Impacts of Windmill Visibility on Property Values in Madison County, New York.

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Table of Contents

List of Figures and Tables

Abstract

Potentially adverse effects of windfarm visibility on property values can represent real costs to communities, yet few studies exist on the subject. The studies that are available are contradictory, and suffer from statistical flaws. A clearer understanding of actual effects of existing wind facilities will inform future decisions. To explore this subject this report analyzes 280 arms-length single-family residential sales using a hedonic regression model. The sales took place from 1996 to 2005 and are within 5 miles of a 20 turbines - 30 megawatt (MW) windfarm in Madison County, New York. The report differentiates itself from previous studies by visiting all homes ("ground truthing") in the sample to ascertain the actual level of turbine visibility. The analysis finds an absence of measurable effects of windfarm visibility on property transaction values. This result holds even when concentrating on homes within a mile of the facility and those that sold immediately following the announcement and construction of the windfarm in 2001. These results dispel the proposition that effects, either positive or negative, are universal. The report concludes by making recommendations to stakeholders and outlining possible considerations for further research.

Key Words

Viewshed, view, vista, wind energy, windfarm, turbines, property values, transactions, hedonic, regression, review, GIS, ground cover

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1 Executive Summary

With federal renewable energy tax credits and a number of state incentive packages in place (AWEA, 2005b), U.S. states are increasingly relying on wind energy to mitigate risks related to resource scarcity, increasing costs of fossil fuel extraction, greenhouse gas emissions and other environmental hazards (CRS, 2005). This shift has caused wind energy development to grow at an unprecedented rate. In 2005 new capacity totaling 2,400 megawatts (MW) was installed in the U.S., an increase of 35% over 2004 U.S. capacity (AWEA, 2006).[1] At the same time windmill sizes have become increasingly large in order to capture greater efficiencies per turbine, and the numbers of turbines installed per windfarm has increased to capture economies of scale (AWEA, 2005c). Litigious conflicts between community members and facility developers have occurred (Adams, 2005) and are likely to increase if the industry trends of increasing size and number continue. Community attitudes regarding wind energy are often promoted by small groups of organized opponents or proponents, therefore the sentiments of the entire community on average may be missed. One way to measure the community's disposition is to use property transaction prices (transaction values) as a proxy. If the visibility of a windfarm is believed by the members of the community to adversely affect the view from the home, the transaction value, with all else being equal, will be lower as compared to other homes without a view. Alternatively, if residents find the view acceptable, no change in property values will be discernable.

Many opinions exist on the effects of wind development on surrounding property values. For example, the two largest studies completed in the U.S. reach contradictory

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[1] The American Wind Energy Association (AWEA) estimates that 2,400 MW of wind energy will supply energy for 600,000 homes (AWEA, 2006)

results. Haughton (2004) predicts sizable negative effects from windfarm development on property values in Cape Cod, Massachusetts while Sterzinger (2003) concludes from his analysis of 10 communities around the U.S. there are strong positive effects. Despite these contradictory results no studies to date have rigorously analyzed the subject by using a large sample of arms-length home transaction values combined with a verification to what degree each home in the sample can see the wind farm or not. Instead, with each new wind development interested parties are forced to rely on poorly constructed or inconclusive studies (Jordal-Jorgensen, 1996; Grover, 2002; Sterzinger *et al.*, 2003; Poletti, 2005), or comparisons to inappropriately analogous research (Zarem, 2005a). For instance in 2004, the Public Service Commission (PSC) of Wisconsin heard opposing conclusions of studies conducted by experienced economists (Poletti, 2005; Zarem, 2005b). Both cited, in their testimony, their frustration with the lack of available evidence in this subject area.

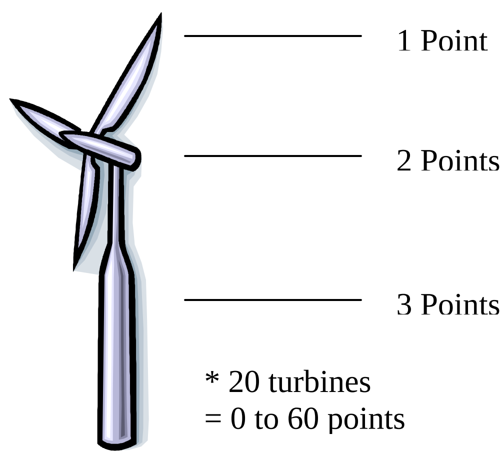
Compounding the lack of data problem, changes in property values are not likely to be taken into consideration by the developer and the community. These "hidden costs" or "externalities" are not weighed against the benefits of a project. Without proper analysis of these potential costs or externalities and a thorough understanding of when and how they affect property values, facilities may be either needlessly delayed or inappropriately approved. This report studies property values and windfarms with the hope of shedding light on these issues.

First the report reviews the existing literature on property values and windfarms finding in most cases a lack of rigor and insufficient detail to capture the complex relationship between home transaction prices and views, such as those found in research of high voltage transmission lines (HVTL) and property values (e.g. Des-Rosiers, 2002). Then using data from a Madison County, New York community surrounding a 20 turbine windfarm, the report analyses home transaction values in an effort to ascertain if effects exist and to create a potential blueprint for future analysis of other communities. The data contains 280 arms-length single-family residential home sales which took place between 1996 and 2005; 140 occurred after facility construction began in 2001. None of the home sales were on properties that contained turbines, or received compensation from the operation of the turbines. Two methods of measuring the degree to which each home can see the turbines are developed, a simulated method and one involving field visits. Ultimately, as is discussed below, the method involving field visits was used for the regression model. The simulated method uses a geographical information system (GIS) model to predict visibility. Ten meter digital elevation model (DEM)[2] data provided by the United States Geological Survey (USGS) is combined with 10 meter ground-cover data by estimating heights of ground cover types and adding these heights to the surface elevations. The ESRI 3-D analyst viewshed algorithm, which is included in the Arc Map product, is used to analyze visibility. Then, GIS predictions are compared to field collected data. Although it incorporates techniques not previously used and reaches an accuracy rate of 85%, which is higher than the 50% accuracy rate found in the literature (Dean, 1997; Maloy and Dean, 2001), it is deemed an unsatisfactory level of accuracy for this report's hedonic analysis which requires greater than 95% accuracy. Therefore, the second, field visit method is used.

[2] The DEM is a digital representation of the elevation of locations on the land surface. A DEM is often used in reference to a set of elevation values representing the elevations at points in a rectangular grid on the earth's surface.

For this method, each home in the sample is visited and the degree to which each of these homes can see the windfarm is quantified using a scoring method which attempts to minimize bias. From each home each of the twenty turbines is given a 0 (no view) to 3 (full view) score, which are then totaled resulting in a 0 to 60 score specific to that property.[3]

Figure I: Turbine Visibility Scoring Method



As well, a GIS is used to quantify the exact distance from each home to the nearest turbine. These two characteristics, view of and distance from turbines, are combined with a number of house and neighborhood characteristics. The combination of characteristics is then used in a hedonic regression model to investigate the marginal effect that the view of and distance from turbines has on home sale prices. The hedonic pricing model is well established in its usefulness in investigating the effects environmental characteristics have on home values (e.g. Dale *et al.*, 1999).

The report finds that the model significantly predicts home values (f-value 49-56, p-value 0.000, R^2 0.792), and on average that there are no measurable effects on property values based on the view of and distance from turbine characteristics (p-value 0.410 and

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[3] The actual range of scores for the sample set used in this report is 0 to 43.

0.679 respectively). This finding holds both temporally and spatially. In other words, homes which sold in the year the project was announced and constructed (2001), and had a clear view of the turbines, are not affected uniquely (p-value 0.742); and no measurable effect is found for homes located within a mile of the facility (p-value 0.656)[4].

Additional tests are run to see if the township of Fenner in which the turbines are located, and to which payments are made by the facility owner, is accordingly perceived to have a positive value in the eyes of home purchasers as compared to the other townships. If the payment to the township is considered to be a distinct advantage by home purchasers, by adding needed dollars to the town budget, for example, it might be found the homes in Fenner are priced at a premium to other townships, all else being equal. In our analysis no measurable premium is found (p-value 0.689).

These results are important to policy makers and other stakeholders because they dispel the supposition that windfarm development has universally negative effects on home values. They support the results previously collected via surveys which find that a majority of residents in communities surrounding other wind facilities not only perceive the turbines to be "acceptable" (Warren *et al.*, 2005), but also "relatively nonexistent," by rarely (< 3.0%) spontaneously mentioning them in descriptions of their surroundings (Braunholtz and MORI-Scotland, 2003).

[4] A p-value is a measure of statistical significance, which can be reported in a number of ways in studies (e.g. margin of error, probability, or significance). They all report the same thing, the degree of confidence that the results were not reached by simple chance. As sample sizes grow, and variation among them becomes more predictable, more confidence can be had that "statistically significant" results from the analysis of the sample set can be transferred to the entire population. Conversely, if sample sizes are small, and variation among them is less predictable, results can not be validated against an average, and therefore present difficulties in being extrapolated to the population. In these cases results should be taken anecdotally or should not be transferred outside of the sample set.

With a paucity of research on the subject of effects of wind facilities on property values and a great deal of speculation regarding the actual effects, policy makers are forced to rely on poorly constructed studies and opinions. This report attempts to move the discussion toward the facts. Its research finds that in this community of 280 homes no effect is found. To the degree that these results are corroborated by further analytical research in other communities, the issue of negative impacts of windfarms on property values might take a lower priority in the decision making process. This report makes policy recommendations to stakeholders based on the results of this study and outlines possible areas for consideration which should be explored in future research.

2 Introduction

With federal renewable energy tax credits and a number of state incentive packages in place (AWEA, 2005b), the States are increasingly relying on wind energy to mitigate risks related to resource scarcity, increasing costs of fossil fuel extraction, green house gas emissions and other environmental hazards (CRS, 2005). Because wind energy, "is one of the lowest-priced renewable energy technologies available today" (USDOE, 2005, p. 1) and its resources are well distributed around the country, it has enjoyed an average annual growth of almost 20% over the last decade (GWEC, 2005) and is expected to continue its growth into the future (EIA, 2006). In the United States, twenty-one states have implemented a Renewable Portfolio Standard (RPS) which requires a percentage of retail sales to be from renewable sources (AWEA, 2005b). The American Wind Energy Association (AWEA) forecasts a 7-fold increase in the use of wind energy in the U.S. by 2020 (AWEA, 2005e). In 2005 alone roughly 2,400 MW (or 1666 turbines[5] in 140 "windfarms"[6]) have come online in the U.S. (AWEA, 2006).

Not only have the amount of windfarms been increasing but the number of turbines in each development has increased to capitalize on economies of scale. Additionally the sizes of the structures over the last 20 years have changed dramatically in order to increase turbine efficiency. As the height and rotor diameter of turbines increase, the power generated from the turbines grows exponentially (AWEA, 2005c). In 1980 when the Altamont Pass wind facility was erected outside of San Francisco in California (CA),

[5] Estimated by using an average turbine size of 1.5 MW and farm size of 100 MW. Using this same estimate, if New York State is to meet its RPS goals of 25% by 2013 (NYSDPS, 2004) 30 new windfarms will have to be sited.
[6] These wind energy production facilities usually contain groupings of 10 or more turbines referred to as a "windfarm, " because they are laid out, "as a farmer might approach…a field" (Gipe, 2002).

turbines averaged 30 meters in height (Pasqualetti, 2002). Now land based turbines sit on towers as high as 90 meters, and have blade lengths of 45 meters (AWEA, 2005c) totaling 135 meters (442 feet) from base to tip.[7] While increasing efficiency, this difference in heights makes them considerably more visible from long distances.

With the high number of windfarm installations expected to occur in the U.S. to meet RPS goals over the next decade and the ever increasing size of the facilities and the turbines themselves, it is inevitable that there will increasingly be conflicts between developers and members of the communities in which the windfarms are sited. Often these clashes revolve around environmental "aesthetics," or how well the turbines fit into the surrounding environment in the eyes of community members. Findings suggest that respondents prefer smaller turbines over larger ones (e.g. Wolsink, 1989; SEI, 2003) and fewer structures rather than more in each group (e.g. Devine-Wright, 2004). Accordingly, homeowners have often claimed a proposed wind facility will ruin or "mar their view" (e.g. AP, 2006).

How can this claim be tested? When property owners say windmills will "ruin" their view, they are claiming both that there is some intrinsic value of "vista" (or view)[8] from their home, and that if the proposed windmills can be seen from the home this value will be diminished. It follows that if you can analyze home sales that have visual contact with the windmills in comparison with ones that do not, all others things being equal, an average effect can be verified. In other words, community attitudes of a wind development

[7] Offshore turbines can be even bigger ranging up to 165 meters from base to tip.
[8] For this report, a distinction is made between "vista" and view or viewshed. "Vista" will always refer to the value of a home that is derived from a "good view" from the property. "View" or "Viewshed" will refer to the degree to which a property can see the windmills. In other words, "A property not only had a beautiful vista, but had a view of the windmills too."

can be translated into home values, just as, for instance, the perceptions of a safe neighborhood or good quality public schools are translated into sale prices. This correlation of community attitude and property values has been confirmed in studies of other environmental attributes such as open space (e.g. Irwin, 2002), high voltage transmission lines (HVTL) (e.g. Des-Rosiers, 2002) and environmental stigmas (e.g. Dale *et al.*, 1999).

What are the ramifications to the community or society of such potential connections? If the effect of visibility of wind facilities on property values is universally highly negative, these costs might be very high. Haughton (2004), in his study of the proposed Cape Cod windfarm forecasts depreciation of property values in the billions! Yet, often changes in home values are outside the normal transactions of a developer and a community and are thus "hidden costs" or "externalities" of a project. These externalities are often grouped together and termed "environmental impacts" (EMC, 2005). Windfarm developers are often required, depending on the state or local laws, to investigate the nature and magnitude of these externalities by preparing an environmental impact statement (EIS) or something similar[9] often modeled after the Federal requirements as directed by the National Environmental Policy Act (NEPA)[10] regulations. An EIS is a report describing the investigations conducted by the developer of potential effects the facility will have on the surrounding environment. The report has a number of functions. First, it allows interested parties and stakeholders an opportunity to peel back, investigate and in some cases challenge the development's declared environmental impacts. Secondly, it provides a record that can be later challenged if assertions are found to be incorrect. Lastly, it provides

[9] More often than not, local laws will permit development to take place without a full environmental review (GAO, 2005), but often some type of impact assessment is required.
[10] National Environmental Policy Act (42 U.S.C. & 432l)

a schedule of expected environmental costs that can be compared against the proposed benefits any project will provide. In order for a project to proceed, "it must be demonstrated that the need for the proposal outweighs all adverse impacts" (EMC, 2005, p. 10).

Because of the importance of understanding actual effects on property values as costs to be weighed against benefits, it may be expected that this issue has been widely studied. However, this is not the case. Some studies exist using actual real estate transaction prices, but have made critical errors which weaken the results (e.g. Sterzinger *et al.*, 2003; Poletti, 2005), as explained in section 3. In the absence of actual prices, studies have used surveys of real estate professionals and homeowners as a proxy (e.g. Jordal-Jorgensen, 1996; Grover, 2002; Haughton *et al.*, 2004). Yet none of these studies reported their results accompanied by levels of significance.[11] Accordingly decision makers are forced to make educated guesses as to the predicted effects of a proposed windfarm. One controversy was played out in Wisconsin as two experts argued over the potential effects of the proposed Forward Wind Facility (Zarem, 2005b) and (Poletti, 2005) with each reaching distinctly different conclusions. Without well-designed studies with solid conclusions to work with, planners, developers, and potentially impacted communities will continue to needlessly delay or inappropriately rule on projects that might otherwise be decided differently.

This report examines whether property values were affected by a windfarm installed in Madison County in 2001. 280 home sales, which took place between three quarters and

[11] Refer to discussion of "significance" in footnote 4 on page vii.

five miles of a 20 turbine windfarm, are analyzed using a hedonic pricing model[12] to establish the degree of impact that a view of windmills might have had on the transaction values of these homes. The report first outlines previous studies on the subject. Next the report presents methodology and results. Lastly the report discusses conclusions and makes policy recommendations to interested parties and research recommendations concerning decisions on siting wind facilities.

[12] A hedonic pricing model, as discussed in section 5.1, is a statistical device which allows market goods to be broken into their component characteristics. It is often used to value individual characteristics of cars, such as the value of a sunroof, and homes, such as the value of a pool.

3 Overview of Previous Studies

The literature on wind energy facilities and surrounding property values can be grouped into three categories of increasing order of relevance for our research: survey-based studies (Jordal-Jorgensen, 1996; Grover, 2002; Haughton *et al.*, 2004; Khatri, 2004), transaction-based studies of analogous high voltage transmission lines (HVTL) structures (e.g. Delaney and Timmons, 1992; Hamilton and Schwann, 1995; Des-Rosiers, 2002), and transaction-based studies of windfarms (Sterzinger *et al.*, 2003; Poletti, 2005).

3.1 Survey based studies

When transaction data are not available either because a windfarm has only been proposed or data are not recorded or available for public use,[13] surveys can be used to estimate values of viewshed impacts. Surveys specifically asking questions regarding values can be directed at assessors and real estate agents who have professional knowledge of how values can be impacted by a change in the surrounding environment (Grover, 2002; Haughton *et al.*, 2004; Khatri, 2004) or to residents who can offer their value judgments (Jordal-Jorgensen, 1996; Haughton *et al.*, 2004). Both of these methods can suffer from inflated and unrealistic values (Kroll and Priestley, 1991), and therefore it would be inappropriate to use these values as a replacement for actual economic impacts, as is discussed below. In the absence of other data, and if the surveys are taken using random and unbiased methods, they can be illustrative of community attitudes and indicate areas for further study.

Jordal-Jorgenson (1997) conducts two types of surveys using contingent evaluation methods. Contingent evaluation methods attempt to establish in monetary terms “non-

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[13] In the U.K., for example, residential transactional values are not public information.

market" environmental values by asking people how much they are willing to pay for an environmental amenity or to have an environmental nuisance removed.[14] Jordal-Jorgenson surveys 342 homeowners living "near" windmills in Denmark, inquiring if they find the turbines a nuisance and, if so, what they would be willing to pay to have them removed. 13% of the homeowners find them a nuisance and are willing to pay $140 per household per year on average to have them removed.[15] Additionally, Jordal-Jorgensen asks respondents what they would be willing to pay to not live near the windmills. The study finds that people are willing to pay between $2,314 and $13,429 dollars to not live "near" a single or a group of turbines respectively.[16] The term "near" is not defined. The study points out that because the result is an average, a wide variety of impacts could be found among the homes, with individual homes experiencing potentially large impacts. Additionally, the author admits that the small number of houses, 26 out of 342, available for analysis near the turbines did not provide a statistically significant result, and that therefore the results could be "due to coincidental factors" (p. 2).[17] This is a problem, as well, with a number of other studies outlined below. Without a reported level of confidence in the results, readers are recommended to use the findings anecdotally.

Similarly, Grover's (2002) survey results of 13 county tax assessors around Kittitas County, Oregon should also be used anecdotally because he both uses a very small sample size, and implies causality where only correlation has been found. Of the 13 county assessors that are interviewed, 6 state that their county's residential properties have views of

[14] Surveyors use various techniques to improve the predictive power of this method. For further reading on this subject, Bateman (2002) is a good resource.
[15] Converted from Dutch Kroners (DKK) using 1996 exchange rates.
[16] Converted from Dutch Kroners (DKK) using 1996 exchange rates.
[17] Refer to footnote 4, on page vii, for a brief discussion on statistical significance, and how results which are reported without measures of significance should be used anecdotally and not empirically.

turbines, and 5 out of 6 report no complaints from residents. The report declares, “There is no evidence indicating that views of wind turbines decreased property values.” (p. 4). Technically this is true, but with only 6 assessors reporting it is not possible to have a great deal of confidence in the results. Additionally, the fact that residents did not complain (correlation) does not mean conclusively that property values are not affected (causation). It is possible other reasons intervened, such as either ignorance of residents that a reduction in assessed values could be requested, that the process would be futile, or perceptions that evidence warranting a decrease would be difficult to collect on their own.[18]

Although previous studies leave much room for criticism, the work by Haughton *et al*. (2004) is more solid because it largely uses accepted rigorous techniques of sampling and survey construction. Yet, predicting actual effects on property values based on these results would be risky because the results are descriptive,[19] not analytic, no significance values are reported, and survey responses might be influenced by other variables. Despite these limitations the results are illustrative of a community searching for solid answers to questions of property value impacts. As part of an economic analysis of the proposed offshore windfarm in Nantucket Sound, Haughton *et al*. (2004) conducts a survey of 546 real estate agents (*n*=45) and residents (*n*=501). It is the first large scale survey concerning wind energy in the U.S. since the late 1980s (Pasqualetti and Butler, 1987; Thayer and Freeman, 1987; Thayer and Hansen, 1988). The report concludes that there is an adverse expectation about the proposed windfarm on property values from both residents (21%) and realtors (49%). Homeowners believe that average values will decrease by 4.0% with losses

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[18] Grover (2002, p.5) states that in Lincoln WI, the assessor asked a complaining resident to show that nearby properties had diminished in value. This most likely is outside the abilities of the average homeowner.
[19] Descriptive results describe the distribution of variables without regard for causal or other hypothesis. Analytic studies are designed to examine these associations. (Last, 1995)

of 10.9% expected for waterfront properties. Realtors expect losses to total 4.6% on average. To extrapolate from these results is risky though. In a comparison of survey and hedonic approaches Brookshire *et al.* (1982) caution that, “biases due to lack of experience must be considered” (p. 176). The responder’s estimates for anticipated impacts might be higher than those actually experienced. For example, the results of a survey in Scotland of 1,810 adults living near 10 windfarms with 9 or more turbines (Braunholtz and MORI-Scotland, 2003, p. 10) found that:

> “Of those that lived in their homes prior to the construction, concerns about specific problems that might arise as a result of the windfarm do not seem to have materialized in many cases…Furthermore, while around half (54%) anticipated no problems over a range of issues associated with the windfarm development, as many as eight in ten (82%) say that there actually have been no problems.”

This is corroborated by Warren (2005), in a study of residents surrounding windfarms in South-West Ireland who stated, “73% of residents across all [spatial] zones feel that their fears have not been realized” (p. 864). Finally, the predicted amount of value degradation as reported by Haughton *et al.* could be confounded by other variables, such as whether the respondent’s home has a view of the sound, if they believe wind energy to be necessary, to what degree they believe it might contribute to positive environmental change, or if they had seen an actual windfarm. Yet Haughton does not report these interactions between these variables.

Despite these weaknesses, their results are important in other ways. They illuminate a belief that the brunt of the effects will be felt by residents on the water in full view of the sound. Haughton found that 69% of realtor respondents believed the effects of the windfarm would be felt to a greater extent on ocean front houses, with only 2% expecting the effects to be distributed evenly (29% no opinion). The reasoning for this follows the logic that the "vista" of the sound provide value to the houses (e.g. Rodriguez and Sirmans, 1994; Seiler *et al.*, 2001). Incorporated with the belief that the addition of windmills will decrease the beauty of that "vista," it follows that the values of these homes will be diminished. Further, it might be the case that *ceteris paribus*, home values more dependent on "vista" will experience an effect where others will not. There might be some threshold where an effect begins such as that found with HVTL in Des-Rosiers (2002) study where he found effects (positive and negative!) completely disappear outside of 500 feet from the transmission line. All told, it would be difficult to entirely dismiss the results of Haughton *et al.* as the musings of the inexperienced or the hysterias of those in fear. The proposed windfarm will consist of 130 turbines, and as mentioned above, people have a preference for smaller windfarms over larger ones (Wolsink, 1989; SEI, 2003). It seems likely that house values in that region will react in concert to some degree with resident dislike; the question will be in what amount.

The results of Khatri's (2004) survey, for reasons similar to Haughton (2004) are illustrative of perceptions rather than actual values. Khatri mailed 1,942 surveys to licensed surveyors in Great Britain (U.K.); 405 voluntarily responded, and roughly 80 were surveyors who had experience with residential transactions near windfarms. The report finds that a majority (60%) of surveyors reported that property values will be adversely affected, though closer inspection finds dilutions to the results in three ways. The experienced respondents were concentrated in Wales and Scotland, where 43% of U.K. wind projects are located,[20] yet the percentage of Welsh (45%) and Scottish (55%)

[20] from www.bwea.org as cited by Khatri (2004)

respondents reporting decreased values is below the survey's national average (60%).[21] This implies that the national average is not appropriate to use as a final result. Secondly, because responses were voluntary, there might be a selection bias as the sample was unlikely to represent the population (Heckman, 1979).[22] Lastly the actual survey is not provided so it is difficult to assess the quality of the research, for example the nature of the questions.[23]

3.1.1 Conclusions drawn from survey studies

The survey studies do not give a clear indication as to whether there is an actual decrease in value. Even Haughton's (2002) study suffers from the likelihood that without actually experiencing what windmills look like in Nantucket Sound, respondents will overestimate the impacts. Haughton does elucidate, though, the possibility of thresholds of sensitivity for price devaluation. The results of these studies reinforce the need for more research and lead us into the next category of studies that are often used as a proxy for windfarm property value analysis: transaction-based studies of analogous HVTL structures.

3.2 Transaction based studies of analogous HVTL structures

With little to go on from existing research of wind energy and property values, interested parties have turned to property value studies of high voltage transmission lines (HVTL) in an attempt to make a benefits transfer from these structures to windfarms. It has been found that HVTL structures are perceived negatively and often adversely affect property values

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[21] A decrease in experienced effects is more recently corroborated by Warren (2005, p.853) "inverse NIMBYism"

[22] It is possible that only those that were bothered by the wind farms responded because they cared the most. If that is the case, than the results are skewed and in actuality less assessors feel there will be a decrease in property values.

[23] The report results "60% agreeing" imply that a leading question was used such as, "Do you agree the windfarms hurt property values?"

(e.g. Kroll and Priestley, 1991; Des-Rosiers, 2002). Because newer windmills are larger, and often more noticeable because of moving parts than HVTL, the temptation is there to assume turbines will have an equal or greater effect on property values (e.g. Zarem, 2005a).

3.2.1 Are HVTL structures and windmills viewed similarly?

Research conducted in 2003 in Ireland, based on a survey of 1,200 people indicated that windfarms were preferred over HVTL towers (as well as cellular towers and fossil fuel stations) (SEI, 2003). Why is this? Thayer and Hansen (1988) found that perceptions of windfarms were based on symbolic aspects in addition to aesthetic ones. Devine-Wright (2004) concurs, stating that symbolic aspects "could include the degree to which turbines are associated with wider environmental concerns such as climate change and feelings of personal responsibility to address such problems" (p. 129). This more complicated view of turbines is echoed in Warren (2005). When respondents living around windfarms were asked to rank the most positive and most negative aspects of the turbines, their presence in the landscape topped both categories (34% and 44% respectively). People either love them or loathe them.[24] It follows that if the U.S. effort in building windfarms is increasingly perceived as a reduction of risks, and therefore a solution to problems of energy scarcity and security, reaction to them will improve. Conversely, it is unlikely that HVTL would ever be perceived as offering a greater good. In fact, however unfounded,[25] electromagnetic radiation from HVTL is still a concern for individuals.[26] Because of these differences in

[24] This turn of phrase has been used often to describe public sentiment (e.g. Bishop and Proctor, 1994; Freris, 1998).
[25] Goeters (1997) reports that no study has provided scientific evidence of a relationship between cancer and HVTL proximity.
[26] Delaney (1992) reports that, "Even appraisers who had not appraised such property [near HVTL] believe that power lines contribute negatively to property values [for health reasons]." (p. 315).

perception between windmills and HVTL it would be imprudent to make a one for one comparison between the two.

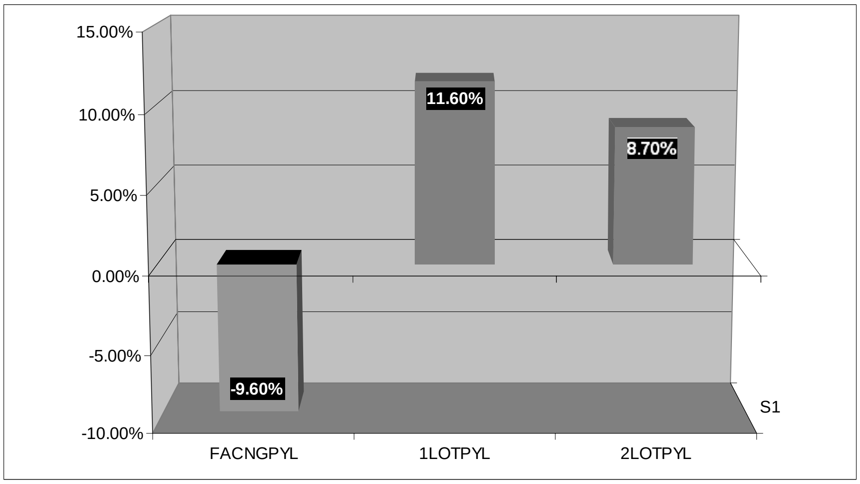
3.2.2 Are spatial property value effects of HVTL similar to windfarms?

Des-Rosiers (2002) found that effects from HVTL and their accompanying easements[27] disappeared outside of 500 ft. Additionally his results show a very sensitive interplay between proximity to the tower structure and proximity to the easement. Des-Rosiers (2002) found both an unambiguous negative effect due to towers and an unambiguous positive effect due to easement of HVTL on house values. In his review of the HVTL literature Des Rosier's (2002) finds that most studies conclude that, "Other physical as well as neighborhood attributes prevail [over proximity to HVTL] in the price determination process." (p. 277). This conclusion is also borne out in his findings that the negative effects of a view of a tower from a house immediately adjacent to it are overwhelmed by the positive effects of living near a HVTL easement just a few doors away (Figure I).

If HVTL and windmills exhibit similar effects on values, can it be assumed that property value effects of windmills will entirely disappear outside of 500 ft? Perhaps they will disappear, but at what point; one tenth of one mile, a half of one mile, or some other distance? Additionally, what effect will some overriding positive attribute, such as "vista" of sunsets, a bucolic field, or a mountain range, have on the potentially adverse effects of a view of windmills in close proximity?

[27] In the case of HVTL easements are clearings through which transmission lines pass. They have benefits, for example, in that ensure a development free zone and can provide access to green space.

Figure II: Property Value Effects of HVTL and Distance



Source: (Des-Rosiers, 2002, p.293) Effects on houses adjacent to towers (FACNGPYL), are negative (-9.60%). Those on lots 1 or 2 away (1LOTPYL & 2LOTPYL) are positive (11.60% and 8.70 % respectively).

Lastly, it is interesting to consider Warren's (2005) theory "inverse-NIMBYism" that there is an increased appreciation for wind turbines as you move closer to them, and the findings of Braunholtz (2003) which show largely ambivalent and positive reactions of residents to nearby turbines. Braunholtz finds that of the people living within 5 km (3 miles) of turbines 45% had largely positive views (with 6% having negative views and 49% ambivalent/no opinion), which differed significantly from those residents living outside of 10 km (6 miles) of which 17% had positive views (with 6% negative and 77% ambivalent/no opinion). The logical extension of inverse-NIMBYism on property values would have values increasing as distance from turbines decreases! Despite this possibility the report assumes the conventional stance that windmills will either decrease values or not change them at all.

3.2.3 Are temporal property value effects of HVTL similar to windfarms?

Kroll (1991) finds that where newly installed HVTL have effects on property values, they tend to fade away entirely over four to ten years. This is similar to results of some studies conducted near wind energy facilities. Exeter-Enterprises-Ltd (1993) found via its longitudinal study of facilities in the U.K. that negative perceptions diminish over time. "The results show that any change of attitude…is toward thinking that wind power is better." (p. 53) On the other hand, Devine-Wright (2004) believes the opposite. His re-analysis of Krohn's (1999) results show that negative perceptions of development can increase over time. Is this because older turbines are often decommissioned yet are not removed? Thayer (1988) believes so, finding that community sentiment is correlated with the number of turbines in operation, and if turbines are standing idle, negative perceptions increase. Given these contradictory results, a generalization of the similarities of HVTL and windfarm's temporal effects is not appropriate.

3.2.4 Conclusions drawn from analogous HVTL studies

The comparisons of HVTL effects on property values and those of windmills seem unclear. HVTL structures are not viewed the same as windmills, and windmills can even take on positive connotations. Moreover the interplay between HVTL and property values is both tenuous and very sensitive to distance and other neighborhood characteristics. There are spatial and temporal thresholds for HVTL property value effects which also could exist for windmills. As with the survey study analysis above, a careful look at HVTL studies reinforce the need for more research. Possibly other structures, for instance offshore drilling platforms, could be used as a more appropriate proxy as will be discussed further in the recommendations section. The studies conducted using actual property transaction values surrounding wind facilities offer more empirical data, but are also inconclusive as to the effects of windfarms on these values.

3.3 Transaction based studies of windmills

To date only two studies have been conducted using actual transaction values of homes surrounding wind facilities. The results of these are varied. Sterzinger *et al.*, (2003) conclude that property values rise in the area of windfarms, and Poletti (2005) comes to the conclusion that no effect exists.

Sterzinger *et al*., (2003) analyses roughly 24,000 transactions near 11 windfarms in the U.S., and compared average transaction values for houses in a control area outside the viewshed of the windfarm with transactions occurring within the viewshed (a 5-mile radius). The study comes to the conclusion that, "There is no support for the claim that wind development will harm property values." (p. 9), and even declares, "For the great majority of projects [windfarms] the property values rose more quickly in the viewshed than they did in the comparable community." (p. 2). Although this study is often quoted,[28] its methods have been criticized (e.g. ECW, 2004) for four reasons. First, the authors attempt to calculate a value for the variable "view of windmills," without properly controlling for it. There is no attempt to discern which properties within the ten different 5-mile viewsheds can see the windfarm or not. In effect, the study makes the erroneous assumption that all properties in the 5-mile radii can see the windfarm, when many houses' views in fact are obstructed by geological features, trees, and other houses (RBA, 1998a; Poletti, 2005).[29]

[28] A "Google" internet search using all of the following words, "REPP", "wind" and "property" generates 18,600 results. [tested 2-20-06]

[29] Sterzinger *et al* analyze the community surrounding the Madison County windfarm, which is the subject of this report. We found 66% of the homes sampled in the 5 mile radius could not see the windfarm at all.

Secondly, the analysis does not control for distance to the turbines, thereby making the assumption that the "viewshed" effect is the same, on average, for homes five miles from the windfarm and those in immediate proximity to the turbines. Third, there are problems with how the study validates its results. The report provides readers with only R^2 (or goodness-of-fit) values for its outcomes, and this is problematic, since, by itself, the R^2 statistic is a poor indicator of explanatory power (Halcoussis, 2005). Compounding this problem, the report gives R^2 values which are very low, for instance 0.02 for some models, which is saying in essence the model describes only 2% of the actual movement of property values. Despite this somewhat flagrant disregard for rigor it treats these models as it does models where the statistic is high, for example 0.85. This inconsistency is not addressed by the report. The last reason this research is often criticized is that no attempt is made to sort out inappropriate transactions. Sales that are not arms-length (divorce, sales between family members, estate sales etc.) are included. By doing so the report includes transactions that do not represent the agreement between a willing buyer and a willing seller, a requirement for accurate analysis. Combined, these four omissions in rigor render the results of the report extremely weak, if not entirely misleading.

The analysis by Poletti (2005) improves on that of Sterzinger *et al.* (2003) by culling out transactions that were not arms-length. As well, it excludes sales of homes built before 1960, in an effort to control for house-specific characteristics such as construction quality, amenities and condition. Poletti looks at roughly 300 sales that occurred in and around two windfarms in Wisconsin and Illinois. He comes to the conclusion that there is not sufficient evidence in the data to warrant rejection of the claim that windfarms have an effect on property values. Poletti compares average values of properties surrounding the windfarms, which he entitles “target area” with those in a “control area,” which is outside the view of the windfarm. However, Poletti does not attempt to measure to what degree, if any, homes can see the windfarm. The author describes the area surrounding the windfarms as rolling with potentially obscuring features, so the implication is that some of the properties have no view of the windfarm. Further, no effort is made to control for distance. Although statistically sound techniques were used to compare the control area to the target area, by not properly controlling for view and distance, the study results are inconclusive at predicting the effects of the windfarm on property values.

3.3.1 Conclusions drawn from transaction studies

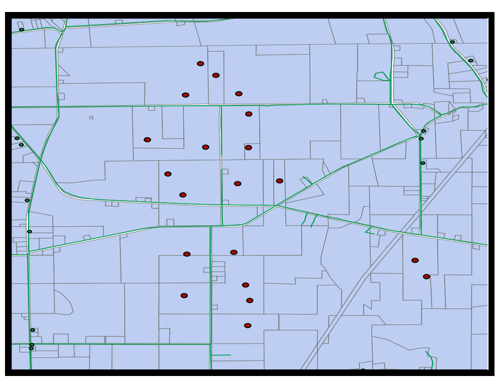
Taken together, the two studies using transaction values still leave open to conjecture the question as to the actual effects of windfarms on property values. By not appropriately sorting out misleading data, empirically establishing the degree to which houses could see the windfarm, and not factoring in distance, these studies most likely miss the potentially subtle interaction between view and value that has been found with other environmental stigmas (Des-Rosiers, 2002).

If results of studies of property values and windfarms can be confidently applied in windfarm siting decision making, the above analysis makes clear the importance of using large samples (>30), of measuring the actual visibility of and distance from turbines from each house, and of testing the results for significance. The following analysis attempts to do this. First there will be a brief discussion of the study area, then methodology, results, conclusions and recommendations.

4 Study Area

The Fenner windfarm was announced near the end of 2000; construction commenced in the spring of 2001 and was completed in the fall of 2001 (Moore, 2005). The 30 megawatt (MW) installation consists of 20 turbines, each 218 feet tall, with a rotor radius of 110 feet, making the top of the turbine blade's sweep roughly 328 feet above the ground. The windfarm sits atop 14 different parcels over 2,000 rolling acres. The Fenner Township receives $150,000 as a payment in lieu of taxes (PILOT) from the project owner which goes to increased road maintenance and schools (Cary, 2005). As is required under the New York State Environmental Quality Review Act (SEQRA) an Environmental Assessment Form (EAF) was prepared and submitted to the lead agency which was the Town of Fenner Board. It issued a Negative Declaration on the project based on the EAF, citing adverse impacts as insignificant. The public was given a number of opportunities to participate in the decision making process at town board and planning board meetings, which were characterized as both numerous and without much opposition (Moore, 2005). Larger maps of the study area are included in Appendix B.

Figure III: Fenner Turbines & Parcels



Source: Madison County Tax Office
(Large dots are windmills, rectangles are parcels, parallel lines are HVTL, and the dark lines are roads.

5 Methodology

The general purpose of this case study is to test if the view of the Fenner windfarm from homes inside of 5 miles from the windfarm has any significant effect on transaction values. “View” is defined using a continuous variable from 0 (no view) to 60 (a full view of all 20 turbines). The study additionally investigates how this effect varies with distance (spatially), time (temporally) and house value. Lastly, the effect and degree of the PILOT payment to Fenner Township is investigated.

The hedonic pricing model is well suited to dissect these issues revolving around windfarm acceptance. The rigor of the instrument in measuring the marginal contribution housing and neighborhood characteristics have on home transaction values is well supported in the literature for assessment purposes (Brookshire *et al.*, 1982; Malpezzi, 2002; Sirmans, G.S. *et al.*, 2005a; Sirmans, G. Stacy *et al.*, 2005b), in establishing effects of HVTL (Kroll and Priestley, 1991; Delaney and Timmons, 1992; Hamilton and Schwann, 1995; Des-Rosiers, 2002), in valuing the contribution “vista” has to value (Rodriguez and Sirmans, 1994; Benson *et al.*, 2000; Seiler *et al.*, 2001; Bond *et al.*, 2002), and in determining the effect of open space (Irwin, 2002) and environmental stigmas (Dale *et al.*, 1999). The model, given enough data, is sensitive enough to allow sales to be grouped temporally (e.g. by year), spatially (e.g. by distance from an amenity such as a body of water), and economically (by the value of the home). Once these divisions are made, variables of interest (e.g. the marginal contribution of fireplaces to homes values) from one group can be compared to other groups, both in terms of significance and the level of contribution.

5.1 The non-linear hedonic model

The non-linear hedonic pricing model in its present form is often attributed to Sherwin Rosen (1974) for his contribution to its utility in deciphering housing prices. A number of reviews (Malpezzi, 2002; Sirmans, G. Stacy *et al.*, 2005b) validate his construction in its ability to rigorously predict changes in residential transaction values based upon characteristics of the homes.

The model takes the form:

$$\text{Log (Sale\_Price)} = f\,\text{(Physical Characteristics, Other Factors).}$$

"Physical Characteristics" often used include square footage of the home, lot size, number of bathrooms, number of bedrooms, type of construction, etc. "Other Factors" often include proximity to amenities, school district, local tax rates, and in this case study, "view" of and distance from turbines.

5.2 Variable selection

Although inclusion of the most commonly significant variables as taken from the literature (e.g. Sirmans, G. Stacy *et al.*, 2005b) is important and necessary, often local conditions can direct the proper construction of the model more than convention. Local assessors, realtors, and residents often have considerable insight into how prices are affected by changes in characteristics and other factors. Therefore in constructing the model used for this report Sirman's (2005b) recommendations for variables were included as well as those cited by a survey of two local assessors and two real estate agents. The results of the two inquiries are listed in Table I and Table II.

Sirman's list included all of the variables on the local expert list except School District, the distinction between distance to I90 and distance to State Route 20, local tax rates and building styles. All of the available variables from both the Sirman list and the local expert list were included.

Table I: Sixteen Most Significant Hedonic Variables in Housing Studies

Variable	Appearances	# Times Positive	# Times Negative	% Time Significant
Square Feet (SFLA)	69	62	4	96%
Central Air	37	34	1	95%
Age at Time of Sale	78	7	63	90%
Pool	31	27	0	87%
Acres	52	45	0	87%
# of Full Baths	37	31	1	86%
# of Stories	13	4	7	85%
Deck	12	10	0	83%
# of Fireplaces	57	43	3	81%
# of Garage Spaces	61	48	0	79%
# Rooms	14	10	1	79%
Basement Type	21	15	1	76%
# of Bedrooms	40	21	9	75%
Brick or Stone Extr.	13	9	0	69%
Distance	15	5	5	67%
Time On Market	18	1	8	50%

Source: (Sirmans, G. Stacy et al., 2005b)

5.3 Data collection

The data concerning transaction values and assessor information is collected from Madison County Real Property Tax Office. From January 1, 1996 through June 1, 2005, 452 sales took place that were coded "arms-length" transactions by county assessors, and were within 5 miles of the windfarm. Of these, 152 were removed as land-only sales[30], and upon closer inspection 20 sales (15 land-only and 5 non arms-length) were found to have been coded incorrectly and were removed. For the remaining 280 sales, assessor records from the

[30] "Land Only" sales refer to sales of parcels that did not contain a house at the time of sale.

closest preceding inspection were collected providing information about structural characteristics and location.

Although most of the recommended variables were included in the Madison County records, there were many gaps in the records for the following variables which made them unusable: Pool, deck, number of stories, number of rooms, and garage spaces.[31] Data for time on the market was not available, and therefore was not included.[32]

Table II: Twelve Most Influential Characteristics Recommended by Local Experts

Variable	**Percent of the 4 Local Experts Recommending this Variable**
# of Full Baths	100%
# of Bedrooms	100%
Overall Condition	100%
Basement Type	75%
# of Fireplace	75%
Acres	75%
Square Feet (SFLA)	75%
Age at Time of Sale	75%
Building Style	50%
Distance to I90	50%
School District & Taxes	50%
Distance to State Route 20	50%

Source: Joel Arsenault, Century 21 Real Estate; Jenny Chapin, Don Kinsley Real Estate; Priscilla Suits, Assessor Fenner & Nelson Townships, Madison County; Tanya Pifer, Assessor Lincoln Township, Madison County

Sale price was adjusted to 1995 dollars by using the Department of Labor's CPI for Rural New York (SALE_PRICE_95) and then converted to its natural log

[31] During field analysis decks and pools were rarely present, and the number of rooms and stories was expected to be highly correlated with the square feet, so their exclusion was not expected to compromise the results. The County is conducting a reassessment of every house in its records, which should be completed in 2006, which is expected to fill in the gaps of these characteristics.

[32] Although time on the market generally has the effect of lowering the price it has in some cases produced higher prices. It is assumed that this is because buyers can wait for the price that they want, or that the market slowly appreciates up to their asking price (Sirmans, G. Stacy *et al.*, 2005b).

(LNSALE_PRICE_95).[33] The thoroughness of this adjustment was tested by including a continuous variable (DEED_YEAR) to account for a potential linear escalation in market price which exceeded the CPI inflation rate. Four binary variables (WINTER_SALE, SPRING_SALE, SUMMER_SALE, and FALL_SALE) were included in the model to account for seasonality in the housing market. Descriptive statistics for all non-viewshed variables are given in Appendix A: Tables IX and X.

A geographic information system (GIS) was used to calculate distance from the houses to the nearest turbine (DIS_TO_MILLS). Elevation and spatial location layers were populated using the 10 meter digital elevation model (DEM) provided by the United States Geological Survey (USGS), ortho-imagery was provided by New York's Department of Environmental Conservation (NYDEC), and roads, windmill locations and parcels were provided by the Madison County Planning Department. Parcel shapefiles did not contain actual house location, so a housepoint file was constructed using the ortho images overlaid with the parcel map, for each parcel that sold during the study period.

All layers were projected using the NAD 1983 Coordinate System and the New York State Plane Central projection. Where possible, shapefiles were corroborated with ortho-images, as was the case with the windmills, to ensure locational accuracy. Distances to major roadways (Route 20: DIS_TO_RT20 and U.S. Route 90: DIS_TO_I90) were calculated using linear distance. Although this is not a measurement of actual driving time

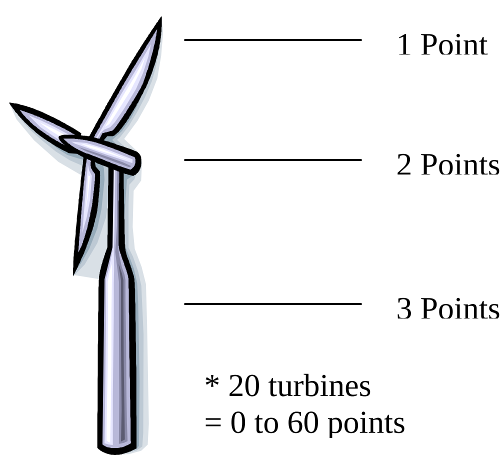
[33] To account for the "bubble" in the housing market binary variables for all years were tested but were found to be insignificant, so the CPI 1995 adjusted prices were used without these variables.

to these arteries, field experience indicated that the high density of roads in this area allowed residents a fairly direct route to the arteries at roughly the same speed.[34]

5.4 Construction of viewshed variables

To populate the variables for windfarm viewshed (VIEW) two methods were developed: a GIS simulated method and one involving field visits, and one method was ultimately used: the field visit method. The GIS method, as discussed in Appendix C, achieved an accuracy rate of 85% which improved on previous studies (Dean, 1997; Maloy and Dean, 2001) but did not meet accuracy requirements for this report's analysis of greater than 95%. Therefore the second method involving field analysis was used to ensure complete accuracy of the "view" variables. Visits were made to each of the 280 homes which sold after Jan 1, 2001 and were within 5 miles of the windfarm (138 homes visited) to assess the degree to which the home could see the windfarm. By standing at or near the house a rating of 1 to 60 was established for each home. This rating was based on the degree to which viewers could see each of the 20 windmills in the Fenner windfarm (Figure III).

Figure IV: Turbine Visibility Scoring Method



[34] A more accurate measurement would be a shortest elapsed time traveled incorporating speed limits of roads, and distance traveled on them. This is similar to the algorithms used by, for instance, Mapquest.

If the viewer could see only the top 1/3 of the turbine blades one point was given for that turbine, visibility of the nacelle (or hub) was a second point and visibility below the sweep of the turbine blades a third. Therefore a total of 3 points per turbine were possible, with a total of 60 points for the 20 turbines. No distinction was made for the direction the house faced because it was assumed purchasers were likely to walk around the house and inspect all views. If the turbines were clearly in view from the property surrounding the house, and the purchasers had a strong reaction to their visibility, it was assumed they were not likely to make a distinction between front, back and side windows at the time of purchase. Inspections were done on October 30 and 31, 2005 when deciduous trees had partially dropped their leaves. A slight distinction between winter (leaves off) or summer (leaves on) sale dates could be made from some properties; therefore visibility was calculated using the appropriate condition. Finally photographs of the house and of the predominant view were taken to corroborate results at a later time if needed.

Table III: Description of Viewshed Variables

DIS_TO_MILLS	The distance from the home to the nearest turbine as calculated by the GIS.
VIEW	The view of the turbines as recorded from the field analysis with possible range from 0 to 60. If house sold before Jan 1, 2001 the value is 0.
VIEW1MILE	The VIEW of the home if 0>DIS_TO_MILLS<=1, otherwise 0
VIEW2MILE	The VIEW of the home if 1>DIS_TO_MILLS<=2, otherwise 0
VIEW3MILE	The VIEW of the home if 2>DIS_TO_MILLS<=3, otherwise 0
VIEW4MILE	The VIEW of the home if 3>DIS_TO_MILLS<=4, otherwise 0
VIEW5MILE	The VIEW of the home if 4>DIS_TO_MILLS<=5, otherwise 0
VIEW2001	The VIEW of the home if the year of sale was 2001, otherwise 0
VIEW2002	The VIEW of the home if the year of sale was 2002, otherwise 0
VIEW2003	The VIEW of the home if the year of sale was 2003, otherwise 0
VIEW2004	The VIEW of the home if the year of sale was 2004, otherwise 0
VIEW2005	The VIEW of the home if the year of sale was 2005, otherwise 0

5.5 Discussion of Descriptive Statistics

Of the 280 properties in the sample, the mean value of homes was $102,384, the mean number of acres was 8.8 and the mean age of the home at the time of sale was 42 years old. Approximately 28% of all the houses in the sample could see the windfarm; of the 149 sales that took place after January 1, 2001, 43 were from homes which could see the windfarm. A full description of all the variables is included in Appendix A.

5.6 Testing for violations of OLS assumptions

After the model had been constructed the data were tested in accordance with the ordinary least squares (OLS) assumptions which govern hedonic regression models. These assumptions include: multicollinearity, the independence of the error term and the independent variables, homoskedasticity and temporal autocorrelation.[35]

5.6.1 Multicollinearity

The assumption of multicollinearity posits that the independent variables are in fact independent and not highly correlated with each other. If one variable is highly dependent on one or a combination of variables, the *p*-values will be inappropriately increased. This assumption can be tested for by regressing each independent variable on the others and then looking at the unadjusted R^2 values. Convention holds that R^2 values less than 0.75 indicate a multicollinearity low enough to allow results to be largely undisturbed (Halcoussis,

[35] A fifth assumption which is commonly considered in OLS models, but rarely in hedonic literature is simultaneity, when the dependent variable affects the independent variables. This was not directly tested for, but its effect on coefficient significance is to increase it. In the case of this report, this does not alter our results.

2005).[36] In our case all R^2 values were under this threshold, and most (80%) were considerably under it (in the .5 to .2 range).

During initial analysis of the variables, a correlation matrix was generated. It was found that the number of bedrooms (NBR_BEDROOMS) was highly correlated (0.746) with square feet (SFLA), but the number of bathrooms (NBR_BATHROOMS) (0.474) and the number of half baths (NBR_HALF_BATHS) (0.361) were acceptably correlated with square feet and each other (0.044), so bedrooms was dropped from the model and half baths was added. Additionally it was found that distance to I90 (DIS_TO_I90) was highly negatively correlated to distance to Route 20 (DIS_TO_RT20) (-0.977) because they run roughly parallel to each other. Therefore, I90 was dropped from the model.

5.6.2 Independence of Error Term and Independent Variables

Independence of the error term and the independent variables is important in assuring that the variables are the best predictor of the dependent variable. To test this assumption, the residuals were regressed on the independent variables. None of the independent variables were significant (*p*-value range from 0.138 – 0.913) and the model itself is non- significant (*f*-value 0.258, *p*-value 0.999, adjusted R^2 -0.059).

5.6.3 Homoskedasticity

Homoskedasticity of the variables assumes that the error terms of any range of values of a continuous variable are similar. The values of the variables are ordered in ascending or descending order and divided into thirds. The Levine test statistic compares the variances

[36] Actually the measure used is the Variance Influence Factor (VIF) which is calculated as follows: $1/ (1- R^2)$. A VIF of 4 or below is appropriate to reject the claim of a high degree of Multicollinearity. An R^2 more than 0.75 will result in a VIF more than 4.

of the thirds. If that statistic falls outside the acceptable range (*p*-value > 0.05) the assumption holds. In our case all continuous variables returned values exceeding 0.05 therefore the OLS assumption of homoskedasticity was met.

5.6.4 Temporal Autocorrelation

The existence of temporal autocorrelation violates the OLS requirement that the residuals are independent of each other. If temporal autocorrelation exists, the values of the dependent variable, and therefore their residuals, are affected by the value in the previous temporal term. By arraying the residuals in chronological order and testing the correlation of any residual against its preceding residual their autocorrelation can be determined. The Durbin Watson test statistic ranges from 0 to 4. Within a range of 1.5 to 2.5 there is considered to be no autocorrelation. A statistic either more or less than that range is considered to have either a positive or a negative autocorrelation respectively. All of the models had a Durbin Watson test statistic between 1.798 and 2.047, therefore no autocorrelation was detected.[37]

[37] Spatial autocorrelation was not tested for, yet it is possible that it would exist within the data, following the logic that a neighbor's transaction value affects the surrounding transactional values both on the sellers and buyers side of the transaction.

6 Analysis

Results of the six models that were run are reported in Appendix F. Initially, the model was run with all potentially significant variables (Model #1), as recommended by the literature (Table I) and the local experts (Table II). Many building styles and school districts did not meet initial significance criteria (*p*-value < 0.75). As well, the variable for air conditioning (CENTRAL_AIR) was found to be insignificant. These variables were removed. As expected these changes improved the model's overall significance (Model #2). Model #3 is further refined with all non-significant (*p*-value > 0.1) variables removed except those for seasonality (e.g. FALL_SALE). This model (Model #3) had an F-value (63.764) considerably higher than that of Model #2 (39.185) indicating the removed variables created undue "noise" in the model. All variables had the expected sign except for the Fenner Township binary variable, which is discussed below. Model #3 was then used to test the significance of the viewshed variables.

Initially the variables for distance to the windmills (DIS_TO_MILLS) and view of the windmills (VIEW) were added to the model (Model #4). The coefficients for these variables were both positive yet non-significant at both the 95% or 90% levels of confidence (0.679 and 0.410 respectively). Models #5 and #6 explore the potential micro-spatial and temporal effects of view in 1 miles bands (VIEW1MILE thru VIEW5MILE) and subsequent years (VIEW2001 thru VIEW2005) respectively. Although both models are significant in general, all 10 variables did not meet the significance criteria (*p*-value < 0.10), therefore interpretation of the coefficient value or sign is not appropriate.

As mentioned above the sign (coeff. -0.083) and significance (*p*-value 0.018) of the binary variable for the Fenner Township (FENNER) is surprising. This variable measures the marginal change in value for homes in Fenner Township as compared to all other townships. We included this variable to explore if the payment the township receives in lieu of taxes from windfarm operations (PILOT) has had an effect on the values of homes in the township all else being equal. The assumption is that if the payments, which largely go to the school system in the township, are considered to have significantly improved conditions in the township in the eyes of home purchasers, this variable would be both positive and significant. But, in our model the coefficient was negative and quite large (the coefficient -0.083 corresponds roughly to a decrease of 8%). Therefore, to further explore we added binary variables for all townships including Fenner (Smithfield was the omitted township). The results of this test indicated that none of the townships had a significant influence on price when taken together. This indicated that the influence of Fenner was being spread among the townships. Therefore, finally we omitted the Fenner variable and included all of the other township variables and found both Cazenovia (coeff. 0.106, *p*-value 0.095) and Nelson (coeff. 0.105, *p*-value 0.081) were significant and positive. Results for these variables are in Table IV. The positive sign implies that in relation to Fenner *ceteris paribus* the placement of the house in Cazenovia and Nelson adds value. We explored whether this had to do with the wind energy facility by adding view variables to the model. Because distance to turbines can be largely explained by the township variables[38] we only included the variable VIEW [of turbines]. We found that neither the magnitude nor the significance for the township variables changed when we took view into account. This implies that the decreased value of homes in Fenner is not related to the wind facility. To investigate the effects of township further we contacted a local realtor (Arsenault, 2006).

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[38] Regressing distance on the township variables produced adj. R^2 of 0.579 and a *p*--value of 0.000.

He believed there was a correlation between the township (Fenner) and the value of homes, in that homes of higher values were not being built in the Township. He attributed this to the windmills, and believed that there was a correlation between values of home and the

Table IV: Testing for the Influence of Township on Home Value

	Coeff.	p-vlu	Coeff.	p-vlu	Coeff.	p-vlu.	Coeff.	p-vlu	Coeff.	p-vlu
CAZENOVIA	0.077	0.301	0.106	0.095	0.117	0.141	0.113	0.077	0.118	0.076
LINCOLN	0.009	0.880	0.056	0.505	0.073	0.404	0.072	0.405	0.067	0.456
NELSON	0.095	0.115	0.105	0.081	0.109	0.147	0.105	0.079	0.109	0.071
SULLIVAN	0.038	0.564	0.079	0.290	0.100	0.244	0.097	0.215	0.092	0.250
SMITHFIELD			0.029	0.628	0.036	0.567	0.035	0.566	0.032	0.616
FENNER	-0.023	0.689								
DIS_TO_MILLS					-0.002	0.930				
VIEW					0.001	0.428	0.001	0.411		
VIEW1MILE									0.001	0.716
VIEW2MILE									0.000	0.913
VIEW3MILE									0.006	0.113
VIEW4MILE									0.002	0.676
VIEW5MILE									-0.002	0.711
Model R^2		**0.791**		**0.806**		**0.790**		**0.790**		**0.789**
F/Significance	**53.921**	**0.000**	**51.184**	**0.000**	**46.524**	**0.000**	**48.827**	**0.000**	**41.132**	**0.000**

Note: Non viewshed variables were included in the model but were not shown above. Coefficients roughly correspond to percentages (e.g. 0.100 ≈ 10% increase), and p-values correspond to the likelihood that this result was reached by chance (e.g. 0.100 ≈ 10%).

affect “view of the turbines” had on them. He said, “Higher priced homes were not being built in the Fenner area because of the view of the turbines.” To analyze this claim we broke sample set of home sales into thirds and investigated whether the variable for view was affected. In so doing we tested the claim that homeowners of higher priced homes care more about the view than those of lower value. Table V contains the results. We found that view did not have a significant effect at any price range. We also found that although splitting the groups did not affect the significance of the overall model, it did dramatically decrease the R^2 statistic as compared to previous models (roughly 0.80 to 0.23). A portion of this decrease can be explained by the decrease in the number of cases in each group (*n)*,

Table V: Testing for Significance of View among 3 Price Levels

Price Level	**Lower 3rd**		**Middle 3rd**		**Upper 3rd**	
	Coeff.	**p-value**	**Coeff.**	**p-value**	**Coeff.**	**p-value**
DIS_TO_MILLS	-0.009	0.773	0.023	0.132	-0.022	0.285
VIEW	0.003	0.313	0.002	0.361	0.000	0.918
***n*/Adjusted R^2**	**92**	**0.472**	**93**	**0.226**	**92**	**0.627**
F/Significance	**6.13**	**0.000**	**2.507**	**0.003**	**9.605**	**0.000**

Note: All non-viewshed variables were included in the model but are not shown above. Coefficients roughly correspond to percentages (e.g. 0.100 ≈ 10% increase), and p-values correspond to the likelihood that this result was reached by chance (e.g. 0.100 ≈ 10%).

but not all. It could reflect the variance between the income levels, and indicates a need for further research into how each income level makes home buying decisions, based on the non-viewshed variables that were included in the model (i.e. number of bathrooms, square feet, and number of acres).

7 Conclusions

Our analysis of 280 home sales within 5 miles of the Fenner windfarm, in Madison County, New York failed to uncover any statistically significant relationship between either proximity to or visibility of the windfarm and the sale price of homes. Additionally, the analysis in this report failed to uncover a relationship even when concentrating on homes within a mile or that sold immediately following the announcement and construction of the windfarm. Therefore it is safe to conclude, in this community, a view of the windfarm does not produce either a universal or localized effect, adverse or not. To the degree that other communities emulate the Fenner rural farming community, these results should be transferable. But, to be safe in these conclusions, let us first consider the possibility that: 1) effects exists, but the instruments which were used in this study were not effective in measuring them, and 2) effects exists but because those effects are situated outside the sample area our analysis did not discover them.

First we investigate the possibility: whether the instruments were not effective in measuring an effect. The instruments in question are 1) the hedonic pricing model and 2) the methods used to calculate turbine visibility. The hedonic model is appropriate as it has been well tested in various applications including, but not limited to, assessments, in valuing nearby open spaces and in valuing the effects of HVTL and environmental stigmas. It is particularly effective at discerning universal influences, and the question of effects on property values is not whether one or two houses are affected but rather if groups of houses are affected in a predictable universal way. The construction of the model, used in this report, follows the convention described as “test, test, test” (Kennedy, 2003), which refers to a model construction method that, “discovers which models of the economy are tenable, and to test rival views." (p. 83) By carefully testing the assumptions behind the model, as were described in section 5.8, the model that was ultimately chosen can be considered to be, "the best estimated regression line" (Halcoussis, 2005).

In regards to the tests of "visibility" from each of the homes, the method chosen was intended to reduce bias and allow for a robust set of measurements (0 to 60). View was measured not in a subjective way, but rather by counting the numbers of points seen from the house. The distance was measured by linear calculations produced by a GIS. Because the range of the two measurements is relatively large, a small miscalculation of "view" (0-60 scale) or distance (0.00 to 5.99 miles) will not adversely affect the ability of the model to explain variations in sale price. It is therefore safe to say that the instruments this report used are both appropriate.

The second possibility of error concerns whether effects exist outside the sample area and therefore were not measured by our analysis. In other words, is it possible that a house inside of 0.76 miles, outside of 5 miles or that will sell after June 2005 will be affected differently than what our sample describes? The possibility should be investigated in other studies, but in the case of Fenner it is unlikely unless the situation on the ground changes.[39] Our sample set includes *all* arms-length transactions of single family homes which occurred from January, 1996 to June, 2005 within 5 miles of (and as close to 0.76 miles from) the windfarm. If one is to attempt to address the question of whether effects exist, a sample set containing all transactions cannot be improved upon.[40] If houses were

[39] For example, if the turbines are taken out of operation yet are not decommissioned or removed. Thayer (1987) found a strong negative reaction to just such a situation in California in the 1980s.
[40] The sample data is normally distributed as would be expected of 280 transactions. See Appendix F.

measurably affected outside the sample set, it seems unlikely that concurrently no effect, weak or strong, would be found inside the sample set.

If the potential inadequacy of the instruments has largely been ruled out, and we are confident that the study area represents an adequate sample we can conclude no effect exists for this community, or, if they do, the effects are random and therefore, by definition, unpredictable. The result of "no effect" has been corroborated by peer-reviewed large sample survey studies. Warren (2005) found, on average, windfarms were of little concern to residents stating, "The data reveal a clear pattern of public attitudes becoming significantly more positive following personal experience of operational windfarms" (p. 866). Further, Braunholtz (2003) finds,

> "It is extremely rare for people to spontaneously mention their local windfarm as either a positive [<3.0% of sample] or negative [0.3% of sample] aspect of their area. This fact that suggests that, for most at least, [the windfarm] is not foremost in their minds when thinking of, and describing, the area" (p. 5).

A rural setting with a history of farming, these townships might accept harvesting wind energy as an extension of the use of their land. The wind farm does not seem to have been in contest with the sense of place that is mentioned in Devine-Wright's (2004) discussion. Possibly the non-linear layout is desirable. It is rather undulating as is the landscape itself. There are many opportunities for hide and reveal[41] in this landscape, which might allow viewers to keep an emotional distance from the turbines if they are in opposition to them, or to look at them more affectionately if they are in favor of them.

[41] "Hide and reveal" or "miegakure" (jap.) is a phrase used in landscaping where even in small spaces portions screening of features (the "hide") encourages viewers to see what lies just around that bend (the "reveal").

Thayer (1987) found that public sentiment was strongly tied to the bureaucracy behind the decision to erect the windfarm (local officials, developer). This is echoed by Wolsink (1989) and Krohn (1999), who states “decision making over the heads of local people is the direct route to protest” (p.959). In the case of Fenner the developer was required to prepare and submit for public review an EAF. And the Town of Fenner was the lead agency overseeing the approval of permits. Therefore, to the degree that the EAF process effectively addressed and corrected negative concerns, the community might not have retained much negative sentiment toward the project going into construction. Possibly the research of Devine-Wright (2004) offers an explanation. He states, “the opinions of significant others such as friends and family living in the local area are important in determining public perceptions of wind farms” (p.130). In Fenner, one civically involved couple who leased their land to the developer is not only a proponent of wind energy, but also talks with great pride of the Fenner Township and surrounding area. They host tours and offer t-shirts and hats for wind farm visitors. They might have influenced the community positively. In fact an imminent windfarm expansion in Fenner from 20 to 29 turbines has been met with no opposition. This matches with Warren’s (2005) results. He samples residents both with and without experience living near windfarms and found those with experience are much more likely to favor expansion of them.

To the degree that other similar communities exist in the US, in that they have similar land uses, median home prices, and homeowner profiles, these results should be transferable. Extrapolation of these results to communities which do not fit this description, without careful consideration, is not recommended until more research is conducted. Specific recommendations for further research are outlined below.

8 Policy Implications and Recommendations

Contrary to the notion that adverse effects are universal, this report did not produce any significant relationship between distance from, or visibility of the windfarm and the sale prices of homes. These results fit with those reported in other empirical studies that surveyed public attitudes, which found that people living near turbines find them "acceptable" and, in fact, rarely spontaneously mention them (Braunholtz and MORI-Scotland, 2003). Together these studies suggest that in communities similar to the one surrounding the Fenner windfarm, the question of property value effects should be lessened in importance in the decision making process. Further, if these results are substantiated in further research as discussed below, the implications for stakeholders are significant.

Specific recommendations for many of the stakeholders in the windfarm planning process are as follows:

- Town Officials/Planners: Town planners should realize that the methods for facility approval can greatly contribute to placating community concerns. A transparent process which allows residents to address siting concerns such as the size of the project, the placement of the turbines as it relates to dwellings, and the provisions for dealing with maintenance and decommissioning are very important. If steps such as these are followed, local decision makers should be able to enjoy favorable community sentiment and avoid property devaluation.

- Community Members: This research should provide some confidence to community members that a windfarm siting does not guarantee a devaluation of property values, and that assertions to that effect should be thoroughly investigated. In fact, if more studies corroborate these findings devaluation might be considered unlikely. If residents believe their community is similar to Fenner's, factors other than property devaluation should be concentrated on. These could include the level of payments in lieu of taxes (PILOT), the quality of decommissioning assurances and the level of transparency in the planning process. Based on the findings of this study these factors could play a more important role than potential property devaluation in a community's proposed windfarm evaluation process. Additionally, urging local, state and federal policy makers to promote continuing research into public attitudes surrounding other wind energy facilities will allow for greater understanding of upcoming development proposals, and a larger area of transferability of results.

- State lawmakers: This report's findings of "no effect" might indicate that the planning process used for the Fenner windfarm should be used as a model. Currently some state laws allow the review process to be entirely avoided (GAO, 2005), yet an environmental review and subsequent community involvement can help ensure that appropriate decisions are made and development is accepted by the community going forward. State regulations should require all wind developments to participate in the EIS process, to ensure that the planning process is transparent, and that community involvement is encouraged. Additionally, through an intense effort to research and disseminate findings, such as reactions of other communities to wind development in the U.S., lawmakers can give local officials the tools needed to weigh real costs and benefits. In so doing, decision makers can avoid having to rely on insufficient information and speculation.

- Wind industry representatives: Although these findings seem to show that property devaluation did not occur in the community surrounding the Fenner windfarm, it should be clear that property value effects are strongly tied to public attitudes, a cooperative planning process, and might be influenced by characteristics not present in the Fenner community. These are discussed below and include the number of second homes, the proximity to the wind turbines, and the percentage of "vista" included in the home value. Accordingly, encouraging further empirical research of public attitudes and property transaction values surrounding wind developments might provide decision makers with the information needed to make appropriate decisions regarding development proposals going forward.

8.1 Future research considerations

For communities, especially ones that are not similar to Fenner, there is an intense need for more research. With this, policy makers and other stakeholders will have better answers to this contentious issue. More information is needed regarding the following categories:

- Other windfarm communities: Roughly 90 sites in the U.S. are larger than the Fenner site (AWEA, 2005d), and many of them would be appropriate for study. Sites should be chosen with a variety of socio-economic characteristics, windfarm sizes, and population densities. Studies should analyze homes closer than 4000 feet, and include variables for "vista,"[42] level of community cooperation in approval process, degree that farming matches sense of place (such as the percentage of large tract vs. small), and whether homes are the primary or secondary residences.
    - Distance: This study contains homes only as close as 0.75 miles or 4000 feet to the turbines. HVTL studies have found effects exist only inside 500 feet

[42] As discussed in footnote 8 on page 2

(Des-Rosiers, 2002). Future studies should find communities with homes closer than 0.75 miles, and preferably as close as 500 feet if they exist.[43]

- Vista: This study does not include a separate measurement for "vista" (or good view) in its analysis. For example, Haughton (2004) finds that homes with a high percentage of "vista" represented in their value (such as might be found in homes on the coast) might be affected differently by wind development.
- Cooperative Process: The community studied in this report was at least partially involved in the planning process, in so far as they were invited to attend and submit comments at a number of meetings (Moore, 2005). The degree to which the project developer includes the community in the planning process of other communities might influence results (Warren *et al.*, 2005) and should be studied.
- Sense of Place: Anecdotal evidence implies that this community still largely embraces the farming nature of its past. How well wind energy "harvesting" fits with other community's sense of appropriate land use might also alter outcomes (Devine-Wright, 2004). Using an average tract size for a sample might be a proxy for this variable.
- Size of Project: The Fenner windfarm is 20 turbines. Because there is evidence that community's prefer smaller windfarms over larger ones

[43] Homes within 500 feet of the turbines, in this study area, were situated on the same parcels that had turbines, and therefore the homeowners received income from the windfarm owners. This coincidence could present complications in analysis of sale prices. Additionally, none were sold during the study period.

(Wolsink, 1989; SEI, 2003) studies conducted using homes surrounding facilities larger than 20 might reach different results.

- Primary Residence: This study does not include a separate variable describing if homes are primary residences or not. It is possible that homeowners of non-primary residences might be more sensitive to changes in their viewshed. Future studies should include this variable.

- Other potentially analogous structures: Although the research from HVTL is helpful in establishing potential effects of windfarms on property values, research concerning other infrastructures might be more applicable. For instance, investigating transaction value effects on coastal homes having views of offshore drilling platforms could shed light on the property value effects when a high “vista” value is present.

- Comparisons of hedonic and survey results: Because survey results are often used as a proxy for actual effects, studies to determine the appropriateness of these methods as it applies to windfarms would be very fruitful for policy makers. If combined hedonic and survey studies were conducted in communities with existing windfarms, which started before announcement and continued well after construction, policy makers and stakeholders could determine the applicability of using surveys to determine present and future property value effects.

- GIS visibility determinations: By continuing research into this area, and using the most up to date data, such as that being newly collected by light detecting and ranging (LIDAR) radar techniques, policy makers and stakeholders may find a very inexpensive method for determining visibility and therefore conducting analysis on communities.

By conducting and disseminating further research, policy makers and other stakeholders can more fully understand the subtle interaction between a view of windfarms and property values. As a result, they will have more appropriate tools to make well informed decisions regarding wind energy siting proposals. For now, it is safe to say property value effects are not guaranteed, and in fact, in the case of Fenner, do not seem to exist at all.

Appendix A: Definitions and Descriptions of Variables

Table VI: Definitions of Non-Viewshed Variables

ACRES	The number of acres in parcel
AGE_AT_SALE	The age of home at time of sale. Calculated by subtracting year built from Deed_Year.
BLDSTYL-AFRM	Building style binary variable equal to 1 for A Frame houses and 0 otherwise
BLDSTYL-CAPE	Building style binary variable equal to 1 for Cape houses and 0 otherwise
BLDSTYL-CNTMP	Building style binary variable equal to 1 for Contemporary houses and 0 otherwise
BLDSTYL-COLNL	Building style binary variable equal to 1 for Colonial houses and 0 otherwise
BLDSTYL-CTTG	Building style binary variable equal to 1 for Cottage houses and 0 otherwise
BLDSTYL-LOG	Building style binary variable equal to 1 for Log Cabin houses and 0 otherwise
BLDSTYL-OLDSTYL	Building style binary variable equal to 1 for Old Style houses and 0 otherwise
BLDSTYL-RANCH	Building style binary variable equal to 1 for Ranch houses and 0 otherwise
BLDSTYL-RSRNCH	Building style binary variable equal to 1 for Raised Ranch houses and 0 otherwise
BLDSTYL-SPLIT	Building style binary variable equal to 1 for Split Level houses and 0 otherwise
CAZENOVIA	Binary variable equal to 1 if township is Fenner, otherwise 0.
CENTRAL_AIR	House has central air conditioning
DIS_TO_I90	Distance from home to Interstate I 90 in miles
DIS_TO_RT_20	Distance from home to State Route 20 in miles
DIS_TO_TOWN	Distance from home to nearest town center in miles
DEED_YEAR	Year of sale as recorded on the deed.
DEED_YEAR_SQRD	Year of sale as recorded on the deed - Squared
FALL_SALE	Binary variable equal to 1 for transactions in quarter 4 and 0 otherwise
FENNER	Binary variable equal to 1 if township is Fenner, otherwise 0.
LINCOLN	Binary variable equal to 1 if township is Lincoln, otherwise 0.
LNSALE_PRICE_95	Natural Log of Sale Price in 1995 dollars
NBR_BEDROOMS	Number of bedrooms house contains
NBR_FIREPLACES	Number of fireplaces house contains
NBR_FULL_BATHS	Number of full bathrooms house contains
NBR_HALF_BATHS	Number of half bathrooms house contains
NELSON	Binary variable equal to 1 if township is Nelson, otherwise 0.
OVERALL_COND	Overall condition of home at time of last assessment
RBSMNT_TYP_DUM	Binary variable equal to 1 for full or finished basement and 0 otherwise
SALE_PRICE_95	Sale price converted to 1995 dollars
SCHDIS-CAZ	School district binary variable equal to 1 for Cazenovia school district and 0 otherwise
SCHDIS-CHTNGO	School district binary variable equal to 1 for Chittenango school district and 0 otherwise
SCHDIS-CNSTO	School district binary variable equal to 1 for Canastota school district and 0 otherwise
SCHDIS-MORS	School district binary variable equal to 1 for Morrisville school district and 0 otherwise
SCHDIS-ONIEDA	School district binary variable equal to 1 for Oneida school district and 0 otherwise
SCHDIS-STKBRDG	School district binary variable equal to 1 for Stockbridge school district and 0 otherwise
SFLA	Number of square feet in the home
SMITHFIELD	Binary variable equal to 1 if township is Smithfield, otherwise 0.
SPRING_SALE	Binary variable equal to 1 for transactions in quarter 2 and 0 otherwise
STONE_WALL_MAT	Binary variable equal to 1 for stone or brick exterior and 0 otherwise
SULLIVAN	Binary variable equal to 1 if township is Sullivan, otherwise 0.
SUMMER_SALE	Binary variable equal to 1 for transactions in quarter 3 and 0 otherwise
WINTER_SALE	Binary variable equal to 1 for transactions in quarter 1 and 0 otherwise.

Table VII: Definitions of Viewshed Variables

DIS_TO_MILLS	The distance from the home to the nearest turbine as calculated by the GIS.
VIEW	The view of the turbines as recorded from the field analysis with possible range from 0 to 60. If house sold before Jan 1, 2001 the value is 0.
VIEW1MILE	The VIEW of the home if 0>DIS_TO_MILLS<=1, otherwise 0
VIEW2MILE	The VIEW of the home if 1>DIS_TO_MILLS<=2, otherwise 0
VIEW3MILE	The VIEW of the home if 2>DIS_TO_MILLS<=3, otherwise 0
VIEW4MILE	The VIEW of the home if 3>DIS_TO_MILLS<=4, otherwise 0
VIEW5MILE	The VIEW of the home if 4>DIS_TO_MILLS<=5, otherwise 0
VIEW2001	The VIEW of the home if the year of sale was 2001, otherwise 0
VIEW2002	The VIEW of the home if the year of sale was 2002, otherwise 0
VIEW2003	The VIEW of the home if the year of sale was 2003, otherwise 0
VIEW2004	The VIEW of the home if the year of sale was 2004, otherwise 0
VIEW2005	The VIEW of the home if the year of sale was 2005, otherwise 0

Note: This table also appears in the main text

Table VIII: Description of Viewshed Variables

VIEWSHED VARIABLES	**Mean**	**Minimum**	**Maximum**	**Frequency**
DIS_TO_WNDMILS	3.50	0.76	5.98	280
VIEW	3.09	0	46	43
VIEW1MILE	0.60	0	40	5
VIEW2MILE	0.81	0	46	15
VIEW3MILE	0.46	0	46	6
VIEW4MILE	0.84	0	32	11
VIEW5MILE	0.38	0	38	6
VIEW2001	0.60	0	39	11
VIEW2002	0.55	0	40	9
VIEW2003	0.79	0	46	8
VIEW2004	1.03	0	46	12
VIEW2005	0.11	0	17	3

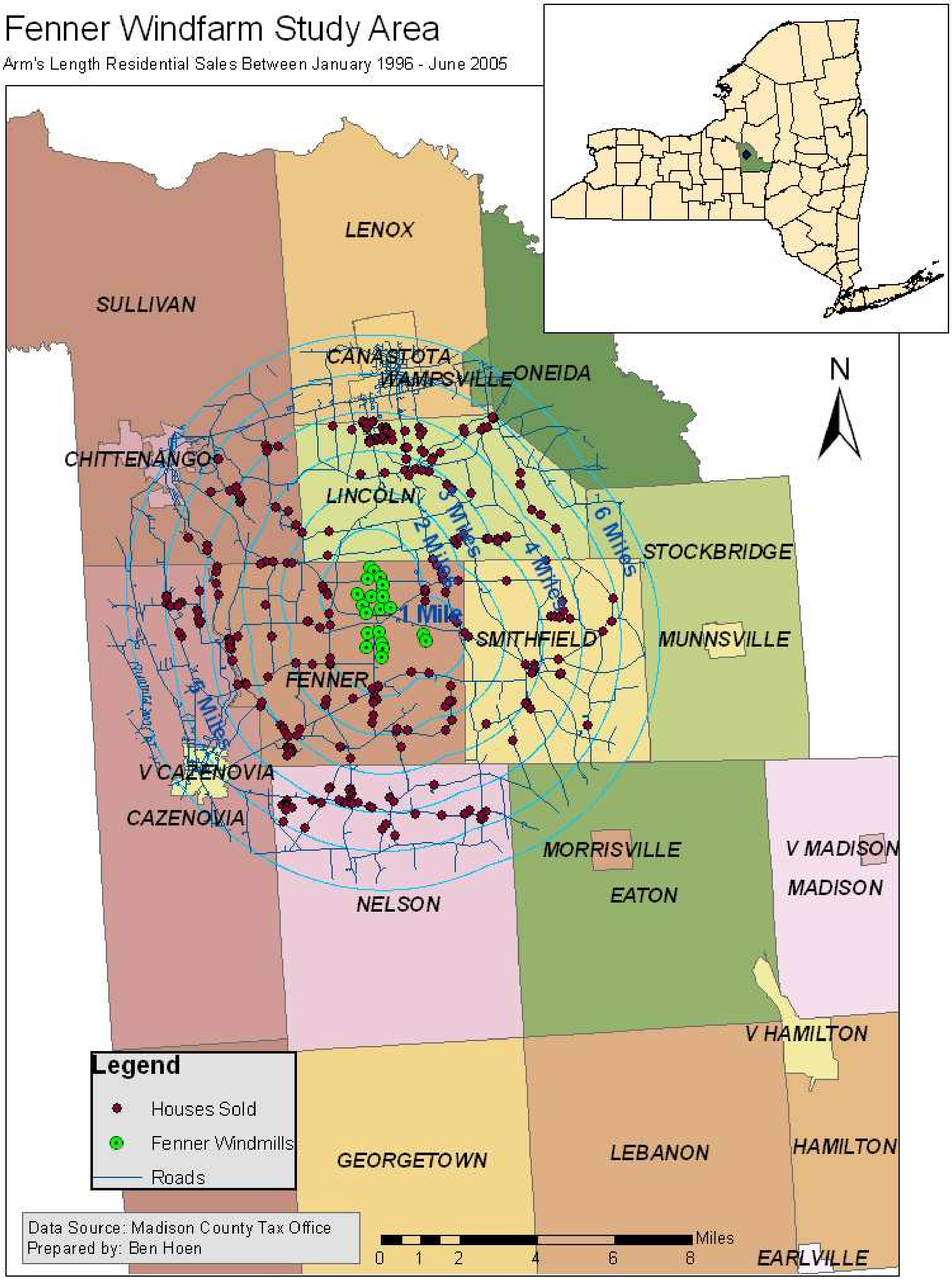
Table IX: Description of Binary Variables

	Median	Mean	Minimum	Maximum	Frequency
BINARY VARIABLES					
BLDSTYL-CAPE	0	0.07	0	1	20
BLDSTYL-CNTMP	0	0.11	0	1	30
BLDSTYL-COLNL	0	0.15	0	1	41
BLDSTYL-CTTG	0	0.01	0	1	2
BLDSTYL-LOG	0	0.04	0	1	10
BLDSTYL-OLDSTYL	0	0.21	0	1	59
BLDSTYL-RANCH	0	0.34	0	1	96
BLDSTYL-RSDRNCH	0	0.04	0	1	11
BLDSTYL-SPLIT	0	0.03	0	1	9
CENTRAL_AIR	0	0.06	0	1	280
FENNER_DUM	0	0.29	0	1	80
RBSMNT_TYP_DUM	1	0.80	0	1	224
STONE_WALL_MAT	0	0.01	0	1	2
SCHDIS-CAZ	0	0.47	0	1	131
SCHDIS-CHTNGO	0	0.14	0	1	39
SCHDIS-CNSTO	0	0.18	0	1	51
SCHDIS-MORS	0	0.15	0	1	43
SCHDIS-ONIEDA	0	0.03	0	1	8
SCHDIS-STKBRDG	0	0.03	0	1	8
SPRING_SALE	0	0.28	0	1	78
SUMMER_SALE	0	0.34	0	1	94
FALL_SALE	0	0.24	0	1	67
WINTER_SALE	0	0.15	0	1	41

Table X: Description of Continuous Variables

CONTINUOUS VARIABLES	Median	Mean	Minimum	Maximum	Frequency
SALE_PRICE_95	$91,293	$102,371	$10,049	$284,935	280
LNSALE_PRICE_95	11.42	11.41	9.215	12.560	280
ACRES	2.26	8.61	0.13	237.26	280
AGE_AT_SALE	20.5	42.36	0	205	280
DEED_YEAR	2001	2001	1995	2005	280
DEED_YEAR_SQRD	49	54.40	1	121	280
DIS_TO_RT20	4.66	4.69	0.01	10.17	280
DIS_TO_TOWN	3.68	3.78	1.51	6.87	280
NBR_FIREPLACES	0	0.51	0	5	116
NBR_FULL_BATHS	2	1.63	0	4	278
NBR_HALF_BATHS	0	0.39	0	1	110
OVERALL_COND	3	3.09	1	5	280
SFLA	1715	1804	420	5194	280

Appendix B: Map of Study Area



Appendix C: Technique for Creating GIS Viewshed Prediction Algorithm

A predicted view from each home was calculated using GIS techniques. The accuracy of the best performing predicted view was 85% as compared to actual view measurements. Since this did not meet confidence requirements, it was not used in the model.

To create a viewshed that effectively mimics the reality of a landscape the ground surface elevations as well the ground cover need to be simulated. In our case the 10 meter USGS DEM was used for surface elevations. The DEM was converted to a 3 dimensional ESRI raster file with the ARCGIS 9 "DEM to RASTER" algorithm using float and no z-value conversion. 10 meter data from the Multi-resolution Land Characterization (MRLC) Consortium[44] depicted the ground cover. Then by estimating heights for each ground cover type in our sample area, and reclassifying the raster fields to these heights, a raster addition was possible between the DEM and the MRLC. Four sets of heights for deciduous, conifer, and mixed forests, shrubs and grass (cultivated land) were tested (See Table IV). All other groundcover types were given a height of 0.

Table XI: Description of Heights for Ground Cover Raster Files (in feet)

Set	Conifer	Deciduous	Mixed	Grass & Shrubs
WINTER	100	0	50	5
80 NO-GRASS	80	70	75	0
80	80	70	75	5
100	100	90	95	10

[44] Partners include the USGS (National Mapping, Biological Resources, and Water Resources divisions), USEPA, the U.S. Forest Service, and the National Oceanic and Atmospheric Administration

Road and turbine location shapefiles were provided by the Madison County Tax Office, and a river shapefile was provided by the USGS National Map. House locations were derived as described in section 5.3. Because MRLC raster cells often spanned roads and covered houses and turbine locations, buffer shapefiles were created around each. 10 foot buffers were created around roads and houses, and 30 foot buffers surrounded turbines. To improve viewshed algorithm performance each raster grid (both DEM alone and DEM/MRCL additions) was converted to a triangulated irregular network (TIN) (Dean, 1997; Reeves, 2004). Z coordinates were not provided for the road, river, turbine, house shapefiles and accompanying buffers so these were derived from the DEM TIN. Buffers were added to the DEM/MRLC TINs using hard replace, and rivers were added using hardline which effectively erased all ground cover in the buffer areas and along the lines of the rivers. A map depicting the landscape is provided in Appendix D.

To calculate the viewsheds that simulated the 3 point score used in field analysis, three values for OFFSETA[45] were used corresponding to the heights on the turbines. The top height was 430 ft, the middle height was 328 ft and the lowest height was 210 ft. Additionally a value for OFFSETB of 10 ft was used.[46] Then the viewshed algorithm was run for the 20 "observation" points of the

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[45] OFFSETA is the field name used by ESRI Arc viewshed algorithms of values of vertical distance in surface units that are added to the z-value of each cell as it is considered for visibility.
[46] OFFSETB is the field name used by ESRI Arc viewshed algorithms of values of vertical distance in surface units that are added to the z-value of the observation point.

turbines at each of the three heights (top, middle, lowest). This produced three 10 meter raster grids with values from 0 to 20 possible. All were added together to produce a grid with values from 0 to 60 possible. These raster values were extracted using the house point locations giving a discrete value (from 0 to 60) for each home in our sample set. Of the four sets of heights used to create the ground cover raster values originally (see Table IV) the 80 No-Grass set was best at neither over nor under predicting visibility (See results in Appendix C) but still did not meet confidence threshold of 95% that we had hoped for.

Suggestions for improving GIS viewshed predictions

The reasons we believe our estimates are off is because of inherent errors in the DEM which then transferred to our TIN surface. We test this theory by using 63 geodetic markers from the USGS which were within our study area. Roughly 15% (10/63) of the two elevations differ by more than 1%, which in some cases is more than 5 feet (max = 7 feet). The direction of the errors are 60/40 peaks to pits[47] ("peaks" = 37, "pits" = 26). Errors are smaller for the largest 26 peaks (mean =1.51 feet) versus the largest 26 pits (mean = -2.76 feet). The errors in the viewshed calculations are well distributed between over predicting the homes' view of the turbines and under predicting it. Therefore, we conclude if the surface of the entire study area is similar in inaccuracies to the test points, predicted

[47] "Peaks" refers to points on the TIN that are at a higher elevation than the geodetic markers, and "pits" refers to the opposite, where the TIN surface is at a lover elevation than the marker.

viewshed inaccuracies could be entirely based on pits and peaks in the DEM. A 5-foot peak in the TIN surface could obscure a large portion of the landscape a few miles away from predicted visibility. Concurrently an observer on a 5-foot peak could be predicted to see a great deal more than actually can be seen. Methods for correcting or smoothing these errors were not investigated, and therefore additional research in this area would be important.

Another contributing factor for viewshed inaccuracies might be ground cover representation. It is observed in field analysis that canopy heights are not similar across all forests of the same type. For instance some deciduous forests have been planted in the last 15 years and have not grown to a mature height, while other forests are in late stage progression with mature heights. We use the same height for all forests of the same type. Further, square raster cells do not accurately depict non-uniform patterns of forest growth, and are particularly bad at depicting lines of trees that cross diagonally to the raster grid. Lastly the depiction of the top of the canopy is flat, but in reality the top is non-uniform. Field analysis proves it was possible to view turbines through the variation of the canopy. Combined these inaccuracies could add to the errors in our visibility prediction results. A smaller grid than 10 meters for the ground cover layer and access to ground cover data that includes z-values would greatly improve depiction and therefore viewshed analysis.

Appendix D: Results of GIS Viewshed Prediction Algorithm

Table XII: Description of Heights for Ground Cover Raster Files (in feet)

Set	Conifer	Deciduous	Mixed	Grass
Winter	100	0	50	5
80 No-Grass	80	70	75	0
80	80	70	75	5
100	100	90	95	10

Table XIII: Results of Viewshed Predictions for 4 Sets of Ground Cover Heights

	Winter	**OBSERVED**		
PREDICTED		See	No See	**Total**
	See	42	47	**89**
	No See	3	37	**40**
	Total	**45**	**84**	**129**

	Winter	**OBSERVED**			
PREDICTED		See	No See	**Total**	**Correct**
	See	33%	36%	**69%**	61%
	No See	2%	29%	**31%**	**Incorrect**
	Total	**35%**	**65%**	**100%**	39%

	80 No-Grs	**OBSERVED**		
PREDICTED		See	No See	**Total**
	See	36	10	**89**
	No See	9	74	**40**
	Total	**45**	**84**	**129**

	80 No-Grs	**OBSERVED**			
PREDICTED		See	No See	**Total**	**Correct**
	See	28%	8%	**36%**	85%
	No See	7%	57%	**64%**	**Incorrect**
	Total	**35%**	**65%**	**100%**	15%

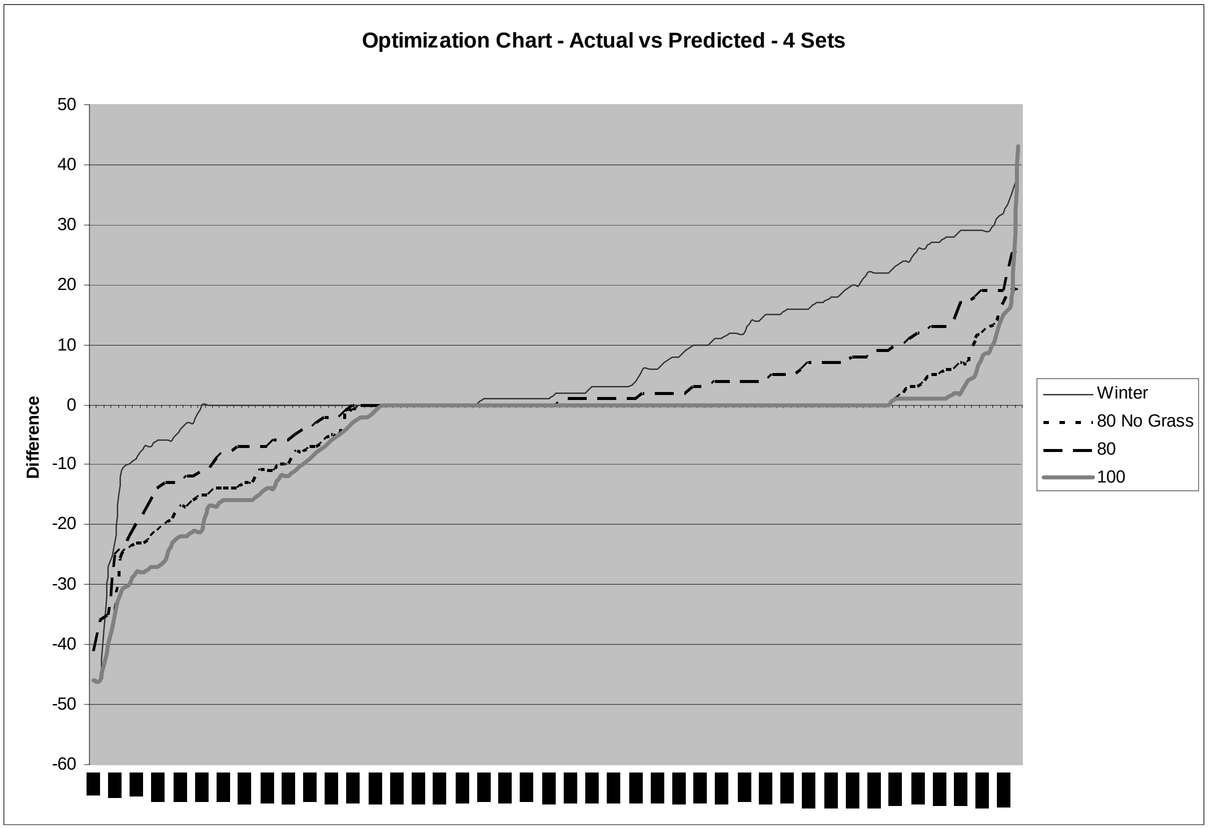
	100	**OBSERVED**		
PREDICTED		See	No See	**Total**
	See	26	13	**89**
	No See	19	71	**40**
	Total	**45**	**84**	**129**

	100	**OBSERVED**			
PREDICTED		See	No See	**Total**	**Correct**
	See	20%	10%	**30%**	75%
	No See	15%	55%	**70%**	**Incorrect**
	Total	**35%**	**65%**	**100%**	25%

	80	**OBSERVED**		
PREDICTED		See	No See	**Total**
	See	42	55	**89**
	No See	3	29	**40**
	Total	**45**	**84**	**129**

	800	**OBSERVED**			
PREDICTED		See	No See	**Total**	**Correct**
	See	33%	43%	**75%**	55%
	No See	2%	22%	**25%**	**Incorrect**
	Total	**35%**	**65%**	**100%**	45%

Figure V: Four Sets of Predicted Views versus the Actual Readings



Note: Results for each set are arrayed in ascending order without regard to house location. Therefore the amount of difference for one set for a particular house might not be similar for another set. Results are for 129 separate view readings. It is important to note the relatively even distribution of differences between positive and negative implying that the predicted viewshed models were most likely effected by forces outside the model such as random errors in the DEM

Appendix E: Landscape Constructions for Viewshed Prediction

Figure VI: Depiction of the Study Area without Ground Cover

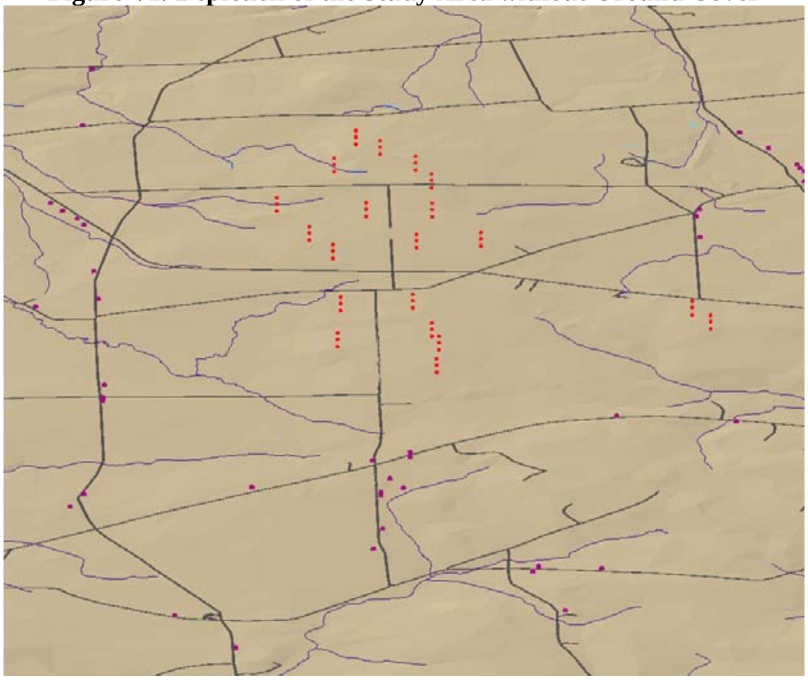


Figure VII: Depiction of the Study Area with Ground Cover

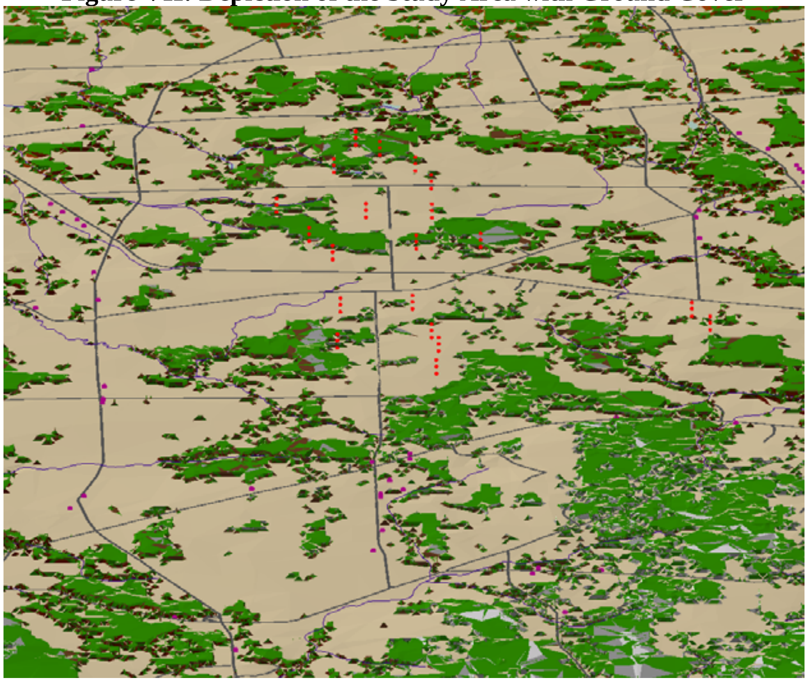
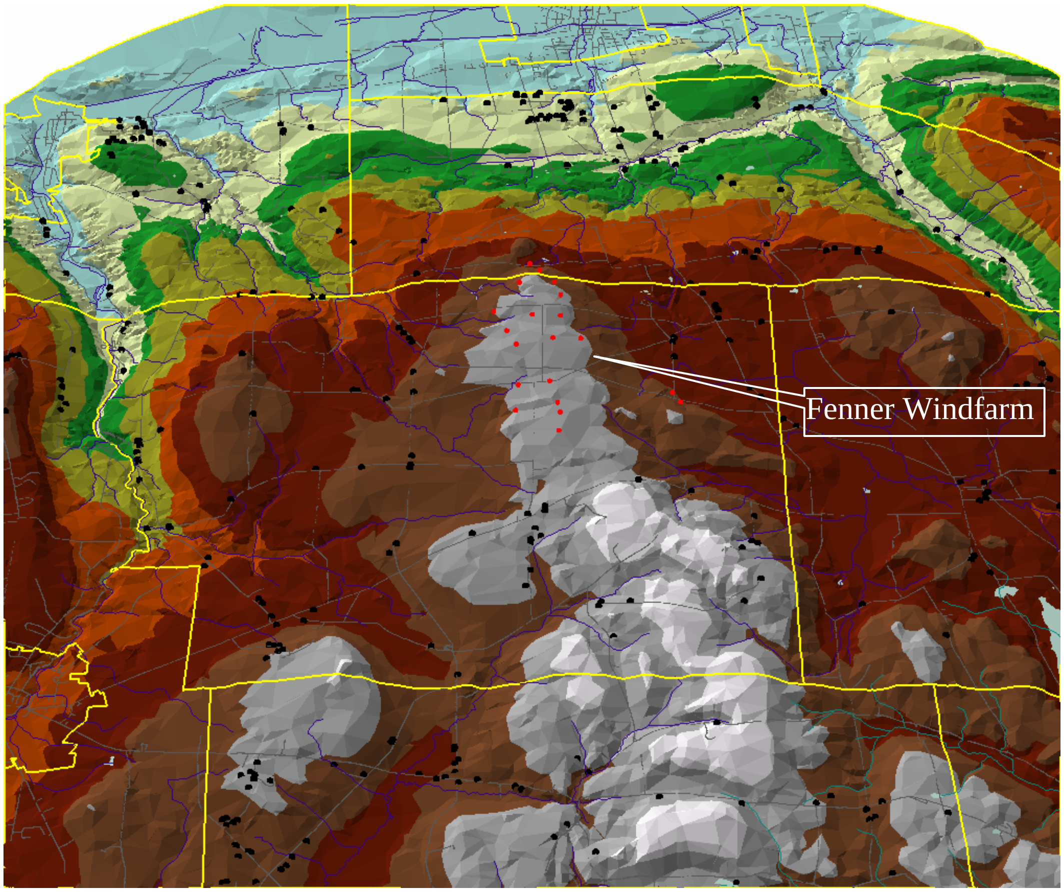


Figure V and VI notes: Groups of three red dots are top, middle and low heights of turbines, randomly spaced purple dots are houses sold after 2001, heavy grey lines are roads, thin blue lines are rivers and raised green areas are depictions of ground cover

Figure VIII: 3D Rendering of Study Area



Note: Depiction has elevation exaggerated 10 times. Except for where indicated dots are houses which sold after 1996, and lines are township borders. If possible rendering should be viewed in color.

Appendix F: Model Results

Table XIV: Results - Models 1-3

	Model # 1		Model # 2		Model # 3	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
(CONSTANT)	-32.240	0.632	-30.185	0.647	9.830	0.000
CONTINUOUS VARIABLES						
ACRES	0.005	0.000	0.005	0.000	0.005	0.000
AGE_AT_SALE	-0.001	0.053	-0.001	0.003	-0.002	0.000
SALE_YEAR	0.021	0.532	0.049	0.456		
SALE_YEAR_SQR	-0.002	0.523	0.110	0.090		
DIS_TO_RT_20	-0.012	0.198	-0.013	0.156	-0.009	0.072
DISTOTOWN-MILES	-0.021	0.198	0.090	0.093		
NBR_FIREPLACES	0.051	0.058	0.050	0.059	0.053	0.041
NBR_FULL_BATHS	0.151	0.000	0.152	0.000	0.153	0.000
NBR_HALF_BATHS	0.054	0.170	0.060	0.123	0.088	0.014
OVERALL_COND	0.205	0.000	0.202	0.000	0.197	0.000
SFLA (in 1000s)	0.233	0.000	0.234	0.000	0.261	0.000
BINARY VARIABLES						
BLDSTYL-CAPE	0.101	0.703	0.022	0.688		
BLDSTYL-CNTMP	0.187	0.476	0.199	0.001	0.158	0.003
BLDSTYL-COLNL	0.082	0.752				
BLDSTYL-CTTG	-0.003	0.992	0.004	0.984		
BLDSTYL-LOG	0.287	0.287	0.297	0.000	0.287	0.000
BLDSTYL-OLDSTYL	0.003	0.991	0.052	0.461		
BLDSTYL-OTHR	-0.076	0.836				
BLDSTYL-RANCH	-0.009	0.972	0.020	0.542		
BLDSTYL-RSDRNCH	0.052	0.846	-0.001	0.542		
BLDSTYL-SPLIT	-0.089	0.743	-0.020	0.206		
CENTRAL_AIR	0.008	0.915				
FENNER_DUM	-0.060	0.129	-0.058	0.142	-0.083	0.018
RBSMNT_TYP_DUM	0.239	0.000	0.241	0.000	0.268	0.000
STONE_WALL_MAT	0.372	0.043	0.377	0.036	0.363	0.037
SCHDIS-CHTNGO	0.050	0.457	-0.143	0.214		
SCHDIS-CNSTO	0.048	0.508	-0.068	0.790		
SCHDIS-MORS	0.024	0.676				
SCHDIS-ONIEDA	-0.151	0.197				
SCHDIS-STKBRDG	-0.437	0.000	-0.437	0.000	-0.489	0.000
SPRING_SALE	0.055	0.278	0.054	0.287	0.058	0.239
SUMMER_SALE	0.027	0.596	0.026	0.597	0.026	0.587
FALL_SALE	0.085	0.101	0.086	0.091	0.097	0.052
ADJUSTED R2		**0.793**		**0.793**		**0.793**
F/SIGNIFICANCE	**32.857**	**0.000**	**39.185**	**0.000**	**63.764**	**0.000**

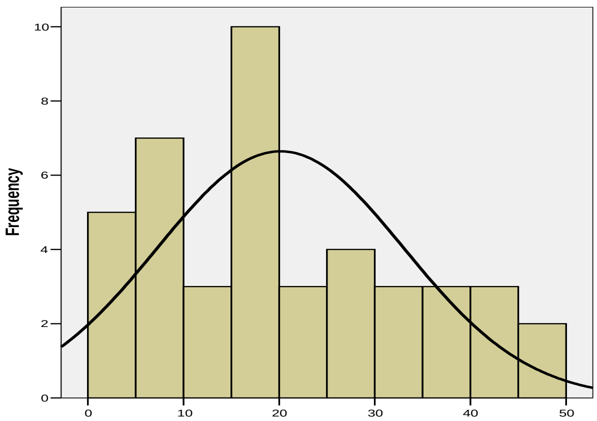
Table XV: Results - Models 4 - 6

	Model # 4		Model # 5		Model # 6	
	Coeff.	**p-value**	**Coeff.**	**p-value**	**Coeff.**	**p-value**
(CONSTANT)	9.803	0.000	9.826	0.000	9.840	0.000
CONTINUOUS VARIABLES						
ACRES	0.005	0.000	0.005	0.000	0.005	0.000
AGE_AT_SALE	-0.002	0.000	-0.002	0.000	-0.002	0.000
DIS_TO_RT20	-0.009	0.082	-0.009	0.066	-0.010	0.046
NBR_FIREPLACES	0.050	0.053	0.048	0.071	0.051	0.048
NBR_FULL_BATHS	0.153	0.000	0.157	0.000	0.152	0.000
NBR_HALF_BATHS	0.085	0.018	0.091	0.012	0.084	0.022
OVERALL_COND	0.196	0.000	0.196	0.000	0.196	0.000
SFLA (in 1000s)	0.263	0.000	0.262	0.000	0.263	0.000
BINARY VARIABLES						
BLDSTYL-CNTMP	0.154	0.004	0.161	0.003	0.162	0.002
BLDSTYL-LOG	0.286	0.000	0.286	0.000	0.287	0.000
FENNER_DUM	-0.076	0.108	-0.092	0.015	-0.094	0.010
RBSMNT_TYP_DUM	0.271	0.000	0.273	0.000	0.268	0.000
STONE_WALL_MAT	0.359	0.041	0.366	0.037	0.367	0.035
SCHDIS-STKBRDG	-0.491	0.000	-0.485	0.000	-0.482	0.000
SPRING_SALE	0.056	0.260	0.058	0.243	0.055	0.270
SUMMER_SALE	0.026	0.592	0.024	0.624	0.029	0.550
FALL_SALE	0.094	0.060	0.093	0.063	0.095	0.061
VIEWSHED VARIABLES						
DIS_TO_WNDMILLS	0.007	0.679				
VIEW	0.001	0.410				
VIEW1MILE			0.001	0.656		
VIEW2MILE			0.000	0.936		
VIEW3MILE			0.006	0.115		
VIEW4MILE			0.001	0.881		
VIEW5MILE			-0.001	0.764		
VIEW2001					-0.001	0.742
VIEW2002					0.006	0.175
VIEW2003					-0.002	0.613
VIEW2004					0.003	0.224
VIEW2005					0.001	0.906
ADJUSTED R2		**0.792**		**0.791**		**0.792**
F/SIGNIFICANCE	**56.822**	**0.000**	**48.990**	**0.000**	**49.210**	**0.000**

(Coefficients roughly correspond to the percentage change of sale price for each unit of change of the underlying variable. For example, adding an additional full bathroom to a house (coeff. = 0.153) adds roughly 15% to the value of the home, for homes that are near the sample mean value of $91.293.)

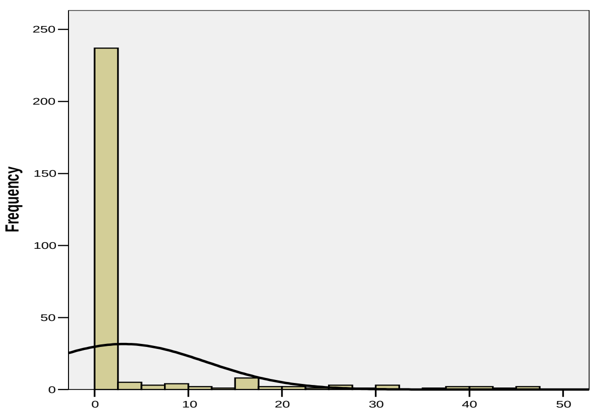
Appendix G: Histograms

Figure IX: Histogram of VIEW >0



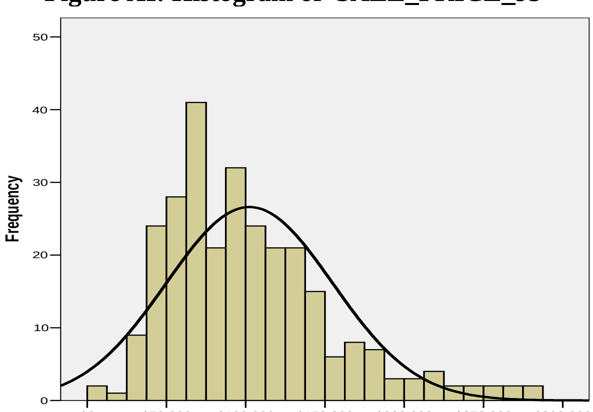
Notes: Line represents normal curve. n=43

Figure X: Histogram of VIEW



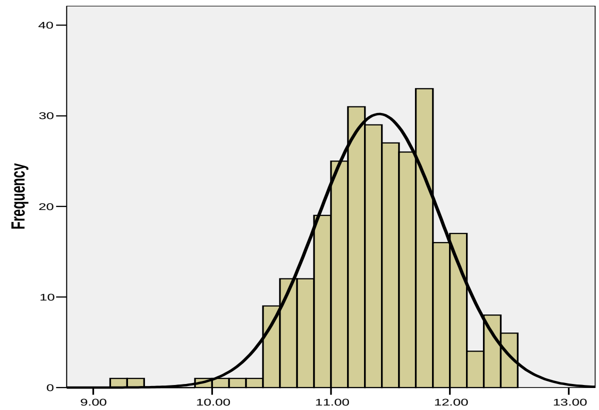
Notes: Line represents normal curve. n=280

Figure XI: Histogram of SALE_PRICE_95



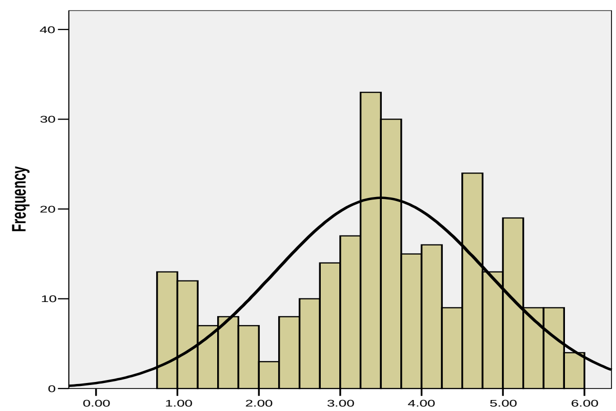
Notes: Line represents normal curve. n=280

Figure XII: Histogram of LogSALE_PRICE_95



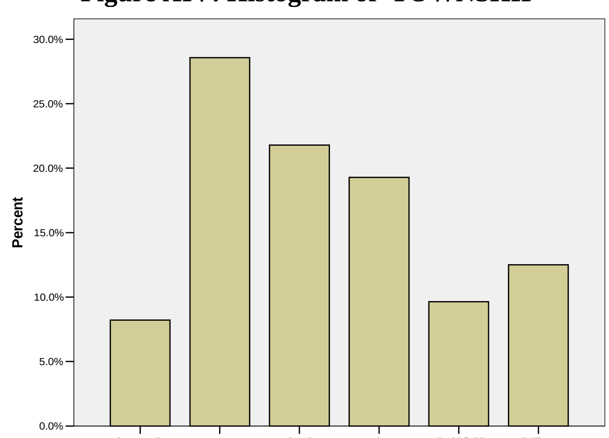
Notes: Line represents normal curve. n=280

Figure XIII: Histogram of DIS_TO_MILLS



Notes: Line represents normal curve. n=280

Figure XIV: Histogram of TOWNSHIP



Notes: n=280

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