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BERKELEY NATIONAL LABORATORY**

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

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**Environmental Energy
Technologies Division**

December 2009

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Prepared for the

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

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Abstract

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

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Executive Summary

Overview

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

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

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

Although concerns about the possible impact of wind energy facilities on the property values of nearby homes are reasonably well established, the available literature¹ that has sought to quantify the impacts of wind projects on residential property values has a number of shortcomings:

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

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

This report builds on the previous literature that has investigated the potential impact of wind projects on residential property values by using a hedonic pricing model and by avoiding many of the shortcomings enumerated above.

The hedonic pricing model is one of the most prominent and reliable methods for identifying the marginal impacts of different housing and community characteristics on residential property values (see side bar). This approach dates to the seminal work of Rosen (1974) and Freeman (1979), and much of the available literature that has investigated the impacts of potential disamenities on property values has relied on this method.²

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

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

What Is a Hedonic Pricing Model?

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

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

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

Analysis Findings

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

Table ES - 1: Description of Statistical Models

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

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

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

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

Base Model Results

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

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

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

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

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

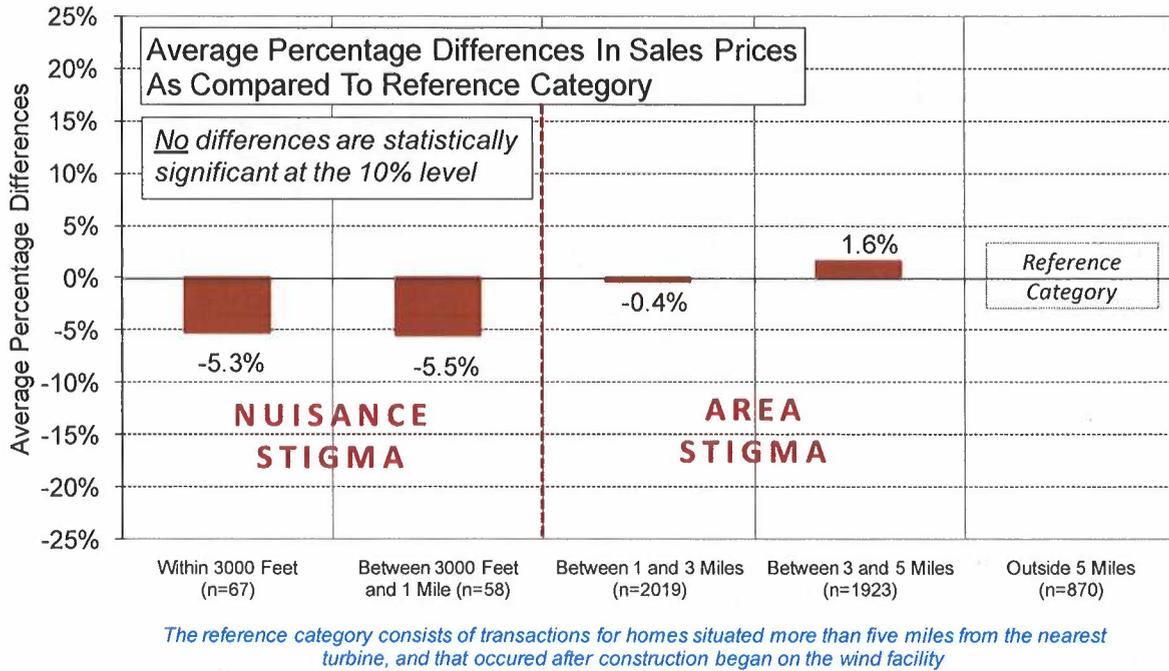


Figure ES-2: Base Model Results: Scenic Vista

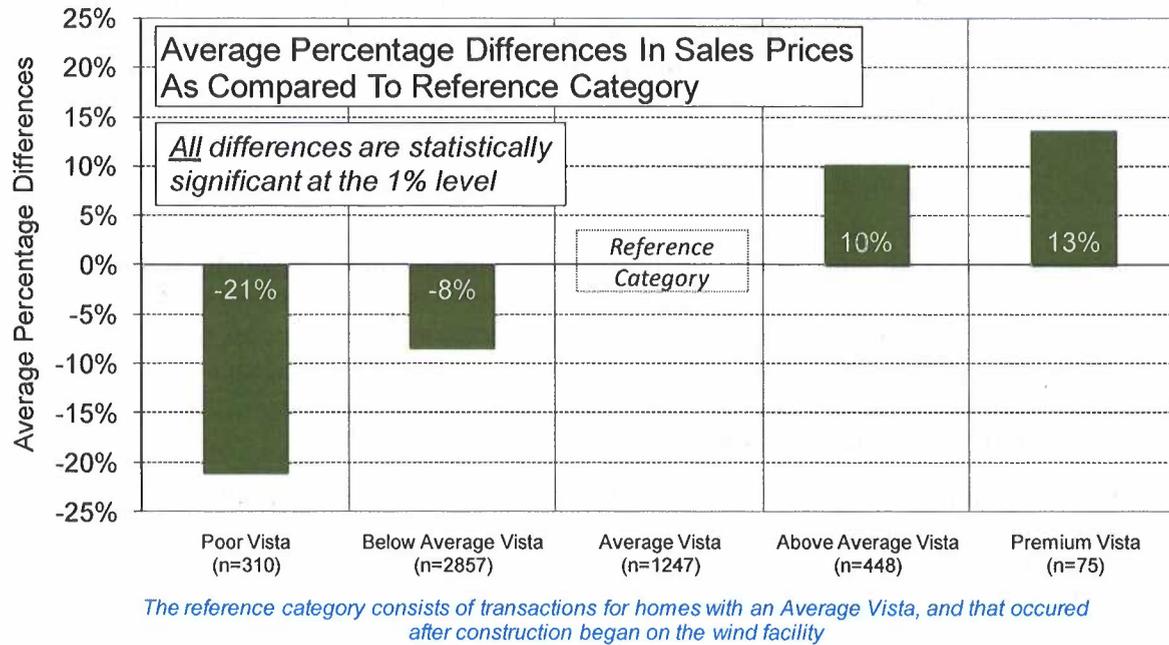
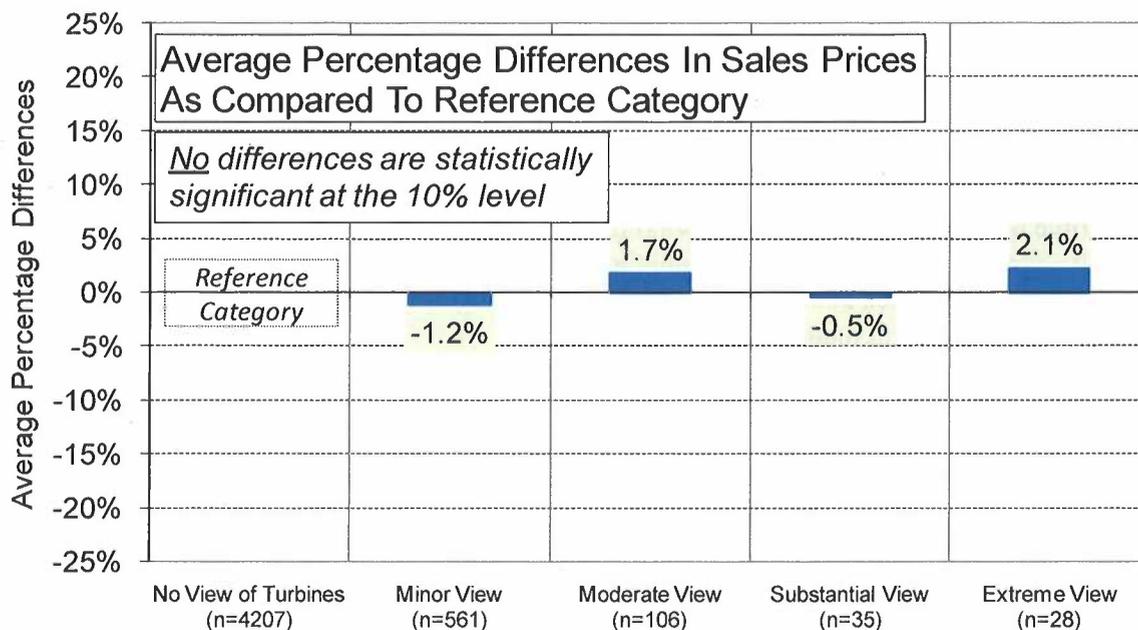


Figure ES-3: Base Model Results: Scenic Vista Stigma



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

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

Area Stigma: Other Model Results

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

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

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

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

Scenic Vista Stigma: Other Model Results

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

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

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

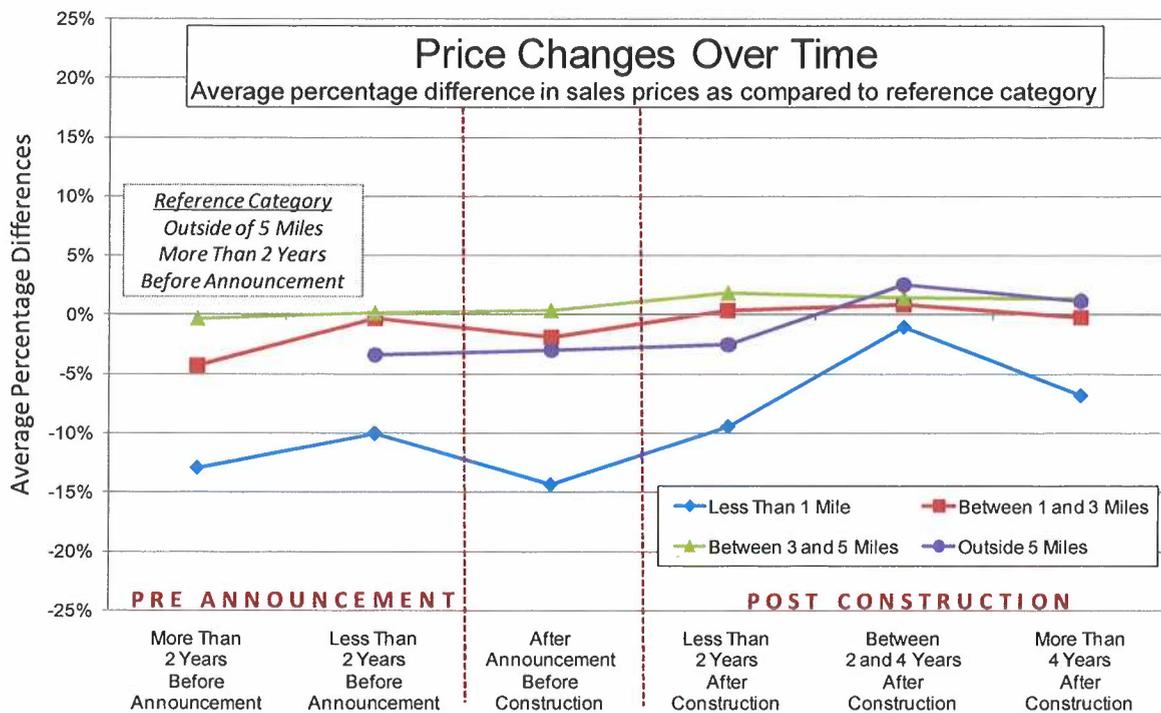
Nuisance Stigma: Other Model Results

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

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

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

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



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

Conclusions and Further Research Needs

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

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