The Effect of Wind Development on Local Property Values

REPP
Renewable Energy Policy Project

George Sterzinger
Fredric Beck
Damian Kostiuk

Analytical Report | May 2003

Authors

George Sterzinger, REPP Executive Director
gsterzinger@repp.org

Fredric Beck, REPP Research Manager
fbeck@repp.org

Damian Kostiuk, REPP Research & Communications Specialist
dkostiuk@repp.org

All authors can be reached at REPP's offices: (202) 293-2898

Notice

This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

The authors wish to thank the following for their careful reviews and comments on this report: James Barrett, Jack Cadogan, Jim Caldwell, Tom Gray, Tom Priestley, Randy Swisher, and Ryan Wiser. In addition, the authors wish to thank the property tax assessors and county officials, too numerous to name here, who were willing to discuss their communities and provide data and insight into local property sales.

Renewable Energy Policy Project
1612 K Street, NW, Suite 202
Washington, D.C. 20006
Tel: (202) 293-2898
Fax: (202) 293-5857
www.repp.org

Published May 2003, Washington, D.C.
PRINTED IN THE UNITED STATES OF AMERICA

Table of Contents

Chapter I. Project Overview 1

Chapter II. Methodology 10

Chapter III. Site Reports 17
- Site Report 1.1: Riverside County, California 17
- Site Reports 2.1 and 2.2: Madison County, New York 24
- Site Report 3: Carson County, Texas 32
- Site Report 4: Bennington County, Vermont 38
- Site Report 5: Kewaunee County, Wisconsin 43
- Site Report 6: Somerset County, Pennsylvania 49
- Site Report 7: Buena Vista County, Iowa 54
- Site Report 8: Kern County, California 62
- Site Report 9: Fayette County, Pennsylvania 67
- Site Report: Projects Excluded From Analyses 72

References 76

Appendix 1. County Classification Descriptions 77

Chapter I. Project Overview

The Claim Against Wind Development

Wind energy is the fastest growing domestic energy resource. Between 1998 and 2002 installed capacity grew from 1848 MW to 4685 MW, a compound growth rate of 26 percent. Since wind energy is now broadly competitive with many traditional generation resources, there is wide expectation that the growth rate of the past five years will continue. (Source for statistics: www.awea.org).

As the pace of wind project development has increased, opponents have raised claims in the media and at siting hearings that wind development will lower the value of property within view of the turbines. This is a serious charge that deserves to be seriously examined.

No Existing Empirical Support

As a result of the expansion of capacity from 1998 to 2002, it is reasonable to expect any negative effect would be revealed in an analysis of how already existing projects have affected property values. A search for either European or United States studies on the effect of wind development on property values revealed that no systematic review has as yet been undertaken.

As noted above, the pace of development and siting hearings is likely to continue, which makes it important to do systematic research in order to establish whether there is any basis for the claims about harm to property values. (For recent press accounts of opposition claims see: The Charleston Gazette, WV, March 30, 2003; and Copley News Service. Ottawa, IL, April 11, 2003).

This REPP Analytical Report reviews data on property sales in the vicinity of wind projects and uses statistical analysis to determine whether and the extent to which the presence of a wind power project has had an influence on the prices at which properties have been sold. The hypothesis underlying this analysis is that if wind development can reasonably be claimed to hurt property values, then a careful review of the sales data should show a negative effect on property values within the viewshed of the projects.

A Serious Charge Seriously Examined

The first step in this analysis required assembling a database covering every wind development that came on-line after 1998 with 10 MW installed capacity or greater. (Note: For this Report we cut off projects that came on-line after 2001 because they would have insufficient data at this time to allow a reasonable analysis. These projects can be added in future Reports, however.) For the purposes of this analysis, the wind developments were considered to have a visual impact for the area within five miles of the turbines. The five mile threshold was selected because review of the literature and field experience suggests that although wind turbines may be visible beyond five miles, beyond this distance, they do not tend to be highly noticeable, and they have relatively little influence on the landscape's overall character and quality. For a time period covering roughly six years and straddling the on-line date of the projects, we gathered the records for all property sales for the view shed and for a community comparable to the view shed.

For all projects for which we could find sufficient data, we then conducted a statistical analysis to determine how property values changed over time in the view shed and in the comparable community. This database contained more than 25,000 records of property sales within the view shed and the selected comparable communities.

Three Case Examinations

REPP looked at price changes for each of the ten projects in three ways: Case 1 looked at the changes in the view shed and comparable community for the entire period of the study; Case 2 looked at how property values changed in the view shed before and after the project came on-line; and Case 3 looked at how property values changed in the view shed and comparable community after the project came on-line.

Case 1 looked first at how prices changed over the entire period of study for the view shed and comparable region. Where possible, we tried to collect data for three years preceding and three years following the on-line date of the project. For the ten projects analyzed, property values increased faster in the view shed in eight of the ten projects. In the two projects where the view shed values increased slower than for the comparable community, special circumstances make the results questionable. Kern County, California is a site that has had wind development since 1981. Because of the existence of the old wind machines, the site does not provide a look at how the new wind turbines will affect property values. For Fayette County, Pennsylvania the statistical explanation was very poor. For the view shed the statistical analysis could explain only 2 percent of the total change in prices.

Case 2 compared how prices changed in the view shed before and after the projects came on-line. For the ten projects analyzed, in nine of the ten cases the property values increased faster after the project came on line than they did before. The only project to have slower property value growth after the on-line date was Kewaunee County, Wisconsin. Since Case 2 looks only at the view shed, it is possible that external factors drove up prices faster after the on-line date and that analysis is therefore picking up a factor other than the wind development.

Finally, **Case 3** looked at how prices changed for both the view shed and the comparable region, but only for the period after the projects came on-line. Once again, for nine of the ten projects analyzed, the property values increased faster in the view shed than they did for the comparable community. The only project to see faster property value increases in the comparable community was Kern County, California. The same caution applied to Case 1 is necessary in interpreting these results.

If property values had been harmed by being within the view-shed of major wind developments, then we expected that to be shown in a majority of the projects analyzed. Instead, to the contrary, we found that for the great majority of projects the property values actually rose more quickly in the view shed than they did in the comparable community. Moreover, values increased faster in the view shed after the projects came on-line than they did before. Finally, after projects came on-line, values increased faster in the view shed than they did in the comparable community. In all, we analyzed ten projects in three cases; we looked at thirty individual analyses and found that in twenty-six of those, property values in the affected view shed performed better than the alternative.

This study is an empirical review of the changes in property values over time and does not attempt to present a model to explain all the influences on property values. The analysis we conducted was done solely to determine whether the existing data could be interpreted as supporting the claim that wind development harms property values. It would be desirable in future studies to expand the variables incorporated into the analysis and to refine the view shed in order to look at the relationship between property values and the precise distance from development. However, the limitations imposed by gathering data for a consistent analysis of all major developments done post-1998 made those refinements impossible for this study. The statistical analysis of all property sales in the view shed and the comparable community done for this Report provides no evidence that wind development has harmed property values within the view shed. The results from one of the three Cases analyzed are summarized in Table 1 and Figure 1 below.

Regression Analysis

REPP used standard simple statistical regression analyses to determine how property values changed over time in the view shed and the comparable community. In very general terms, a regression analysis "fits" a linear relationship, a line, to the available database. The calculated line will have a slope, which in our analysis is the monthly change in average price for the area and time period studied. Once we gathered the data and conducted the regression analysis, we compared the slope of the line for the view shed with the slope of the line for the comparable community (or for the view shed before and after the wind project came on-line).

Table 1: Summary of Statistical Model Results for Case 1

Project/On-Line Date	Monthly Average Price Change ($/month)	
	View Shed	Comparable
Riverside County, CA	$1,719.65	$814.17
Madison County, NY (Madison)	$576.22	$245.51
Carson County, TX	$620.47	$296.54
Kewaunee County, WI	$434.48	$118.18
Searsburg, VT	$536.41	$330.81
Madison County, NY (Fenner)	$368.47	$245.51
Somerset County, PA	$190.07	$100.06
Buena Vista County, IA	$401.86	$341.87
Kern County, CA	$492.38	$684.16
Fayette County, PA	$115.96	$479.20

While regression analysis gives the best fit for the data available, it is also important to consider how "good" (in a statistical sense) the fit of the line to the data is. The regression will predict values that can be compared to the actual or observed values. One way to measure how well the regression line fits the data calculates what percentage of the actual variation is explained by the predicted values. A high percentage number, over 70%, is generally a good fit. A low number, below 20%, means that very little of the actual variation is explained by the analysis. Because this initial study had to rely on a database constructed after the fact, lack of data points and high variation in the data that was gathered meant that the statistical fit was poor for several of the projects analyzed. If the calculated linear relationship does not give a good fit, then the results have to be looked at cautiously.

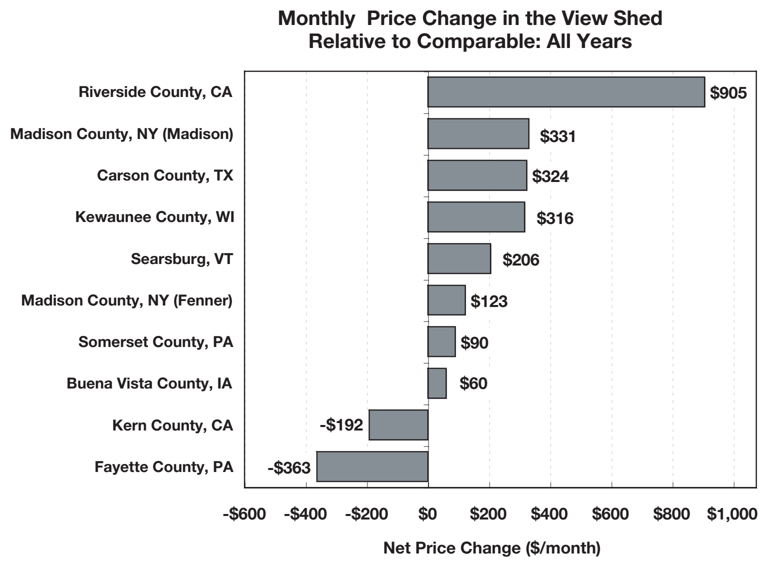


Figure 1: Monthly Price Change in the View Shed
Relative to Comparable: All Years

Case Result Details

Although there is some variation in the three Cases studied, the results point to the same conclusion: the statistical evidence does not support a contention that property values within the view shed of wind developments suffer or perform poorer than in a comparable region. For the great majority of projects in all three of the Cases studied, the property values in the view shed actually go up faster than values in the comparable region. Analytical results for all three cases are summarized in Table 2 below.

Table 2: Detailed Statistical Model Results

Location: Buena Vista County, IA
Project: Storm Lake I & II

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 96 - Oct 02 Jan 96 - Oct 02	$401.86 $341.87	0.67 0.72	The rate of change in average view shed sales price is 18% greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 96 - Apr 99 May 99 - Oct 02	$370.52 $631.12	0.51 0.53	The rate of change in average view shed sales price is 70% greater after the on-line date than the rate of change before the on-line date.
Case 3	View shed, after Comparable, after	May 99 - Oct 02 May 99 - Oct 02	$631.12 $234.84	0.53 0.23	The rate of change in average view shed sales price after the on-line date is 2.7 times greater than the rate of change of the comparable after the on-line date.

Location: Carson County, TX
Project: Llano Estacado

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 98 - Dec 02 Jan 98 - Dec 02	$620.47 $296.54	0.49 0.33	The rate of change in average view shed sales price is 2.1 times greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 98 - Oct 01 Nov 01 - Dec 02	$553.92 $1,879.76	0.24 0.83	The rate of change in average view shed sales price after the on-line date is 3.4 times greater than the rate of change before the on-line date.
Case 3	View shed, after Comparable, after	Nov 01 - Dec 02 Nov 01 - Dec 02	$1,879.76 -$140.14	0.83 0.02	The rate of change in average view shed sales price after the on-line date increased at 13.4 times the rate of decrease in the comparable after the on-line date.

Location: Fayette County, PA
Project: Mill Run

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Dec 97-Dec 02 Dec 97-Dec 02	$115.96 $479.20	0.02 0.24	The rate of change in average view shed sales price is 24% of the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Dec 97 - Nov 01 Oct 01-Dec 02	-$413.68 $1,562.79	0.19 0.32	The rate of change in average view shed sales price after the on-line date increased at 3.8 times the rate of decrease before the on-line date.
Case 3	View shed, after Comparable, after	Oct 01-Dec 02 Oct 01-Dec 02	$1,562.79 $115.86	0.32 0.00	The rate of change in average view shed sales price after the on-line date is 13.5 times greater than the rate of change of the comparable after the on-line date.

Location: Kern County, CA
Project: Pacific Crest, Cameron Ridge, Oak Creek Phase II

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 96 - Dec 02 Jan 96 - Dec 02	$492.38 $684.16	0.72 0.74	The rate of change in average view shed sales price is 28% less than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 96-Feb 99 Mar 99 - Dec 02	$568.15 $786.60	0.44 0.75	The rate of change in average view shed sales price is 38% greater after the on-line date than the rate of change before the on-line date.
Case 3	View shed, after Comparable, after	Mar 99 - Dec 02 Mar 99 - Dec 02	$786.60 $1,115.10	0.75 0.95	The rate of change in average view shed sales price after the on-line date is 29% less than the rate of change of the comparable after the on-line date.

Location: Kewaunee County, WI
Project: Red River (Rosiere), Lincoln (Rosiere), Lincoln (Gregorville)

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 96 - Sep 02 Jan 96 - Sep 02	$434.48 $118.18	0.26 0.05	The rate of change in average view shed sales price is 3.7 times greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 96 - May 99 Jun 99 - Sep 02	-$238.67 $840.03	0.02 0.32	The increase in average view shed sales price after the on-line date is 3.5 times the decrease in view shed sales price before the on-line date.
Case 3	View shed, after Comparable, after	Jun 99 - Sep 02 Jun 99 - Sep 02	$840.03 -$630.10	0.32 0.37	The average view shed sales price after the on-line date increases 33% quicker than the comparable sales price decreases after the on-line date.

Location: Madison County, NY
Project: Madison

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 97 - Jan 03 Jan 97 - Jan 03	$576.22 $245.51	0.29 0.34	The rate of change in average view shed sales price is 2.3 times greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 97 - Aug 00 Sep 00 - Jan 03	$129.32 $1,332.24	0.01 0.28	The rate of change in average view shed sales price after the on-line date is 10.3 times greater than the rate of change before the on-line date.
Case 3	View shed, after Comparable, after	Sep 00 - Jan 03 Sep 00 - Jan 03	$1,332.24 -$418.71	0.28 0.39	The rate of change in average view shed sales price after the on-line date increased at 3.2 times the rate of decrease in the comparable after the on-line date.

Location: Madison County, NY
Project: Fenner

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 97 - Jan 03 Jan 97 - Jan 03	$368.47 $245.51	0.35 0.34	The rate of change in average view shed sales price is 50% greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 97 - Nov 01 Dec 01 - Jan 03	$587.95 -$418.98	0.50 0.04	The rate of decrease in average view shed sales price after the on-line date is 29% lower than the rate of sales price increase before the on-line date.
Case 3	View shed, after Comparable, after	Dec 01 - Jan 03 Dec 01 - Jan 03	-$418.98 -$663.38	0.04 0.63	The rate of decrease in average view shed sales price after the on-line date is 37% less than the rate of decrease of the comparable after the on-line date.

Location: Riverside County, CA
Project: Cabazon, Enron, Energy Unlimited, Mountain View Power Partners I & II, Westwind

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 96 - Nov 02 Jan 96 - Nov 02	$1,719.65 $814.17	0.92 0.81	The rate of change in average view shed sales price is 2.1 times greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 96 - Apr 99 May 99 - Nov 02	$1,062.83 $1,978.88	0.68 0.81	The rate of change in average view shed sales price is 86% greater after the on-line date than the rate of change before the on-line date.
Case 3	View shed, after Comparable, after	May 99 - Nov 02 May 99 - Nov 02	$1,978.88 $1,212.14	0.81 0.74	The rate of change in average view shed sales price after the on-line date is 63% greater than the rate of change of the comparable after the on-line date.

Location: Bennington and Windham Counties, VT
Project: Searsburg

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 94 - Oct 02 Jan 94 - Oct 02	$536.41 $330.81	0.70 0.45	The rate of change in average view shed sales price is 62% greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 94 - Jan 97 Feb 97 - Oct 02	-$301.52 $771.06	0.88 0.71	The rate of change in average view shed sales price after the on-line date increased at 2.6 times the rate of decrease before the on-line date.
Case 3	View shed, after Comparable, after	Feb 97 - Oct 02 Feb 97 - Oct 02	$771.06 $655.20	0.71 0.78	The rate of change in average view shed sales price after the on-line date is 18% greater than the rate of change of the comparable after the on-line date.

Location: Somerset County, PA
Project: Excelon, Green Mountain

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 97 - Oct 02 Jan 97 - Oct 02	$190.07 $100.06	0.30 0.07	The rate of change in average view shed sales price is 90% greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 97 - Apr 00 May 00 - Oct 02	$277.99 $969.59	0.37 0.62	The rate of change in average view shed sales price after the on-line date is 3.5 times greater than the rate of change before the on-line date.
Case 3	View shed, after Comparable, after	May 00 - Oct 02 May 00 - Oct 02	$969.59 -$418.73	0.62 0.23	The rate of change in average view shed sales price after the on-line date increased at 2.3 times the rate of decrease in the comparable after the on-line date.

Each of the three Cases takes a different approach to evaluating the price changes in the view shed and comparable community. By finding consistent results in all three Cases, the different approaches help to address concerns that could be raised about individual approaches. The selection of the comparable community is based upon a combination of demographic statistics and the impressions of local assessors and is inherently subjective. It is possible that arguments about the legitimacy of the selection of the comparable could arise and be used to question the legitimacy of the basic conclusion. However, since Case 2 looks only at the view shed and since the results of the Case 2 analysis are completely consistent with the other Cases, the selection of the comparable community will not be crucial to the legitimacy of the overall conclusion. To take another example, Case 1 uses data from the entire time period, both before and after the on-line date. We anticipate possible criticisms of this Case as masking the "pure" effect of the development that would only occur after the project came on-line. However, Cases 2 and 3 look separately at the before and after time periods and produce results basically identical to the Case 1 results. Because all three Cases produce similar results, Cases 2 and 3 answer the concerns about Case 1.

The Database

The results of the analysis depend greatly upon the quality of the database that supports the analysis. The Report is based on a detailed empirical investigation into the effects of wind development on property values. The study first identified the 27 wind projects over 10 MW installed capacity that have come on-line since 1998. REPP chose the 1998 on-line date as a selection criterion for the database because it represented projects that used the new generation of wind machines that are both taller and quieter than earlier generations. (REPP did not consider projects that came on-line in 2002 or after since there would be too little data on property values after the on- line date to support an analysis. These projects can be added to the overall database and used for subsequent updates of this analysis, however.) REPP chose the 10 MW installed capacity as the other criterion because if the presence of wind turbines is having a negative affect it, should be more pronounced in projects with a large rather than small number of installations. In addition, we used the 10 MW cut-off to assure that the sample of projects did not include an over-weighting of projects using a small number of turbines.

Of the 27 projects that came on-line in 1998 or after and that were 10MW or larger installed capacity, for a variety of reasons, 17 had insufficient data to pursue any statistical analysis. For six of the 17 projects we acquired the data, but determined that there were too few sales to support a statistical analysis. For two of the remaining 11, state law prohibited release of property sales information. The remaining nine projects had a combination of factors such as low sales, no electronic data, and paper data available only in the office. (For a project-by-project explanation, see Chapter 2 of the Report.)

For each of the remaining ten projects, we assembled a database covering roughly a six-year period from 1996 to the present. For each of these projects we obtained individual records of all property sales in the "view shed" of the development for this six-year period. We also constructed a similar database for a "comparable community" that is a reasonably close community with similar demographic characteristics. For each of the projects, we selected the comparable community on the basis of the demographics of the community and after discussing the appropriateness of the community with local property assessors. As shown in Table 3 below, the database of view shed and comparable sales included more than 25,000 individual property sales. The initial included database of view shed and comparable sales included over 25,000 individual property sales. After review and culling, the final data set includes over 24,300 individual property sales, as shown in Table 3 below.

Table 3: Number of Property Sales Analyzed, by Project

Project/On-Line Date	Viewshed Sales	Comparable Sales	Total Sales
Searsburg, VT / 1997	2,788	552	3,340
Kern County, CA / 1999	745	2,122	2,867
Riverside County, CA / 1999	5,513	3,592	9,105
Buena Vista County, IA / 1999	1,557	1,656	3,213
Howard County, TX / 1999*	2,192	n/a	2,192
Kewaunee County, WI / 1999	329	295	624
Madison Co./Madison, NY / 2000	219	591	810
Madison Co./Fenner, NY / 2000**	453	591	1,044
Somerset County, PA / 2000	962	422	1,384
Fayette County, PA / 2001	39	50	89
Carson County, TX / 2001	45	224	269
TOTAL	14,842	9,504	24,346

*Howard County, TX comparable data not received at time of publication.

**Both wind projects in Madison County, NY, use the same comparable. Column totals adjusted to eliminate double counting.

Recommendations

The results of this analysis of property sales in the vicinity of the post-1998 projects suggest that there is no support for the claim that wind development will harm property values. The data represents the experience up to a point in time. The database will change as new projects come on-line and as more data becomes available for the sites already analyzed. In order to make the results obtained from this initial analysis as useful as possible to siting authorities and others interested in and involved with wind development, it will be important to maintain and update this database and to add newer projects as they come on-line.

Gathering data on property sales after the fact is difficult at best. We recommend that the database and analysis be maintained, expanded and updated on a regular basis. This would entail regularly updating property sales for the projects already analyzed and adding new projects when they cross a predetermined threshold, for example financial closing. In this way the results and conclusions of this analysis can be regularly and quickly updated.

Chapter II. Methodology

The work required to produce this report falls into two broad categories – data collection and statistical analysis. Each of these areas in turn required attention to several issues that determine the quality of the result.

According to the American Wind Energy Association (AWEA), approximately 225 wind projects were completed or under development in the United States as of 2002. The first wave of major wind project development in the United States took place between approximately 1981 and 1995. Wind farm development slowed considerably in 1996, with only three wind projects installed, the largest of which was 600 kW. The first major post-1996 project was the 6 MW Searsburg site in Bennington County, Vermont, which came on-line in 1997.

A. Project Selection Criteria

This report focuses on major wind farm projects that constitute the second wave of wind farm development. This second wave of projects employs modern wind turbine technology likely to be installed over the next several years as part of continuing U.S. wind farm development. Compared to the previous generation of wind turbines, modern wind turbines generally have greater installed capacities, taller towers, larger turbine blades, lower rotational speeds and reduced gearbox noise.

In addition to the 6 MW Searsburg wind farm, this report analyses potential property value effects for wind farms of 10 MW capacity or greater installed from 1998 through 2001. Projects completed in 2002 and later are excluded from this analysis because not enough time has elapsed to collect sufficient data to statistically determine post-installation property value effects. To determine property value trends prior to wind farm installation, we collected property sales data from three years prior to the on-line year to the present for each of the wind farms analyzed.

Twenty-seven wind farm projects met the project selection criteria.

B. Data Compilation

Once the projects were selected for analysis, the process of acquiring data was initiated through phone calls to county assessment offices. For each project, varying sources of data and information were available, ranging from websites with on-line data, purchased data on CD-ROM or via e-mail from government offices, purchased data from private vendors or postal carried paper records. In many cases data was only available in paper, but not by mail – a person would physically have to appear before the assessment office clerk and search storage boxes, which in some cases had been archived to remote locations for long-term storage. Many states do not require local offices to retain records past certain age limits, often between one to five years. After that, files may be destroyed, and in some cases had been.

Where paper records were obtained, data was transferred into electronic form through scanning or manual data entry. In many cases, both with paper and/or electronic data, the fields we received did not provide good geographic specificity. For example, in some cases, townships and/or cities, but not street addresses were identified. Where street addresses were included, in some cases not all properties had street addresses given, or street addresses were truncated or otherwise incomplete.

Out of the 27 counties with wind farms meeting the project selection criteria, ten sites were selected for statistical analysis based on availability of property sales data. The other 17 eligible sites were excluded from statistical analysis for a number of reasons, including insufficient sales to perform statistical analysis (for example, one site had only five sales in five years), lack of readily available data (data requiring in-person visits to the Assessors Office to manually go through paper files), and two cases where state law prohibited the Assessors Office from releasing property sales data to the public.

This report contains one section for each of the ten sites analyzed, with project site and community descriptions, view shed and comparable selection details, and analytical results and discussion. In addition, the report contains one section providing detailed explanations of why each of the 17 other sites are excluded from analysis. The dataset used in this report, exclusive of proprietary data, is available on the REPP web site at www.repp.org, or by request from REPP.

C. View Shed Definition

In order to determine whether the presence of a wind farm has an adverse effect on property values in the wind farm's vicinity, the area potentially affected by the wind farm must be defined. In this report, the area in which potential property value effects are being tested for is termed the "view shed."

How the view shed is defined will affect the type of data required to test for property value effects, as well as the analytical model employed. Choosing the value of the appropriate radius for such a view shed is subjective. To help determine the radius, numerous studies regarding line-of-sight impacts were reviewed, and interviews with a power industry expert on visual impacts of transmission lines were conducted. In the end, three separate resources for estimates of visual impact were used to support defining the view shed as the area within a five-mile radius of the wind farms. These resources are:

- The U.S. Department of Agriculture (USDA). In a handbook titled "National Forest Landscape Management" (1973) developed for the Forest Service by the USDA, three primary zones of visual impact are defined: foreground, middleground and background. These zones relate to the distance from an object in question, be it a fire lookout tower, tall tree, or mountain in the distance. In this definition, foreground is 0 to 1/2 mile, middleground is 1/4 to 5 miles and background is 3 to 5 miles. The USDA handbook states that for foreground objects people can discern specific sensory experiences such as sound, smell and touch, but for background objects little texture or detail are apparent, and objects are viewed mostly as patterns of light and dark.

- The Sinclair-Thomas Matrix. This is a subjective study of the visual impact of wind farms published in the report Wind Power in Wales, UK (1999). Visual impact is defined in a matrix of distance from a wind turbine versus tower hub height. At the highest hub height considered in the matrix, 95 meters [312 feet], the visual impact of wind towers is estimated to be moderate at a distance of 12 km [7.5 miles]. The matrix estimates that not until a distance of 40 km [25 miles] is there "negligible or no" visual impact from wind turbines under any atmospheric condition. Of the ten sites considered in this REPP report, the majority of towers have hub heights of 60 to 70 meters, which, according to the Sinclair-Thomas matrix, corresponds to moderate visual impact at a distance of 9 to 10 km [5.6– 6.2 miles].

- Interviews with Industry Experts. A power industry analyst with extensive experience in quantitative analysis of visual impacts of transmission lines stated in an interview that a rule of thumb used for the zone of visual influence of installations such as transmission lines and large wind turbines is a distance of approximately five miles.

There are other possible definitions of the view shed. At present, new proposals are sometimes required to conduct a Zone of Visual Influence (ZVI) analysis to determine the extent of visibility of a development. The zone comprises a visual envelope within which it is possible to view the development, notwithstanding the presence of any intervening obstacles such as forests, buildings, and other objects. Digital terrain computer programs are used to calculate and plot the areas from which the wind farm can be seen on a reference grid that indicates how many turbines can be seen from a given point. One weakness of the standard ZVI analysis is that all turbines are given equal weight of visual impact. That is, a turbine 20 miles from the viewer is assigned the same visual impact as a turbine one mile away.

Possible definitions for view sheds include the set of real properties that have a view of one or more wind turbines from inside the residence, that have a view of one or more turbines from any point on the property, or that are simply within some defined distance from the wind turbines, whether there is a view from each property in that area or not. In the last case, it is assumed that property owners in the area will still be potentially affected by views of the wind farms, as they will see them while traveling and conducting business in their vicinity.

Because this project lacked the resources to determine (through site visits, interviews, or other means) whether or not individual properties in the vicinity of the ten selected wind farms have a direct view of the wind turbines, the view shed is defined as all properties within a given radius of the outermost wind turbines in a wind farm. The value of this radius will clearly affect the results of the analysis. If the radius is too large, including many properties not potentially affected will overshadow the potential effect of the presence of wind turbines on property values. If the radius is too small, not all potentially effected properties will be accounted for in the analysis, and the number of data points gathered may be too small to yield valid statistical results.

D. Comparable Criteria

With the view shed of the wind farm defined, a set of neighboring communities outside of the view shed is selected to evaluate trends in residential house sales prices without the potential effects of wind farms on property values. These townships and incorporated cities are required to be clearly outside of the view shed area and not containing any large wind turbines. This selection is the "comparable" region. To define the comparable REPP consulted with local County Assessors and analyzed 1990 and 2000 U.S. Census data for the townships and incorporated cities under consideration.

Criteria used in selection of comparable communities include economic, demographic, and geographic attributes and trends. The goal in selecting comparable communities is to have communities that are as similar as possible with respect to variables that might affect residential house values, with the exception of the presence or absence of wind farms. When possible, comparable communities are selected in the same county as the wind farm location. If this is not possible due to placement of wind farm or availability of suitable data, comparable communities are selected from counties immediately adjacent to the county containing the wind farm.

After considering a number of criteria, including population, income level, poverty level, educational attainment, number of homes, owner occupancy rate, occupants per household, and housing value, five criteria from 1990 and 2000 U.S. Census were selected for evaluation:

- Population
- Median Household Income
- Ratio of Income to Poverty Level
- Number of Housing Units
- Median Value of Owner-occupied Housing Units

Data for these criteria is obtained for both the wind farm and comparable communities. Percent change from 1990 to 2000 for each criterion is calculated for each township or city considered as potentially comparable areas. The criteria are used in the following manner:

a) Change in population is calculated to identify any communities that had excessively large changes in population relative to the change in population from 1990 to 2000 in the wind farm area. Such large changes could indicate either a major construction boom, or major exodus of habitants from an area, which could skew comparisons in residential home values over the period in question. These communities are eliminated as possible comparables.

b) The average median household income in the wind farm communities in 1990 and 2000 is calculated. The first criterion is that comparable communities should have similar median household incomes in 2000. The second criterion is that median incomes should not have changed at significantly different rates from 1990 to 2000 between wind farm and comparable communities. Communities that meet both criteria are considered as potential comparables.

c) The percent of the population whose income is below poverty level is calculated from the ratio of income to poverty level. Absolute poverty levels and percent changes in poverty levels from 1990 to 2000 are compared. Communities that have significantly different poverty levels or rates of change of these levels as compared to the wind farm areas are eliminated as possible comparables.

d) Change in the number of housing units is used to identify any communities that had excessively large changes in housing relative to the change in housing from 1990 to 2000 in the wind farm area. Such large changes could indicate a major construction boom, or reduction in housing stock, which could skew comparisons in residential home values over the period in question. These communities are eliminated as possible comparables.

e) The average median house value in the wind farm communities in 1990 and 2000 is obtained from Census data. These values are owner-reported, and therefore may not accurately reflect actual market value of the properties. The criterion is that comparable communities should have similar median house values. Communities meeting these criteria are considered as potential comparables.

Communities that meet all five of the above criteria are selected for consideration as comparable communities. In addition to analysis of Census data, interviews with County Assessors, other local and state officials, and in some cases with knowledgeable real estate agents are taken into account in the selection of comparables.

E. Analysis

i. Literature Review

In selecting the type of analysis to use in determining whether there is any statistical evidence that wind farms negatively affect property values, we first conducted literature research to identify any studies previously conducted for this purpose. We found only four studies relating wind and property value effects, three of which are only qualitative.

A 1996 quantitative study, Social Assessment of Wind Power (Institute of Local Government Studies, Denmark), applied regression analysis to determine the effect of individual wind turbines, small wind turbine clusters, and larger wind parks on residential property values. The regression used the hedonic method, discussed in more detail below, in which site-specific data on a number of quantitative and qualitative variables is used to predict housing values. The study concluded that homes close to a wind turbine or turbines ranged in value from DKK 16,200 to 94,000 [approximately $2,900 to $16,800] less than homes further away. The study had a number of weaknesses, including a lack of definition of the distance from turbines, lack of specification of the size and number of turbines, and regression on a very small data sample. In contrast, a 2002 qualitative study, Public Attitudes Towards Wind Power (Danish Wind Industry Association), quoted the 1997 Sydthy Study as concluding that residents closer than 500 meters to the nearest wind turbine tend to be more positive about wind turbines than residents further away.

A 2001 qualitative study, Social Economics and Tourism (Sinclair Knight Mertz), said that for highly sought after properties along Salmon Beach, Australia closer than 200 meters from wind turbines, the general consensus among local real estate agents is that "property prices next to generators have stayed the same or increased after installation." However, the study concluded that while properties with wind turbines on them may increase in value, other properties may be adversely affected if within sight or audible distance of the wind turbines. Finally, the 2002 qualitative study, Economic Impacts of Wind Power in Kittitas County (ECO Northwest), concluded from interviews with assessors around the United States that there is no evidence of a negative impact on property values from wind farms. The weakness of the study is that it relies on subjective comment to arrive at its conclusion.

We also reviewed several studies that attempt to quantify the visual and property value impacts of electric transmission towers and lines. There is a large body of information on this subject, as transmission lines have been the subject of scrutiny and regulation for many years.

A 1992 study, The Effects of Overhead Transmission Lines on Property Values (C.A. Kroll and T. Priestley), reviews the methodology and conclusions of a number of studies on overhead transmission lines and property values over the 15 year period of 1977 through 1992. This study was very helpful in identifying the types of analysis, and their strengths and weaknesses, which could be adopted for use in this REPP report. The study concluded that appraisal offices have the longest history of studying and evaluating line impacts, but lack in-depth statistical analysis to verify obtained results. Data collected from face-to-face conversation and through surveys attempts to ascertain the attitudes and reactions of property owners to transmission equipment, but personal opinions were found to produce widely varying results. Statistical analysis of appraiser findings provided a better interpretation of appraiser information, but produced varying results due to different methodologies.

ii. Choice of Analytic Method

A number of analytic methods may be used to assess property value impacts from wind farms, ranging from interviews with assessors and surveys of residents to simple regression models and hedonic regression analysis. In order to produce results that could determine whether or not there was statistical evidence that wind farms have a negative impact on property values, simple linear regression analysis on property sales price as a function of time was selected.

A more complex method, hedonic regression analysis, can also be used to gauge property value impacts. Hedonic analysis, used in a number of studies on visual impacts of transmission lines, employs both quantitative and qualitative values to describe the property and local, regional, and even national parameters that may influence housing values. Property data such as number of bedrooms and bathrooms, linoleum or tile floors, modern appliances, kitchen cabinets or not are collected for each property in the study area, as well community information such as school district quality, subjective criteria derived from interviews with every resident in a study area, and other parameters. However, because this report is based on historic data, much of the detail needed for a hedonic analysis may not be available. An important consideration for this analysis, given the limits of the data, was to apply a consistent methodology to the site analyses. The only data consistent across all sites is sales date and sales price.

iii. Data Analysis

The key variables used in this analysis are sale price, sale date, and one locational attribute allowing data to be separated into view shed and comparable data sets. The first step of analysis was to remove any erroneous data from the dataset. Sales with incomplete information, duplicate sales, and zero price were removed. Parcel sales under $1,000 were also removed, as they often represent transfer within a family or business, rather than a bona fide sale. Finally, any sales with values much higher than any other sales were researched to determine whether or not that sale was bona fide. Interviews with assessors with knowledge of the properties in question were used to determine whether these high value sales were erroneous. Where they were, they were removed.

The second step in data analysis was to reduce cyclic effects of the real estate market on sales prices, as well as to reduce the high variability and heterogeneity of the data when viewed on a day sale basis. First, for each month, we calculated the monthly average sales price for each month to eliminate the variability of day-to-day sales. In some cases data supplied was already in monthly averaged form. Second, a six-month trailing average of the average monthly sales price is used to smooth out seasonal fluctuations in the real estate market. The averaging technique used the current month sales plus the previous six months of sales to compute trailing averages.

Third, a unit of analysis is defined. Because this project generally lacks resources to identify properties by street address, the smallest units of geographical analysis used are townships and incorporated cities within each county. Townships that are partly but not fully within the view shed radius are excluded from the view shed. In some cases zip code 4-digit ZIP+4 regions are used to identify location, and in some cases where the data offered no other alternative, individual street locations were manually identified in order to define the location of properties within the view shed and comparable.

Fourth, as stated above, linear regression is selected as the method to test for potential property value impacts. A least-squares linear regression of the six-month trailing average price is constructed for the view shed and comparable areas to determine the magnitude and rate of change in property sales price for each of the areas. The regression yields an equation for the line that best fits the data. The slope of this line gives the month-by-month expected change in the price of homes in the view shed and comparable areas. The regression also yields a value for "R2."

The R2 value measures the goodness of fit of the linear relationship to the data, and equals the percentage of the variance (change over time) in the data that is described by the regression model. The value of R2 ranges from zero to one. If R2 is small, say less than 0.2 to 0.3, the model explains only 20 to 30 percent of the variance in the data and the slope calculated is a poor indicator of the change in sales price over time. If R2 is large, say 0.7 or greater, then the model explains 70 percent or more of the variance in the data, and the slope of the regression line is a good indicator for quantifying the change in sales price over time. Regression models with low R2 values must be interpreted with caution. Often, knowledge and examination of factors not included in the regression model can help one understand why the regression provides a poor fit.

iv. Case I, II, and III Definitions

This report tests for effects of wind farms on property sales prices using three different models, or cases. All employ linear regression on six-month trailing averaged monthly residential sales data as outlined above.

> **Case 1** compares changes in the view shed and comparable community sales prices for the entire period of the study. If wind farms have a negative effect, we would expect to see prices increase slower (or decrease faster) in the view shed than in the comparable. Case 1 takes into account the wind farm on-line date only in that the data set begins three years before the on-line date. An appropriate comparable is important in this case in order that meaningful comparison of sale price changes over time can be made.
>
> **Case 2** compares property sales prices in the view shed before and after the wind farm in question came on-line. If wind farms have a negative effect, we would expect to see prices increase slower (or decrease faster) in view shed after the wind farm went on-line than before. Case 2 is susceptible to effects of macroeconomic trends and other pressures on housing prices not taken into account in the model. Because Case 2 looks only at the view shed, it is possible that external factors change prices faster before or after the on-line date, and the analysis may therefore pick up factors other than the wind development.
>
> **Case 3** compares property sales prices in the view shed and comparable community, but only for the period after the projects came on-line. If wind farms have a negative effect, we would expect to see prices increase slower (or decrease faster) in view shed than comparable after the on-line date. Again, an appropriate comparable is important in this case in order that meaningful comparison of sale price changes over time can be made.

Chapter III. Site Reports

Site Report 1: Riverside County, California

A. Project Description

The topography ranges from desert flats to arid mountains with views of snow capped peaks in winter – all of which encompass areas both in and out of the view shed.

The area has extreme elevation changes from the Palm Springs flats at an elevation of 450 feet, to the San Gorgonio Pass at an elevation of 2,500 feet. The Pass cuts through the two peaks of Mt. San Gorgonio to the north and Mt. San Jacinto to the southeast, and is five miles from the western edge of Palm Springs (15 to downtown), and about 80 miles east of Los Angeles.

Figure 1.1 View of wind farms at San Gorgonio Pass, Riverside County, CA

Photo by David F. Gallagher, 2001 - www.lightningfield.com

The projects are located in the San Gorgonio Pass immediately west of the Palm Springs area in Riverside County, California. Developers installed 3,067 turbines from 1981 to 2001, with the tallest turbine at 63 meters (207 feet). Repowering projects built 130 modern turbines. They begin northwest of Palm Spring heading up Interstate 10 from Indian Avenue; then they extend more than 10 miles along the flats up into the San Gorgonio Mountains, along the Pass, and stop shortly before reaching Cabazon.

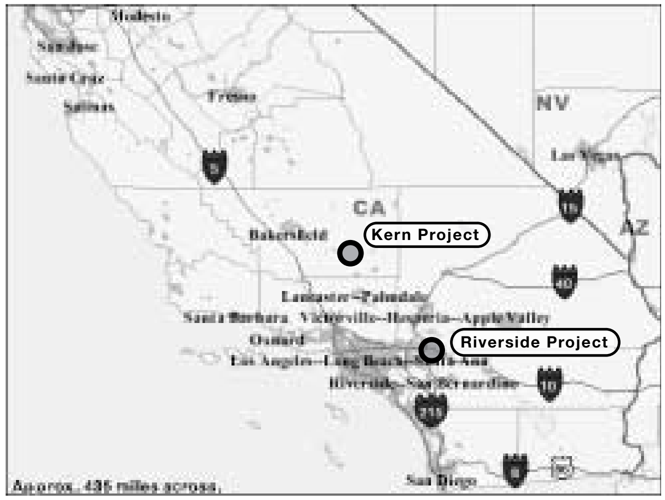


Figure 1.2 Regional Wind Project Location
(Dots approximate wind farm locations)

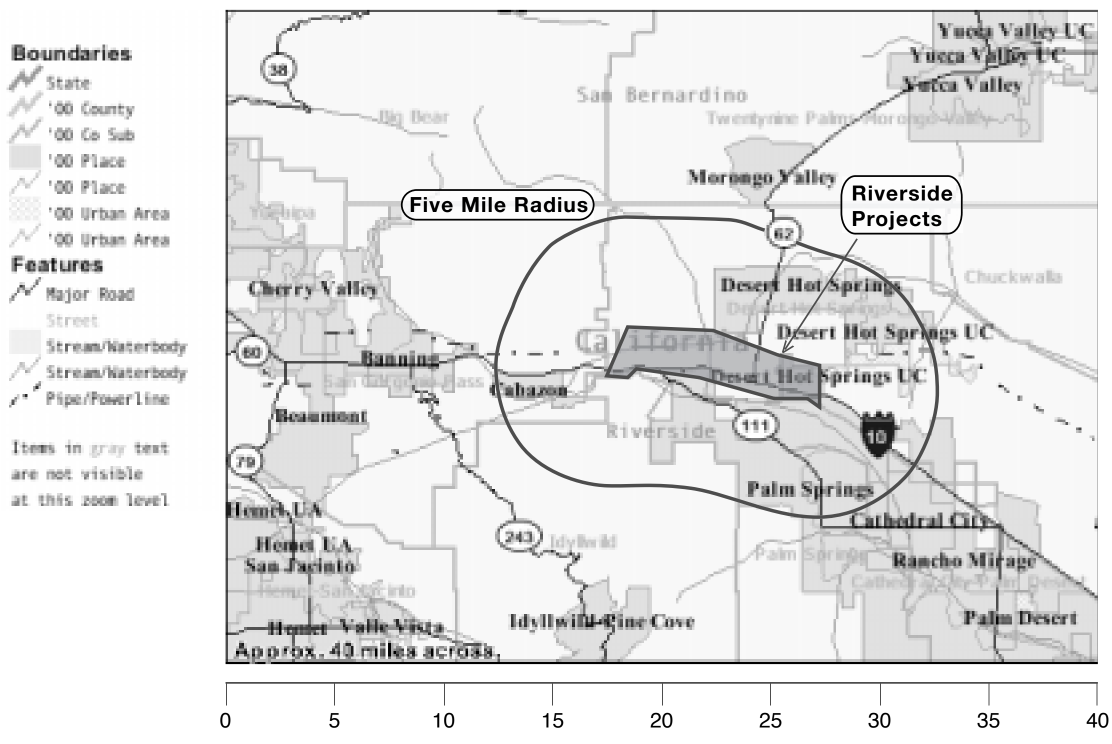


Figure 1.3 San Gorgonio, Riverside County, California View shed
(5 Mile Radius from project edge)
Map Source: U.S. Census Bureau Website
Project Location Details: Interviews and Aerial Photographs

The county is considered a metro area with 1 million population or more, but that is due to the population of the Los Angeles area. See Appendix 1 for a definition of rural urban continuum codes. The view shed represents fewer than 30,000 people.

B. Project Timeline

Table 1.1 Wind Project History, San Gorgonio, CA

Project Name	Completion Date	Capacity (MW)	Project Name	Completion Date	Capacity (MW)
Mountain View Power Partners I	2001	44.4	Altech 3	1981-1995	21.7
Mountain View Power Partners II	2001	22.2	Westwind Trust	1981-1995	15.7
Enron Earth Smart/Green Power	1999	16.5	Painted Hills B & C	1981-1995	15.3
Energy Unlimited	1999	10.0	Difwind, Ltd.	1981-1995	15.0
Pacific West I	1999	2.1	Energy Unlimited	1981-1995	14.5
Westwind-Repower	1999	47.3	Edom Hill	1981-1995	11.0
Cabazon-Repower	1999	39.8	So. Cal. Sunbelt	1981-1995	10.5
Westwind - PacifiCorp-Repower	1999	1.5	Difwind V	1981-1995	7.9
East Winds-Repower	1997	4.2	Meridian Trust	1981-1995	7.5
Karen Avenue-Repower	1995	3.0	Kenetech/Wintec	1981-1995	7.3
Dutch Pacific	1994	10.0	San Jacinto	1981-1995	5.0
Kenetech (various)	1981-1995	30.3	Painted Hills B & C	1981-1995	4.0
Zond-PanAero Windsystems	1981-1995	29.9	Altech 3	1981-1995	3.3
Alta Mesa	1981-1995	28.2	San Gorgonio Farms	1981-1995	3.2
Section 28 Trust	1981-1995	26.2	San Gorgonio Farms	1981-1995	2.0
San Gorgonio Farms	1981-1995	26.1			

C. Analysis

i. Data

Real property sales data for 1996 to 2002 was obtained from First American Real Estate Solutions in Anaheim, CA. The dataset is quite detailed and contains many property and locational attributes, among them nine-digit zip code (ZIP+4) locations. Sales data was purchased for four zip codes encompassing the wind farm area and surrounding communities. These zip codes are Palm Springs (92262), White Water (92282), Cabazon (92230), and Banning (92220).

Sales for the following residential property types were included in the analysis: Condominiums, Duplexes, Mobile Homes, and Single-Family Residences. Upon initial analysis, of the 9105 data points analyzed, approximately 10 sales in the view shed had unusually high prices. Conversations with the Assessors Office confirmed these were incorrect values for the data points. Correct values were obtained and the data corrected.

Projects that went on-line during the study period are the Cabazon, Enron, Energy Unlimited, Mountain View Power Partners I & II, and Westwind sites. Of these, two sites added 87 MW of repowered capacity in May 1999, two sites added 27 MW of new capacity in June 1999, and two sites added 66 MW of new capacity in October 2001.

ii. View shed Definition

All ZIP+4 regions within five miles of the wind turbines define the view shed. The location of the ZIP+4 regions were derived from the latitude and longitude of the ZIP+4 areas obtained from the U.S. Census TIGER database. The view shed includes the northwest portion of Palm Springs, Desert Hot Springs, and Cabazon, and 5,513 sales from 1996 to 2002. The view shed portion of northwest Palm Springs corresponds very closely to the boundaries of Palm Springs zip code 92262.

Interviews with State of California Palm Springs Regional Assessors Office were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. In Assessment District Supervisor Gary Stevenson's opinion, over 80 percent of Cabazon properties can see some wind turbines; over 80 percent of Desert Hot Springs properties can see some wind turbines; almost all of the properties on the outer edge of northwest Palm Springs can see some wind turbines, but due to foliage (mainly palm trees) and tall buildings, only five percent or less of the properties in the interior of Pam Springs can see any wind turbines.

iii. Comparable Selection

The comparable community was selected through interviews with State of California San Gorgonio Regional Assessors Office personnel, as well as analysis of demographic data from the 1990 and 2000 U.S. Census for communities near but outside of the view shed. Selection of the comparable in this case was difficult, as the eastern side of the view shed is close to downtown Palm Springs, which is growing fairly quickly, while the western portion of the view shed, including Cabazon, is not growing quickly and has more stable housing sales prices. Tables 1.2 and 1.3 summarize the Census data reviewed. Because Census data by zip code is not available for 1990, we were unable to determine 1990 demographic statistics for the Palm Springs view shed, as it is not separable from the Palm Springs non-view shed area.

Based on his extensive experience in the area, Assessment District Supervisor Gary Stevenson suggested Banning and Beaumont in Riverside County, to the west of the wind farms, and Morongo Valley in San Bernardino County, to the north of the wind farms as appropriate comparables to the view shed area. Banning and Beaumont are visually separated from the wind farm area by a ridge, and Morongo Valley is separated by approximately seven miles distance.

In order to determine the most appropriate comparable community we looked at the demographics of 10 surrounding areas. The 92264 zip code area of Palm Springs to the south of northwest Palm Springs was initially considered as a comparable, but Supervisor Stevenson said that this area was closer to the metropolitan center and had significantly different demographics than the view shed area. Towns adjacent to Banning and Beaumont, including Hemet, San Jacinto, and Cherry Valley, were considered but rejected for use after discussion with Supervisor Stevenson. Upon examination of Census data, sales data availability, and review of Assessor comments, Banning was selected as the comparable, with a total of 3,592 sales from 1996 to 2002.

Table 1.2 Riverside County, California: 1990 Census Data

Year	View shed	Location	Population	Median Household Income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
1990	Y	Cabazon CDP	1,588	$13,830	19%	754	$64,000
1990	Y	Palm Springs City*	n/a	n/a	n/a	n/a	n/a
1990	Y	White Water**	n/a	n/a	n/a	n/a	n/a
1990	VIEW SHED DEMOGRAPHICS		n/a	n/a	n/a	n/a	n/a
1990	COMP	Banning City	20,570	$22,514	17%	8,278	$89,300
1990	COMPARABLE DEMOGRAPHICS		20,570	$22,514	17%	8,278	$89,300
1990	N	Beaumont City	9,685	$22,331	23%	3,718	$89,700
1990	N	Cathedral City	30,085	$30,908	13%	15,229	$114,200
1990	N	Cherry Valley CDP	5,945	$29,073	9%	2,530	$127,500
1990	N	Hemet City	36,094	$20,382	14%	19,692	$90,700
1990	N	Idyllwild-Pine Cove CDP	2,937	$31,507	4%	3,635	$147,200
1990	N	Morongo Valley CDP***	1,554	$38,125	23%	827	$74,100
1990	N	Rancho Mirage City	9,778	$45,064	7%	9,360	$252,400
1990	N	San Jacinto City	16,210	$20,810	16%	6,845	$90,200
1990	N	Valle Vista CDP	8,751	$22,138	8%	4,444	$125,500

*Census data by zip code not available for 1990. Unable to determine demographics of view shed as the Palm Springs view shed area is not separable from the Palm Springs non-view shed area.
**White Water not listed in 1990 U.S. Census.
***San Bernardino County.

Table 1.3 Riverside County, California: 2000 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
2000	Y	Cabazon-- Zip Code 92230	2,442	$22,524	32%	884	$48,200
2000	Y	Palm Springs- Zip Code 92262	24,774	$32,844	18%	15,723	$133,100
2000	Y	White Water-- Zip Code 92282	903	$35,982	23%	380	$82,400
2000	VIEW SHED DEMOGRAPHICS		28,119	$30,450	24%	16,987	$87,900
2000	COMP	Banning City—Zip Code 92220	23,443	$32,076	20%	9,739	$97,300
2000	COMPARABLE DEMOGRAPHICS		23,443	$32,076	20%	9,739	$97,300
2000	N	Beaumont City	11,315	$29,721	20%	4,258	$93,400
2000	N	Cathedral City	42,919	$38,887	14%	17,813	$113,600
2000	N	Cherry Valley CDP	5,857	$39,199	6%	2,633	$121,700
2000	N	Hemet City	58,770	$26,839	16%	29,464	$69,900
2000	N	Idyllwild-Pine Cove CDP	3,563	$35,625	13%	4,019	$164,700
2000	N	Morongo Valley CDP*	2,035	$36,357	19%	972	$73,300
2000	N	Rancho Mirage City	12,973	$59,826	6%	11,643	$251,700
2000	N	San Jacinto City	23,923	$30,627	20%	9,435	$78,500
2000	N	Valle Vista CDP	10,612	$32,455	12%	4,941	$76,500

*San Bernardino County.

iv. Analytical Results and Discussion

In all three of the regression models, monthly average sales prices grew faster in the view shed than in the comparable area, indicating that there is no significant evidence that the presence of the wind farms had a negative effect on residential property values. For Cases II and III, the on-line date is defined as the month the first wind project came on-line during the study period, May 1999.

In Case I, the monthly sales price change in the view shed is twice the monthly sales price change of the comparable over the study period. The Case I model provides a good fit to the data, with over 80 percent of the variance in the data explained by the linear regression. In Case II, the monthly sales price change in the view shed is 86 percent greater after the on-line date than before the on-line date. The Case II model provides a good fit to the data, with over two-thirds of the variance in the data explained by the linear regression. In Case III, the monthly sales price change in the view shed after the on-line date is 63 percent greater than the monthly sales price change of the comparable after the on-line date. The data for the full study period is graphed in Figure 1.4, and regression results for all cases are summarized in Table 1.4 below.

Table 1.4 Riverside County, California: Regression Results

Projects: Cabazon, Enron, Energy Unlimited, Mountain View Power Partners I & II, Westwind

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data	Jan 96 - Nov 02	$1,719.65	0.92	The rate of change in average view shed sales price is 2.1 times greater than the rate of change of the comparable over the study period.
	Comparable, all data	Jan 96 - Nov 02	$814.17	0.81	
Case 2	View shed, before	Jan 96 - Apr 99	$1,062.83	0.68	The rate of change in average view shed sales price is 86% greater after the on-line date than the rate of change before the on-line date.
	View shed, after	May 99 - Nov 02	$1,978.88	0.81	
Case 3	View shed, after	May 99 - Nov 02	$1,978.88	0.81	The rate of change in average view shed sales price after the on-line date is 63% greater than the rate of change of the comparable after the on-line date.
	Comparable, after	May 99 - Nov 02	$1,212.14	0.74	

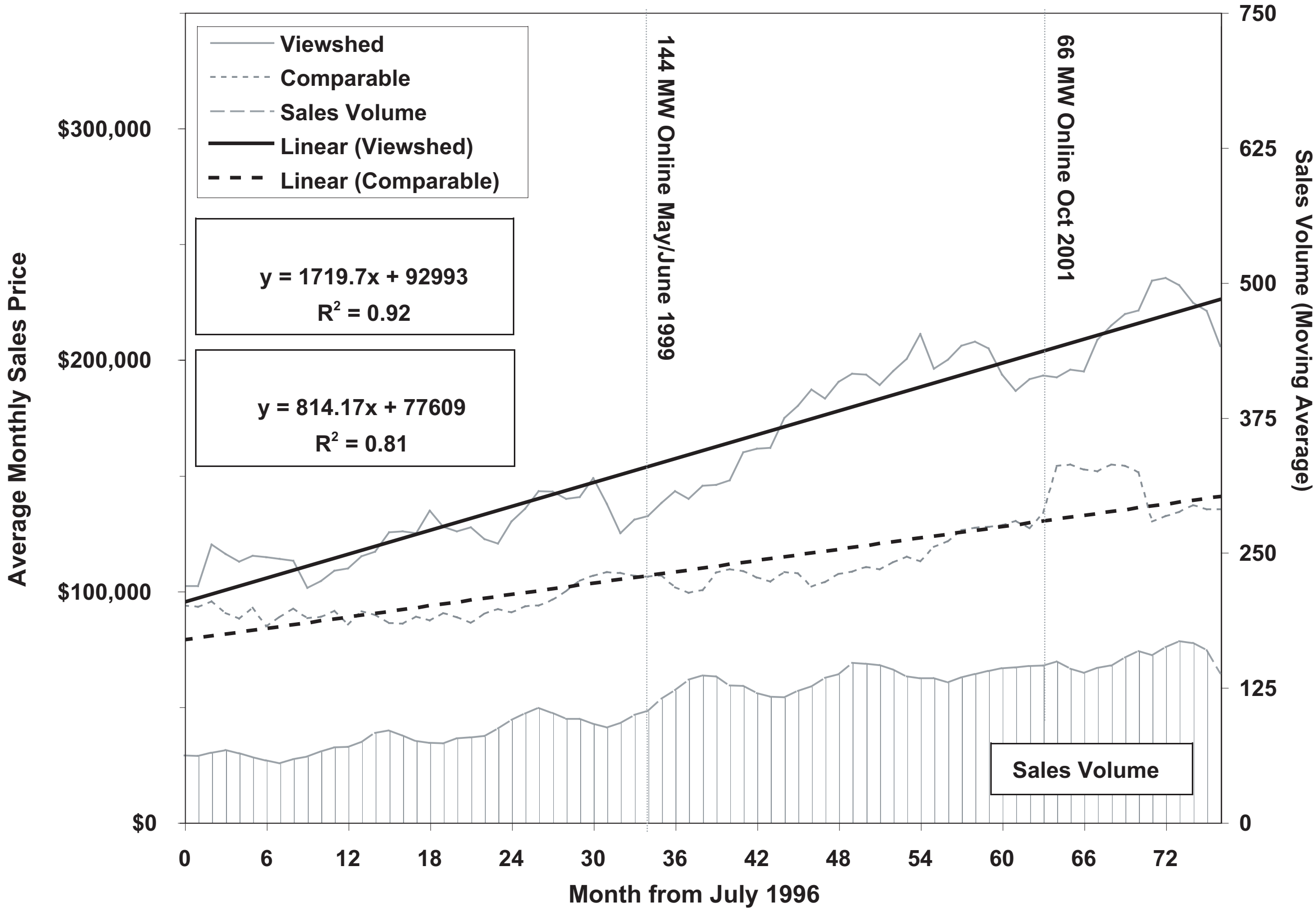


Figure 1.4 Average Residential Housing Sales Price

Riverside County, California 1996-2002

D. Additional Interviewee Comments

Jack Norie of Desert Hot Springs, who provides tours of the wind projects, said that since 1998 there has been a discernable sense that more turbines were in the area. Norie felt that the 41 new turbines built high up along the nearest peaks facing Palm Springs near the intersection of Highway 111 and Interstate 10 on the north side, contributed to this impression. (These are possibly the Mountain View Power Partners II project with 37 turbines). Mr. Norie's descriptions of project locations and aerial photographs available from Microsoft's Terraserver and Mapquest, allowed us to determine project locations.

Site Reports 2.1 and 2.2: Madison County, New York

A. Project Description

Madison County has two wind farms meeting the criteria for analysis, Madison and Fenner. Because they are separated by distance, and have different on-line dates, each wind farm is analyzed separately. However, since they are in the same county and share the same comparable region, both analyses are presented in this section.

The Fenner turbines are seated in a primarily agricultural region southeast of Syracuse and southwest of Utica, with 20 turbines at 100 meters (328 feet). The Madison project is about 15 miles southeast of Fenner, and 2.5 miles east of Madison town with seven turbines standing 67 meters (220 feet).

Madison County is classified as a "county in a metro area with 250,000 to 1 million population." See Appendix 1 for a definition of rural urban continuum codes. The view shed areas have a population less than 8,000.

Figure 2.1 View of Fenner wind farm.

Photo Courtesy: New York State Energy Research and Development Authority (NYSERDA)

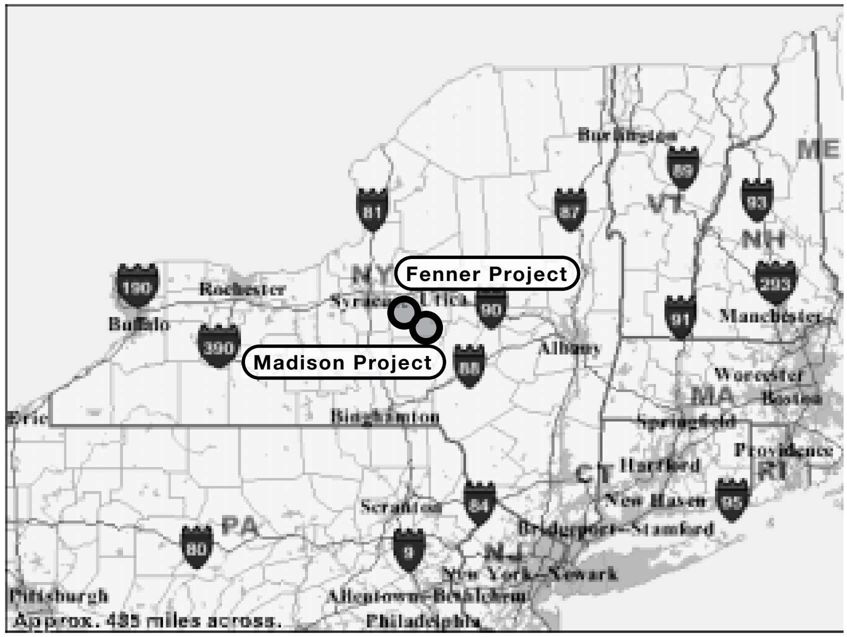


Figure 2.2. Regional Wind Project Location
(Dots approximate wind farm locations)

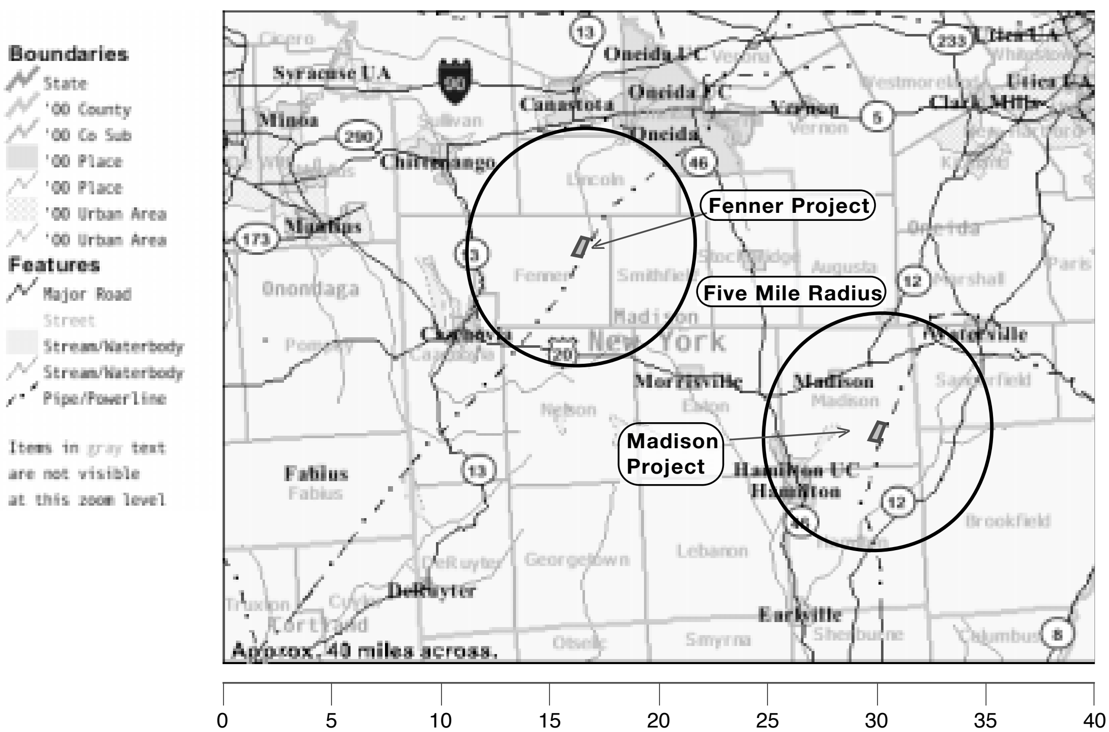


Figure 2.3. Location of Wind Projects in Madison County
Site Locations Source: Madison Assessors Office
Base Map Source: U.S. Census Bureau

B. Project Timeline

Table 2.1 Wind Project History, Madison County, NY

Project Name	Completion Date	Capacity (MW)
Fenner Wind Power Project	2001	30.0
Madison Windpower	2000	11.6

C. Analysis

i. Data

Real property sales data for 1997 to 2002 was purchased on CD-ROM from Madison County Real Property Tax Services in Wampsville, NY. The sales data was purchased for the townships and cities encompassing the wind farm areas and surrounding communities. The unit of analysis for this dataset is defined by either township or incorporated city boundaries. Though street addresses are included in the dataset, this analysis lacked the resources to identify the location of properties by street address.

In addition to basic sales data, the dataset included property attributes such as building style, housing quality grade, and neighborhood ratings. The CD-ROMs contained four files that required merging on a common field to create the composite database of all sales. A significant number of redundant, incomplete, and blank entries were deleted prior to analysis. Sales for the following residential property types were included in the analysis: one-, two-, and three-family homes, rural residences on 10+ acres, and mobile homes.

Upon initial analysis, of the 1,263 data points analyzed, approximately six sales in the Madison view shed had unusually high prices. Conversations with the Assessors Office confirmed four of these were valid sales, but that two were not. The invalid sales were eliminated from the analysis.

Projects that went on-line during the study period are the Madison wind farm, which went on-line September 2000 with a capacity of 11.6 MW, and the Fenner wind farm, which went on-line December 2001 with a capacity of 30 MW. The wind farms are approximately 15 miles apart.

ii. View Shed Definition

Two separate view sheds are defined for Madison County, one for each wind farm. A five-mile radius around the Madison wind farm encompasses the town of Madison and over 95 percent of Madison Township. The view shed also encompasses portions of three townships in Oneida County. However, due to lack of resources to identify the location of individual properties within townships, the Oneida townships were excluded from the analysis. The Madison view shed is defined as Madison town and all of Madison Township. The Fenner view shed is defined as all of Fenner, Lincoln, and Smithfield Townships, which are fully within a five-mile radius around the Fenner wind farm, with the exception of a small corner of Smithfield Township. The Madison and Fenner view sheds accounts for 219 and 453 sales over the study period, respectively.

Interviews with the State of New York Madison County Assessors Office were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. In Fenner Assessment District Supervisor Russell Cary's opinion, over 80 to 85 percent of Fenner properties can see some wind turbines, over 85 percent of Lincoln properties can see some wind turbines, over 75 percent of Madison properties can see some wind turbines, and approximately 60 percent of Smithfield properties can see some wind turbines. Cary said that in his opinion, only a few properties in Fenner Township, near Route 13, could not see some wind turbines.

iii. Comparable Selection

The comparable community was selected through interviews with State of New York Madison County Assessors Office personnel, as well as analysis of demographic data from the 1990 and 2000 U.S. Census for communities near but outside of the view shed. Tables 2.2 and 2.3 summarize the Census data reviewed. In order to determine the most appropriate comparable community, we looked at the demographics of 13 surrounding areas. Based on his experience in the area, Assessment District Supervisor Russell Cary suggested Lebanon, Deruyter and Stockbridge Townships along with villages of Deruyter, Munnsville and Hamilton, all in Madison County, as appropriate comparables for both view sheds. However, Cary added that Hamilton has higher property values than Madison because it is home to Colgate University. Upon examination of Census data, sales data availability, and review of Assessor comments, Lebanon, Deruyter, Hamilton, Stockbridge Townships, and the Villages of Deruyter and Munnsville were selected as the comparable for both view sheds, with a total of 591 sales from 1997 to 2002.

Table 2.2 Madison County, New York: 1990 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
1990	Y	Fenner town	1,694	$31,875	13%	609	$73,700
1990	Y	Lincoln town	1,669	$32,073	8%	587	$63,900
1990	Y	Smithfield town	1,053	$23,355	13%	380	$52,200
FENNER DEMOGRAPHICS			4,416	$29,101	11%	1,576	$63,267
1990	Y	Madison town	2,774	$29,779	10%	1,239	$65,200
1990	Y	Madison village	316	$26,250	12%	135	$50,000
MADISON DEMOGRAPHICS			3,090	$28,015	11%	1,374	$57,600
1990	COMP	DeRuyter town	1,458	$26,187	11%	811	$51,800
1990	COMP	DeRuyter village	568	$24,125	10%	218	$52,200
1990	COMP	Hamilton town	6,221	$28,594	17%	1,820	$69,800
1990	COMP	Lebanon town	1,265	$26,359	12%	581	$49,600
1990	COMP	Munnsville village	438	$23,194	15%	174	$54,700
1990	COMP	Stockbridge town	1,968	$24,489	11%	723	$53,600
COMPARABLE DEMOGRAPHICS			11,918	$25,491	13%	4,327	$55,283
1990	N	Cazenovia town	6,514	$39,943	4%	2,372	$122,300
1990	N	Cazenovia village	3,007	$31,622	5%	995	$101,100
1990	N	Chittenango village	4,734	$34,459	7%	1,715	$72,400
1990	N	Earlville village	883	$28,839	5%	362	$44,300
1990	N	Georgetown town	932	$25,000	10%	287	$42,700
1990	N	Hamilton village	3,790	$31,960	16%	869	$88,000
1990	N	Morrisville village	2,732	$26,875	30%	443	$55,500

Table 2.3 Madison County, New York: 2000 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
2000	Y	Fenner town	1,680	$43,846	7%	651	$84,400
2000	Y	Lincoln town	1,818	$46,023	5%	700	$85,000
2000	Y	Smithfield town	1,205	$35,109	16%	446	$61,900
FENNER DEMOGRAPHICS			4,703	$41,659	9%	1,797	$77,100
2000	Y	Madison town	2,801	$35,889	13%	1,325	$77,100
2000	Y	Madison village	315	$27,250	13%	151	$68,400
MADISON DEMOGRAPHICS			3,116	$31,570	13%	1,476	$72,750
2000	COMP	DeRuyter town	1,532	$34,911	12%	867	$68,200
2000	COMP	DeRuyter village	531	$31,420	12%	231	$70,300
2000	COMP	Hamilton town	5,733	$38,917	14%	1,725	$79,300
2000	COMP	Lebanon town	1,329	$34,643	14%	631	$62,900
2000	COMP	Munnsville village	437	$35,000	15%	176	$66,400
2000	COMP	Stockbridge town	2,080	$37,700	13%	802	$67,900
COMPARABLE DEMOGRAPHICS			11,642	$35,432	13%	4,432	$69,167
2000	N	Cazenovia town	6,481	$57,232	4%	2,567	$142,900
2000	N	Cazenovia village	2,614	$43,611	7%	1,031	$115,200
2000	N	Chittenango village	4,855	$43,750	6%	1,968	$75,700
2000	N	Earlville village	791	$32,500	12%	329	$51,400
2000	N	Georgetown town	946	$37,963	11%	315	$54,600
2000	N	Hamilton village	3,509	$36,583	19%	785	$104,600
2000	N	Morrisville village	2,148	$34,375	20%	398	$73,900

iv. Analytical Results and Discussion

In five of the six regression models, monthly average sales prices grew faster or declined slower in the view shed than in the comparable area. However, in the case of the underperformance of the view shed, the explanatory power of the model is very poor. Thus, there is no significant evidence in these cases that the presence of the wind farms had a negative effect on residential property values.

Madison View shed

In Case I, the monthly sales price change in the view shed is 2.3 times the monthly sales price change of the comparable over the study period. However, the Case I model provides a poor fit to the data, with approximately 30 percent of the variance in the data explained by the linear regression. In Case II, the monthly sales price change in the view shed is 10.3 times greater after the on-line date than before the on-line date. However, the Case II model provides a poor fit to the data, with less than 30 percent of the variance in the data after the on-line date, and only 1 percent of the variance before the on-line date explained by the linear regression. In Case III, average monthly sales prices increase in the view shed after the on-line date, but decrease in the comparable region. The average view shed sales price after the on-line date increased at 3.2 times the rate of decrease in the comparable after the on-line date. The Case III model describes less than 30 percent of the variance in the view shed, but almost 40 percent of the variance in the comparable. The poor fit of the models, at least for the view shed, is partly due to a handful of property sales that were significantly higher than the typical view shed property sale. The data for the full study period is graphed in Figure 2.4, and regression results for all cases are summarized in Table 2.4 below.

Table 2.4 Madison County, New York: Regression Results
Project: Madison

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 97 - Jan 03 Jan 97 - Jan 03	$576.22 $245.51	0.29 0.34	The rate of change in average view shed sales price is 2.3 times greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 97 - Aug 00 Sep 00 - Jan 03	$129.32 $1,332.24	0.01 0.28	The rate of change in average view shed sales price after the on-line date is 10.3 times greater than the rate of change before the on-line date.
Case 3	View shed, after Comparable, after	Sep 00 - Jan 03 Sep 00 - Jan 03	$1,332.24 -$418.71	0.28 0.39	The rate of change in average view shed sales price after the on-line date increased at 3.2 times the rate of decrease in the comparable after the on-line date.

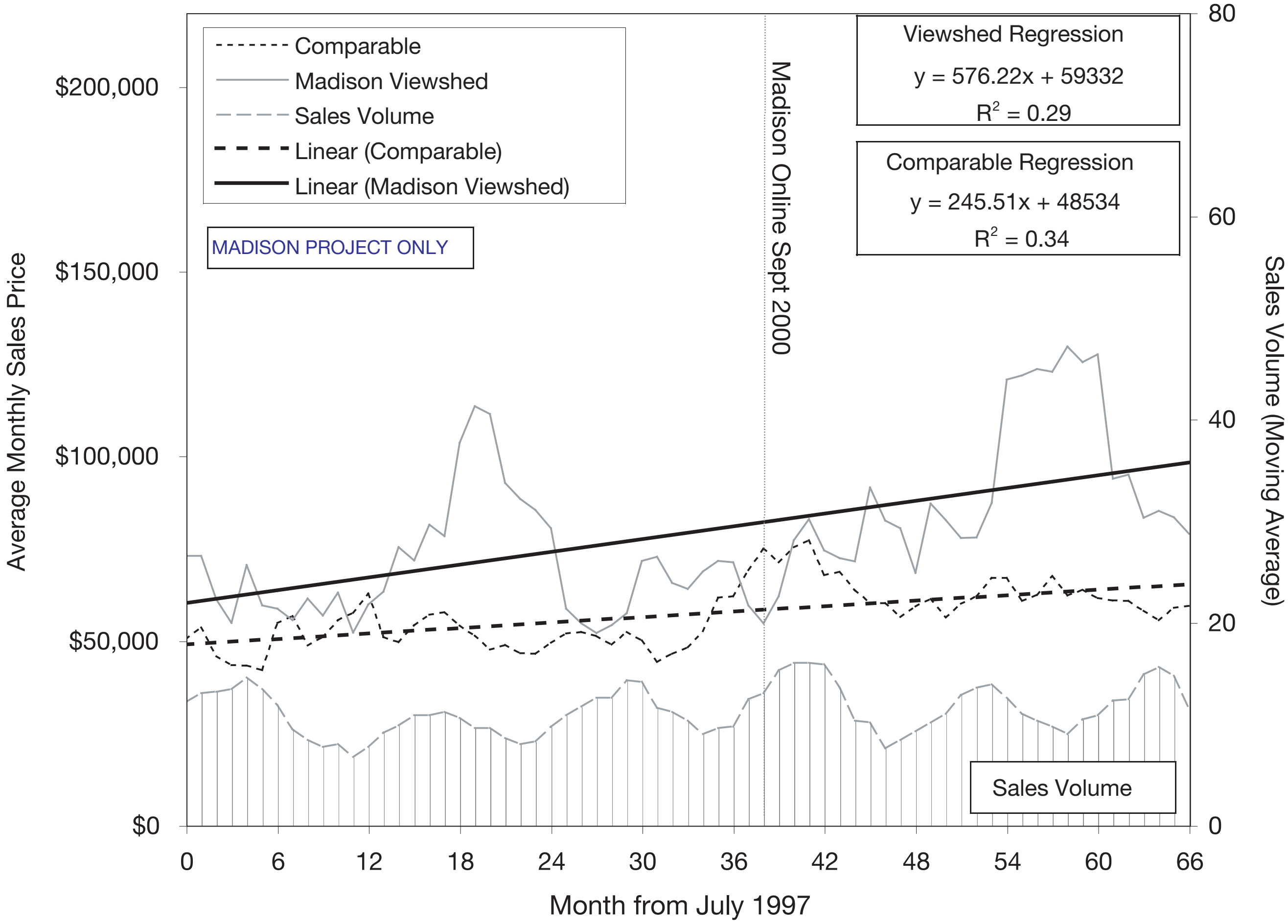


Figure 2.4 Average Residential Housing Sales Price For Madison Project

Madison County, New York 1997-2002

Fenner View shed

In Case I, the monthly sales price change in the view shed is 50 percent greater than the monthly sales price change of the comparable over the study period. The Case I model explains approximately one-third of the variance in the data. In Case II, average monthly sales prices increase in the view shed prior to the on-line date, but decrease after the on-line date. The average view shed sales price after the on-line date decreased at 29 percent of the rate of increase before the on-line date. The Case II model provides a fair fit to the data before the on-line date, with half of the variance in the data explained by the linear regression, but a poor fit after the on-line date, explaining only 4 percent of the variance in the data. The poor fit is partly due to having only 14 months of data after the on-line date, which may not be enough data establish clear price trends in a housing market that exhibits significant price fluctuations over time. In Case III, average monthly sales prices decrease in both the view shed and comparable after the on-line date, with the view shed decreasing less quickly. The decrease in average view shed sales price after the on-line date is 37 percent less than the decrease of the comparable after the on-line date. The Case III model again describes only 4 percent of the variance in the view shed, but over 60 percent of the variance in the comparable. The data for the full study period is graphed in Figure 2.5, and the regression results are summarized in Table 2.5.

Table 2.5 Madison County, New York: Regression Results
Project: Fenner

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data	Jan 97 - Jan 03	$368.47	0.35	The rate of change in average view shed sales price is 50% greater than the rate of change of the comparable over the study period.
	Comparable, all data	Jan 97 - Jan 03	$245.51	0.34	
Case 2	View shed, before	Jan 97 - Nov 01	$587.95	0.50	The rate of decrease in average view shed sales price after the on-line date is 29% lower than the rate of sales price increase before the on-line date.
	View shed, after	Dec 01 - Jan 03	-$418.98	0.04	
Case 3	View shed, after	Dec 01 - Jan 03	-$418.98	0.04	The rate of decrease in average view shed sales price after the on-line date is 37% less than the rate of decrease of the comparable after the on-line date.
	Comparable, after	Dec 01 - Jan 03	-$663.38	0.63	

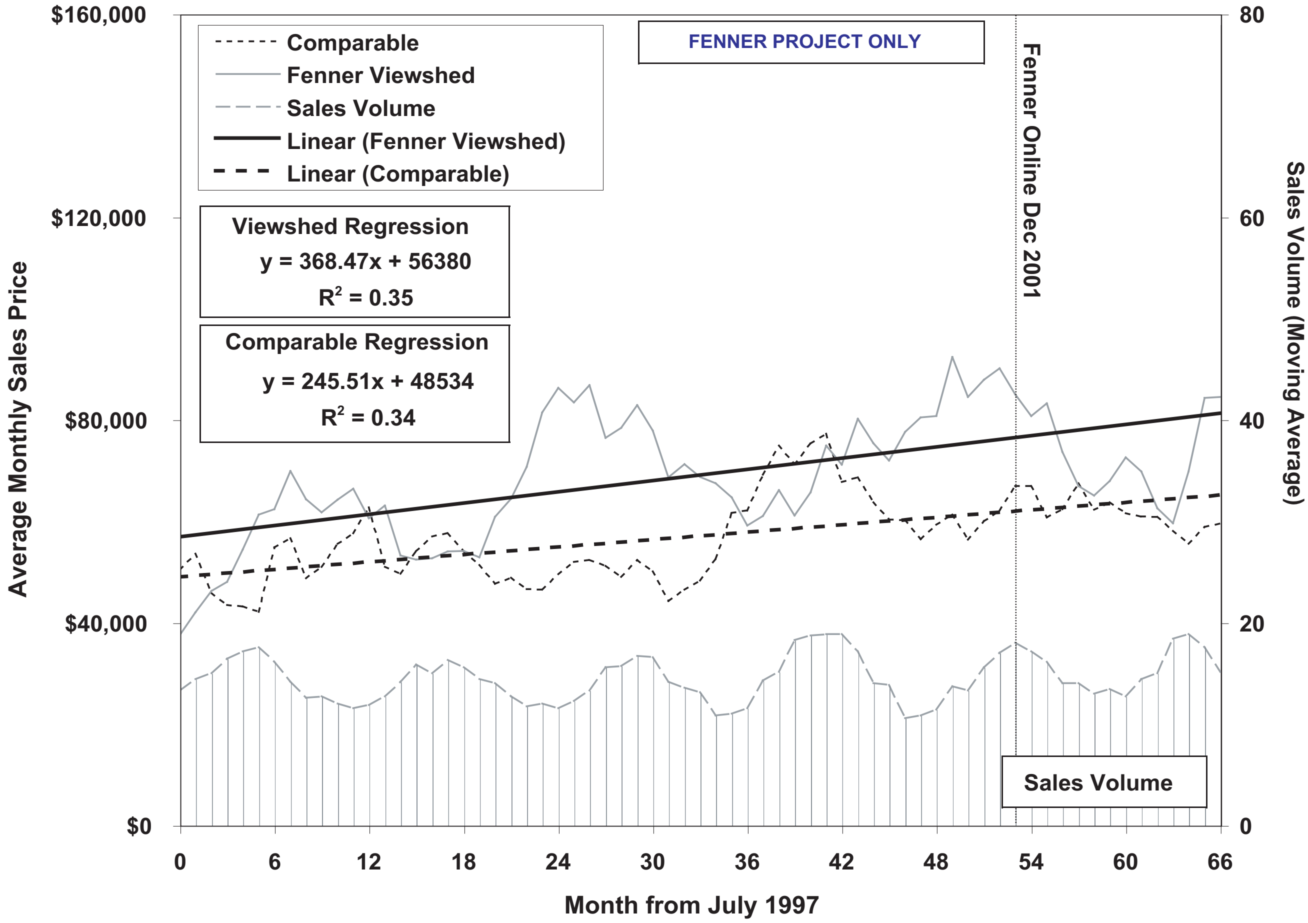


Figure 2.5 Average Residential Housing Sales Price For Fenner Project
Madison County, New York 1997-2002

D. Additional Interviewee Comments

Madison County assessors Carol Brophy and Priscilla Suits said they have not seen any impact of the turbines on property values, and Suits added, "There's been no talk of any impact on values." Assessor Russell Cary noted that there were worries about views of the turbines, and that the project siting was designed such that the town of Cazenovia could not see the project – it rests just outside the five-mile perimeter view shed this study designated.

Site Report 3: Carson County, Texas

A. Project Description

Situated in the middle of the Texas panhandle among large agricultural farms and small herds of cattle on fallow, 80 turbines stand at 70 meters (230 feet) high. Southwest of the project by 2.5 miles is White Deer town, which is 41 miles northeast of Amarillo.

The area is just about dead flat since Carson is right on the edge of the Texas High Plains. The general classification of the county is "completely rural or less than 2,500 urban population, but adjacent to a metro area." See Appendix 1 for a definition of rural urban continuum codes. The view shed represents fewer than 1,200 people.

Figure 3.1 : White Deer Wind Farm
Photo Courtesy: Ted Carr © 2003

B. Project Timeline

Table 3.1 Wind Project History, Carson County, TX

Project Name	Completion Date	Capacity (MW)
Llano Estacado Wind Ranch	2001	80

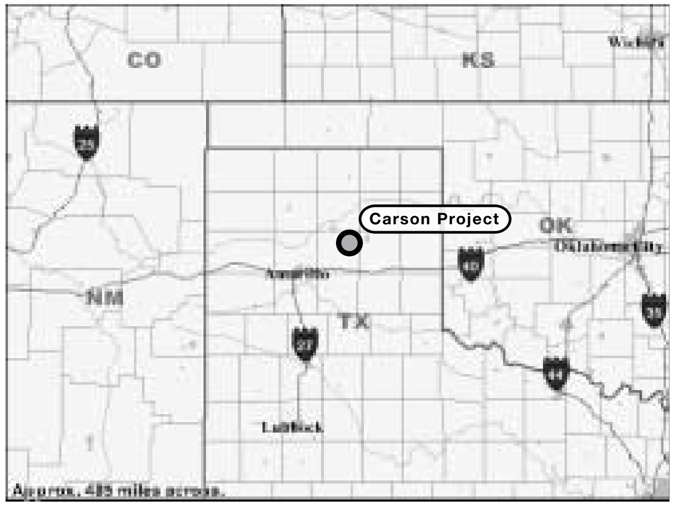


Figure 3.2. Regional Wind Project Location
(Dots approximate wind farm locations)

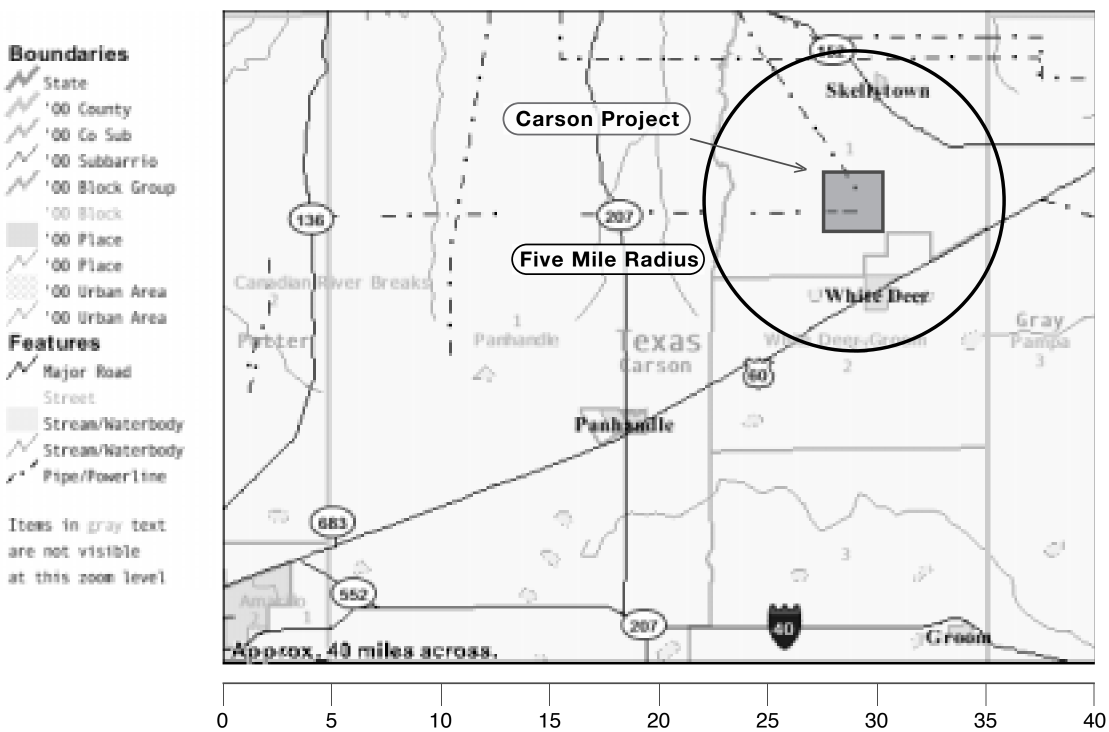


Figure 3.3. Carson County, Texas View shed
Site Location Source: Carson Appraisal District

Base Map Source: U.S. Census Bureau

C. Analysis

i. Data

Real property sales data for 1998 to 2002 was purchased in paper format from Carson County Appraisal District in Panhandle, TX. The sales data was purchased for the entire county, including the wind farm area and surrounding communities. The unit of analysis for this dataset is defined by census block and section and incorporated city boundaries. A detailed landowners map from for the County that identified every parcel, section, and block in the county was purchased. The Appraiser marked the exact parcel locations of the wind farms on the map, eliminating any estimation of the actual wind farm location.

The dataset included only a few property attributes, such as residence square footage and age of home. While the dataset included all sales of land, commercial property, and residential property, the analysis included only improved lots with residential housing, with a total of 269 sales over the study period. While there were no questions about unusual data points, the view shed had only 45 sales over the five years of data analyzed. This meant that many months had no sales in the view shed. While the six-month trailing average smoothed out most of the gaps, there was a seven-month gap in view shed data from August 2001 through February 2002. As a proxy for the missing data, the average of the two previous months with sales was used to fill in the gap. In addition, a few low value sales and a number of months with no sales contributed to a very low average sale price in the view shed between July 2000 and May 2001.

ii. View Shed Definition

View shed definition using the five-mile radius was straightforward given the land owner map, exact wind farm location, and one-mile reference scale on the map. The town of White Deer lies entirely within the view shed. The region of Skellytown lies just outside the edge of the five-mile radius, too far to be defined as view shed, but too close given the flat land and easily seen wind turbines to be considered as part of the comparable. Thus Skellytown, with a total of 16 sales, was excluded from the analysis. The view shed accounts for 45 sales over the study period.

Interviews with the State of Texas Carson County Appraisal District officers were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. In Appraiser Mike Darnell's opinion, 90 to 100 percent of White Deer residents can see the project.

iii. Comparable Selection

The comparable community was selected through interviews with State of Texas Carson County Appraisal District personnel, as well as analysis of demographic data from the 1990 and 2000 U.S. Census for communities near but outside of the view shed. Tables 3.2 and 3.3 summarize the Census data reviewed. In order to determine the most appropriate comparable community we looked at the demographics of three remaining residential areas in the county that were not part of the view shed and not excluded by being too close to the view shed.

Based on his experience in the area, Appraiser Mike Darnell suggested that Groom would be an appropriate comparable to the view shed area. However, Darnell said that homes in Fritch and Panhandle are more expensive, and have been increasing in value faster over time. Upon examination of Census data, sales data availability, and review of Assessor comments, all three residential areas, Fritch, Groom, and Panhandle were selected as the comparable, with a total of 224 sales from 1998 to 2002.

Table 3.2 Carson County, Texas: 1990 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
1990	Y	White Deer-Groom division	2,863	$23,883	8%	1,319	$34,700
1990	N	Panhandle division	3,713	$28,569	10%	1,537	$44,100
1990 COUNTY DEMOGRAPHICS			6,576	$26,226	9%	2,856	$39,400

Table 3.3 Carson County, Texas: 2000 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
2000	Y	White Deer-Groom CCD	2,702	$36,117	9%	1,261	$46,900
2000	N	Panhandle CCD	3,814	$43,349	6%	1,554	$59,400
2000 COUNTY DEMOGRAPHICS			6,516	$39,733	7%	2,815	$53,150

iv. Analytical Results and Discussion

In all three of the regression models, monthly average sales prices grew faster in the view shed than in the comparable area, indicating that there is no significant evidence that the presence of the wind farms had a negative effect on residential property values.

In Case I, the monthly sales price change in the view shed is 2.1 times the monthly sales price change of the comparable over the study period. The Case I model provides a fair fit to the view shed data, with almost half of the variance in the data explained by the linear regression. However, the model only explains one-third of the variance in the comparable data. In Case II, the monthly sales price change in the view shed is 3.4 times greater after the on-line date than before the on-line date. The Case II model provides a poor fit to the data prior to the on-line date, with a quarter of the variance in the data explained by the linear regression. However, the fit after the on-line date is good, with over 80 percent of the variance explained. In Case III, average monthly sales prices increase in the view shed after the on-line date, but decrease in the comparable region. The average view shed sales price after the on-line date increased at 13.4 times the rate of decrease in the comparable after the on-line date. The Case III model describes over 80 percent of the variance in the view shed, but provides a very poor fit with only 2 percent of the variance explained in the comparable. The data for the full study period is graphed in Figure 3.4, and regression results for all cases are summarized in Table 3.4 below.

Table 3.4 Carson County, Texas: Regression Results
Project: Llano Estacado Wind Ranch

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 98 - Nov 02 Jan 98 - Nov 02	$620.47 $296.54	0.49 0.33	The rate of change in average view shed sales price is 2.1 times greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 98 - Oct 01 Nov 01 - Nov 02	$553.92 $1,879.76	0.24 0.83	The rate of change in average view shed sales price after the on-line date is 3.4 times greater than the rate of change before the on-line date.
Case 3	View shed, after Comparable, after	Nov 01 - Nov 02 Nov 01 - Nov 02	$1,879.76 -$140.14	0.83 0.02	The rate of change in average view shed sales price after the on-line date increased at 13.4 times the rate of decrease in the comparable after the on-line date.

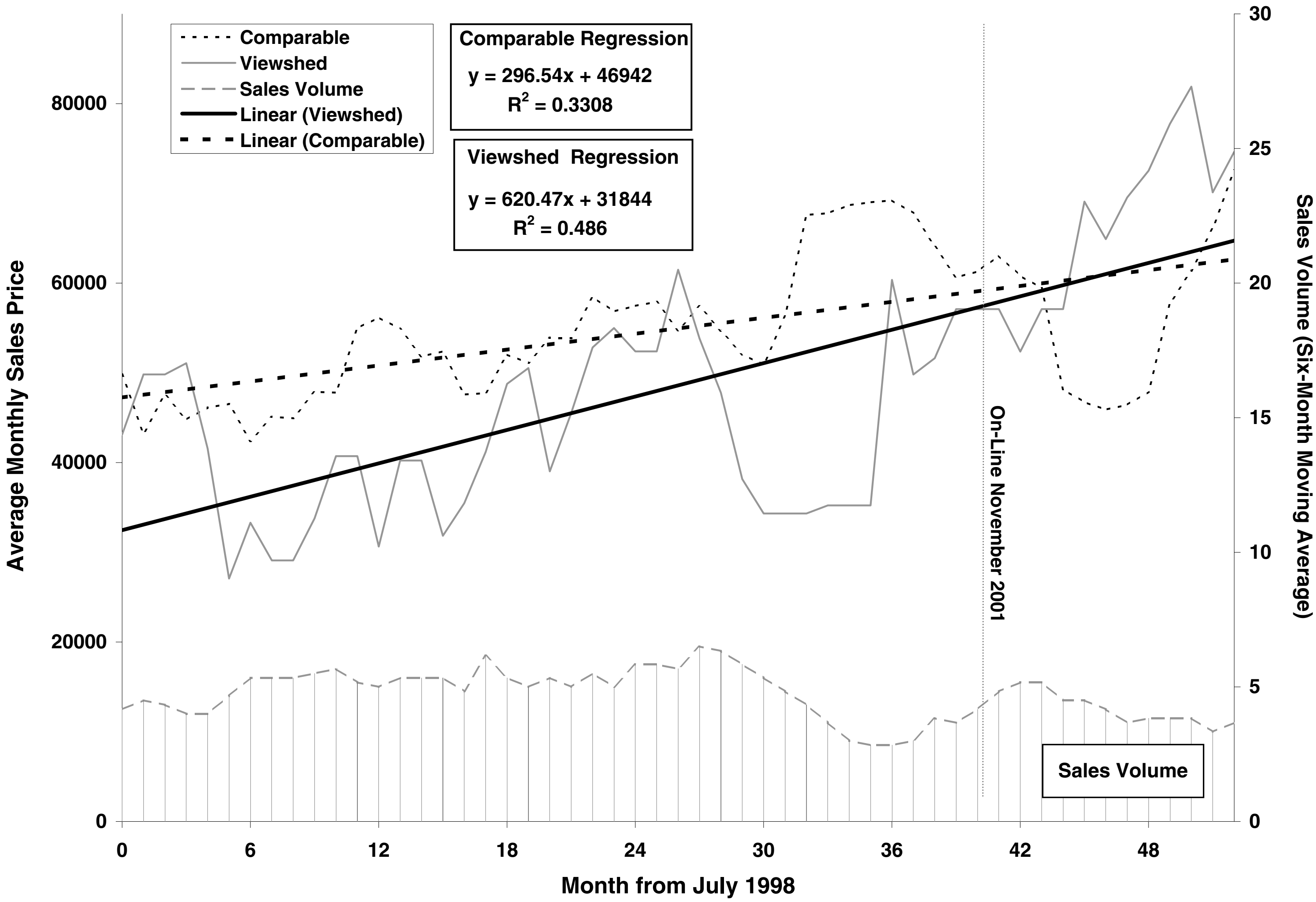


Figure 3.4 Average Residential Housing Sales Price

Carson County, Texas 1998-2002

D. Additional Interviewee Comments

Carson County officers Mike Darnell, appraisal district office, and Barbara Cosper, tax office, said most of the land in the view shed were farms, and that most residents in White Deer worked on the farms. Therefore, White Deer residents' interest in housing values was wholly dependent on their proximity to farms with no concern for the wind towers, she said. Darnell added that most residents in White Deer liked the turbines because they brought new jobs to the area, and there has been no talk of discontent with the turbines.

The county's main claim to fame is it's the home of Pantex; the only nuclear armament production and disassembly facility in the U.S., according to Department of Energy's www.pantex.com website.

Site Report 4: Bennington County, Vermont

A. Project Description

One mile due south of Searsburg, atop a ridge, stand 11 turbines with 40-meter (131 foot) hub heights in a line running north-south. The solid, white, conical towers rise well above dense woods, but the black painted blades are virtually invisible – especially when in motion. The site is in Bennington County less than a mile west of Windham County, and is midway between the two medium-size towns of Bennington and Brattleboro.

The area is defined as a non-metro area adjacent to a metro area, though not completely rural and with a population between 2,500 and 19,999. See Appendix 1 for a definition of rural urban continuum codes. The view shed has a population of fewer than 4,000.

Figure 4.1 Searsburg wind project turbines
Photo courtesy Vermont Environmental Research Associates, 2002. www.northeastwind.com

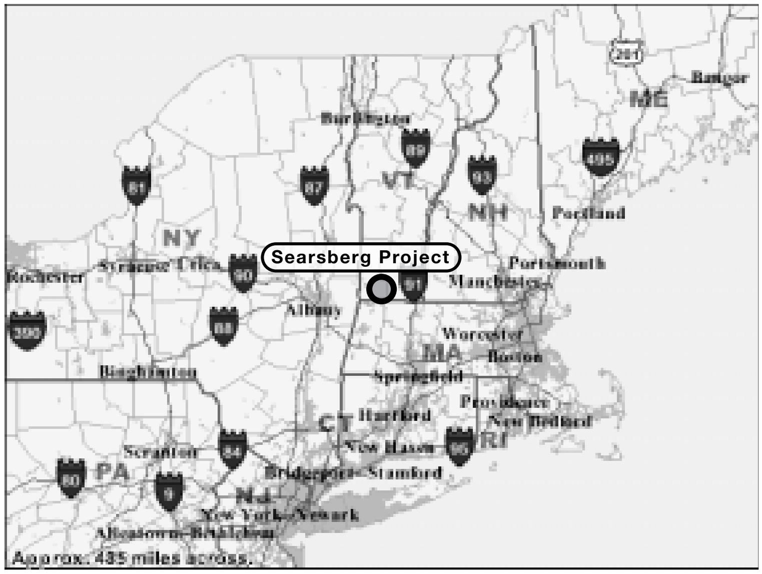


Figure 4.2 The Searsburg wind project is located in Southern Vermont
Base map image source: U.S. Census Bureau

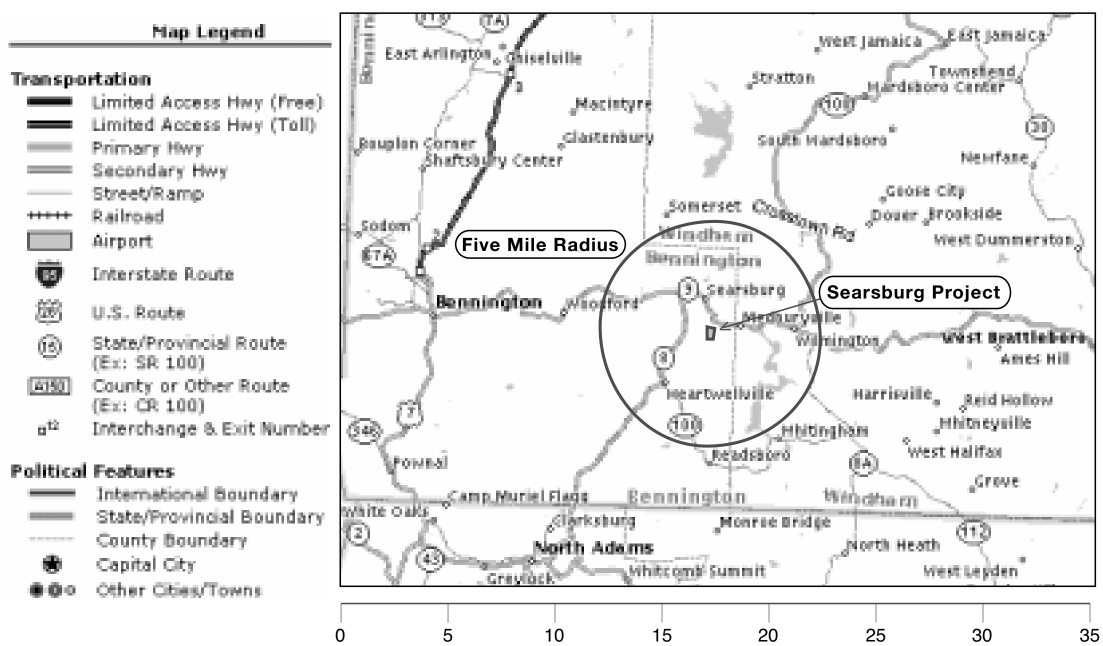


Figure 4.3. Searsburg, Vermont area View shed
Location Source: Vermont Environmental Associates

Base Map Source: MapQuest.com

B. Project Timeline

Table 4.1 Wind Project History, Bennington County, VT

Project Name	Completion Date	Capacity (MW)
Searsburg	1997	6

C. Analysis

i. Data

Real property sales data for 1994 to 2002 was purchased in electronic form from Phil Dodd of VermontProperty.com in Montpelier, VT. Sales data was purchased for the townships and cities encompassing the wind farm area and surrounding communities, and was provided in two separate datasets. The first dataset, covering years 1994 through 1998, contained only annual average property sale prices and sales volumes, by town. No other locational data or property attributes were included. Property types from this dataset used in the analysis are primary residences and vacation homes, accounting for 1,584 sales.

The second dataset, contained information on individual property sales from May 1998 through October 2002, and accounted for 2,333 sales. The unit of analysis for the second dataset is towns. Some street addresses were included in the property descriptions, but many of these were only partial addresses. Property types from this dataset used in the analysis are primary homes, primary condominiums, vacation condominiums, and camp or vacation homes. The Searsburg wind farm went on-line in February 1997, with a capacity of 6 MW, during the time when only annually averaged sales data was available.

ii. View Shed Definition

The view shed is defined by a five-mile radius around the wind farm, and encompasses four incorporated towns: Searsburg in Bennington county, and Dover, Somerset, and Wilmington in Windham County. Interviews with the State of Vermont Windham County Listers Office were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. According to Newfane town Lister Doris Knechtel, approximately 10 percent of the Searsburg homes can see the wind farm. Listers were unable to estimate what percentage of properties could see the wind farms in the other view shed towns. The final view shed dataset contained 1,055 sales from 1994 to 1998 and 1,733 sales for 1999 to 2002, for a total of 2,788 sales.

iii. Comparable Selection

The comparable community was selected through interviews with Phil Dodd of VermontProperty.com, interviews with State of Vermont Listers, as well as analysis of demographic data from the 1990 and 2000 U.S. Census for communities near but outside of the view shed. Tables 4.2 and 4.3 summarize the census data reviewed. In order to determine the most appropriate comparable community, we looked at the demographics of seven surrounding areas. Upon examination of Census data, sales data availability, and review of interview comments, Newfane and Whitingham in Windham County were selected as the comparable. The final comparable dataset contained 288 sales from 1994 to 1998 and 264 sales for 1999 to 2002, for a total of 552 sales from 1994 to 2002.

iv. Analytical Results and Discussion

In all three of the regression models, monthly average sales prices grew faster in the view shed than in the comparable area, indicating that there is no significant evidence that the presence of the wind farms had a negative effect on residential property values.

Table 4.2 Bennington and Windham Counties, Vermont: 1990 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
1990	Y	Searsburg village, Bennington Cty.	85	$26,875	9%	92	$61,500
1990	Y	Dover village, Windham Cty.	994	$30,966	7%	2450	$103,000
1990	Y	Wilmington village, Windham Cty.	1,968	$27,335	6%	2,176	$110,600
1990	VIEW SHED DEMOGRAPHICS		3,047	$28,392	7%	4,718	$91,700
1990	COMP	Newfane town, Windham Cty.	1,555	$31,935	7%	974	$103,000
1990	COMP	Whitingham village, Windham Cty.	1,177	$28,580	8%	737	$88,500
1990	COMPARABLE DEMOGRAPHICS		2,732	$30,258	8%	1,711	$95,750
1990	N	Halifax village, Windham Cty.	588	$23,750	15%	473	$81,600
1990	N	Readsboro village, Bennington Cty.	762	$25,913	12%	478	$65,400
1990	N	Stratton village, Windham Cty.	121	$31,369	2%	864	$162,500
1990	N	Woodford village, Bennington Cty.	331	$24,118	18%	267	$75,000
1990	N	Marlboro village, Windham Cty.	924	$29,926	10%	474	$103,300

Table 4.3 Bennington and Windham Counties, Vermont: 2000 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
2000	Y	Searsburg village, Bennington Cty.	114	$17,500	18%	65	$86,700
2000	Y	Dover village, Windham Cty.	1410	$43,824	10%	2749	$143,300
2000	Y	Wilmington village, Windham Cty.	2,225	$37,396	9%	2,232	$120,100
2000	VIEW SHED DEMOGRAPHICS		3,749	$32,907	12%	5,046	$116,700
2000	COMP	Newfane town, Windham Cty.	1,680	$45,735	5%	977	$123,600
2000	COMP	Whitingham village, Windham Cty.	1,298	$37,434	8%	802	$111,200
2000	COMPARABLE DEMOGRAPHICS		2,978	$41,585	6%	1,779	$117,400
2000	N	Halifax village, Windham Cty.	782	$36,458	16%	493	$98,800
2000	N	Readsboro village, Bennington Cty.	803	$35,000	7%	464	$78,600
2000	N	Stratton village, Windham Cty.	136	$39,688	5%	1,091	$125,000
2000	N	Woodford village, Bennington Cty.	397	$33,929	17%	355	$91,300
2000	N	Marlboro village, Windham Cty.	963	$41,429	4%	495	$150,000

In Case I, the monthly sales price change in the view shed is 62 percent greater than the monthly sales price change of the comparable over the study period. The Case I model provides a reasonable fit to the view shed data, with 70 percent of the variance in the data for the view shed and 45 percent of the variance in the data for the comparable explained by the linear regression. In Case II, sales prices decreased in the view shed prior to the on-line date, and increased after the on-line date. The average view shed sales price after the on-line date increased at 2.6 times the rate of decrease in the view shed before the on-line date. The Case II model provides a good fit to the data, with 71 percent of the variance in the data for the view shed after the on-line date and 88 percent of the variance in the data before the on-line date explained by the linear regression. In Case III, average view shed sales prices after the on-line date are 18 percent greater than in the comparable. The Case III model describes over 70 percent of the variance in the data. The data for the full study period is graphed in Figure 4.4, and regression results for all cases are summarized in Table 4.4 below.

D. Additional Interviewee Comments

Newfane town Lister[1] Doris Knechtel said the area has a wide cross section of home values, styles, and uses (permanent residential and vacation homes). The other primary community in the view shed was Wilmington, which Knechtel said was a resort destination with more turnover than Searsburg.

Table 4.4 Regression Results, Bennington and Windham Counties, VT
Project: Searsburg

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 94 - Oct 02 Jan 94 - Oct 02	$536.41 $330.81	0.70 0.45	The rate of change in average view shed sales price is 62% greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 94 - Jan 97 Feb 97 - Oct 02	-$301.52 $771.06	0.88 0.71	The rate of change in average view shed sales price after the on-line date increased at 2.6 times the rate of decrease before the on-line date.
Case 3	View shed, after Comparable, after	Feb 97 - Oct 02 Feb 97 - Oct 02	$771.06 $655.20	0.71 0.78	The rate of change in average view shed sales price after the on-line date is 18% greater than the rate of change of the comparable after the on-line date.

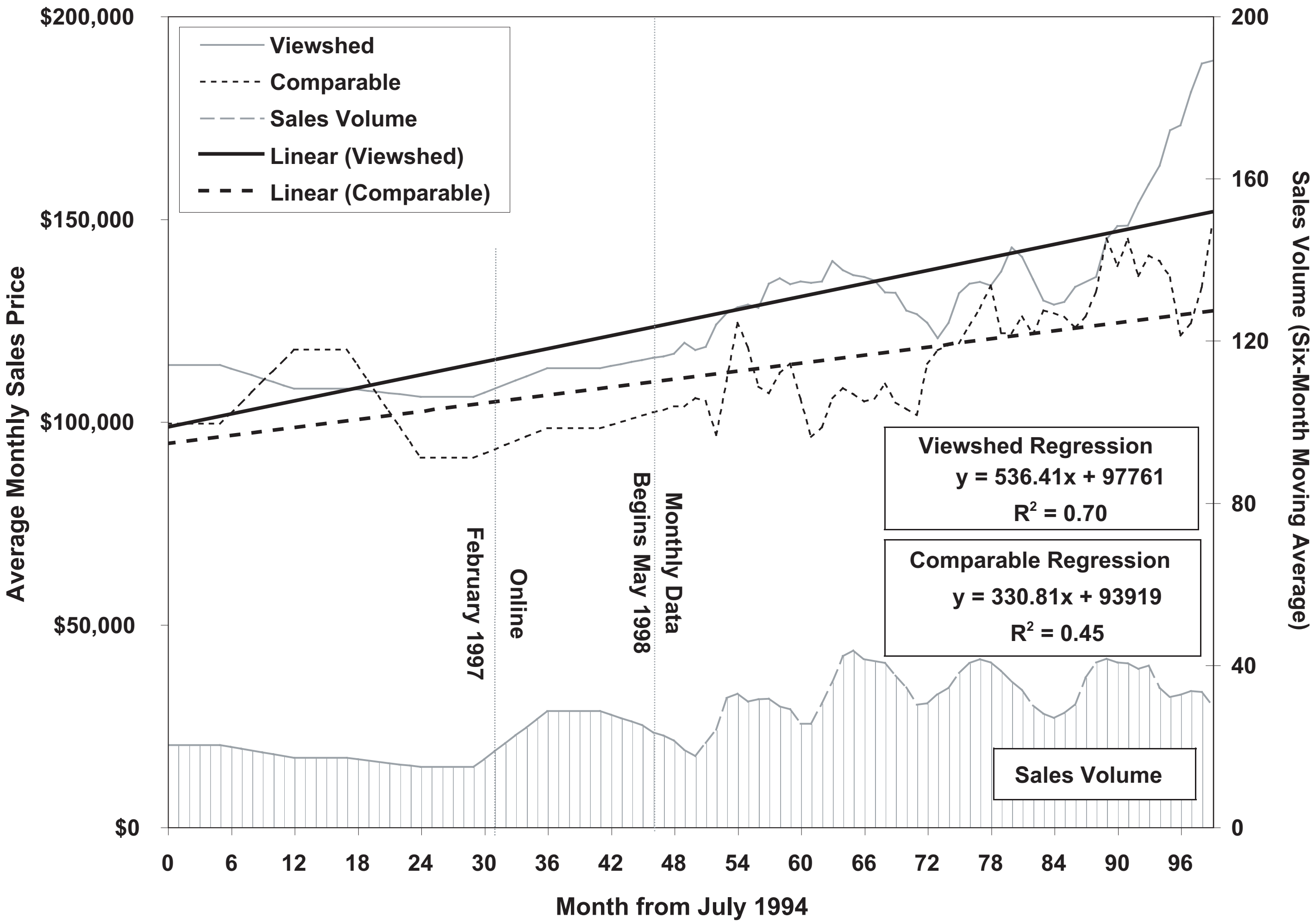


Figure 4.4 Average Residential Housing Sales Price
Bennington and Windham Counties, Vermont 1994-2002

1 Vermont property assessors are organized differently from any other state researched for this analysis. Assessors are called "listers" and operate per town – not on a township or county level. With small tax regions to support officials, local town offices are infrequently available, and in many cases neither had answering machines nor computers. The county government office confirmed that many Vermont offices didn't have computers, but were in the process of receiving them as of October 2002.

Site Report 5: Kewaunee County, Wisconsin

A. Project Description

The regional topography has slight elevation changes with some rolling hills, but is mostly cleared agricultural land with intermittent groves. The two major wind farm projects occupy three sites that are all within five miles of each other, two in Lincoln Township and one in Red River Township. There are several small communities in Red River and Lincoln Townships that primarily work the agricultural lands.

The projects, installed in 1999, consist of 31 turbines with hub heights of 65 meters (213 feet). The nearest incorporated towns are Algoma to the east, Kewaunee to the southeast, and Luxemburg to the southwest. The wind farms are roughly 15 miles from the center of the Green Bay metropolitan area, and 10 miles from the outer edges of the city. The area is defined as a non-metro area adjacent to a metro area, though not completely rural and with a population between 2,500 and 19,999. See Appendix 1 for a definition of rural urban continuum codes. The view shed has a population of approximately 3,000.

Figure 5.1 Wind Projects in Red River and Lincoln Townships

Photo Courtesy Wisconsin Public Service Corporation

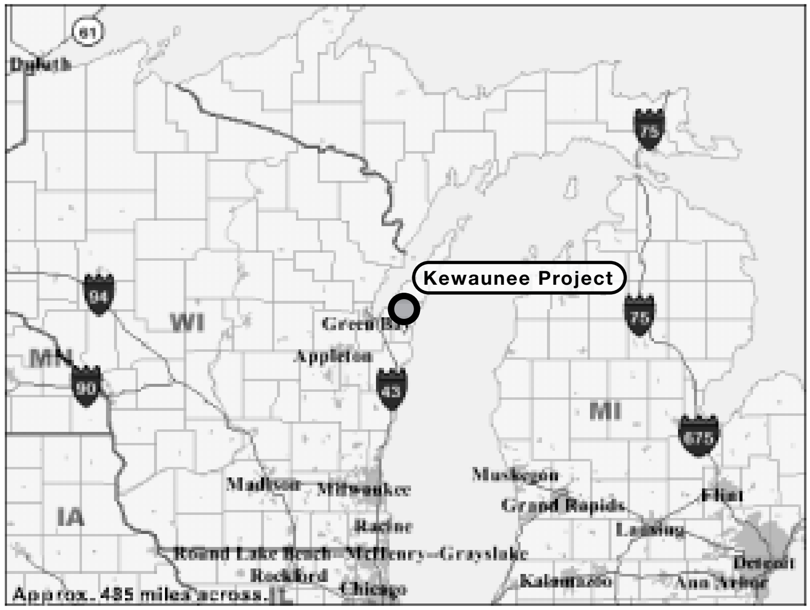


Figure 5.2 Location of Kewaunee County wind projects

Base map image source: U.S. Census Bureau

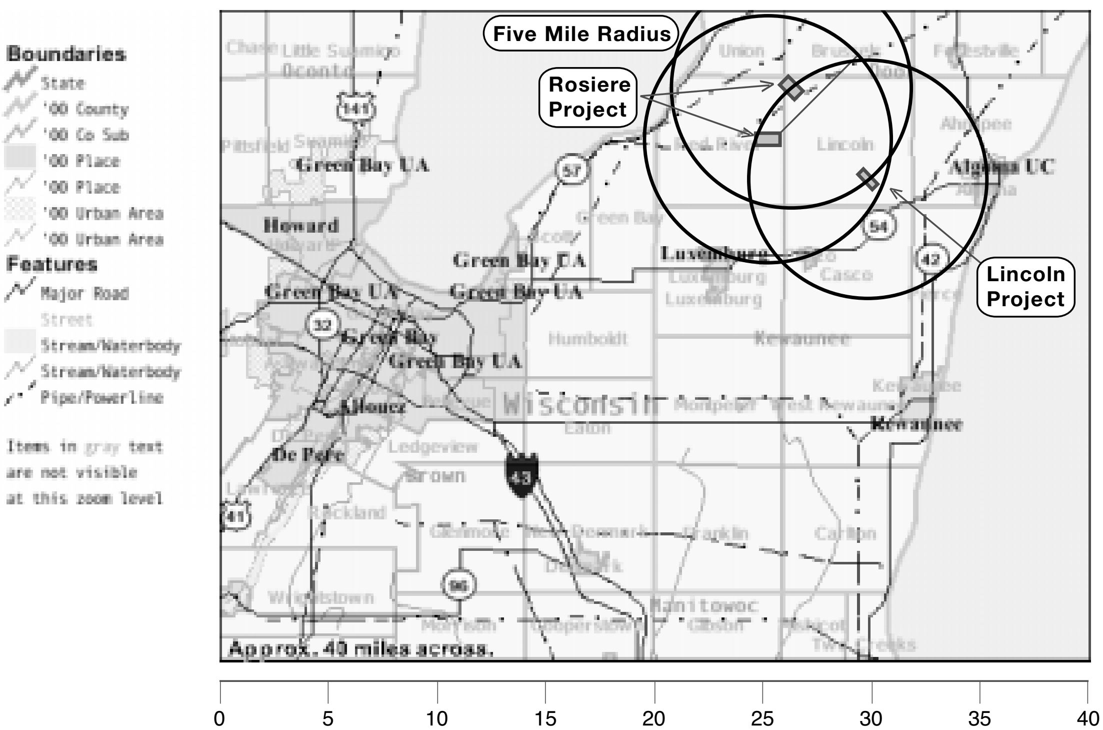


Figure 5.3. Kewaunee County View shed

Location Source: Kewaunee County Assessors Office

Base Map Source: U.S. Census Bureau

B. Project Timeline

Table 5.4 Wind Project History, Kewaunee County, WI

Project Name	Completion Date	Capacity (MW)
Lincoln (Gregorville, Lincoln Township)	1999	9.2
Rosiere (Lincoln and Red River Townships)	1999	11.2

C. Analysis

i. Data

Real property sales data for 1996 to 2002 was purchased in paper and electronic form from the State of Wisconsin Department of Revenue Bureau of Equalization Green Bay Office. Sales data was obtained for the townships and cities encompassing the wind farm area and surrounding communities, and was provided in two separate datasets. The first dataset consisted of paper copy of Detailed Sales Studies for residential properties from 1994 to 1999. These contained individual property sales by month, year, and township or district. Parcel numbers were included, but no other locational data or property attributes were available. The second dataset consisted of electronic files containing residential property sales data for 2000 to 2002. This dataset contained no detailed property attributes, and only partial street addresses. The units of analysis for the combined dataset are townships and villages. After discussion with the Property Assessment Specialist, three unusually high value sales were removed from the view shed dataset. The final dataset included 624 sales from 1996 to 2002.

The Lincoln wind farm near Gregorville and the Rosiere wind farm on the Lincoln/Red River Township Border both went on-line June 1999, with capacities of 9.2 MW and 11.2 MW, respectively.

ii. View Shed Definition

The view shed is defined by a five-mile radius around the wind farms. Because the view sheds of the individual wind farm sites overlap, and because all wind farms went on-line at the same time, a single view shed was defined. It encompasses all of Lincoln and Red River Townships, and the incorporated town of Casco in Casco Township. To assist in the view shed definition, detailed Plat maps for Lincoln and Red River Townships were obtained from the State of Wisconsin Bureau of Equalization Green Bay Office. These maps indicated every block and parcel in each township, and provided a one square mile grid to allow distance measurements. The location of each wind farm was marked on the map by the Bureau, and detailed aerial photos of each wind farm were also provided. This information allowed concise definition of the view shed area. Because only portions of Ahnapee, Luxemborg, and Casco Townships are in the view shed, these townships were excluded from consideration for either the view shed or comparable. The final view shed dataset contained 329 sales from 1996 to 2002.

Interviews with Kewaunee County Assessors were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. Assessor Dave Dorschner said 20 to 25 percent of Red River Township properties have views of the turbines. No one interviewed was able to estimate the percentage of properties in Lincoln Township or Casco Village with a view of the wind farms.

iii. Comparable Selection

The comparable community was selected through interviews with James W. Green, Bureau of Equalization Property Assessment Specialist, and analysis of demographic data from the 1990 and 2000 U.S. Census for communities near but outside of the view shed. Tables 5.2 and 5.3 summarize the Census data reviewed. In order to determine the most appropriate comparable community, we looked at the demographics of eight surrounding areas. Upon examination of Census data, sales data availability, and review of interview comments, Carlton, Montpelier, and West Kewaunee Townships were selected as the comparable. The final comparable dataset contained 295 sales from 1996 to 2002.

Table 5.2 Kewaunee County, Wisconsin: 1999 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
1990	Y	Casco village	544	$25,313	6%	223	$54,200
1990	Y	Lincoln town	996	$28,958	7%	338	$44,800
1990	Y	Red River town	1,407	$32,614	3%	552	$60,600
VIEW SHED DEMOGRAPHICS			2,947	$28,962	6%	1,113	$53,200
1990	COMP	Carlton town	1,041	$30,385	8%	383	$42,600
1990	COMP	Montpelier town	1,369	$31,600	8%	457	$61,300
1990	COMP	West Kewaunee town	1,215	$31,094	8%	451	$51,300
COMPARABLE DEMOGRAPHICS			3,625	$31,026	8%	1,291	$51,733
1990	N	Ahnapee town	941	$26,850	7%	406	$47,500
1990	N	Algoma City	3,353	$21,393	8%	1,564	$44,000
1990	N	Casco town	1,010	$33,807	4%	344	$57,200
1990	N	Franklin town	990	$32,625	14%	360	$53,300
1990	N	Kewaunee City	2,750	$22,500	14%	1,213	$46,600
1990	N	Luxemburg town	1,387	$35,125	5%	424	$60,600
1990	N	Luxemburg village	1,151	$24,702	6%	460	$58,200
1990	N	Pierce town	724	$25,812	12%	369	$60,400

Table 5.3 Kewaunee County, Wisconsin: 2000 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
2000	Y	Casco village	572	$44,583	4%	236	$88,700
2000	Y	Lincoln town	957	$42,188	9%	346	$100,000
2000	Y	Red River town	1,476	$47,833	6%	601	$117,900
VIEW SHED DEMOGRAPHICS			3,005	$44,868	6%	1,183	$102,200
2000	COMP	Carlton town	1,000	$50,227	3%	383	$98,900
2000	COMP	Montpelier town	1,371	$51,000	4%	492	$112,000
2000	COMP	West Kewaunee town	1,287	$47,059	6%	485	$101,300
COMPARABLE DEMOGRAPHICS			3,658	$49,429	4%	1,360	$104,067
2000	N	Ahnapee town	977	$47,500	3%	426	$95,200
2000	N	Algoma City	3,357	$35,029	5%	1,632	$74,500
2000	N	Casco town	1,153	$46,250	4%	404	$107,800
2000	N	Franklin town	997	$52,019	2%	359	$114,900
2000	N	Kewaunee City	2,806	$36,420	11%	1,237	$79,700
2000	N	Luxemburg town	1,402	$54,875	1%	459	$121,600
2000	N	Luxemburg village	1,935	$45,000	6%	754	$105,100
2000	N	Pierce town	897	$43,000	15%	407	$98,900

iv. Analytical Results and Discussion

In all three of the regression models, monthly average sales prices grew faster in the view shed than in the comparable area, indicating that there is no significant evidence that the presence of the wind farms had a negative effect on residential property values. However, the fit of the linear regression is poor for all cases analyzed. Very low sales volumes, averaging 3.6 sales per month from 1996 to 1999, lead to large fluctuations in average sales prices from individual property sales. This contributes to the low R2 values.

In Case I, the monthly sales price change in the view shed is 3.7 times the monthly sales price change of the comparable over the study period. However, the Case I model provides a poor fit to the view shed data, with 26 percent and 5 percent of the variance in the data explained by the linear regression in the view shed and comparable, respectively. In Case II, sales prices decreased in the view shed prior to the on-line date, and increased after the on-line date. The average view shed sales price after the on-line date increased at 3.5 times the rate of decrease in the view shed before the on-line date. The Case II model provides a poor fit to the data, with 32 percent of the variance in the data for the view shed after the on-line date and 2 percent of the variance in the data before the on-line date explained by the linear regression. In Case III, average monthly sales prices increase in the view shed after the on-line date, but decrease in the comparable region. The average view shed sales price after the on-line date increases 33 percent quicker than the comparable sales price decreases after the on-line date. The Case III model describes approximately a third of the variance in the data. The data for the full study period is graphed in Figure 5.4, and regression results for all cases are summarized in Table 5.4 below.

Table 5.4 Regression Results, Kewaunee County, WI
Projects: Red River (Rosiere), Lincoln (Rosiere), Lincoln (Gregorville)

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 96 - Sep 02 Jan 96 - Sep 02	$434.48 $118.18	0.26 0.05	The rate of change in average view shed sales price is 3.7 times greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 96 - May 99 Jun 99 - Sep 02	-$238.67 $840.03	0.02 0.32	The increase in average view shed sales price after the on-line date is 3.5 times the decrease in view shed sales price before the on-line date.
Case 3	View shed, after Comparable, after	Jun 99 - Sep 02 Jun 99 - Sep 02	$840.03 -$630.10	0.32 0.37	The average view shed sales price after the on-line date increases 33% quicker than the comparable sales price decreases after the on-line date.

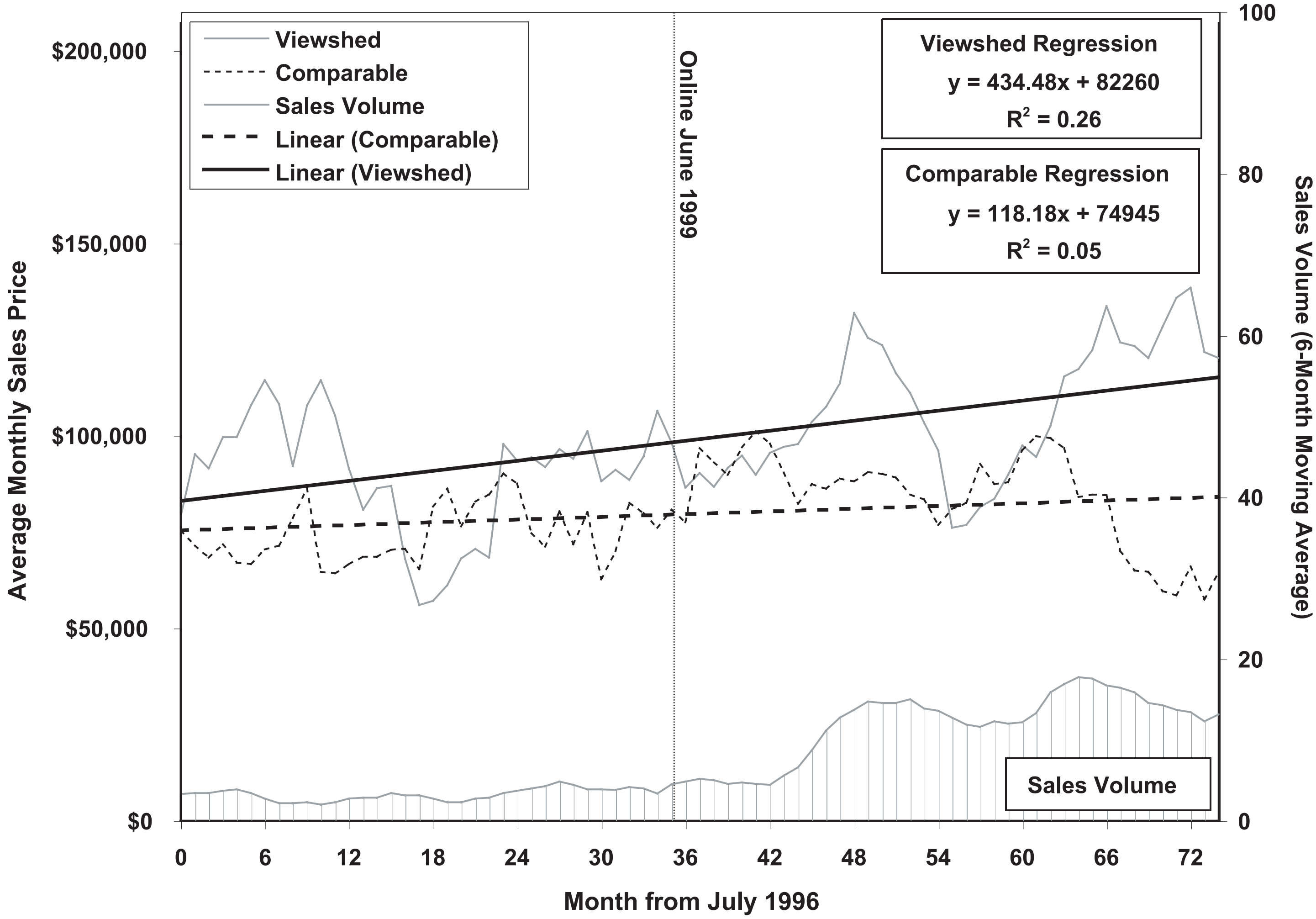


Figure 5.4 Average Residential Housing Sales Price

Kewaunee County, Wisconsin 1996-2002

D. Additional Interviewee Comments

Assessor Dave Dorschner said he has not seen an impact on property values except for those immediately neighboring the project sites. In the cases of neighboring property, he said some homes were sold because of visual and/or auditory distraction, but some of the properties were purchased speculatively in hope that a tower might be built on the property.

James W. Green, Wis. Bureau of Equalization property assessment specialist, also said he has not seen any impact of the turbines on property values. He added that he has seen greater property value increases in the rural areas than in the city because people were moving out of the Green Bay area opting for rural developments or old farmhouses.

Site Report 6: Somerset County, Pennsylvania

A. Project Description

There are two major wind farms in Somerset County, Somerset and Green Mountain. They are about 20 miles due east of the wind farm in Fayette County, PA. The Somerset project has six turbines 64 meters (210 feet) high along a ridge crest east Somerset town. The Green Mountain project has eight turbines at 60 meters (197 feet). They are about 10 miles southwest of the Somerset project, and a mile west of Garret town.

The area is almost the same as Fayette County, but slightly less hilly – dense populations of tall trees, frequent overcast, and primarily rural development. The area is classified as a "county in a metro area with fewer than 250,000." See Appendix 1 for a definition of rural urban continuum codes. The view shed has a population of approximately 19,000.

Figure 6.1 Somerset wind tower

Photo courtesy GE Wind Energy © 2002

Figure 6.2 General location of Somerset and Fayette County wind projects
Base map image source: U.S. Census Bureau

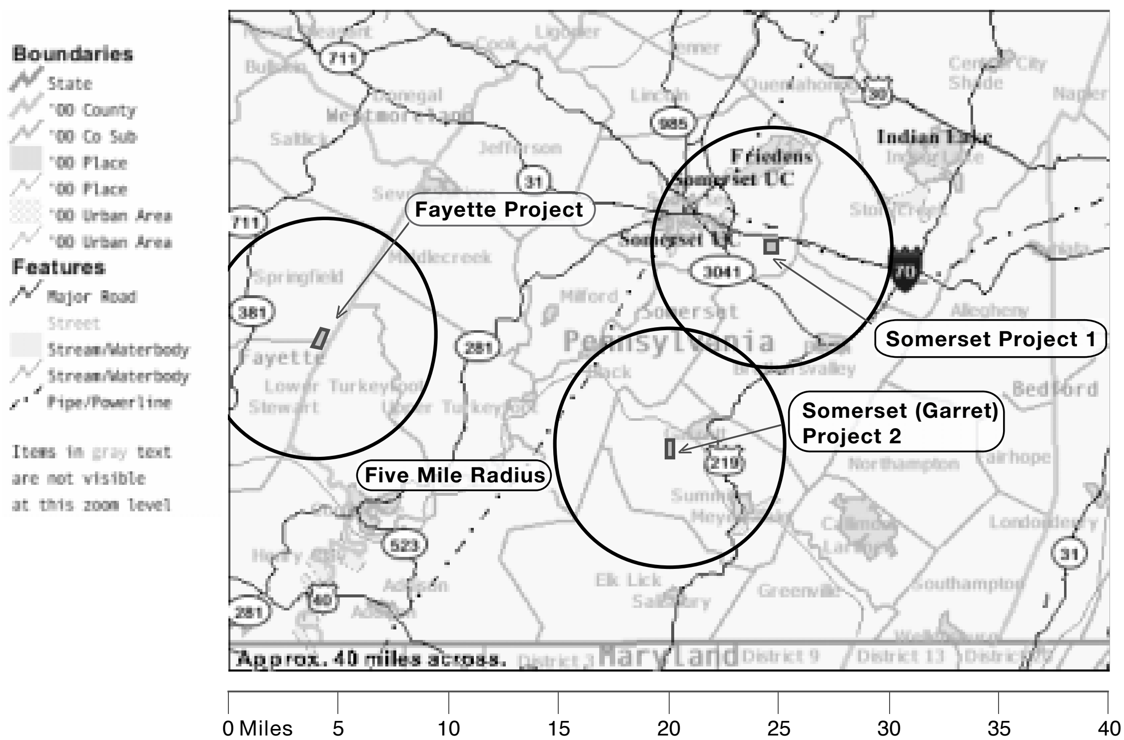


Figure 6.3. Somerset County, Pennsylvania View shed
Location Source: Somerset County Assessors office

Base Map Source: U.S. Census Bureau

B. Project Timeline

Table 6.1 Wind Project History, Somerset County, PA

Project Name	Completion Date	Capacity (MW)
Somerset	2001	9.0
Green Mountain Wind Farm	2000	10.4

C. Analysis

i. Data

Real property sales data for 1997 to 2002 was obtained in electronic form from the State of Pennsylvania Somerset County Assessment Office in Somerset, PA. Sales data was obtained for the townships and cities encompassing the wind farm area and surrounding communities. The electronic files contain residential property sales data for 2000 to 2002. Residential types included in the analysis are homes, homes converted to apartments, mobile homes with land, condominiums, townhouses, and one mobile home on leased land. The dataset contained lot acreages and brief building descriptions, and some, but not all, records provided additional property attributes. As street addresses were not provided, the units of analysis for the dataset are townships and villages. The final dataset included 1,506 residential property sales from 1997 to 2002.

The Somerset wind farm went on-line October 2001 and the Green Mountain wind farm near Garrett went on-line May 2000, with capacities of 9.0 MW and 10.4 MW, respectively.

ii. View Shed Definition

The view shed is defined by a five-mile radius around the wind farms. Because the view sheds of the individual wind farm sites overlap, a single view shed was defined. It encompasses all of Somerset and Summit Townships, and the Garrett and Somerset Boroughs within these townships. Locational data for the wind farms was obtained from utility and wind industry web sites, and used in conjunction with maps and interviews with the Somerset County Mapping Department to identify the exact location and extent of the wind farms and view shed. Townships only partially within the view shed were excluded from consideration for either the view shed or comparable. The final view shed dataset contains 962 sales from 1997 to 2002.

Interviews with Somerset County Assessors were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. In Assessor Hudack's opinion, 10 percent of Somerset properties can see the turbines, and roughly 20 percent of Garrett properties have a view.

iii. Comparable Selection

The comparable community was selected through interviews with Assessors John Riley and Joe Hudack of the State of Pennsylvania Somerset County Assessment Office, and analysis of demographic data from the 1990 and 2000 U.S. Census for communities near but outside of the view shed. Tables 6.2 and 6.3 summarize the Census data reviewed. In order to determine the most appropriate comparable community we looked at the demographics of three surrounding areas. Upon examination of Census data, sales data availability, and review of interview comments, Conemaugh Township was selected as the comparable. The final comparable dataset contained 422 sales from 1997 to 2002.

iv. Analytical Results and Discussion

In all three of the regression models, monthly average sales prices grew faster in the view shed than in the comparable area, indicating that there is no significant evidence that the presence of the wind farms had a negative effect on residential property values.

In Case I, the monthly sales price change in the view shed is 90 percent greater than the monthly sales price change of the comparable over the study period. The Case I model provides a poor fit to the view shed data, with 30 percent of the variance in the data for the view shed and 7 percent of the variance in the data for the comparable explained by the linear regression. In Case II, the monthly sales price change in the view shed is 3.5 times greater after the on-line date than before the on-line date. The Case II model provides a poor fit to the data prior to the on-line date, with 37 percent, of the variance in the data explained by the linear regression, but a reasonable fit after the on-line date, with 62 percent of the variance explained. In Case III, average monthly sales prices increase in the view shed after the on-line date, but decrease in the comparable region. The average view shed sales price after the on-line date increased at 2.3 times the rate of decrease in the comparable after the on-line date. The Case III model describes 62 percent of the variance in the view shed, but only 23 percent of the variance in the comparable. The data for the full study period is graphed in Figure 6.4, and regression results for all cases are summarized in Table 6.4 below.

Table 6.2 Somerset County, Pennsylvania: 1990 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
1990	Y	Garrett Borough	520	$16,071	26%	218	$27,100
1990	Y	Somerset Borough	6,454	$19,764	18%	3,100	$58,800
1990	Y	Somerset Twsp	8,732	$25,631	10%	3,296	$57,100
1990	Y	Summit Twsp	2,495	$22,868	17%	942	$40,800
VIEW SHED DEMOGRAPHICS			18,201	$21,084	18%	7,556	$45,950
1990	COMP	Conemaugh Twsp	7,737	$25,025	8%	3,070	$43,100
COMPARABLE DEMOGRAPHICS			7,737	$25,025	8%	3,070	$43,100
1990	N	Boswell Borough	1,485	$16,128	29%	670	$39,700
1990	N	Milford Twsp	1,544	$24,821	9%	666	$47,400

Table 6.3 Somerset County, Pennsylvania: 2000 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
2000	Y	Garrett Borough	449	$24,609	16%	180	$38,600
2000	Y	Somerset Borough	6,762	$29,050	12%	3,313	$87,200
2000	Y	Somerset Twsp	9,319	$33,391	9%	3,699	$76,300
2000	Y	Summit Twsp	2,368	$32,115	17%	930	$67,700
VIEW SHED DEMOGRAPHICS			18,898	$29,791	13%	8,122	$67,450
2000	COMP	Conemaugh Twsp	7,452	$30,530	7%	3,089	$61,800
COMPARABLE DEMOGRAPHICS			7,452	$30,530	7%	3,089	$61,800
2000	N	Boswell Borough	1,364	$20,875	29%	681	$54,000
2000	N	Milford Twsp	1,561	$34,458	14%	658	$75,300

Table 6.4 Regression Results, Somerset County, PA
Projects: Somerset, Green Mountain

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 97 - Oct 02 Jan 97 - Oct 02	$190.07 $100.06	0.30 0.07	The rate of change in average view shed sales price is 90% greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 97 - Apr 00 May 00 - Oct 02	$277.99 $969.59	0.37 0.62	The rate of change in average view shed sales price after the on-line date is 3.5 times greater than the rate of change before the on-line date.
Case 3	View shed, after Comparable, after	May 00 - Oct 02 May 00 - Oct 02	$969.59 -$418.73	0.62 0.23	The rate of change in average view shed sales price after the on-line date increased at 2.3 times the rate of decrease in the comparable after the on-line date.

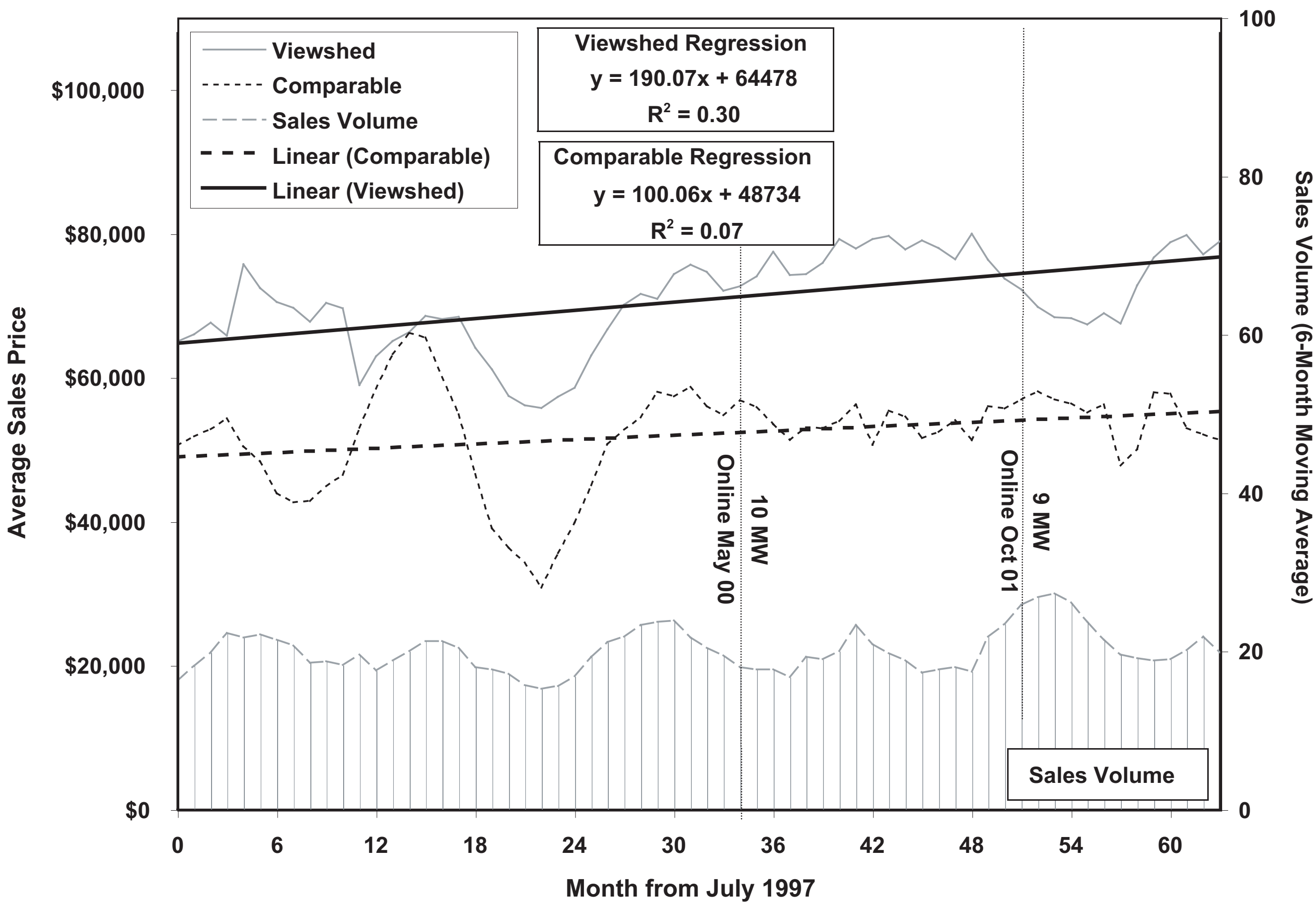


Figure 6.4 Average Residential Housing Sales Price
Somerset County, Pennsylvania 1997-2002

D. Additional Interviewee Comments

Assessor Joe Hudack said he has not seen any impact on property values from wind farms. The turbines outside Somerset were also "not glaring," but could be seen from the PA Turnpike. The Green Mountain turbines outside Garret were noticeable, but because there were so few people residing there, he hasn't seen much housing turnover to base an opinion, he said.

Site Report 7:
Buena Vista County, Iowa

A. Project Description

The geography of the view shed and comparable regions is flat with minimal elevation changes. The region is mostly cleared land for agricultural production, with trees along irrigation ditches or planted around homes for shade and wind dampening.

Figure 7.1 750 kW Zond wind turbines 1.5 miles east of Alta, Iowa
Photo Courtesy: Waverly Light and Power © 2002

Surrounding Alta, Iowa and west of the town along the Buena Vista and Cherokee counties' border, 257 towers with 63 meter [207 ft] hub heights stand among agricultural farms and scattered homes. Project Storm Lake I comprises 150 towers around Alta extending 1.5-2.5 miles east and west, 1.5 miles south, and five miles north. Throughout the project, the turbines are consistently spaced 3.6 rotor diameters, or about 180 m (590 ft) apart. Project Storm Lake II comprises 107 towers, eight miles northwest of Alta, with several towers over the county border into neighboring Cherokee County. The exact location of all turbines was obtained from the Waverly Power and Light website. All towers have white color blades and hubs with either grey, trussed towers or white solid towers. Solid red lights are required by the FAA on the nacelles of alternate turbines.

Buena Vista County is classified as an "urban population with 2,500 to 19,999 not adjacent to a metro area." See Appendix 1 for a definition of rural urban continuum codes. This analysis defines two possible view sheds, depending on whether Storm Lake City is included in the analysis. Accordingly, the view shed has a population of either 4,000 or 14,000, depending on its definition.

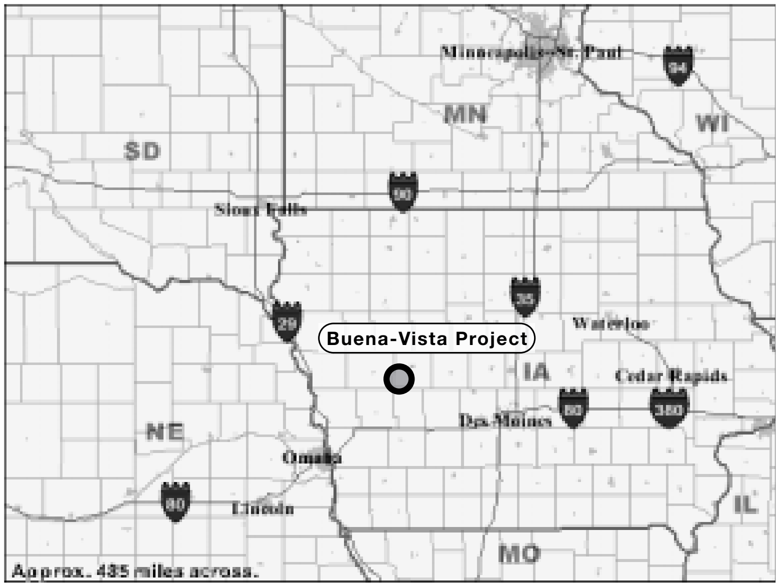


Figure 7.2 Regional Wind Project Location
(Dot approximate wind farm locations)

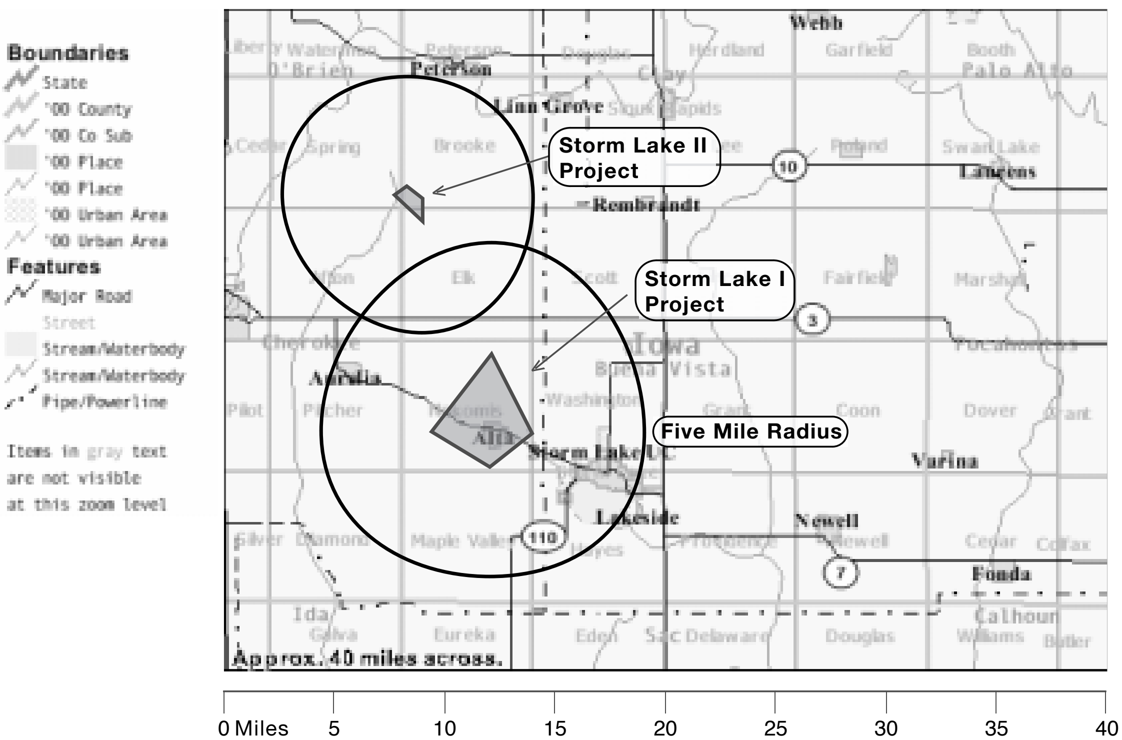


Figure 7.3. Buena-Vista, County, Iowa View shed
Location Source: Buena-Vista County Assessors Office

Base Map Source: U.S. Census Bureau

B. Project Timeline

Table 7.1 Wind Project History, Somerset County, PA

Project Name	Completion Date	Capacity (MW)
Storm Lake I	1999	112.5
Storm Lake II	1999	80.2

C. Analysis

i. Data

Real property sales data for 1996 to 2002 was obtained in electronic form from the Iowa State Assessors Office Website at www.iowaassessors.com. Sales data was obtained for the townships and cities encompassing the wind farm area and surrounding communities. The electronic data gathered contains residential property sales prices, parcel numbers, street addresses, year built and square footage. The unit of analysis for this dataset is defined by either township or incorporated city boundaries. Though street addresses are included in the dataset, this analysis lacked the resources to identify the location of properties by street address. The final dataset included 3,213 residential property sales from 1996 to 2002.

The Storm Lake II wind farm went on-line June 1999 and the Storm Lake I wind farm went on-line May 1999, with capacities of 112.5 MW and 80.2 MW, respectively.

ii. View Shed Definition

The view shed is defined by a five-mile radius around the wind farms. Because the view sheds of the individual wind farm sites overlap, and the on-line dates are within a month of each other, a single view shed was defined. Locational data for the wind farms was obtained from utility and wind industry web sites, and used in conjunction with maps and phone interviews to identify the exact location and extent of the wind farms and view shed. Townships only partially within the view shed were excluded from consideration for either the view shed or comparable.

Interviews with Somerset County Assessors were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. In Buena Vista County Assessor Ted Van Groteest's opinion, 100 percent of the properties in Alta have views of turbines, 75 percent of Nokomis Township have views, and five to 10 percent of Storm Lake City properties have views. However, he estimated that all the waterfront properties on the southeast side of Storm Lake can see turbines when looking northwest. Storm Lake City has a population of approximately 10,000, while Nokomis Township and Alta City have a combined population of approximately 2,000.

This report examines two cases for Buena Vista County.

Analysis #1: Storm Lake City Excluded from View Shed

For the first analysis, the view shed consists only of the village and township in which the wind turbines are located. In this case approximately 75 to 100 percent of the residential properties sold are within view of the wind farm, and are at most 3.5 miles from wind turbines, and in most cases much closer. We believe that if wind farms negatively effect property values, this effect would be strongest in this smaller radius view shed. The Analysis #1 view shed dataset contains 288 sales from 1996 to 2002.

Analysis #2: Storm Lake City Included in View Shed

For the second analysis, the view shed contains Storm Lake City, which is mainly within the five-mile view shed radius, in addition to Alta City and Nokomis Township as included in Analysis #1. Because Storm Lake City's population is five times larger than that of the Alta and Nokomis combined, and because estimates are that roughly 5 percent of Storm Lake City properties can see the wind farms, we believe that any negative property value effects from the wind farms may be overshadowed by economic and demographic trends in Storm Lake City that are distinct from any effect the wind farms may have. The Analysis #2 view shed dataset contains 1,557 sales from 1996 to 2002.

iii. Comparable Selection

The comparable community was selected through interviews with Buena Vista County Assessor Ted Van Groteest, and analysis of demographic data from the 1990 and 2000 U.S. Census for communities near but outside of the view shed. Tables 7.2 and 7.3 summarize the Census data reviewed. In order to determine the most appropriate comparable community, we looked at the demographics of five comparable communities. Upon examination of Census data, sales data availability, and review of interview comments, one city and four townships in Clay County, just to the north of Buena Vista County, were selected as the comparable. The comparables are Spencer City, and Meadow, Riverton, Sioux, and Summit Townships. The final comparable dataset contained 1,656 sales from 1996 to 2002.

Table 7.2 Buena Vista County, Iowa: 1990 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
1990	Y	Nokomis Township, Buena Vista County	2,174	$24,915	10%	872	$41,300
1990	Y	Alta City, Buena Vista County	1,824	$23,043	12%	754	$40,400
VIEW SHED DEMOGRAPHICS #1			3,998	$23,979	11%	1,626	$40,850
1990	Y	Nokomis Township, Buena Vista County	2,174	$24,915	10%	872	$41,300
1990	Y	Storm Lake City, Buena Vista County	8,769	$23,755	9%	3,557	$47,000
1990	Y	Alta City, Buena Vista County	1,824	$23,043	12%	754	$40,400
VIEW SHED DEMOGRAPHICS #2			12,767	$23,904	11%	5,183	$42,900
1990	COMP	Meadow Township, Clay County	432	$24,000	12%	142	$60,500
1990	COMP	Riverton Township, Clay County	323	$26,875	19%	115	$47,500
1990	COMP	Sioux Township, Clay County	348	$35,417	2%	134	$42,100
1990	COMP	Spencer City, Clay County	11,066	$24,573	10%	4,824	$45,200
1990	COMP	Summit Township, Clay County	409	$27,266	5%	201	$30,400
COMPARABLE DEMOGRAPHICS			12,578	$27,626	9%	5,416	$45,140

Table 7.3 Buena Vista County, Iowa: 2000 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
2000	Y	Nokomis Township, Buena Vista County	2,261	$33,533	11%	922	$69,800
2000	Y	Alta City, Buena Vista County	1,848	$31,941	11%	791	$66,700
VIEW SHED DEMOGRAPHICS #1			4,109	$32,737	11%	1,713	$68,250
2000	Y	Nokomis Township, Buena Vista County	2,261	$33,533	11%	922	$69,800
2000	Y	Storm Lake City, Buena Vista County	10,150	$35,270	12%	3,732	$70,300
2000	Y	Alta City, Buena Vista County	1,848	$31,941	11%	791	$66,700
VIEW SHED DEMOGRAPHICS #2			14,259	$33,581	11%	5,445	$68,933
2000	COMP	Meadow Township, Clay County	323	$49,167	2%	129	$82,900
2000	COMP	Riverton Township, Clay County	323	$49,200	3%	116	$124,100
2000	COMP	Sioux Township, Clay County	324	$37,417	0%	144	$107,400
2000	COMP	Spencer City, Clay County	11,420	$32,970	10%	5,177	$80,700
2000	COMP	Summit Township, Clay County	411	$36,500	1%	179	$68,000
COMPARABLE DEMOGRAPHICS			12,801	$41,051	3%	5,745	$92,620

iv. Analytical Results and Discussion

Analysis #1: Storm Lake City Excluded from View Shed

In all three of the regression models, monthly average sales prices grew faster in the view shed than in the comparable area, indicating that there is no significant evidence that the presence of the wind farms had a negative effect on residential property values.

In Case I, the monthly sales price change in the view shed is 18 percent greater than the monthly sales price change of the comparable over the study period. The Case I model provides a good fit to the data, with over two-thirds of the variance in the data explained by the linear regression. In Case II, the monthly sales price change in the view shed is 70 percent greater after the on-line date than before the on-line date. The Case II model provides a reasonable fit to the data, with over half of the variance in the data explained by the linear regression. In Case III, average view shed sales prices after the on-line date are 2.7 times greater than in the comparable. The Case III model describes over half of the variance in the data for the view shed, but only 23 percent of the variance for the comparable. The data for the full study period is graphed in Figure 7.4, and regression results for all cases are summarized in Table 7.4 below.

Analysis #2: Storm Lake City Included in View Shed

In all three of the regression models, monthly average sales prices grew slower in the view shed than in the comparable area.

In Case I, the monthly sales price change in the view shed is 34 percent less than the monthly sales price change of the comparable over the study period. The Case I model provides a good fit to the data, with over 60 percent of the variance in the data explained by the linear regression. In Case II, the monthly sales price change in the view shed is 59 percent less after the on-line date than before the on-line date. The Case II model explains over half of the variance in the data prior to the on-line date explained, but only 27 percent of the variance after the on-line date. In Case III, average view shed sales prices after the on-line date are 22 percent lower than in the comparable.

The Case III model provides a poor fit to the data, explaining less than 30 percent of the variance for the data. The data for the full study period is graphed in Figure 7.5, and regression results for all cases are summarized in Table 7.5 below.

Table 7.4 Regression Results, Buena Vista County, IA
Projects: Storm Lake I & II (Without Storm Lake City)

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data	Jan 96 - Oct 02	$401.86	0.67	The rate of change in average view shed sales price is 18% greater than the rate of change of the comparable over the study period.
	Comparable, all data	Jan 96 - Oct 02	$341.87	0.72	
Case 2	View shed, before	Jan 96 - Apr 99	$370.52	0.51	The rate of change in average view shed sales price is 70% greater after the on-line date than the rate of change before the on-line date.
	View shed, after	May 99 - Oct 02	$631.12	0.53	
Case 3	View shed, after	May 99 - Oct 02	$631.12	0.53	The rate of change in average view shed sales price after the on-line date is 2.7 times greater than the rate of change of the comparable after the on-line date.
	Comparable, after	May 99 - Oct 02	$234.84	0.23	

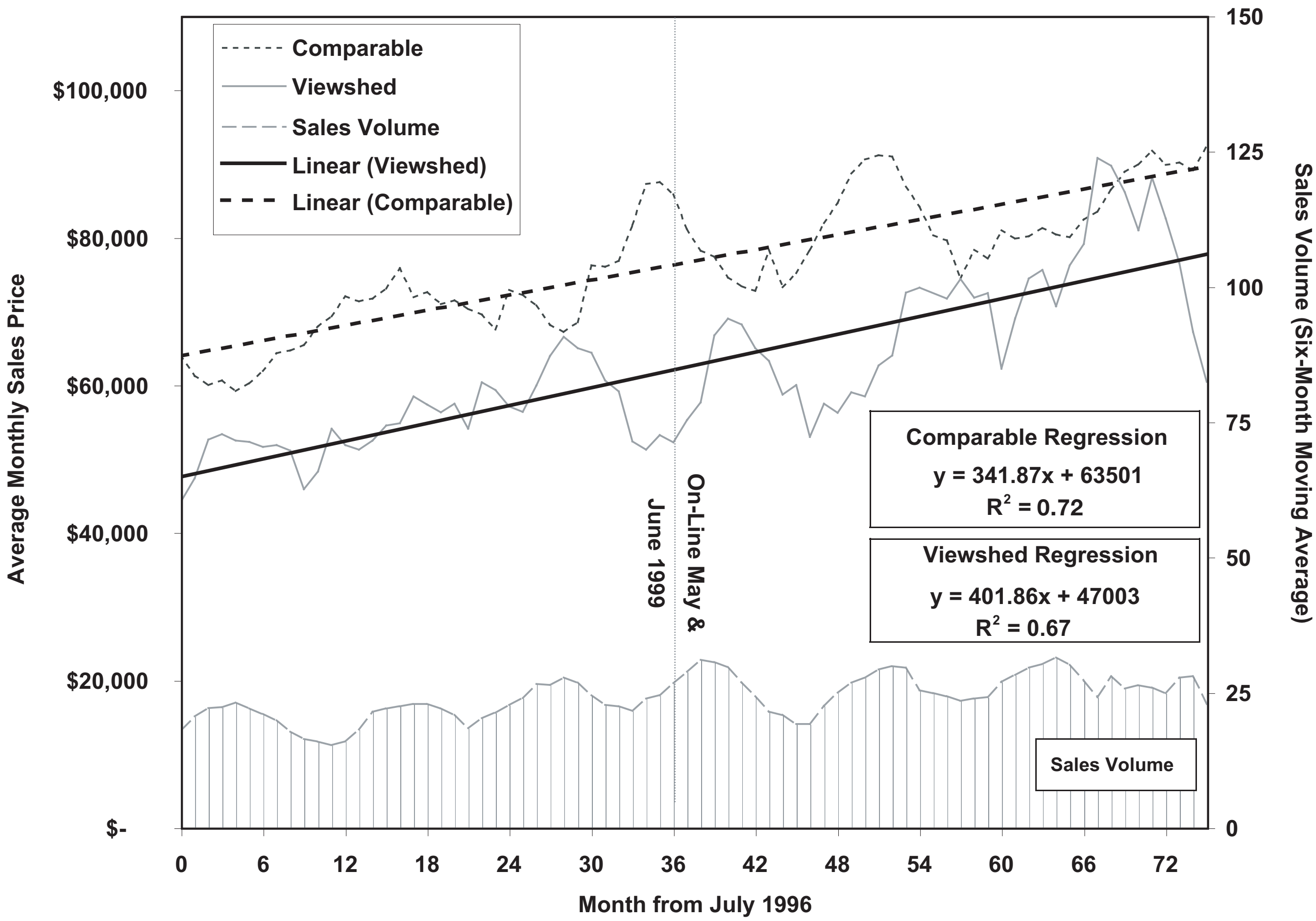


Figure 7.4 Average Residential Housing Sales Price
Analysis #1: Storm Lake City Excluded from View Shed
Buena Vista County, Iowa 1996-2002

Table 7.5 Regression Results, Buena Vista County, IA
Project: Storm Lake I & II (With Storm Lake City)

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data	Jan 96 - Oct 02	225.97	0.60	The rate of change in average view shed sales price is 34% less than the rate of change of the comparable over the study period.
	Comparable, all data	Jan 96 - Oct 02	341.87	0.72	
Case 2	View shed, before	Jan 96 - Apr 99	450.11	0.59	The rate of change in average view shed sales price is 59% less after the on-line date than before the on-line date.
	View shed, after	May 99 - Oct 02	183.92	0.27	
Case 3	View shed, after	May 99 - Oct 02	183.92	0.27	The rate of change in average view shed sales price after the on-line date is 22% lower than the rate of change of the comparable after the on-line date.
	Comparable, after	May 99 - Oct 02	234.84	0.23	

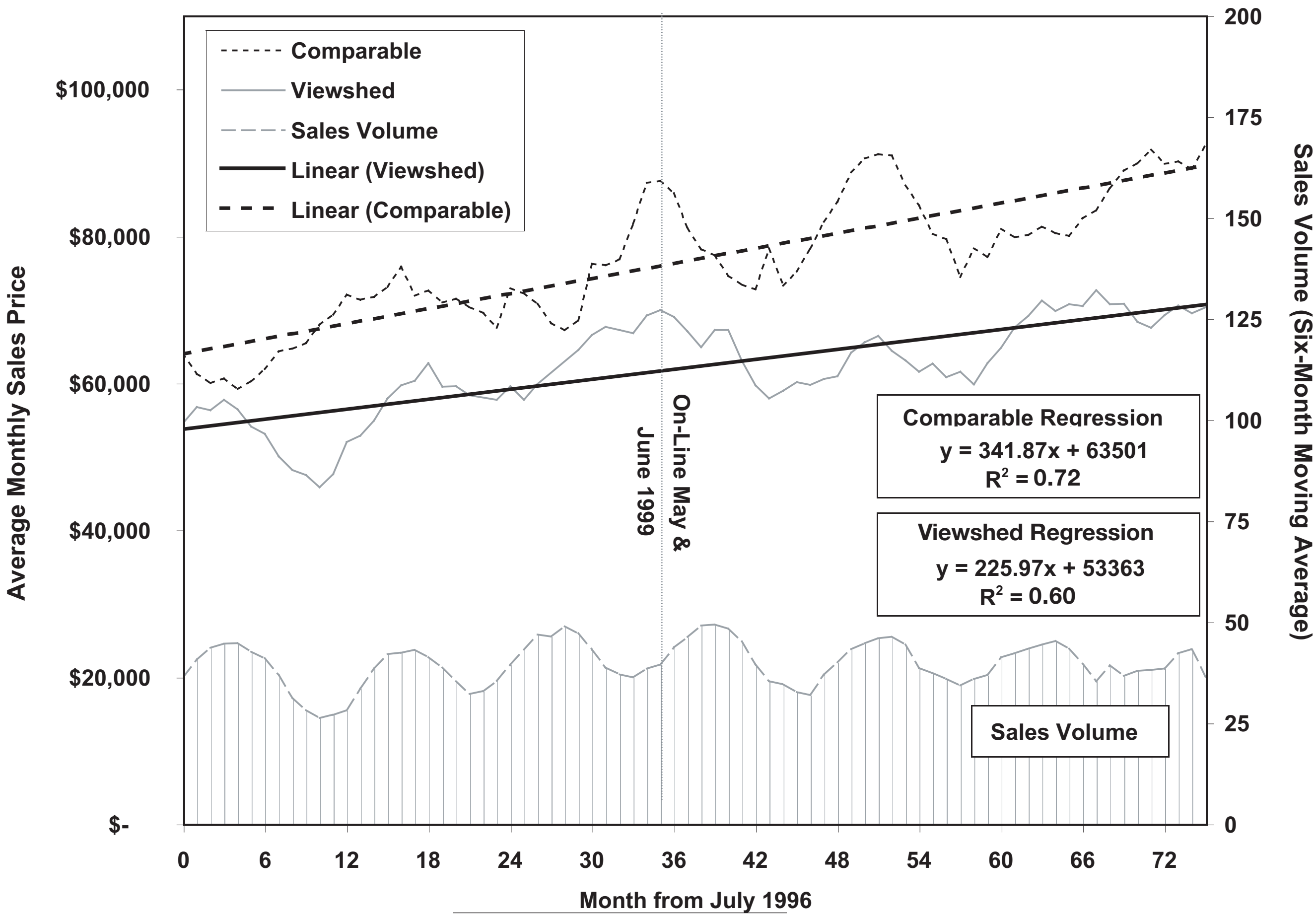


Figure 7.5 Average Residential Housing Sales Price
Analysis #2: Storm Lake City Included in View Shed

Buena Vista County, Iowa 1996-2002

D. Additional Interviewee Comments

Buena Vista County Assessor Ted Van Groteest said the comparable area around Spencer City in the northern neighboring county, Clay, would have higher property values because of its proximity to recreational lakes to the north, but that the two areas' property values rose at equal rates. He added that the predominate business mix was similar, but that the productive value of the land in Clay might be a little higher.

Between October 2002 and March 2003 the following information was obtained through other interviews with Groteest:

- Most of the residences at the Lake Creek Country Club, a golf course community located just west of Storm Lake City (between the city and the wind farms), have views of the towers. Several towers are one-half mile north and southwest of the Country Club. The assessor owns a home at the Country Club.
- In the assessor's opinion, the wind projects have no impact on property values. According to the assessor, the only issue that influences prices is the school district.
- There is also a hog farm on the west side of Storm Lake – the same direction as the wind projects. Groteest said the property values did not change around the hog farm.

Site Report 8: Kern County, California

A. Project Description

The Tehachapi Mountains stretch northeast and southwest with Tehachapi City and neighboring communities seated within a flat valley inside the range. Despite the arid climate, Tehachapi's elevation of 4,000 feet affords it four seasons. This region is known for its extensive wind farm development, which has been ongoing for over two decades.

Figures 8.1 – 8.2: Views of the Tehachapi region wind farms
Top Photo Courtesy Jean-Claude Criton © 2000 ~ Bottom Photo Courtesy Windland Inc. © 2003

Between 1981 and 2002 developers installed 3,569 towers with varied hub heights up to 55 meters (180.5 feet), and repowered six sites with 199 towers between 1997 and2002. The projects nestle within the Tehachapi pass five miles east of Tehachapi City, through the Tehachapi mountains, and scatter along the east-face just as Highway 58 drops sharply southeast toward Mojave and California cities bordering the Mojave Desert. The wind farm locations are shown in the regional area map, Figure 8.3, and view shed map, Figure 8.4, below.

To the east of the mountains are the cities of Mojave, California, and Rosamond. The incorporated limits of these cities are all approximately three to four miles from the base of the range, where the Mojave Desert begins.

Foliage is patchy with many areas covered in wild, dry grasses, Juniper, and Cottonwood much like the terrain between Albuquerque and Santa Fe, New Mexico. However, there are some green portions with dense grasses allowing for cattle grazing or equestrian spreads.

Although Kern County is classified as a "county in a metro area with 250,000 to 1 million population," the view shed has a population of less than 15,000. See Appendix 1 for a definition of rural urban continuum codes. Also, Tehachapi is 40 miles to the nearest metro area of Bakersfield, and 115 miles to Los Angeles.

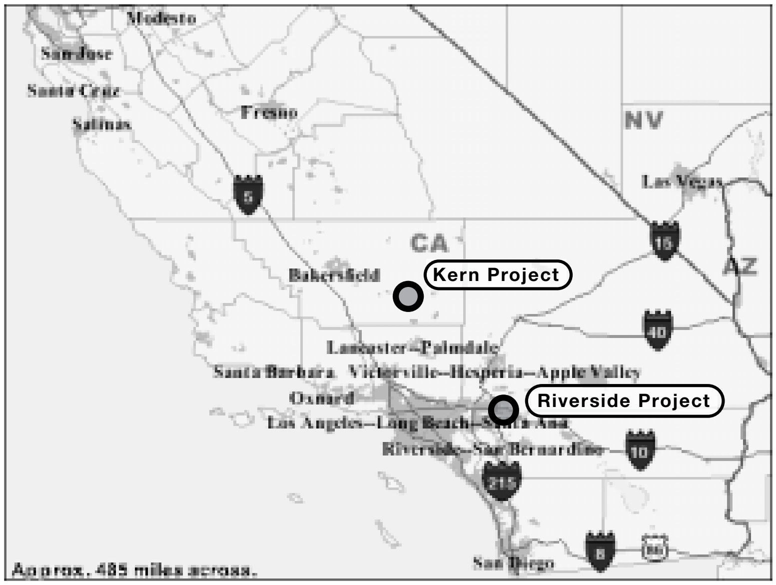


Figure 8.3. Regional Wind Project Location

(Dots approximate wind farm locations)

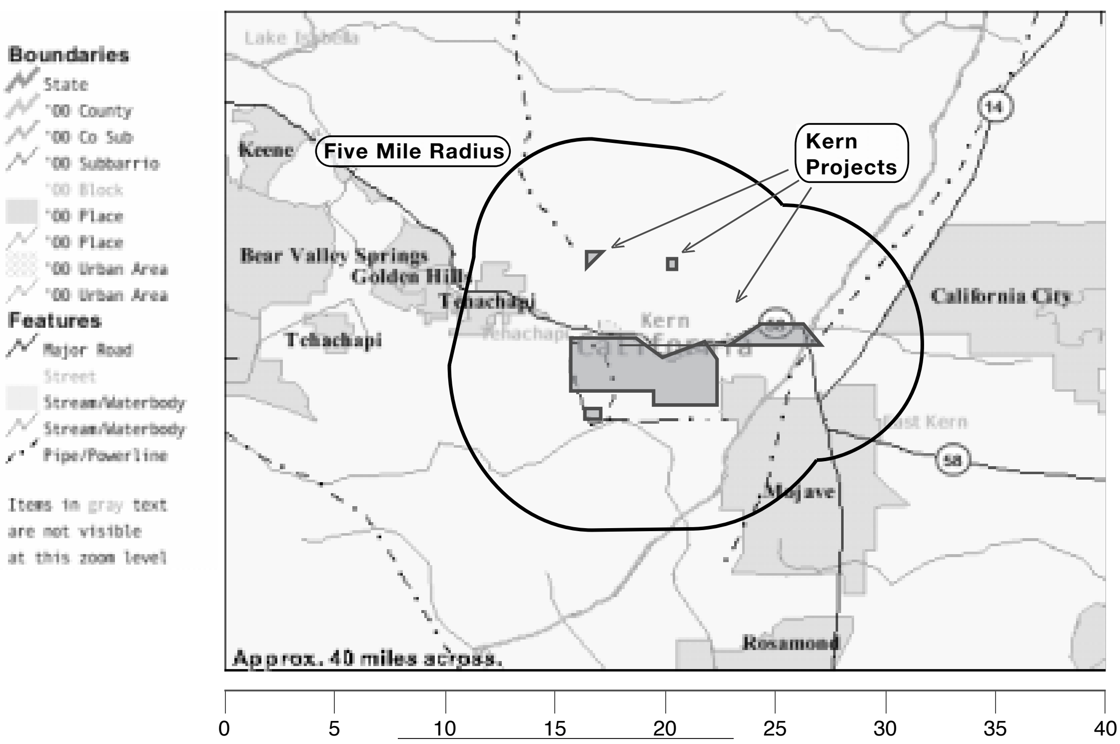


Figure 8.4. Kern County, California View shed

Project Location Source: Kern County Assessors Office

Base Map Source: U.S. Census Bureau

B. Project Timeline

Table 8.1 Wind Project History, Tehachapi, CA

Project Name	Completion Date	Capacity (MW)	Project Name	Completion Date	Capacity (MW)
Oak Creek	2002	2.5	Coram Energy Group	1981-1995	6.8
Oak Creek-Phase 2A-Repower	1999	0.8	Cannon (various)	1981-1995	4.5
Pacific Crest-Repower	1999	45.5	Mogul Energy	1981-1995	4.0
Cameron Ridge-Repower	1999	56.0	Coram Energy Group	1981-1995	4.0
Oak Creek Phase 2-Repower	1999	23.1	Windridge	1981-1995	2.3
Victory Gardens -Repower	1999	6.7	Coram Energy Group	1981-1995	1.9
Oak Creek Phase 1-Repower	1997	4.2	Victory Gardens I & IV	1981-1995	1.0
Mojave 16, 17 & 18	1981-1995	85.0	Sky River	1993	77.0
Mojave 3, 4 & 5	1981-1995	75.0	Victory Gardens Phase IV	1990	22.0
Ridgetop Energy	1981-1995	32.6	Various Names	1982-87	64.0
Calwind Resources	1981-1995	14.1	Various Names	1982-87	24.0
Cannon	1981-1995	13.5	Various Names	1986	0.2
Calwind Resources	1981-1995	8.7	Windland (Boxcar II	Mid-1980s	14.3
AB Energy-Tehachapi	1981-1995	7.0			

C. Analysis

i. Data

Real property sales data for 1996 to 2002 was obtained from First American Real Estate Solutions in Anaheim, CA. The dataset is quite detailed and contains many property and locational attributes, among them 9-digit zip code (ZIP+4) locations. Sales data was purchased for two zip codes encompassing the wind farm area and surrounding communities. These zip codes are Mohave (93501) and Tehachapi (93561).

Sales for the following residential property types were included in the analysis: single-family residences, condominiums, apartments, duplexes, mobile homes, quadruplexes, and triplexes. Of 21 apartment sales in the database, five in the view shed had unusually high sales prices. After discussion with the local Assessor, it was determined that these did not represent single sale data points, and they were eliminated from the analysis. A total of 2,867 properties are used in the analysis.

Projects that went on-line during the study period are the Cameron Ridge, Pacific Crest, and Oak Creek Wind Power Phase II sites. All three are repowering projects, with installed capacities of 56, MW, 45 MW, and 23 MW, respectively. Cameron Ridge went on-line March 1999, and the other two came on-line June 1999.

ii. View Shed Definition

All ZIP+4 regions within 5 miles of the wind turbines define the view shed. The location of the ZIP+4 regions were derived from the latitude and longitude of the ZIP+4 areas obtained from the U.S. Census TIGER database. Because the view sheds of the individual wind farm sites overlap, and because all projects went on-line within three months of each other, a single composite view shed is defined. The view shed is approximated by two rectangles that overlap the combined area swept out by a five-mile radius from each wind farm location.

Locational data for the wind farms was obtained from utility and wind industry web sites, and used in conjunction with detailed block maps, wind farm site maps, topographic maps and interviews to identify the exact location and extent of the wind farms and the composite view shed. The final view shed dataset contains 745 sales from 1996 to 2002.

Interviews with Kern County Assessors were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. Assessor Ron Stout said 50 to 60 percent of residents within Tehachapi City could see the turbines, but the Golden Hills area was too far and had views only if one intentionally tried to see them. He said about 30 percent of residents in the northwest corner of Mojave (north of Purdy Avenue and West of the Airport) could see turbines.

iii. Comparable Selection

The comparable community was selected through extensive interviews with Assessor Ron Stout of the State of California Kern County Assessment Office and analysis of topographic and site maps. Because the U.S. Census does not provide Census data at the resolution of individual ZIP+4 regions, we were unable to use Census data as part of the comparable selection process in this case. Based on review of the Assessor interviews, the ZIP+4 regions in Golden Hills, Bear Valley Springs, Stallion Springs and the central and southeastern portions of Mohave, all within Mohave zip code 93501 and Tehachapi zip code 93561, were selected as the comparable. The final comparable dataset contained 2,122 sales from 1996 to 2002.

iv. Analytical Results and Discussion

In one of the regression models, monthly average sales prices grew faster in the view shed than in the comparable area, and in two of the regression models it did not.

In Case I, the monthly sales price change in the view shed is 28 percent less than the monthly sales price change of the comparable over the study period. The Case I model provides a good fit to the view shed data, with over 70 percent of the variance in the data explained by the linear regression. In Case II, the monthly sales price change in the view shed is 38 percent greater after the on-line date than before the on-line date. The Case II model provides a good fit to the post on-line data, with 75 percent of the variance in the data explained by the linear regression. For the pre-on-line period, the regression explains 44 percent of the variance in the data. In Case III, average view shed sales prices after the on-line date are 29 percent less than in the comparable. The Case III model provides a good fit to the data, with 75 percent of the variance in the view shed data and 95 percent of the variance in the comparable data explained by the regression. The data for the full study period is graphed in Figure 8.4, and regression results for all cases are summarized in Table 8.2 below.

D. Additional Interviewee Comments

Assessor Stout also said that Mojave has not seen any new residential development in eight years. Both Stout and Assessor James Maples said they have not seen any impact of the farms on property values. However, Maples said the area was so agricultural or lightly populated that it would be hard to isolate price changes due to the wind projects. Maples, added that over 30 years of wind project development an industrial cement manufacturer, among other projects, was built close to Tehachapi on the east. The cement plant spewed out dust for 10 years or more until county and federal government inspectors required upgrades 15 years ago, said Stout.

Tehachapi is the busiest single-tracked [locomotive] mainline in the world, according to the Tehachapi Chamber of Commerce. It runs through the Tehachapi Mountains between Mojave and Bakersfield. Of other notable businesses, Tehachapi has a manufacturing plant for GE Wind Energy (formerly Zond) wind turbines.

Table 8.2 Regression Results, Kern County, CA
Projects: Pacific Crest, Cameron Ridge, Oak Creek Phase II

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 96 - Dec 02 Jan 96 - Dec 02	$492.38 $684.16	0.72 0.74	The rate of change in average view shed sales price is 28% less than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 96-Feb 99 Mar 99 - Dec 02	$568.15 $786.60	0.44 0.75	The rate of change in average view shed sales price is 38% greater after the on-line date than the rate of change before the on-line date.
Case 3	View shed, after Comparable, after	Mar 99 - Dec 02 Mar 99 - Dec 02	$786.60 $1,115.10	0.75 0.95	The rate of change in average view shed sales price after the on-line date is 29% less than the rate of change of the comparable after the on-line date.

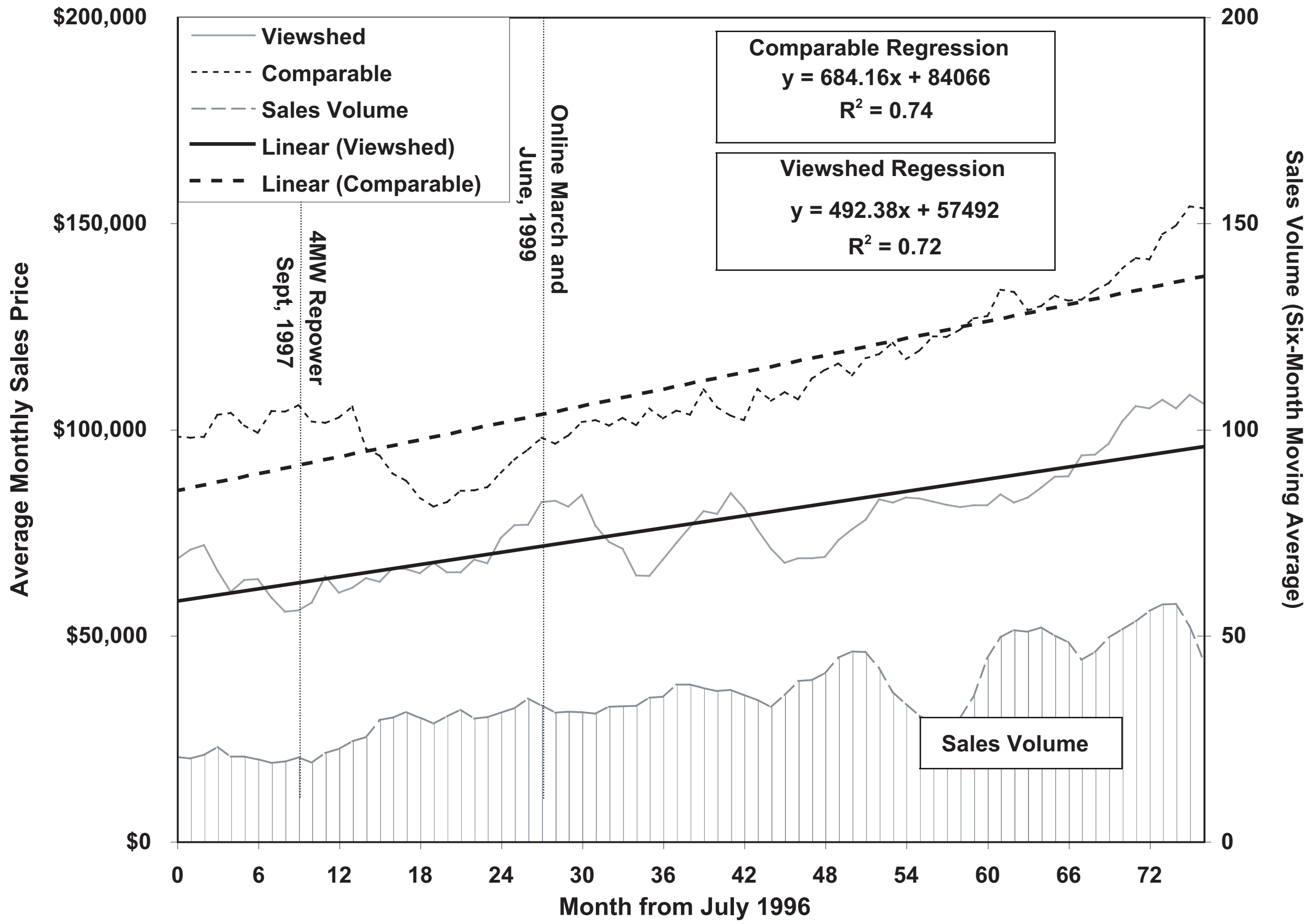


Figure 8.4 Average Residential Housing Sales Price

Kern County, California 1996-2002

Site Report 9: Fayette County, Pennsylvania

A. Project Description

Although the area is famous for being the home of Frank Lloyd Wright's Falling Water House built for a wealthy Pittsburgh family, much of the area is low-income and rural. The 10 turbines rising 70 meters (230 feet) were built along a ridge on the border of Stewart and Springfield Townships, and run north/south against the county border with Somerset. The land is owned primarily by one family who rents some of the acreage to a petroleum pumping company and for the turbines.

The area is very hilly with densely populated tall trees. The project site is approximately 62 miles from Pittsburgh with several ski lodges in the vicinity. The local economy is primarily agricultural or tourism related.

The view shed area of Springfield and Stewart Townships is rural with a combined population less than 2,000 although the county is classified as a "fringe county of a metro area with 1 million population or more." See Appendix 1 for a definition of rural urban continuum codes. This discrepancy is because the southeastern periphery of suburban Pittsburgh creeps a little into northwest Fayette. The view shed is at least 62 miles from downtown Pittsburgh.

Figure 9.1 View of a Mill Run Turbines
Photo Courtesy GE Wind Energy © 2002

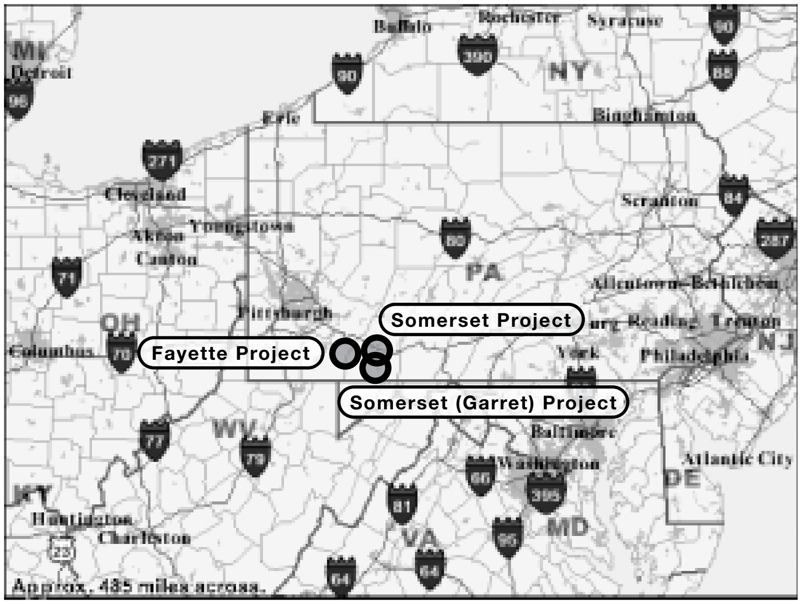


Figure 9.2. Regional Wind Project Location
(Dots approximate wind farm locations)

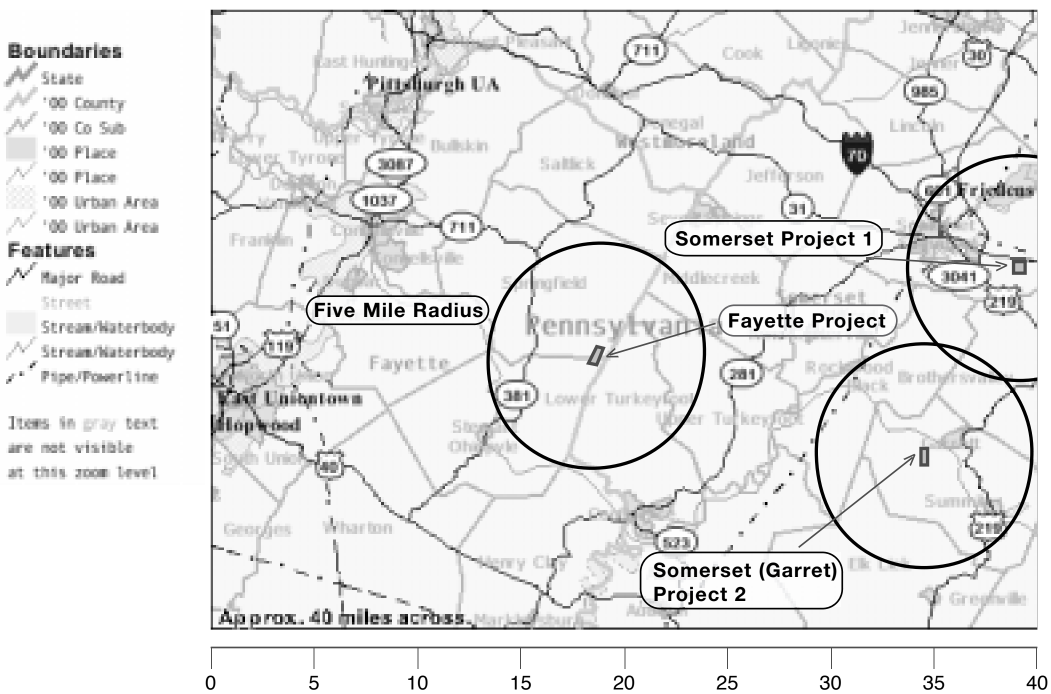


Figure 9.3. Fayette County, Pennsylvania View shed
Project Location Source: Fayette County Assessors Office
Base Map Source: U.S. Census Bureau

B. Project Timeline

Table 9.1 Wind Project History, Fayette County, PA

Project Name	Completion Date	Capacity (MW)
Mill Run Windpower LLC	2001	15.0

C. Analysis

i. Data Source

Real property sales data for 1998 to 2002 was obtained electronically from the Fayette County Assessment Office Website, www.fayetteproperty.org/assessor. The dataset contains all property sales in Stewart and Springfield Townships. The sales volume is the smallest of all sites analyzed, with only 89 sales over the five-year period studied. The wind farm went on-line October 2001, with an installed capacity of 15 MW.

Complete addresses and detailed sales data are available on the website only by clicking on each parcel individually. However, there is no parcel map of the entire township to help identify parcel locations. We combined over 50 local parcel maps into one composite parcel map for the view shed, and used this in combination with street maps to identify the view shed and non-view shed areas.

ii. View Shed Definition

The view shed is defined by a five-mile radius around the wind farm. The view shed covers the eastern portion of both Springfield and Stewart Townships in Fayette County. The five-mile radius also covers portions of Lower Turkey Foot, Upper Turkey Foot, and Middlecreek Townships in Somerset County. Because the Somerset County Townships are only partially in the view shed, and because the Somerset data we obtained is identified primarily by township or city, these areas are not included in the analysis. The view shed is therefore defined as the portions of Springfield and Stewart Townships falling within the five-mile radius. The view shed accounts for 39 sales over the study period.

Interviews with the State of Pennsylvania Fayette County Assessors Office were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. In Fayette County Chief Assessor James A. Hercik's opinion, 10 to 20 percent of residents have views of the turbines.

iii. Comparable Selection

The comparable community was selected based on the availability of parcel-level data and through interviews with Fayette County Chief Assessor James A. Hercik. Assessor James Hercik said properties to the west of the view shed had no views of the wind turbines. Upon examination of sales data availability and review of Assessor comments, the western portions of Springfield and Stewart Townships, outside the five-mile view shed radius, were selected as the comparable, with a total of 50 sales from 1997 to 2002.

Demographic data from the 1990 and 2000 U.S. Census for Springfield and Stewart Townships was gathered, but not used because both the view shed and comparable are in the same township. Tables 9.2 and 9.3 summarize the Census data reviewed.

Table 9.2 Fayette County, Pennsylvania: 1990 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
1990	partial	Springfield Township	2,968	$15,686	28%	1,137	$40,200
1990	partial	Stewart Township	734	$18,235	24%	331	$42,500
VIEW SHED DEMOGRAPHICS			3,702	$16,961	26%	1,468	$41,350

Table 9.3 Fayette County, Pennsylvania: 2000 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
2000	partial	Springfield Township	3,111	$29,133	22%	1,283	$57,400
2000	partial	Stewart Township	743	$32,917	11%	338	$64,000
VIEW SHED DEMOGRAPHICS			3,854	$31,025	16%	1,621	$60,700

iv. Analytic Results and Discussion

In two of the three regression models, monthly average sales prices grew faster or declined slower in the view shed than in the comparable area. However, in the case of the underperformance of the view shed, the explanatory power of the model is very poor. Thus, there is no significant evidence in these cases that the presence of the wind farms had a negative effect on residential property values.

In Case I, the monthly sales price increase in the view shed is only 24 percent that of the comparable over the study period. However, the Case I model provides a poor fit to the view shed data, with only two percent of the variance in the data for the view shed and 24 percent of the variance in the data for the comparable explained by the linear regression. In Case II, sales prices decreased in the view shed prior to the on-line date, and increased after the on-line date. The average view shed sales price after the on-line date increased at 3.8 times the rate of decrease in the view shed before the on-line date. The Case II model provides a poor fit to the data, with less than one-third of the variance in the data explained by the linear regression. In Case III, average view shed sales prices after the on-line date are 13.5 times greater than in the comparable. However, the Case III model describes only 32 percent of the variance in the view shed data, and none of the variance in the comparable data. The data for the full study period is graphed in Figure 9.4, and regression results for all cases are summarized in Table 9.4 below.

The poor fit of the model, as evidenced by the low R2 values, is partly due to the very small sales volume, on average only 2.1 sales per month in the view shed and comparable combined. As can be seen from Figure 9.4, the small sales volume leads to very high variability in average sale price from month to month. In addition, for regressions fit to data after the on-line date, only 13 months' sales data was available, accounting for 18 sales total, which leads to the caveat that these results should be viewed carefully.

Table 9.4 Fayette County, Pennsylvania: Regression Results
Project: Mill Run

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data	Dec 97-Dec 02	$115.96	0.02	The rate of change in average view shed sales price is 24% of the rate of change of the comparable over the study period.
	Comparable, all data	Dec 97-Dec 02	$479.20	0.24	
Case 2	View shed, before	Dec 97 - Nov 01	-$413.68	0.19	The rate of change in average view shed sales price after the on-line date increased at 3.8 times the rate of decrease before the on-line date.
	View shed, after	Oct 01-Dec 02	$1,562.79	0.32	
Case 3	View shed, after	Oct 01-Dec 02	$1,562.79	0.32	The rate of change in average view shed sales price after the on-line date is 13.5 times greater than the rate of change of the comparable after the on-line date.
	Comparable, after	Oct 01-Dec 02	$115.86	0.00	

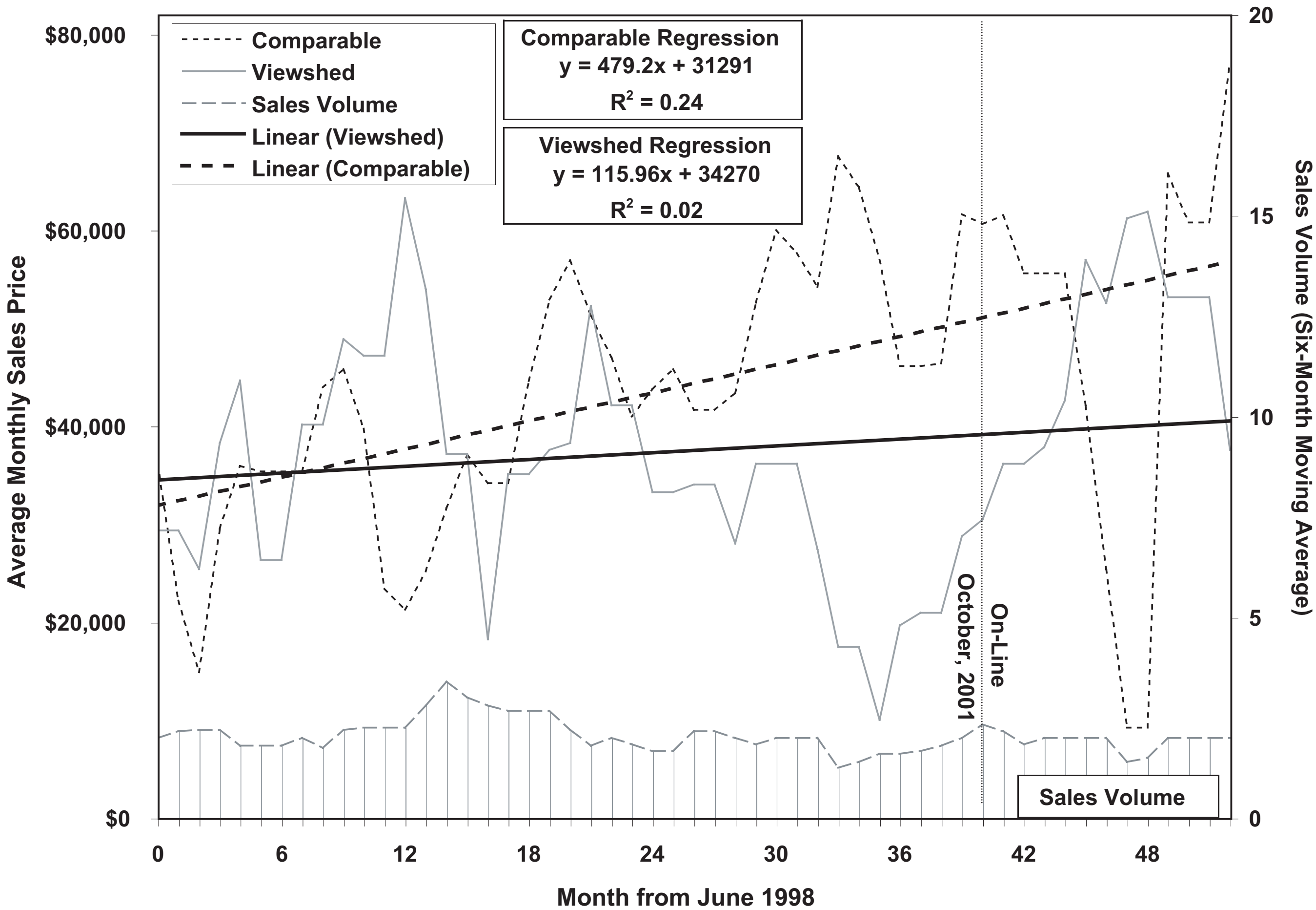


Figure 9.4 Average Residential Housing Sales Price
Fayette County, Pennsylvania 1998-2002

D. Additional Assessor Comments

James A. Hercik, Fayette County chief assessor/director of assessments, said he has not seen any impact of the wind farms on property values, with the exception that the assessed value of properties with turbines went up. He also noted that on the same property as the turbines are on, there are natural gas wells, which additionally impact valuations. Finally, Hercik said that often, sales in the view shed were family-to-family sales that may reflect sales prices lower than assessed value.

Site Report:
Projects Excluded From Analyses

Of the 27 projects selected for analysis, four were excluded from analysis because there were not enough sales in the view shed for statistical analysis; one was excluded because comparable data was not available at time of publication of this report; and an additional 12 projects were excluded because property sales data was unavailable, not readily available, or because there were not enough sales in the view shed for statistical analysis. Table S1 below summarizes the reasons for project exclusion from analysis.

Table S1: Summary of Projects Excluded from Analyses

I. Data acquired, but insufficient for analysis

County	State	Reason for Exclusion
Logan	CO	Not enough sales to make a valid judgment (5 Sales)
Worth	IA	Not enough sales to make a valid judgment (38 sales over 7 years)
Umatilla	OR	Not enough sales to make a valid judgment (28 sales)
Howard	TX	Comparable data not acquired at time of publication (1,896 view shed sales)
Upton	TX	Not enough sales to make a valid judgment (7 sales)

II. Data not acquired

County	State	Reason for Exclusion
Weld	CO	Not enough sales to make a valid judgment
Cerro Gordo	IA	No electronic data - accessible in office on paper only
Gray	KS	State law prohibits access to information
Pipestone	MN	No electronic data - accessible in office on paper only - and not enough sales
Lincoln	MN	No electronic data - accessible in office on paper only
Gilliam	OR	No electronic data - accessible in office on paper only
Culberson	TX	No electronic data - accessible in office on paper only
Pecos	TX	No electronic data - accessible in office on paper only - and no sales in view shed
Taylor	TX	No electronic data - accessible in office on paper only
Benton	WA	Not enough sales to make a valid judgment (Project came on-line in 2002)
Walla Walla	WA	No sales in the view shed since project completion
Iowa	WI	No electronic data - accessible in office on paper only
Carbon	WY	State law prohibits access to information

I. Data Acquired, but Insufficient for Analysis

County State Reason for Exclusion

Logan CO Not enough sales to make a valid judgment (Five Sales)

Years Reviewed: 1996 to 2002

Assessor comments: Assessor Ann Rogers-Ridnour said her office has seen no impact from the wind project, and that it was hard gauge because there are so few sales.

<u>Worth IA Not enough sales to make a valid judgment (38 sales over seven years)</u>

Years Reviewed: 1996 to 2002

Assessor comments: Assessor said the project was surrounded only by agricultural land, that it was hard to pinpoint home locations on farms if any because addresses are vague, and that they felt the wind projects have been welcomed.

<u>Umatilla OR Not enough sales to make a valid judgment (28 sales)</u>

Years Reviewed: 1995 to 2002

Assessor comments: Assessor Lee Butler said there were only 28 sales in view shed.

<u>Howard TX Comparable not available at time of publication</u>

Years Reviewed: 1996 to 2002

The exact location of the Big Spring wind farm in Howard County, TX, and thus definition of the view shed, was elusive. While site maps with individual turbine locations were obtained, they were hand drawn and not to scale. Interviews with county Assessors and on-site operations staff yielded conflicting descriptions of the exact location of the turbines. In the end, the wind farm location was fixed in an interview with one of the original site developers, Mark Haller of Zilkha Inc. According to Mr. Haller, the turbine towers reach out far away from the Big Spring, but the closest one is only 100 yards or so from the third tee of a golf course on the south side of town – close enough for golfers often take chip shots at it.

The view shed covers portions, but not all of, the three school districts in the county: Coahoma, Big Spring, and Forsan. Approximately 70 percent of Big Spring City, all of Coahoma City, and none of Forsan City are within the view shed. Because this project lacks the resources to identify every property by street address, the view shed is defined to include all of Big Spring City, which is equivalent to using a six-mile radius view shed instead of a five-mile radius view shed for this case only. The final view shed dataset contains 1,896 sales from 1996 to 2002.

Interviews with Howard County Assessors were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. In Chief Assessor Keith Toomire's opinion, 30 percent of Big Spring City properties can see the turbines. Mr. Haller added that due to the various plateaus surrounding Big Spring, there are portions of the town that cannot see the turbines.

The selection of an appropriate comparable for Big Spring is difficult because the area has experienced an economic downturn and loss of jobs for a number of years. According to Howard County Chief Assessor Keith Toomire, the two major employment categories in the Big Spring are agriculture and petroleum extraction. Due to a 10-year draught in the region, crop yields are severely reduced, with significant economic impacts for the city. Additionally, depletion of petroleum resources has led to the closing of wells and economic downturn in the local petroleum industry.

Because the view shed for Big Spring was defined very late in the process of producing this report, data for a comparable has not yet been obtained.

<u>Upton TX Not enough sales to make a valid judgment (Seven sales)</u>

Years Reviewed: 1996 to 2002

Assessor comments: Chief Appraiser Shari Stevens said no sales near southwest Mesa, and only seven sales near the King Mountain project.

II. Data Not Acquired

County State Reason for Exclusion

Weld CO Not enough sales to make a valid judgment

Years Reviewed: 1996 to 2002

Assessor comments: Office staff said there were very few people in the project area and didn't think anybody could see it.

Cerro Gordo IA No electronic data - accessible in office on paper only

Years Reviewed: 1996 to 2002

Assessor comments: Assessor said we were the third group to call them about the same question and that they've looked into every way they could to parse their data, and could find no proof that there was any impact on county property values.

Gray KS State law prohibits access to information

Years Reviewed: 1996 to 2002

Assessor comments: Assessor Jerry Dewey said area had only small populations and that most land was agricultural; therefore he said they have seen no impact, primarily because the land is assessed for productive use.

Pipestone MN No electronic data - accessible in office on paper only – and not enough sales

Years Reviewed: 1991 to 2002

Assessor comments: Interim Assessor "Farley" said he's not seen any impact on property values. Also, he added that there haven't been enough sales to make a judgment call, and all property surrounding the project is agricultural land which is valued on productive use (so unless the turbines were on the property itself, then the property value would not go up).

Lincoln MN No electronic data - accessible in office on paper only

Years Reviewed: 1991 to 2002

Assessor comments: Assessor "Bruce" (last name unavailable) said the project was a "non-issue" and has not seen any impact on values. Specifically, the projects were welcomed and some people tried to have the turbines built on their land.

Gilliam OR No electronic data - accessible in office on paper only

Years Reviewed: 1997 to 2002

Assessor comments: Assessor Pat Shaw said area around project had a population less than 700 all living dispersed among agricultural land. Also, he expressed no sense of impact on property values

Culberson TX No electronic data - accessible in office on paper only

Years Reviewed: 1992 to 2002

Assessor comments: Appraiser Sally Carrasco said they've been very happy with the wind farms. She added that because they have a terrible economy, she wasn't sure if they would even have a town were it not for the revenue from turbines that support the schools.

Pecos TX No electronic data - accessible in office on paper only – and no sales in view shed

Years Reviewed: 1997 to 2002

Assessor comments: Assessor Santa S. Acosta said there were no residences with a view, and that there are so few sales in general that the area wasn't due for re-appraisal until 2003.

Taylor TX No electronic data - accessible in office on paper only

Years Reviewed: 1997 to 2002

Assessor comments: Assessor Ralf Anders said no homes had a view.

Benton WA Not enough sales to make a valid judgment

(Project came on-line in 2002)

Years Reviewed: 1996 to 2002

Assessor comments: Office clerk "Harriet" said they only have the past three months of data in electronic form; everything else is in paper and a person must go to office to search records.

Walla Walla WA No sales in the view shed since project completion

Years Reviewed: 1996 to 2002

Assessor comments: Walla-Walla County Assessor Larry Shelley said there have been no sales since the wind project was built.

Iowa WI No electronic data - accessible in office on paper only

Years Reviewed: 1996 to 2002

Assessor comments: Assessor said only small village areas had views, but that the wind projects were welcomed. –Assessor specifically made a comment that a bowling alley has built a small tourist attraction around the project.

Carbon WY State law prohibits access to information

Years Reviewed: 1996 to 2002

Assessor comments: Assessor Darrell Stubbs said that although it is illegal to release individual property information, he has seen no impact on values. Specifically, he noted if any impact occurred, property values have risen because the population is so small that the infusion of a few jobs from the project in the area is enough to raise prices.

References

AES Calgary ULC. Application comments. 525-MW Natural Gas-Fired Power Plant Application No. 2001113 to Alberta Energy and Utilities Board. 2001.

California Energy Commission. Decision. Application for the Sutter Power Plant Project: Docket No. 97-AFC-2. 1999.

Campaign for the Protection of Rural Wales. The "Sinclair-Thomas Matrix" in Evidence to the House of Lords European Communities Committee, Sub-Committee B-Energy and Transport. Appendix 1: The Potential Visual Impact of Wind Turbines in relation to distance. March 1999. Available electronically at http://www.cprw.org.uk/wind/Hlords/hlcont.htm

Damborg, Steffen. Public Attitudes Towards Wind Power. Danish Wind Industry Association. June 2002. Available electronically at www.windpower.org/articles/surveys.htm

Dempsey, William E. The DUPA Technique for Electric Transmission-Line Easement Acquisitions. The Appraisal Journal. July 1981.

Des Rosiers, François. Power Lines. Visual Encumbrance and House Values: A Microspatial Approach to Impact Measurement. Journal of Real Estate Research. 2002.

Grover, Stephen. Economic Impacts of Wind Power in Kittitas County. Phoenix Economic Development Group/ECO Northwest. 2002.

Ignelzi, Patrice and Priestley, Thomas. A Statistical Analysis of Transmission Line Impacts on Residential Property Values in Six Neighborhoods. Edison Electric Institute. 1991.

Ignelzi, Patrice and Priestley, Thomas. A Methodology for Assessing Transmission Line Impacts in Residential Communities. Edison Electric Institute. 1989.

Jørgensen, Jørden Jordal. Social Assessment of Wind Power: Visual Effect and Noise from Windmills—Quantifying and Evaluation. Institute of Local Government Studies. Denmark. April 1996. Available electronically at www.akf.dk/eng/wind0.htm

Kroll, Cynthia A. and Priestley, Thomas. The Effects of Overhead Transmission Lines on Property Values. A Review and Analysis of the Literature. Prepared for Edison Electric Institute Siting & Environmental Planning Task Force. July 1992.

Kung, Hsiang-te and Seagle, Charles. Impact of Power Transmission Lines on Property Values: A Case Study. The Appraisal Journal. July 1992.

McCann, Richard. A Review of Literature on Property Value Impacts from Industrial Activities. Metcalf Energy Center. 1999.

Priestley, Thomas. Public Perceptions of Electric Facilities: An Advanced Workshop. Edison Electric Institute. 1997.

Sinclair Knight Mertz. Social Economics and Tourism. Environmental Effects Statement Supplement for the Pacific Hydro Limited Portland Wind Energy Project, Volume C. 2001. Available electronically at http://www.pacifichydro.com.au/files/PWEP/VolC_SET_Pt6on.pdf

Thomas, Gareth Wyn. An Environmental Assessment of Visual and Cumulative Impacts arising from Wind farm Developments: A Welsh Planning Policy Perspective. University of Wales, Aberystwyth. March 1996. Available electronically at http://users.aber.ac.uk/zwk/distlearn/virtlib/theses/thomas/thomas.html

U.S. Department of Agriculture. National Forest Landscape Management, Volume I. Agriculture Handbook Number 434. 1973.

Appendix 1. County Classification Descriptions

U.S. Department of Agriculture, Economic Research Service Rural-Urban Continuum Codes

Metro counties:	
0	Central counties of metro areas of 1 million population or more.
1	Fringe counties of metro areas of 1 million population or more.
2	Counties in metro areas of 250,000 to 1 million population.
3	Counties in metro areas of fewer than 250,000 population.
Nonmetro counties:	
4	Urban population of 20,000 or more, adjacent to a metro area.
5	Urban population of 20,000 or more, not adjacent to a metro area.
6	Urban population of 2,500 to 19,999, adjacent to a metro area.
7	Urban population of 2,500 to 19,999, not adjacent to a metro area.
8	Completely rural or less than 2,500 urban population, adjacent to a metro area.
9	Completely rural or less than 2,500 urban population, not adjacent to a metro area.

Note: New Rural-Urban Continuum Codes based on the 2000 Census are not expected to be available until 2003. The development of the updated codes requires journey-to-work commuting data from the long form of the 2000 Census and delineation of the new metropolitan area boundaries by the Office of Management and Budget. OMB's work is not scheduled to be completed until 2003. www.ers.usda.gov/briefing/rurality/RuralUrbCon/

The Renewable Energy Policy Project (REPP) supports the advancement of renewable energy technology through policy research. We seek to define growth strategies for renewables that respond to competitive energy markets and environmental needs. Since its inception in 1995, REPP has investigated the relationship among policy, markets and public demand in accelerating the deployment of renewable energy technologies, which include biomass, hydropower, geothermal, photovoltaic, solar thermal, wind and renewable hydrogen. The organization offers a platform from which experts in the field can examine issues of medium- to long-term importance to policy makers, green energy entrepreneurs, and environmental advocates.

REPP receives generous support from the U.S. Department of Energy, the Energy Foundation, and the U.S Environmental Protection Agency, the National Renewable Energy Laboratory (NREL), the Oak Foundation, the Surdna Foundation, and the Turner Foundation.

To order REPP publications, contact REPP at (202) 293-2898.

REPP publications are available free of charge on the Internet at www.repp.org

REPP
Renewable Energy Policy Project
1612 K Street, NW, Suite 202
Washington, DC 20006

Wind Turbine Neuro-Acoustical Issues

Dora Anne Mills, MD, MPH Maine CDC/DHHS

June, 2009

1. What protections are in Maine law regarding excessive noise and vibrations?

Maine DEP has rules that apply to all developments in unorganized areas of the state and in all municipalities without a more restrictive noise ordinance. The rules recognize in its text that excessive noise can degrade health and welfare of nearby neighbors, and they provide limits based on the type of development in the area surrounding the noise. For instance, they limit noise levels for routine operation of a proposed development: to 75 dBA at any time; to 60 dBA during the daytime and 50 dBA during the nighttime for non-commercial and non-industrial areas; and to 55 dBA daytime and 45 dBA nighttime for areas in which ambient sounds are 45 dBA or less daytime or 35 dBA or less nighttime.

Maine DEP also has retained the services of a noise expert to review noise study submissions as part of wind turbine applications and compliance evaluations.

DEP's ambient, post development monitoring at the Mars Hill wind farm shows dBA levels higher than 45, sometimes exceeding 60 when there are windy conditions both at ground level and at turbine height. This presents an example of how ambient noise from wind at these locations (which is why turbines are placed there) is in excess of the optimal nighttime 45 dBA. The DEP rules and compliance monitoring provide for distinguishing between the ambient contribution to noise and that from turbines at wind farms.

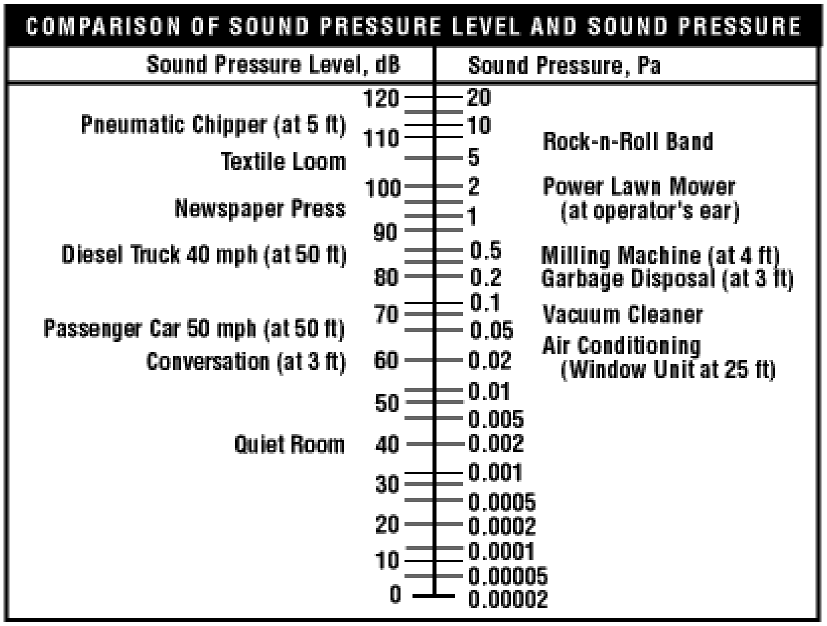
In summary: Maine law appears to essentially place a 45 dBA noise limit on most wind turbine projects in Maine. A 5 dBA variance to limits may be granted upon specific findings that concern pre-development existing ambient noises that are in excess of a particular standard. For compliance with the rule, noise levels are measured at the boundary of the property owned by the proposed developer.

Sources:

- Maine DEP rule-making authority on noise is in Title 38 Section 343
  Rules are in Chapter 375, Section 10:
  http://www.maine.gov/sos/cec/rules/06/096/096c375.doc
- Maine SPO Noise Technical Assistance Bulletin
  http://www.maine.gov/spo/landuse/docs/techassist/techassistbulletins/noisetabulletin.pdf

2. What do different noise levels compare to?

40 dBA is comparable to a quiet room. 55 dBA is comparable to a household room or office in which there is normal background vibration and sounds such as is commonly found from household appliances.



Canadian Centre for Occupational Health and Safety
(see www.ccohs.ca/oshanswers/phys_agents/noise_basic.html).

3. What kinds of noises are expected from wind turbines?

According to several resources, new wind turbines are relatively quiet, and meet federal and international standards and regulations for noise, including Maine's regulations. According to the US Department of Energy, a modern wind farm at a distance of 750 – 1,000' is no louder than a kitchen refrigerator or a moderately quiet room.

However, there are people who live about these distances from wind turbines who disagree with this federal agency statement. It appears from the research that distance from the wind turbine, height of the wind turbine relative to the surrounding topography, the quality of the sound (repetitive low frequency sound), wind conditions, and wind direction all affect how the wind turbine noise affects people. Research done on wind turbines, airport and other sources of noise indicates that annoyance levels are difficult to assess. However, taking in account the above factors as well as careful measurements need to be considered when siting wind turbines near residential properties.

Sources:

- US Dept of Energy's Wind Energy Guide for County Commissioners:
  http://www.nrel.gov/wind/pdfs/40403.pdf
  Page 6: An operating modern wind farm at a distance of 750'-1,000' is no louder than a kitchen refrigerator or moderately quiet room.
- University of Massachusetts Renewable Research Energy Laboratory:
  http://www.windpoweringamerica.gov/pdfs/workshops/mwwg_turbine_noise.pdf
  Contains a number of resources on sounds emitted from wind turbines
- Noise levels of small residential wind turbines:

Dept of Energy's Consumer Guide on Small Wind Turbines
http://apps1.eere.energy.gov/consumer/your_home/electricity/index.cfm/mytopic=10930
Comparable sounds to wind turbines

- Wind Turbine Noise Issues: A white paper prepared by Renewable Energy Research Laboratory, U of Massachusetts, 2004: http://www.town.manchester.vt.us/windforum/aesthetics/WindTurbineNoiseIssues.pdf

4. Are there health effects to the levels of sound heard by wind turbines?
According to a 2003 Swedish EPA review of noise and wind turbines:
"Interference with communication and noise-induced hearing loss is not an issue when studying effects of noise from wind turbines as the exposure levels are too low."

In my review I found no evidence in peer-reviewed medical and public health literature of adverse health effects from the kinds of noise and vibrations heard by wind turbines other than occasional reports of annoyances, and these are mitigated or disappear with proper placement of the turbines from nearby residences. Most studies showing some health effects of noise have been done using thresholds of 70 dBA or higher outdoors, much higher than what is seen in wind turbines.

Sleep disturbance is another commonly raised concern, and the WHO guidelines for community noise recommend that nighttime outdoor noise levels in residential areas not exceed 45 dBA, which is consistent with Maine law.

Sources:

- Noise Annoyance from Wind Turbines – A Review 2003 Sweden Environmental Protection Agency
  http://www.barrhill.org.uk/windfarm/noise/10%20pederson.pdf
  This study found no evidence of health problems, reviews the variety of noise regulation laws in place in Europe
- British Medical Journal 2007 Swedish Study (Eja Pedersen)
  http://oem.bmj.com/cgi/content/full/64/7/480?ijkey=b1a1ae4a98c9453315a90941395e0a05262aca53
  Survey in Sweden of residents near wind turbines found annoyance increased with increased sound pressure levels (SPLs), and increased annoyance was associated with lower sleep quality and negative emotions.
- Noise Pollution: Non-Auditory Effects on Health, 2003
  http://bmb.oxfordjournals.org/cgi/content/full/68/1/243
- World Health Organization Community and Occupational Noise
  http://www.who.int/mediacentre/factsheets/fs258/en/
- World Health Organization 2002 Technical Meeting on Relationship Between Noise and Health
  http://www.euro.who.int/document/NOH/exposerespnoise.pdf Page 52 says that WHO standard is for nighttime noise not to exceed 45 dB.

5. What about low frequency noises (LFN)?

Some have pointed to LFN emitted from wind turbines as a possible source of adverse health effects. The reasons LFN are focused on include: LFN encounter less absorption as they travel through air than higher frequency sound, so they persist for a longer distance; the amount of sound transmitted from the outside to the inside of a building is higher with LFN; and some models for assessing impact of noise do not adequately include LFN.

Low frequency and infrasound (lower than what is perceptible) vibrations are very common in our background, and known to be emitted from many household appliances and vehicles as well as in neighborhoods near airports and trains. Exposure to very intense LFN can be annoying and may adversely affect overall health, though these levels appear to be more intense than what is measured from modern wind turbines.

The DEP noise regulations are based on the "A" frequency range of noise, which measures the higher frequency end of the noise spectrum, and is denoted with the term dbA. Because the dbA measurement deemphasizes noises from the lower end of the frequency spectrum (or "C" weighted noise, dbC), Maine DEP has been evaluating noise models and predicted noise levels from proposed wind power facilities using a handicapping system that requires an applicant to prove that dbA noise levels will be at such a level at property boundaries that they are effectively controlling for low frequency noises in the dbC range. The Land Use Regulation Commission has required monitoring for dbC noise at one of its recently permitted wind turbine facilities in order to evaluate dbC noise levels at property boundaries.

One recent study commonly cited by proponents of the belief of the physiological impacts of LFN is: "Tuning and sensitivity of the human vestibular system to low-frequency vibration", Todd, et al. Neuroscience Letters, 2008, which can be found at: http://www.ncbi.nlm.nih.gov/pubmed/18706484. This study indicates that the human vestibular system is sensitive, which means it shows a physiological response, to low-frequency and infrasound vibrations of -70 dB, indicating that human seismic receptor sensitivity of the vestibular system may possibly be on par with the frog ear. However, sensitivity, i.e. showing a physiological response, does not mean there are adverse effects.

Summary:

Reviews found in peer reviewed journals of the possible health effects of low frequency noise have not found evidence of significant health effects (several references are listed below).

Sources:

- Infrasound from Wind Turbines: Fact, Fiction, or Deception? Journal of Canadian Acoustics, Volume 34, no 2, 2006. http://www.wind.appstate.edu/reports/06-06Leventhall-Infras-WT-CanAcoustics2.pdf

"Infrasound from wind turbines is below the audible threshold and of no consequence. Low frequency noise is normally not a problem, except under conditions of unusually turbulent in flow air. The problem noise from wind turbines is the fluctuating swish. This may be mistakenly referred to as infrasound by those with a limited knowledge of acoustics, but it is entirely in the normal audio range and is typically 500Hz to 1000Hz. It is difficult to have a useful discourse with objectors whilst they continue to use acoustical terms incorrectly. This is unfortunate, as there are wind turbine installations which may have noise problems. It is the swish noise on which attention should be focused, in order to reduce it and to obtain a proper estimate of its effects. It will then be the responsibility of legislators to fi x the criterion levels, However, although the needs of sensitive persons may influence decisions, limits are not normally set to satisfy the most sensitive."

- Sources and Effects of Low-Frequency Noise 1996 http://scitation.aip.org/getabs/servlet/GetabsServlet?prog=normal&id=JASMAN000099000005002985000001&idtype=cvips&gifs=yes
  J. Acoust. Soc. Am. Volume 99, Issue 5, pp. 2985-3002 (May 1996)
- Characteristics of low frequency signals emitted from home electric appliances: http://sciencelinks.jp/j-east/article/200507/000020050705A0229983.php,
- Magnetic Emission Ranking of Electrical Appliances: http://rpd.oxfordjournals.org/cgi/content/abstract/ncm460v1)
- International Meeting on Low Frequency Noise and Vibration and Its Control, the Netherlands, 2004 http://www.viewsofscotland.org/library/docs/LF_turbine_sound_Van_Den_Berg_Sep04.pdf

6. What are the health benefits to wind turbines?

- There are tremendous potential health benefits to wind turbines, including reductions in deaths, disability, and disease due to asthma, other lung diseases, heart disease, and cancer. Maine has among the highest rates in the country of asthma and cancer.
- Wind turbines mean less dependency on foreign oil and coal that contribute to global warming and pollution (coal produces carbon dioxide, acid rain, smog, particulate pollution, carbon monoxide, and mercury), which in turn contribute to the diseases above.
- According to the Maine DEP, if Maine generated 5% of its electricity from wind power, there would be significant pollution cuts:
  - 464,520 tons per year of CO_2
  - 252 tons per year of SO_2
  - 147 tons per year of NO_x

7.What about a moratorium on wind turbine projects?

- I do not find evidence to support a moratorium on wind turbine projects at this time. The articles cited by those who are in favor of a moratorium are either from non-peer reviewed journals (though some are labeled as "peer reviewed") or are misinterpreted analyses from peer reviewed journals.

- If there is any evidence for a moratorium, it is most likely on further use of fossil fuels, given their known and common effects on the health of our population.

Basic Wind Turbine Noise-Related Resources:

- US Dept of Energy's New England Wind Power Website on Wind Turbine Sound – this has a good summary and links to references http://www.windpoweringamerica.gov/ne_issues_sound.asp
- Massachusetts DEP Regulations http://www.nonoise.org/lawlib/states/mass/mass.htm
  "A source of sound will be considered to be violating the Department's noise regulation (310 CMR 7.10) if the source: Increases the broadband sound level by more than 10 dB(A) above ambient, or Produces a "pure tone" condition - when any octave band center frequency sound pressure level exceeds the two adjacent center frequency sound pressure levels by 3 decibels or more. These criteria are measured both at the property line and at the nearest inhabited residence. Ambient is defined as the background A-weighted sound level that is exceeded 90% of the time measured during equipment operating hours. The ambient may also be established by other means with the consent of the Department."
- Ongoing Research is being done by the US Dept of Energy Wind Turbine Aeroacoustic Research: http://www1.eere.energy.gov/windandhydro/wind_research_enable.html#research
  "Turbine noise can be caused by rotor speed, blade shape, tower shadow, and other factors. The program is sponsoring both wind tunnel and field tests to develop a noise prediction code that turbine manufacturers can use to ensure that new rotor designs and full systems aren't too noisy. This is especially true for high-growth U.S. markets for small wind turbines that will demand quieter rotors, especially when turbines are sited in residential neighborhoods. Small turbines operate at high rotational speeds and tend to spin even if they are furled (pointed out of the wind).
- **Background Information on Noise:**
  http://www.osha.gov/dts/osta/otm/noise/health_effects/physics.html
  http://www.ccohs.ca/oshanswers/phys_agents/noise_basic.html
  http://www.phys.unsw.edu.au/jw/dB.html
  The decibel (**dB**) is used to measure the intensity of sound. It uses a logarithmic scale and describes a ratio where 0 is at the threshold of human hearing. When measuring sound, filters are usually used. The A scale filter results in sound level meters called dBA that are less sensitive to very high or very low frequencies. The C filter provides more of a measurement of low frequency noise.

Exhibit 27

Health Sciences

Exponent®

Evaluation of the Scientific Literature on the Health Effects Associated with Wind Turbines and Low Frequency Sound

Exponent®

Evaluation of the Scientific Literature on the Health Effects Associated with Wind Turbines and Low Frequency Sound

Prepared for

Wisconsin Public Service Commission
Docket No. 6630-CE-302

Prepared by

Mark Roberts, M.D., Ph.D.
Jennifer Roberts, Dr.PH, MPH
Exponent
185 Hansen Court
Suite 100
Wood Dale, Illinois 60191

October 20, 2009

0903940.000 F0T0 0809 JR03

Contents

List of Figures 5

List of Tables 6

Executive Summary 7

Overview of Epidemiology 8

Epidemiology, Association, and Causation 10

Peer Review Process 13

Public Health Issues 16

Precautionary Principle 19

Background on Infrasound and Low Frequency Sound 21

Infrasound 23

Low Frequency Sound 24

Background on Wind Turbines and Noise 27

Evaluation of Scientific Literature on Health Effects 29

Applicability and Utility 30

Soundness 31

Clarity and Completeness 31

Uncertainty and Variability 32

Evaluation and Review 32

Final Included Literature 33

Health Effects of Infrasound and Low Frequency Sound 34

Human Effects 34

Annoyance 38

Disease vs. DIS-ease 39

Limitations of Scientific Literature 40

Conclusions 42

References 45

Appendix A 51

Final Literature 51

List of Figures

Figure 1. The Scientific Process 11
Figure 2. The Scientific Method 12
Figure 3. Peer Review Process 14
Figure 4. Normal Equal-Loudness Level Contours 23
Figure 5. Horizontal Axis Wind Turbine 28

List of Tables

Table 1.	Risk Perception Factors For the Acceptability of Risk	18
Table 2.	Human Sound Intensity Levels	22
Table 3.	Sound Frequency Spectrum	24
Table 4.	Literature Search Queries	29
Table 5.	Applicability and Utility Ranking System	30
Table 6.	Soundness	31
Table 7.	Clarity and Completeness	31
Table 8.	Uncertainty and Variability	32
Table 9.	Evaluation and Review	32

Executive Summary

This white paper presents a review of the human health effects associated with infrasound and low frequency sound, preceded by an introduction to the basic concepts of epidemiology, causation, the peer review process, the science of public health, and the precautionary principle.

The goal of this white paper was to highlight key points regarding the health concerns of those involved with the positioning of wind turbines, rather than an in-depth review of the science of sound. The research involving sound is massive in its depth and breadth and is expanding daily. Research on health effects associated with human exposure to sound has evolved from the study of physical damage to the study of psychological and other effects, from ringing in the ears to non-specific physical symptoms. Early research in low frequency noise exposures is difficult to evaluate due to the diversity of the exposure and non-specific nature of the reported health effects. As of this review, there has not been a specific health condition documented in the peer reviewed published literature to be classified as a disease caused by exposure to sound levels and frequencies generated by the operation of wind turbines. That does not mean that there cannot be an effect. Numerous scientific papers document physiological responses to low frequency sound, but the majority of these effects are consistent with human response to environmental stimuli of varied nature and at higher decibel levels than produced by wind turbines. One of the most prominent non-physiological effects noted across the gamut of scientific as well as lay press literature is the annoying qualities of sound as was so vividly pointed out in one of the discussions when it was said that "one man's music is another man's unbearable noise." Annoyance is a normal response and is not predictable based on the sound level below the painful level. It is clear that some people respond negatively to the noise qualities generated by the operation of wind turbines, but there is no peer-reviewed, scientific data to support a claim that wind turbines are causing disease or specific health conditions. Annoyance regarding the wind turbines is an elusive factor that could underlie a majority of the health complaints being attributed to wind turbine operations.

Overview of Epidemiology

Epidemiology is the study of the distribution and determinants of health events in populations (Last JM. 2001). The key elements of epidemiology are comparisons of health outcomes and exposures between populations (which allows for the calculation of relative risk estimates) and the careful evaluation of underlying determinants that may affect the outcome of comparisons of the study populations (bias and confounding). The study of health claims related to wind turbines is an excellent example of the potential influence of both bias (voluntary and involuntary exposures) and confounding (health outcome potentially related to direct and indirect exposure).

The scientific body of knowledge relative to a particular disease often starts with observations by clinicians (case reports and case series). These reports are not analytical studies because they have no comparison group or other means to test for associations. Case reports and reports of series of cases help generate scientific hypotheses; however, they cannot be used in testing for association or causation (Checkoway H. 2004). Surveys of only those persons claiming an effect give only one part of the total equation needed to assess the magnitude of risk associated with living near wind turbines. A collection of observations, no matter how well documented, are not sufficient to prove an increased risk, but instead are a first step in the scientific process. One must rely upon peer reviewed, published studies that are designed to reduce bias and confounding as much as possible.

The two most common types of analytical epidemiologic studies used to evaluate potential disease causation are cohort studies and case-control studies. In cohort studies, the researcher identifies two groups of individuals: individuals who have been exposed to a substance considered a possible cause of disease (“exposed” group) and individuals who have not been exposed (“unexposed” or “comparison” group). The researcher then follows both groups for a length of time and compares the rate of disease among the exposed individuals with the rate of disease among the unexposed individuals. The researchers determine whether there is an association between the exposure and the disease by calculating a relative risk (RR), which divides the rate of disease among the exposed by the rate of disease among the unexposed, with a value statistically greater than 1.0 indicating a positive association. One type of cohort study is a standardized mortality (incidence) ratio study (SMR/SIR). In SMR/SIR studies of occupational groups, the number of observed cases for a particular occupational group is compared to the number one would expect for that group based on rates in the general population. These studies divide the observed number of cases by the expected number of cases, with a value statistically greater than 1.0 indicating a positive association.

In case-control studies, the researcher begins with a group of individuals who have the disease (cases) and then selects a group of individuals who do not have the disease (controls). The researcher then compares the case and control groups looking for differences in past exposures. An association is measured by dividing the odds of exposure among the diseased by the odds of exposure among the non-diseased, with a value statistically greater than 1.0 indicating a positive association.

Another type of epidemiologic study is a proportionate mortality (incidence) ratio study (PMR/PIR). PMR/PIR studies compare the proportions of selected causes of death or disease incidence in the exposed study group to the proportion in the unexposed study population, with a value statistically greater than 1.0 indicating a positive association.

No matter the study design, the researcher applying epidemiological principles and the reader of the studies must have a clear understanding of what constitutes the "disease" being studied. The description of the disease has to be sufficiently specific and described such that the comparisons are truly comparing "like to like." In the case of health complaints related to wind turbines, there is a lack of specificity as to the health complaints. A disease or group of symptoms classified as "Wind Turbine Syndrome" has not been adopted by the medical community. The underlying complaint of annoyance is in and of itself not a disease or a specific manifestation of a specific exposure but instead a universal human response to a condition or situation that is not positively appreciated by the human receptor. Annoyances are highly variable in type (noise, smell, temperature, taste, vision) and vary from person to person. One can be annoyed by the action of others, as well as their own individual actions. Thus, "annoyance" is not a disease but a universal human response that is highly non-specific. In conclusion, it has been found that there is a lack of epidemiologic research studies showing an association between health effects and exposure to noise at low frequency in combination with low sound pressure (dBA) generated by wind turbines.

Epidemiology, Association, and Causation

Historically, there have been careful clinical observations (case reports and series) that have stimulated a number of now-classic epidemiology research efforts that have identified important associations and ultimately the determinants of causal relationships. There have also been case reports identifying associations that did not hold up under epidemiological scrutiny, for example, those associating blunt force trauma and cancer. For this reason, case studies cannot be used to determine causation. A causal association can only be established by the evaluation of well designed and executed epidemiologic studies.

A landmark discussion of the process of moving from a disease being associated with a risk factor to a point where the scientific community is comfortable attributing causation to a risk factor was put forth by Sir Austin Bradford Hill in 1965. It was during this time that a number of papers, including the Surgeon General Report issued in 1964, began to more formally delineate the scientific reasoning process that justifies a conclusion that observed associations between an exposure and a disease are the result of a causal relationship between the exposure and the disease. Key statements from scientists during that time include the following:

> "Disregarding then any such problem in semantics we have this situation. Our observations reveal *an association between two variables, perfectly clear-cut* and beyond what we would care to attribute to chance. What aspects of that association should we especially consider before deciding that the most likely interpretation of it is causation?" [italics added] (Hill AB. 1965). Hill's nine criteria for causation have been described in a number of ways. They are commonly referred to as strength, consistency, specificity, temporality, biological gradient, plausibility, coherence, experiment, and analogy (Hill AB. 1965).
>
> *"If it be shown that an association exists*, then the question is asked, 'Does the association have a causal significance?' … To judge or evaluate the causal significance of the association between the attribute or agent and the disease, or effect on health, a number of criteria must be utilized…" [italics added] (Bayne-Jones S et al. 1964).

Finally, it should be noted that greater weight can be provided to the strength of an association when several epidemiologic studies performed by different researchers arrive at the same conclusions. And as a final step, researchers often submit their work for publication which then typically undergoes a peer review process for completeness and scientific soundness.

Figure 1. The Scientific Process

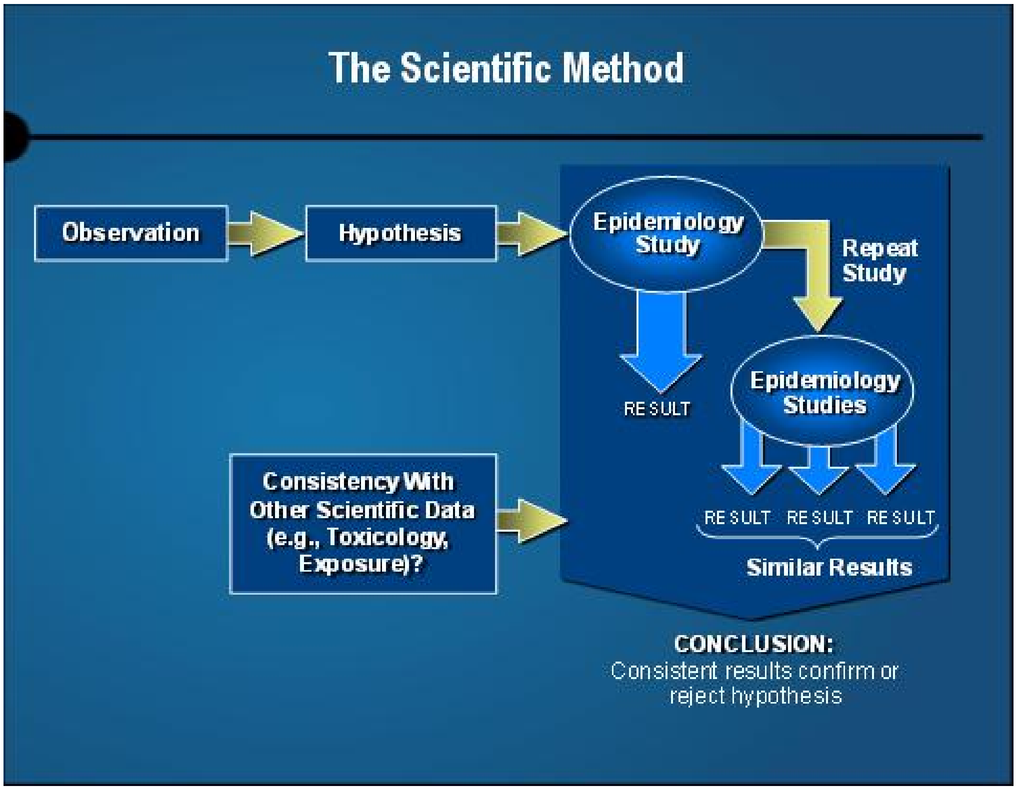


Figure 2. The Scientific Method

Peer Review Process

According to the Centers of Disease Control and Prevention (CDC), the peer review process is an "independent assessment of the scientific merit of research by panels of experts who provide written assurance that their reviews are free of real or perceived conflicts of interest. Results of the peer review process should therefore be without inherent bias and can be viewed as fair and just…" (CDC 2009).

Publication in a peer-reviewed journal remains the standard means of disseminating scientific results and has been since 1665, when the first recorded peer review process was performed at The Royal Society by the founding editor, Henry Oldenburg (UK Parliament and House of Commons 2004). Consequently, publications that have not undergone a peer review are likely to be regarded with skepticism and doubt by scholars and professionals.

Generally, the peer review process uses anonymity and employs a double-blind process whereby the authors and peer reviewers remain unknown or blinded to each other. Reviewers are often required to disclose conflicts of interest. The use of anonymity preserves the integrity of the peer review process and discourages favoritism shown by colleagues, friends, or relatives. Although not fool-proof, the peer review process can also maintain and enhance the quality of work by detecting flaws, plagiarism, fraud, unsound science, or personal views. Hence, the peer review process fosters scholarship and encourages authors to meet the accepted standards of their discipline.

The typical peer review process for scientific journals begins with the author submitting a manuscript. The editor of the journal reviews the article and determines whether or not the article is appropriate for the journal. If the article is determined to be appropriate, the editor assigns peer reviewers to read and critique the work. The reviewers then submit their comments to the editor and a decision is made with respect to the publication status of the article: (1) accept for publication; (2) accept for publication with modifications; (3) reject for publication (Figure 3). An average acceptance rate for publication in peer reviewed journals has been reported to be between 25% and 50%, although journals such as New England Journal of Medicine and the British Medical Journal have been known to be much lower (Elsevier 2009).

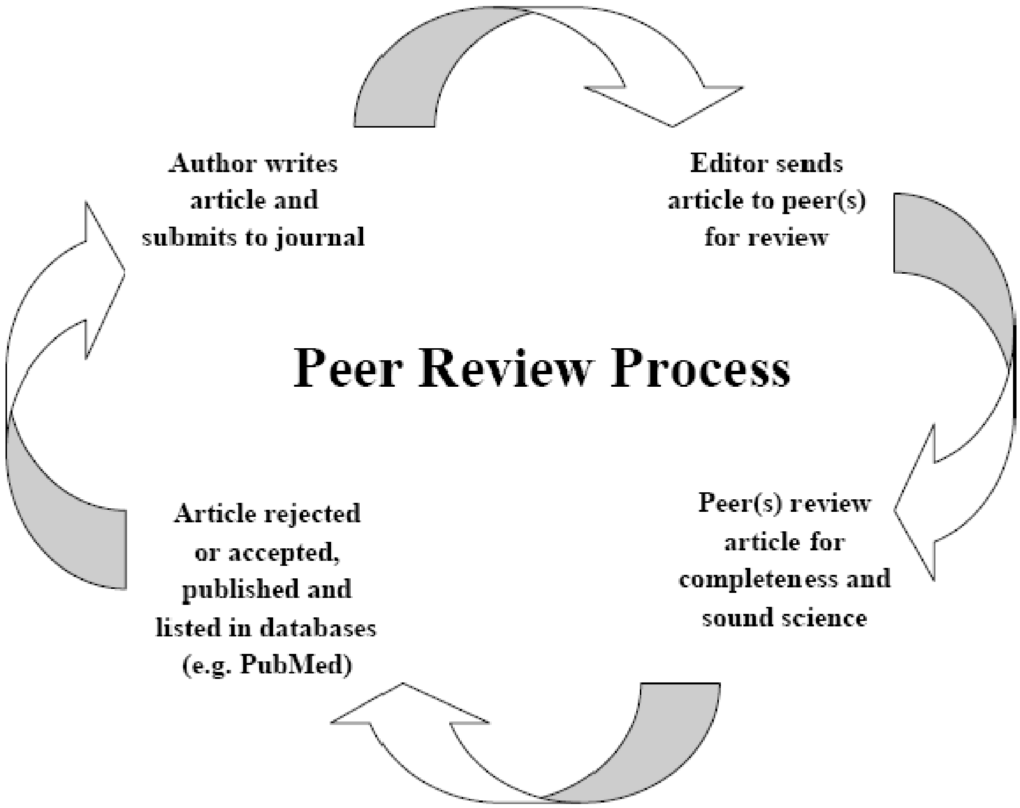


Figure 3. Peer Review Process

A thorough and complete peer review gives the reader some confidence that the article meets appropriate scientific rigor. Seldom does an article submitted for publication get accepted without addressing issues brought to light in the peer review process. At one point in time, "publication" of a scientific work in a peer-reviewed journal was a stamp of quality; however, in today's world, opinions, ideas, and hypothesis can be "published" by a number of methods (websites, blogs, and media articles), without the scientific rigor of critical peer review.

The key aspect of the peer review is a critical appraisal of the research, a continuous challenge of the scientific hypothesis and comparison with the body of scientific knowledge relevant to that research. While the process can never be totally free of bias (we all have opinions that influence our thinking), a clear effort to seek out those who are not directly connected to the researcher(s) is an important first step. The second part of the review process and assessment of the scientific merit of the research is the publication of the research so that others interested in the topic can benefit from the knowledge, apply it in their research efforts, or learn from the mistakes of other researchers. Opinion pieces, media interviews, court testimony, and testimony before legislative bodies, while informative, do not have the weight, standing, or status of peer-reviewed published scientific work. Unfortunately, because of their high visibility, emotional nature, and understandability, these sources outside of the peer-reviewed journals are often perceived as being of high reliability without having the benefit of careful scrutiny and response from those most knowledgeable in the research field being discussed. For example, Dr. Nina Pierpont has received a considerable amount of attention regarding the upcoming publication of her book, Wind Turbine Syndrome: A Report on a Natural Experiment, which uses non-traditional references such as newspaper articles and television interviews. In addition, this book is apparently being published by a publishing company which will have only one published book (this one) and that consists of an editorial board of which Dr. Pierpont and her husband make up two of the members.

Public Health Issues

“Public Health” refers to the overall wellbeing of a group of people. The description of Public Health incorporates the science of identifying major effectors of health status of a population and taking measures to prevent disease, prolong life, and promote health through private, academic, governmental, and corporate efforts. A physician treats a patient and considers the family, whereas a public health professional “examines” populations and takes broader actions to improve the health of the individuals that make up the population. Public health efforts primarily focus on prevention rather than treatment of disease. The United Nations' World Health Organization defines health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.” This is a lofty goal to strive for, but if public health history is any indication of things to come, as we conquer the leading causes of disease, new diseases become more prominent.

There have been major successes in Public Health (e.g., smallpox eradication, control of malaria, nationwide immunization programs to prevent vaccine-preventable diseases, chlorination of municipal water supplies). However, for every public health accomplishment, there have been new health challenges related to lifestyle issues and changing health expectations. According to the U.S. Census Bureau, the final data for 2003 indicated that life expectancy at birth for the total population in America has reached an all-time high level of 77.5 years. This is up from 49.2 years at the turn of the 20th century. Record-high life expectancies were found for white females (80.5 years) and black females (76.1 years), as well as for white males (75.3 years) and black males (69.0 years). With this increase in life expectancy, there has also been an expectation of a life as free of health concerns as possible. Unfortunately, this public health progress has brought the realization of the health effects of the very activities that helped extend our lives (e.g. chlorination of drinking water, mercury-based preservatives in some vaccines).

Along with these advances has come the development of a very expansive information system called the internet, a growing environmental awareness, and a growing expectation of a long and healthy life. The advances that have been made to support a growing and aging population have brought risks with them such as automobiles, massive highway systems, and large-city problems such as crime and pollution. These more familiar risks have been generally been accepted or forgotten, but new risks are less tolerated. Herein lays the difficulty of public health today. Population growth and societal demands have pressured public health professionals to provide guidance in the assessment of risks of new technological advancements and to reduce or eliminate risk.

While assessing a level of risk may be done in a sterile, scientific fashion, assessing the acceptability of that risk level risk becomes a preference choice. A community may choose to accept a level of risk that an individual finds unacceptable. That discrepancy between community and individual acceptability moves the decision from a public health issue to a political and social decision. Public health can bring science to the discussion, but in the end, a decision that weighs all the factors must be made for the larger group as a matter of policy.

In addition to the debate over what levels of risk are acceptable or tolerable, there is also the pressure of clearly delineating between actual risks and perceived risks. Once the analysis of the risk assessment is completed, the responsibility of the risk manager is to explain to the public and all involved stakeholders. A common perception among risk assessors and managers is that individuals who have a lack of information or information that is distorted about a risk are often subjected to unreasonable fears (Vertinsky I. And Wehrung D. 1989). These fears typically are not calmed even when accurate information is provided and unfortunately many expect a level of certainty from science that is almost always impossible to achieve. Several identified risk perception factors have been found to dictate the acceptability of risk regardless of the presentation of science which quantifies and qualifies the actual risk (Table 1).

Table 1. Risk Perception Factors For the Acceptability of Risk

"Acceptable" Risk	**"Unacceptable" Risk**
Controllable	Uncontrollable
Voluntary	Involuntary
Not Dread	Dread
Natural	Man-made
Beneficial	Of Little or No Benefit
Immediate Effects	Delayed Effects
Not Global Catastrophic	Global Catastrophic
Consequences Not Fatal	Fatal Consequences
Equitable	Inequitable
Affects Adults	Affects Children
Low Risk to Future Generations	High Risk to Future Generations
Easily Reduced	Not Easily Reduced
Risk Decreasing	Risk Increasing
Doesn't Affect Me	Affects Me

Reference: (Slovic P. et al. 1982)

There are many examples in public health where the assessed risk of an event or environmental conditions is perceived differently than an interested segment of the population. In these situations, the public health officials must make the best decision they can using the scientific method. There comes a point where a decision must be made for the good of the largest segment of the population. The ramifications and effectiveness of these decisions are not always seen as positive from a historical perspective. Take for example the "Swine Flu" immunization program of 1976 under the Ford Administration. That program resulted in a segment of the immunized population developing Guillain-Barre Syndrome. The same sort of decision process is being carried out now as public health officials embark on a campaign to protect the population for an H1N1 Pandemic. Part of the analysis included an estimation of how many persons can be expected to develop Guillain-Barre Syndrome from the new vaccine.

Societal decisions, like Public Health decisions, must be made with the benefit of the best, most sound information. Few historical efforts to advance health or societal development have come without concerns from many segments of the population and a few that may be affected.

Precautionary Principle

Some groups and organizations have addressed the acceptability of risk by adopting a position or philosophy that when risk may exist, but the level of risk is in doubt, actions should be taken to avoid the risk much in tune with the idea that "if in doubt, don't." Similarly, a process potentially producing risk is "guilty until proven innocent." This view is commonly referred to as the "precautionary principle." While seemingly attractive, the precautionary principle fails to acknowledge that in reality, every human activity has risk, and the balance between the potential risk and the value of that activity depends on the individual.

The precautionary principle is an attempt to set a goal for environmental planning and response to perceived health threats based less on science and more on the social basis of the issue being examined. While the principle was developed during the discussion of environmental issues, it can be applied to any function of mankind and all our activities. It is a high standard to compare activities of the earth's inhabitants based on social values and less on science. There are few arguments when a solid body of science has been amassed showing an association and meeting the criteria for "causation." The difficulty arises when new discoveries and applications are evaluated on what effect they "could have" rather than on the scientific data obtained during they development and regulatory review. The philosophy of "new is not necessarily good" and the "fear of the unknown" result in an almost instant increased level of concern in a segment of most populations. This is partially due to the easy access to information provided by media and the internet, the risk aversion that has become prevalent in our society, and the pressures of our evolving societies. The precautionary principle should be applied in the light of the science of the day and with the understanding that no scientific study of a sample of the population can "prove" there is no association between a technology and a perceived health threat.

The precautionary principle has evolved in both the legal and social context to the point of being prominent in national and international treaty and agreements. While the principle incorporates an extremely cautious approach, it embodies concepts that we have embraced in our daily lives e.g. “an ounce of prevention is worth a pound of cure,” “look before you leap,’ and “better safe than sorry.” On an individual basis, the precautionary principle is relatively easy to apply, and the risk and benefit directly applies to the individual. Application of the precautionary principle at a community or national level involves societal decisions that may include legal, economic, and political aspects. The application of the scientific process and sharing of knowledge gained through scientific investigation can provide objective information to assist in these decisions. Science will reduce the uncertainty, but not eliminate it entirely. Society must decide what is an acceptable level of risk (e.g. allowing passengers to fly in airplanes without parachutes, allowing people to ride ferryboats without wearing lifejackets). Delineation and comparison of risk is a scientific process, but determination of acceptable risk is beyond the realm of science.

Background on Infrasound and Low Frequency Sound

Sound is an energy generated by a source (e.g., bell), transmitted through a medium (e.g., air), and received by a receiver (e.g., human ear). Sound travels from the source in the form of waves or fluctuations of pressure within the medium. As the human ear detects these vibrating waves, they are translated into electrical signals that are transmitted to the brain for decoding.

Sound is perceived and recognized by its loudness (pressure) and pitch (frequency). The indicator of loudness is the decibel (dB), which is a logarithmic ratio of sound pressure level to a reference level.[1] With a logarithmic scale, sound levels from two or more different sources cannot be arithmetically added together to determine a combined sound level. Specifically, the dB is a logarithmic unit of measurement that expresses the magnitude of a physical quantity such as power or intensity relative to a specified reference level. Human hearing of sound loudness ranges between 0 dB (threshold of sound for humans) and 140 dB (very loud and painful sound for most humans) (NMCPHC 2009; NASD 1993) (Table 2). Not all sound pressures are perceived as being equally loud by the human ear due to the fact that the human ear does not respond equally to all frequencies. The frequency range of human hearing has been found to be between 20 Hz and 20,000 Hz for young individuals with a declining upper frequency range correlating with increasing age (Berglund B. et al. 1996). The frequency of sound is expressed in Hertz (Hz)[2] which is equal to 1 cycle per second. The sound perception, "hearing," for humans is less sensitive to lower frequency (low pitch) and higher frequency (high pitch) sounds. As a result, the human ear can most easily recognize sounds in the middle of the audible spectrum, which is ideally between 1 kHz to 4 kHz (1,000 to 4,000 vibrations per second) (UNSW 2005). As a result, devices used to measure sound (sound meters[3]) are

---

1 Reference Level - A special value of a quantity expressing the degree of modulation of a recording medium, in terms of which other degrees of modulation are expressed, usually in decibels (IEC).

2 Hertz (Hz) - A unit of frequency defined as the number of cycles per second (1 Hz equals 1 cycle per second). Hertz can be used to measure any periodic event within a sinusoidal context, such as radio and audio frequencies (IEC).

3 Sound Level Meter – Instrument used for the measurement of sound level with a standard frequency weighting and a standard exponential time weighting (IEC).

designed with filters that have a response to frequency similar to human. The A scale is the most commonly used sound level filter and the sound pressure level is given in units of dB(A) or dBA. With the A weighting filter, the sound level meter is less sensitive to very high and very low frequencies. Sound measurements made on the C scale, which are linear over several octaves and suitable for subjective measurements of very high frequency sound levels, are expressed as dB(C) or dBC. Another weighting filter, the B scale, is a rarely used intermediate between the A and C scales (UNSW 2005).

Table 2. Human Sound Intensity Levels

Decibel Level (dB)	**Source**
140	Threshold of pain: gunshot, siren at 100 feet
135	Jet take off, amplified music
120	Chain saw, jack hammer, snowmobile
100	Tractor, farm equipment, power saw
90	OSHA limit - hearing damage if excessive exposure to noise levels above 90 dB
85	Inside acoustically insulated tractor cab
75	Average radio, vacuum cleaner
60	Normal conversation
45	Rustling leaves, soft music
30	Whisper
15	Threshold of hearing
0	Acute threshold of hearing

Reference: (NASD 1993)

In the 1930s, researchers Fletcher and Munson conducted experiments on the response of the human ear and the relationship between sound frequency and pressure (Fletcher H. and Munson WA. 1933). Fletcher and Munson developed curves to approximate this relationship which were then revised by the International Organization for Standardization (ISO) and are now referred to as Normal Equal-Loudness Level Contours. Hence, an equal-loudness contour is a measure of the sound pressure (dB) level required to cause a given loudness for a listener as a function of frequency (Hz) (Figure 2).

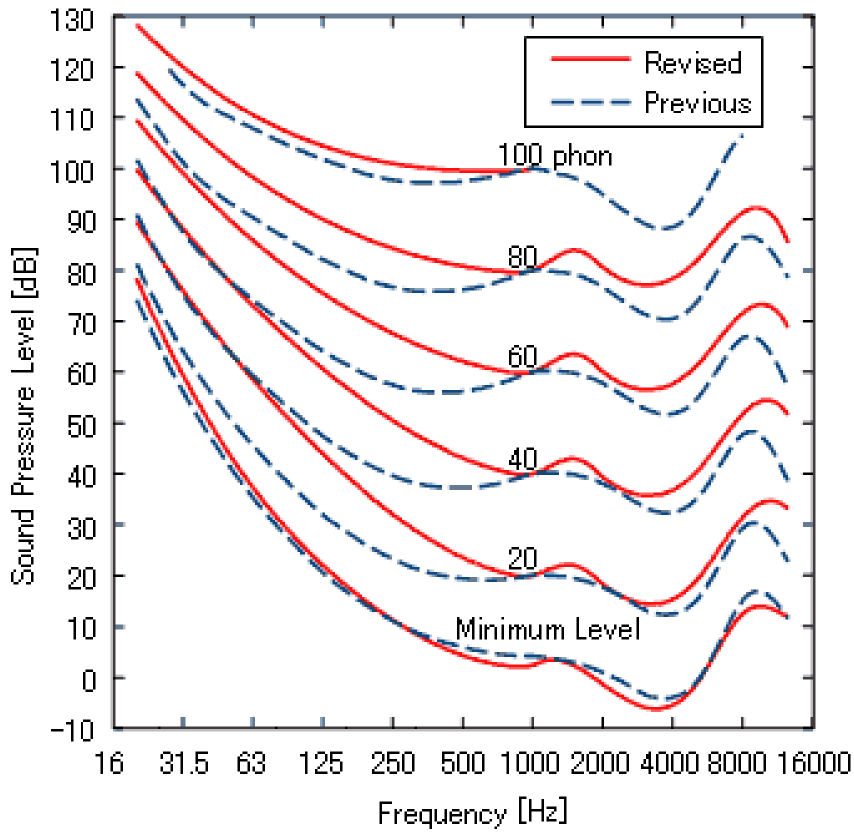


Figure 4. Normal Equal-Loudness Level Contours

Infrasound

Infrasound is generally accepted to be sound between 0 Hz and 20 Hz (Leventhall G. 2007) (Table 3). Infrasound occurs when the frequency of acoustic oscillations (Hz) is lower than the low frequency limit of audible sound, which is approximately 16 Hz according to the International Electrotechnical Commission (IEC) (Leventhall 2007). Although the human hearing threshold has been found to be as low as 4 Hz in an acoustic chamber, a level of 20 Hz, arises from the lower frequency limit of the Normal Equal-Loudness Level Contours. At 1,000 Hz, the contour ranges a span of 100 dB, but at lower frequencies the contours are grouped more closely together. Thus, the change of grouping at 20 Hz or below leads to a greater rate of growth in loudness with increasing level for frequencies in the infrasound region (Leventhall G. 2007).

Although it has been believed that infrasound is inaudible, that belief has been determined to be a misconception (Berglund B. et al. 1996; Leventhall G. 2007; Maschke C. 2004). Infrasound at frequencies lower than 20 Hz are audible at very high levels and these sounds may occur from many natural sources, such as meteors or volcanic eruptions. Anthropogenic (i.e., human-caused) sources, which often are the predominant type of source, can also generate infrasonic noise and include machinery, ventilation, or large combustion processes (Berglund B. et al. 1996; Leventhall G. 2007; Sienkiewicz Z. 2007). In addition, the human body has multiple sources of sound. For example, heart sounds are in the range of 27 to 35 dB at 20-40 Hz (Sakai A. et al. 1971) and lung sounds are reported in the range of 5-35 dB at 150-600 Hz (Fiz JA. Et al. 2008).

The threshold of human hearing has been found to be well in the range of infrasound, but it has been suggested that detection does not occur through hearing in the normal sense. Infrasound detection has been theorized to result from nonlinearities of conduction in the middle and inner ear which produces a harmonic distortion in the higher frequency range (Berglund B. et al. 1996). Also, the definition of infrasound detection has not only considered direct hearing, but also subjective reactions such as annoyance as well as detection occurring through the resonance of other body organs (Berglund B. et al. 1996).

Table 3. Sound Frequency Spectrum

Frequency (Hz)				
0	**10**	**20**	**100/250**	**20,000**
Infrasound (With Body Resonance)	Infrasound	Low Frequency Sound	Non-Low Frequency Audible Sound	Ultrasound

Low Frequency Sound[4]

The low frequency sound range is approximately between 10 or 20 Hz and 100 or 250 Hz (Berglund B. et al. 1996). The setting of a lower and upper limit of a continuum has been

[4] The word "sound" and "noise" are terms that can be used interchangeably. "Noise" often implies an unwanted sound. The use of "noise" also depends on the intensity of the sound or the complex temporal pattern. The classification of a "sound" or "noise" may also depend of cultural factors, the individual, or the time and circumstance (Berglund B. et al. 1996).

problematic due to the arbitrary nature of setting those limits. However, it has generally been accepted that low frequency sound is below 100 Hz (Takahashi Y. et al. 2005) or 200 Hz (Maschke C. 2004). Due to the long wavelengths of low frequency noise, it has been known to travel long distances and pass through walls and windows with little attenuation (Waye K. 2004).

With respect to reception, the hearing sensitivity of the human ear declines at low frequencies (Takahashi Y. et al. 2005). Occupational and residential activities have been found to be a common source of low frequency sound (Berglund B. et al. 1996). Many sources of low frequency noise are transportation vehicles such as buses, trains, and some aircraft. Other stationary sources of low frequency noise include heating, cooling, or ventilation of buildings (Waye K. 2004). Low frequency sound possesses features that are not commonly shared by higher pitch noises.

A review of the literature related to sound indicates that there are uncertainties associated with the measurement and characterization of low frequency sound. As mentioned previously, the A scale is the most commonly used sound level filter (Sienkiewicz Z. 2007; Takahashi Y. et al. 2005; Takahashi Y. et al. 2001; Takahashi Y. et al. 1999). Furthermore, it was recommended that either a scale with a more appropriate response be developed and used for characterizing low frequency sound or that the details of the acoustic environment be provided for each exposure scenario (Sienkiewicz Z. 2007).

As mentioned previously, human hearing becomes less sensitive for decreasing frequency. In addition to the sensitivity of sound, the perceived character of that sound also changes at lower frequencies. The threshold[5] for hearing is standardized by ISO for frequencies down to 20 Hz, but there has been research and some agreement among investigators regarding a possible threshold for frequencies below this level (Moller H. and Pedersen CS. 2004). Men and women have the same hearing threshold with the standard deviation between individuals being

---

[5] Threshold - For a specified signal and method of presentation, amount in decibels by which the threshold of hearing for a listener, for either one or two ears, exceeds a specified standard threshold of hearing (IEC).

approximately 5dB. Furthermore, low frequency sound may be inaudible to some, but that same sound may be loud to others.

Background on Wind Turbines and Noise

There are two types of noise generated from wind turbines. One is a mechanical noise originating from the gearbox, generator, and yaw motors. The other type of noise, aerodynamic noise, originates from the flow of air around the components of the wind turbine (blades and tower) produces a “whooshing” sound in the range of 500 to 1000 Hz (Hau E. 2006). This type of noise is typically the dominant component of wind turbine noise because manufacturers have been able to reduce the mechanical noise to a level that is below the aerodynamic noise (Pedersen E. and Waye KP. 2004). However, the whooshing sound is highly variable and dependent upon mechanical as well as atmospheric conditions. Hence, the sound power levels reached by wind turbines are determined by the mechanical and aerodynamic specifications.

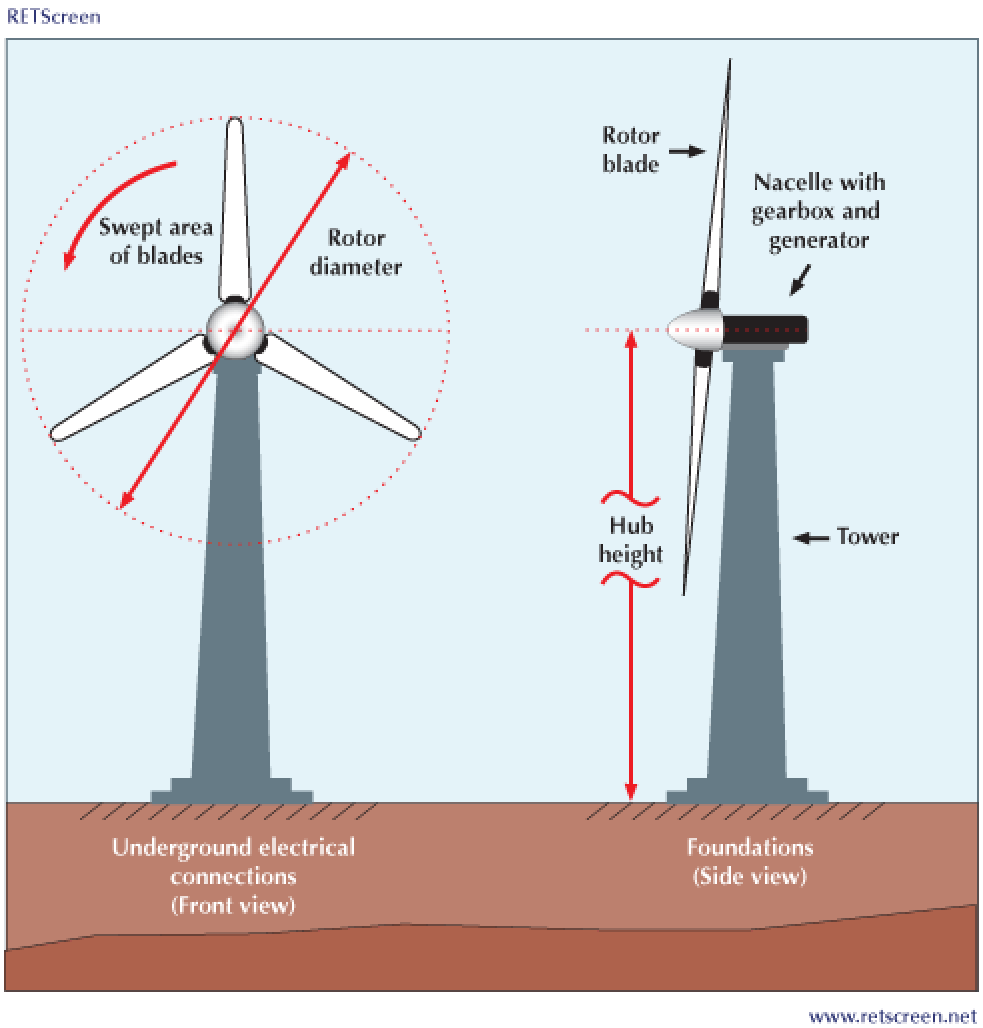


Figure 5. Horizontal Axis Wind Turbine

Evaluation of Scientific Literature on Health Effects

A thorough search was performed of the peer-reviewed scientific literature using the PubMed[6] search engine which is maintained by the United States National Library of Medicine. The purpose of the search was to identify literature that has addressed the known or unknown health effects associated with infrasound and low frequency sound. The following search criteria terms were used for each search query with some overlapping results.

Table 4. Literature Search Queries

Search Query	Number of Articles Found
Infrasound AND Health Effects	16
Low-Frequency Noise AND Health Effects	59
Low-Frequency Sound AND Health Effects	40
Wind Power AND Noise	18
Wind Turbines	20
Wind Turbines AND Noise	3
Total	**156**

In 2003, the U.S. Environmental Protection Agency (EPA) published a document entitled "A Summary of General Assessment Factors for Evaluating the Quality of Scientific and Technical Information" which outlined general assessment factors to evaluate the quality and relevance of scientific and technical information (U.S. EPA 2003). The assessment factors include (1) soundness; (2) applicability and utility; (3) clarity and completeness; (4) uncertainty and variability; and (5) evaluation and review. These factors use a weight-of-evidence approach that considers the information provided in an integrative assessment. These factors also take into account the quality and quantity as well as the strengths and weaknesses of the information. These EPA guidelines were used to evaluate the articles identified in this literature search.

[6] Pub Med is a searchable database that comprises more than 19 million citations for biomedical articles from MEDLINE and life science journals.

Applicability and Utility

The extent to which the information is relevant for the intended use, or how relevant the study is to current conditions of interest (U.S. EPA 2003).

With each identified article, the research and research subjects were ranked as a whole based on the applicability to the overall purpose of the literature search. The following ranking system was employed, and then we eliminated articles with a rank of one or two from further review (Table 6). These ratings and those used in later tables were also used in the appendix. Although it has been found in animal experiments, during the last 50 years, that high levels of low frequency noise and vibration can influence the respiratory rate, cardiac, digestive and central nervous systems, (Maschke C. 2004) animal studies were not reviewed in this white paper. At this time only human studies were reviewed and evaluated, which also eliminated articles with a rank of three. It was assumed that animal studies would not provide the necessarily applicability to effects of wind turbines on humans, thus resulting in an extrapolation layered with assumptions. Articles that were not written in the English language were also eliminated. Background research consisted of articles that reviewed infrasound and low frequency sound in general.

Table 5. Applicability and Utility Ranking System

Rank	Rank Description
1	No applicability at all
2	Limited applicability (e.g. *in vitro* studies)
3	Some applicability (e.g. animal studies)
4	Applicable (e.g. human studies)
5	Very applicable (e.g. human studies and wind turbines)
**	Background research

Soundness

The extent to which the scientific and technical procedures, measures, methods or models employed to generate the information are reasonable for, and consistent with, the intended application (U.S. EPA 2003).

The articles were evaluated based on whether or not the study purpose was reasonable and consistent with its design. If articles did not employ sound scientific theory or accepted approaches, such as the use of an adequate sample size or the validation of a survey instrument, they were graded accordingly.

Table 6. Soundness

Rank	Rank Description
1	Not sound (e.g. study instrument not validated)
2	Sound with limitations (e.g. useful research but not consistent with design)
3	Very sound (e.g. study reasonable and consistent with design)
**	Background research

Clarity and Completeness

The degree of clarity and completeness with which the data, assumptions, methods, quality assurance, sponsoring organizations and analyses employed to generate the information are documented (U.S. EPA 2003).

Articles were assessed for clarity and completeness and whether or not the results were clearly described and comparable to other study results. The description of the study design and methods was also assessed to determine if the description was clear enough for reproducibility.

Table 7. Clarity and Completeness

Rank	Rank Description
1	Several limitations
2	Complete with some limitations
3	Very complete (e.g. clear enough to be reproduced)
**	Background research

Uncertainty and Variability

The extent to which the variability and uncertainty (quantitative and qualitative) in the information or in the procedures, measures, methods or models are evaluated and characterized (U.S. EPA 2003).

The level of uncertainty and variability of the study methodology and results and how these uncertainties were handled were also evaluated. Potential sources of error and study bias were considered as well.

Table 8. Uncertainty and Variability

Rank	Rank Description
1	High uncertainty and variability
2	Medium uncertainty and variability
3	Low uncertainty and variability
**	Background research

Evaluation and Review

The extent of independent verification, validation and peer review of the information or of the procedures, measures, methods or models (U.S. EPA 2003).

Independent verification was measured by whether or not the methodology used and survey instruments were used on other similar, peer-reviewed studies. The consistency of the results with other relevant studies performed by the same or different authors was also accounted for in this analysis.

Table 9. Evaluation and Review

Rank	Rank Description
1	Low validation (e.g. no independent verification or similar results)
2	Medium validation (e.g. result consistent with same author)
3	High validation (e.g. results consistent in peer-review literature)
**	Background research

Final Included Literature

Of the original 156 articles identified, 21 were included for the literature review (Appendix A). Based on the previously outlined five assessment factors, the most relevant and scientifically appropriate articles were selected for this review. Many articles were excluded from this review due to the fact that the research focused in animal responses as opposed to human. Furthermore, with the exception of articles dealing with annoyance, articles were excluded if the sound studied was above the established range of low frequency sound.

Health Effects of Infrasound and Low Frequency Sound

Human Effects

It has been demonstrated that high levels of low frequency sound can excite body vibrations, such as a chest resonance vibration that can occur at a frequency of 50 Hz to 80 Hz (Leventhall G. 2007). These chest wall and body hair vibrations have also been shown to occur at the infrasonic range (Mohr GC. et al. 1965; Schust M. 2004). It is of interest to note that various body organs and physical activities of the human body produce low frequency, low amplitude sounds, some of which are key diagnostic tools for physicians (e.g., heart, lung, and gastrointestinal).

Vibroacoustic disease, a thickening of cardiovascular structures, such as cardiac muscle and blood vessels, was first described and documented by Castelo Branco *et al.* among airplane technicians, commercial and military pilots, mechanical engineers, restaurant workers, and disc jockeys for exposure to large pressure amplitude and low frequency (LPALF) sound (> or = 90 dB SPL, < or = 500 Hz) (Maschke C. 2004; Castelo Branco NA. and Rodriguez E. 1999). Castelo Branco *et al.* concluded that workers who were exposed to high level low frequency noise for more than 10 years exhibited extra-aural[7] symptoms such as thickening of heart valve issue (Castelo Branco NA. and Rodriguez E. 1999; Takahashi Y. et al. 2001; Maschke C. 2004). However, this association was not determined to be causally related and a dose response relationship was not established.

Takahashi *et al.* has explored the effects of acoustic excitation by measuring the resulting vibration (Takahashi Y. et al. 1999; Takahashi Y et al. 2001; Takahashi Y. et al 2005). In 1999, six male subjects were exposed to pure tones in the 20 Hz to 50 Hz frequency range, and vibration was measured on the subjects' chest and abdomen. There were 15 kinds of the low frequency noise stimuli (5 frequencies x 3 sound pressure levels) reproduced by loud speakers.

---

[7] Aural - Of or relating to the ear or to the sense of hearing

All of them were pure tones frequencies of 20, 25, 30.5, 40 and 50 Hz with each of the corresponding sound pressure levels of 100,105 and 110 dB (SPL).

It was found that measured noise induced vibration negatively correlated with the subject's body mass index and the researchers concluded that the health effects of low frequency noise depended on the physical constitution of the human body (Takahashi Y. et al. 1999). However, it was also concluded by the researchers that it was still unknown if or how vibrations measured on the body surface related to vibrations in the body's internal organs, and that no conclusions could be determined as to the possible chronic health effects caused by long term exposure to low frequency noise (Takahashi Y. et al. 1999). Similarly, in a later article, Takahashi *et al.* reported that low frequency noise (same frequency and sound pressure levels as previously reported) induced vibration measured on the chest was higher than the vibration measured on other parts of the body (Takahashi Y. et al. 2001). By taking this research a step further; Takahashi *et al.* examined the level of unpleasantness of human body vibration and low frequency sound (same frequency and sound pressure levels as previously reported). It was found through the use of a rough rating scale for subjective unpleasantness that there was a significant correlation between the measured body surface vibration induced by the low frequency noise and the rating of unpleasantness (Takahashi Y. et al. 2005). This finding was similar to research conducted by Inukai *et al*., who discovered that the slopes of the equal-unpleasantness level contours are very similar to those of the equal-loudness level contours. This similarity supported the fact that hearing sensation was an influential component in the perception of unpleasantness or annoyance among those exposed to low frequency noise (Inukai Y. et al. 2000; Takahashi Y. et al. 2005). This perception of unpleasantness was also determined to be independent of the audibility of the noise (Takahashi Y. et al. 2005). Inukai *et al*. also recognized the fact that the human psychological responses to low frequency noise, such as unpleasantness or annoyance, were based not only on hearing sensation, but also on three other factors: sound pressure, vibration, and loudness (Inukai Y. et al. 1986; Takahashi Y. et al. 2005).

In a general review of the effects of low frequency noise up to 100 Hz, Schust stated that the use of frequency weighting with an attenuation of low frequencies, such as G-weighting, was not appropriate for evaluating the health risk caused by low frequency noise (Schust M. 2004). Karprova *et al* (1970) ((5, 10 Hz / 100, 135 dB) for 15 minutes) and Slarve *et al*. (1975) (144 dB / 1 Hz - 20 Hz for 8 minutes) also indicated that study subjects reported aural complains after exposure to high level industrial infrasound in the range of 1 Hz to 20 Hz (Karpova NI. et al. 1970; Schust M. 2004; Slarve RN. and Johnson DL. 2009). Non-aural effects, such as a significantly increased diastolic blood pressure and decreased systolic blood pressure, were also mentioned after exposure to high levels of low frequency noise (125 dB, 16 Hz for 1 hour) (Danielsson A. and Landstroem U. 1985; Schust M. 2004). Karprova *et al* also reported complaints of fatigue, feelings of apathy, loss of concentration, somnolence, and depression following exposure to high levels of low frequency noise (5 Hz and 10 Hz (100 dB and 135 dB) for 15 minutes) (Karprova NI. et al. 1970; Schust M. 2004). Furthermore, the effects of low frequency noise among 439 employees working in offices, laboratories, and industries were also evaluated in another study. It was shown that there was a relationship between fatigue and tiredness after work and increasing low frequency noise. There were no employees that were exposed to low frequency noise with C-A differences greater than 20 dB (Schust M. 2004; Tesarz M. et al. 1997).

Ising *et al.* conducted a study that examined the effect of low frequency nighttime traffic noise by measuring saliva cortisol concentrations in children. Based on a previous study, the authors stated that the full spectrum of truck noise in the children's bedroom was at a maximum of 100 Hz (Ising H. et al. 2004; Ising H. and Kruppa B. 2004). It was found that the children under high noise exposure (8h = 54-70dB(A)) had a significantly increased morning saliva cortisol concentration compared to a control population, which indicated an activation of the hypothalamus-pituitary-adrenal (HPA) axis (Ising H. et al. 2004). This endocrine change was found to be an indication of restless sleep and a further aggravation of bronchitis in the children.

Finally, in 2000, a multidisciplinary group of clinicians and researchers called the Study Group on Neonatal Intensive Care Unit (NICU) Sound and the Expert Panel gathered and reviewed over 50 studies on the effects of sound on the fetus, newborn, and preterm infants. Upon the completion of review, the panel recommended that women should avoid prolonged exposure to low frequency sound levels (< 250 Hz) above 65 dB(A) during pregnancy (Graven SN. 2000). This recommendation was based on research that was conducted on sheep fetuses, which determined that after sustained periods of intense low frequency sound, the fetuses experienced injury to the hair cells of cochlea (Graven SN. 2000).

There have been some studies that have looked at the effect of low frequency noise on nighttime sleep (Maschke C. 2004). Unfortunately, for many of these studies, it was difficult to determine what percentage of the nightly noise was actually low frequency noise. Case studies have reported that low frequency noise (low-frequency noise reaching levels between 72 and 85 dB(A)) affects sleep quality and results in insomnia and concentration problems (Berglund B. et al. 1996; Waye K. 2004). A cross-sectional study of 279 individuals, it was determined that there were no significant differences detected in reported sleep among those exposed to flat frequency noise (>100 Hz; 24 to 33 dBA and 41 to 49 dBC) in their homes as compared to low frequency noise (50 Hz – 200 Hz; 26 to 36 dBA and 49 to 60 dBC) from ventilation and heat pumps (Persson Waye K. and Rylander R. 2001; Waye K. 2004). However, it was determined that fatigue, difficulty falling asleep, feeling tense and irritable were reported significantly more often among those individuals who were annoyed by low frequency noise than those who were exposed to the same noise but did not report being annoyed. Additionally, a dose-response relationship was identified between reported annoyance/disturbed rest and degree of low frequency noise before and after correction for differences in A-weighted sound pressure levels (Persson Waye K. and Rylander R. 2001; Waye K. 2004). In another study, six individuals were exposed to sinusoidal tones as 10, 20, 40, and 63 Hz with sound pressure levels ranging from 75 to 105 dB for 10 Hz and 20 Hz and 50 to 100 dB for 40 Hz and 63 Hz. No significant difference was found between the exposure and control nights in sleep efficiency index, number of changes in sleep state, or changes in the proportion of each sleep stage evaluated by electroencephalogram recordings (Inaba R. and Okada A. 1988; Waye K. 2004).

Annoyance

The World Health Organization (WHO) definition of the adverse effects of noise is as follows:

> *Change in the morphology and physiology of an organism that results in impairment of functional capacity to compensate for additional stress, or increases in the susceptibility of an organism to the harmful effects of other environmental influences. Includes any temporary or long-term lowering of the physical, psychological or social functioning of humans or human organs* (WHO 2001).

An earlier definition of annoyance was "a feeling of displeasure associated with any agent or condition, known or believed by an individual or group to adversely affect them" (Koelega HS.(ed.) 1987; Lindvall T. and Radford EP.(eds.) 1973; WHO 1999). The WHO considers annoyance an adverse health effect of noise in addition to sleep disturbance, performance effects, and psychological effects such as irritability (WHO 2001). Annoyance was also defined as a feeling of displeasure with varying tolerance levels. WHO also characterized annoyance as a feeling that increases with noise impulses as opposed to a steady noise (WHO 2001).

As specifically related to low frequency noise generated from wind turbines, Pedersen *et al.* noted a dose response relationship between calculated A-weighted sound pressure levels from wind turbines and noise annoyance in a cross-sectional study that was conducted in five dwelling areas in Sweden. It was determined that the study respondents were annoyed by the wind turbines at a higher level than other community noises, such as road traffic (Pedersen E. and Waye KP. 2004). It was also found the noise annoyance was related to visual or aesthetic interference, and attitude or sensitivity toward to wind turbine (Pedersen E. and Waye KP. 2004). Importantly, it should be noted that the Swedish wind turbines were all upwind devices which had a blade passage frequency of 1.4 Hz, but unlike earlier downwind turbines with contained low frequency noise, these turbines had upwind rotor blades and the noise was much more broadband (Pedersen E. and Waye KP. 2004).

In addition to annoyance, the relationship between wind turbine noise and self-reported health and well-being factors was also researched by Pedersen *et al.* It was confirmed that there was no correlation between A-weighted sound pressure levels from wind turbines and any health or well-being factors, such as the respondent's status of chronic disease, diabetes, or cardiovascular disease (Pedersen E. and Persson, Waye K. 2007). However, among the 31 respondents who stated that they were annoyed by the wind turbine noise, out of 754 respondents, 36% reported that their sleep was disturbed and 19% reported being tired (Pedersen E. and Persson, Waye K. 2007). Both of these findings were statistically significantly higher in comparison to those respondents who were not annoyed. Recall bias is likely to occur among annoyed individuals, and it is not apparent that this bias was considered in this study. Furthermore, Pedersen *et al.* also identified that living in a rural area, as opposed to an urban area, increased the risk of perceiving wind turbine noise and being annoyed by it (Pedersen E. and Persson, Waye K. 2007).

The underlying complaint of annoyance is, in and of itself, not a disease or a specific manifestation of a specific exposure, but instead a universal human response to a condition or situation that is not positively appreciated by the human receptor. The variability of annoyance and its link to undesirable factors makes it a prime indicator for the possibility of recall bias. Annoyances are highly variable in types (noise, smell, temperature, taste, vision) and vary from person to person. One can be annoyed by the action of others as well as their own individual actions. Thus "annoyance" is not a disease but a human response that is highly non-specific.

Disease vs. DIS-ease

The state of being in which individuals are uneasy, agitated or without ("dis") freedom from labor, pain, anxiety or physical annoyance ("ease") can often be undistinguishable from the state of disease as related to morbidity. Both states of being can be assessed objectively and subjectively. However, with physical illnesses, objective measureable indicators can be obtained through instrumentation testing that is typically absent of human error or influence. Subjective responses to stimuli are much harder to prove or disprove which is why it is very important to supplement a subjective response with an objective assessment.

Limitations of Scientific Literature

The research and scientific literature on the human health effects of low frequency noise exposure are limited. Most researchers have agreed that there are some uncertainties associated with the measurement and characterization of low frequency sound. The most important limitation of the current research involves the use of the A-weight scale. The WHO and other researchers have stated that the conventional method of using an A-weighted equivalent sound level may be inadequate for low frequency noise. There are other researchers who advocate that the current research using various weighted measures is sufficiently robust to be depended upon for the evaluation of the potential for sound related health effects. As a result of these diverse opinions, biased or conflicting conclusions may have been made about the level of low frequency sound and its human health effects.

Another significant limitation of the current research is the use of a small number of subjects or those with prejudicial views of wind turbines. Although it was noted in some studies that the questionnaires used were masked, it was quite possible the participants still had negative or unfavorable attitudes about the wind turbines and the low frequency noise that was generated. The presence of wind turbines has instigated heightened levels of annoyance and NIMBY (*Not In My Back Yard)* attitudes by the nearby residents. With such levels of annoyance and discontent, it is very plausible that the associated anxiety can engender health effects or amplify already existing health conditions. It would be beneficial to examine the health effects of low frequency noise among residents that did not experience the annoyance of the presence of wind turbines. There are health effects and adverse health effects and it is important to differentiate the between the two types of effects.

A common effect that has been observed with low frequency noise is vibration. Although the effects of low frequency noise and vibration have not been well characterized, objective body vibration results only from very high levels of low frequency noise, greater than those produced by wind turbines. Sleeplessness and insomnia have also been associated with low frequency noise, but this finding has been poorly correlated and lacking in consistency. However, the level of annoyance with low frequency noise was found to be correlated with insomnia.

Conclusions

Noise exposures outside the workplace have not been studied as extensively as those that occur in the workplace. There have been pockets of research centering on population exposures to highway traffic noise, noise exposures associated with living near commercial airports, and a scattering of other community noise sources, but there is not an extensive amount of research specifically on the health effects related to the sound exposure generated by wind turbines. However, wind turbines have been used in the U.S. since the late 1800s that has provided a baseline of knowledge and experience of their usage and presence in American lives. The first windmill for electricity production in the United States was built in Cleveland, Ohio by Charles Brush (Windpower.org 2003). In addition, wind turbines have continued to evolve (e.g. vertical to horizontal designs, downwind to upwind blade positioning and numerous sound reduction design changes with the mechanics of the turbine.) This evolution of design and the use of improved technology have resulted in quieter and more efficient wind turbines. Possibly the biggest change beyond these design changes is the trend to build more wind farms.

The implementation of wind turbines has resulted in a steadily growing population of individuals who live in their geographical and visual proximity. The literature clearly delineates a subset of this population that is annoyed by the nearby presence of wind turbines, but there has not been a specific disease or condition that has been found by the research community to be caused by the wind turbines. However, there have been illnesses, symptom complexes, and other health events attributed to wind turbines. This is to be expected given the circumstances and emotions that often surround the presence of wind turbine farms. This is a common phenomenon that is associated with activities that are perceived as a social disruption or infringement on personal rights or freedom.

The literature, both scientific and lay, clearly indicates the diversity of concerns regarding the presence of wind turbines near residences and communities. The science of sound is robust and has identified a number of health-related links to high level industrial sound in the workplace. This same science has not identified a causal link between any specific health condition and exposure to the sound patterns generated by wind turbines of the type used today, perhaps because they generate far lower decibel levels than most vocational sources. However, the same science has determined that there is a range of sounds (some would say noise) that is clearly described by some as annoying. The process of being annoyed is a universal response that is not specific to wind turbines. The nonspecificity of annoyance leads to confusion and concern that the peer reviewed published scientific literature has not been able to adequately clarify. It appears that the scientific process of research and discussion before acceptance of new principles, or redefinition of previously accepted principles, has to some extent gotten caught up in rush of the lay media. Jumping from observations and speculation to cause and effect has been the result of this rush. This type of short cut has historically led to misdirection of resources and efforts.

The subjective nature of annoyance makes the job of epidemiological investigation difficult due to the biases that this subjectivity brings to any study. One cannot assess the level of effect of an activity by analyzing the experience and perceptions of those who are annoyed, without an appropriate comparison group and study design that reduces or delineates the biases that commonly hamper studies of emotionally-charged activities such as the positioning of wind turbines.

Believing without question can lead to positions of unnecessary vulnerability. It is often stated that the best advocate for a patient's rights, well-being and infallible medical care is the actual patient. Therefore, second medical opinions are often highly recommended despite who is giving the first opinion or what that opinion may be. Likewise, the rush to accept opinions without an adequate scientific or medical basis (e.g. objective medical tests) may actually lead to adverse health outcomes originating from the perception of health effects. From the positive perspective, there can be a healing effect or belief, as in the "placebo effect", which is often a key part of a medical encounter. Unfortunately, the reverse can also occur in the situation where a person is given "bad health news" that is unfounded or incorrect and person actually becomes physically and/or emotionally ill. It is a delicate balance that must be maintained as health care professionals and public health officials weigh the science in making decisions.

Based on the literature review that was conducted for this white paper, there was not any scientifically peer-reviewed information found demonstrating a link between wind turbines and negative health effects.

References

Agrawal Y., Platz E.A., and Niparko J.K. (2009). Risk Factors for Hearing Loss in U.S. Adults: Data From the National Health and Nutrition Examination Survey, 1999 to 2002. *Otology & Neurotology.* 30.139 -145).

Baerwald, E. F., D'Amours, G. H., Klug, B. J., and Barclay, R. M. (8-26-2008). Barotrauma is a significant cause of bat fatalities at wind turbines. 18(16), (R695 -R696).

Bayne-Jones S., Burdette WJ., Cochran WG., Farber E., Fieser LF., Furth J., Hickam JB., LeMaistre C., Schuman LM., and Seevers MH. (1964). Smoking and Health. Report of the Advisory Committee to the Surgeon General of the Public Health Service. Report No. PublicHealth Services Publication No.1103.Washington, DC: Public Health Service.

Berglund, B., Hassmen, P., and Job, R. F. (1996). Sources and effects of low-frequency noise. *Journal of the Acoustical Society of America.* 99(5), (2985 -3002).

Bernstein, L. R., Trahiotis, C., and Hyde, E. L. (1998). Inter-individual differences in binaural detection of low-frequency or high-frequency tonal signals masked by narrow-band or broadband noise. *Journal of the Acoustical Society of America.* 103(4), (2069 -2078).

Bjor, B., Burstrom, L., Karlsson, M., Nilsson, T., Naslund, U., and Wiklund, U. (2007). Acute effects on heart rate variability when exposed to hand transmitted vibration and noise. 81(2), (193 -199).

Castelo Branco N.A.A. and Rodriguez E. (1999). The Vibroacoustic Disease - An Emerging Pathology. *Aviation Space & Environmental Medicine.* 70(3,Pt2), (A1 -A6).

CDC.Centers for Disease Control and Prevention. Peer Review Process of Research Applications. (4-13-2009), Available at http://www.cdc.gov/od/science/PHResearch/peerreview.htm.

Checkoway, H. (2004). Case-crossover designs in occupational health. *Journal of Occupational and Environmental Medicine.* 61(12), (953 -954).

Danielsson A. and Landstroem U. (1985). Blood Pressure Changes in Man During Infrasonic Exposure. *Acta Medica Scandinavica.* 217.531 -535).

Davies H.W., Teschke K., Kennedy S.M., Hodgson M.R., and Demers P.A. (2009). Occupational Noise Exposure and Hearing Protector Use in Canadian Lumber. *Journal of Occupational and Environmental Hygiene.* 6.32 -41).

Deans, J. K., Powell, A. D., and Jefferys, J. G. (9-1-2007). Sensitivity of coherent oscillations in rat hippocampus to AC electric fields. 583(Pt 2), (555 -565).

Desholm M. and Kaahlert J. (2005). Avian Collision Risk at an Offshore Wind Farm. *Biology Letters.* 1.296 -298).

Dobie, R. A. (2007). Noise-induced permanent threshold shifts in the occupational noise and hearing survey: an explanation for elevated risk estimates. 28(4), (580 -591).

DOE and EIA.U.S.Department of Energy, Energy Information Administration. Wind Energy -- Energy from Moving Air. (2008), Available at http://www.eia.doe.gov/kids/energyfacts/sources/renewable/wind.html.

Elsevier.Elsevier. The Peer Review Process. (2009), Available at http://www.elsevier.com/wps/find/intro.cws_home/review_process.

Findeis, H. and Peters, E. (2004). Disturbing effects of low frequency sound emissions and vibrations in residential buildings. 6(23), (29 -35).

Fiz, J. A., Gnitecki, J., Kraman, S. S., Wodicka, G. R., and Pasterkamp, H. (2008). Effect of body position on lung sounds in healthy young men. 133(3), (729 -736).

Fletcher H. and Munson W.A. (1933). Loudness, its definition, measurement and calculation. *Journal of the Acoustical Society of America.* 5.82 -108).

Graven S.N. (2000). The Full-Term and Premature Newborn. *Journal of Perinatology.* 20.S88 - S93).

Harding, G., Harding, P., and Wilkins, A. (2008). Wind turbines, flicker, and photosensitive epilepsy: characterizing the flashing that may precipitate seizures and optimizing guidelines to prevent them. 49(6), (1095 -1098).

Hau E., W*ind Turbines: Fundamentals,Technologies, Application,Economics*,2nd ed.(Springer, Berlin, 2006).

Hill AB. (1965). The Environment and Disease: Association or Causation? *Proc R Soc Med.* 58295 -300).

Inaba R. and Okada A. (1988). Study on the Effects of Infra- and Low Frequency Sound on the Sleep by EEG Recordings. *Journal of Low Frequency Noise, Vibration and Active Control.* 7.15 -19).

Inukai Y., Taya H., Miyano H., and Kuriyama H. (1986). A Multidimensional Evaluation Method for the Psychological Effects of Pure Tones at Low and Infrasonic Frequencies. *Journal of Low Frequency Noise, Vibration and Active Control.* 5.104 -112).

Inukai Y., Nakamura N., and Taya H. (2000). Unpleasantness and Acceptable Limits of Low Frequency Sound. *Journal of Low Frequency Noise, Vibration and Active Control.* 19.135 -140).

Ising, H., Lange-Asschenfeldt, H., Moriske, H. J., Born, J., and Eilts, M. (2004). Low frequency noise and stress: bronchitis and cortisol in children exposed chronically to traffic noise and exhaust fumes. *Noise and Health.* 6(23), (21 -28).

Ising, H. and Kruppa, B. (2004). Health effects caused by noise: evidence in the literature from the past 25 years. *Noise and Health.* 6(22), (5 -13).

Jauchem, J. R. and Cook, M. C. (2007). High-intensity acoustics for military nonlethal applications: a lack of useful systems. *Journal of Military Medicine.* 172(2), (182 -189).

Karpova N.I., Alekseev S., Erokhin V.N., Kadyskina E.N., and Reutov O.V. (1970). Early Response of the Organism to Low Frequency Acoustical Oscillations. *Noise and Vibration Bulletin.* 11(65), (100 -103).

Kim, J., Morest, D. K., and Bohne, B. A. (1997). Degeneration of axons in the brainstem of the chinchilla after auditory overstimulation. 103(1-2), (169 -191).

Koelega HS.(ed.), *Environmental Annoyance: Characterization, Measurement, and Control*,(Elsevier, Amsterdam, Netherlands, 1987).

Kondoh, Y., Arima, T., Okuma, J., and Hasegawa, Y. (1993). Response dynamics and directional properties of nonspiking local interneurons in the cockroach cercal system. 13(6), (2287 -2305).

Last JM, *A Dictionary of Epidemiology*,Fourth Edition ed.(Oxford University Press, 2001).

Leighton, T. G. (2007). What is ultrasound? 93(1-3), (3 -83).

Leventhall, G. (2007). What is infrasound? 93(1-3), (130 -137).

Leventhall, H. G. (2004). Low frequency noise and annoyance. 6(23), (59 -72).

Lindvall T. and Radford EP (eds.). (1973). Measurement of annoyance due to exposure to environmental factors. *Environmental Research.* 6.1 -36).

Maschke, C. (2004). Introduction to the special issue on low frequency noise. *Noise and Health.* 6(23), (1 -2).

McConnell, S. O., Schilt, M. P., and Dworski, J. G. (1992). Ambient noise measurements from 100 Hz to 80 kHz in an Alaskan fjord. 91(4 Pt 1), (1990 -2003).

MDHEHD.Minnesota Department of Health Environmental Health Division. Public Health Impacts of Wind Turbines. (5-22-2009), Available at http://www.health.state.mn.us/divs/eh/hazardous/topics/windturbines.pdf.

Mohr G.C., Cole J.N., Guild E., and Gierke von, H. E. (1965). Effects of Low Frequency and Infrasonic Noises on Man. 36.817 -827).

Moller, H. and Pedersen, C. S. (2004). Hearing at low and infrasonic frequencies. *Noise and Health.* 6(23), (37 -57).

Muly, S. M., Gross, J. S., Morest, D. K., and Potashner, S. J. (2002). Synaptophysin in the cochlear nucleus following acoustic trauma. *Experimental Neurology.* 177(1), (202 - 221).

Nakashima, A., Abel, S. M., Duncan, M., and Smith, D. (2007). Hearing, communication and cognition in low-frequency noise from armoured vehicles. 9(35), (35 -41).

NASD.National Agricultural Safety Database. Noise: The Invisible Hazard. (1993), Available at http://www.nasdonline.org/docs/d000801-d000900/d000882/d000882.html.

NMCPHC.NMCPHC (Navy and Marine Corps Public Health Center). Physics of Sound. (4-15-2009), Available at http://www-nmcphc.med.navy.mil/downloads/occmed/toolbox/PHYSICSOFSOUND.ppt.

NRC. (2007). Environmental Impacts of Wind-Energy Projects. *National Research Council.* Committee on Environmental Impacts of Wind-Energy Projects, Board on Environmental Studies and Toxicology, Division on Earth and Life Studies140 -179).

Pedersen, E. and Waye, K. P. (2004). Perception and annoyance due to wind turbine noise--a dose-response relationship. *Journal of the Acoustical Society of America.* 116(6), (3460 - 3470).

Pedersen, E. and Persson, Waye K. (2007). Wind turbine noise, annoyance and self-reported health and well-being in different living environments. 64(7), (480 -486).

Pedersen, E. and Waye, K. P. (2008). Wind Turbines - Low Level Noise Sources Interfering With Restoration. *Environmental Research Letters.* 3.

Pei, Z., Sang, H., Li, R., Xiao, P., He, J., Zhuang, Z., Zhu, M., Chen, J., and Ma, H. (2007). Infrasound-induced hemodynamics, ultrastructure, and molecular changes in the rat myocardium. 22(2), (169 -175).

Persson Waye K. and Rylander R. (2001). The Extent of Annoyance and Long-Term Effects Among Persons Exposed to LFN in the Home Environment. 240.483 -497).

Sakai, A., Feigen, L. P., and Luisada, A. A. (1971). Frequency distribution of the heart sounds in normal man. *Cardiovascular Research.* 5(3), (358 -363).

Schust, M. (2004). Effects of low frequency noise up to 100 Hz. *Noise and Health.* 6(23), (73 - 85).

Shields, F. D. (2005). Low-frequency wind noise correlation in microphone arrays. *Journal of the Acoustical Society of America.* 117(6), (3489 -3496).

Sienkiewicz, Z. (2007). Rapporteur report: Roundup, discussion and recommendations. *Progress in Biophysics and Molecular Biology.* 93(1-3), (414 -420).

Silva, M. J., Dias, A., Barreta, A., Nogueira, P. J., Castelo-Branco, N. A., and Boavida, M. G. (2002). Low frequency noise and whole-body vibration cause increased levels of sister chromatid exchange in splenocytes of exposed mice. 22(3), (195 -203).

Slarve R.N. and Johnson D.L. (2009). Human Whole - Body Exposure to Infrasound. 46(4), (428 -431).

Slovic P., Fischhoff B., and Lichtenstein S. (1982). Why Study Risk Perception. *Risk Analysis.* 2(2), (83 -93).

Takahashi, Y., Yonekawa, Y., Kanada, K., and Maeda, S. (1999). A pilot study on the human body vibration induced by low frequency noise. *Industrial Health.* 37(1), (28 -35).

Takahashi, Y., Yonekawa, Y., and Kanada, K. (2001). A new approach to assess low frequency noise in the working environment. *Industrial Health.* 39(3), (281 -286).

Takahashi, Y., Kanada, K., Yonekawa, Y., and Harada, N. (2005). A study on the relationship between subjective unpleasantness and body surface vibrations induced by high-level low-frequency pure tones. *Industrial Health.* 43(3), (580 -587).

Tesarz M., Kjellberg A., Landstroem U., and Holmberg K. (1997). Subjective Response Patterns Related to Low Frequency Noise. *Journal of Low Frequency Noise, Vibration and Active Control.* 16(2), (145 -149).

U.S.EPA.U.S.Environmental Protection Agency. A Summary of General Assessment Factors for Evaluating the Quality of Scientific and Technical Information. (2003), Available at http://www.epa.gov/osa/spc/pdfs/assess2.pdf.

UK Parliament and House of Commons.House of Commons, The United Kingdom Parliament. The Origin of the Scientific Journal and the Process of Peer Review. (2004), Available at http://eprints.ecs.soton.ac.uk/13105/1/399we23.htm.

UNSW.The University of New South Wales. dB: What is a decibel? (2005), Available at http://www.phys.unsw.edu.au/jw/dB.html.

Waye K. (2004). Effects of Low-Frequency Noise on Sleep. *Noise and Health.* 6(23), (87 -91).

WHO.World Health Organization. WHO Guidelines for Community Noise - A complete, authoritative guide on the effects of noise pollution on health: 3. Adverse health effects of noise. (1999), Available at http://www.ruidos.org/Noise/Comnoise-3.pdf.

WHO.World Health Organization, Presentation at the TRB Session 391 "Setting an Agenda for Transportation Noise Management Policies in the United States" 10 January 2001, Washington DC, USA. World Health Organization Guidelines on Community Noise. (2001), Available at http://www.adc40.org/docs/schwela.pdf.

Windpower.org.Danish Wind Industry Association. A Wind Energy Pioneer: Charles F. Brush. (7-23-2003), Available at http://www.windpower.org/en/pictures/brush.htm.

Appendix A

Final Literature

List #	Year	Author	Title	Journal	Soundness	Applicability and Utility	Clarity and Completeness	Uncertainty and Variability	Evaluation and Review	Did Not Review
Search Term: Infrasound AND Health Effects										
1	2007	Sienkiewicz Z.	Rapporteur report: Roundup, discussion and recommendations.	Prog Biophys Mol Biol.	**	**	**	**	**	
2	2007	Leventhall G.	What is infrasound?	Prog Biophys Mol Biol.	**	**	**	**	**	
3	2004	Feldmann J. et al.	Effects of low frequency noise on man--a case study.	Noise Health.		4				x
4	1999	Pawlaczyk-Luszczyńska M.	Evaluation of occupational exposure to infrasonic noise in Poland.	Int J Occup Med Environ Health.		4				x
5	1996	Pawlaczyk-Luszczyńska M.	Infrasound in the occupational and general environment: a three-element microphone measuring method for locating distant sources of infrasound.	Int J Occup Med Environ Health.		4				x

List #	Year	Author	Title	Journal	Soundness	Applicability and Utility	Clarity and Completeness	Uncertainty and Variability	Evaluation and Review	Did Not Review
Search Term: Low-Frequency Noise AND Health Effects										
6	2005	Hori K. et al.	Influence of sound and light on heart rate variability	J Hum Ergol (Tokyo).		4				x
7	2005	Takahashi Y et al.	A study on the relationship between subjective unpleasantness and body surface vibrations induced by high-level low-frequency pure tones.	Ind Health.	2	4	2	2	2	
8	2004	Schust M. et al.	Effects of low frequency noise up to 100 Hz	Noise Health.	**	**	**	**	**	
9	2004	Ising H. et al.	Low frequency noise and stress: bronchitis and cortisol in children exposed chronically to traffic noise and exhaust fumes	Noise Health.	1	4	1	1	2	

List #	Year	Author	Title	Journal	Soundness	Applicability and Utility	Clarity and Completeness	Uncertainty and Variability	Evaluation and Review	Did Not Review
10	2002	Silva MJ. et al.	Low frequency noise and whole-body vibration cause increased levels of sister chromatid exchange in splenocytes of exposed mice.	Teratog Carcinog Mutagen.	2	3	2	1	1	
11	2001	Takahashi Y et al.	A new approach to assess low frequency noise in the working environment	Ind Health.	2	4	1	2	1	
12	2000	Graven SN.	Sound and the developing infant in the NICU: conclusions and recommendations for care	J Perinatol.	**	**	**	**	**	
13	1999	Silva MJ. et al.	Sister chromatid exchange analysis in workers exposed to noise and vibration	Aviat Space Environ Med.		4				x
14	1999	Alves-Pereira M.	Noise-induced extra-aural pathology: a review and commentary	Aviat Space Environ Med.		4				x

List #	Year	Author	Title	Journal	Soundness	Applicability and Utility	Clarity and Completeness	Uncertainty and Variability	Evaluation and Review	Did Not Review
15	1999	Takahashi Y et al.	A pilot study on the human body vibration induced by low frequency noise	Ind Health.	2	4	2	2	1	
16	1996	Berglund B. et al.	Sources and effects of low-frequency noise.	J Acoust Soc Am.	**	**	**	**	**	
17	1993	Seidel H.	The problem of a "vibration disease" caused by low-frequency whole-body vibration (wbv) is critically discussed.	Am J Ind Med.	**	**	**	**	**	
Search Term: Low-Frequency Sound AND Health Effects										
18	2008	Carrubba S. et al.	The effects of low-frequency environmental-strength electromagnetic fields on brain electrical activity: a critical review of the literature	Electromagn Biol Med.		4				x

Search Term: Wind Power AND Noise										
List #	**Year**	**Author**	**Title**	**Journal**	**Soundness**	**Applicability and Utility**	**Clarity and Completeness**	**Uncertainty and Variability**	**Evaluation and Review**	**Did Not Review**
19	2005	Shields FD.	Low-frequency wind noise correlation in microphone arrays	J Acoust Soc Am.	**	**	**	**	**	
20	2004	Pedersen E. et al.	Perception and annoyance due to wind turbine noise--a dose-response relationship	J Acoust Soc Am.	3	5	5	2	3	
21	1998	Munro KJ. et al.	Are clinical measurements of uncomfortable loudness levels a valid indicator of real-world auditory discomfort?	Br J Audiol.		4				x
22	1992	McConnell SO. et al.	Ambient noise measurements from 100 Hz to 80 kHz in an Alaskan fjord.	J Acoust Soc Am.	**	**	**	**	**	
Search Term: Wind Turbines										
23	2008	Harding G. et al.	Wind turbines, flicker, and photosensitive epilepsy: characterizing the flashing that may precipitate seizures and optimizing guidelines to prevent them	Epilepsia.	**	**	**	**	**	

List #	Year	Author	Title	Journal	Soundness	Applicability and Utility	Clarity and Completeness	Uncertainty and Variability	Evaluation and Review	Did Not Review
24	2007	Pedersen E. et al.	Wind turbine noise, annoyance and self-reported health and well-being in different living environments.	Occup Environ Med.	3	5	5	2	3	
Search Term: Wind Turbines AND Noise										
ALREADY INCLUDED IN OTHER SEARCHES										
Other articles found in *Noise and Health*										
25	2004	Waye K.	Effects of low frequency noise on sleep.	Noise and Health	**	**	**	**	**	
26	2004	Moller H. et al.	Hearing at low and infrasonic frequencies	Noise and Health	**	**	**	**	**	
27	2004	Maschke C.	Introduction to the special issue on low frequency noise	Noise and Health	**	**	**	**	**	
28	2004	Leventhall H.	Low frequency noise and annoyance	Noise and Health	**	**	**	**	**	
29	2004	Findeis H. et al.	Disturbing effects of low frequency sound emissions and vibrations in residential buildings	Noise and Health	**	**	**	**	**	

The Potential Health Impact of Wind Turbines

Chief Medical Officer of Health (CMOH) Report

May 2010

Summary of Review

This report was prepared by the Chief Medical Officer of Health (CMOH) of Ontario in response to public health concerns about wind turbines, particularly related to noise.

Assisted by a technical working group comprised of members from the Ontario Agency for Health Protection and Promotion (OAHPP), the Ministry of Health and Long-Term Care (MOHLTC) and several Medical Officers of Health in Ontario with the support of the Council of Ontario Medical Officers of Health (COMOH), this report presents a synopsis of existing scientific evidence on the potential health impact of noise generated by wind turbines.

The review concludes that while some people living near wind turbines report symptoms such as dizziness, headaches, and sleep disturbance, the scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects. The sound level from wind turbines at common residential setbacks is not sufficient to cause hearing impairment or other direct health effects, although some people may find it annoying.

1

Introduction

In response to public health concerns about wind turbines, the CMOH conducted a review of existing scientific evidence on the potential health impact of wind turbines in collaboration and consultation with a technical working group composed of members from the OAHPP, MOHLTC and COMOH.

A literature search was conducted to identify papers and reports (from 1970 to date) on wind turbines and health from scientific bibliographic databases, grey literature, and from a structured Internet search. Databases searched include MEDLINE, PubMed, Environmental Engineering Abstracts, Environment Complete, INSPEC, Scholars Portal and Scopus. Information was also gathered through discussions with relevant government agencies, including the Ministry of the Environment and the Ministry of Energy and Infrastructure and with input provided by individuals and other organizations such as Wind Concerns Ontario.

In general, published papers in peer-reviewed scientific journals, and reviews by recognized health authorities such as the World Health Organization (WHO) carry more weight in the assessment of health risks than case studies and anecdotal reports.

The review and consultation with the Council of Ontario Medical Officers of Health focused on the following questions:

- What scientific evidence is available on the potential health impacts of wind turbines?
- What is the relationship between wind turbine noise and health?
- What is the relationship between low frequency sound, infrasound and health?
- How is exposure to wind turbine noise assessed?
- Are Ontario wind turbine setbacks protective from potential wind turbine health and safety hazards?
- What consultation process with the community is required before wind farms are constructed?
- Are there data gaps or research needs?

The following summarizes the findings of the review and consultation.

2

Wind Turbines and Health

2.1 Overview

A list of the materials reviewed is found in Appendix 1. It includes research studies, review articles, reports, presentations, and websites.

Technical terms used in this report are defined in a Glossary (Page 11).

The main research data available to date on wind turbines and health include:

- Four cross-sectional studies, published in scientific journals, which investigated the relationships between exposure to wind turbine noise and annoyance in large samples of people (351 to 1,948) living in Europe near wind turbines (see section 2.2).
- Published case studies of ten families with a total of 38 affected people living near wind turbines in several countries (Canada, UK, Ireland, Italy and USA) (Pierpont 2009). However, these cases are not found in scientific journals. A range of symptoms including dizziness, headaches, and sleep disturbance, were reported by these people. The researcher (Pierpont) suggested that the symptoms were related to wind turbine noise, particularly low frequency sounds and infrasound, but did not investigate the relationships between noise and symptoms. It should be noted that no conclusions on the health impact of wind turbines can be drawn from Pierpont's work due to methodological limitations including small sample size, lack of exposure data, lack of controls and selection bias.
- Research on the potential health and safety hazards of wind turbine shadow flicker, electromagnetic fields (EMFs), ice throw and ice shed, and structural hazards (see section 2.3).

A synthesis of the research available on the potential health impacts of exposure to noise and physical hazards from wind turbines on nearby residents is found in sections 2.2 and 2.3, including research on low frequency sound and infrasound. This is followed by information on wind turbine regulation in Ontario (section 3.0), and our conclusions (section 4.0).

2.2. Sound and Noise

Sound is characterized by its sound pressure level (loudness) and frequency (pitch), which are measured in standard units known as decibel (dB) and Hertz (Hz), respectively. The normal human ear perceives sounds at frequencies ranging from 20Hz to 20,000 Hz. Frequencies below 200 Hz are commonly referred to as "low frequency sound" and those below 20Hz as "infrasound," but the boundary between them is not rigid. There is variation between people in their ability to perceive sound. Although generally considered inaudible, infrasound at high-enough sound pressure levels can be audible to some people. Noise is defined as an unwanted sound (Rogers et al. 2006, Leventhall 2003).

Wind turbines generate sound through mechanical and aerodynamic routes. The sound level depends on various factors including design and wind speed. Current generation upwind model turbines are quieter than older downwind models. The dominant sound source from modern wind turbines is aerodynamic, produced by the rotation of the turbine blades through air. The aerodynamic noise is present at all frequencies, from infrasound to low frequency to the normal audible range, producing the characteristic "swishing" sound (Leventhall 2006, Colby et al. 2009).

Environmental sound pressure levels are most commonly measured using an A-weighted scale. This scale gives less weight to very low and very high frequency components that is similar to the way the human ear perceives sound. Sound levels around wind turbines are usually predicted by modelling, rather than assessed by actual measurements.

The impact of sound on health is directly related to its pressure level. High sound pressure levels (>75dB) could result in hearing impairment depending on the duration of exposure and sensitivity of the individual. Current requirements for wind turbine setbacks in Ontario are intended to limit noise at the nearest residence to 40 dB (see section 3). This is a sound level comparable to indoor background sound. This noise limit is consistent with the night-time noise guideline of 40 dB that the World Health Organization (WHO) Europe recommends for the protection of public health from community noise. According to the WHO, this guideline is below the level at which effects on sleep and health occurs. However, it is above the level at which complaints may occur (WHO 2009).

Available scientific data indicate that sound levels associated with wind turbines at common residential setbacks are not sufficient to damage hearing or to cause other direct adverse health effects, but some people may still find the sound annoying.

Studies in Sweden and the Netherlands (Pedersen et al. 2009, Pedersen and Waye 2008, Pedersen and Waye 2007, Pedersen and Waye 2004) have found direct relationships between modelled sound pressure level and self-reported perception of sound and annoyance. The association between sound pressure level and sound perception was stronger than that with annoyance. The sound was annoying only to a small percentage of the exposed people; approximately 4 to 10 per cent were very annoyed at sound levels between 35 and 45dBA. Annoyance was strongly correlated with individual perceptions of wind turbines. Negative attitudes, such as an aversion to the visual impact of wind turbines on the landscape, were associated with increased annoyance, while positive attitudes, such as direct economic benefit from wind turbines, were associated with decreased annoyance. Wind turbine noise was perceived as more annoying than transportation or industrial noise at comparable levels, possibly due to its swishing quality, changes throughout a 24 hour period, and lack of night-time abatement.

2.2.1 Low Frequency Sound, Infrasound and Vibration

Concerns have been raised about human exposure to “low frequency sound” and “infrasound” (see section 2.2 for definitions) from wind turbines. There is no scientific evidence, however, to indicate that low frequency sound generated from wind turbines causes adverse health effects.

Low frequency sound and infrasound are everywhere in the environment. They are emitted from natural sources (e.g., wind, rivers) and from artificial sources including road traffic, aircraft, and ventilation systems. The most common source of infrasound is vehicles. Under many conditions, low frequency sound below 40Hz from wind turbines cannot be distinguished from environmental background noise from the wind itself (Leventhall 2006, Colby et al 2009).

Low frequency sound from environmental sources can produce annoyance in sensitive people, and infrasound at high sound pressure levels, above the threshold for human hearing, can cause severe ear pain. There is no evidence of adverse health effects from infrasound below the sound pressure level of 90dB (Leventhall 2003 and 2006).

Studies conducted to assess wind turbine noise indicate that infrasound and low frequency sounds from modern wind turbines are well below the level where known health effects occur, typically at 50 to 70dB.

A small increase in sound level at low frequency can result in a large increase in perceived loudness. This may be difficult to ignore, even at relatively low sound pressures, increasing the potential for annoyance (Jakobsen 2005, Leventhall 2006).

A Portuguese research group (Alves-Pereira and Castelo Branco 2007) has proposed that excessive long-term exposure to vibration from high levels of low frequency sound and infrasound can cause whole body system pathology (vibro-acoustic disease). This finding has not been recognized by the international medical and scientific community. This research group also hypothesized that a family living near wind turbines will develop vibro-acoustic disease from exposure to low frequency sound, but has not provided evidence to support this (Alves-Pereira and Castelo Branco 2007).

2.2.2 Sound Exposure Assessment

Little information is available on actual measurements of sound levels generated from wind turbines and other environmental sources. Since there is no widely accepted protocol for the measurement of noise from wind turbines, current regulatory requirements are based on modelling (see section 3.0).

2.3 Other Potential Health Hazards of Wind Turbines

The potential health impacts of electromagnetic fields (EMFs), shadow flicker, ice throw and ice shed, and structural hazards of wind turbines have been reviewed in two reports (Chatham-Kent Public Health Unit 2008; Rideout et al 2010). The following summarizes the findings from these reviews.

- **EMFs**
  Wind turbines are not considered a significant source of EMF exposure since emissions levels around wind farms are low.

- **Shadow Flicker**
  Shadow flicker occurs when the blades of a turbine rotate in sunny conditions, casting moving shadows on the ground that result in alternating changes in light intensity appearing to flick on and off. About 3 per cent of people with epilepsy are photosensitive, generally to flicker frequencies between 5-30Hz. Most industrial turbines rotate at a speed below these flicker frequencies.

- **Ice Throw and Ice Shed**
  Depending on weather conditions, ice may form on wind turbines and may be thrown or break loose and fall to the ground. Ice throw launched far from the turbine may pose a significant hazard. Ice that sheds from stationary components presents a potential risk to service personnel near the wind farm. Sizable ice fragments have been reported to be found within 100 metres of the wind turbine. Turbines can be stopped during icy conditions to minimize the risk.

- **Structural hazards**
  The maximum reported throw distance in documented turbine blade failure is 150 metres for an entire blade, and 500 metres for a blade fragment. Risks of turbine blade failure reported in a Dutch handbook range from one in 2,400 to one in 20,000 turbines per year (Braam et al 2005). Injuries and fatalities associated with wind turbines have been reported, mostly during construction and maintenance related activities.

3

Wind Turbine Regulation in Ontario

The Ministry of the Environment regulates wind turbines in Ontario. A new regulation for renewable energy projects came into effect on September 24, 2009. The requirements include minimum setbacks and community consultations.

3.1 Setbacks

Provincial setbacks were established to protect Ontarians from potential health and safety hazards of wind turbines including noise and structural hazards.

The minimum setback for a wind turbine is 550 metres from a receptor. The setbacks rise with the number of turbines and the sound level rating of the selected turbines. For example, a wind project with five turbines, each with a sound power level of 107dB, must have its turbines setback at a minimum 950 metres from the nearest receptor.

These setbacks are based on modelling of sound produced by wind turbines and are intended to limit sound at the nearest residence to no more than 40 dB. This limit is consistent with limits used to control noise from other environmental sources. It is also consistent with the night-time noise guideline of 40 dB that the World Health Organization (WHO) Europe recommends for the protection of public health from community noise. According to the WHO, this guideline is below the level at which effects on sleep and health occurs. However, it is above the level at which complaints may occur (WHO 2009).

Ontario used the most conservative sound modelling available nationally and internationally, which is supported by experiences in the province and in other jurisdictions (MOE 2009). As yet, a measurement protocol to verify compliance with the modelled limits in the field has not been developed. The Ministry of the Environment has recently hired independent consultants to develop a procedure for measuring audible sound from wind turbines and also to review low frequency sound impacts from wind turbines, and to develop recommendations regarding low frequency sound.

Ontario setback distances for wind turbine noise control also take into account potential risk of injury from ice throw and structural failure of wind turbines. The risk of injury is minimized with setbacks of 200 to 500 metres.

3.2 Community Consultation

The Ministry of the Environment requires applicants for wind turbine projects to provide written notice to all assessed land owners within 120 metres of the project location at a preliminary stage of the project planning. Applicants must also post a notice on at least two separate days in a local newspaper. As well, applicants are required to notify local municipalities and any Aboriginal community that may have a constitutionally protected right or interest that could be impacted by the project.

Before submitting an application to the Ministry of the Environment, the applicant is also required to hold a minimum of two community consultation meetings to discuss the project and its potential local impact. To ensure informed consultation, any required studies must be made available for public review 60 days prior to the date of the final community meeting. Following these meetings the applicant is required to submit as part of their application a Consultation Report that describes the comments received and how these comments were considered in the proposal.

The applicant must also consult directly with local municipalities prior to applying for a Renewable Energy Approval on specific matters related to municipal lands, infrastructure, and services. The Ministry of the Environment has developed a template, which the applicant is required to use to document project-specific matters raised by the municipality. This must be submitted to the ministry as part of the application. The focus of this consultation is to ensure important local service and infrastructure concerns are considered in the project.

For small wind projects (under 50 kW) the public meeting requirements above are not applicable due to their limited potential impacts.

4 Conclusions

The following are the main conclusions of the review and consultation on the health impacts of wind turbines:

- While some people living near wind turbines report symptoms such as dizziness, headaches, and sleep disturbance, the scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects.
- The sound level from wind turbines at common residential setbacks is not sufficient to cause hearing impairment or other direct adverse health effects. However, some people might find it annoying. It has been suggested that annoyance may be a reaction to the characteristic “swishing” or fluctuating nature of wind turbine sound rather than to the intensity of sound.
- Low frequency sound and infrasound from current generation upwind model turbines are well below the pressure sound levels at which known health effects occur. Further, there is no scientific evidence to date that vibration from low frequency wind turbine noise causes adverse health effects.
- Community engagement at the outset of planning for wind turbines is important and may alleviate health concerns about wind farms.
- Concerns about fairness and equity may also influence attitudes towards wind farms and allegations about effects on health. These factors deserve greater attention in future developments.

The review also identified that sound measurements at residential areas around wind turbines and comparisons with sound levels around other rural and urban areas, to assess actual ambient noise levels prevalent in Ontario, is a key data gap that could be addressed. An assessment of noise levels around wind power developments and other residential environments, including monitoring for sound level compliance, is an important prerequisite to making an informed decision on whether epidemiological studies looking at health outcomes will be useful.

Glossary

A-weighted decibels (dBA)
The sound pressure level in decibels as measured on a sound level meter using an A-weighted filter. The A-weighted filter de-emphasizes the very low and very high frequencies of the sound in a manner similar to the frequency response of the human ear.

Decibel (dB)
Unit of measurement of the loudness (intensity) of sound. Loudness of normal adult human voice is about 60-70 dB at three feet. The decibel scale is a logarithmic scale and it increases/decreases by a factor of 10 from one scale increment to the next adjacent one.

Downwind model turbines
Downwind model turbines have the blades of the rotor located behind the supporting tower structure, facing away from the wind. The supporting tower structure blocks some of the wind that blows towards the blades.

Electromagnetic fields (EMFs)
Electromagnetic fields are a combination of invisible electric and magnetic fields. They occur both naturally (light is a natural form of EMF) and as a result of human activity. Nearly all electrical and electronic devices emit some type of EMF.

Grey literature
Information produced by all levels of government, academics, business and industry in electronic and print formats not controlled by commercial publishing, i.e., where publishing is not the primary activity of the producing body.

Hertz (Hz)
A unit of measurement of frequency; the number of cycles per second of a periodic waveform.

Infrasound
Commonly refers to sound at frequencies below 20Hz. Although generally considered inaudible, infrasound at high-enough sound pressure levels can be audible to some people.

Low frequency sound
Commonly refers to sound at frequencies between 20 and 200 Hz.

Noise
Noise is an unwanted sound.

Shadow Flicker
Shadow flicker is a result of the sun casting intermittent shadows from the rotating blades of a wind turbine onto a sensitive receptor such as a window in a building. The flicker is due to alternating light intensity between the direct beam of sunlight and the shadow from the turbine blades.

Sound
Sound is wave-like variations in air pressure that occur at frequencies that can be audible. It is characterized by its loudness (sound pressure level) and pitch (frequency), which are measured in standard units known as decibel (dB) and Hertz (Hz), respectively. The normal human ear perceives sounds at frequencies ranging from 20Hz to 20,000 Hz.

Upwind model turbines
Upwind model turbines have the blades of the rotor located in front of the supporting tower structure, similar to how a propeller is at the front of an airplane. Upwind turbines are a modern design and are quieter than the older downwind models.

Wind turbine
Wind turbines are large towers with rotating blades that use wind to generate electricity.

Appendix 1: List of Documents on Wind Turbines

Journal Articles and Books

Braam HGJ, et al. Handboek risicozonering windturbines. Netherlands: SenterNovem; 2005.

Jakobsen J. Infrasound emission from wind turbines. *J Low Freq Noise Vib Active Contr*. 2005;24(3):145-155.

Keith SE, Michaud DS, Bly SHP. A proposal for evaluating the potential health effects of wind turbine noise for projects under the Canadian Environmental Assessment Act. *J Low Freq Noise Vib Active Control*. 2008;27(4):253-265.

Leventhall G. Infrasound from wind turbines: fact, fiction or deception. *Can Acoust*. 2006;34(2):29-36.

Pedersen E, Hallberg LR-M, Waye KP. Living in the vicinity of wind turbines: a grounded theory study. *Qual Res Psychol*. 2007;4(1-2):49-63.

Pedersen E, Larsman P. The impact of visual factors on noise annoyance among people living in the vicinity of wind turbines. *J Environ Psychol*. 2008;28(4):379-389.

Pedersen E, Persson Waye K. Wind turbines: low level noise sources interfering with restoration? *Environ Res Lett*. 2008;3:015002. Available from: http://www.iop.org/EJ/article/1748-9326/3/1/015002/erl8_1_015002.pdf.

Pedersen E, Persson Waye K. Wind turbine noise, annoyance and self-reported health and well-being in different living environments. *Occup Environ Med*. 2007;64(7):480-6.

Pedersen E, van den Berg F, Bakker R, Bouma J. Response to noise from modern wind farms in The Netherlands. *J Acoust Soc Am*. 2009;126(2):634-43.

Pedersen E, Waye KP. Perception and annoyance due to wind turbine noise – a dose-response relationship. *J Acoust Soc Am*. 2004;116(6):3460-70.

van den Berg GP. Effects of the wind profile at night on wind turbine sound. *J Sound Vib*. 2004;277(4-5):955-970. Available from: http://www.nowap.co.uk/docs/windnoise.pdf.

Grey Literature

Chatham-Kent Public Health Unit. The health impact of wind turbines: a review of the current white, grey, and published literature. Chatham, ON: Chatham-Kent Municipal Council; 2008 [cited 2010 Mar 5]. Available from: http://www.wind-works.org/LargeTurbines/Health%20and%20Wind%20by%20C-K%20Health%20Unit.pdf.

Colby WD, Dobie R, Leventhall G, Lipscomb DM, McCunney RJ, Seilo MT, et al. Wind turbine sound and health effects. An expert panel review: American Wind Energy Association & Canadian Wind Energy Association; 2009 [cited 2009 Dec 21]. Available from: http://www.canwea.ca/pdf/talkwind/Wind_Turbine_Sound_and_Health_Effects.pdf.

Rideout K, Copes R, Bos C. Wind turbines and health. Vancouver: National Collaborating Centre for Environmental Health; 2010 Jan [cited 2010 Mar 5]. Available from: http://www.ncceh.ca/files/Wind_Turbines_January_2010.pdf.

Wind turbines and Health: a review of evidence. Toronto: Ontario Agency for Health Protection and Promotion; 2009 [cited 2010 Mar 5]. Available from: http://www.oahpp.ca/resources/documents/presentations/2009sept10/Wind%20Turbines%20-%20Sept%2010%202009.pdf.

Environmental Protection Agency, Office of Water. Auxiliary and supplemental power fact sheet: wind turbines. Washington, DC: Environmental Protection Agency; 2007 [cited 2010 Jan 7]. Available from http://www.epa.gov/owm/mtb/wind_final.pdf.

Leventhall G, Pelmear P, Benton S. A review of published research on low frequency noise and its effects. London, England: Department for Environment, Food and Rural Affairs; 2003 [cited 2010 Mar 5]. Contract No.: EPG 1/2/50. Available from: http://www.defra.gov.uk/environment/quality/noise/research/lowfrequency/documents/lowfreqnoise.pdf.

Minnesota Department of Health, Environmental Health Division. Public health impacts of wind turbines.

Saint Paul, MN: Minnesota Department of Commerce, Office of Energy Security; 2009 [cited 2010 Mar 5]. Available from: http://energyfacilities.puc.state.mn.us/documents/Public%20Health%20Impacts%20of%20Wind%20Turbines,%205.22.09%20Revised.pdf.

National Research Council, Committee on Environmental Impacts of Wind-Energy Projects. Environmental impacts of wind-energy projects. Washington, DC: National Academies Press; 2007.

Ontario. Ministry of the Environment. Frequently asked questions: renewable energy approval. Toronto: Queen's Printer for Ontario; 2009. Available from: http://www.ene.gov.on.ca/en/business/green-energy/docs/FAQs%20-final.pdf.

Ontario. Ministry of the Environment. Noise guidelines for wind farms: interpretation for applying MOE NPC publications to wind power generation facilities. Toronto: Queen's Printer for Ontario; 2008 [cited 2010 Mar 5]. Available from: http://www.ene.gov.on.ca/publications/4709e.pdf.

Ontario. Ministry of the Environment. Development of noise setbacks for wind farms: requirements for compliance with MOE noise limits. Toronto, ON: Queen's Printer for Ontario; 2009. Available from http://www.ene.gov.on.ca/en/business/green-energy/docs/WindNoiseSetbacks.pdf.

Pedersen E. Human response to wind turbine noise: perception, annoyance and moderating factors. Göteborg, Sweden: Göteborgs Universitet, Sahlgrenska Acedemy, Department of Public Health and Community Medicine; 2007 [cited 2010 Mar 5]. Available from: http://gupea.ub.gu.se/dspace/bitstream/2077/4431/1/gupea_2077_4431_1.pdf.

Pierpont N. Wind turbine syndrome: a report on a natural experiment [pre-publication draft]. Santa Fe, NM: K-Selected Books; 2009 [cited 2010 Mar 5]. Available from: http://www.windturbinesyndrome.com/wp-content/uploads/2009/03/ms-ready-for-posting-on-wtscom-3-7-09.pdf.

Ramakrishnan R (Aiolos Engineering Corporation). Wind turbine facilities noise issues. Toronto: Queen's Printer for Ontario; 2007 [cited 2010 Mar 5]. Report No.: 4071/2180/AR155Rev3. Available from: https://ozone.scholarsportal.info/bitstream/1873/13073/1/283287.pdf.

Rogers AL, Manwell JF, Wright S. Wind turbine acoustic noise: a white paper. Amherst, MA: University of Massachusetts at Amherst, Department of Mechanical and Industrial Engineering, Renewable Energy Research Laboratory; 2006 [cited 2010 Mar 5]. Available from: http://www.ceere.org/rerl/publications/whitepapers/Wind_Turbine_Acoustic_Noise_Rev2006.pdf.

van den Berg F, Pedersen E, Bouma J, Bakker R. Project WINDFARMperception: visual and acoustic impact of wind turbine farms on residents: final report. Groningen, Netherlands: University of Groningen; 2008 [cited 2010 Mar 5]. Published jointly by the University of Groningen and the University of Gothenburg. Available from: http://www.wind-watch.org/documents/wp-content/uploads/wfp-final-1.pdf.

Whitford J. Model wind turbine by-laws and best practices for Nova Scotia municipalities: final report. Halifax, NS: Union of Nova Scotia Municipalities; 2008 [cited 2009 Apr 21]. Contract No.: 1031581. Available from: http://www.sustainability-unsm.ca/our-work.html.

World Health Organization

World Health Organization, Regional Office for Europe. Night noise guidelines for Europe. Geneva, Switzerland: World Health Organization; 2009 [cited 2010 Mar 5]. Available from: http://www.euro.who.int/document/e92845.pdf.

World Health Organization. Occupational and community noise. Fact sheet no. 258. Geneva, Switzerland: World Health Organization; 2001 [cited 2010 Mar 5]. Available from: http://www.who.int/mediacentre/factsheets/fs258/en/.

Community Concerns about Health Effects of Wind Turbines

Archives and Collections Society. Some health aspects of wind driven industrial turbines. Picton, ON: Archives and Collections Society; c2003-2004 [cited 2010 Mar 5]. Available from: http://www.aandc.org/research/wind_community_health.html.

Gillis L, Krogh C, Kouwen N. A self-reporting survey: adverse health effects with industrial wind turbines and the need for vigilance. London, ON: WindVOiCe: Wind Vigilance for Ontario Communities; 2009. Available from: http://windconcernsontario.files.wordpress.com/2009/04/windvoice__sept__24__20091.pdf.

McMurtry R. Deputation to the Ontario Standing Committee on General Government regarding Bill C-150. Scarborough, ON: Wind Concerns; 2009 Apr 22 [cited 2010 Mar 5]. Available from: http://windconcernsontario.files.wordpress.com/2009/04/deputation-to-standing-committee-mcmurtry.pdf

National Wind Watch: presenting the facts about industrial wind power. Rowe, MA: National Wind Watch; [cited 2010 Mar 5]. Available from: http://www.wind-watch.org/.

Wind Concerns Ontario: bringing sanity to wind development in Ontario. Scarborough, ON: Wind Concerns; [cited 2010 Mar 5]. Available from: http://windconcernsontario.wordpress.com/.

Conference Papers

Alves-Pereira M, Castelo Branco NAA. Infrasound and low frequency noise dose responses: contributions. In: Proceedings of the Inter-Noise Congress; 2007 Aug 28-31; Istanbul, Turkey.

Alves-Pereira M, Castelo Branco NAA. In-home wind turbine noise is conductive to vibroacoustic disease. In: Proceedings of the 2nd International Meeting on Wind Turbine Noise. 2007 Sep 20-21; Lyon, France.

Alves-Pereira M, Castelo Branco NAA. Public health and noise exposure: the importance of low frequency noise. In: Proceedings of the Inter-Noise Congress; 2007 Aug 28-31; Istanbul, Turkey.

Alves-Pereira M, Castelo Branco NAA. The scientific arguments against vibroacoustic disease. In: Proceedings of the Inter-Noise Congress. Istanbul; 2007 Aug 28-31; Istanbul, Turkey.

van den Berg GP. Do wind turbines produce significant low frequency sound levels? In: Proceedings of the 11th International Meeting on Low Frequency Noise and Vibration and its Control. 2004 Aug 30-Sep 1; Maastricht, Netherlands.

Catalogue No. 014894 ISBN: 978-1-4435-3288-4 500 May 2010