on house prices and we find evidence that the effect also reaches just beyond 2 km, up to 2250m, but not beyond 2.5 km. Moreover, we show that low turbines (<50m) have a small impact on house prices that is confined to about 1 km.

5.6. *Solar farms and house prices*

In Table 4 we report results regarding solar farms, based on equation (3). Column (1) shows the effect of the opening of a solar farm within 1 km of a home using the full extent of our data. This effect is -3.7% (=($e^{-0.0380}$-1)×100%) and statistically significant at the 1% significance level. However, this specification does not take into account local price trends that may be correlated with the placement of solar farms. Moreover, it is not a priori clear that the effect is confined to 1 km.

To take these issues into account, a specification is estimated in column (2) in which the control group are transactions that take place within 2–5 km of a solar farm. The effect now becomes -4.6% and it is still highly statistically significant. Finally, in column (3) we decompose the effect for 500m distance bands. In Fig. 7 we show that the effect within 500m is -5.9%. It is -3.8% up to 1 km and it approaches zero and is no longer statistically significant beyond 1 km.

Next, we undertake some robustness checks. In column (4) we consider a more local control group by only including observations within 2 km of a (future) solar farm. The estimated coefficient is somewhat smaller: house prices decrease on average by 2.6% after the opening of a solar farm. The effect is highly statistically significant. We consider this estimate as our preferred estimate as it is rather conservative and the control group is more local.

Furthermore, it could be argued that the effect of solar farms picks up the effect of wind turbines, because they might be located close to each other. Hence, we add a dummy indicating whether there is a wind turbine within 2 km in column (5). The effect of solar farms is still -2.6%. This is not too surprising as the correlation between wind turbine locations within 2 km and solar farms within 1 km is only 0.005. The negative effect of wind turbines is statistically insignificant because the sample only includes very few turbines.

Finally, we identify the effect based on variation in the opening dates of solar farms only. The result is reported in column (6). In this case, the point estimate is still -1.5% but the effect is no longer statistically significant. This is not surprising as we include just 12,650 observations in the regression. More importantly, given the standard error, this estimate is not statistically significantly different from our preferred estimate.

We interpret these findings as robust evidence that property values decrease within 1 km of solar farms. The coefficient estimates range

Table 4
Average effects of solar farms on property prices (2009–2019).

	(Dependent variable: the logarithm of house prices)					
	(1)	(2)	(3)	(4)	(5)	(6)
	Whole Netherlands	*Control group 2-5 km*	*Distance profile*	*Control group 1-2 km*	*+ Wind turbine treatment*	*Temporal variation only*
Solar farm placed <1 km	−0.0380*** (0.0093)	−0.0469*** (0.0099)	see Fig. 7	−0.0263*** (0.0090)	−0.0263*** (0.0090)	−0.0156 (0.0253)
Wind turbine placed <2 km					0.0018 (0.0166)	
Housing characteristics	✓	✓	✓	✓	✓	✓
Postcode fixed effects	✓	✓	✓	✓	✓	✓
Year and month fixed effects	✓	✓	✓	✓	✓	✓
Observaties	1,470,808	355,235	405,164	62,579	62,579	12,650
R^2	0.90	0.90	0.90	0.89	0.89	0.90

Notes: This table is based on data between 2009 and 2019. Standard errors are clustered at the neighborhood level and are within parentheses. ***p< 0.01, **p< 0.05, *p<0.10.

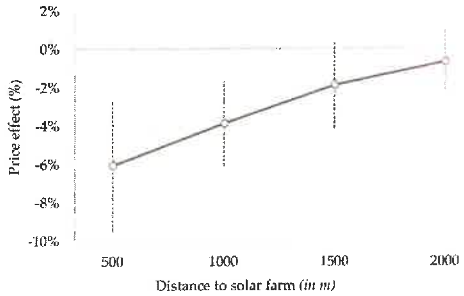

Fig. 7. Price effects at different distances, solar farms (2009–2019)
Notes: The dotted lines represent the 95% confidence intervals. This regression includes observations within 5 km of solar farms present in 2019 and controls for housing characteristics, postcode fixed effects, as well as year and month fixed effects. The number of observations is 405,164 and the R^2 is 0.90.

between -1.5% and -5.9%, depending on the specification. Again, we see the results in column (4) as our preferred model estimate: it takes into account possible unobserved trends and includes enough observations to accurately estimate the effect. The effect is of the same order of magnitude as for turbines, but more localized.

5.7. *Overall losses in property values*

Given the regression estimates, we can calculate the 'back-of-the-envelope' total loss in housing values as a result of the construction of wind turbines and solar farms in the Netherlands. For wind turbines, we use the estimates that discriminate between the height of a turbine and the distance of a property to the nearest turbine reported in Fig. 6. For solar farms, we rely on the estimate reported in column (4) in Table 4.

Using data from BAG (*i.e.* the Building Register) we calculate the number of residential properties in each distance band from each wind turbine and solar farm. Furthermore, we calculate real average house prices (in 2019 prices) within 2 km of a wind turbine and 1 km of each solar farm using the NVM data. We then multiply the estimated price effects with real prices and the number of residential properties around each turbine or solar farm. Before we move to the results, we caution that the numbers should be interpreted as back-of-the-envelope calculations as we have to make several simplifying assumptions. First, we assume that the relative price decrease estimated for the owner-occupied housing market carries over to the rental market. Second, we

Table 5
Wind turbines and solar farms: total effects on house prices.

	(1)	(2)	(3)	(4)	(5)
	Wind turbines				Solar farms
	All	≤50m	50-150m	≥150m	All
Total loss in € *(in millions)*	4993	427	3789	777	800
Average loss in € per turbine/ farm	4,153,672	2,102,069	4,271,443	6,939,494	7,477,965
Average loss in € per MWh	953.14	2191.89	1033.84	763.82	835.59
Median loss in € per turbine/ farm	140,175	250,599	114,562	116,652	1,901,138
Median loss in € per MWh	53.41	276.96	34.15	11.30	364.80

Notes: We assume that a wind turbine of 1 MW delivers $365 \times 24 \times 0.304 = 2,663$MWh, where 0.304 represents the capacity factor, which we obtain from the Energey Information Agency. A solar farm with a nominal peak power of 1 MWh delivers $0.85 \times 1,000,000 \times 1 = 0.85$ million kWh.

assume that the average price effects of turbines and solar farms apply to properties throughout the Netherlands; so we abstract from any heterogeneity in the price effect other than the heterogeneity in distance to and height of the wind turbine. The results are still informative as they point towards the overall economic magnitude of the effect.

The results for wind turbines, reported in Table 5 show that the total loss in housing value is about €5 billion, which is substantial.[20] Because there are so few properties within 500m of a turbine, only 0.7% of the total loss accrues to properties within 500m of a turbine, while 10% of the loss is borne by properties within 1 km of a turbine. The average loss per turbine built on land is €4.1 million. The average loss per MWh is about €1 thousand. These results suggest that when placing wind turbines it is important to take into account the additional external costs.

However, the average loss per turbine may be somewhat misleading

[20] For comparison purposes, the Dutch GDP was about 725 billion in 2017.

as most of the total loss is due to a few turbines that are close to residential neighborhoods. More specifically, it appears that just 25 turbines account for almost 50% of the total loss. This shows that it is very important to build turbines not too close to residential properties. Indeed, the median loss per turbine is much lower and about €140 thousand, or about €53 per MWh. Given the construction costs of about €1.27 million per MW, we calculate the median loss in housing values as 16.5% of the construction costs.[21]

Note that the median loss per MWh varies considerably across turbines of different heights. For example, because tall turbines generate more power, the median loss per MWh is about €11, while it is €277 for low turbines. Hence, despite the smaller effects of low turbines, the loss in power does not make it more efficient to build low turbines.

Let us now consider the impact of solar farms. Because there are yet much fewer solar farms constructed, the total loss is just over €800 million. The *average loss* per solar farm is of the same order magnitude as the external costs of wind turbines. Here it also seems more informative to look at the median loss of a solar farm, which amounts to about €2 million, which is considerably larger than the median loss for one turbine. However, this is mainly because solar farms are generally larger and generate more energy. In addition, the median loss per MWh is €365, which is also considerably larger than the median loss of a wind turbine. The reason is that solar farms are often large so that it is hardly avoidable to have a solar farm that is not close to residential properties. Indeed, the median number of properties within 1 km is 178, while this is just 3 properties for wind turbines.[22]

These results seem to suggest that – even though the impact area is smaller – building solar farms does not mitigate the external effects of renewable energy production in comparison to wind turbines, at least given the current spatial distribution and available technology. Still, the large differences between the average and median loss per turbine/solar farm strongly confirm that choosing sparsely populated areas to build turbines/solar farms is important. For solar farms, these areas may be easier to find, as the impact area of solar farms seems to be confined to 1 km instead of about 2 km for turbines. On the other hand, the land beneath solar farms cannot be used for other purposes, while land close to turbines can be used for crops or livestock farming.

6. Conclusions and policy implications

Producing energy sustainably is an important step towards a climate-neutral economy with net-zero greenhouse gas emissions. Wind and solar energy are important sources of renewable energy. However, while reductions in CO_2 emissions benefit the whole population, external effects are borne only by households living close to production sites. Hence, insights into these external effects is paramount for renewable energy policy as the size of external effects is informative on whether there is local support for the opening of production sites, such as wind turbines and solar farms. In this study, a panel dataset on house prices between 1985 and 2019 from the Netherlands is used to measure the effect of the proximity of wind turbines and solar farms on property values.

Our results suggest that the opening of a wind turbine decreases local house prices by 1.8%. The impact of turbines does not reach beyond 2250m. It is particularly the first turbine that reduces house prices; hence to mitigate external effects, turbines should be concentrated in wind farms. Moreover, we are particularly interested in the effects of turbine height, as turbines have become much taller over time. For a turbine taller than 150m we find that the effect is on average -5.4%. The impact area is about 2 km. Instead, a small turbine below 50m has only a small effect which at most distances is statistically insignificant and quickly dissipates beyond 1 km. Thus, turbine height is an important source of heterogeneity in the effect of turbines on property values.

This study also investigates the impact of solar farms on house prices. Due to possible noise disturbance, the reflection of the sun, but also visual pollution, a solar farm can have a negative impact on property values. The effects of this are expected to be more local because these solar farms are less visible than wind turbines; and noise reflection also probably does not reach that far. We find evidence of a decrease in property values of about 2.6% after the placement of a solar farm. This effect is confined to 1 km.

Our back-of-the-envelope calculations document that the total loss in house value as a result of wind turbines is about €5 billion, which is about equal to the replacement costs. Interestingly, 1% of the turbines account for almost 50% of the loss in housing values. This confirms that the choice where to build turbines is key; to mitigate losses in housing values turbines should be placed in sparsely populated areas. The median loss per MWh produced is €53, but this varies considerably across turbines of different heights. For example, for tall turbines, the median loss per MWh is about €11. This suggests that it is worthwhile to build tall turbines. The median loss per MWh for solar farms is €365, which is much higher than the median loss for wind turbines (but note that the average losses are about the same). Hence, building solar farms instead of wind turbines will not mitigate the external effects of renewable energy production.[23]

The results in this paper highlight that careful placement of wind turbines and solar farms is paramount as the total loss in housing wealth can quickly increase if turbines and solar farms are built too close to residential properties. We argue that the external costs of wind turbines and solar farms should be taken into account when constructing such renewable energy production facilities and this study clarifies what those potential costs are. However, whether and to what extent homeowners should be compensated for the loss in housing values is a political question. Currently, the Dutch government compensates homeowners for losses in housing values due to area redevelopment exceeding 2% and this will be increased to 4% in 2022. Homeowners are only compensated for a loss in housing value over and above the threshold. We showed that only close to turbines or solar farms, the loss in housing values exceeds 4%, so that this compensation scheme, at least for most homeowners, will be of limited use in the future.

CRediT authorship contribution statement

Martijn I. Dröes: Methodology, Conceptualization, and, Formal analysis. **Hans R.A. Koster:** Methodology, Conceptualization, and, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.enpol.2021.112327.

[21] For each turbine, we calculate the loss per MW. We then take the median of this loss.

[22] Within 2 km of a turbine, the median number of properties is 15.5. This stark difference is also due to regulations that prohibit wind turbine construction close to residential properties.

[23] For future research and renewable energy policy, it would be useful to also compare the results with the potential negative external effects of other (non-renewable) energy production alternatives.

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