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

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Lawrence Berkeley National Laboratory

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The Impact of Wind Power Projects on Residential Property Values in the U.S.

- Motivation and Study Methods

  - Motivation

  - Overview and Methods

  - Data Summary

- Summary of Analysis Results

- Conclusions and Further Research

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Proximity to and Views of Environmental (Dis)Amenities Can Impact Property Values

Highway	Transmission Lines	Average Home	Green Space	Ocean Front
↓ $	↓ $	SOLD	↑ $	↑ $

This linkage is well studied generally, but not for wind power facilities

Aesthetics and Property Values Rank as Key Concerns for Wind Stakeholders

"Aesthetic perceptions, both positive and negative, are the strongest single influence on individuals' attitudes towards wind power projects." (Warren, 2005, p. 853)

US developers rank aesthetics & property values as the #1 and #3 concerns of those in opposition to wind development (Paul, 2006)

100% and 85% of those opposed to offshore wind development believe aesthetics and property values, respectively, will be adversely impacted (Firestone et. al., 2007)

Having structures on the Vermont hilltops was considered a "big disadvantage" by the majority of those surveyed before the Searsburg, VT wind facility was erected (Palmer, 1997)

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Property Value Concerns for Wind Energy Fall Into Three Potential Categories

1. **Area Stigma:** Concern that rural areas will appear more developed

   No one will move here!

2. **Scenic Vista Stigma:** Concern over decrease in quality of scenic vistas from homes

   It will ruin my view!

3. **Nuisance Stigma:** Concern that factors that occur in close proximity will have unique impacts

   I won't be able to live in my home!

Each of these effects could impact property values; none are mutually exclusive

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Relatively Few Existing Wind and Property Studies: A List of the Most Publicized

- **Variety of methods used**, from surveys to sales analyses, with varying levels of sophistication

- **Results are diverse**, and in many instances unpersuasive due to limitations in data and methodology

Document Type Author(s)	Year	Number of Transactions or Respondents	Before or After Wind Facility Construction Commenced	Area Stigma	Scenic Vista Stigma	Nuisance Stigma
Homeowner Survey						
Haughton et al.	2004	501	Before	- *	- *	
Goldman	2006	50	After	none		
Firestone et al.	2007	504	Before	- *	- *	
Bond	2008	~300	After		- ?	- ?
Expert Survey						
Grover	2002	13	After	none		none
Haughton et al.	2004	45	Before	- *	- *	
Khatri	2004	405	Before‡	- ?		- ?
Goldman	2006	50	After	none		none
Kielisch	2009	57	Before‡			- ?
Transaction Analysis - Simple Statistics						
Jerabek	2001	25	After			none
Jerabek	2002	7	After			none
Sterzinger et al.	2003	24,000	After	none		
Beck	2004	2	After			none
Poletti	2005	187	After	none		none
DeLacy	2005	21	Before†	none		
Goldman	2006	4	After	none		
Poletti	2007	256	After	none		none
McCann	2008	2	After			- ?
Kielisch	2009	103	After			- ?
Transaction Analysis - Hedonic Model						
Jordal-Jorgensen	1996	?	After			- ?
Hoen	2006	280	After		none	
Sims & Dent	2007	919	After			- *
Sims et al.	2008	199	After		-/+ *	

"none" indicates the majority of the respondents do not believe properties have been affected (for surveys) or that no effect was detected at 10% significance level (for transaction analysis)

"- ?" indicates a negative effect without statistical significance provided

*"- *"* indicates statistically significant negative effect at 10% significance level

*"-/+ *"* indicates positive and negative statistically significant effects at 10% significance level

† *Sales were collected after facility announcement but before construction*

‡ *Some respondents had experience with valuations near facilities while others did not*

Limitations of Existing Research

- **Many studies have relied on surveys** of homeowners or real estate professionals, rather than quantifying real impacts based on market data

- **Most studies have relied on simple statistical techniques** that have limitations and that can be dramatically influenced by small numbers of sales transactions or survey respondents

- **Most studies have used small datasets** that are concentrated in only one wind project study area, making it difficult to extrapolate findings

- **Many studies have not reported the statistical significance** of their results, making it difficult to determine if those results are meaningful

- **Many studies have concentrated on Area Stigma**, and have ignored Scenic Vista and/or Nuisance Stigma

- **Only a few studies have included field visits** to homes to determine wind turbine visibility and collect other important information

- **Only two studies have been published** in peer-reviewed journals

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Berkeley Lab Project Involves Most Data-Rich and Comprehensive Analysis To Date

Research Questions

1) Is there evidence that views of turbines measurably affect sales prices?

2) Is there evidence that proximity to turbines measurably affect sales prices?

3) Do the results change over time, and are there other observable impacts?

Relevance

Provides stakeholders in siting/permitting processes greater confidence in the likely effects of proposed wind energy facilities, allowing greater consensus on often-contentious setback requirements and viewshed valuations

Team

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Funder

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Wind & Hydropower Technologies Program
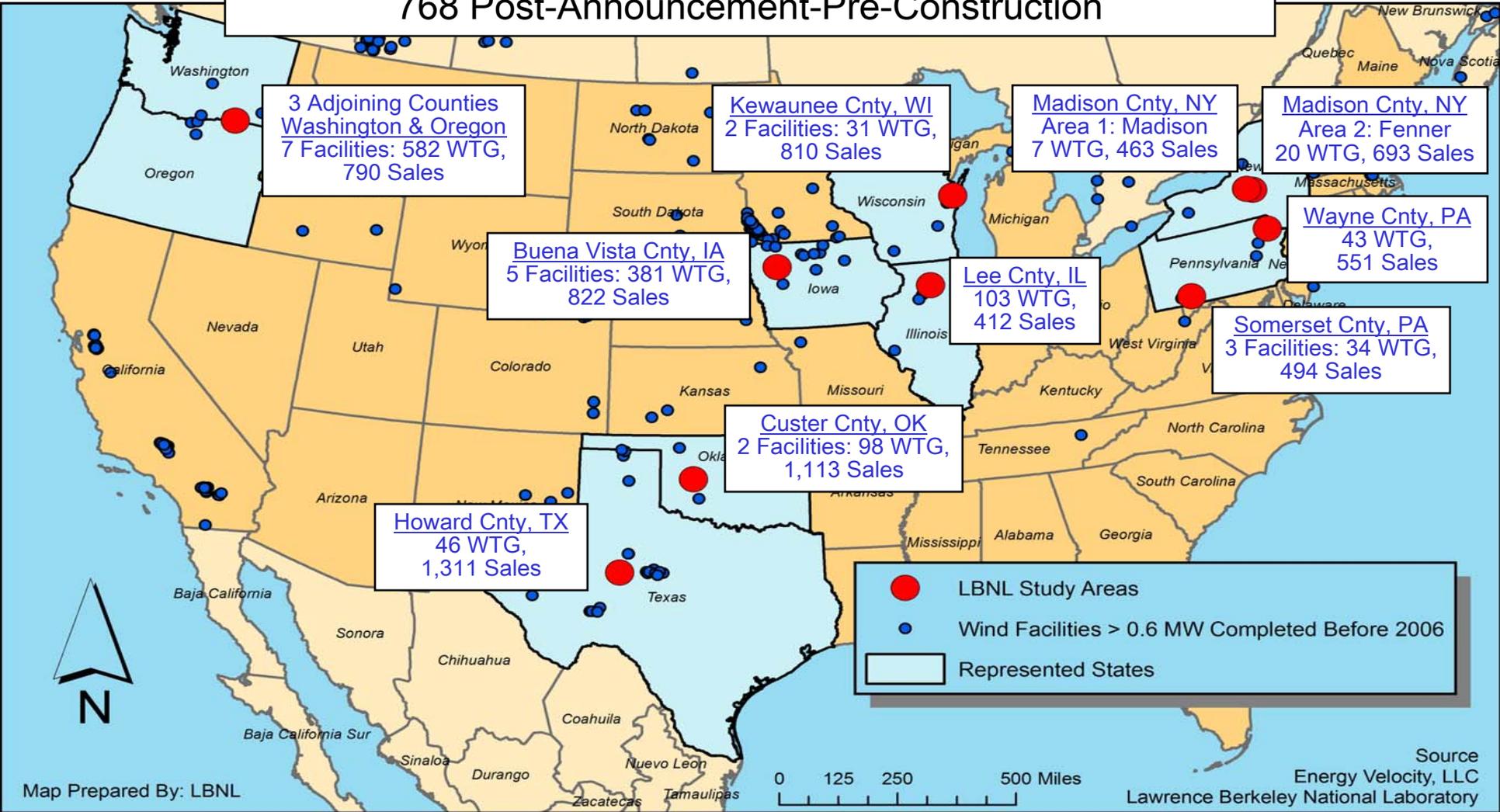
Research Approach Responds to Limitations of Previous Work

- **Conduct literature review** of previous wind / property value studies and wind facility public acceptance surveys, as well as potentially analogous studies on other disamenities (e.g. roads, power lines, power plants)

- **Collect large amount of data** on residential sales transactions occurring both pre- and post-construction surrounding a **representative sample** of wind facilities at **multiple locations** in the U.S.

- **Visit each home** to determine wind turbine visibility and to collect other important information about the home (e.g., the quality of the scenic vista)

- **Use multiple statistical models** to explore magnitude and statistical significance of potential effects, relying primarily on **hedonic model**

- **Test for the presence of all three stigmas** – Area Stigma, Scenic Vista Stigma, and Nuisance Stigma

- **Rigorously analyze** the data, culminating in an LBNL report and at least one journal paper

Collected Sales Data from 10 Study Areas Surrounding 24 Wind Facilities in 9 States

7,459 Residential Sales Transactions
1,754 Pre-Announcement, 4,937 Post-Construction, and
768 Post-Announcement-Pre-Construction

3 Adjoining Counties
Washington & Oregon
7 Facilities: 582 WTG,
790 Sales

Kewaunee Cnty, WI
2 Facilities: 31 WTG,
810 Sales

Madison Cnty, NY
Area 1: Madison
7 WTG, 463 Sales

Madison Cnty, NY
Area 2: Fenner
20 WTG, 693 Sales

Wayne Cnty, PA
43 WTG,
551 Sales

Buena Vista Cnty, IA
5 Facilities: 381 WTG,
822 Sales

Lee Cnty, IL
103 WTG,
412 Sales

Somerset Cnty, PA
3 Facilities: 34 WTG,
494 Sales

Custer Cnty, OK
2 Facilities: 98 WTG,
1,113 Sales

Howard Cnty, TX
46 WTG,
1,311 Sales

- ● LBNL Study Areas
- ● Wind Facilities > 0.6 MW Completed Before 2006
- Represented States

N

Map Prepared By: LBNL

0   125   250   500 Miles

Source
Energy Velocity, LLC
Lawrence Berkeley National Laboratory

Research Relies on Hedonic Pricing Model in Addition to Other Models

	Coef.	SE	p Value	n
Intercept	7.62	0.18	0.00	
Nbr_LN_SalePrice96_hat	0.29	0.02	0.00	4,937
AgeatSale	-0.006	0.0004	0.00	4,937
AgeatSale_Sqrd	0.00002	0.000003	0.00	4,937
Sqft_1000	0.28	0.01	0.00	4,937
Acres	0.02	0.00	0.00	4,937
Baths	0.09	0.01	0.00	4,937
ExtWalls_Stone	0.21	0.02	0.00	1,486
CentralAC	0.09	0.01	0.00	2,575
Fireplace	0.11	0.01	0.00	1,834
FinBsmt	0.08	0.02	0.00	673
Cul_De_Sac	0.10	0.01	0.00	992
Water_Front	0.33	0.04	0.00	87
Cnd_Low	-0.45	0.05	0.00	69
Cnd_BAvg	-0.24	0.02	0.00	350
Cnd_Avg	Omitted	Omitted	Omitted	2,727
Cnd_AAvg	0.14	0.01	0.00	1,445
Cnd_High	0.23	0.02	0.00	337
Vista_Poor	-0.21	0.02	0.00	310
Vista_BAvg	-0.08	0.01	0.00	2,857
Vista_Avg	Omitted	Omitted	Omitted	1,247
Vista_AAvg	0.10	0.02	0.00	448
Vista_Prem	0.13	0.04	0.00	75
WAOR	Omitted	Omitted	Omitted	519
TXHC	-0.75	0.03	0.00	1,071
OKCC	-0.44	0.02	0.00	476
IABV	-0.24	0.02	0.00	605
ILLC	-0.09	0.03	0.00	213
WIKCDC	-0.14	0.02	0.00	725
PASC	-0.31	0.03	0.00	291
PAWC	-0.07	0.03	0.01	222
NYMCOC	-0.20	0.03	0.00	346
NYMC	-0.15	0.02	0.00	469
Post_Con_NoView	Omitted	Omitted	Omitted	4,207
View_Minor	-0.01	0.01	0.40	561
View_Mod	0.02	0.03	0.58	106
View_Sub	-0.01	0.07	0.94	35
View_Extrm	0.02	0.09	0.80	28
Mile_Less_0_57	-0.05	0.06	0.40	67
Mile_0_57to1	-0.05	0.05	0.30	58
Mile_1to3	0.00	0.02	0.80	2,019
Mile_3to5	0.02	0.01	0.23	1,923
Mile_Gtr5	Omitted	Omitted	Omitted	870

"Omitted" = reference category for fixed effects variables
*"n" indicates number of cases in category when category = "1"*

Model Information

Model Equation Number	1
Dependent Variable	LN_SalePrice96
Number of Cases	4937
Number of Predictors (k)	37
F Statistic	442.8
Adjusted R Squared	0.77

What Is a Hedonic Pricing Model?

- **Well respected model** used by economists and real estate practitioners for over 40 years

- **Heterogeneous** residential sales data are used

- **Measures marginal price differences** between homes that vary by the variables of interest, after controlling for other characteristics

- **Controlling characteristics** include square feet, acres, bathrooms, fireplaces, age, condition and scenic vista of the home, location, etc.

- **Variables of interest** include view of turbines, distance from turbines, and development period (e.g. before or after construction began)

- **Results and significance levels** are important

Other Models Used in Analysis

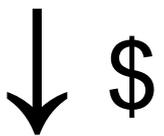Repeat Sales and Sales Volume Models

To Test for Scenic Vista Stigma, Scenic Vista Itself Is Controlled For

They might pull in two directions…
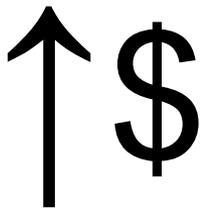
↑ $ By separating out scenic vista, a potential bias is removed from measurements of the effects of the view of wind turbines   ↓ $

Five Qualitative Ratings Are Used for Quality of Scenic Vista

Poor

Below Average

Average

Each home is given a scenic vista rating, based on field visits

Premium

Above Average

Four Qualitative Ratings Are Used for Dominance of View of Wind Turbines

Each home is given a view of turbines dominance rating, based on field visits

Minor

Extreme

Moderate

Substantial

To Test for Area and Nuisance Stigmas,
Distance to Nearest Turbine at Time of Sale Is Determined

Map Prepared By: LBNL

Source
Lee County
Lawrence Berkeley National Laboratory

Legend:
+ Turbines
• Sold Homes
— 3000 Foot Buffer
— 1 Mile Buffer
— 3 Mile Buffer
— 5 Mile Buffer
— 10 Mile Buffer

0 2 4 8 Miles

"Sold Homes" include all homes sold both before and after construction of the wind facility

Five Distance Bands Are Created

Nuisance Stigma

- Inside of 3000 Feet
- Between 3000 Feet and 1 Mile

Area Stigma

- Between 1 and 3 Miles
- Between 3 and 5 Miles
- Outside of 5 Miles

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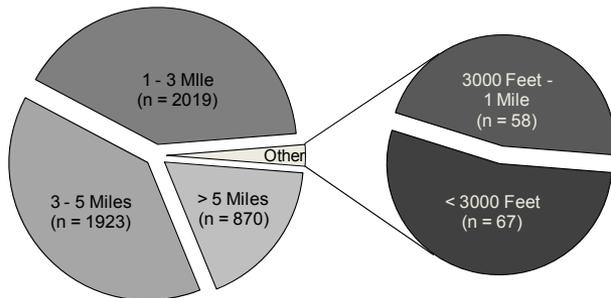- ## Summary of Analysis Results

- ## Conclusions and Further Research

Data Summary: Development Period, and Distance from and View of Wind Facilities
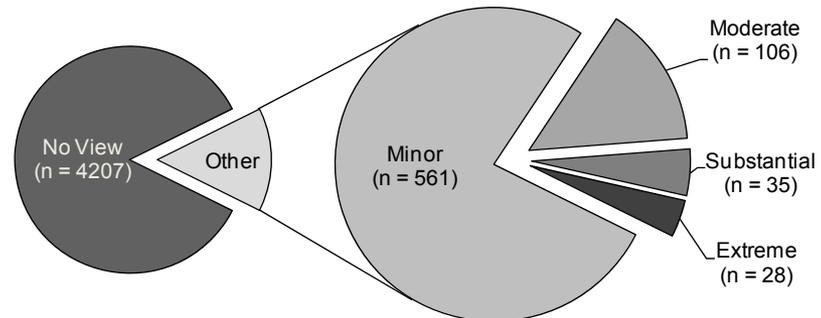
Summary of Transactions across Study Areas and Development Periods

	Pre Announcement	Post Announcement Pre Construction	1st Year After Construction	2nd Year After Construction	2+ Years After Construction	Total
Benton/Walla Walla, WA & Umatilla, OR (WAOR)	226	45	76	59	384	**790**
Howard, TX (TXHC)	169	71	113	131	827	**1311**
Custer, OK (OKCC)	484	153	193	187	96	**1113**
Buena Vista, IA (IABV)	152	65	80	70	455	**822**
Lee, IL (ILLC)	115	84	62	71	80	**412**
Kewaunee/Door, WI (WIKCDC)	44	41	68	62	595	**810**
Somerset, PA (PASC)	175	28	46	60	185	**494**
Wayne, PA (PAWC)	223	106	64	71	87	**551**
Madison/Oneida, NY (MYMCOC)	108	9	48	30	268	**463**
Madison, NY (NYMC)	59	165	74	70	325	**693**
TOTAL	**1755**	**767**	**824**	**811**	**3302**	**7459**

Frequency of DISTANCE Ratings for Post-Construction Transactions

- 1 - 3 Mile (n = 2019)
- 3 - 5 Miles (n = 1923)
- > 5 Miles (n = 870)
- Other
- 3000 Feet - 1 Mile (n = 58)
- < 3000 Feet (n = 67)

Frequency of VIEW Ratings for Post-Construction Transactions

- No View (n = 4207)
- Other
- Minor (n = 561)
- Moderate (n = 106)
- Substantial (n = 35)
- Extreme (n = 28)

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Eight Hedonic Models Used, as Well as Repeat Sales and Sales Volume Analyses

Variety of models used to investigate reliability of "Base Hedonic Model" results and to explore myriad of other potential effects from variety of perspectives

Data across study areas are pooled in this analysis; many other hedonic model specifications, including those with no pooling of data, are investigated

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

Data collection, cleaning, validity, and regression tests are all discussed in detail in the full report

Each Model Fails to Uncover Conclusive Evidence of Any of the Three Stigmas

Home Prices in Sample Are Not Measurably Impacted by Either the View of or Distance to Wind Facilities

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

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

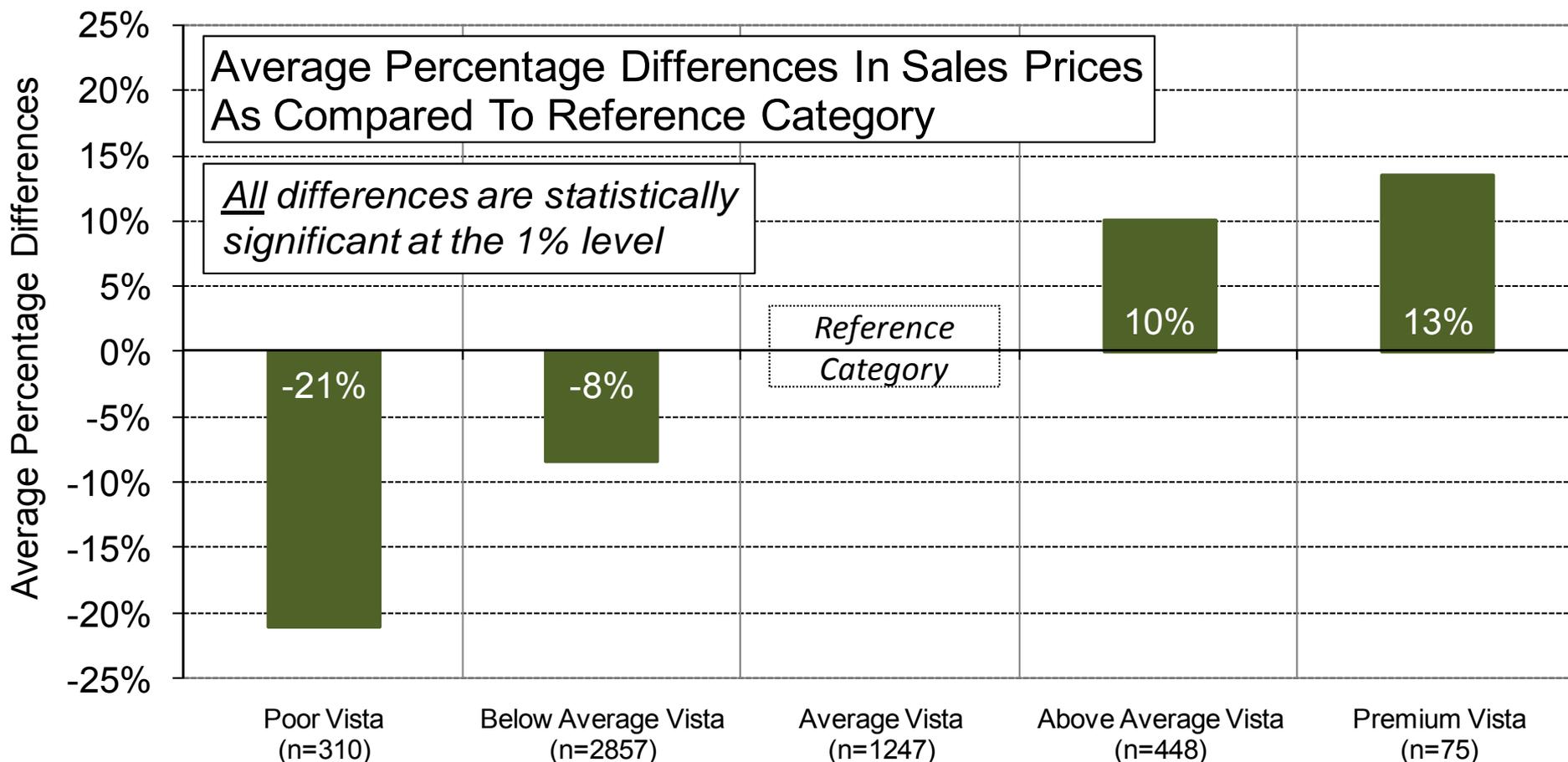Energy Markets and Policy Group • Energy Analysis Department

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Base Hedonic Model Results:
There Is Strong Statistical Evidence that the Quality of the Scenic Vista Affects Sales Prices

Average Percentage Differences In Sales Prices As Compared To Reference Category

All differences are statistically significant at the 1% level

Reference Category

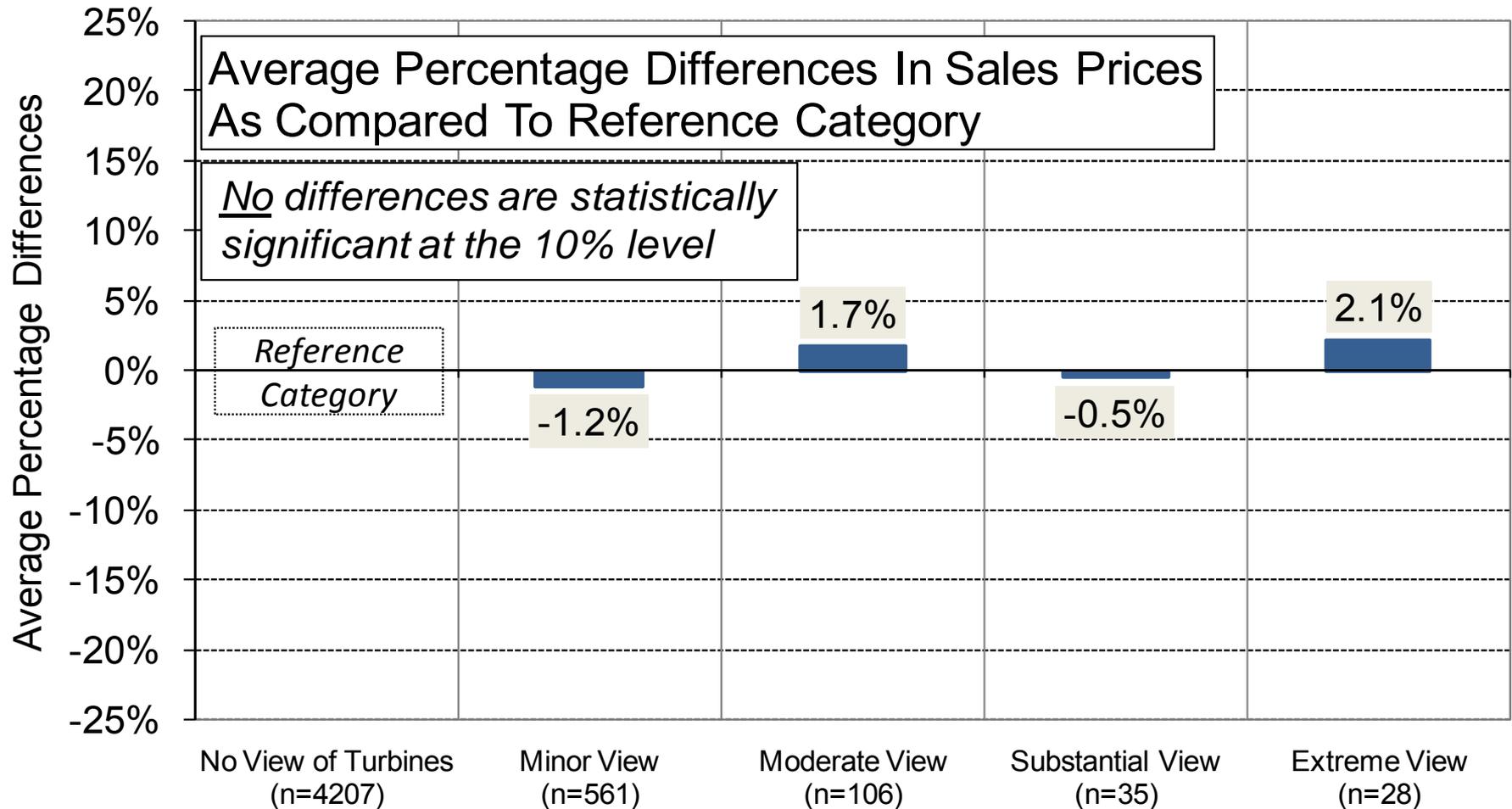| Poor Vista (n=310)	Below Average Vista (n=2857)	Average Vista (n=1247)	Above Average Vista (n=448)	Premium Vista (n=75)
-21%	-8%		10%	13%

The reference category consists of transactions for homes with an Average Vista, and that occured after construction began on the wind facility

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Base Hedonic Model Results:
There Is a Lack of Statistical Evidence that the Dominance of the Views of Turbines Affects Sales Prices

Average Percentage Differences In Sales Prices As Compared To Reference Category

No differences are statistically significant at the 10% level

Reference Category

- No View of Turbines (n=4207)
- Minor View (n=561): -1.2%
- Moderate View (n=106): 1.7%
- Substantial View (n=35): -0.5%
- Extreme View (n=28): 2.1%
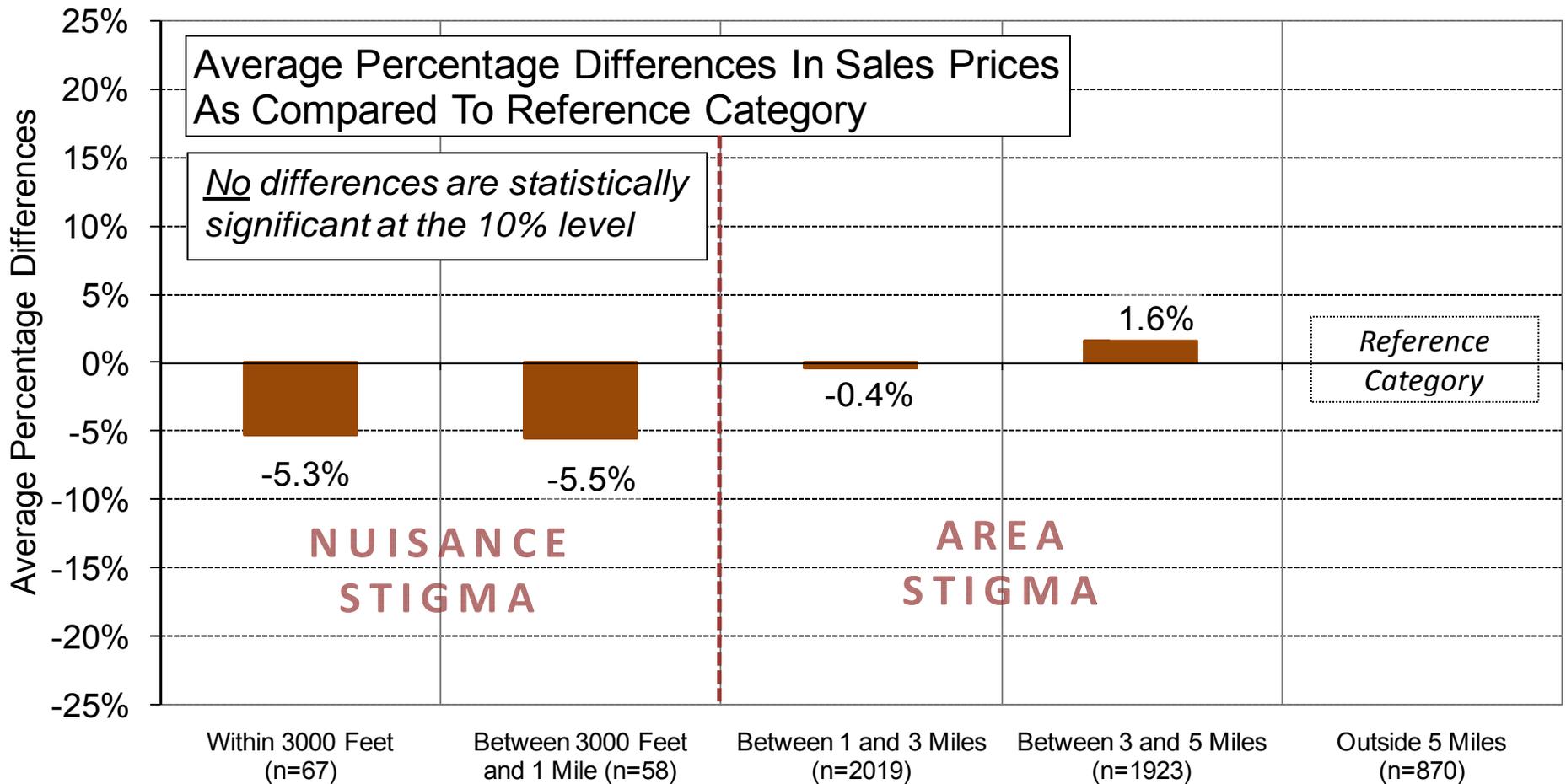
Y-axis: Average Percentage Differences (25% to -25%)

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

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Base Hedonic Model Results:
There Is <u>a Lack of</u> Statistical Evidence that the Distance to the Nearest Turbine Affects Sales Prices

Average Percentage Differences In Sales Prices As Compared To Reference Category

<u>No</u> differences are statistically significant at the 10% level

Y-axis: Average Percentage Differences (from -25% to 25%)

Category	Value
Within 3000 Feet (n=67)	-5.3%
Between 3000 Feet and 1 Mile (n=58)	-5.5%
Between 1 and 3 Miles (n=2019)	-0.4%
Between 3 and 5 Miles (n=1923)	1.6%
Outside 5 Miles (n=870)	Reference Category

NUISANCE STIGMA

AREA STIGMA

The reference category consists of transactions for homes situated more than five miles from the nearest turbine, and that occured after construction began on the wind facility
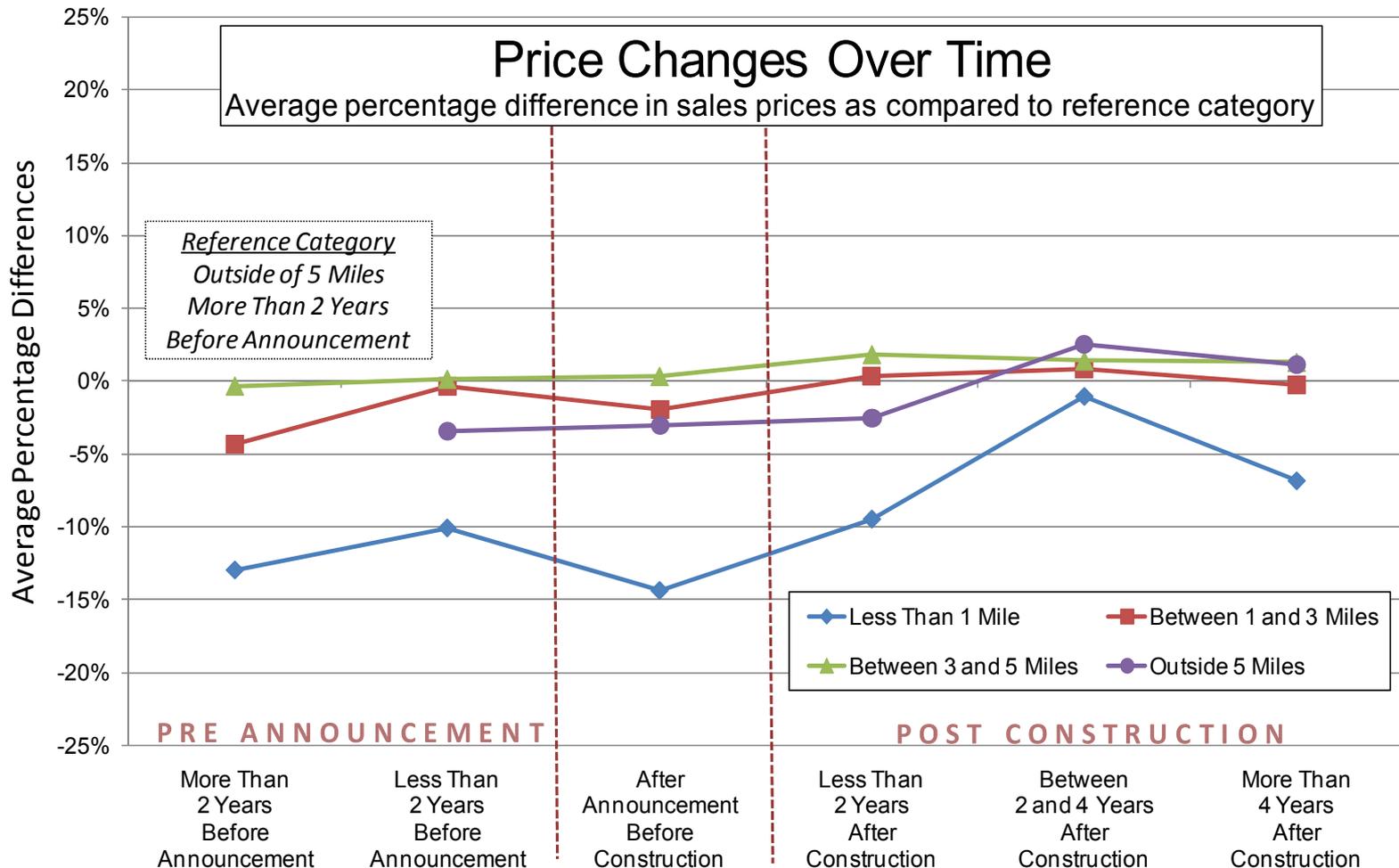
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Temporal Aspects Model Results:

Homes Nearest the Turbines Were Depressed in Value Before Construction and Appreciated the Most After Construction While Homes Further Away Were Largely Unchanged Over Time

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

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Results from Other Models Support Basic Conclusions from Base Hedonic Model

Some examples are…

Repeat Sales Model: Investigated appreciation rates between houses that sold twice with various views of and distances from turbines

Sales Volume Model: Investigated the numbers of homes that sold as a percentage of those that were available to sell at various distances from the turbines

Hedonic Orientation Model: Investigated whether a home's orientation to the view of turbines has an effect on selling price

Hedonic Overlap Model: Investigated whether the degree to which the view of the turbines overlaps the scenic vista has an effect

The results are consistent across all models in that none uncovers conclusive evidence of the existence of any widespread property value impacts for any of the three stigmas

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Conclusions

Although the analysis cannot dismiss the possibility that individual homes have been or could be negatively impacted, the Berkeley Lab research finds that if these impacts do exist in the sample of homes analyzed, they are either too small and/or too infrequent to result in any widespread, statistically observable effect

- **Area Stigma:** Homes in the study areas analyzed do not appear to be measurably stigmatized by the arrival of a wind facility

- **Scenic Vista Stigma:** None of the various models finds strong statistical evidence that the view of a nearby wind facility impacts sales prices in a significant and consistent manner

- **Nuisance Stigma:** Homes in the sample that are within a mile of the nearest wind facility, where various nuisance effects have been posited, have not been broadly and measurably affected by the presence of those wind facilities

Further Research Recommendations

- **Complete "primer"** to summarize findings, place results into broader literature of disamenities, and outline options to measure, mitigate, and manage property value risks

- **Survey homeowners** living close to existing wind facilities especially those who have bought and sold homes in proximity to wind facilities after facility construction

- **Conduct more detailed analysis on sales volume** impacts including time on the market prior to sale

- **Revisit hedonic analysis** when more data are available for homes located particularly close to and having dominating view of wind facilities

For More Information...

See full report for additional findings, a discussion of the sources of data used, etc.

- **http://eetd.lbl.gov/ea/ems/re-pubs.html**

To contact the primary authors

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