Rhode Island Office of Energy Resources

In RE: Proposed 2016 Rhode Island Land-Based Wind Siting Guidelines

RESPONSE TO COMMENTS

Introduction

On February 19, 2016, a notice was posted on the websites of the Rhode Island Office of Energy Resources (OER) and the Rhode Island Office Secretary of State, and was forwarded to interested parties, announcing a public comment period to accept comments on the adoption of the “Proposed 2016 Rhode Island Land-Based Wind Siting Guidelines” (Guidelines). Copies of the proposed Guidelines were made available at the OER offices, on OER’s website (www.energy.ri.gov), by calling OER at (401) 574-9106 or by writing to Rhode Island Department of Administration, Office of Energy Resources, One Capitol Hill, Providence, Rhode Island. A Public Meeting notice stating that a public meeting would be held on February 22, 2016 at 7:00 pm, at the Warwick Public Library, Large Conference Room, 600 Sandy Lane, Warwick, Rhode Island was posted on February 10, 2016. The public meeting provided an overview of the proposed Guidelines and allowed the public to share their comments and insights. Meeting minutes and the PowerPoint presentation from the public meeting are available on the Rhode Island Secretary of State website.

The proposed land-based wind siting guidelines were prepared by OER as an update to the Division of Planning’s 2012 technical report, “Interim Siting Factors for Terrestrial Wind Energy Systems. The updated guidelines are meant to provide information and helpful guidance for Rhode Island municipalities interested in establishing new (or revising existing) land-based wind turbine siting ordinances for their community. The information and recommendations presented within should not be deemed mandates by the Rhode Island Office of Energy Resources (OER).

Response to Comments

The following are the paraphrased comments of Charles Brown – Wildlife Biologist, Rhode Island Department of Environmental Management (DEM), presented at the public meeting and also in writing, followed by OER’s response:

Comment:

Consider adding to the “Environmental Impacts – Description of Impact” section, the direct habitat loss due to land clearing, road construction and turbine construction.

Response:

The environmental impacts described in the “Environmental Impacts – Description of Impact” section, are limited to those impacts specific to large scale wind turbines. Environmental impacts common to many types of develop, such as habitat loss and road construction, are not discussed. It is assumed that municipalities have experience addressing more common environmental impacts and can use language from other, previously drafted ordinances.

However, OER does provide a full list of items to be considered by municipalities in Appendix A of the Guidelines, “Municipal Development Proposal Checklist”. This list includes construction issues such as erosion, water quality, noise, habitat fragmentation, and component transportation. An edit has been made to include habitat loss under the construction issues section of the Municipal Development Proposal Checklist.

Comment:

Given the lack of information regarding avian and bat mortalities attributed to wind turbines it is *recommended that Figure 5 "Annual avian mortality in the USA" be removed as it is deceptive.*

Response:
Instead of removing Figure 5, OER has added further explanation below the figure. Specifically, a note was added to explain how the number of wind turbines compared to the number of domestic cats, transmission lines, buildings and windows, and other categories is extremely low. With this note, OER believes that the figure does provide helpful information and context for municipal officials.

Comment:
It is recommended that the following paragraph in the "Environmental Impacts – Description of Impacts" section be edited as shown: "However, the relatively small number of ***documented*** *avian deaths from wind turbines does not mean that the mortality rates should be ignored.* ***Low reported mortality rates could be due to lack of consistent or standardized monitoring and reporting, various factors affecting the detection rates of carcasses, and a number of other factors.*** *As the number of turbines increases, negative avian and bat effects* ***will likely increase*** *~~may become more dramatic~~. In addition, even a ~~few deaths~~* ***small increase in the mortality rate*** *can be harmful to ~~small~~* ***some*** *populations, especially for long-lived species* ***such as bats*** *with slow maturity and low reproductive rates."*

Response:
All recommended edits were made, save for one. The following words were not included due to their lack of specificity: "…and a number of other factors." OER believes the inclusion of the other edits achieve what the Mr. Brown wished to clarify.

Comment:
During the technical review of the Guidelines (before the public review) Mr. Brown recommended that the paragraph addressing "All Fauna" in the "Environmental Impacts – Description of Impacts" section be rewritten. Previously, one study that showed an increase in prairie chicken survival rates near wind turbines was specifically called out. Mr. Brown suggested that highlighting this study would be deceiving as, "the authors hypothesized the increased survival of prairie chickens was related to a decrease in avian predators, possibly avoiding turbine areas of being killed by them."

Response:
This was done prior to public review.

Comment:
In the "Environmental Impacts – Recommended Standard" section Mr. Brown recommends word/sentence changes that remove OER's original recommendation that a wind project's scale/size be considered in regards to its potential environmental impact. He indicates that it is hard to predict the environmental impact that even a small, single turbine could have. Mr. Brown also recommends that the description of areas to be avoided be expanded to include large, unfragmented, undeveloped lands, especially those adjacent to lands protected primarily for the purpose of preserving and protecting wildlife habitat and species, and coastal areas.

Response:
OER believes that the size and scale of a wind development is an important, though not the sole, factor when considering environmental impacts. If the U.S. Fish and Wildlife Service guidelines are followed, as recommended in the document, many other factors are weighed including presence of species of concern, habitat fragmentation, direct and indirect building and operating

impacts, and others. These considerations also address Mr. Brown's second request of including large, unfragmented, undeveloped lands in the areas to be avoided for wind development. OER does not feel that all large parcels of undeveloped land should be considered ineligible for wind development. Instead, the considerations of the USFWS guidelines will help to pinpoint where species of concern may be minimally impacted. Therefore, no change was made to the Guidelines document.

Comment:
In the "Environmental Impacts – Recommended Standard" section Mr. Brown recommends that the qualifications and funding source for the expert used to conduct a site characterization visit be clarified.

Response:
OER has not specified the funding source or qualifications needed for site characterization visits or any other scientific or analytical work needed for the recommended standards. OER believes each municipality will know how to best setup a funding and/or result verification process to ensure unbiased and accurate wind development information. Depending on the expertise in house, a municipality may be able to verify study results and processes conducted by the wind development companies, subcontractors or developers without hiring a third party consultant. However, it is more likely that a municipality will need to hire a third party to verify study results. OER has not recommended how to fund or structure such processes, since OER expects each municipality to prefer slightly different methods. OER is willing to provide assistance to municipalities as they navigate these issues, but specific recommendations have not be added to the Guidelines document. Instead the following sentence was added to a bullet in the "Siting Impacts and Recommended Standards" section:
"•Expert reviewers or consultants may be needed by a municipality to evaluate the technical aspects of a wind turbine project proposal. It is recommended that municipalities set a limit or negotiate a maximum cost to the wind developer for these services prior to a proposal review. ***OER is able and willing to provide assistance to municipalities as they navigate issues related to hiring third party consultants."***

Comment:
It is pointed out that there is no person or process within DEM to currently review wind project proposals.

Response:
OER recognizes that this is an issue at the State level. However, the U.S. Fish and Wildlife Service, in their voluntary Land-Based Wind Siting Guidelines, does indicate how the Service should be included in the process and the specific assistance they can provide. OER only recommends that a developer attempt to engage the RI DEM and other appropriate environmental organizations, the recommendation does not require that comments be received. If DEM or other appropriate organizations are able to provide feedback for a wind development project, their more local expertise would be beneficial. However, if DEM and/or other groups are unable to provide feedback, the Service's input is all that should be required.

To clarify this recommendation, the following edits were made to the last paragraph in the "Environmental Impacts – Recommended Standard" section:

"Wind turbine developers should be required to engage the U.S. FWS, the RI DEM, and other appropriate environmental advisory groups as early in the proposal process as possible. In general, the environmental impacts of wind turbines are best handled at the state and federal

*levels. Therefore, project guidance from ~~these authorities~~ **the U.S. FWS, and when possible RI DEM and other appropriate environmental advisory groups,** should be obtained prior to a municipality's project review. All relevant recommendations and comments from these environmental groups/agencies should be addressed in a project proposal and considered by a municipality during the permitting process. Mitigation strategies should be identified and included in plans prior to construction approval in case post-construction monitoring indicates an unacceptable level of environmental impact. Post-construction monitoring data, if deemed necessary to collect, should be shared with the municipality. If ~~state and~~ federal **(and state, if received)** environmental recommendations are met by a proposal, a municipality should not retain the right to reject a proposal for environmental reasons."*

Comment:

It is recommended that mitigation strategies not only be identified, but develop and adopted into operational plans before construction approval. In the original document it was only stated that they be identified before construction.

Response:

*OER reworked the two sentences related to the comment. They now read, "Mitigation strategies should be identified and included in plans prior to construction **approval** in case post-construction monitoring indicates an unacceptable level of environmental impact" and "Mitigation strategies such as tubular tower construction, operation curtailment, limited lighting…, and/or avian detection technologies can also be incorporated into construction **and operation plans**" respectively.*

Comment:

Mr. Brown suggests that the response to FAQ 1 in the "Environmental Impacts – FAQ's" section be reworked. He provided the following information to help rework the answer: "There is much that is not well understood about migratory pathways and how and when they are used, especially for bats. It is well known that during migration, particularly in the fall, that migrating birds are concentrated at the coast due to a variety of factors. It can be assumed that this also is true for migratory bats. The timing of migratory movements is somewhat predictable, coinciding with certain weather events. Known concentration areas along the coast should be avoided for wind turbine placement.

With fall migration, birds are leaving the interior and heading generally south, and not necessarily together in a specific line or pathway, until they encounter the ocean. At that point they become concentrated, most not wanting to fly over the ocean. In our case they turn "right" and follow the coast south. If they overshoot the coast they will reorient back to land, often at first light. Most migrate at night. It appears bats move in similar patterns. The highest numbers of birds and bats move when weather conditions are favorable, often after the passage of a cold front. Turbines placed in coastal areas could potentially have devastating impacts if they are sited in locations where birds and bats become concentrated, or come to ground to rest or roost at daylight."

Response:

*The response was reworked to more appropriately answer the FAQ. The reworked section is as follows: "In general, birds and bats do not tend to follow a particular line or pathway until they encounter the ocean. **However, particularly in the fall**, ~~once near the coastline~~ they tend to concentrate **near the coastline** and follow the coast south. **Most migrate at night with the timing of their migratory movements coinciding with certain weather events.** Unfortunately, little more is well understood about migratory pathways. Many questions regarding how and when they are* *used remain unanswered. A lack of information regarding current population levels can also prevent an accurate understanding of the effects of turbine-caused mortalities. Therefore, post-construction monitoring is important to ensure the real-life impacts are close to those predicted by the pre-construction survey(s). In addition, known concentration areas* ***and ground resting or roosting places*** *along the coast should generally be avoided by wind turbine development."*

Comment:
It is recommended that the response to FAQ 4 in the "Environmental Impacts – FAQ's" section be rewritten to support the need for pre and post construction environmental studies irrespective of study costs. Specifically, Mr. Brown suggests the following text: "Environmental studies can be expensive. Given the lack of knowledge that currently exists with respect to bird and bat migration behaviors and the impact that wind turbine construction and operation may have on other wildlife species, these expenses should be considered an investment toward in our knowledge of how wind turbines impact wildlife and guide future planning, development, and operation of land-based wind energy projects."

Response:
OER understands that pre- and post- construction environmental studies are the best way to gain better data regarding wind turbine impacts on the environment. However, the expense of these studies should be weighed against the usefulness of the data to be collected. Not every wind development should be required to conduct extensive studies, if there is little reason to expect environmental harm. Instead, OER recommends the use of the U.S. Fish and Wildlife Service's voluntary Land-Based Wind Siting Guidelines which provides guidance on when studies are and are not necessary.

Within the response to FAQ 4, OER also includes the following sentence, "In general, collecting pre- and post-construction data, though costly, is likely the best way to improve and simplify future environmental impact standards." OER beliefs this sentence highlights Mr. Brown's concern. Therefore, no change to the Guidelines document was made.

The following are the paraphrased comments of Wind Energy Development (WED), presented at the public meeting and also in writing, followed by OER's response:

Comment:
Include the preservation of open space as a potential benefit of wind development.

Response:
In the "Introduction" section of the Guidelines, the following sentence was edited as shown: "For individual cities and towns, wind projects may provide tax or lease revenues, ***preservation of open space,*** *price stability, diversified electricity sources, and local jobs."*

Comment:
Use the terms "turbine collapse" and "ice shedding" instead of "turbine collapse/topple" and "ice shedding/throw" respectively. The suggested terminology is more accurate.

Response:
Although WED's recommended term names may be more accurate, OER will keep the originally used impact names of "turbine collapse/topple" and "ice shedding/throw." OER believes the terms "throw" and "topple", though not as accurate, are used commonly. Therefore, it is in the interest of clarity that OER keeps the impact names as descriptive as possible.

Comment:
In the "Background – Overview of Wind Energy in Rhode Island" section, add that modern wind turbines are now able to perform effectively at lower wind speeds which is making wind development viable throughout the state. Also update the sentence about turbines in the Town of Coventry. They are now all under construction. Finally, please edit the following sentence as shown: "Instead, Rhode Island's wind power potential lies in ***the opportunity to develop multiple*** *municipal or small-scale commercial projects consisting of one or a few wind turbines, and in offshore wind farms."*

Response:
The following sentence was added to the first paragraph of this section in order to highlight the low wind speed technologies: "However, some modern day commercial scale wind turbines are designed to perform more effectively at low wind speeds and these turbines can be economically viable throughout portions of the state."

The last sentence of this section was updated as follows: ".In addition, ten 1.5 MW land-based wind turbines are currently ~~proposed~~ ***in construction in*** *the Town of Coventry.~~, three of which have received final permitting approval~~"*

Also, the recommended sentence edit was included in the section.

Comment:
WED expects that wind development in Rhode Island will exceed the 70MW predicted in the State Energy Plan by 2035. WED recommends removing this number or increasing it as it vastly underestimates the potential for wind in Rhode Island.

Response:
OER removed references to the 70 MW number.

Comment:
*The following edits are suggested for FAQ 3 in the "Background – Overview of Wind Energy in Rhode Island" section: "****As of 2014*** *Rhode Island consumes approximately 8,000 GWh of electricity each year. Assuming a 20% capacity factor (see question 4 below),* ***existing*** *Rhode Island wind turbines generate a total of about 16,000 MWh per year."*

Response:
The suggested edits were made.

Comment:
Recommend differentiating between low-density residential and high-density residential zones in all illustrative tables. Farms are often low-density zones and are suitable for wind.

Response:
OER recognizes that low-density and high-density residential areas are very different zone types, therefore the recommendation was implemented.

Comment:
As written, the most restrictive flicker standard is unnecessarily prohibitive. Flicker should be measured at receptors such as occupied buildings using a realistic case-scenario. The area affected by shadow flicker can be very large (thousands of feet in multiple directions).

It would be impossible to prevent it from occurring on any portion of nearby land.

Response:
OER recognizes how restrictive the originally drafted shadow flicker standard was. The section has now been re-worked. The shadow flicker recommended standard now reads as follows: "Shadow flicker should be limited to no more than 30 hours per year at occupied structures or sites permitted for occupied structure construction at the time of wind project permitting. This limit should be based on worst-case scenario modeling, which assumes flat, open land, constant sunshine during the day and constant wind turbine operation. Appropriate modeling software such as WindPro should be used for these analyses. This standard should only be applied to occupied structures not located on the wind development property. If an occupied structure located on the property being developed will experience shadow flicker in excess of the standard, the developer should notify the land owner and submit an acknowledgement of the higher shadow flicker impact signed by the land owner to the municipality. Increased impact special use permits (IISUPs) for higher shadow flicker exposure on occupied structures located outside of the wind development property should be allowed. In addition, a standard should require complaint collection, disclosure, and investigation procedures, and should establish a pre-set limit on the frequency and/or total number of times compliance testing can be required."

Comment:
It should be explicitly stated that all recommended standards should be applied at the time of permitting. Standards should not be applied retroactively. Having standards apply retroactively would jeopardize project financing.

Response:
This was the intent of OER when writing the recommended standards. The following sentence has been added to the Guidelines document under the "Siting Impacts and Recommended Standards" section in order to clarify: "Recommended standards should be applied at the time of project permitting."

Comment:
Blade throw is not a concern if using certified turbines. WED recommends the guidelines promote certified technologies so no need to worry about blade throw or turbine falling.

Response:
The Guidelines already state "Only turbines meeting International Electrotechnical Commission (IEC) or similar certifications should be permitted." Therefore, no change was made to the document.

Comment:
OER should not recommend that viewshed analyses and photographic renderings be required by municipalities. There are no standards to dictate how these items should be used by a municipality to make a permitting decision. They will likely only be used for NIMBYism.

Response:
The document does not recommend any standard for evaluating viewshed analyses or photographic renderings. Specifically, the document states, "unless pre-existing visual impact standards are violated, a turbine project proposal should not be rejected on the basis of visual impacts."

OER believes conducting and submitting visual analyses in a project proposal shows a good faith effort by a developer to engage a community and optimize a turbine's location. To clarify that visual impact standards should not be created as a means of prohibiting wind development, the following sentences were added to the "Other Impacts – Description of Impacts – Visual Impacts" section: "Wind development should not be treated differently from other types of development with respect to visual impacts. If a municipality has pre-existing visual impact standards, wind development should be required to abide by those standards. However, if no visual impact standards exist in a municipality at the time of an application submittal, none should be applied to the review of a wind development proposal."

Comment:
As written, the Guidelines require that additional transmitter masts be installed at a wind developer's expense if communication issues arise. Instead, the Guidelines should recommend that the wind turbine developer be responsible for finding a mutually agreeable solution. There may be cases when installing additional transmitter masts is not the best solution.

Response:
The recommendation was adjusted in the "Siting Impacts and Recommended Standards" section as follows: "If communication issues arise additional transmitter masts should be installed at the wind developer's expense ***or the developer should be responsible for finding another, mutually agreeable, solution****."*

Comment:
OER should not recommend that the USFWS's voluntary guidelines be used in all cases to assess the environmental impacts of a wind development. As written, the process could add unnecessary process, delay, and cost. Instead, there should be a preliminary screening method to determine if more studies/investigation is warranted.

Response:
The USFWS's voluntary guidelines follow a tiered structure. The first tier is a type of screening methodology that determines if more environmental studies or investigations are needed. Therefore, no change was made to the recommended standard.

Comment:
In the "Siting Impacts and Recommended Standards" section, WED commented: WED agrees that siting standards need to be flexible. However, WED also believes that all municipalities should allow wind siting in some designated areas by right. This makes for a transparent process for both municipalities and developers. For example, the Massachusetts's Green Communities Act and the Telecommunications Act, allow municipalities to say where they would like specific developments to go, but don't allow them to prohibit the specific development types from the entire municipality.

Response:
OER believes that municipalities understand their zoning designations and goals best. Therefore, OER thinks each municipality should have the right to decide where wind development should or should not be permitted. As described in the "Zoning Considerations for Municipalities" section, OER recommends the following: "Municipalities should review their "use tables" and identify whether wind turbines should be a permitted use, special (or "conditional") use, or prohibited use in different types of zoning districts. Use tables allow municipalities to steer potential development activities to locations well-suited for wind projects relative to existing or planned land use activities, and away from areas that a municipality may view as less suitable for wind

development." Although this recommendation does not require municipalities to permit wind development, OER hopes municipalities will use this process to find at least one zone that could accommodate wind projects. No changes were made to the Guidelines document based on the above comment.

Comment:
WED asks that OER cite a source for the following sentence in the "Setbacks – Description of Impacts" section: "These concerns are usually ties to extreme weather events such as hurricanes and nor'easters." WED does not believe a turbine has collapsed from a nor'easter.

Response:
OER has adjusted this sentence and added a citation.

Comment:
In the "Setbacks – Description of Impacts" section, WED calls into question the paper referenced: [1] G. Carbone and L. Afferrante, "A novel probabilistic approach to assess the blade throw hazard of wind turbines," *Renew. Energy*, vol. 51, pp. 474–481, 2013. *WED believes that the data on blade-related accidents referenced in the paper comes from an anti-wind farm website in the UK.*

Response:
The paper in question was published in a peer reviewed scientific journal. The overall analysis and conclusions of the paper are therefore believed to be sound. The data in question are referenced in the introduction of the paper in order to highlight the relevance of the topic. The data do not play a role in the paper's overall findings. OER sees no reason that references to this paper should be removed from the Guidelines.

Comment:
WED stresses that blade throw and turbine collapse do not happen to certified wind turbines. Therefore it is important to emphasize prevention/safety through quality requirements.

Response:
OER feels that this point has been stressed sufficiently by the inclusion of the following sentence in the recommended setback standard: "Only turbines meeting International Electrotechnical Commission (IEC) or similar certifications should be permitted."

Comment:
WED recommends that additional information be provided in the paragraph addressing ice throw/shedding in the "Setbacks – Description of Impacts" section: 1. there are technologies that address ice shedding. The turbine is shut down as soon as the blades become unbalanced due to ice accumulation, and 2. ice shedding is less dangerous in secluded areas versus locations near residents or road ways. Therefore, WED recommends that ice shedding requirements be location/setting dependent.

Response:
OER edited the sentence at the end of the fourth paragraph within the "Setbacks – Description of Impacts" section as follows: This equation only provides a rough estimate of a risk zone, but when ~~paired~~ ***coupled*** *with conservative operation protocols* ***and/or modern ice-sensing technologies*** *it can actively prevent dangerous ice throw scenarios.*

The setback recommendation was not adjusted to be location/setting dependent because the *recommended 1.5x turbine height setback was set to mitigate blade throw and turbine collapse/topple risks in addition to ice shedding risks. Although the argument can be made that all these risks may be less in secluded areas, due to the lack of failure rate data for U.S. wind turbines, OER believes the safety setback standard should be consistent no matter where the location.*

Comment:
Manufacturers do not provide recommendations for setback distances. Therefore, the third bullet point in the "Setbacks – Recommended Standards" section should be re-worked.

Response:
Although today's manufacturers usually do not provide setback distances, historically a few provided recommendations. If a manufacturer feels a need to provide a recommendation then that recommendation should be followed if it requires a larger setback than the standard described in the Guidelines. OER sees no harm, only potentially added safety, by leaving the recommendation as currently written. Therefore, no changes were made to the document.

Comment:
In the "Noise – Description of Impact" section, WED would like OER to remove the word "negatively" in the second sentence of this section. This word assumes that turbines will have a negative impact.

Response:
The sentence in question describes the reason for creating noise siting standards for wind turbines. The goal, as stated, is to reduce "noise emanating from wind turbines that will negatively impact people in the surrounding area." Standards should not attempt to mitigate sound in general but should focus on limiting negative impacts. Therefore OER regards the word "negatively" as an important part of the sentence and did not make the recommended change.

Comment:
In the "Shadow Flicker – Description of Impact" section, WED recommends the following sentences be edited as shown: "It should be noted that shadow flicker only occurs on sunny days ***when turbine is spinning at sunrise or sunset****.* ~~*In stormy or overcast conditions*~~ ***cloudy****, if the sun is not bright enough to cast shadows, it will not bright enough to cause shadow flicker"*

Response:
Edits were completed as follows: It should be noted that shadow flicker only occurs on sunny days ***when a turbine is spinning****. In stormy,* ~~*or*~~ *overcast****, or cloudy*** *conditions, if the sun is not bright enough to cast shadows, it will not bright enough to cause shadow flicker.*

Comment:
In the "Shadow Flicker – Recommended Standard" section, WED stresses that the standard should not be applied to "any portion of a nearby property" but only as receptors/occupied structures.

Response:
The shadow flicker recommended standard has been changed as suggested by the comment above.

Comment:
WED disagrees with bringing up the visual impacts of wind turbines in the document. WED does

not believe visual impact analyses are required for other buildings or structures and recommending them for wind turbine developments singles out wind unfairly and unjustifiably.

Response:
Large-scale terrestrial wind turbines are likely to have significant visual impacts. As written the Guidelines do not recommend any evaluation of visual impacts unless visual impact standards have already been established by a municipality for other types of development. In fact, the Guidelines explicitly state, "…unless pre-existing visual impact standards are violated, a turbine project proposal should not be rejected on the basis of visual impacts." However, OER does recommend that viewshed or another visual analysis be submitted as part of a proposal as a show of a good faith effort by a developer to engage a community and optimize a turbine's location. Therefore, no change was made to the Guidelines document.

Comment:
WED commented that they did not find any "as of right" provisions in the "Model As-of-Right Zoning Ordinance or Bylaw" in Appendix C.

Response:
The Model As-of-Right Zoning Ordinance or Bylaw was created by the Massachusetts Executive Office of Environmental Affairs. It is not meant to be directly applicable to Rhode Island, but is meant to serve as a sample for municipalities as they begin to draft their own wind siting ordinances. No change to the Guidelines document was made to address the above comment.

Comment:
WED also suggested that using a worst case scenario modeling procedure for shadow flicker would be simpler and easy for everyone to understand. Although realistic calculations can be a nice informational tool, worst case scenario standards can be easier with respect to site planning.

Response:
OER agrees with this comment and has adjusted the recommended shadow flicker standard to use worst-case scenario modeling for residential zones.

Comment:
WED clarified that WindPRO (a commonly used shadow flicker analysis software) cannot currently use Rhode Island's LIDAR data for contour lines. The LIDAR data is not easily converted to a format WindPRO can use. In addition, WindPRO does not look at wind speed data for wind turbine operational hours. Instead it requires that operational hours for a turbine be inputted by month. Therefore, accurate operational hours would require a year of testing/data before accurate results could be obtained. These limitations, support the need to use worst-case scenario modeling for shadow flicker.

Response:
OER has adjusted the recommended shadow flicker standard to use worst-case scenario modeling.

The following are the paraphrased comments of Andrew M. Teitz, Esq., AICP, presented at the public meeting and also in writing, followed by OER's response:

Comment:
Mr. Teitz's main concern was that the model ordinance sections of the document were taken from Massachusetts and Connecticut, and some of the waiver/permit language borrowed from Rhode

Island liquor licensing. As written, the guidelines would allow a solitary objector to effectively veto a second tier special use permit.

Response:
OER recognizes that original tie to liquor licensing is not appropriate for wind siting decisions. Therefore, the section regarding waivers/special use permits has been amended. The re-written section now places the final decision regarding the issuance of a special use permit on the Zoning Board of a municipality. The ability of any one neighbor to effectively veto a development has been removed. However, the Guidelines document still strongly encourages the Zoning Board to hear all neighbor opinions and thoroughly review any objections.

Comment:
Mr. Teitz recommended that Appendix A be edited to provide a Rhode Island-specific sample ordinance for wind development. OER had originally provided a Massachusetts-specific sample bylaw in Appendix A that had been created by Massachusetts's Department of Energy Resources and Massachusetts Executive Office of Environmental Affairs. Mr. Teitz provided an edited version of Appendix A that he believed would be more applicable for Rhode Island municipalities.

Response:
OER thanks Mr. Teitz for commenting on and re-working Appendix A to better apply to Rhode Island. If a municipality would like to see Mr. Teitz edits and comments, they should contact OER at energy.resources@energy.ri.gov. OER did not include Mr. Teitz edits in the final Guidelines document because they need to be further reviewed by legal counsel. OER also wanted to avoid any confusion regarding the use of Appendix A materials by municipalities. In the original Guidelines document, OER felt it was clear that the sample As-A-Right Bylaw from Massachusetts was not directly applicable to Rhode Island municipalities. It is solely meant to provide a starting place from which municipalities can draft their own ordinance(s).

No changes were made to the Guidelines document based on this comment.

The following are the paraphrased comments of Mr. Barry Wenskowicz, Narragansett Bay Commission presented at the public meeting and also in writing, followed by OER's response:

Comment:
OER may want to consider changing the subtitle of the guidelines to "Applicable to proposed turbines 200 feet or taller or with a nameplate capacity of 100 kW or greater".

Response:
Suggested edit was completed.

Comment:
Note that on page 12 there is a reference to turbines greater than 100 kW which should instead state greater than or equal to 100 kW if it is intended to agree with the title page.

Response:
Suggested edit was completed.

Comment:
Please consider incorporating the following from page 33 of the Appendix into the body of the guidelines proper: "applies to all utility scale …….wind facilities proposed to be constructed after the effective date of this……"

Response:
The Guidelines document is not meant to serve as an adoptable Ordinance. Instead it is meant to help municipalities to draft their own Ordinance documents. Moving or replicating the suggested sentence into the body of the Guidelines document could make the document appear like an Ordinance that could be adopted by a municipality. In order to avoid this kind of confusion, OER did not complete the recommended change.

Comment:
The Introduction on page 5 describes some benefits of wind turbines but fails to mention that they help achieve distributed generation. Benefits of DG include avoiding the energy losses (i.e. stack loses and line loses) associated with conventional utility generation and delivery. This reduces/delays the need to site expensive new fossil fuel based generation facilities. Another benefit that wasn't mentioned is that producing power locally keeps more energy dollars in-state which benefits the local economy.

Response:
The following sentence was edited as follows to ensure these benefits were conveyed within the Guidelines: "Local wind projects can also help reduce energy purchase costs, provide a hedge against future price volatility, ***support distributed generation,*** *and generate in-state investment and economic activity."*

Comment:
In the introduction on page 5 or the background on page 7, you may want to acknowledge that a large wind turbine operated in RI on Block Island at least as early as the early 1980s.

Response:
On page 7 the following edits were made within the third paragraph on the page: "The first ***modern*** *commercial-scale wind turbine was installed in 2006 at the Portsmouth Abbey.* ***However, a large wind turbine with a 100ft tower did operate on Block Island as early as 1979 [1].****"*

Comment:
Your update has recommended a new setback of 1.5 x (total turbine height) away from wind turbine site structures including buildings (page 15). As this doesn't seem related to protecting the public, shouldn't a site owner have the unrestricted choice to locate a turbine they own close to a building they own?

Response:
As written the Guidelines do allow for flexibility in the setback requirements. In the case of the specific scenario described, the site owner would need to get an IISUP (an increased impact special use permit) from the municipality's Zoning Board. The Zoning Board would ask if there were any objections by those who would experience the "increased impact" (in this case the site owner not having a 1.5x setback distance). If the site owner did not object then an IISUP would be issued and the development would be allowed. OER believes this structure is appropriate as it ensures that the site owner is aware of the recommended standard for the public and has been encouraged to consider the benefits and risks.

No change was made to the document.

Comment:
The maximum limit of 30 minutes of <u>modelled</u> flicker for any day seems to me to be overly strict

for protecting a business located near a wind turbine under certain circumstances (a table listing various flicker limits was in the presentation but not in the guidelines). I think a more practical limit would be 30 minutes daily of actual flicker experienced by a sensitive receptor. Stating it this way takes into account the possibilities that the business may have no windows that face the source of the flicker and that the business may be closed when the flicker occurs.

Response:
OER believes that worst-case scenario modeling of shadow flicker is more conservative than realistic-modeling. The "Shadow Flicker" section has been re-written based on other public comments received. The re-written section now includes the following paragraph: "A realistic modeling standard that accounts for topology, obstacles, and normal weather and wind patterns could be used by a municipality to lessen the shadow flicker requirement on occupied structures in non-residential zones. Figure 3 on page 12 of this document provides an example of how realistic versus worst-case scenario modeling can be applied to adjust the conservativeness of the shadow flicker standard. It is recommended that a municipality work with a developer to determine which variables and data should or should not be used in a realistic model. All assumptions made in a realistic model should be carefully reviewed by a municipality." No further changes were made to the Guidelines document based on this comment.

Comment:
Using the term "increased impact special use permit" (IISUP) is misleading since once (and if) an impact is abated there may be no increased impact. Perhaps a better term would be "potential increased impact special use permit".

Response:
OER appreciates that the name of the second-tier special use permits is not particularly eloquent. However, these second-tier permits would only be pursued if a standard required by the municipality could not be met through abatement or mitigation practices. For example, if a wind development chose to meet the 30 hours per year shadow flicker limit at occupied structures through a limited operating schedule, then an IISUP would not be needed. Therefore OER feels the phrase "increased impact special use permit" is accurate. OER made no change to the Guidelines document based on this comment.

Comment:
OER seems to have considered the considerable costs associated with testing or modelling to demonstrate compliance to sound and/or flicker guidelines (page 13). OER should also consider that there are significant costs associated with shutting down wind turbines even for relatively short periods of time to abate impacts and that these costs affect economic viability of a proposed project.

Response:
OER recognizes the costs associated with shutting down wind turbines. For this reason, all effort was made to ensure ice throw and shadow flicker standards were reasonable for both the public and wind developers. No specific change was made to the document based on this comment.

Comment:
In general, please consider prominently highlighting that there are common and practical abatement methods available to reduce most impacts that could otherwise be problematic. No one, potentially developable wind turbine site is ever completely perfect, no risk can ever be entirely eliminated. This is why guidelines are useful. They can help choose one site over a limited number (if any) of other alternate sites that may be available to a viable developer.

Response:
In an effort to address this point, OER had included information about common mitigation strategies in some Frequently Asked Questions (FAQs) sections of the Guidelines document. In addition, the two-tiered permit structure is meant to provide flexibility for siting requirements since, as Mr. Wenskowicz pointed out, "no one, potentially developable wind turbine site is ever completely perfect." No changes were made to the document to further address these points.

The following are the paraphrased comments of Kevin Maloney, presented at the public meeting and also in writing, followed by OER's response:

Comment:
Mr. Maloney would like the OER to revisit the property value study included in the guidelines document. The included study, conducted by the University of Rhode Island, only looked at Rhode Island based wind turbines. Mr. Maloney explains that Rhode Island's wind turbines are fairly new with a limited history of property turnover. Furthermore, wind turbines in Falmouth or Fairhaven which are only 2 hours away, have reported decreased property values. Specifically, Mr. Maloney commented that the Falmouth Zoning Board of Review has found that property values decreased by as much as 20%. To support this assertion, Mr. Maloney provided the following link to the Falmouth Zoning Board's 2013 decision and referenced the following page of a Falmouth appraisal document.

http://www.falmouthmass.us/agenda.php?depkey=zbadec&number=6148

Supplemental Addendum

File No. Ridgeview27

Borrower/Client	N/a						
Property Address	27 Ridgeview Drive						
City	West Falmouth	County	Barnstable	State	MA	Zip Code	02574
Lender	(Client) Barry A. & Diane C. Funfar						

Intended Use and the Intended User:

The Intended Use of this Appraisal is to provide an opinion of the Current Market Value of the subject property only. This report is not intended for any other use.

Barry A. and Diane C. Funfar.

Highest and Best Use Analysis:

In the Highest & Best Use Analysis, the appraiser has performed and considered the four test criteria and stated his conclusion in the body of the report.

Definition of Market Value:

For the purpose of this report, the source for the Definition of Market Value, as stated in the limiting conditions, is from regulations published by federal regulatory agencies pursuant to title xi of the federal institutions reform, recovery, and enforcement act (firrea) of 1989.

Scope of Work:

This is a Uniform Residential Appraisal Report which reports the market value of the subject property as of a given date.
a physical inspection is made on the subject property, including actual measurements of the perimeter of the dwelling. Depending on the assignment, an interior inspection is made or if assignment is an exterior only, information on our analysis is based on public records.
Research is conducted in the immediate and surrounding areas to determine the best sales which are most similar to the subject property for the sales comparison approach and local cost estimates from contractors & builders and/or rs means, which may be utilized in the cost approach and included in the report. A market analysis is determined along with aspects of the site are analyzed and reported to the best of our knowledge. Information is obtained from a number of sources available including mls, assessor's records, registry of deeds, owners, brokers, builders, national, state, and local real estate services and publications. Information not available to the appraiser is documented in the report.
This report utilizes the sales comparison approach and, depending on the assignment , cost approach. If this is not an income producing property and there is insufficient rental data available, hence the income approach will be deemed not applicable.
given all the above, the report is compiled to arrive at opinions and conclusions which are stated in the report.

Comments on Sales Comparison Analysis:

In the Sales Comparison Approach the location, site and view are based on overall site value as compared to the subject site. **The site value for the subject is estimated at $125,000.**

The site value for sales #1 + 2 is also estimated at $125,000 with no net adjustment necessary.

The site value for comparable #3 is estimated at $100,000 with a net adjustment of $25,000 made in the location field.

A prior sale at 25 Brantwood Drive, sold on 8/10/2012 for $480,000 with 2,980 sf and 10 rooms/4bedrooms/3bathrooms. **This sale matched with 64 Ridgeview Drive and 114 Ambleside Drive in 2013, show the adverse affect of the turbines on market value.**

The subject dwelling is located 1,662 feet from the town of Falmouth Wind 1 Turbine and 1,558 feet from the town of Falmouth Wind 2 Turbine. Some residents have experienced various symptoms possibly related to the turbines. To reflect an adverse market reaction, a 20% external obsolescence is given in the cost approach. All sales are within a .5 mile of either Wind Turbine 1 or 2 and are affected in the same negative way a the subject. The subject is also impacted by traffic noise at the site.

External obsolescence is defined as a diminution in value caused by negative externalities and generally is incurable on the part of the landowner.

Exposure Time

'Exposure Time' ; Is the estimated time that a property interest being appraised would have been offered on the market prior to the hypothetical consummation of a sale at market value on the effective date of the appraisal.

The exposure time of the subject property falls into a range of 3-6 months due to the limited number of buyers in this value range, and the current supply of competing homes. Properly priced homes sell within reasonable time frames. Over priced homes generally take a longer time to sell.

I have not performed a prior appraisal of the subject property within the 3 year period immediately preceding acceptance of this appraisal assignment.

Fiscal year 2014 assessed value is $589,500.

He also provided a link to an article describing a wind farm that was required to dismantle units in Europe. Mr. Maloney commented that Europe has more experience with wind development that Rhode Island and that OER is doing a disservice to State residents if the property value issue is not re-visited.

http://www.dailymail.co.uk/news/article-2531219/Wind-farms-slash-THIRD-value-nearby-homes--developers-pocket-millions.html

Response:
At Mr. Maloney's request, OER did look further into the question of property values. Further research provided unearthed a highly credible report issued by the University of Connecticut and the Lawrence Berkeley National Laboratory in 2014 that studied wind turbines and property values in Massachusetts. This study analyzed 122,198 single-family home sales, occurring between 1998 and 2012, within 5 miles of 41 wind turbines. The results of the study were very similar to the findings reported in the Rhode Island property value study included in the Guidelines document. In particular, the study states, "The results of this study do not support the claim that wind turbines affect nearby home prices." OER believes this study helps to alleviate some of the lingering concerns with respect to property values. For the publics benefit, the Massachusetts report has been appended to these public comments. The study has also been added to the Guidelines document as a reference.

The following are the paraphrased comments of John W. Bagwell, presented at the public meeting and also in writing, followed by OER's response:

Comment:
The list of Large Wind Energy Systems in the Guidelines is not complete. Mr. Bagwell would like to ensure that the turbine in North Kingstown is included and that the replacement turbine at Portsmouth High School is accurately described. Mr. Bagwell believes the replacement tower at Portsmouth High School will be taller than the current tower.

Response:
OER has attempted to update the list of Rhode Island Wind Turbine Case Studies to the best of the Office's ability.

Comment:
Mr. Bagwell asks that the terms "realistic modeling" and "worst case scenario modeling" be defined in the Shadow Flicker sections of the guidelines.

Response:
Worst-case scenario modeling has been defined as follows: "…assumes flat, open land, constant sunshine during the day and constant wind turbine operation." A descriptive definition of realistic modelling is also provided: "A realistic modeling standard that accounts for topology, obstacles, and normal weather and wind patterns could be used by a municipality to lessen the shadow flicker requirement on occupied structures in non-residential zones."

However, OER hopes that municipalities will work with wind developers to precisely define what variables should or should not be included in a realistic model. In some cases, accurate data may not be available until after the turbine has been in operation for a year or more. Therefore, the developer will need to justify any assumptions made in the case of a realistic model. The following sentences were added to the "Shadow Flicker: Recommended Standard" section to *address this issue: "It is recommended that a municipality work with a developer to determine which variables and data should or should not be used in a realistic model. All assumptions made in a realistic model should be carefully reviewed by a municipality."*

Comment:
*Mr. Bagwell would like to emphasize how important it is for communities to develop standards which **prevent** shadow flicker and control and prevent nuisances within surrounding structures and on properties.*

Response:
OER recognizes the nuisance factor of shadow flicker. With the final, recommended shadow flicker standards included in the Guidelines, OER is confident that wind developers will be required to prevent and/or mitigate excessive shadow flicker on surrounding structures. Unfortunately, this does not guarantee that absolutely no shadow flicker will be experienced on nearby properties, but it does ensure that shadow flicker effects will be in compliance with widely accepted shadow flicker exposure limits. No changes were made to the Guidelines document to further address this comment.

Comment:
Mr. Bagwell suggests that a clarifying note be added to the PowerPoint that was used to provide an overview of the Guidelines at the public meeting. He asks that the PowerPoint slides addressing shadow flicker have a note to refer to the full Guidelines document. He believes that the slides only reference a 30min/day shadow flicker limit and not the hours/year limit described in the Guidelines.

Response:
OER has made a note on the OER website that the full Guidelines document should be referenced for complete and accurate Guideline recommendations. OER does not feel that the public PowerPoint should be altered since the public meeting has already occurred. However, the note on the website is meant to ensure that interested parties recognize that the PowerPoint deck may be missing critical information needed in the development of an Ordinance.

Comment:
Mr. Bagwell recommends that a sentence similar to the following be added to the Shadow Flicker and Noise sections of the Guidelines: "Noise and shadow flicker standards should be restrictive enough to prevent value impacts to surrounding properties."

Response:
In response to a previous public comment (see page 17), OER had conducted further research into the effects of wind turbines on property values. A study conducted by the University of Connecticut and the Lawrence Berkeley National Laboratory concluded that wind turbines have little to no effect on surrounding property values. Therefore, OER does not feel that a sentence like the one suggested above is an appropriate addition to the Guidelines. All effort has been made to ensure that the recommended standards for both shadow flicker and noise reasonably limit the potential for nuisance. No changes were made to the Guidelines document based on this comment.

Comment:
A note should be made in the Visual Impacts section that special considerations should exist for wind developments in the view sheds of recognized historic sites or scenic vistas.

Response:
OER does not believe that wind turbines should be subject to visual impact requirements not imposed on other types of construction. If a municipality has a visual impact standard in place, OER believes wind development should need to comply with those pre-existing standards. However, OER does not recommend that wind-specific visual impact standards be created by municipalities.

OER does state within the Guideline document that "it is advisable that visual impacts to recognized historic, cultural, archeological, or scenic sites be minimized." This sentence and the recommendation that viewshed/sightline analyses be completed for wind developments are included in the Guidelines to encourage developers to proactively consider the visual impacts of their turbines.

OER made no changes to the Guidelines document based on this comment.

Comment:
Mr. Bagwell would like the following requirement to be a part of the final Guidelines: "Projects may be asked to guarantee no effect on real estate values of abutters." He feels it is very important that noise and shadow flicker standards be restrictive enough to prevent property value impacts to surrounding properties.

Response:
OER does not believe wind developers or owners would be able to meet the requirement set by Mr. Bagwell's recommended sentence. Not only would it be difficult for a single developer to actively monitor the impacts of nearby property values, but multiple, comprehensive studies have concluded that wind turbines do not negatively affect surrounding property values. Therefore, it seems unreasonable to require that individual wind developments actively prove that no impacts on property values are caused. Larger studies that can consider multiple wind development sites and thousands of building sales are more likely to create accurate results.

No changes were made to the Guideline document based upon this comment.

The following is a letter of support received from Lynne Harrington, President of the West Bay Land Trust, followed by OER's response:

Comment:

February 24, 2016

Danny Musher, Chief
RI Office of Energy Resources
One Capitol Hill
Providence, RI 02908

Greetings Mr. Musher,

The West Bay Land Trust wishes to applaud and thank you for your superlative work regarding the development of the State's first comprehensive **Rhode Island Land-Based Wind Siting Guidelines** document (Proposed, January 2016). This effort involved substantial scientific research and community involvement and we are pleased to offer our support for its acceptance as a model siting standard for Rhode Island Cities and Towns.

Your outline of the process and steps that municipalities should take to develop and support Comprehensive Plan alignment is logical and actionable. It is even conceivable that Steps 1. and 2. in the Zoning Considerations for Municipalities section could be reversed, with an analysis of desired locations performed initially, with siting standards to fit the unique municipality's needs and goals secondarily.

The RI OER is clearly authorized 42-140-3 to develop such guidance and its leadership with this effort provides a considered and workable wind siting standard for Rhode Island. We are grateful for this guidance and urge its adoption as a statewide model.

Regards,

Lynne Harrington
President, The West Bay Land Trust

C: Dr. Marion Gold, Commissioner

The West Bay Land Trust 50 Taft Street Cranston, Rhode Island 02905
The West Bay Land Trust is an IRS designated 501(c)(3) nonprofit corporation

Response:

No comments were provided suggesting any changes be made to the proposed document.

The following are the paraphrased comments of Christopher Raithel from the Rhode Island Department of Environmental Management, presented at the public meeting and also in writing, followed by OER's response:

Comment:
Mr. Raithel states that the figure showing the cumulative bird mortality from various causes is misleading. He suggests OER remove it and replace it with a statement that recognizes that bird and bat mortality may occur and that there is potential to mitigate the volume of mortality by appropriate siting and other means. He further comments that he believes it is more straightforward to scale the potential mortality of birds (at least in a relative way) than it is for bats, so more research on whether bats are disproportionately affected by turbines is desirable.

Response:
OER has decided to leave the figure in the Guidelines document since it helps readers understand the current scale of bird mortality occurring due to wind farms. However, the following sentence was added to the explanatory paragraph following the figure to ensure that readers fully understand the context and background of the data presented: "It's important to note that the number of wind turbines compared to the number of domestic cats, transmission lines, buildings and windows, and other categories shown in the above figure is extremely low."

Mr. Raithel's point regarding bat mortalities and their scalability with the number of constructed turbines is well taken. The following sentence was also added to the "Environmental Impacts – Description of Impact – Birds & Bats" section: "More research is also needed to determine if bats are disproportionately affected by wind turbines compared to birds."

Comment:
The recommendation to consult with the U.S. Fish and Wildlife Service and Rhode Island's Department of Environmental Management on effects to wildlife from wind projects is a logical extension of the siting process. However, it is not clear to Mr. Raithel that these agencies have the resources or staff to take on an expanded role in such consultations. He believes more thought about a potential review processes is necessary.

Response:
OER recognizes that this would likely be an issue at the State level. However, the U.S. Fish and Wildlife Service, in their voluntary Land-Based Wind Siting Guidelines, does indicate how the Service should be included in the process and the specific assistance they can provide. OER only recommends that a developer attempt to engage the RI DEM and other appropriate environmental organizations, the recommendation does not require that comments be received. If DEM or other appropriate organizations are able to provide feedback for a wind development project, their more local expertise would be beneficial. However, if DEM and/or other groups are unable to provide feedback, the Service's input is all that should be required.

Edits had previously been made to clarify this recommendation. Please see responses to Charles Brown's comments for exact edits made to the "Environmental Impacts – Recommended Standard" section.

The following are the paraphrased comments of Robert Connors from STV Incorporated, presented at the public meeting and also in writing, followed by OER's response:

Comment:
Mr. Connors believes a 5dB over ambient limit for residential areas, as provided in an illustrative example in the Guidelines, would make it very difficult to find a site for a commercial size wind turbine anywhere near a residential property.

Response:
The example in the Guidelines was changed to a 10 dB(A) increase in residential areas and a 15 dB(A) in industrial zones. OER recommends that each municipality review their own specific zones and decide on the most appropriate values for their city or town.

Comment:
He provided the following link to a MassCEC study and encouraged OER to review it:
http://files.masscec.com/research/RelationshipWindTurbinesandResidentialPropertyValuesinMassachusetts.pdf

Response:
OER has reviewed this study and has added it to the references section of the Guidelines document.

The following are the paraphrased comments of Francis Pullaro, Executive Director of RENEW Northeast, presented at the public meeting and/or in writing, followed by OER's response:

Comment:
The guidelines call for LEQ values in dB(A) to be predicted by the modeling efforts for each abutting property line. Property lines might not be representative of the sensitive areas particularly if there are large parcels. While this may not be a substantial concern in Rhode Island, a dwelling in the state's more agricultural areas on a large tract could be located far from the property line. RENEW recommends measurements be taken at least 7.5 meters from the existing wall of any existing permanently occupied building on a non-participating landowner's property, or at the non-participating landowner's property line if it is less than 300 feet from an existing occupied building.

Response:
OER believes that measuring noise at property lines is a more conservative and effective standard than measuring at or near occupied buildings. This method ensures that all areas within a property meet the noise standards. If there are scenarios in which the noise standards cannot be met, a second tier special use permit should be pursued by the developer as described in the Guidelines document.

No changes were made to the document based on this comment.

Comment:
For the purpose of clarity, RENEW suggests a few worked examples be provided as to what is meant by the "municipal maximum sound limits (MMSL)" first discussed on page 18 and why the predicted project sound level would be added to it as part of the assessment process. For example, if the applicable MMSL is 50 dBA and the conservatively predicted project level is 48 dBA it would seem that the project complies with the limit. However, the process of acoustically summing 50 dBA and 48 dBA yields 52 dBA which exceeds the noted 1 dBA allowance above the MMSL and would be a violation. Upon receiving the requested clarifications, RENEW would appreciate the opportunity to provide further comment on sound limits.

Response:
The noise standard described in this comment (Option 1 in the wind Guidelines document) does not require ambient noise monitoring. Instead, the method assumes that the ambient noise in the area of the turbine is the municipal maximum sound limit (MMSL). The predicted turbine noise and the MMSL are then summed to provide an overall sound level prediction for the turbine development.

Because sounds are not experienced in isolation, new sounds must be summed with already existing, ambient sound levels to accurately represent the sound levels to be experienced by nearby property owners. This is the reason why a 48 dB(A) wind development in a 50 dB(A) MMSL zone would not pass. By adding 48 dB(A) to an assumed background noise of 50 dB(A), residents could be subject to 52 dB(A) (a decibel level well above the MMSL).

As a rule of thumb, using Option 1 as a the noise standard would require that a turbine development be 6 or more dB(A) below the MMSL. Since many municipalities in Rhode Island have MMSLs of 55 or 60 dB(A) for residential zones, OER feels that this threshold is appropriate for wind development. Once again, it is also important to note that a second tier special use permit could also be pursued by a developer if a noise standard cannot be met.

OER made no revisions to the Guidelines document based on this comment.

Comment:
On page 20, the "CONs of Option 1" indicate that, "Without knowing the ambient sound levels, it is impossible to determine if the turbine is at fault for increasing the sound level above the permitted level". While this may be true, this challenge is likely not unique to Option 1, so it is unclear how "this method can add a layer of difficulty to post-construction compliance monitoring." These complications may be minimized if measurements conducted in accordance to IEC 61400-11 are allowed to confirm the turbine is performing as modeled.

With regards to Option 2, "ambient" is more typically ascribed to the Leq metric whereas "background" or "residual" sound level would be described by the L90 metric. While RENEW agrees that a pre-defined detailed method is appropriate, it should be noted that the Massachusetts regulatory approach is unique and currently under review and the MassCEC guidelines may not be appropriate.

Response:
OER recognizes that the unknown changes in ambient sound levels could also pose a challenge to Option 2 with respect to compliance. Therefore, this CON has also been added to Option 2 in the Guidelines document.

Although the compliance complications described in the comment above, could be minimized if measurements were conducted in accordance to IEC 61400-11, OER recognizes that most Rhode Island municipalities do not own or have access to the necessary sound equipment for these types of measurements. Therefore, OER did not feel it was practical to recommend the use of these methods for compliance testing. Instead, the recommended noise standards are meant to minimize noise issues and allow the municipalities to determine their own specific strategy for compliance testing.

Comment:
Suggestions to increase technical clarity and include precise acoustical terminology to language under Option 1 on page 18 are provided below:

The following substitute language is suggested for the language under Option 1 on page 18 to increase technical clarity and include precise acoustical terminology:

"The turbine developer will need to predict the turbine's sound pressure level via modeling at the points of interest. It is recommended that the most up-to-date IEC standards for the proposed turbines sound power levels (IEC 61400-11 ed 3 as of 2015) be used in additional to anticipated sound power levels for other sound emitting equipment (for example, substation transformers). These sound power levels should be used in the most current ISO outdoor sound pressure propagation methods (ISO 9613-2 as of 2015) to develop a sound contour map of the predicted project sound pressure level a. Other accurate sound modeling options, such as NORD200 software, should also be accepted. All efforts to be reasonably conservative in this modeling should be considered at residential dwellings. The predicted sound levels at residences should include one scenario that is based on the maximum turbine sound power level with a typical (e.g. +2 dBA) vendor uncertainty using mixed or hard ground conditions (i.e., ISO 9613-2 Ground Absorption factor (G) for fully absorptive ground (G=1) should not be relied on).

The predicted project sound levels or sound contours are representative of project-only sound levels. That is, predictions are representative of the steady state or continuous Leq sound level attributable to the project for conditions modeled. The total sound level that one would hear or measure is the acoustic sum of the project sound level and the existing sound level. Over the time period of interest (e.g., 10-minutes, 1 hour or 1 day) the existing sound levels will vary based on a number of factors (for example, fluctuations in vehicle traffic). The Leq metric is a common means to describe sound levels that vary over time, resulting in a single decibel value which takes into account the total sound energy over the period of time of interest. The total sound level would then be the acoustic sum of the predicted project Leq plus the existing Leq for the conditions of interest."

Response:

Many of the suggested edits above were incorporated into the "Noise: Recommended Standards: Option 1" section. The section now reads: "The turbine developer will need to predict the turbine's sound pressure level via modeling at the points of interest. It is recommended that the most up-to-date IEC standards for sound power levels (IEC 61400-11 ed 3 as of 2015) be used for the proposed turbines and any additional anticipated sound emitting equipment (for example, substation transformers). These sound power levels should then be used in the most current ISO outdoor sound pressure propagation methods (ISO 9613-2 as of 2015) to develop a sound contour map of the project and to predict turbine sound at surrounding property lines. Other accurate sound modeling options, such as NORD200 software, should also be accepted. All efforts to be reasonably conservative in this modeling should be taken. The predicted sound levels should include one scenario that is based on the maximum turbine sound power level with a typical vendor uncertainty (e.g. +2 dB(A)) using mixed or hard ground conditions (i.e., ISO 9613-2 Ground Absorption factor (G) for fully absorptive ground (G=1) should not be relied on).

The predicted project sound levels or sound contours are representative of project-only sound levels. The total sound level that one would hear or measure after project completion is the acoustic sum of the project sound level and the existing, background sound level. Therefore, L_{EQ} *values in dB(A) should be predicted by the modeling efforts for each abutting property line. The* L_{EQ} *metric is a common way to describe sound levels that vary over time. It is a single A-weighted decibel value which takes into account the total sound energy over the period of time of interest (please see the Glossary of Terms for an explanation of A-weighted decibel level). All efforts to be conservative in modeling this* L_{EQ} *value for wind developments should be taken—i.e. worst* *case scenarios should be applied where appropriate.*

The resulting conservative L_{EQ} value(s) that represent project-only sound levels, should be compared to the municipal maximum sound limits (MMSL). If the logarithmic sum of MMSL + L_{EQ} is less than or equal to 1 dB(A) above MMSL, then the turbine should be permitted with respect to noise. If the logarithmic sum of MMSL + L_{EQ} is greater than 1dB(A) above MMSL, then the turbine would be considered too loud for the abutting property(ies) unless increased impact special use permits (IISUPs) are obtained."

Comment:
The limit on shadow flicker of the 30 hours per year follows the National Association of Regulatory Utility Commissioners ("NARUC") guidelines and are reflective of typical shadow flicker rules across jurisdictions in the United States. The 30 hours per year limit recommendation in those guidelines ensures residences are free of shadow flicker for 99.7 percent of the year. To be consistent with the NARUC best practices document, the RI Guidelines should recommend the time limits apply only to occupied buildings. Participating land owners should have the freedom to waive shadow-flicker limits to allow for agreements with project developers or, if waivers cannot be allowed under Rhode Island law, RENEW supports other approaches be taken, which are discussed on page 14 of the RI Guidelines that can provide this flexibility.

Response:
To be consistent with other State standards and to address other public comments regarding the shadow flicker standard, the language has been changed throughout the Guidelines document. The shadow flicker standard now applies only to occupied structures.

Comment:
Wind energy resources provide clean energy at an affordable price. Many companies are seeking to develop wind energy projects in Rhode Island. They will create jobs and boost tax revenues to the state and host municipalities. The host towns and the Rhode Island economy will benefit from further growth in wind energy development all while helping the state meet its renewable energy goals.

Response:
No comments were provided suggesting any changes be made to the proposed document.

The following are the paraphrased comments of Benjamin C. Riggs, Jr., presented at the public meeting and/or in writing, followed by OER's response:

Comment:
Mr. Riggs states the following in a letter to OER: "Ice buildup on blades can be thrown a considerable distance. In addition, ice buildup can cause imbalance that leads to gearbox failures and fires. (There have been many documented cases of this.) Such fires can only be reached and put out by helicopters. And because up to 6800 pounds of a highly toxic rare earth material called neodymium is used in the magnets, the downwind dangers from smoke from a fire are potentially lethal. (See Attachment 1.)"

Attachment 1 is provided below:

PRODUCING MAGNETS FOR WIND TURBINES CAUSES SEVERE POLLUTION

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Read more: http://www.dailymail.co.uk/home/moslive/article-1350811/In-China-true-cost-Britains-clean-green-wind-power-experiment-Pollution-disastrous-scale.html#ixzz1DCQlkVr1

On the outskirts of one of China's most polluted cities, an old farmer stares despairingly out across an immense lake of bubbling toxic waste covered in black dust. He remembers it as fields of wheat and corn.

Yan Man Jia Hong is a dedicated Communist. At 74, he still believes in his revolutionary heroes, but he despises the young local officials and entrepreneurs who have let this happen.

'Chairman Mao was a hero and saved us,' he says. 'But these people only care about money. They have destroyed our lives.'

Vast fortunes are being amassed here in Inner Mongolia; the region has more than 90 per cent of the world's legal reserves of rare earth metals, and specifically neodymium, the element needed to make the magnets in the most striking of green energy producers, wind turbines.

Live has uncovered the distinctly dirty truth about the process used to extract neodymium: it has an appalling environmental impact that raises serious questions over the credibility of so-called green technology.

The reality is that, as Britain flaunts its environmental credentials by speckling its coastlines and unspoiled moors and mountains with thousands of wind turbines, it is contributing to a vast man-made lake of poison in northern China. This is the deadly and sinister side of the massively profitable rare-earths industry that the 'green' companies profiting from the demand for wind turbines would prefer you knew nothing about.

Hidden out of sight behind smoke-shrouded factory complexes in the city of Baotou, and patrolled by platoons of security guards, lies a five-mile wide 'tailing' lake. It has killed farmland for miles around, made thousands of people ill and put one of China's key waterways in jeopardy.

This vast, hissing cauldron of chemicals is the dumping ground for seven million tons a year of mined rare earth after it has been doused in acid and chemicals and processed through red-hot furnaces to extract its components.

Wind power's uncertainties don't end with intermittency. There is huge controversy about how much energy a wind farm will produce (Pictured above, wind turbines in Dun Law, Scotland)

PRODUCING MAGNETS FOR WIND TURBINES CAUSES SEVERE POLLUTION

Official studies carried out five years ago in Dalahai village confirmed there were unusually high rates of cancer along with high rates of osteoporosis and skin and respiratory diseases. The lake's radiation levels are ten times higher than in the surrounding countryside, the studies found.

Since then, maybe because of pressure from the companies operating around the lake, which pump out waste 24 hours a day, the results of ongoing radiation and toxicity tests carried out on the lake have been kept secret and officials have refused to publicly acknowledge health risks to nearby villages.

There are 17 'rare earth metals' – the name doesn't mean they are necessarily in short supply; it refers to the fact that the metals occur in scattered deposits of minerals, rather than concentrated ores. Rare earth metals usually occur together, and, once mined, have to be separated.

Neodymium is commonly used as part of a Neodymium-Iron-Boron alloy ($Nd2Fe14B$) which, thanks to its tetragonal crystal structure, is used to make the most powerful magnets in the world. Electric motors and generators rely on the basic principles of electromagnetism, and the stronger the magnets they use, the more efficient they can be. It's been used in small quantities in common technologies for quite a long time – hi-fi speakers, hard drives and lasers, for example. But only with the rise of alternative energy solutions has neodymium really come to prominence, for use in hybrid cars and wind turbines. **A direct-drive permanent-magnet generator for a top capacity wind turbine would use 4,400lb of neodymium-based permanent magnet material.**

Jamie Choi, an expert on toxics for Greenpeace China, says villagers living near the lake face horrendous health risks from the carcinogenic and radioactive waste.

The fact that the wind-turbine industry relies on neodymium, which even in legal factories has a catastrophic environmental impact, is an irony Ms Choi acknowledges.

'It is a real dilemma for environmentalists who want to see the growth of the industry,' she says. 'But we have the responsibility to recognise the environmental destruction that is being caused while making these wind turbines.'

One unit cell of Nd2Fe14b, the alloy used in neodymium magnets. The structure of the atoms gives the alloy its magnetic strength.

http://www.weather.com/series/great-outdoors/video/chinese-toxic-lake-of-black-sludge-is-a-result-of-mining-for-tech?pl=pl-hot-list

2

Response:

OER feels it has thoroughly addressed the issue of ice throw within the Guidelines document. Furthermore, most modern wind turbines use sensors or other technologies to detect ice accumulation on the blades. This prevents blade imbalances from damaging the turbine.

Within the Guidelines document, OER also recommends that fire safety protocols be put in place *(please see the Municipal Development Proposal Checklist in the Guidelines Document).*

With respect to the environmental impacts of rare earth metals, OER feels that investigating the material sources of any type of development is beyond the scope of an ordinance Guidelines document. For these reasons, no changes were made to the Guidelines document based on this comment.

Comment:
Mr. Riggs states the following in a letter to OER: "Health effects are a problem that can only be addressed by allowing for greater distances from people than is likely possible in a state like Rhode Island. Shadow flicker and noise are the primary ones. According to the USDA guidelines created for wind turbine installations in Vermont with the input of the EPA and WHO, noise levels need to be below 40 dBA. (See Attachment 2.) And a peer-reviewed paper published in the Journal of the College of Family Physicians of Canada summarizes some of the other effects. (See Attachment 3.) Conclusions in the UK determined that the minimum distance required was 6 miles to avoid "life threatening" effects. (See Attachment 4.) The experience of residents near the now defunct Portsmouth wind turbine bear some of this out."

Attachments 2, 3, and 4 follow below:

Attachment 2:

Table 3.4-2. Summary of Standards and Guidelines for Exterior Noise

	Agency/ Organization	Applicable to	Sound Level
Standards	Federal Highway Administration and Vermont Agency of Transportation	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.	57 dBA Leq(1) or 60 dBA L10(1)
Standards	Federal Highway Administration and Vermont Agency of Transportation	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, hotels, motels, schools, libraries, churches, and hospitals.	67 dBA Leq(1) or 70 dBA L10(1)
Standards	Federal Highway Administration and Vermont Agency of Transportation	All other areas.	increase over background cannot exceed 18 dBA
Standards	Federal Energy Regulatory Commission	Compressor facilities under FERC jurisdiction	55 dB Ldn
Guidelines	Environmental Protection Agency	To protect public health and welfare with an adequate margin of safety	55 dB Ldn
Guidelines	Bureau of Land Management	For the development of wind turbines on federal lands managed by BLM. Refers to EPA guideline.	55 dB Ldn
Guidelines	World Health Organization	For community noise. Designed to protect against moderate annoyance during the day, and against sleep disturbance at night.	50 dBA Leq (day) and 45 dBA Leq (night)
Guidelines	World Health Organization	For nighttime noise. Designed to protect vulnerable groups against health effects of night noise exposure.	40 dB Lnight,outside[1]

[1] Lnight,outside, as defined by the European Union Directive 2002/49/EC, is the A-weighted yearly average of night noise outside the dwelling (WHO, 2009). Project consistency with this guideline is addressed in Section 3.4.2.

Pursuant to 30 V.S.A. § 248, the Vermont PSB issued an Amended Certificate of Public Good on July 17, 2009. Condition #28 of the Certificate specifically addressed noise standards, establishing enforceable noise limits for the Project. These limits appear to be based on the WHO community noise guidelines, but are more protective, since the outdoor threshold of 45 dBA must be calculated over the span of any given one-hour period instead of over the entire eight-hour night. "Deerfield shall construct and operate the Project so that the turbines emit no prominent discrete tones pursuant to ANSI [American National Standards Institute] standards at the receptor locations; and Project related sound levels at any existing surrounding residences do not exceed 45 dBA(exterior)(Leq)(1 hr) or 30 dBA(interior bedrooms)(Leq)(1 hr)" (PSB, 2009). Should the Responsible Official decide to issue a land use authorization for the Proposed Action or one of the action alternatives, the Forest Service permit would require compliance with the terms and conditions of the CPG. Noise monitoring/modeling of interior sound levels would require access to the bedrooms of private residences near the Project site, which would be overly intrusive to area residents. Therefore, the Forest Service analysis has adopted the noise standard of 45 dBA(exterior)(Leq)(1 hr) for the Project.

Table 3.4-3: Summary of Overall Background Monitoring Results by Site

Background Monitoring Location	Distance to Existing Turbines (meters)	Day (dBA)			Night (dBA)		
		Leq	L50	L90	Leq	L50	L90
Site MB1	4,500	45	33	32	39	29	28
Site MB2	4,350	50	45	43	46	38	37
Site B1	3,550	56	49	46	52	39	38
Site MB3	2,750	51	29	28	49	33	32
Site B2	2,350	56	41	40	51	41	40
Site B3	800	57	42	42	50	43	42
Site B4	20	63	56	55	62	62	61

Source: RSG, 2007b.

The existing Searsburg facility turbines contribute to the background noise in a portion of the geographic area, particularly in and around the Eastern Project site. The existing turbines, which have been in operation since mid-1997, have a single rotational speed that revolves at approximately 29 revolutions per minute above a certain minimum wind speed. Each wind turbine begins to generate power in winds above 10 mph and has a rated output of 550 kilowatt (kW) in winds of 30 to 65 mph. Above the 65 mph, the wind turbines are programmed to shut down either by pitching their blades or yawing parallel to the wind direction.

It was determined during the study period of December 1-5, 2005 that the sound emissions from two existing Searsburg facility turbines (Turbines 8 and 9) gradually increased by 2.4 dBA for every m/s (2.2 mph) increase in wind speed, up to a maximum sound level of approximately 66 dBA at wind speeds of 10 to 11 m/s (22.4 to 24.6 mph). However, the sound levels were found to be relatively constant (around 63 dBA) between 6 to 17 m/s (13.4 and 38 mph). Above 17 m/s (38 mph), the turbine blades started to pitch to prevent damage. It was determined that since the turbines operate at a single rotational speed, sound levels from the existing turbines are relatively constant. Most of the sound was created by air turbulence around the blades, the yaw motors, and the generator. Incidents of malfunctions that created unusual sounds have occasionally occurred since the existing turbines have been in operation, but these were fixed soon after reports were made.

3.4.2 Direct and Indirect Impacts Presented by Alternative

Although noise impacts were not identified during public scoping as a significant issue, a number of noise-related issues and concerns were raised by the public. Specifically, people are concerned about the noise levels of the turbines and the extent this noise would be disruptive to their residences and while recreating in the Project area. People are also concerned that the Proposed Action would adversely affect the solitude and wildland attributes of the nearby Lamb Brook Area and the Aiken Wilderness. In addition, a number of public comments received on the SDEIS raised concerns about reported impacts to human health from wind turbines. In response to those comments, a new appendix has been added to this FEIS. See Appendix K for a summary of potential health effects turbines and turbine noise. This section addresses potential noise-related direct and indirect impacts due to the construction and operation of the Proposed Action. The Project impacts are in addition to

Attachment 3:

Adverse health effects of industrial wind turbines

April, 2013 by Roy D. Jeffery, MD FCFP, Carmen Krogh, Brett Horner, CMA

Summary:

This peer-reviewed paper published in the Journal of the College of Family Physicians of Canada examines the health impacts of industrial-scale wind turbines when sited in proximity of where people live. The introduction and conclusion of the paper is excerpted below. The full report can be accessed by clicking on the links at the bottom of this page.

Introduction

Canadian family physicians can expect to see increasing numbers of rural patients reporting adverse effects from exposure to industrial wind turbines (IWTs). People who live or work in close proximity to IWTs have experienced symptoms that include decreased quality of life, annoyance, stress, sleep disturbance, headache, anxiety, depression, and cognitive dysfunction. Some have also felt anger, grief, or a sense of injustice. Suggested causes of symptoms include a combination of wind turbine noise, infrasound, dirty electricity, ground current, and shadow flicker.1 Family physicians should be aware that patients reporting adverse effects from IWTs might experience symptoms that are intense and pervasive and might feel further victimized by a lack of caregiver understanding.

Conclusion

Industrial wind turbines can harm human health if sited too close to residents. Harm can be avoided if IWTs are situated at an appropriate distance from humans. Owing to the lack of adequately protective siting guidelines, people exposed to IWTs can be expected to present to their family physicians in increasing numbers. The documented symptoms are usually stress disorder–type diseases acting via indirect pathways and can represent serious harm to human health. Family physicians are in a position to effectively recognize the ailments and provide an empathetic response. In addition, their contributions to clinical studies are urgently needed to clarify the relationship between IWT exposure and human health and to inform regulations that will protect physical, mental, and social well-being.

Web link: http://www.cfp.ca/content/59/5/473.full#sec-3
Download File(s):
AdverseHealthEffects-Canada.pdf (85.22 kB)

Attachment 4:

UK NEWS

FEARS WIND TURBINES CAN BE HEALTH HAZARD

Experts claimed that living within six miles of a turbine can cause “life threatening” illnesses

Monday November 28,2011

By Dean Herbert

Have your say(6)

MINISTERS were yesterday urged to abandon the race to build wind farms after experts claimed that living within six miles of a turbine can cause “life threatening” illnesses.

Scientists have called for exclusion zones to be set up around new structures after finding that people who live nearby have developed conditions including high blood pressure, insomnia and migraines.

They say that anyone living within a six mile radius of the turbines can be affected by the vibrations and noise they generate.

The Scottish Government is determined to turn the country into the renewable energy powerhouse of Europe.

SNP ministers have set new targets for the country to meet its full electricity requirements by wind, wave and tidal power by 2020.

Research by Dr Sarah Laurie, director of Australian medical body the Waubra Foundation, concluded that the turbines can spark “real, serious and at times life threatening” illnesses.

“

The Japanese government implemented a four-year programme of research into the health effects of wind turbine noise. Pressure should be placed on the UK governments to do likewise

”

Dr Chris Hanning

Her research has documented people living near turbines in Australia developing conditions including sudden adrenalin surges, severe headaches and dangerously high blood pressure.

She said: "There's an urgent need for research at existing wind developments to determine what the dose of noise and vibration is that these people are exposed to and what their symptoms are before more turbines are built closer than 10km (6.2 miles) to homes."

Residents living near the Hadyard Hill wind farm near Girvan, Ayrshire, have reported feeling "constantly tired" because of the constant sound of their blades spinning. In Scotland, wind farms can be built as close as a mile to residential areas. But there are now growing calls for the turbines to be moved further away.

Dr Chris Hanning, a retired consultant in sleep medicine, added: "The health impacts of wind farms are serious. I have no doubt that many people have suffered serious adverse effects.

"The Japanese government implemented a four-year programme of research into the health effects of wind turbine noise. Pressure should be placed on the UK governments to do likewise."

Tory MSP Struan Stevenson, who has long opposed the construction of wind farms, also backed Dr Laurie's calls.

He said: "The constant noise, vibration and flicker-effect have caused extreme stress, nausea, migraine and panic attacks in people living within a 10km zone. I am convinced that having a 10km exclusion zone is correct."

Earlier this year conservation charity the John Muir Trust revealed that wind farms ran at less than 20 per cent of capacity more than half the time.

A Scottish Government spokeswoman said: "There is no evidence of health effects arising from wind farms, and Dr Laurie's examples relate to other countries

"The Scottish Government will only approve the right wind farm applications in the right places, and applications that do not meet strict criteria are rejected.

"Our planning guidance for local authorities makes clear that developments must be carefully sited to mitigate and minimise impacts on local amenity."

Response:

Based on a review of published, peer-reviewed, scientific studies, OER does not feel that wind developments should be banned from Rhode Island. Instead, concerns about noise and shadow flicker should be addressed through appropriate zoning and siting processes. OER, has provided the World Health Organization's noise recommendation in the "Noise – FAQs" section of the Guidelines document. In addition, OER has summarized what the scientific literature finds with respect to health effects: "The scientific literature has only connected wind turbine noise with increased self-reported annoyance and sleep disturbance[1]" Unfortunately, as Mr. Rigg's attachment 4 shows, there is fear and worry regarding wind development throughout the world. OER believes the Guidelines document, as written, attempts to alleviate those fears with current and accurate scientific facts.

No changes were made to the Guidelines document based on this comment.

Comment:

Mr. Riggs states the following in a letter to OER: "The presence of wind turbines results in a negative impact on local real estate values. (See Attachment 5.) This in return can result in an illegal "taking" of neighboring property. (See Attachment 6.) And, of course, this can result in an impact on the public view shed. (See example re the Newport Naval Station in Attachment 7.)"

Attachments 5, 6, and 7 follow below:

Attachment 5:

[1] J. H. Schmidt and M. Klokker, "Health Effects Related to Wind Turbine Noise Exposure: A Systematic Review," *PLoS One*, vol. 9, no. 12, p. 28, 2014.

Values in the Wind: A Hedonic Analysis of Wind Power Facilities

Martin D. Heintzelman

Clarkson University School of Business

Carrie Tuttle

affiliation not provided to SSRN

July 15, 2011
Land Economics, Forthcoming

Abstract:
The siting of wind facilities is extremely controversial. This paper uses data on 11,369 property transactions over 9 years in Northern New York to explore the effects of new wind facilities on property values. We use a repeat-sales framework to control for omitted variables and endogeneity biases. **We find that nearby wind facilities significantly reduce property values.** Decreasing the distance to the nearest turbine to 1 mile results in a decline in price of between 7.73% and 14.87%. These results indicate that there remains a need to compensate local homeowners/communities for allowing wind development within their borders

The Impact of Wind Farms on Property Values: A Geographically Weighted Hedonic Pricing Model

Yasin Sunak

RWTH Aachen University - E.ON Energy Research Center

Reinhard Madlener

RWTH Aachen University; German Institute for Economic Research (DIW Berlin)

May 1, 2012
FCN Working Paper No. 3/2012 (revised March 2013)

Abstract:
Wind power is the most important renewable energy source in many countries today, characterized by a rapid and extensive diffusion since the 1990s. However, it has also triggered much debate with regard to the impact on landscape and vista. Therefore, siting processes of wind farm projects are often accompanied by massive public protest, because of visual and aural impacts on the surrounding area. These mostly negative consequences might be reflected in property values and house prices. The aim of this paper is to investigate the impacts of wind farms on the surrounding area through property values, by means of a hedonic pricing model, using both a spatial fixed (viewshed) effects (accounting for spatially clustered unobserved influences) and a Geographically Weighted Regression model (accounting for spatial heterogeneity). The analysis is the first of its kind undertaken for a local region in Continental Europe (North Rhine-Westphalia, Germany). Viewsheds are calculated for each property using a digital surface model. Focusing on proximity and visibility effects caused by wind farm sites, **we find that proximity, measured by the inverse distance to the nearest wind turbine, indeed causes significant negative impacts on the surrounding property values.** Thereby, local statistics reveal varying spatial patterns of the coefficient estimates across and within the city areas and districts. In contrast, no evidence is found for a statistically significant impact of the visibility of the wind farm turbines.

Attachment 6:

Wind turbines constitute a “taking” of private property value (Mass.)

Mar 22, 2012

The approval of wind energy projects within close proximity to occupied homes is tantamount to an *inverse condemnation*, or *regulatory taking* of private property rights, as the noise and impacts are in some respects a physical invasion, an *easement in gross* over neighboring properties, and the direct impacts reduce property values and the rights of nearby neighbors.”

Michael S. McCann, CRA
McCann Appraisal, LLC
Chicago, IL

“Mr. McCann has confirmed a 25-40 percent reduction is to be expected within two miles and that smaller reductions over a larger area should also be anticipated.”

“Based on her experience in Falmouth, MA, Mrs. Cool says, ‘I know that the installation of industrial wind turbines is a *Negative Material Fact*.’”

Annie Hart Cool
Annie Hart Cool Team
Sotheby’s International Realty

—Walter Cudnohufsky, *Shelburne Falls Independent* (3/22/12)

The proposal to install wind turbines on Mt. Massaemet (Mass.) has already dramatically lowered all property values in the 11 square miles of Shelburne (MA) and Buckland (MA) lying within the most impacted two miles of the turbines. The turbines already cast a shadow on the title and expected benefits to residential property.

Chicago real estate appraiser Michael McCann, who spoke in Shelburne Falls recently at the invitation of the Friends of Mt. Massaemet advocacy group, suggests that industrial wind installations can be tantamount to “inverse condemnation,” or a regulatory and private taking of others’ private property rights.

At his March 3 presentation, Mr. McCann suggested that, given his well documented and conservative estimate of 25 percent value decline, an impressive $45 million tax base depreciation would be anticipated in Shelburne alone. Buckland would certainly have a significant tax base impact as well. The depreciation has, in his studies, reached 40 percent. McCann has conducted 20 recent industrial turbine-related evaluations, zoning compliance and impact studies across the country.

Attachment 7:

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS
HISTORICAL PRESERVATION & HERITAGE COMMISSION
Old State House • 150 Benefit Street • Providence, R.I. 02903-1209
TEL (401) 222-2678 FAX (401) 222-2968
TTY (401) 222-3700 Website www.preservation.ri.gov

19 December 2011

Captain J.P. Voboril, USN
Commanding Officer
Naval Station Newport
690 Peary Street
Newport, Rhode Island 02841-1522

Re: Proposed Wind Turbine Locations
Comments for Environmental Assessment
Naval Station Newport
Newport, Middletown, and Portsmouth, Rhode Island

Dear Captain Voboril:

U.S. Naval Station Newport has conducted an Environmental Assessment of the impacts resulting from potential installation of up to 12 wind turbines ranging in height from 459 feet to as little as 211 feet to be located at one or more of 12 sites that were investigated. The Rhode Island Historical Preservation and Heritage Commission (RIHPHC) staff has reviewed reports for "Historical Resources Assessment for the Naval Station Newport Viewshed Study, Newport County, Rhode Island" prepared by Gray & Pape, Inc. for Tetra-Tech, Inc. The reports, which summarized viewshed analyses regarding sites proposed by the Navy for the location of wind turbines, have been well done and thorough.

In a letter to you dated 22 July 2011, the RIHPHC informed you that we had begun to share the revised photographic simulation information for this project with our peers whose properties are located in the area around the project. We also stated that following our receipt of comments from those groups, we would evaluate the project based on the Criteria of Adverse Effect as defined in Section 106 and issue our Section 106 determinations of effect for the project.

As you are aware, most of the groups that we contacted requested the opportunity to have representatives attend information sessions on the project that you had previously offered to conduct. We thank you for conducting these meetings on 28 October and 17 November 2011. We received responses from five of the eight groups to whom we sent information. The responses were generally in favor of a wind energy project, however, there were concerns expressed, mostly about the southernmost sites, including multiple single turbines versus one or more clusters, and the potentially out-of-scale relationship between the turbines and the built and natural environment of the area.

Based on the photographic simulations that have been provided by the Navy and in consideration of the comments that we have received from our peers, we have made a preliminary determination that the installation of wind turbines at the 12 locations under consideration will have a visual effect on the following properties:

- United States Naval War College, a National Register of Historic Places (NR) -listed and National Historic Landmark (NHL) district which includes Luce Hall, an NR-listed property: as illustrated by the photographic simulation from Battery Park (#11);
- Newport Historic District, an NR-listed and NHL district: as illustrated by photographic simulations from Battery Park (#11), Island Cemetery (#13, 13a), and Bowen's Wharf (#3);
- Bellevue Avenue National Historic Landmark District, an NR-listed and NHL district, and Ochre Point-Cliffs Historic District, an NR-listed district, both in Newport: as illustrated by photographic simulations from the Breakers (#10, 10a);
- Bellevue Avenue-Casino Historic District and the Newport Casino (and the Van Alen Casino Theatre and Newport Performing Arts Center) in Newport, an NR-listed and an NR-listed and NHL property, respectively: as illustrated by the photographic simulation from Bellevue Avenue at Casino Terrace (#5);
- Ocean Drive Historic District in Newport, an NR-listed and NHL district: as illustrated by a photographic simulation from Ida Lewis Yacht Club in Newport (#6);
- Fort Adams Historic District in Newport, an NR-listed and NHL district: as illustrated by photographic simulations from both outside and inside the Fort (#7, 8, 9);
- Windmill Hill Historic District and Jamestown Windmill in Jamestown, both of which are listed in the NR: as illustrated in two photographic simulations from the Windmill property (#25, 25a);
- Rose Island Lighthouse off the west coast of Newport, an NR-listed property: as illustrated by photographic simulations from Narragansett Bay (#12, 12a);
- Shoreby Hill Historic District in Jamestown, an NR-listed district: as illustrated by the photographic simulation from Jamestown Harbor (#26);
- Newport Naval Hospital Historic District in Newport, which is considered eligible for listing in the NR: as illustrated by photographic simulations from Cypress Street in Newport (#1, 2);
- Agricultural District at Green Lane and West Main Road in Middletown, which is considered potentially eligible for listing in the NR: as illustrated by photographic simulations from 1942 West Main Road, in Middletown (#20, 20a).

It is possible that there will also be visual effects on other historic properties within the above-listed districts.

The southernmost six proposed turbines (Katy Field, Bishop Rock, Prichard Field South, Prichard Field North, Navy Lodge, and Coddington Point), due in part to their proximity to the large number of National Register of Historic Places-listed and -eligible and National Historic Landmark-designated properties, have the greatest possibility of causing adverse visual effects to historic resources. If constructed, turbines at these locations would have adverse effects on views of the United States Naval War College NHL District, of Luce Hall, of the President's House (aka Quarters AA), of the

Point section of the Newport NHL District, and of Rose Island Lighthouse, and views within the Common Burying Ground and Island Cemetery, which is individually listed in the NR and within the bounds of the Newport NHL district, and from the Fort Adams Historic NHL District.

Additionally, the construction of the proposed turbine at Tank Farm 5 would have an adverse visual effect on the Agricultural District at Green Lane and West Main Road in Middletown, located just to the east of the turbine. Even at its FAA-maximum allowed height of 211 feet, the photographic simulations of the proposed turbine show a significant presence in this sparsely built agricultural district.

In order to reach our conclusion that the undertaking would result in adverse effects to historic properties, RIHPHC carefully considered the comments of the interested public, and we considered the visual qualities that are integral to the properties' historical significance and historical character. We concluded that simple visibility of a proposed wind turbine from a historic property would not, by itself, constitute an adverse effect. However, when the visual impact of one turbine or the cumulative effect of multiple turbines diminished the integrity of the historic property's setting, feeling, and association, we concluded that an adverse effect would result as described in the federal Procedures of the Advisory Council on Historic Preservation (36 CFR Part 800.5(a)). For example, the southern-most turbines significantly intrude on the historic waterfront character of the Point section of the Newport NHL District, and they seriously alter the visual setting of historic properties on Coasters Island, Rose Island, and Fort Adams. The visibility of any turbines would significantly intrude on the historic landscape character of the Common Burying Ground and Island Cemetery.

In addition to identifying visual impacts to specific historic properties, RIHPHC agrees with comments of the Preservation Society of Newport County that: "The viewshed of Newport and its Harbor, its component landscapes and structures represents a globally significant cultural resource. This year nearly ten million vehicles will have crossed the Bridge onto or off the island, and approximately 121,000 visitors arrived by cruise ship to tour Newport. We believe their view of historic Newport would have been adversely impacted if wind turbines were installed on the proposed sites 6-12 [Building 6CC aka Derecktor Shipyard, Building 1112 aka Coddington Point, Building 1285 aka Navy Lodge, Bishops Rock, Prichard Field – North, Prichard Field – South, and Katy Field, respectively]." Acceptance of adverse visual effects from Navy turbines not only would diminish the integrity of significant historic properties, but could also affect Newport's attractiveness as a destination for cultural tourism.

We understand that the Navy is in the process of gathering information for consolidation in an environmental assessment, after which it will review and evaluate the document in order to make a decision whether or not to construct wind turbines at these locations. At such time that the Navy decides to pursue and construct wind turbines, we will expect to review those plans under the regulations set forth in Section 106 of the National Historic Preservation Act.

Based on the information that has been provided by the Navy, we have made a preliminary determination that the project will not have a direct, physical impact to any above-ground historic property.

We have reviewed the draft of the Phase I archaeological investigation that was transmitted to our office; we assume that the final version will include information on who did the work, information on the project impacts, and additional historical and archaeological context for the areas investigated.

We concur that no additional archaeological survey is required at the following areas:

- Tank Farm 3
- Tank Farm 4 Turbine Site B
- NUWC
- Derecktor Shipyard
- Coddington Point
- Navy Lodge
- Bishops Rock
- Prichard Field North
- Prichard Field South
- Katy Field

At Tank Farm 5, a historical site, RI 2519, was discovered to the north of the proposed wind turbine. We concur that no further survey is need for this site at the present time. However, if the wind turbine location should shift to the north, additional survey would be needed to determine the spatial extent of RI 2519, and, depending on the results of that survey, a Phase II investigation might be necessary to determine if RI 2519 is eligible for listing on the National Register of Historic Places.

At Tank Farm 4 Turbine Site A, prehistoric artifacts were recovered from the plow zone. It is our opinion that this site, designated RI 2520, could potentially be eligible for listing on the National Register. A Phase II survey should be conducted to determine if this is the case.

These comments are provided in accordance with Section 106 of the National Historic Preservation Act. We look forward to working with the Navy and its team to complete this important project. If you have any questions, please contact Jeffrey Emidy, Project Review Coordinator, or Charlotte Taylor, Staff Archaeologist, of this office.

Very truly yours,

Edward F. Sanderson
Executive Director
State Historic Preservation Officer

cc: John Brown, NITHPO
D.D. Dorocz, Environmental Department Head, Naval Station Newport
Shannon Kam, Naval Station Newport
Keith Stokes, Executive Director, RI Economic Development Corporation

cc, cont:

Dana Corson, Preservation Planner, Newport Historic District Commission, by email
Trudy Coxe, Chief Executive Officer, Preservation Society of Newport County, by email
Beth Cullen, President, The Point Association, by email
Grover Fugate, Executive Director, RI Coastal Resources Management Council, by email
John Grosvenor, Commissioner, RIHPHC, by email
Eric Hertfelder, Executive Director, Fort Adams Trust, by email
David McCurdy, Executive Director, Rose Island Foundation, by email
Ronald Onorato, Commissioner, RIHPHC, by email
Linnea Petersen, President, Jamestown Historical Society
Pieter Roos, Executive Director, Newport Restoration Foundation, by email
Mark Stenning, Chief Executive Officer, Int'l Tennis Hall of Fame & Museum, by email
Valerie Talmage, Executive Director, Preserve Rhode Island, by email

111219.02jde

Response:
In response to a previous public comment (see page 17), OER had conducted further research into the effects of wind turbines on property values. A study conducted by the University of

Connecticut and the Lawrence Berkeley National Laboratory concluded that wind turbines have little to no effect on surrounding property values. Therefore, OER does not feel that a change to the Guidelines document to further address property values is necessary.

Mr. Rigg's, through attachment 7, also brings up the matter of visual impacts. OER does not believe that wind developments should be rejected on the basis of visual impact, unless pre-existing visual impact standards are violated. In other words, wind development should be subject to the same visual standards as any other development. In addition, OER includes the following sentence in the Guideline's "Other Impacts: Visual Impacts" section: "It is advisable that visual impacts to recognized historic, cultural, archeological, or scenic sites be minimized." OER believes that these visual impact recommendations are fair and reasonable. Therefore, no changes were made to the Guidelines document based on this comment.

Comment:
Mr. Riggs states the following in a letter to OER: "Further, numerous studies have shown that wind turbines cause radar clutter that degrades not only aircraft radar systems, but others, such a weather radars."

Response:
OER feels it has accurately addressed this concern in the Guideline's "Other Impacts: Signal Interference" section. A subset of the text of this section follows:

"Previously, when wind turbines were predominately made with metal, they had the potential to cause signal variations due to signal deflection. However, modern turbines are now made with synthetic materials that have minimal impacts on broadcast signal transmission[2,3]."

No changes were made to the Guidelines document based on this comment.

Comment:
Mr. Riggs states the following in a letter to OER: "While nearly all forms of energy production require acceptance of some level of negative environmental impact in order to realize the benefits, numerous studies have shown that there are no benefits from wind power. For example, the 5 year ERCOT Bentek IV study done on the impact of 2300 wind turbines on the Texas electrical grid concluded that they not only failed to reduce either carbon emissions or fossil fuel use, but in some cases they actually increased them. That's because the intermittency of wind power makes the conventional sources ramp up and down, decreasing their efficiency. (See ***Attachment 8****.) As a result, all this effort to include wind power in a state like Rhode Island are not really justified."*

Attachment 8 follows below:

Attachment 8:

[2] D. Al Katsaprakakis, "A review of the environmental and human impacts from wind parks. A case study for the Prefecture of Lasithi, Crete," *Renew. Sustain. Energy Rev.*, vol. 16, no. 5, pp. 2850–2863, 2012.
[3] K. Dai, A. Bergot, C. Liang, W.-N. Xiang, and Z. Huang, "Environmental issues associated with wind energy – A review," *Renew. Energy*, vol. 75, pp. 911–921, 2015.

Wind Integration Realities: The Bentek Study for Texas (Part IV)

By Kent Hawkins
May 26, 2010

[Editor's note: This is the final post in the series reviewing studies for the Netherlands, Colorado and Texas on (elevated) fossil-fuel emissions associated with firming otherwise intermittent wind power. Part I introduced the issues. Part II showed negated emission savings for the Netherlands at current wind penetration (about 3 percent). Part III extended the Netherland's experience to the higher wind penetration in Colorado (6%) which demonstrates *higher* emissions. Part IV concludes with the Bentek results for Texas, which confirms those for Colorado.]

SUMMATION: As wind penetration is increased, the Colorado and Texas experience shows that the savings become negative, that is, fossil fuel and CO2 emissions are increased. The integration of all the considerations for the three approaches is complex and necessarily simplified.
NOTE: The Electric Reliability Council of Texas (ERCOT) manages the flow of electric power to 23 million Texas customers - representing 85 percent of the state's electric load and 75 percent of the Texas land area. As the independent system operator for the region, ERCOT schedules power on an electric grid that connects 40,500 miles of transmission lines and more than 550 generation units. It also manages financial settlement for the competitive wholesale bulk-power market and administers customer switching for 6.6 million Texans in competitive choice areas.

There are a number of relevant, notable characteristics of the 2008 Texas electricity production profile, 85% of which is managed by ERCOT:

- The utility portion of the total electricity production is only about 24% of the total, with independent suppliers providing 57% and CHP installations, 19%. This distribution suggests that ERCOT's ability to balance wind production is more limited than what might first appear.
- Wind production is 5% of the total (less CHP), but a very large 17% of the utilities portion.
- A large proportion of gas production is provided by independent suppliers and CHP, 45% and 39% respectively, again likely limiting ERCOT's ability to balance wind with gas.
- The ratio of utility gas to wind production is 192%, which suggests that this is tight if dedicated to wind balancing. This, plus high production from wind at night, explains the high degree of cycling of coal plants required.

Because of recycling events, arguably attributable to the presence of wind plants, the results are the same as for PSCO, that is, there is an increase in CO_2 emissions with the presence of wind. In ERCOT, the coal plants produced an additional CO_2 emissions in 2008 of about 0-566,000 tons over running stably without these events, and in 2009, an additional 772,000-1,102,000 tons.

Wind Capacity Factor

Based on the information in the Bentek report, the wind capacity factor within ERCOT in 2009 is 22.7%, which is low and likely due to curtailment of wind, as is the case in Germany, which has a similar wind penetration of about 6% and wind capacity factors below 20%. There is notable curtailment in ERCOT as reported by NREL. The DOE/EIA published information for 2008 indicates a wind capacity factor of 25%. The difference could well be year to year variations in the wind regime. A capacity factor of 23% will be used in calculator runs.

Heat Rate Penalty and CO2 Emissions Increase Factor

From DOE/EIA published information, for Texas in 2008, for utility fossil fuel plants only, at $\Delta F=0$, this is:

ΔR = (16,200/93,400) x 41% = 7.1%

For all fossil fuel plants in the system (less CHP) this becomes:

ΔR = (16,200/265,100) x 41% = 2.5%

Based on the totals used in Figure VI-4 (2009 data) for ERCOT, there might be some suggestion of using independent suppliers to balance wind. The 2.5% value assumes all the independent suppliers are used, which is unlikely. In the absence of more information, the PSCO calculated ΔR of 3.3% will be used for the deriving the calculator input for heat rate penalty, which is the same as for PSCO at starting at 35% but adjusted down to 20-25% for the lower capacity factor as used in Figure 4 of the calculator Part V post.

Calculator Results for ERCOT

The resulting calculator CO_2 emissions increases are: coal cycling only – 0.7 million tonnes (0.77 million tons) per year.

As for PSCO, a reasonable view is that both coal and gas plants will be involved in cycling at different times. Although coal and gas production are about the same in ERCOT, because wind is strongest at night, coal is more heavily weighted in the wind balancing mix at 67% coal and 33% gas. The total ERCOT gas mix is heavily weighted to CCGT production, but for wind balancing about an equal split with OCGT is assumed. This means more production from existing OCGT or possibly some CCGT plants being run as OCGT. Frequent cycling of CCGT plants damages the HRSGs so single stage operation is needed. In summary, more OCGT production is used than would be required if wind was not present in the system. The emissions increase over normal coal/CCGT operations becomes 2.3 million tons per year. This is an aspect not addressed in the Bentek paper. Table 1 shows the comparison of the Bentek results with the calculator.

Table 1 – Comparison of Bentek Study and Calculator results for ERCOT

	Bentek Results – Coal Cycling (million tons)		Calculator Results (million tons)	
	2008	2009	Coal Cycling	Coal/Gas Cycling*
CO_2 Emissions Increase per Year	0-0.6	0.8-1.1	0.8	2.3

*No comparable Bentek results

The calculator results directly comparable to the Bentek findings are very close to Bentek's. It should be emphasized that this is not likely the whole story as the gas cycling impacts should also be taken into account.

Summary of Dutch and Bentek Studies

Table 2 provides an overview of the findings of this series on wind integration. In summary, the Netherlands experience is that at wind penetration of about 3% the fossil fuel and CO_2 emissions saving is reduced to zero. As wind penetration is increased, the Colorado and Texas experience shows that the savings become negative, that is, fossil fuel and CO2 emissions are increased. The integration of all the considerations for the three approaches is complex and necessarily simplified. Any additional insights are welcome.

Table 2 – Summary of the Three Approaches Analyzed in this Series

	The Netherlands	Bentek		Comments
		PSCO	ERCOT	
Total Electricity Production	105 TWh	53 TWh	405 TWh	
Total Wind Production	3.4 TWh	3.2	16.2 TWh	
Wind Penetration	3.2%	6%	5% **	
Percent Coal Production	27%	66%	36%	
Percent Gas Production	58%	23% *	29% **	
Wind Curtailment	?	Small?	Some	
Efficiency Loss ΔR	2.11%	3.3%	3.3%	
Efficiency Loss (Heat Rate Penalty) in Wind Mirroring Plants	25%	35%	20-25%	ERCOT is adjusted as explained above.
Wind Capacity Factor	25%	35%	23%	
Netherlands Study				
Netherlands Study Fossil Fuel Increase	0%			
Calculator Fossil Fuel Increase (Saving)	(0.5%)-1.7%			The range shown is for two runs (1) CCGT only, (2) CCGT/OCGT
Calculator CO_2 Emissions Increase	0.8%			This is run (3) which includes some coal plants
Bentek Study				
Bentek CO_2 Emissions Increase		0.1-0.15 million tons/year	0-1.1 million tons/year	Coal cycling only
Calculator CO_2 Emissions Increase		0.11 million tons/year	0.8 million tons/year	Coal cycling only

*Includes non-utility suppliers (otherwise is 9%)
** Excludes CHP plants

There is a notable consistency among these three approaches. Look for more studies, based on actual experience, to emerge from countries not now dependent on foreign markets for export of wind turbine products and services, confirming the inability of new renewables, especially wind, to contribute to the reduction in fossil fuel use and CO_2 emissions reduction in electricity generation. *In the absence of comprehensive, objective and transparent studies that finally settle the matter, policies in support of new renewables should be severely curtailed.*

Response:

OER recognizes the complexities of the Rhode Island electric grid and believes that wind developments do offer the potential to decrease greenhouse gas emissions for the region. In *addition, as described in the "Policy Context" of the Guidelines document, OER believes, "Wind projects can help diversify Rhode Island's electricity supply portfolio, which is currently dominated by natural gas both in-state and regionally. Local wind generation can reduce costs and power losses associated with transporting electricity long distances. It can also reduce the demands on the grid during periods of peak electricity use. By reducing the need to burn fuel, local wind projects can provide health and environmental benefits, price predictability and a hedge against volatile fossil fuel and electricity prices. In-state investment, economic growth, and job creation can also be spurred through the construction and operation of local wind projects." For all these reasons, OER believes wind development can offer large benefits for the State when sited appropriately.*

No changes were made to the Guidelines document based on this comment.

Decision

It is the decision of the Rhode Island Office of Energy Resources to approve the Rhode Island Land-Based Wind Siting Guidelines with the aforementioned additions and edits. The Guidelines are appended to this Decision.

2/1/17
Date

Carol J. Grant, Commissioner
Office of Energy Resources

A Copy of Decision has been posted on the following webpage: www.energy.ri.gov/renewable/landwind/

Relationship between Wind Turbines and Residential Property Values in Massachusetts

A Joint Report of University of Connecticut and Lawrence Berkeley National Laboratory

January 9, 2014

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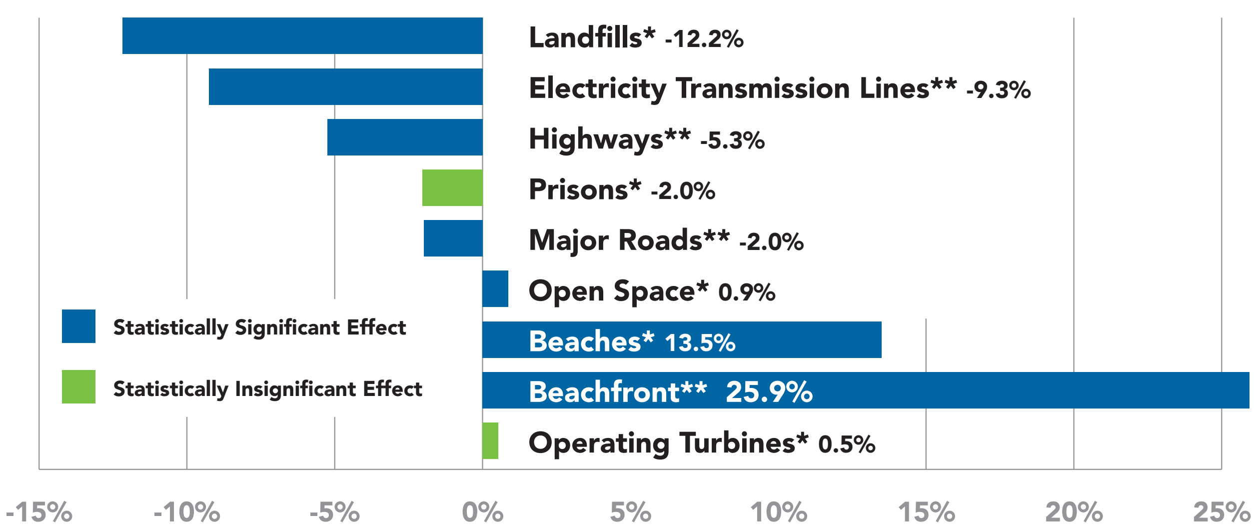
CONTENTS

EXECUTIVE SUMMARY

This study investigates a common concern of people who live near planned or operating wind developments: How might a home's value be affected by the turbines? Previous studies on this topic, which have largely coalesced around non-significant findings, focused on rural settings. Wind facilities in urban[1] locations could produce markedly different results. Nuisances from turbine noise and shadow flicker might be especially relevant in urban settings, where negative features, such as landfills or high voltage utility lines, have been shown to reduce home prices. To determine if wind turbines have a negative impact on property values in urban settings, this report analyzed more than 122,000 home sales, between 1998 and 2012, that occurred near the current or future location of 41 turbines in densely-populated Massachusetts communities.

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

Figure 1: Summary of Amenity, Disamenity and Turbine Home Price Impacts



*Distance to MA Homes: * within 1/2 mile; ** within 500 feet*

1 The term "urban" in this document includes both urban and suburban areas.

OVERVIEW

Wind power generation has grown rapidly in recent decades. In the United States, wind development centered initially on areas with relatively sparse populations in the Plains and West. Increasingly, however, wind development is occurring in more populous, urbanized areas, prompting additional concerns about the effects of wind turbine construction on residents in those areas.

One important concern is the potential for wind turbines to create a "nuisance stigma"—due to turbine-related noise, shadow flicker, or both—that reduces the desirability and thus value of nearby homes. Government officials who are called on to address this issue need additional reliable research to inform regulatory decisions, especially for understudied populous urban areas. Our study helps meet this need by examining the relationship between home prices and wind facilities in densely-populated Massachusetts.

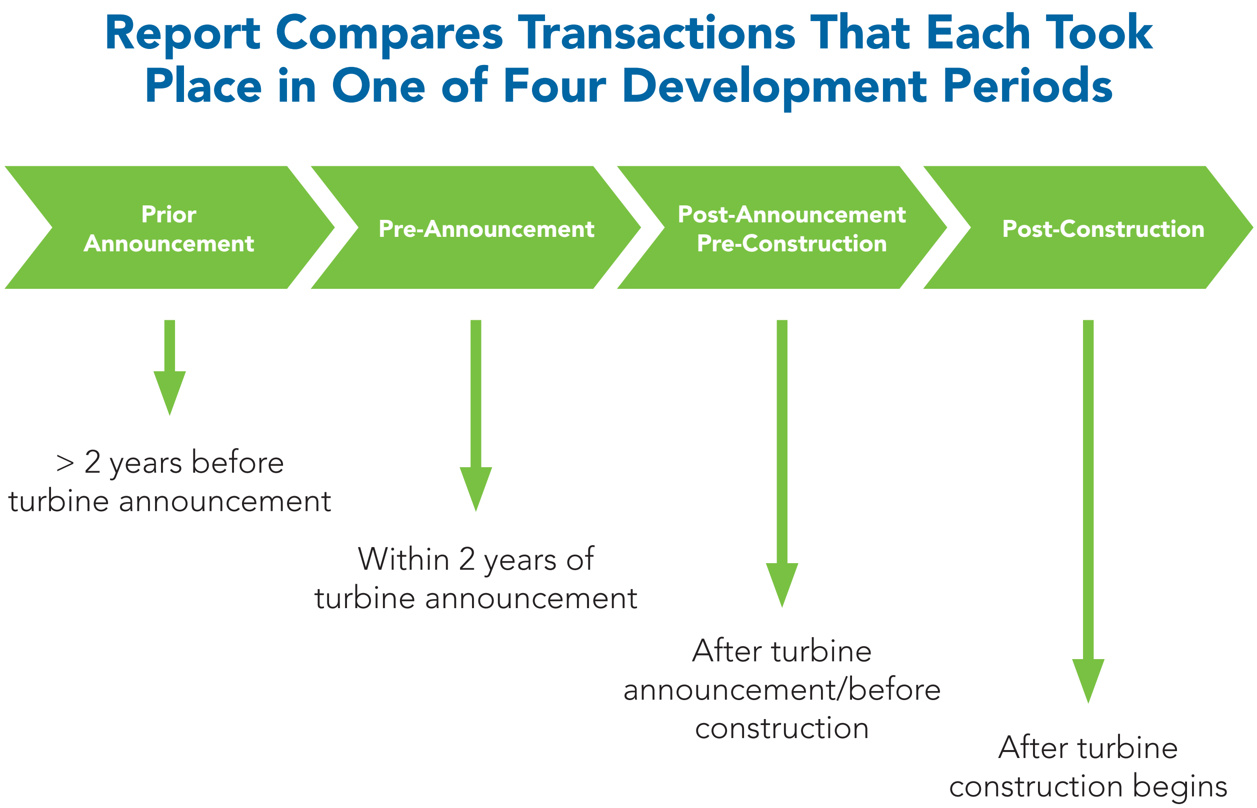
A variety of methods can be used to explore the effects of wind turbines on home prices. Statistical analysis of home sales, using a hedonic model, is the most reliable methodology because it (a) uses actual housing market sales data rather than perceptions of potential impacts; (b) accounts for many of the other, potentially confounding, characteristics of the home, site, neighborhood and market; and (c) is flexible enough to allow a variety of potentially competing aspects of wind development and proximity to be tested simultaneously. Previous studies using this hedonic modeling method largely have agreed that post-construction home-price effects (i.e., changes in home prices after the construction of nearby wind turbines) are either relatively small or sporadic. A few studies that have used hedonic modeling, however, have suggested significant reductions in home prices after a nearby wind facility is announced but before it is built (i.e., post-announcement, pre-construction) owing to an "anticipation effect." Previous research in this area has focused on relatively rural residential areas and larger wind facilities with significantly greater numbers of turbines.

This previous research has done much to illuminate the effects of wind turbines on home prices, but a number of important knowledge gaps remain. Our study helps fill these gaps by exploring a large dataset of home sales occurring near wind turbine locations in Massachusetts. We analyze 122,198 arm's-length single-family home sales, occurring between 1998 and 2012, within 5 miles of 41 wind turbines in Massachusetts. The home sales analyzed in this study occurred in one of four periods based on the development schedule of the nearby turbines (see Figure 2).[2] To estimate the effect proximity to turbines has on home sale prices, we employ a hedonic pricing model in combination with a suite of robustness tests[3] that explore a variety of different model specifications and sample sets, organized around the following five research questions:

2 The analysis focuses on the 41 turbines in Massachusetts that are larger than 600 kilowatt and that were operating as of November 2012.

3 These tests included a comparison of a "base" model to a set of different models, each with slightly different assumptions, to explore the robustness of the study's findings.

Figure 2: Wind Turbine Development Periods Studied



Q1) Have wind facilities in Massachusetts been located in areas where average home prices were lower than prices in surrounding areas (i.e., a "pre-existing price differential")?

Q2) Are post-construction (i.e., after wind-facility construction) home price impacts evident in Massachusetts and how do Massachusetts results contrast with previous results estimated for more rural settings?

Q3) Is there evidence of a post-announcement/pre-construction effect (i.e., an "anticipation effect")?

Q4) How do impacts near turbines compare to the impacts of amenities and disamenities also located in the study area, and how do they compare with previous findings?

Q5) Is there evidence that houses near turbines that sold during the post-announcement and post-construction periods did so at lower rates (i.e., frequencies) than during the pre-announcement period?

The study makes five major unique contributions:

1. It uses the largest and most comprehensive dataset ever assembled for a study linking wind facilities to nearby home prices.[4]

2. It encompasses the largest range of home sale prices ever examined.[5]

3. It examines wind facilities in urban areas (with relatively high-priced homes), whereas previous analyses have focused on rural areas (with relatively low-priced homes).

4. It largely focuses on wind facilities that contain fewer than three turbines, while previous studies have focused on large-scale wind facilities (i.e., wind farms).

5. Our modeling approach controls for seven environmental amenities and disamenities in the study area, allowing the effect of wind facilities to be compared directly to the effects of these other factors.

The models perform exceptionally well given the volatility in the housing market during the study period, with an adjusted-R^2 of approximately 0.80[6] and highly statistically significant[7] and appropriately signed controlling parameters (e.g., square feet, acres, and age of home at the time of sale). The amenity and disamenity variables (proximity to beaches, open space, electricity transmission lines, prisons, highways, major roads, and landfills) are significant in a large portion of the models and appropriately signed—indicating that the models discern a strong relationship between a home's environment and its selling price—and generally accord with the results of previous studies. To test whether the results of the analysis would change if the model was specified in a different way, or run using a differently-specified dataset, we ran a suite of robustness tests. The results generated from the robustness tests changed very little, suggesting that our approach is not dependent on the model specification or the data selection.

The results do not support the claim that wind turbines affect nearby home prices. Despite the consistency of statistical significance with the controlling variables, statistically significant results for the variables focusing on proximity to operating turbines are either too small or too sporadic to be apparent. Post-construction home prices within a half mile of a wind facility are 0.5% higher than they were more than 2 years before the facility was announced (after controlling for

4 Four of the most commonly cited previous studies (Carter, 2011; Heintzelman and Tuttle, 2012; Hinman, 2010; and Hoen et al., 2011) analyzed a *combined total* of 23,977 transactions, whereas the present study analyzes more than five times that number.

5 Existing studies analyzed the impact of wind turbines on homes with a median price of less than \$200,000, whereas the current study examines houses with a median price of \$265,000 for the 122,198 observations located within 5 miles of a wind turbine (with values ranging from \$40,200 to \$2,495,000).

6 In statistics, the coefficient of determination, denoted R^2 (pronounced "R squared"), indicates how well data points fit a line, curve or, in our case, a regression estimation. An R^2 of 1 indicates that the regression line perfectly fits the data.

7 Statistical significance allows one to gauge how likely sample data are to exhibit a definitive pattern rather than, instead, have occurred by chance alone. Significance is denoted by a *p*-value (or "probability" value) which can range between 0 and 1. A very low *p*-value, for example <0.001, is considered highly unlikely (in this case with a probability of less than 0.1%) to have occurred by chance. In general, an appropriate *p*-value is chosen by the researchers consistent with the area of research being conducted, under which results are considered "significant" and over which are considered "non-significant". For the purposes of this research, a *p*-value of 0.10 or below is considered "statistically significant", with *p*-values between 0.10 and 0.05 being "weakly statistically significant", between 0.05 and 0.01 being "significant", and below 0.01 being "highly statistically significant".

What Is a Hedonic Pricing Model?

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

market inflation/deflation). This difference is not statistically significant. Post-announcement, pre-construction home prices within a half mile are 2.3% lower than their pre-announcement levels (after controlling for inflation/deflation), which is also a non-significant difference, though one of the robustness models suggests weak evidence that wind-facility announcement reduced home prices. An additional tangential, yet important, result of the analysis is the finding of a statistically significant "pre-existing price differential": prices of homes that sold more than 2 years before a future nearby wind facility was announced were 5.1% lower than the prices of comparable homes farther away from the future wind location. This indicates that wind facilities in Massachusetts are associated with areas where land values are lower than the surrounding areas, and, importantly, this "pre-existing price differential" needs to be accounted for in order to correctly measure the "post construction" impact of the turbines. Finally, our analysis finds no evidence of a lower rate (i.e., frequency) of home sales near the turbines.

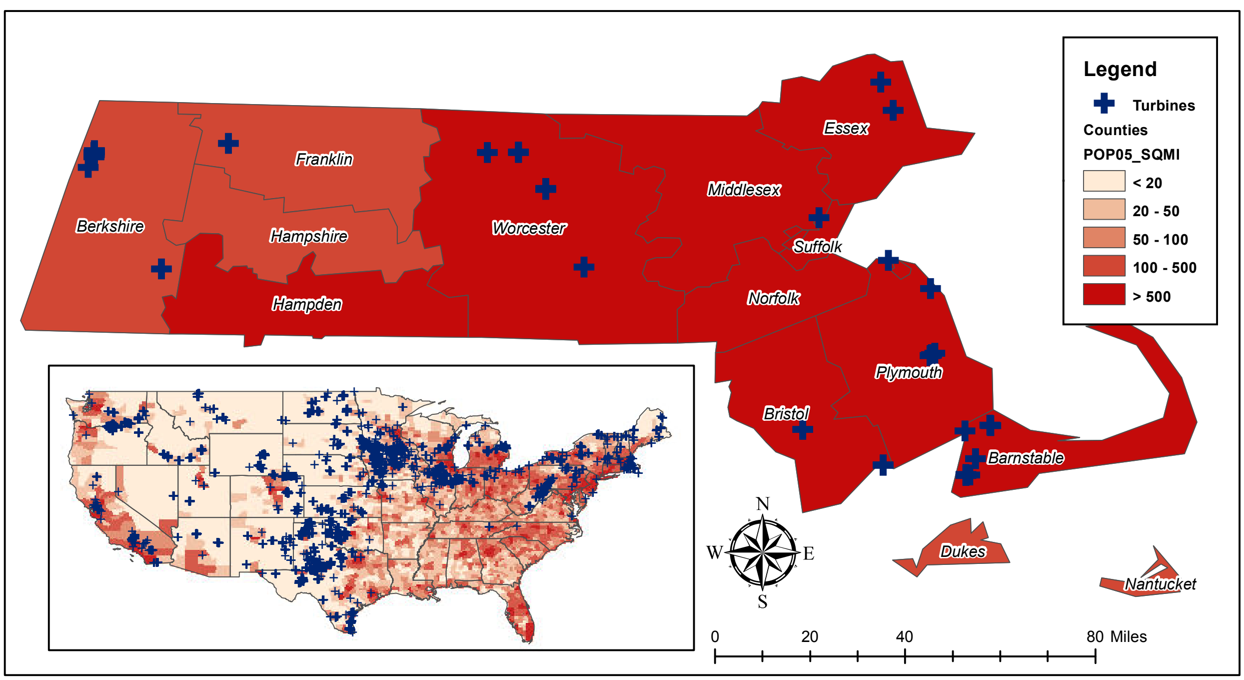
As discussed in the literature review, the effects of wind turbines may be somewhat context specific. Nevertheless, the stability of the results across models and across subsets of the data, and the fact that they agree with the results of existing literature, suggests that the results may be generalizable to other U.S. communities, especially where wind facilities are located in more urban settings with relatively high-priced homes. These results should inform the debate on actual impacts to communities surrounding turbines. Additional research would augment the results of this study and previous studies, and our report concludes with recommendations for future work.

1. INTRODUCTION

Growing concern about global climate change and energy security are prompting reconsideration of how energy—particularly electricity—is generated, transmitted, and consumed in the United States and across the globe (Ekins, 2004; Devine-Wright, 2008; Pasqualetti, 2011). Internationally, greater use of renewable wind energy to mitigate the threat of climate change has broad-based support, primarily because, once facilities are constructed, wind power emits no greenhouse gases (Hasselmann et al., 2003; Watson, 2003; Jager-Waldau and Ossenbrink, 2004). Many jurisdictions have set ambitious renewable energy goals, targeting 20% to 33% of their electricity to be generated by renewable sources by 2020 (see for example, the European Union target of 20% EU, 2012 and California's updated RPS goal of 33%). Wind energy offers several advantages over other low-emission alternatives such as nuclear power and large-scale hydropower projects, but the siting of wind projects remains controversial in many countries (Firestone and Kempton, 2007; Moragues-Faus and Ortiz-Miranda, 2010; Nadai and van der Horst, 2010; Wolsink, 2010).

Figure 3: Map of Massachusetts Turbines included in study (through November 2012) and U.S. Wind Turbines through 2011 and population densities

Population Density in US and Massachusettes (2005 pop per sq. mile)



Source: Lawrence Berkeley National Laboratory, FAA, Ventyx, US Census Bureau, MassCEC

In the United States, large-scale wind installations have tended to be built in sparsely populated locations in the Plains and West (Figure 3). Given that many existing turbines have been located in fairly rural areas, opposition to wind power has largely been attributed to concerns about the transformation of natural landscapes into "landscapes of power" (Pasqualetti et al., 2002 p. 3). Some have extended this place-based perspective and framed the wind-energy debate as being a new kind of environmental controversy, which divides environmentalists of different persuasions who attach contrasting priority to global and local concerns (see for example Warren et al., 2005). Others have delved more deeply into the discourse surrounding renewable energy projects in general, and wind-energy projects specifically, and pointed out that, depending on the narrative, they can be portrayed as representing either development or conservation, localization or globalization (van der Horst and Vermeylen, 2011).

Regardless of what is driving community attitudes towards wind power, government at all spatial scales needs to navigate the complex political terrain of introducing public policies that reduce carbon emissions and fossil fuel dependency in ways that simultaneously protect private property rights and meet with the community's approval (Jepson et al., 2012; Slattery et al., 2012). As such, one of the roles of government is to support independent research to characterize and communicate the potential impacts that public policy decisions, for example for wind facilities, may have on the price of surrounding private property. Existing studies of the effect that wind turbines have had on the price of residential properties have tended to focus on large-scale wind farms located in rural settings, because this is where the majority of projects have been developed. To date, no large-scale studies have focused on smaller-scale facilities in more urban settings, but Massachusetts affords such an opportunity. Massachusetts also has relatively high-priced homes near turbines compared to homes near turbines in other, less urban parts of the country.

Massachusetts has regions with substantial wind resources and strong policies that support the adoption of clean energy. Its first utility-scale (600 kW and larger) wind turbine was installed in Hull in 2001. Since then, wind generation capacity has increased substantially. As of January 2013, Massachusetts had 42 wind projects larger than 100 kW, consisting of 78 individual turbines totaling 99 MW of capacity. This compares to less than 3 MW in Rhode Island and Connecticut combined (Wiser and Bolinger, 2012). Turbines have been located in a variety of settings across the state, including the mountainous Berkshire East Ski Resort, heavily urbanized Charlestown, and picturesque Cape Cod. The average gross population density surrounding the Massachusetts turbines (approximately 416 persons per square mile, based on 2005 population levels and turbines as of 2012) far exceeds the national average of approximately 11 persons per square mile around turbines (Hoen, 2012).

In this study, we analyze the effect of Massachusetts' wind turbines larger than 600 kilowatts (kW) of rated capacity on nearby home prices to inform the debate about the siting and operation of smaller-scale, wind projects across a broad range of land use types in high-home-value areas of the United States. Our study makes five major unique contributions:

1. It uses the largest and most comprehensive dataset ever assembled for a study linking wind facilities to nearby home prices.[8]

2. It encompasses the largest range of home sale prices ever examined.[9]

3. It examines wind facilities in areas across a range of land use and zoning types from rural to urban/industrial (with relatively high-priced homes), whereas previous analyses have focused on rural areas (with relatively low-priced homes).

4. It largely focuses on wind facilities that contain fewer than three turbines, while previous studies have focused on large-scale wind facilities.

5. Our modeling approach controls for seven environmental amenities and disamenities in the study area, allowing the effect of wind facilities to be compared directly to the effects of these other factors.

The remainder of this report is organized as follows. The next section (Section 2) reviews literature related to public opposition to and support for wind turbines, the hypothetical stigmas associated with turbines near homes, policies and guidelines which address the siting and operation of wind facilities, ways to quantify whether turbines are a disamenity, and the impact on home values of other types of environmental amenities and disamenities—followed by a discussion of gaps in the literature. Section 3 presents our empirical analysis, including descriptions of the study area, data, methods, and results. The final section (Section 4) discusses the findings, provides preliminary conclusions, and offers suggestions for future research.

8 Four of the most commonly cited previous studies (Carter, 2011; Heintzelman and Tuttle, 2012; Hinman, 2010; and Hoen et al., 2011) analyzed a *combined total* of 23,977 transactions, whereas the present study analyzes more than five times that number.

9 Existing studies analyzed the impact of wind turbines on homes with a median price of less than $200,000, whereas the current study examines houses with a median price of $265,000 for the 122,198 observations located within 5 miles of a wind turbine (with values ranging from $40,200 to $2,495,000) and a median price for the 312,674 observations located within 10 miles of a wind turbine of $287,000 (with values ranging from $41,100 to $2,499,000).

2. LITERATURE REVIEW

2.1 Public Acceptance of and Opposition to Wind Energy

Wind energy is one of the fastest growing sources of power generation in the world, and public and political support for it are generally strong (Ek, 2005; Graham et al., 2009). Despite this strong support, the construction of wind projects provokes concerns about local impacts (Toke et al., 2008; Jones and Eiser, 2009; Devine-Wright and Howes, 2010; Jones and Eiser, 2010; Moragues-Faus and Ortiz-Miranda, 2010; Wolsink, 2010; Pasqualetti, 2011). Thus, some researchers have studied the factors shaping public attitudes toward wind energy and renewable energy technologies in general (see for example Devine-Wright, 2005; Firestone and Kempton, 2007; Pedersen et al., 2007; Wolsink, 2007; Devine-Wright, 2009; Jones and Eiser, 2009; Devine-Wright and Howes, 2010; Jones and Eiser, 2010; Swofford and Slattery, 2010; Brannstrom et al., 2011; Devine-Wright, 2011). Others have downplayed the importance of local opposition to wind energy in hindering wind's expansion, pointing instead to hindrances related to institutional barriers, such as how wind energy projects are funded, and the heavy handedness of "legislate, announce, defend" approaches to siting turbines (Wolsink, 2000).

In the early stages of wind development, opposition to wind turbines was often simplistically conceptualized as NIMBY-ism, with NIMBY ("not in my backyard") referring to people opposing the local installation of technologies they otherwise support in principle (Devine-Wright, 2005; Wolsink, 2007; Devine-Wright, 2009). More recently, researchers have suggested that the factors shaping public sentiment towards renewable energy technologies are much more complex than the concept of NIMBY-ism suggests. Of note is the quantitative research aimed at understanding public attitudes towards wind farms in the Netherlands conducted by Wolsink (2007). His work, and the work of others (e.g., Devine-Wright, 2012), which is grounded in theories from social psychology, found that public attitudes towards wind projects were shaped by perceptions of risk and equity. Based on these findings, Wolsink concluded that a collaborative—rather than a "top-down"—approach to siting wind farms was the most likely to produce positive outcomes. These findings were echoed in an examination of public attitudes towards wind turbine construction in Sheffield, England, where researchers found little evidence of NIMBY-ism in respondents living close to proposed developments compared to a control group (Jones and Eiser, 2009). Rather, opposition could be attributed to uncertainty regarding the details of the facilities being constructed, which underscores the importance of continued and responsive community involvement in siting wind turbines.

Some researchers have studied whether communities are more accepting of wind turbines if the facilities are community owned (Warren and McFadyen, 2010). Comparing attitudes towards wind farms on two islands in Scotland, one community owned and one not, the researchers discovered that residents near the community owned facilities had a much more positive perception of the facilities. Locals affectionately referred to their wind turbines as "The Three

Dancing Ladies," which the researchers interpreted as indicating the positive psychological effects of community ownership. Warren and McFadyen (2010) concluded that a change of development model towards community ownership could improve public attitudes towards wind farms in Scotland.

Another strand of research has focused on community perceptions before and after wind-facility construction. Some studies showed that local people become more supportive of wind facilities after they have been constructed (Wolsink, 2007; Eltham et al., 2008; Walker et al., 2010) and that the degree of support increases with proximity to the facilities (Braunholtz and MORI, 2003; Warren et al., 2005; Slattery et al., 2012).

2.2 Hypothetical Stigmas Associated with Wind Turbines

To understand the basis of public opposition to wind facilities, researchers have hypothesized the existence of three types of stigma that might be associated with these facilities (Hoen et al., 2011). An "area stigma" would be a concern that wind-turbine construction will alter the rural sense of place; this resonates with the suggestion made by Pasqualetti et al. (2002) that people object to the creation of "landscapes of power." This is distinct from a "scenic vista stigma," the possible concern that homes might be devalued because of the view of a wind facility. Finally, a "nuisance stigma" would be associated with people located near turbines who might be affected by the turbines' noise and shadow flicker,[10] which fade quickly with distance. Our study focuses on the potential existence of a nuisance stigma by searching for turbine-related impacts on the sale of homes located a short distance away. However, if they exist, the effects of all three stigma types hypothetically could interact, and all are described briefly below.

The spatial and temporal combinations of community and wind-facility characteristics that might produce one or more of these stigmas are not entirely clear. Theoretically, an area stigma would have the largest geographic impact, although its exact reach would depend on the spatial distribution and types of land use in the surrounding area. In their comprehensive analysis, Hoen et al. (2009, 2011) were unable to uncover area stigma effects across their large set of U.S. wind facilities. Recent research has suggested, however, that this type of stigma depends on the "place identity" of local residents (Pedersen et al., 2007; Devine-Wright, 2009; Devine-Wright and Howes, 2010). For those who view the countryside as a place for economic activity and technological development or experimentation, which is potentially consistent with the locations studied in Hoen et al. (2009, 2011), wind turbines might not carry a stigma because they could represent a new use for the land, and the turbine sounds and sights might be insignificant in the context of existing machinery and land practices. Conversely, rural residents who view the countryside as a place for peace and restoration might oppose turbines even if they do not live near them. The "place identity" of the landscape likely varies among wind facility- locations and among individuals in those locations, making some local residents more accepting of turbines than others.

Acceptance of turbines might also relate to their economic benefits. For example, a study in West Texas and Iowa found that community members had positive impressions of large-scale wind facilities built to generate long-term social and economic benefits, including creation of a local industry that

10 Shadow flicker occurs when the sun is behind rotating turbine blades and produces an intermittent shadow.

brought jobs and increased property values as well as increased tax revenue that benefited the community and schools (Slattery et al., 2012; Kahn, 2013). These findings conform to other research suggesting that equitable distribution of economic benefits is a key method of increasing local support for turbines (Pasqualetti et al., 2002) and that the perception of how tax benefits will be shared locally can influence people's acceptance of wind projects (Toke, 2005; Brannstrom et al., 2011). Economic factors appear to be more of a consideration where the economy is perceived to be in decline (Toke et al., 2008); this finding is echoed in studies of other environmental disamenities that show that communities are more willing to accept facilities if jobs are associated with them (Braden et al., 2011). Many of these studies were conducted in rural areas, thus their findings may not be generalizable to more urban settings, where community reactions might be entirely different.

Similarly, if a scenic vista stigma exists, it might have different levels of impact depending on wind-facility locations, the place identity of nearby residents, and the distance of residents from the turbines. Hoen et al. (2009, 2011) meticulously examined effects from views of turbines at many different spatial scales and predicted levels of impacts in rural areas, but they found no evidence of impacts to support the scenic vista stigma claim. However, an urban setting might connote different landscape values and therefore generate different reactions to turbines and produce different effects on home values. For example, Sims et al. (2008) found weak evidence that a house's orientation to a wind facility (and therefore the prominence of the view of the turbines) affected its sales price in Cornwall, United Kingdom, an area of relatively high population.[11]

11 As of 2011, Cornwall had a population density of 390 persons per square mile. (See http://en.wikipedia.org/wiki/Cornwall)

More than the other stigma types, any potential wind-related nuisance stigma would depend on the close proximity of residents to turbines and likely would have the most constrained spatial scale. Two studies in Germany evaluated more than 200 participants living near wind turbines with regard to shadow flicker exposure, stress, behaviors, and coping and found that stress levels and annoyance increased the closer people were to wind turbines in all directions (Pohl et al., 1999, 2000). Similarly, wind turbine noise, which is less direction dependent than shadow flicker, might have an even greater impact on stress levels. Studies have shown that residents experience genuine annoyance and stress responses to "normal" turbine noise levels (Pedersen and Waye, 2007), perceiving the noise as an intrusion into their space and privacy, especially at night (van den Berg, 2004; Pedersen et al., 2007) and when the turbines can be seen (Pedersen and Waye, 2007). Governments around the world have addressed potential turbine-related nuisances via regulations and guidelines, which are discussed in the next subsection.

2.3 Policies and Guidelines Which Address the Siting and Operation of Wind Facilities

Noise is the most prominent potential nuisance associated with wind turbines and thus has been the focus of much regulatory effort. The quality and magnitude of sound produced by turbines results from the complex interaction of numerous variables, such as the size and design of the turbine as well as the wind speed and direction, temperature gradients that affect wind turbulence, and vertical and directional wind shear (Hubbard and Shepherd, 1991; Berglund et al., 1996; Oerlemans et al., 2006; Pedersen et al., 2010; Bolin et al., 2012; Wharton and Lundquist, 2012). For practical purposes, governments, both here in the U.S. and abroad, at a variety of spatial scales have tended to adopt setback metrics for the distance between a wind turbine and housing as a proxy for noise limits (NARUC, 2012). Very few countries have mandatory turbine setback distances beyond what would be required for safety in the event of a collapse (and therefore 1-1.5 times the turbines' height), nor do they often impose mandatory limits to shadow flicker; they do often have mandatory or, at least, stronger regulation of noise.

Although there is no worldwide standard limit for noise associated with wind turbines (Haugen, 2011), many European countries base their regulations on recommended noise limits published by the World Health Organization (WHO) Regional Office for Europe (WHO, 2011). The WHO recommends noise limits of 40 (A-weighted) decibels dB(A) for the average nighttime noise outside a dwelling, which translates to a noise limit of 30 dB(A) inside a bedroom.[12] These limits are based on noise levels that do not harm a person's sleep. Above these limits, it is believed, people have a lower amount and quality of sleep, which can lead to major health issues (WHO, 2011).

In the United States, turbine sound and setback regulation is limited: only "a handful of states have published setback standards, sound standards, or both" (NARUC, 2012, p. 15). Ten states have published voluntary guidelines for wind siting and zoning, and five have published model ordinances intended to guide local governments. Similar to other countries, required or recommended setbacks vary widely from state to state, both in terms of the distances cited and the legal weight they carry (some are formal limits while others are merely guidelines).

In Massachusetts, the Model Wind Bylaw and the Massachusetts Department of Environmental Protection (MADEP) Noise Policy provide guidelines and regulatory standards respectively for the siting and operation of wind facilities to address public safety and minimize local impacts. The former provides some guidance on setbacks from the nearest existing residential or commercial structure using a multiple (e.g., 3 times) of blade tip height (BTH) (i.e., the hub height plus the length of the blade) as a means to determine the project specific setback.[13] However, all of the wind turbines in the state have been permitted at the local level, with varying degrees of adherence to the guidance, while still others were permitted prior to the Model Bylaw's preparation, and still others have had few structures near the turbines from which to setback. Therefore, in practice, setbacks to the nearest structure have varied from as much as 4,679 feet (0.89 miles, 24.4 x BTH) to as little as 520 feet (0.1 miles, 1.3 x BTH), with an average Massachusetts project being 1,925 feet (0.36 miles, 5.9 x BTH) (Studds, 2013).[14] Because, in part, of the variety of ways in which the guidelines have been applied, setbacks remain one of the more controversial aspects of wind-facility siting. Also, adding to the controversy are the results of one recent study of two wind facilities in Maine that claimed noise effects are experienced as far as 1.4 kilometers (4,590 feet, 0.87 miles) from the turbines (Nissenbaum et al., 2012).

12 A-weighted decibels abbreviated to dBa, dBA or dB(a), are an expression of the relative loudness of sounds in air as perceived by the human ear. In the A-weighted system, the decibel values of sounds at low frequencies are reduced, compared with unweighted decibels, in which no correction is made for audio frequency (http://whatis.techtarget.com)

13 MA EEA/DOER Model Wind Bylaw. Accessed on 1/23/12 from: http://www.mass.gov/eea/docs/doer/gca/wind-not-by-right-bylaw-june13-2011.pdf. The Executive Office of Environmental Affairs, Department of Environmental Quality Engineering, Division of Air Quality Control, "DAQC Policy 90-001," February 1, 1990.

14 These setbacks do not include structures of participating landowners, that either might own the turbine, or are being compensated by the turbine owner.

Finally, in response to noise concerns, wind-technology developers are investigating numerous ways to suppress noise including passive noise reduction blade designs, active aerodynamic load control, new research on inflow turbulent and turbine wakes, low-noise brake linings, and cooling fan noise mufflers (Leloudas et al., 2009; Wilson et al., 2009; Barone, 2011; Petitjean et al., 2011), some of which have been shown to lower annoyance when applied (Hoen et al., 2010; Hessler, 2011). How these strategies might eventually affect setback and noise regulations and guidelines is unclear.

For the purposes of this study, suffice it to say that wind turbine setbacks vary, and they are often smaller than the distances at which (at least some) turbine noise effects have been claimed to exist. If a resulting nuisance stigma exists near turbines, it should be reflected in nearby home prices. By evaluating the relationship between wind turbines and home prices this study might help inform appropriate setbacks and noise recommendations in Massachusetts.

2.4 Methods to Quantify Whether Wind Turbines are a Disamenity

If a wind turbine near homes does produce a meaningful stigma, it could be considered a disamenity similar to other disamenities such as proximity to electricity transmission lines and major roads. A variety of research techniques can be used to determine the impact of wind energy projects on residential properties, including homeowner surveys, expert surveys (such as interviewing real estate appraisers), and statistical analysis of property transactions using cases studies or the well-established method of hedonic modeling (see e.g., Jackson, 2003). The latter technique is firmly established in the literature as the most reliable approach to determining the impact of a particular development on property prices, because it (a) uses transactions data that reflect actual sales in the housing market rather than perceptions of potential impacts; (b) controls for a set of potentially confounding home, site, neighborhood and market influences; and, (c) is flexible enough to allow a variety of potentially competing aspects of wind development and proximity to be tested simultaneously (Jackson, 2001).

An extensive meta-analysis of studies that had quantified the effect of environmental amenities and disamenities found that the use of case study techniques provide larger estimates of property losses associated with environmental disamenities than regression studies using hedonic models (Simons and Saginor, 2006). Simons and Saginor attributed this differential to the fact that case studies may be subjective based on the case researcher, and they argue that case study observations may even have been chosen because of their dramatic, atypical conditions. Surveys, which were generally based on respondents' estimates of impacts, were considered to suffer from similar bias due to the subjectivity of respondents and their potential lack of effect-estimation expertise.

The hedonic-modeling approach is based on the idea that any property's sales price is composed of a bundle of attributes, including the characteristics of the individual property and its location (Rosen, 1974). Sales can be compared to one another, taking into account the effects of time (i.e., inflation/deflation), to determine the value of any specific attribute (Butler, 1982; Clapp and Giaccotto, 1998; Jackson, 2001; Simons and Saginor, 2006; Jauregui and Hite, 2010; Kuminoff et al., 2010; Zabel and Guignet, 2012).

The approach has been used extensively to quantify the effects of public policies (specifically infrastructure) on home prices by examining the value associated with being close to a facility before and after it was constructed (see Atkinson-Palombo, 2010 and the extensive references therein). If the particular initiative being studied (for example, a transportation facility) is perceived as an amenity, it would be expected to increase property values, all else being equal. If the initiative is perceived as a disamenity, it would be expected to decrease property values. This hedonic method measures average impacts across the study area and therefore can help policy makers understand costs and benefits at a broad scale.

Our study uses the hedonic-modeling approach to quantify the effect of wind facilities on home values. This involves creating a statistical model with an expression of home price as the dependent variable and independent variables consisting of factors that influence home price. These independent variables include features of the specific housing unit, locational characteristics, a variable that represents distance to a wind turbine at discrete stages of the construction process, and various controls such as the time when a transaction took place to account for changes in the housing market over time (inflation and deflation). If a wind turbine creates a disamenity, then house prices closer to the turbine would be expected to decline (all else being equal) compared to their values before the turbine was installed and compared to the prices of houses farther away that sold during the same period.

The peer-reviewed, published studies that used hedonic modeling largely agree in finding non-significant post-construction effects (i.e., non-significant effects on home prices occurring after construction of wind turbines) (Sims et al., 2008; Hoen et al., 2011; Heintzelman and Tuttle, 2012), implying that average impacts in their study areas were either relatively small or sporadic near existing turbines. Three academic studies found similar results (Hoen, 2006; Hinman, 2010; Carter, 2011). The geographic extent of these studies varied from single counties (Hoen, 2006; Hinman, 2010; Carter, 2011), to three counties in New York (Heintzelman and Tuttle, 2012), to eight states (Hoen et al., 2011), showing that results have been robust to geographic scale. Although the academic and peer-reviewed literature has largely focused on post-construction impacts, some studies have found evidence of pre-construction yet post-announcement impacts (Hinman, 2010; Hoen et al., 2011; Heintzelman and Tuttle, 2012). This "anticipation effect" (Hinman, 2010) correlates with surveys of residents living near wind facilities that have found that once wind turbines are constructed, residents are more supportive of the facilities than they were when the construction of that facility was announced (Wolsink, 2007; Sims et al., 2008). Analysis of home prices related to other disamenities (e.g., incinerators) also has shown anticipation effects and post-construction rebounds in prices (Kiel and McClain, 1995).

2.5 General Literature on the Effects of Amenities and Disamenities on House Prices

While wind turbines are typically limited to high-wind-resource areas, disamenities such as highways, overhead electricity transmission lines, power plants, and landfills are ubiquitous in urban and semi-rural areas, and they have been the focus of many studies. This more established "disamenity literature" (see for example, Boyle and Kiel, 2001; Jackson, 2001; Simons and Saginor, 2006) helps frame the expected level of impact around turbines. For example, adverse home-price effects near electricity transmission lines, a largely visual disturbance, have ranged from 5% to 20%, fading quickly with distance and disappearing beyond 200 to 500 feet, and even in some cases, when afforded with access to the transmission line corridor, home-price effects have found to be positive signaling net benefits over costs of transmission line proximity (e.g., Des Rosiers, 2002). Landfills, which present smell and truck-activity nuisances and potential health risks from groundwater contamination, have been found to decrease adjacent property values by 13.7% on average, fading by 5.9% for each mile a home is further away for large-volume operations (that accept more than 500 tons per day). Lower-volume operations decreased adjacent property values by 2.7% on average, fading by 1.3% per mile, with 20% to 26% of the lower-volume landfills not significantly impacting values at all (Ready, 2010). Finally, a review of literature investigating impacts of road noise on house prices, which might be analogous to noise from turbines, found price decreases of 0.4% to 4% for houses adjacent to a busy road compared to those on a quiet street (see for example Bateman et al., 2001; Day et al., 2007; Kim et al., 2007; Andersson et al., 2010).

Community amenities also have been well studied. Open space (i.e., publicly accessible areas that are available for recreational purposes) has been found to increase surrounding prices (Irwin, 2002; Anderson and West, 2006a); Anderson and West estimated those premiums to be 0.1% to 5%, with an average of 2.6% for every mile that a home is closer to the open space. Proximity to (and access to and views of) water, especially oceans, has been found to increase values (e.g., Benson et al., 2000; Bond et al., 2002); for example, being on the waterfront increased values by almost 90% (Bond et al., 2002).

Although much of the literature on community perceptions of wind turbines suggests that local residents may see turbines as a disamenity, this is not always the case. As discussed above, perceptions about wind turbines are shaped by numerous factors that include the size of the turbine(s) or project, the sense of place of the local residents, the manner in which the planning process is conducted, and the ownership structure. In contrast to disamenities universally disliked by local residents (as discussed above), some literature suggests that wind turbines could be considered amenities (i.e., a positive addition to the community), particularly if benefits accrue to the local community. Thus, whether wind turbines increase or decrease surrounding home prices—and by how much—remains an open question.

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

Additionally, there is evidence that wind facilities are sited in areas where property prices are lower than in surrounding areas—what we are referring to as a "pre-existing price differential". For example, Hoen et al. (2009) found significantly lower prices (-13%) for homes that sold more than 2 years prior to the wind facilities' announcements and were located within 1 mile of where the turbines were eventually located, as compared to homes that sold in the same period and were located outside of 1 mile. Hinman (2010) found a similar phenomenon that she labeled as a "location effect." To that end, Sims and Dent (2007), after their examination of three locations in Cornwall, United Kingdom, commented that the research "highlighted to some extent, wind farm developers are themselves avoiding the problem by locating their developments in places where the impact on prices is minimized, carefully choosing their sites to avoid any negative impact on the locality" (p. 5). Thus, further investigation of whether wind facilities are associated with areas with lower home values than surrounding areas would be worthwhile. It is important to emphasize that any "pre-existing price differential" does not exist because of the turbines, but instead is likely the result of the fact that wind turbines may be located in areas of relative disamenity. For example, in Massachusetts, wind turbines have typically been co-located with industrial facilities such as waste water treatment plants. While we included seven different amenities and disamenities in our model, we could not include all of them because of a lack of accurate data, especially for waste water treatment plants and industrial sites that may have been co-located with wind turbines. Some of the "pre-existing price differential" may therefore be attributable to other disamenities that have not been included in the model. Regardless of the reason, any "pre-existing price differential" needs to be taken into account in order to accurately calculate the net impacts that wind turbines may have on property prices.

Finally, there have been claims that the home sales rate (i.e., sales volume) near existing wind turbines is far lower than the rate in the same location before the turbines' construction and the rate farther away from the turbines, because homeowners near turbines cannot find buyers (see sales volume discussion in Hoen et al., 2009). Obviously, many homes near turbines have sold, as recorded in the literature. If it were true that homeowners near turbines have *chosen* to sell less often because of very low buyer bids, then sales that did take place near turbines should be similarly discounted on average, but evidence of large discounts has not emerged from the academic literature (as discussed above). Moreover, homes farther away from turbines would be taken off the market for similar reasons (sellers do not get offers they accept), thus the comparison group is potentially affected in a similar way. In any case, although Hoen et al. (2009) found no evidence of lower sales volumes near turbines, further investigations of this possible phenomenon using different datasets are warranted.

2.6 Gaps in the Literature

This literature review suggests several knowledge gaps that could be studied further: exploring wind turbine impacts on home prices in urban settings, where the "sense of place" might be different than in the previously studied rural areas; examining post-announcement/pre-construction impacts; testing for relatively small impacts using large datasets; determining whether wind facilities are sited in areas with lower home values; examining turbine impacts in concert with impacts from other disamenities and amenities; and investigating whether home sales volumes are different near existing wind turbines. Our study seeks to address each of these areas.

3. EMPIRICAL STUDY

Because of Massachusetts' density of urban homes near enough to wind turbines to produce potential nuisance effects, our study analyzes Massachusetts data to address gaps in knowledge about turbine effects on home prices. Specifically, the study seeks to answer the following five questions:

Q1) Have wind facilities in Massachusetts been located in areas where average home prices were lower than prices in surrounding areas (i.e., a "pre-existing price differential")?

Q2) Are post-construction (i.e., after wind-facility construction) home price impacts evident in Massachusetts, and how do Massachusetts results contrast with previous results estimated for more rural settings?

Q3) Is there evidence of a post-announcement/ pre-construction effect (i.e., an "anticipation effect")?

Q4) How do impacts near turbines compare to the impacts of amenities and disamenities also located in the study area, and how do they compare with previous findings?

Q5) Is there evidence that houses near turbines that sold during the post-announcement and post-construction periods did so at lower rates (i.e., frequencies) than during the pre-announcement period?

The following subsections detail the study's hedonic-modeling process and base model, the extensive robustness tests used to determine the sensitivity of the base model, the study data, and the results.

3.1 Hedonic Base Model Specification

The price of a home can be expressed as follows:

$$P = f(L, N, A, E, T)$$

where L refers to lot-specific characteristics, N to neighborhood variables, A to amenity/disamenity variables, E to wind-turbine variables, and T to time-dependent variables.

Following from this basic formula, we estimate the following customarily used (see, e.g., Sirmans et al., 2005) semi-log base model to which the set of robustness models are compared.

$$\ln(P) = \beta_0 + \sum \beta_1 L{\bullet}D + \beta_2 N + \sum \beta_3 A{\bullet}D + \sum \beta_4 E{\bullet}D + \sum \beta_5 T + \varepsilon'$$

An explanation of this formula is as follows:

The dependent variable is the log of sales price (P).

L is the vector of lot-specific characteristics of the property, including living area (in thousands of square feet); lot size (in acres); lot size less than 1 acre (in acres if the lot size is less than 1, otherwise 1); effective age (sale year minus either the year built or, if available, the most recent renovation date); effective age squared; and number of bathrooms (the number of full bathrooms plus the number of half bathrooms multiplied by 0.5).

D is the nearest wind turbine's development period in which the sale occurred (e.g., if the sale occurred more than 2 years before the nearest turbine's development was announced, less than 2 years before announcement, after announcement but before construction, or after construction).

N is the U.S. census tract in which the sale occurred.

A is the vector of amenity/disamenity variables for the home, including the amenities: if the home is within a half mile from open space; is within 500 feet or is within a half mile but outside 500 feet of a beach; and, disamenities: is within a half mile of a landfill, and/or prison; and is within 500 feet of an electricity transmission line, highway and/or major road.[15]

T is the vector of time variables, including the year in which the sale occurred and the quarter in which the sale occurred.

E is a binary variable representing if the home is within a half mile from a turbine, and

ε is the error term.[16]

β_0, β_1, β_2, β_3, β_4, β_5 are coefficients for the variables.

The vectors of lot-specific and amenity/disamenity variables are interacted with the development period for three reasons: 1) to allow the covariates to vary over the study period, which will, for example, allow the relationship of living area and sale price to be different earlier in the study period, such as more than 2 years before announcement, than it is later in the study period, such as after construction of the nearest turbine;[17] 2) to ensure that the variables of interest do not absorb any of this variation and therefore bias the coefficients; and 3) to allow the examination of the amenity/disamenity variables for subsets of the data.[18]

The distance-to-the-nearest-turbine variable specified in the base model is binary: one if the home is within a half mile of a turbine and zero if not. The distance can be thought of as the distance, today, when all the turbines in the state have been built. Obviously, for some homes, such as those that sold before the wind facility was announced, there was no turbine nearby at the time of sale, so in those cases the distance variable represents the distance to where the turbine eventually was built. By interacting this distance variable with the turbine development period, we are able to examine how the distance effects might change over the periods and whether or not there was a pre-existing price differential between homes located near turbines and

15 Each of the amenity/disamenity variables are expressed as a binary variable: 1 if "yes," 0 if "no."

16 The error term (i.e., "unexplained variation" or "residual value") defines the portion of the change in the dependent variable (in this case the log of sale price) that cannot be explained by the differences in the combined set of independent variables (in this case the size and age of the home, the number of bathrooms, etc.). For example, a large portion of one's weight can be explained by one's gender, age and height, but differences (i.e., unexplained variation) in a sample of people's weight will still exist for random reasons. Regardless of how well a model performs, some portion of unexplained variation is expected.

17 As discussed in greater detail in the results, the coefficients for the variables of interest are quite small in magnitude, and therefore even a relatively small change in the size of the coefficients can be problematic to the correct interpretation of the results. Moreover, the lot-specific and amenity/disamenity variables vary over the development periods, further reinforcing the need to interact them with period. The results for the wind turbine variables presented herein are robust to alternative specifications without these interactions.

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

those farther away that existed even before the turbines were announced.

Further, we used a binary variable as opposed to other forms used to capture distance. For example, other researchers investigating wind turbine effects have commonly used continuous variables to measure distance such as linear distance (Sims et al., 2008; Hoen et al., 2009), inverse distance (Heintzelman and Tuttle, 2012; Sunak and Madlener, 2013), or mutually exclusive non-continuous distance variables (Hoen et al., 2009; Hinman, 2010; Carter, 2011; Hoen et al., 2011; Heintzelman and Tuttle, 2012; Sunak and Madlener, 2013). We preferred the binary variable because we believe the other forms have limitations. Using the linear or inverse continuous forms necessarily forces the model to estimate effects at the mean distance. In some of these cases those means can be quite far from the area of expected impact. For example, Heintzelman and Tuttle (2012) estimated an inverse distance effect using a mean distance of over 10 miles from the turbines, while Sunak and Madlener (2013) used a mean distance of approximately 1.9 miles. Using this approach makes the model less able to quantify the effect near the turbines, where they are likely to be stronger. More importantly, this method encourages researchers to extrapolate their findings to the ends of the distance curve, near the turbines, despite having few data in this distance band. This was the case for Heintzelman and Tuttle (2010), who had less than 10 sales within a half mile in the two counties where effects were found and only a handful of sales in those counties after the turbines were built. Yet they extrapolated their findings to a quarter mile and even a tenth of a mile, where they had very few, if any, cases. Similarly, Sunak and Madlener (2013) had only six (post-construction) sales within a half mile, yet they extrapolated their findings to this distance band.

One method to avoid using a single continuous function to describe effects at all distances is to use a spline model, which breaks the distances into continuous groups (Hoen et al., 2011), but this still imposes some structure on the data that might not actually exist. By far the most transparent method is to use binary variables for discrete distances that therefore impose only slight structure on the data (Hoen et al., 2009; Hinman, 2010; Hoen et al., 2011). Although this method has been used in existing studies, because of a paucity of data, margins of error for the estimates were large (e.g., 7% to 10% for Hoen et al. 2011). However, as discussed above, the extensive dataset for Massachusetts allows this approach to be taken while maintaining relatively small margins of error. Moreover, although others have estimated effects for multiple distance bins out to 5 or 10 miles, we have focused our estimates on the group of homes that are within a half mile of a turbine—although other groups, such as those within a quarter of a mile and between one half and one mile, are explored in the robustness models. The homes within a half mile of turbines are most likely to be impacted and are, therefore, the first and best place to look for impacts. Further, we use the entire group of homes outside of a half mile as the reference category, which gives us a large heterogeneous comparison group and therefore one that is likely *not* correlated with omitted variables—although we also explore other comparison groups in the robustness tests.

3.2 Robustness Tests

Models are built on assumptions and therefore practitioners often test those assumptions by trying multiple model forms. As was the case for this research, a "base" model is compared to a set of "robustness" models, each with slightly different assumptions, to explore the robustness of the study's findings.

The suite of robustness tests explored changes in: 1) the spatial extent at which both the effect and the comparable data are specified; 2) the variables used to describe fixed effects; 3) the screens that are used to select the final dataset as well as outliers and influencers; 4) the inclusion of spatially and temporally lagged variables to account for the presence of spatial autocorrelation; and 5) the inclusion of additional explanatory variables that are not populated across the whole dataset. Each will be described below.

3.2.1 Varying the Distance to Turbine

The base model tests for effects on homes sold within a half mile of a turbine (and compares the sales to homes located outside of a half mile and inside 5 miles of a turbine). Conceivably, effects are stronger the nearer homes are to turbines and weaker the further they are away—because that roughly corresponds to the nuisance effects (e.g., noise and shadow flicker) that we are measuring—but the base model does not explore this. Therefore, this set of robustness models investigates effects within a quarter mile as well as between a half and 1 mile. It is assumed that effects will be larger within a quarter mile and smaller outside of a half mile.

Additionally, the basis of comparison could be modulated as well. The base model compares homes within a half mile to those outside of a half mile and inside of 5 miles, most of which are between 3 and 5 miles. Conceivably, homes immediately outside of a half mile are also affected by the presence of the turbines, which might bias down the comparison group and therefore bias down the differences between it and the target group inside of a half mile. Therefore, two additional comparison groups are explored: 1) those outside of a half mile and inside of 10 miles, and 2) those outside of 5 miles and inside of 10 miles. It is assumed that effects from turbines are not experienced outside of 5 miles from the nearest turbine.

3.2.2 Fixed Effects

A large variety of neighborhood factors might influence a home price (e.g., the quality of the schools, the crime rate, access to transportation corridors, local tax rates), many of which cannot be adequately measured and controlled for in the model specifically. Thus, practitioners use a "fixed effect" to adjust prices based on the neighborhood, which accounts for all the differences between neighborhoods simultaneously. Examples of these fixed effects, moving from larger and less precise geographic areas to smaller and more precise areas are: zip code; census tract; and, census block group.

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

3.2.3 Screens, Outliers, and Influencers

As described below, to ensure that the data used for the analysis are representative of the sample in Massachusetts and do not contain exceptionally high- or low-priced homes or homes with incorrect characteristics, a number of screens are applied for the analysis dataset. To explore what effect these screens have on the results, they are relaxed for this set of robustness tests. Additionally, a selection of outliers (based on the 1 and 99 percentile of sale price) and influencers (based on a Cook's Distance of greater than 1[19]) might bias the results, and therefore a model is estimated with them removed.

3.2.4 Spatially and Temporally Lagged Nearest-Neighbor Data

The value of a given house is likely impacted by the characteristics of neighboring houses (i.e., local spatial spillovers, defined empirically as W_x) or the neighborhood itself. For example, a house in a neighborhood with larger parcels (e.g., 5 acres lots), might be priced higher than an otherwise identical home in a neighborhood with smaller parcels (e.g., 1 acre lots).

If statistical models do not adequately account for these spatial spillovers, the effects are relegated to the unexplained component of the results contained in the error term, and therefore the other coefficients could be biased. If this occurs, then the error terms exhibit spatial autocorrelation (i.e., similarity on the basis of proximity). Often, in the hedonic literature, more concern is paid to unobserved (and spatially correlated) neighborhood factors in the model.[20]

A common approach for controlling for the unobserved neighborhood factors is to include neighborhood fixed effects (see for example Zabel and Guignet, 2012), which is the approach we took in the base model. To additionally control for the characteristics of neighboring houses a model can be estimated that includes spatial lags of their characteristics as covariates in the hedonic model, as is done for this robustness test. Neighboring houses are determined by a set of *k*-nearest neighbors (*k*, in this case, equals 5), though alternative methods could have been used (Anselin, 2002). Further, although dependence often focuses on spatial proximity, it is also likely that sales are "temporally correlated," with nearby houses selling in the same period (e.g., within the previous 6 months) being more correlated than nearby houses selling in earlier periods (e.g., within the previous 5 years). To account for both of these possible correlations, we include a spatially and temporally lagged set of *k*-nearest neighbor data in a robustness model.

These spatially and temporally lagged variables were created using the set of the five nearest neighbors that sold within the 6 months preceding the sale of each house. These variables contained the average living area, lot size, age, and age squared of the "neighbors."

19 According to Cook, R. D. (1977) Detection of Influential Observations in Linear Regression. Technometrics. 19(1): 15-18.

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

3.2.5 Inclusion of Additional Explanatory Variables

Although the base model includes a suite of controlling variables that encompasses a wide range of home and site characteristics, the dataset contains additional variables not fully populated across the dataset that might also help explain price differences between homes. They include the style of the home (e.g., cape, ranch, colonial) and the type of heat the home has (e.g., forced air, baseboard, and steam). Therefore, an additional robustness model is estimated that includes these variables but uses a slightly smaller dataset for which these variables are fully populated.

Combined, it is assumed that the set of robustness tests will provide additional context and possibly bound the results from the base model. We now turn to the data used for the analysis.

3.3 Data Used For Analysis

To conduct the analysis, a rich set of four types of data was obtained from a variety of sources in Massachusetts, including 1) wind turbine data, 2) single-family-home sale and characteristic data, 3) U.S. Census data, and 4) amenities and disamenities data. From these, three other sets of variables were created: distance-to-turbine data, time-of-sale period relative to announcement and construction dates of nearby turbines, and spatially and temporally lagged nearest-neighbor characteristics. Each is discussed below.

3.3.1 Wind Turbines

Using data from the Massachusetts Clean Energy Center (MassCEC), every wind turbine in Massachusetts that had been commissioned as of November 2012 with a nameplate capacity of at least 600 kW was identified and included in the analysis. This generated a dataset of 41 turbines located in a variety of settings across Massachusetts, ranging in scope from a single turbine to a maximum of 10 turbines, with blade tip heights ranging from 58.5 meters (192 feet) to 390 meters (1,280 feet), with an average of approximately 120 meters (394 feet) (Table 1 and Figure 4). Spatial data for every turbine (e.g., x and y coordinates), derived from MassCEC records and a subsequent visual review of satellite imagery, were added, and wind turbine announcement and construction dates were populated by MassCEC. Announcement date is assumed to be the first instance when news of the projects enters the public sphere via a variety of sources including a news article, the filing of a permit application, or release of a Request for Proposals. Dates were identified in consultation with project proponents, developers or using Google News searches.

3.3.2 Single-Family-Home Sales and Characteristics

A set of arm's-length, single-family-home sales data for all of Massachusetts from 1998 to November 2012 was purchased from the Warren Group.[21] Any duplicate observations, cases where key information was missing (e.g., living area, lot size, year built), or observations where the data appeared to be erroneous (e.g., houses with no bathrooms) were removed from the dataset. These data included the following variables (and are abbreviated as follows in parentheses): sale date (*sd*), sale price (*sp*), living

21 See http://www.thewarrengroup.com/. The Warren Group identified all transactions that were appropriate for analysis. As discussed later, we used additional screens to ensure that they were representative of the population of homes. Single-family homes, as opposed to multi-family or condominiums, were selected because condos and multi-family properties constitute different markets and are generally not analyzed together (Goodman and Thibodeau, 1998; Lang, 2012).

Table 1: List of Locations, Key Project Metrics and Dates of Massachusetts Turbines Analyzed

Project Name	Number of Turbines	Capacity per Turbine (kW)	Project Nameplate Capacity (MW)	Blade Tip Height (meters)	Announcement Date	Construction Date	Commission Date	Wastewater or Water Treatment	Industrial Site	Landfill	Located at a School
Berkshire East Ski Resort	1	900	0.9	87	12/16/08	7/12/10	10/31/10				
Berkshire Wind	10	1500	15	118.5	1/12/01	6/1/09	5/28/11				
Fairhaven	2	1500	3	121	5/1/04	11/1/11	5/1/12	X			
Falmouth Wastewater 1	1	1650	1.65	121	4/1/03	11/1/09	3/23/10	X			
Falmouth Wastewater 2	1	1650	1.65	121	11/1/09	4/5/10	2/14/12	X			
Holy Name Central Catholic Jr/Sr HS	1	600	0.6	73.5	9/21/06	3/21/08	10/4/08				X
Hull 1	1	660	0.66	73.5	10/1/97	11/1/01	12/27/01				X
Hull 2	1	1800	1.8	100	1/1/03	12/1/05	5/1/06			X	
Ipswich MLP	1	1600	1.6	121.5	3/1/03	10/1/10	5/15/11				
Jiminy Peak Mountain Resort	1	1500	1.5	118.5	11/1/05	6/25/07	8/3/07				
Kingston Independence	1	2000	2	123	6/1/06	9/23/11	5/11/12				
Lightolier	1	2000	2	126.5	12/14/06	11/1/11	4/20/12		X		
Mark Richey Woodworking	1	600	0.6	89	11/10/07	11/1/08	2/22/09		X		
Mass Maritime Academy	1	660	0.66	73.5	1/31/05	4/12/06	6/14/06				X
Mass Military Reservation 1	1	1500	1.5	118.5	11/8/04	8/1/09	7/30/10		X		
Mass Military Reservation 2	1	1500	1.5	121	10/1/09	10/1/10	10/28/11		X		
Mass Military Reservation 3	1	1500	1.5	121	10/1/09	10/1/10	10/28/11		X		
Mt Wachusett Community College	2	1650	3.3	121	8/18/08	1/28/11	4/27/11				X
MWRA - Charlestown	1	1500	1.5	111	1/24/10	3/25/10	10/1/11	X			
MWRA - Deer Island	2	600	1.2	58.5	6/1/08	8/1/09	11/15/10	X			
No Fossil Fuel (Kingston)	3	2000	6	125	3/1/10	11/16/11	1/25/12		X		
NOTUS Clean Energy	1	1650	1.65	121	8/31/07	4/1/10	7/28/10		X		
Princeton MLP	2	1500	3	105.5	12/18/99	9/9/09	1/12/10				
Scituate	1	1500	1.5	111	3/15/08	2/15/12	3/15/12	X			
Templeton MLP	1	1650	1.65	118.5	7/24/09	2/1/10	9/1/10				
Williams Stone	1	600	0.6	88.5	1/11/08	5/1/08	5/27/09		X		
Total: 26 projects	**41**							**6**	**8**	**1**	**4**

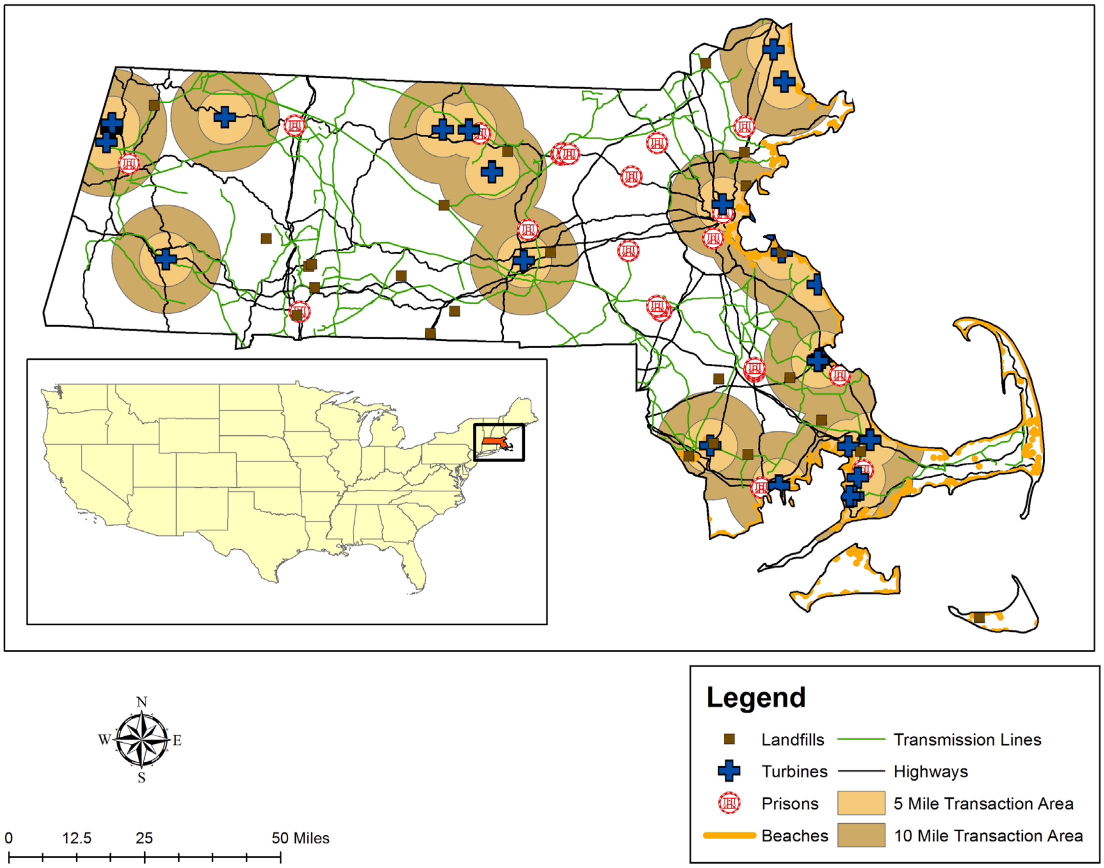
area in thousands of square feet (*sfla1000*), lot size in acres (*acres*), year the home was built (*yb*), most recent renovation year (*renoyear*), the number of full (*fullbath*) and half (*halfbath*) bathrooms, the style of the home (e.g., colonial, cape, ranch) (*style*), the heat type (e.g., forced air, baseboard, steam) (*heat*), and the x and y coordinates of the home.[22] From these, the following variables were calculated: natural log of sale price (*lsp*), sale year (*sy*), sale quarter (*sq*), age of the home at the time of sale (*age = sy – (yb or renoyear)*), age of the home at the time of sale squared (*agesqr = age × age*), lot size less than 1 acre (*acrelt1*), bathrooms (*bath = fullbath + (halfbath × 0.5)*).[23]

To ensure a relatively homogenous set of data, without outlying observations that could skew the results, the following criteria were used to screen the dataset: sale price between $40,000 and $2,500,000; less than 12 bathrooms or bedrooms; lot size less than 25 acres; and sale price per square foot between $30 and $1,250. As detailed below, these screens

22 The style is used in a robustness test.

23 Geocoding of x-y coordinates can have various levels of accuracy, including block level (a centroid of the block), street level (the midpoint of two ends of a street), address level (a point in front of the house – usually used for Google maps etc.), and house level (a point over the roof of the home). Warren provided x and y coordinates that were accurate to the street level or block level but not accurate to the house level. All homes that were within 2 miles of a turbine were corrected to the house level by Melissa Data. See: www.MelissaData.com. This was important to ensure that accurate measurements of distance to the nearest turbine were possible.

Figure 4: Locations of Massachusetts Wind Turbines Included in Study



were relaxed for a robustness test, and no significant alteration to the results was discovered.

3.3.3 Distance to Turbine

Geographic information system (GIS) software was used to calculate the distance between each house and the nearest wind turbine in the dataset (*tdis*) and to identify transactions within a 10-mile radius of a wind turbine. Transactions inside 5 miles were used for the base model, while those outside of 5 miles were retained for the robustness tests. This resulted in a total of 122,198 transactions within 5 miles of a turbine (and 312,677 within 10 miles of a turbine). Additionally, a binary variable was created if a home was within a half mile of a turbine or not (*halfmile*), which was used in the base model. As discussed above, the robustness models used additional distance variables, including if a home was within a quarter mile of a turbine (*qtrmile*) and if a home was outside a half mile but within 1 mile (*outsidehalf*).

3.3.4 Time of Sale Relative to Announcement and Construction Dates of Nearby Turbines

Using the announcement and construction dates of the turbine nearest a home and the sale date of the home, the facility development period (*fdp*) was assigned one of four values: the sale was more than 2 years before the wind facility was announced

Table 2: Distribution of Transaction Data Across Distance and Period Bins

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

(*prioranc*),[24] the sale was less than 2 years before the facility was announced (*preanc*), the sale occurred after facility announcement but prior to construction commencement (*postancprecon*), or the sale occurred after construction commenced (*postcon*). We are assuming that once construction was completed, the turbine went into operation. See Table 2 for the distribution of the 312,677 sales within 10 miles across the distance and period bins.

3.3.5 U.S. Census

Using GIS software, the U.S. Census tract and block group of each home were determined. The tract delineation was used for the base model, and the block group was used for one of the robustness tests. In both cases, the Census designations were used to control for "neighborhood" fixed effects across the sample.

3.3.6 Amenity and Disamenity Variables

Data were obtained from the Massachusetts Office of Geographic Information (MassGIS) on the location of beaches, open space,[25] electricity transmission lines, prisons, highways, and major roads.[26] As discussed above, these variables were included in the model to control for and allow comparisons to amenities and disamenities in the study areas near

24 This first period, more than two years before announcement, was used to ensure that these transactions likely occurred before the community was aware of the development. Often prior to the announcement of the project, wind developers are active in the area, potentially, arranging land leases and testing/measuring wind speeds, which can occur in the two years before an official announcement is made.

25 The protected and recreational open space data layer contains the boundaries of conservation land and outdoor recreational facilities in Massachusetts.

26 Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, Information Technology Division. (www.mass.gov/mgis).

turbines. Based on the data, variables were assigned to each home in the dataset using GIS software. If a home was within 500 feet of a beach, it was assigned the variable *beach500ft*, and if a home was outside of 500 feet but inside of a half mile from a beach it was assigned the variable *beachhalf*. Similarly, variables were assigned to homes within a half mile of a publicly accessible open space with a minimum size of 25 acres (*openhalf*), a currently operating landfill (*fillhalf*), or a prison containing at least some maximum-security inmates (*prisonhalf*). Variables were also assigned to homes within 500 feet of an electricity transmission line (*line500ft*), a highway (*hwy500ft*) or otherwise major road (*major500ft*).[27] Figure 4 shows the location of these amenities and disamenities (except open space and major roads) across Massachusetts.

3.3.7 Spatially and Temporally Lagged Nearest-Neighbor Characteristics

Using the data obtained from Warren Group for the home and site characteristics, x/y coordinates and the sale date, a set of spatially and temporally lagged nearest neighbor variables were prepared to be used in a robustness test. For each transaction the five nearest neighbors were selected that: transacted

Table 3: Summary of Characteristics of Base Model Dataset

Variable	Description	Mean	Std. Dev.	Min	Median	Max
sp	sale price	$322,948	$238,389	$40,200	$265,000	$2,495,000
lsp	log of sale price	12.49	0.60	10.6	12	14.72
sd	sale date	10/19/04	1522	3/3/98	2/6/05	11/23/12
sy	sale year	2004	4	1998	2004	2012
syq	sale year and quarter (e,g., 20042 = 2004, 2nd quarter)	20042	42	19981	20043	20124
sfla1000	square feet of living area (1000s of square feet)	1.72	0.78	0.41	1.6	9.9
acre*	number of acres	0.51	1.1	0.0054	0.23	25
acrelt1*	the number of acres less than one	-0.65	0.31	-0.99	-0.77	0
age	age of home at time of sale	54	42	-1	47	359
agesq	age of home squared	4671	4764	0	3474	68347
bath**	the number of bathrooms	1.9	0.79	0.5	1.5	10.5
wtdis	distance to nearest turbine (miles)	3.10	1.20	0.098	3.2	5
fdp	wind facility development period	1.95	1.18	1	1	4
annacre	average nearest neighbor's acres	0.51	0.93	0.015	0.25	32
annage	average nearest neighbor's age	53.71	30.00	-0.8	52	232
annagesq	average nearest neighbor's agesq	4672	4766	0	3474	68347
annsfla1000	average nearest neighbor's sfla1000	1.72	0.53	0.45	1.6	6.8

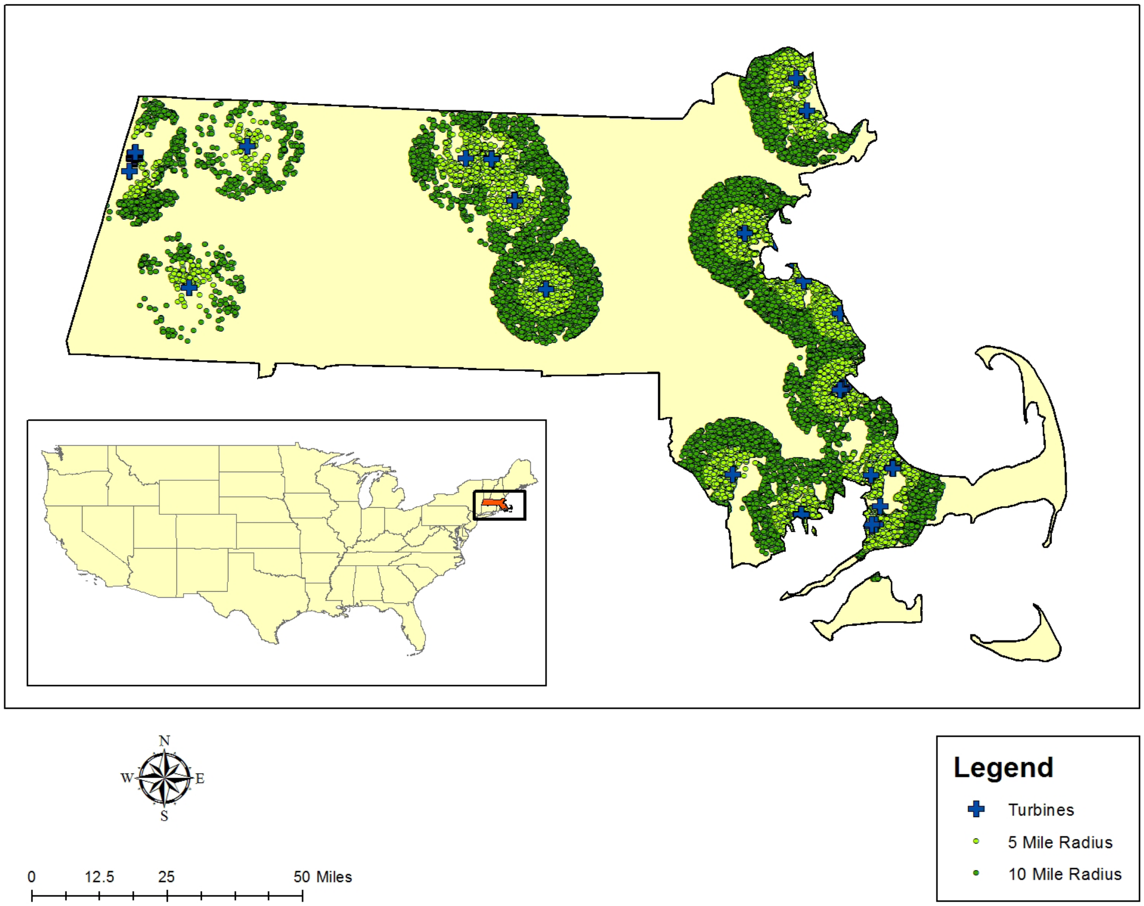
Note: Sample size for the full dataset is 122,198

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

** Bath is calculated as follows: number of bathrooms + (number of half bathrooms *0.5)

27 Highways and majors road are mutually exclusive by our definition despite the fact that highways are also considered major roads.

Figure 5: Locations of Houses in Relation to Wind Turbines



within the preceding 6 months and were the closest in terms of Euclidian distance. Using those five transactions, average 1000s of square feet of living space (*annsfla1000*), average acres (*annacre*), average age (*annage*), and age squared (*annagesq*) of the neighbors were created for each home. These four variables were used in the robustness test.

3.3.8 Summary Statistics

The base model dataset includes all home sales within 5 miles of a wind turbine, which are summarized in Table 2. The average home in the dataset of 122,198 sales from 1998 to 2012 has a sale price of $322,948, sold in 2004, in the 2nd quarter, has 1,728 square feet of living area, is on a parcel with a lot size of 0.51 acres, is 54 years old, has 1.9 bathrooms, and is 3.1 miles from the nearest turbine. As summarized in Table 2, of the 122,198 sales within 5 miles of a turbine, 7,188 (5.9%) are within 1 mile of a turbine, 1,107 (approximately 0.9%) are within a half mile, and 121 (0.1%) are within a quarter mile. In the post-construction period, 1,503 sales occurred within 1 mile of a turbine, and 230 occurred within a half mile. These totals are well above those collected for other analyses and are therefore ample to discover considerably smaller effects. For example, as discussed in Section 2.5 above, an effect larger than 2.5% should be detectable within 1 mile, and an effect larger than approximately 4% should be detectable within a half mile, given the number of transactions that we are analyzing. Figure 5 shows the spatial distribution of sales throughout the sample area.

3.4 Results

3.4.1 Base Model Results

The base model results for the turbine, amenity, and disamenity variables are presented in Table 4 (with full results in the Appendix). The base model has a high degree of explanatory power, with an adjusted-R^2 of 0.80, while the controlling variables are all highly significant and conform to the *a priori* assumption as far as sign and magnitude (e.g., Sirmans et al., 2006).[28] The model interacts the four wind-facility periods with each of the controlling variables to test the stability of the controlling variables across the periods (and the subsamples they represent) and to ensure that the coefficients for the wind turbine distance variables, which are also interacted with the periods, do not absorb any differences in the controlling variables across the periods.[29] The controlling variables do vary across the periods, although they are relatively stable. For example, each additional thousand square feet of living area adds 21%–24% to a home's value in each of the four periods; the first acre adds 14%–22% to home value, while each additional acre adds 1%–2%; each year a home ages reduces the home's value by approximately 0.2% and each bathroom adds 6%–11% to the value. Additionally, the sale years are highly statistically significant compared to the reference year of 2012; prices in 1998 are approximately 52% lower, and prices in 2005 and 2006 are approximately 31% and 28% higher, after which prices decline to current levels. Finally, there is considerable seasonality in the transaction values. Compared to the reference third quarter, prices in the first quarter are approximately 7% lower, while prices in the second and fourth are about 1%–2% lower (see Appendix for full results).

Similar to the controlling variables, the coefficients for the amenity and disamenity parameters are, for the most part, of the correct sign and within the range of findings from previous studies. For example, being within 500 feet of a beach increases a home's value by 21%-30%, while being outside of 500 feet but within a half mile of a beach increases a home's value by 5%–13%, being within 500 feet of a highway reduces value by 5%–7%, and being within 500 feet of a major road reduces value by 2%–3%. Being within a half mile of a prison reduces value by 6%, but this result is only apparent in one of the periods. Similarly, being within a half mile of a landfill reduces value by 12% in only one of the periods, and being within a half mile of open space increases value by approximately 1% in two of the periods. Finally, being within 500 feet of an electricity transmission line reduces value by 3%-9% in two of the four periods. As noted above, the wind development periods are not meaningful as it relates to the amenity/disamenity variables, because they all likely existed well before this sample period began, and therefore the turbines. That said, they do represent different data groups across the dataset (one for each wind development period), and therefore are illustrative of the consistency of findings for these variables, with beaches, highways and major roads showing very consistent results, while electricity transmission lines, open space, landfills and prisons showing more sporadic results.

Turning now to the variables that capture the effects in our sample, for being within a half mile of a turbine, we find interesting results (see Table

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

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

Table 4. Selected Results from Base Model

Variables	Description	Wind Facility Development Period: prioranc	preanc	postanc-precon	postcon
		coefficient / *p*-value	coefficient / *p*-value	coefficient / *p*-value	coefficient / *p*-value
halfmile	within a half mile of a wind turbine	**-5.1%***** *0.000*	**-7.1%***** *0.002*	**-7.4%***** *0.000*	**-4.6%*** *0.081*
Net Difference Compared to *prioranc* Period				**-2.3%** *0.264*	**0.5%** *0.853*
beach500ft	within 500 feet of a beach	**20.8%***** *0.000*	**30.4%***** *0.000*	**25.3%***** *0.000*	**25.9%***** *0.000*
beachhalf	within a half mile and outside of 500 feet of a beach	**5.3%***** *0.000*	**8.8%***** *0.000*	**8.7%***** *0.000*	**13.5%***** *0.000*
openhalf	within a half mile of open space	**0.6%**** *0.021*	**0.1%** *0.729*	**0.1%** *0.903*	**0.9%*** *0.062*
line500ft	within 500 feet of a electricity transmission line	**-3%***** *0.001*	**-0.9%** *0.556*	**-0.9%** *0.522*	**-9.3%***** *0.000*
prisonhalf	within a half mile of a prison	**-5.9%***** *0.001*	**2.6%** *0.291*	**2.8%** *0.100*	**-2.3%** *0.829*
hwy500ft	within 500 feet of a highway	**-7.3%***** *0.000*	**-5.2%***** *0.000*	**-3.7%***** *0.000*	**-5.3%***** *0.000*
major500ft	within 500 feet of a major road	**-2.8%***** *0.000*	**-2.3%***** *0.000*	**-2.5%***** *0.000*	**-2%***** *0.000*
fillhalf	within a half mile of a landfill	**1.8%** *0.239*	**-0.9%** *0.780*	**1%** *0.756*	**-12.2%***** *0.002*
sfla1000	living area in thousands of square feet	**22.9%***** *0.000*	**21.4%***** *0.000*	**22.6%***** *0.000*	**23.5%***** *0.000*
acre	lot size in acres	**1.1%***** *0.000*	**1.9%***** *0.000*	**1.3%***** *0.000*	**-0.02%** *0.863*
acrelt1	lot size less than 1 acre	**21.7%***** *0.000*	**17.2%***** *0.000*	**14.7%***** *0.000*	**22.1%***** *0.000*
age	age of the home at time of sale	**-0.2%***** *0.000*	**-0.2%***** *0.000*	**-0.2%***** *0.000*	**-0.2%***** *0.000*
agesq*	age of the home at time of sale squared*	**0.6%***** *0.000*	**0.5%***** *0.000*	**0.6%***** *0.000*	**0.8%***** *0.000*
bath	number of bathrooms	**6.4%***** *0.001*	**7.9%***** *0.556*	**8.4%***** *0.522*	**11.1%***** *0.000*

***Coefficients** represent the percentage change in price for every unit of change in the characteristic. For example, the model estimates that price increases by approximately 23% for every 1000 additional square feet. Coefficient values are reported as percentages, although the actual conversion is 100*(exp(b)-1)% (Halvorsen and Palmquist, 1980). In most cases, the differences between the two are de minimis, though, larger coefficient values would be slightly larger after conversion.*

***p-value** is a measure of how likely the estimate is different from zero (i.e., no effect) by chance. The lower the p-value, the more likely the estimate is expected to be different from zero. A p-value of less than 0.10 is considered statistically significant, with higher levels of significance being denoted as follows: * 0.10, ** 0.05, ***0.01.*

** coefficient values are multiplied by 1000 for reporting purposes only*

4). The coefficients for the *halfmile* variable over the four periods are as follows: *prioranc* (sale more than 2 years before the nearest wind turbine was announced) -5.1%, *preanc* (less than 2 years before announcement) -7.1%, *postancprecon* (after announcement but before the nearest turbine construction commenced) -7.4%, and *postcon* (after construction commenced) -4.6%.[30] Importantly, our model estimates that home values within a half mile of a future turbine were lower than in the surrounding area even before wind-facility announcement. In other words, wind facilities in Massachusetts are associated with areas with relatively low home values, at least compared to the average values of homes more than a half mile but less than 5 miles away from the turbines. Moreover, when we determine if there has been a "net" effect from the arrival of the turbines, we must account for this preexisting *prioranc* difference. The net *postancprecon* effect is -2.3% ([-7.4%] - [-5.1%] = -2.3%; *p*-value 0.26). The net *postcon* effect is 0.5% ([-4.6%] - [-5.1%] = 0.5%: *p*-value 0.85).[31] Therefore, after accounting for the "pre-existing price differential" that predates the turbine's development, there is no evidence of an additional impact from the turbine's announcement or eventual construction.

3.4.2 Robustness Test Results

To test and possibly bound the results from the base model, several robustness tests were explored (Section 3.2):

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

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

1. Impacts within a quarter mile
2. Impacts between a half and 1 mile
3. Impacts inside of a half mile when data between a half mile and 10 miles were used as a reference category
4. Impacts inside of a half mile when data between 5 miles 10 miles were used as a reference category
5. The inclusion of style (of the home) and heat (type of the home) variables
6. The use of the census block group as the fixed effect instead of census tract
7. Relaxing the screens (e.g., sale price between $40,000 and $2,500,000) used to create the analysis dataset
8. The removal of outliers and influential cases from the analysis dataset
9. The inclusion of spatially/temporally lagged variables to account for the presence of spatial autocorrelation.

Table 5 shows the robustness test results and the base model results for comparison (the robustness models are numbered in the table as they are above). For brevity only the "net" differences in value for the *postancprecon* and *postcon* periods are shown that quantify the *postancprecon* and *postcon* effects after deducting the difference that existed in the Prior period.[32] Throughout the rest of this section, those effects will be referred to as net *postancprecon* and net *postcon.*

There are a number of key points that arise from the results that have implications for stakeholders involved in wind turbine siting. For example, the effects for both the net *postancprecon* and net *postcon* periods for sales within a quarter mile of a turbine are positive and non-significant (which is believed to be a circumstance of the small dataset

32 The full set of robustness results is available upon request.

Table 5: Robustness Results

#	Model Name	n	Adj R^2	Prior Announcement Turbine Effect			"Net" Post Announcement Pre Construction Turbine Effect			"Net" Post Construction Turbine Effect		
				inside 1/4 mile	*inside 1/2 mile*	*between 1/2 and 1 mile*	*inside 1/4 mile*	*inside 1/2 mile*	*between 1/2 and 1 mile*	*inside 1/4 mile*	*inside 1/2 mile*	*between 1/2 and 1 mile*
				coef / *p-value*	**coef** / *p-value*	**coef** / *p-value*	**coef** / *p-value*	**coef** / *p-value*	**coef** / *p-value*	**coef** / *p-value*	**coef** / *p-value*	**coef** / *p-value*
	Base Model	122,198	0.80		**-5.1%***** *0.000*			**-2.3%** *0.264*			**0.5%** *0.853*	
1	Inside 1/4 mile	122,198	0.80	**-5.3%** *0.260*			**12.7%** *0.118*			**0.7%** *0.916*		
2	Between 1/2 and 1 Mile	122,198	0.80		**-5.0%***** *0.000*	**-0.4%** *0.536*		**-2.0%** *0.336*	**1.4%** *0.225*		**1.0%** *0.715*	**1.3%** *0.288*
3	All Sales Out to 10 Miles	312,677	0.82		**-5.8%***** *0.000*			**-3.0%** *0.886*			**1.0%** *0.724*	
4	Using Outside of 5 Miles as Reference	312,677	0.82		**-7.6%***** *0.000*			**1.6%** *0.435*			**1.1%** *0.695*	
5	Including Style & Heat Variables	120,292	0.81		**-3.8%***** *0.004*			**-3.3%** *0.114*			**2.8%** *0.336*	
6	Using Block Group	122,198	0.81		**-3.1%***** *0.024*			**-1.3%** *0.554*			**-2.6%** *0.324*	
7	No Screens	123,555	0.73		**-4.0%***** *0.003*			**-4.6%*** *0.072*			**-0.8%** *0.800*	
8	Removing Outliers and Influencers	119,623	0.79		**-4.3%***** *0.001*			**-2.6%** *0.205*			**0.04%** *0.989*	
9	Including Spatial Variables	122,198	0.80		**-5.3%***** *0.000*			**-1.5%** *0.467*			**1.4%** *0.621*	

*Statistical Significance: * 0.10, ** 0.05, ***0.01. Note: For simplicity, coefficient values are reported as percentages, although the actual conversion is 100*(exp(b)-1)% (Halvorsen and Palmquist, 1980). In most cases, the differences between the two are de minimis, though, larger coefficient values would be slightly larger after conversion.*

in that distance range, see Table 2), providing no evidence of a large negative effect near the turbines. Further, there are weakly significant net *postancprecon* impacts for relaxing the screens (-4.6%), indicating a possible effect associated with turbine announcement that disappears after turbine construction. Finally, and most importantly, no model specification uncovers a statistically significant net *postcon* impact, bolstering the base model results. Moreover, all net *postcon* estimates for homes within a half mile of a turbine fall within a relatively narrow band that equally spans zero (-2.6% to 2.8%), further reinforcing the non-significant results from the base model.

4. DISCUSSION AND CONCLUSIONS

The study estimated a base hedonic model along with a large set of robustness models to test and bound the results. These results are now applied to the research questions listed in Section 3.

4.1 Discussion of Findings in Relation to Research Questions

Q1) Have wind facilities in Massachusetts been located in areas where average home prices were lower than prices in surrounding areas (i.e., a "pre-existing price differential")?

To test for this, we examined the coefficient in the *prioranc* period, in which sales occurred more than 2 years before a nearby wind facility was announced. The -5.1% coefficient for the *prioranc* period (for home sales within a half mile of a turbine compared to the average prices of all homes between a half and 5 miles) is highly statistically significant (p-value < 0.000). This clearly indicates that houses near where turbines eventually are located are depressed in value relative to their comparables further away. Other studies have also uncovered this phenomenon (Hoen et al., 2009; Hinman, 2010; Hoen et al., 2011). If the wind development is not responsible for these lower values, what is?

Examination of turbine locations reveals possible explanations for the lower home prices. Six of the turbines are located at wastewater treatment plants, and another eight are located on industrial sites (Table 1). Some of these locations (for example, Charlestown) have facilities that generate large amounts of hazardous waste regulated by Massachusetts and/or the U.S. Environmental Protection Agency and use large amounts of toxic substances that must be reported to the Massachusetts Department of Environmental Protection.[33] Regardless of the reason for this "pre-existing price differential" in Massachusetts, the effect must be factored into estimates of impacts due to the turbines' eventual announcement and construction, as this analysis does.

Q2) Are post-construction (i.e., after wind-facility construction) home price impacts evident in Massachusetts, and how do Massachusetts results contrast with previous results estimated for more rural settings?

To test for these effects, we examine the "net" *postcon* effects (*postcon* effects minus *prioranc* effects), which account for the "pre-existing price differential" discussed above. In the base model, with a *prioranc* effect of -5.1% and a *postcon* effect of -4.6%, the "net" effect is 0.5% and not statistically significant. Similarly, none of the robustness models reveal a statistically significant "net" effect, and the range of estimates from those models is -2.6% to 2.8%, effectively bounding the results from the base model. Therefore, in our sample of more than 122,000 sales, of which more than 21,808 occurred

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

after nearby wind-facility construction began (with 230 sales within a half mile), no evidence emerges of a *postcon* impact. This collection of *postcon* data within a half mile (and that within 1 mile: n = 1,503) is orders of magnitude larger than had been collected in previous studies and is large enough to find effects of the magnitude others have claimed to have found (e.g., Heintzelman and Tuttle, 2012; Sunak and Madlener, 2012).[34] Therefore, if effects are captured in our data, they are either too small or too sporadic to be identified.

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

Q3) Is there evidence of a post-announcement/pre-construction effect (i.e., an "anticipation effect")?

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

Q4) How do impacts near turbines compare to the impacts of amenities and disamenities also located in the study area, and how do they compare with previous findings?

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

34 Though, as discussed earlier, their findings might be the result of their continuous distance specification and not the result of the data, moreover, although Heintzelman & Tuttle claim to have found a *postcon* effect, their data primary occurred prior to construction.

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

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

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

Q5) Is there evidence that houses that sold during the post-announcement and post-construction periods did so at lower rates than during the pre-announcement period?

To test for this sales-volume effect, we examine the differences in sales rate in fixed distances from the turbines over the various development periods (Table 2). Approximately 0.29% percent of all homes in our sample (i.e., inside of 10 miles from a turbine) that sold in the *prioranc* period were within a half mile of a turbine. That percentage increases to 0.50% in the *postancprecon* period and then drops to 0.39% in the *postcon* period for homes within a half mile of a turbine. Similarly, homes located between a half mile and 1 mile sold, as a percentage of all sales out to 10 miles, at 1.9% in the *prioranc* period, 1.8% in the *postancprecon* period, and 2.2% in the *postcon* period (and similar results are apparent for those few homes within a quarter mile). Neither of these observations indicates that the rate of sales near the turbines is affected by the announcement and eventual construction of the turbines, thus we can conclude that there is an absence of evidence to support the claim that sales rate was affected by the turbines.[35]

35 This conclusion was confirmed with Friedman's two-way Analysis of Variance for related samples using period as the ranking factor, which confirmed that the distributions of the frequencies across periods was statistically the same.

4.2 Conclusion

This study investigates a common concern of people who live near planned or operating wind developments: How might a home's value be affected by the turbines? Previous studies on this topic, which have largely coalesced around non-significant findings, focused on rural settings. Wind facilities in urban locations could produce markedly different results. Nuisances from turbine noise and shadow flicker might be especially relevant in urban settings where other negative features, such as landfills or high voltage utility lines, have been shown to reduce home prices. To determine if wind turbines have a negative impact on property values in urban settings, this report analyzed more than 122,000 home sales, between 1998 and 2012, that occurred near the current or future location of 41 turbines in densely-populated Massachusetts.

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

4.3 Suggestions for Future Research

Although our study is unparalleled in its methodological scope and dataset compared to the previous literature in the subject area, we recommend a number of areas for future work. Because much of the existing work on wind turbines has focused on rural areas—which is where most wind facilities have been built—there is no clear understanding of how residents would view the introduction of wind turbines in landscapes that are already more industrialized. Therefore, investigating residents' perceptions, through survey instruments, of wind turbines in more urbanized settings may be helpful. Policy-makers may also be interested in understanding the environmental attitudes and perceptions towards wind turbines of people who purchase houses near wind turbines after they have been constructed. Also, our study has aggregated the effects of wind turbines on the price of single-family houses for the study area as a whole. Although the data span an enormous range of sales prices, and contain the highest mean value of homes yet studied, it might be fruitful to analyze impacts partitioned by sales price or neighborhood to discover whether the effects vary with changes in these factors.

Finally, in our study we did not investigate the ownership structure of the turbines (i.e., in Massachusetts some projects benefit town budgets while others are owned by private entities) and assess whether any benefits accrued to surrounding communities, factors that the existing literature suggests are important determinants of community perceptions. This was considered beyond the scope of the existing study, but could be addressed in future research.

LITERATURE CITED

Anderson, S. T. and West, S. E. (2006a) Open Space, Residential Property Values and Spatial Context. *Regional Science and Urban Economics.* 36(6): 773-789.

Anderson, S. T. and West, S. E. (2006b) Open Space, Residential Property Values, and Spatial Context. *Regional Science and Urban Economics.* 36(6): 773-789.

Andersson, H., Jonsson, L. and Ogren, M. (2010) Property Prices and Exposure to Multiple Noise Sources: Hedonic Regression with Road and Railway Noise. *Environmental & Resource Economics.* 45(1): 73-89.

Anselin, L. (2002) Under the Hood - Issues in the Specification and Interpretation of Spatial Regression Models. *Agricultural Economics.* 27(3): 247-267.

Atkinson-Palombo, C. (2010) Comparing the Capitalisation Benefits of Light-Rail Transit and Overlay Zoning for Single-Family Houses and Condos by Neighbourhood Type in Metropolitan Phoenix, Arizona. *Urban Studies.* 47(11): 2409-2426.

Barone, M. (2011) Survey of Techniques for Reduction of Wind Turbine Blade Trailing Edge Noise. Prepared for Sandia National Laboratory. August 2011.

Bateman, I., Day, B., Lake, I. and Lovett, A. (2001) The Effect of Road Traffic on Residential Property Values: A Literature Review and Hedonic Pricing Study. Edinburgh, Scotland. 207 pages.

Benson, E. D., Hansen, J. L. and Aurthur L. Schwartz, J. (2000) Water Views and Residential Property Values. *The Appraisal Journal.* 68(3): 260-270.

Berglund, B., Hassmen, P. and Job, R. F. S. (1996) Sources and Effects of Low-Frequency Noise. *Journal of the Acoustical Society of America.* 99(5): 2985-3002.

Blanco, J. C. and Flindell, I. (2011) Property Prices in Urban Areas Affected by Road Traffic Noise. *Applied Acoustics.* 72(4): 133-141.

Bolin, K., Kedhammar, A. and Nilsson, M. E. (2012) The Influence of Background Sounds on Loudness and Annoyance of Wind Turbine Noise. *Acta Acustica United with Acustica.* 98(5): 741-748.

Bond, M. T., Seiler, V. L. and Seiler, M. J. (2002) Residential Real Estate Prices: A Room with a View. *Journal of Real Estate Research.* 23(1/2): 129-137.

Boyle, M. A. and Kiel, K. A. (2001) A Survey of House Price Hedonic Studies of the Impact of Environmental Externalities. *Journal of Real Estate Research.* 9(2): 117-144.

Braden, J. B., Feng, X. and Won, D. (2011) Waste Sites and Property Values: A Meta-Analysis. *Environmental & Resource Economics.* 50(2): 175-201.

Brandt, S. and Maennig, W. (2011) Road Noise Exposure and Residential Property Prices: Evidence from Hamburg. *Transportation Research Part D-Transport and Environment.* 16(1): 23-30.

Brannstrom, C., Jepson, W. and Persons, N. (2011) Social Perspectives on Wind-Power Development in West Texas. *Annals of the Association of American Geographers.* 101(4): 839-851.

Braunholtz, S. and MORI (2003) Public Attitudes to Windfarms: A Survey of Local Residents in Scotland. Prepared for Scottish Executive, Edinburgh, Scotland.

Butler, R. V. (1982) The Specification of Hedonic Indexes for Urban Housing. *Land Economics.* 58(1): 96-108.

Carter, J. (2011) The Effect of Wind Farms on Residential Property Values in Lee County, Illinois. Thesis Prepared for M.A. Illinois State University, Normal, Illinois. Spring 2011. 35 pages.

Clapp, J. M. and Giaccotto, C. (1998) Residential Hedonic Models: A Rational Expectations Approach to Age Effects. *Journal Of Urban Economics.* 44(3): 415-437.

Cook, R. D. (1977) Detection of Influential Observations in Linear Regression. Technometrics. 19(1): 15-18.

Day, B., Bateman, I. and Lake, I. (2007) Beyond Implicit Prices: Recovering Theoretically Consistent and Transferable Values for Noise Avoidance from a Hedonic Property Price Model. *Environmental & Resource Economics.* 37(1): 211-232.

Dent, P. and Simms, S. (2007) What Is the Impact of Wind Farms on House Prices? Prepared for Royal Institute of Chartered Surveyors/Oxford Brookes University, Oxford, UK. March 2007.

Des Rosiers, F. (2002) Power Lines, Visual Encumbrance and House Values: A Microspatial Approach to Impact Measurement. *Journal of Real Estate Research.* 23(3): 275-301.

Devine-Wright, P. (2005) Beyond Nimbyism: Towards an Integrated Framework for Understanding Public Perceptions of Wind Energy. *Wind Energy.* 8(2): 125-139.

Devine-Wright, P. (2008) Reconsidering Public Acceptance of Renewable Energy Technologies: A Critical Review. Section in Delivering a Low Carbon Electricity System: Technologies, Economics and Policy. Cambridge University Press. Cambridge, UK.

Devine-Wright, P. (2009) Rethinking Nimbyism: The Role of Place Attachment and Place Identity in Explaining Place-Protective Action. *Journal of Community & Applied Social Psychology.* 19(6): 426-441.

Devine-Wright, P. (2011) Public Engagement with Large-Scale Renewable Energy Technologies: Breaking the Cycle of Nimbyism. *Wiley Interdisciplinary Reviews-Climate Change.* 2(1): 19-26.

Devine-Wright, P. (2012) Renewable Energy and the Public: From Nimby to Participation. Earthscan. London, UK. 336 pages. ISBN: 978-1-84407-863-9.

Devine-Wright, P. and Howes, Y. (2010) Disruption to Place Attachment and the Protection of Restorative Environments: A Wind Energy Case Study. *Journal of Environmental Psychology.* 30(3): 271-280.

Ek, K. (2005) Public and Private Attitudes Towards "Green" Electricity: The Case of Swedish Wind Power. *Energy Policy.* 33(13): 1677-1689.

Ekins, P. (2004) Step Changes for Decarbonising the Energy System: Research Needs for Renewables, Energy Efficiency and Nuclear Power. *Energy Policy.* 32(17): 1891-1904.

Eltham, D. C., Harrison, G. P. and Allen, S. J. (2008) Change in Public Attitudes Towards a Cornish Wind Farm: Implications for Planning. *Energy Policy.* 36(1): 23-33.

EU. (2012) European Commission Renewable Energy Targets by 2020.

Firestone, J. and Kempton, W. (2007) Public Opinion About Large Offshore Wind Power: Underlying Factors. *Energy Policy.* 35(3): 1584-1598.

Graham, J. B., Stephenson, J. R. and Smith, I. J. (2009) Public Perceptions of Wind Energy Developments: Case Studies from New Zealand. *Energy Policy.* 37(9): 3348-3357.

Halvorsen, R. and Palmquist, R. (1980) The Interpretation of Dummy Variables in Semilogarithmic Equations. *American Economic Review.* 70(3): 474-475.

Hasselmann, K., Latif, M., Hooss, G., Azar, C., Edenhofer, O., Jaeger, C. C., Johannessen, O. M., Kemfert, C., Welp, M. and Wokaun, A. (2003) The Challenge of Long-Term Climate Change. *Science.* 302(5652): 1923-1925.

Haugen, K. M. B. (2011) International Review of Policies and Recommendations for Wind Turbine Setbacks from Residences: Setbacks, Noise, Shadow Flicker, and Other Concerns. Prepared for Minnesota Department of Commerce: Energy Facility Permitting. October 19th, 2011.

Heintzelman, M. D. and Tuttle, C. (2012) Values in the Wind: A Hedonic Analysis of Wind Power Facilities. *Land Economics.* 88: 571-588.

Hessler, D. (2011) Best Practices Guidelines for Assessing Sound Emissions from Proposed Wind Farms and Measuring the Performance of Completed Projects. Prepared for National Association of Regulatory Utility Commissioners, Minnesota Public Utilities Commission. October 13, 2011.

Hinman, J. L. (2010) Wind Farm Proximity and Property Values: A Pooled Hedonic Regression Analysis of Property Values in Central Illinois. Thesis Prepared for M.A. Illinois State University, Normal, Illinois. May 2010. 143 pages.

Hoen, B. (2006) Impacts of Windfarm Visibility on Property Values in Madison County, New York. Thesis Prepared for Master of Arts. Bard College, Annandale-on-Hudson, NY. April 2006. 73 pages.

Hoen, B. (2012) Population Density Surrounding Wind Turbines in the United States. Lawrence Berkeley National Laboratories. New York.

Hoen, B., Wiser, R., Cappers, P., Thayer, M. and Sethi, G. (2011) Wind Energy Facilities and Residential Properties: The Effect of Proximity and View on Sales Prices. *Journal of Real Estate Research.* 33(3): 279-316.

Hoen, B., Wiser, R., Cappers, P., Thayer, M. A. and Gautam, S. (2009) The Impact of Wind Power Projects on Residential Property Values in the United States: A Multi-Site Hedonic Analysis. Prepared for Lawrence Berkeley National Laboratory, Berekley, CA. December 2009. 146 pages. LBNL-2829E.

Hoen, B., Wiser, R. and Eckholdt, H. (2010) Assessing the Impacts of Reduced Noise Operations of Wind Turbines on Neibour Annoyance: A Preliminary Analysis in Vinalhaven, Maine. Prepared for Office of Energy Efficiency and Renewable Energy Program, Wind and Hydropower Technologies Program, US Department of Energy.

Hubbard, H. H. and Shepherd, K. P. (1991) Aeroacoustics of Large Wind Turbines. *Journal of the Acoustical Society of America.* 89(6): 2495-2508.

Irwin, E. G. (2002) The Effects of Open Space on Residential Property Values. *Land Economics.* 78(4): 465-480.

Jackson, T. O. (2001) The Effects of Environmental Contamination on Real Estate: A Literature Review. *Journal of Real Estate Literature.* 9(2): 91-116.

Jackson, T. O. (2003) Methods and Techniques for Contaminated Property Valuation. *The Appraisal Journal.* 17(4): 311-320.

Jager-Waldau, A. and Ossenbrink, H. (2004) Progress of Electricity from Biomass, Wind and Photovoltaics in the European Union. *Renewable & Sustainable Energy Reviews.* 8(2): 157-182.

Jauregui, A. and Hite, D. (2010) The Impact of Real Estate Agents on House Prices near Environmental Disamenities. *Housing Policy Debate.* 20(2): 295-316.

Jepson, W., Brannstrom, C. and Persons, N. (2012) "We Don't Take the Pledge": Environmentality and Environmental Skepticism at the Epicenter of Us Wind Energy Development. *Geoforum.* 43(4): 851-863.

Jones, C. R. and Eiser, J. R. (2009) Identifying Predictors of Attitudes Towards Local Onshore Wind Development with Reference to an English Case Study. *Energy Policy.* 37(11): 4604-4614.

Jones, C. R. and Eiser, J. R. (2010) Understanding 'Local' Opposition to Wind Development in the UK: How Big Is a Backyard? *Energy Policy.* 38(6): 3106-3117.

Kahn, M. E. (2013) Local Non-Market Quality of Life Dynamics in New Wind Farm Communities. *Energy Policy*: Available Online May 14, 2013.

Kiel, K. A. and McClain, K. T. (1995) House Price During Siting Decision Stages - the Case of an Incinerator from Rumor through Operation. *Journal of Environmental Economics and Management.* 28(2): 241-255.

Kim, K. S., Park, S. J. and Kweon, Y.-J. (2007) Highway Traffic Noise Effects on Land Price in an Urban Area. *Transportation Research Part D-Transport and Environment.* 12(4): 275-280.

Kuminoff, N. V., Parmeter, C. F. and Pope, J. C. (2010) Which Hedonic Models Can We Trust to Recover the Marginal Willingness to Pay for Environmental Amenities? *Journal of Environmental Economics and Management.* 60(3): 145-160.

Leloudas, G., Zhu, W. J., Sorensen, J. N., Shen, W. Z. and Hjort, S. (2009). Prediction and Reduction of Noise from a 2.3mw Wind Turbine. Presented at Jounral of Physics, Conference Series 75.

Moragues-Faus, A. M. and Ortiz-Miranda, D. (2010) Local Mobilisation against Windfarm Developments in Spanish Rural Areas: New Actors in the Regulation Arena. *Energy Policy.* 38(8): 4232-4240.

Nadai, A. and van der Horst, D. (2010) Wind Power Planning, Landscapes and Publics. *Land Use Policy.* 27(2): 181-184.

NARUC (2012) Wind Energy & Wind Park Siting and Zoning Best Practices and Guidance for States. Prepared for Prepared for Minnesota Public Utilities Commission., Saint Paul, MN. January 2012.

Nissenbaum, M. A., Aramini, J. J. and Hanning, C. D. (2012) Effects of Industrial Wind Turbine Noise on Sleep and Health. *Noise & Health.* 14(60): 237-243.

Oerlemans, S., Sijtsma, P. and Lopez, B. M. (2006) Location and Quantification of Noise Sources on a Wind Turbine. *Journal of Sound and Vibration.* 299(4-5): 869-883.

Pasqualetti, M. J. (2011) Opposing Wind Energy Landscapes: A Search for Common Cause. *Annals of the Association of American Geographers.* 101(4): 907-917.

Pasqualetti, M. J., Gipe, P. and Righter, R. W. (2002) A Landscape of Power. Section in Wind Power in View: Energy Landscapes in a Crowded World. San Diego Academic Press. San Diego, California.

Pedersen, E., Hallberg, L.-M. and Waye, K. P. (2007) Living in the Vicinity of Wind Turbines-a Grounded Theory Study. *Qualitative Research in Psychology.* 4(1-2): 49-63.

Pedersen, E., van den Berg, F., Bakker, R. and Bouma, J. (2010) Can Road Traffic Mask Sound from Wind Turbines? Response to Wind Turbine Sound at Different Levels of Road Traffic Sound. *Energy Policy.* 38(5): 2520-2527.

Pedersen, E. and Waye, K. P. (2007) Wind Turbine Noise, Annoyance and Self-Reported Health and Well-Being in Different Living Environments. *Occupational and Environmental Medicine.* 64(7): 480-486.

Petitjean, B., Drobeitz, R. and Kinzie, K. (2011) Wind Turbine Blade Noise Mitigation Technologies. Rome, Italy. April 12-14, 2011.

Pohl, J., Faul, F. and Mausfeld, R. (1999) Annoyance Caused by Periodic Shadow Casting (or Shadow Flickering) of Wind Turbines. Prepared for Centrum for Vindbruk, Gotland University.

Pohl, J., Faul, F. and Mausfeld, R. (2000) Harassment by Periodic Shadow of Wind Turbines: Laboratory Pilot Study. Prepared for Centrum for Vindbruk, Gotland University.

Ready, R. C. (2010) Do Landfills Always Depress Nearby Property Values? *Journal of Real Estate Research.* 32(3): 321-339.

Rosen, S. (1974) Hedonic Prices and Implicit Markets - Product Differentiation in Pure Competition. *Journal Of Political Economy.* 82(1): 34-55.

Simons, R. A. and Saginor, J. D. (2006) A Meta-Analysis of the Effect of Environmental Contamination and Positive Amenities on Residential Real Estate Values. *Journal of Real Estate Research.* 28(1): 71-104.

Sims, S., Dent, P. and Oskrochi, G. R. (2008) Modeling the Impact of Wind Farms on House Prices in the Uk. *International Journal of Strategic Property Management.* 12(4): 251-269.

Sirmans, G. S., MacDonald, L., Macpherson, D. A. and Zietz, E. N. (2006) The Value of Housing Characteristics: A Meta Analysis. *Journal of Real Estate Finance and Economics.* 33(3): 215-240.

Slattery, M. C., Johnson, B. L., Swofford, J. A. and Pasqualetti, M. J. (2012) The Predominance of Economic Development in the Support for Large-Scale Wind Farms in the U.S. Great Plains. *Renewable & Sustainable Energy Reviews.* 16(6): 3690-3701.

Studds, T. (2013) Summary of Wind Turbine Setback Distances in Massachusetts. Letter sent to Report Authors. June 25, 2013.

Sunak, Y. and Madlener, R. (2012) The Impact of Wind Farms on Property Values: A Geographically Weighted Hedonic Pricing Model. Prepared for Institute for Future Energy Consumer Needs and Behavior (ACN), RWTH Aachen University. May, 2012 (revised March 2013). 27 pages. FCN Working Paper No. 3/2012.

Sunak, Y. and Madlener, R. (2013) The Impact of Wind Farms on Property Values: A Geographically Weighted Hedonic Pricing Model. Prepared for Institute for Future Energy Consumer Needs and Behavior (ACN), RWTH Aachen University. May, 2012 (revised March 2013). 27 pages. FCN Working Paper No. 3/2012.

Swofford, J. and Slattery, M. (2010) Public Attitudes of Wind Energy in Texas: Local Communities in Close Proximity to Wind Farms and Their Effect on Decision-Making. *Energy Policy.* 38(5): 2508-2519.

Toke, D. (2005) Explaining Wind Power Planning Outcomes: Some Findings from a Study in England and Wales. *Energy Policy.* 33(12): 1527-1539.

Toke, D., Breukers, S. and Wolsink, M. (2008) Wind Power Deployment Outcomes: How Can We Account for the Differences? *Renewable & Sustainable Energy Reviews.* 12(4): 1129-1147.

van den Berg, G. P. (2004) Effects of the Wind Profile at Night on Wind Turbine Sound. *Journal of Sound and Vibration.* 277(4-5): 955-970.

van der Horst, D. and Vermeylen, S. (2011) Local Rights to Landscape in the Global Moral Economy of Carbon. *Landscape Research.* 36(4): 455-470.

Walker, G., Devine-Wright, P., Hunter, S., High, H. and Evans, B. (2010) Trust and Community: Exploring the Meanings, Contexts and Dynamics of Community Renewable Energy. *Energy Policy.* 38(6): 2655-2663.

Warren, C. R., Lumsden, C., O'Dowd, S. and Birnie, R. V. (2005) 'Green on Green': Public Perceptions of Wind Power in Scotland and Ireland. *Journal of Environmental Planning and Management.* 48(6): 853-875.

Warren, C. R. and McFadyen, M. (2010) Does Community Ownership Affect Public Attitudes to Wind Energy? A Case Study from South-West Scotland. *Land Use Policy.* 27(2): 204-213.

Watson, R. T. (2003) Climate Change: The Political Situation. *Science.* 302(5652): 1925-1926.

Wharton, S. and Lundquist, J. K. (2012) Atmospheric Stability Affects Wind Turbine Power Collection. *Environmental Research Letters.* 7(014005).

WHO. (2011). Noise: Facts and Figures.

Wilson, D., Berg, D., Barone, M., Berg, J., Reser, B. and Lobitz, D. (2009) Active Aerodynamic Blade Control Design for Load Reduction on Large Wind Turbines.

Wiser, R. and Bolinger, M. (2012) Wind Technologies Market Report. Prepared for Lawrence Berkeley National Laboratory, Berkeley, California. DOE/GP-102012-3472, LBNL-5559E.

Wolsink, M. (2000) Wind Power and the Nimby-Myth: Institutional Capacity and the Limited Significance of Public Support. *Renewable Energy.* 21(1): 49-64.

Wolsink, M. (2007) Wind Power Implementation: The Nature of Public Attitudes: Equity and Fairness Instead of 'Backyard Motives'. *Renewable & Sustainable Energy Reviews.* 11(6): 1188-1207.

Wolsink, M. (2010) Contested Environmental Policy Infrastructure: Socio-Political Acceptance of Renewable Energy, Water, and Waste Facilities. *Environmental Impact Assessment Review.* 30(5): 302-311.

Zabel, J. E. and Guignet, D. (2012) A Hedonic Analysis of the Impact of Lust Sites on House Prices. *Resource and Energy Economics.* 34(4): 549-564.

APPENDIX: BASE MODEL FULL RESULTS

	Coef	SE	t	p-value
Intercept	12.15	0.01	1133.88	0.000
within a half mile of a wind turbine				
prioranc	-0.051	0.01	-3.95	0.000
preanc	-0.071	0.02	-3.08	0.002
postancprecon	-0.074	0.02	-4.34	0.000
postcon	-0.046	0.03	-1.74	0.081
Net Difference Compared to prioranc Period—within a half mile of a wind turbine				
postancprecon	-0.023	0.02	-1.12	0.264
postcon	0.005	0.03	0.19	0.853
within 500 feet of a electricity transmission line				
prioranc	-0.030	0.01	-3.41	0.001
preanc	-0.009	0.02	-0.59	0.556
postancprecon	-0.009	0.01	-0.64	0.522
postcon	-0.093	0.02	-4.79	0.000
within 500 feet of a highway				
prioranc	-0.073	0.01	-14.28	0.000
preanc	-0.052	0.01	-4.57	0.000
postancprecon	-0.037	0.01	-4.16	0.000
postcon	-0.053	0.01	-3.95	0.000
within 500 feet of a major road				
prioranc	-0.028	0.00	-12.18	0.000
preanc	-0.023	0.00	-5.05	0.000
postancprecon	-0.025	0.00	-5.43	0.000
postcon	-0.020	0.00	-4.01	0.000
within a half mile of a landfill				
prioranc	0.018	0.02	1.18	0.239
preanc	-0.009	0.03	-0.28	0.780
postancprecon	0.010	0.03	0.31	0.756
postcon	-0.122	0.04	-3.08	0.002
within a half mile of a prison				
prioranc	-0.059	0.02	-3.38	0.001
preanc	0.024	0.02	1.05	0.291
postancprecon	0.028	0.02	1.64	0.100
postcon	-0.020	0.09	-0.22	0.829

	Coef	SE	t	p-value
within 500 feet of a beach				
prioranc	0.208	0.02	12.71	0.000
preanc	0.304	0.03	12.09	0.000
postancprecon	0.253	0.02	12.72	0.000
postcon	0.259	0.02	16.95	0.000
within a half mile and outside of 500 feet of a beach				
prioranc	0.053	0.01	10.07	0.000
preanc	0.088	0.01	10.52	0.000
postancprecon	0.087	0.01	11.99	0.000
postcon	0.135	0.01	17.30	0.000
within a half mile of open space				
prioranc	0.006	0.00	2.31	0.021
preanc	0.001	0.00	0.35	0.729
postancprecon	0.001	0.00	0.12	0.903
postcon	0.009	0.00	1.87	0.062
living area in thousands of square feet				
prioranc	0.229	0.00	86.37	0.000
preanc	0.214	0.01	41.62	0.000
postancprecon	0.226	0.00	48.41	0.000
postcon	0.235	0.01	46.58	0.000
lot size in acres				
prioranc	0.011	0.00	6.67	0.000
preanc	0.019	0.00	6.51	0.000
postancprecon	0.013	0.00	4.17	0.000
postcon	-0.001	0.00	-0.17	0.863
lot size less than 1 acre				
prioranc	0.217	0.01	34.79	0.000
preanc	0.172	0.01	18.45	0.000
postancprecon	0.147	0.01	16.03	0.000
postcon	0.221	0.01	21.71	0.000
age of the home at time of sale				
prioranc	-0.0016	0.00	-21.87	0.000
preanc	-0.0016	0.00	-11.33	0.000
postancprecon	-0.0020	0.00	-13.99	0.000
postcon	-0.0025	0.00	-16.47	0.000

	Coef	SE	t	p-value
age of the home at time of sale squared				
prioranc	0.000006	0.00	28.55	0.000
preanc	0.000005	0.00	17.03	0.000
postancprecon	0.000006	0.00	20.01	0.000
postcon	0.000008	0.00	26.4	0.000
number of bathrooms				
prioranc	0.064	0.00	29.22	0.000
preanc	0.079	0.00	17.98	0.000
postancprecon	0.084	0.00	20.31	0.000
postcon	0.111	0.00	25.54	0.000
sale year				
1998	-0.52	0.007	-73.48	0.000
1999	-0.41	0.007	-58.44	0.000
2000	-0.26	0.007	-37.59	0.000
2001	-0.13	0.007	-18.03	0.000
2002	0.02	0.007	2.33	0.020
2003	0.14	0.007	21.26	0.000
2004	0.24	0.007	37.05	0.000
2005	0.31	0.006	49.32	0.000
2006	0.28	0.006	43.94	0.000
2007	0.23	0.006	37.58	0.000
2008	0.12	0.006	18.43	0.000
2009	0.04	0.006	7.29	0.000
2010	0.04	0.006	6.15	0.000
2011	-0.02	0.006	-3.74	0.000
2012	Omitted			
sale quarter				
1	-0.07	0.002	-28.05	0.000
2	-0.02	0.002	-9.56	0.000
3	Omitted			
4	-0.01	0.002	-3.03	0.002

n	**122,198**
R^2	**0.80**
Adj R^2	**0.80**
F	**2418**

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Rhode Island
Land-Based Wind Siting Guidelines

Applicable to proposed turbines ≥ 200 feet in height or rated to produce ≥ 100 kW of power

January 2017

This document provides information and helpful guidance for Rhode Island municipalities interested in establishing new (or revising existing) terrestrial wind turbine siting ordinances for their community. The information within this document is based on best practices in other New England, national, and international jurisdictions; input from the public, state agencies, and industry stakeholders; previous wind siting guidance documents created for Rhode Island; and a literature review of scientific, peer-reviewed journals. The information and recommendations presented within should not be deemed mandates by the Rhode Island Office of Energy Resources (OER). For more information, please contact OER at (401) 574-9100 or energy.resources@energy.ri.gov.

Table of Contents

Glossary of Terms

A-weighted decibel level (dB(A))	The decibel is a unit used to measure the intensity of sound. Specifically, it is a logarithmic measure of sound pressure levels. An A-weighted decibel measurement has been filtered to better represent how humans sense sound. It discounts frequencies near the top and bottom of the human range of hearing.
Capacity Factor	A capacity factor is a ratio or percentage that represents a wind turbine's actual energy output versus its maximum potential energy output. The value is typically reported as an annual figure, not monthly, hourly or instantaneously. The maximum potential energy output assumes the turbine can operate at its nameplate capacity continuously throughout one year.
Cut-in speed	The minimum wind speed needed for a wind turbine to begin generating electricity.
Hub	The hub is part of the turbine's rotor. It is where the blades attach to the turbine.
Nacelle	The housing component located at the top of the tower that contains much of the turbine's mechanical systems. It is connected to the turbine's rotor.
Noise	Any sound that is objectionable, loud, unpleasant, or that causes disturbance.
Octave Band	A frequency band encompassing a range of frequencies, the highest of which is twice the frequency of the lowest. For example, the 1kHz octave band (named for its center frequency) will encompass frequencies from 707Hz to 1,414Hz.
Pure tones	Often defined as when an octave band center frequency sound pressure level exceeds the two adjacent center frequency sound pressure levels by 3 decibels or more.
Rotor	The rotating assembly consisting of a wind turbine's blades and connecting hub, located at the top of the tower.
Short Duration Repetitive Sounds	For wind turbines, this phenomenon is defined as a sequence of repetitive sounds that occur within a 10-minute measurement interval. Each sound must be clearly discernible as an event resulting from the wind development and must cause an increase on the fast meter response of 5 dBA or greater above the sound level observed immediately before and after the event. Each event is typically ±1 second in duration, and must be inherent to the process or operation of the wind development. Please see Maine's No Adverse Environmental Effect Standard of the Site Location Law, Section I:

	Sound Level Standards for Wind Energy Developments[1] for more information.
Sound	Any variation in pressure that the human ear can detect. Sounds that are objectionable or unpleasant are referred to as "noise."
Total height	The distance from the base of the turbine to the tip of a turbine blade when the blade is pointed at the 12 o'clock position.

[1] http://www.maine.gov/sos/cec/rules/06/096/096c375.doc

Introduction

Wind development in Rhode Island dates back over a decade, when the first commercial-scale wind turbine was installed in 2006 at the Portsmouth Abbey. Since then, over 22 MW of wind – representing 21 systems 100 kW or larger – have been installed in the state. Now, policy initiatives, such as the Renewable Energy Growth Program (REG Program) and net metering, are expected to generate increased demand in Rhode Island's growing wind energy market.

Local wind energy projects can provide important energy, economic, and environmental benefits to the people and communities of Rhode Island. Wind projects offer the potential to diversify Rhode Island's electricity supply portfolio while reducing greenhouse gas emissions from the power sector. Local wind projects can also help reduce energy purchase costs, provide a hedge against future price volatility, support distributed generation, and generate in-state investment and economic activity. For individual cities and towns, wind projects may provide tax or lease revenues, preservation of open space, price stability, diversified electricity sources, and local jobs.

On the other hand, wind projects may pose certain types of public safety, community and environmental impacts. These potential impacts can include turbine collapse/topple, blade throw, ice shedding/throw, noise, shadow flicker, environmental impacts such as bird and bat mortalities, and visual and signal interference. However, proper siting of wind turbines can mitigate or avoid such impacts. This document reviews major siting considerations for wind projects in Rhode Island and provides recommended (non-mandated) standards for communities to consider when addressing potential impacts.

In Rhode Island, individual municipalities hold the authority to regulate the siting of wind turbines through zoning ordinances. State law charges the Office of Energy Resources (OER) and Division of Planning (DOP) with issuing guidelines to assist cities and towns as they develop wind siting ordinances.[2] In 2012, DOP issued a technical report, "Interim Siting Factors for Terrestrial Wind Energy Systems,"[3] which put forth guidelines for siting wind turbines in municipalities. This document, prepared by OER, is an update to the interim draft guidelines prepared by DOP in 2012.

Rhode Island cities and towns are required to adopt and maintain community comprehensive plans. These plans must include a section addressing energy issues, including the consideration of renewable energy.[4] However, there is no specific requirement on individual Rhode Island municipalities to pursue wind projects.

This document contains the following sections and appendices:

- **Background** – This section contains background information on wind energy in Rhode Island; policies and programs related to wind; and past wind siting initiatives in the state.

- **Zoning Considerations for Municipalities** – This section outlines the process and steps for municipalities as they embark on developing wind siting ordinances.

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[2] http://webserver.rilin.state.ri.us/Statutes/TITLE42/42-11/42-11-10.HTM
http://webserver.rilin.state.ri.us/Statutes/TITLE42/42-140/42-140-3.HTM
[3] http://www.planning.ri.gov/statewideplanning/land/energy.php
[4] http://www.planning.ri.gov/documents/comp_handbook/0_Standards.pdf
http://www.planning.ri.gov/documents/comp_handbook/9_Energy.pdf
http://www.planning.ri.gov/documents/LU/energy/energy15.pdf

- **Siting Impacts and Recommended Standards** – This section identifies the major potential siting impacts of wind projects and provides recommended standards for addressing impacts.

- **Municipal Development Proposal Checklist** – This section contains a checklist for municipal officials to reference as they consider development proposals for wind projects.

- **Rhode Island Wind Turbine Case Studies** – This section provides case studies of existing wind turbines in Rhode Island, including background information and project details.

- **Sample Wind Ordinance** – This section contains a sample wind ordinance from Massachusetts for municipal officials to reference as they develop zoning ordinances for wind projects.

- **Example Waiver Language** – This section contains waiver language used in the state of Connecticut for wind turbine siting. The language illustrates the need for flexibility in wind siting standards and procedures.

- **Increased Impact Special Use Permit Procedure** – This section provides a sample remonstrance procedure for wind turbine special use permits. The procedure was created by modifying South Kingstown's Liquor License remonstrance process.

Background

This section contains background information on wind energy in Rhode Island; policies and programs related to wind; and past wind siting initiatives in the state.

Overview of Wind Energy in Rhode Island

Wind turbines use the energy of moving air to generate electricity.[5] Turbines produce more power at higher wind speeds, which are typically found in areas with higher elevation relative to surrounding terrain and low surface roughness. In Rhode Island, the most significant wind energy resources are concentrated in areas along the coast and offshore in ocean waters. However, some modern day commercial scale wind turbines are designed to perform more effectively at low wind speeds and these turbines can be economically viable throughout portions of the state.

The use of wind to generate electricity is a relatively new undertaking in Rhode Island. The first modern commercial-scale wind turbine was installed in 2006 at the Portsmouth Abbey. However, a large wind turbine with a 100ft tower did operate on Block Island as early as 1979 [1]. As a small and densely populated state, Rhode Island does not lend itself to large land-based wind farms of the type seen in the Midwestern and Western states. Instead, Rhode Island's wind power potential lies in the opportunity to develop multiple municipal or small-scale commercial projects consisting of one or a few wind turbines, and in offshore wind farms.

As of December 2014, the Ocean State had an installed nameplate wind capacity of approximately 22 MW, with 21 systems 100 kW or larger (Figure 1). In 2016, Deepwater Wind LLC completed construction on the nation's first offshore wind installation, a five-turbine, 30 MW wind farm in state waters off the coast of Block Island. A much larger offshore wind project – up to 1,000 MW – is planned for development in federal waters off of Rhode Island and Massachusetts. In addition, ten 1.5 MW land-based wind turbines are currently in construction in the Town of Coventry..

Figure 1. Rhode Island Wind Turbines

Name	Location	System Size	Height	Date Installed
Portsmouth Abbey	Portsmouth	660 kW	240 ft.	2006
Aquidneck Corporate Park	Middletown	100 kW	157 ft.	2009
New England Tech	Warwick	100 kW	157 ft.	2009
Portsmouth High School*	Portsmouth	1.5 MW	336/414 ft.	2009/2016
Fishermen's Memorial Campground	Narragansett	100 kW	157 ft.	2011
Hodges Badge	Portsmouth	225 kW	158 ft.	2011
Shalom Housing	Warwick	100 kW	157 ft.	2011
Narragansett Bay Commission #1	Providence	1.5 MW	365 ft.	2012
Narragansett Bay Commission #2	Providence	1.5 MW	365 ft.	2012
Narragansett Bay Commission #3	Providence	1.5 MW	365 ft.	2012
Sandywoods Farm	Tiverton	275 kW	231 ft.	2012
North Kingstown Green	North Kingstown	1.5 MW	402 ft.	2013
Coventry Turbine #1	Coventry	1.5 MW	414 ft.	2016

[5] For more information on how wind technology works, visit: http://energy.gov/eere/wind/how-do-wind-turbines-work or http://energy.gov/articles/how-wind-turbine-works

Coventry Turbine #2	Coventry	1.5 MW	414 ft.	2016
Coventry Turbine #2A	Coventry	1.5 MW	414 ft.	2016
Coventry Turbine #2B	Coventry	1.5 MW	414 ft.	2016
Coventry Turbine #3	Coventry	1.5 MW	414 ft.	2016
Coventry Turbine #4	Coventry	1.5 MW	414 ft.	2016
Coventry Turbine #6	Coventry	1.5 MW	414 ft.	2016
Coventry Turbine #6A	Coventry	1.5 MW	414 ft.	2016
Coventry Turbine #6B	Coventry	1.5 MW	414 ft.	2016

*Two values are displayed in the Height and Date Installed columns for this turbine because it was shut down in June of 2012 due to a gearbox failure and replaced with a direct drive turbine in July of 2016.

FAQ's

1. How much wind power potential exists in Rhode Island?

The State's most significant wind energy resource from a power production standpoint is offshore wind. The 2007 RIWINDS study, commissioned by the Rhode Island Economic Development Corporation (now the Rhode Island Commerce Corporation, or Commerce RI), concluded that over 95 percent of the wind energy resources available to Rhode Island are located offshore. Subsequent renewable energy resource assessments conducted in 2012 through the Renewable Energy Siting Partnership (RESP) helped further quantify the resource opportunities for land-based wind. Overall, land-based wind energy resources are modest in Rhode Island compared to other regions of the country. However, important in-state opportunities exist for developing land-based wind energy.

2. How many wind turbines are there in Rhode Island?

As of December 2014, the Ocean State had an estimated installed wind capacity of approximately22 MW, with 21 systems 100 kW or larger. See Appendix B "Rhode Island Wind Turbine Case Studies" to learn more about existing wind turbines in the state.

3. How much of Rhode Island's electricity needs does wind energy provide?

As of 2014 Rhode Island consumes approximately 8,000 GWh of electricity each year. Assuming a 20% capacity factor (see question 4 below), existing Rhode Island wind turbines generate a total of about 16,000 MWh per year. Therefore, in-state wind turbines currently offer enough supply to meet roughly 0.2% of Rhode Island's electricity needs. For perspective, wind energy provided 10.5% of U.S. electricity in 2014.

4. What is a capacity factor and what does it mean for wind power?

Because the wind doesn't always blow and wind speeds often vary, wind turbines don't produce power at their maximum capacity all of the time. A capacity factor is a ratio or percentage that represents a wind turbine's actual energy output versus its maximum potential energy output. Wind turbines located in areas with more wind resources have higher capacity factors. In Rhode Island, onshore wind turbines typically see capacity factors around 20%. Because the wind blows more strongly off the coast, offshore wind turbines in Rhode Island are expected to achieve capacity factors approaching 50%.

5. How many homes can a wind turbine power?

A typical 1.5 MW onshore wind turbine in Rhode Island can power the equivalent of approximately 440 homes annually, assuming a 20% capacity factor and an average monthly household use of 500 kWh. A 6 MW offshore wind turbine in Rhode Island can power the equivalent of more than 4,000 homes annually, assuming a 48% capacity factor and an average monthly household use of 500 kWh.

6. How much carbon dioxide does a wind energy turbine offset?

A typical 1.5 MW onshore wind turbine in Rhode Island can offset approximately 870 metric tons of carbon dioxide annually, assuming a 20% capacity factor and a New England carbon dioxide emissions rate of 730 lb/MWh. Eliminating 870 metric tons of carbon dioxide is the same as preventing the annual emissions of about 180 vehicles.

Policy Context

Energy 2035, the Rhode Island State Energy Plan, adopted in October 2015, demonstrated that renewable and other no-to-low carbon energy resources will play an important role in helping Rhode Island achieve its energy, economic, and environmental goals. The Plan recommends increasing the share of renewable energy in Rhode Island's electricity supply through a mix of clean energy imports, distributed renewable generation, and in-state, utility-scale projects. Local renewable energy projects, such as land-based wind, are part of this multi-tiered approach to promoting renewable energy.

Wind projects can help diversify Rhode Island's electricity supply portfolio, which is currently dominated by natural gas both in-state and regionally. Local wind generation can reduce costs and power losses associated with transporting electricity long distances. It can also reduce the demands on the grid during periods of peak electricity use. By reducing the need to burn fuel, local wind projects can provide health and environmental benefits, price predictability and a hedge against volatile fossil fuel and electricity prices. In-state investment, economic growth, and job creation can also be spurred through the construction and operation of local wind projects.

Land-based wind is anticipated to play a supportive role in helping Rhode Island achieve the goals established in the State Energy Plan. The Plan projects the need for over 500 MW of local, distributed renewable energy systems developed by 2035.

As of 2016, the state has two primary policy initiatives for supporting the development of in-state, land-based wind projects: the Renewable Energy Growth Program (REG Program) and net metering. The two programs are further described below. For more information on Rhode Island's major energy laws, please visit www.energy.ri.gov or see Appendix A of *Energy 2035, Rhode Island State Energy Plan* "Rhode Island Energy Laws."

The REG Program will support the development of 160 MW of new renewable energy projects in Rhode Island between 2015 and 2019. The REG Program is the successor program to the 40 MW Distributed Generation Standard Contracts Program (DG Program) that was in place from 2011 to 2014. The REG Program replaced the contract-based DG Program with a new system of performance-based incentives set in tariffs filed at and approved by the Public Utilities Commission. Eligible technologies include wind, solar, hydropower, and anaerobic digestion.

Net metering requires electric distribution companies to credit energy produced by small renewable energy systems (under 5 MW) installed on the customer's side of the electric meter. Eligible systems must be sized to meet on-site loads, based on a three-year average of electricity consumption at the property. Customers receive credit at the electric distribution company's avoided cost rate for excess generation produced by a net-metered system, up to 125 percent of the customer's own consumption during a billing period. To participate in net metering, a renewable energy system must be sited on the customer's premises, with certain exceptions for public sector projects, farms, affordable housing, and residential projects.

Wind Siting in Rhode Island

Siting wind energy projects involves a careful consideration of both the available wind resource and the potential impacts a project may pose to the surrounding area. A number of public-private partnerships and state initiatives have evaluated siting considerations associated with offshore and onshore wind in Rhode Island:

Ocean Special Area Management Plan (SAMP)

The Ocean Special Area Management Plan (SAMP)[6] was a planning and regulatory development process conducted by the Coastal Resources Management Council (CRMC) to promote, protect, enhance, and honor existing human uses and natural resources in the coastal waters of Rhode Island, while encouraging economic development, creating renewable energy siting zones, and facilitating the coordination of state and federal decision making bodies. Adopted October 19, 2010, the Ocean SAMP informed the siting of Rhode Island's first offshore wind farm in state waters off Block Island and will direct the future siting of utility-scale wind farms in Rhode Island Sound.

Division of Planning Wind Siting Guidelines

In 2012, the Division of Planning (DOP) released a technical report, "Interim Siting Factors for Terrestrial Wind Energy Systems," which put forth guidelines for siting wind turbines in municipalities. DOP produced this report as part of an overarching statutory charge to develop siting guidance for the location of renewable energy facilities in the state. The law directed the DOP to consider standards and guidelines for the location of eligible renewable energy resources and facilities with consideration for the location of such resources and facilities in commercial, industrial, and agricultural areas, areas occupied by public and private institutions, and property of the State, and in other areas of the state as appropriate. For more information on the DOP Wind Siting Guidelines, please visit: www.planning.ri.gov/statewideplanning/land/energy.php.

Renewable Energy Siting Partnership (RESP)

In response to questions about the effects that the increased development of renewable energy may have on the people and communities of Rhode Island, the State initiated the Renewable Energy Siting Partnership (RESP) in 2011. The RESP spearheaded a statewide conversation among residents, municipalities, and other stakeholders about the benefits and impacts of renewable energy development in the state. The RESP evaluated impacts of land-based wind turbines on birds and bats, scenery, cultural values, property values, and public safety, as well as acoustic, shadow flicker, and electromagnetic

[6] http://seagrant.gso.uri.edu/oceansamp/

interference impacts. The RESP also performed an analysis of modeled wind speed values and confirmed modeled estimates with data collected at specific sites. Drawing on analysis of impacts and wind resource data, the RESP performed a siting analysis to visualize the distribution of wind energy opportunities and constraints around the state. For more information on the RESP, please visit: www.crc.uri.edu/projects_page/rhode-island-renewable-energy-siting-partnership-resp/.

Property Values & Acoustic Impacts Studies

The Rhode Island Office of Energy Resources (OER) commissioned two follow-up studies to the RESP: a property values study and an acoustics study. The purpose of the property values study was to assess the effect that existing onshore wind turbines have on nearby residential property values in Rhode Island. The report concluded that "across a wide variety of specifications, the results indicate that wind turbines have no statistically significant impact on house prices…. Our principle finding is that the best estimate is that there is no price effect, and we can say with 90% level of confidence if there is a price effect, it is roughly 5.2% or less." To see the full report, please visit: www.energy.ri.gov/documents/Onshore%20Wind/Final%20Property%20Values%20Report.pdf.

Another report conducted by the University of Connecticut and the Lawrence Berkeley National Laboratory in 2014 studied wind turbines and property values in Massachusetts. This study analyzed 122,198 single-family home sales, occurring between 1998 and 2012, within 5 miles of 41 wind turbines. The results of the study were very similar to the findings reported in the Rhode Island property value study above. In particular, the study states, "The results of this study do not support the claim that wind turbines affect nearby home prices."[2]

The purpose of the acoustics study commissioned by OER was to advance an understanding of the acoustic impacts of wind turbines in Rhode Island. The study recorded and analyzed radiated sound from wind turbines currently installed in Rhode Island. It also discusses the variability of both ambient sounds and sounds emanating from the wind turbines. The full report can be found here: www.energy.ri.gov/documents/Onshore%20Wind/FINAL_REPORT_RIOER%2020140711.pdf

DEM Terrestrial Wind Turbine Siting Report

In 2009, the Rhode Island Department of Environmental Management (DEM) created a Terrestrial Wind Turbine Siting Report. Although several years old, this report still offers some valuable insight related to siting wind turbines in environmentally sensitive, coastal areas. To access the report, please visit: www.dem.ri.gov/cleannrg/pdf/terrwind.pdf.

Zoning Considerations for Municipalities

This section outlines the process and steps for municipalities to consider as they embark on developing wind siting ordinances. The following is a recommended process based on best practices.

Municipalities should use the existing structure built into their zoning to direct wind development to ideal areas and away from controversial areas. This requires two steps:

1. Municipalities should review their "use tables" and identify whether wind turbines should be a permitted use, special (or "conditional") use, or prohibited use in different types of zoning districts. Use tables allow municipalities to steer potential development activities to locations well-suited for wind projects relative to existing or planned land use activities, and away from areas that a municipality may view as less suitable for wind development. Figure 2 displays an illustrative example of wind projects in a use table.

Figure 2. Illustrative Municipal Use Table

Use	**High Density Residential Zone**	**Low Density Residential Zone**	**Commercial Zone**	**Industrial Zone**
Wind Projects (≥100 kW)	Prohibited	Special Use Permit	Special Use Permit	Permitted

2. Municipalities should then identify the required standard for each siting impact in each zone. The "Siting Impacts and Recommended Standards" section provides recommended standards for several categories of siting impacts: public safety impacts, community impacts, and environmental impacts. Public safety standards should not vary by zone. Community impact and environmental impact standards, however, may vary by zone.

3. Figure 3 displays an example of illustrative municipal wind siting standards for different zones. For more details regarding each standard, please see the Setback, Noise, and/or Shadow Flicker sections of this document.

Least Restrictive	(green)
Less Restrictive	(yellow)
Most Restrictive	(red)

Figure 3. Illustrative Municipal Wind Siting Standards

Siting Impact	**High Density Residential Zone**	**Low Density Residential Zone**	**Commercial Zone**	**Industrial Zone**
Setback	1.5x	1.5x	1.5x	1.5x
Noise	40 dB(A)	40dB(A)	65 dB(A)	75 dB(A)
Shadow Flicker	Max 30 hrs/yr at occupied structures or sites permitted for occupied structure construction at time of wind project permitting (using **worst-**	Max 30 hrs/yr at occupied structures or sites permitted for occupied structure construction at time of wind project permitting (using **worst-**	Max 30 hrs/yr & at occupied structures or sites permitted for occupied structure construction at time of wind project permitting (using	Max 30 hrs/yr at occupied structures or sites permitted for occupied structure construction at time of wind project permitting (using

Least Restrictive	(green)
Less Restrictive	(yellow)
Most Restrictive	(red)

	case scenario modeling)	case scenario modeling)	realistic modeling)	realistic modeling)

Siting Impacts and Recommended Standards

This section identifies the major potential siting impacts of wind projects and provides recommended standards for addressing impacts. All recommended standards should be applied at the time of project permitting. Table 1 displays a summary of the wind siting impacts considered and the recommended standards:

Table 1. Summary of Rhode Island Wind Siting Impacts and Recommended Standards

Category	Siting Impact	Recommended Standard
Public Safety Impacts	Setbacks to Prevent Personal Injury and/or Property Damage (turbine collapse/topple, blade throw, and ice shedding/throw)	Setbacks equal to 1.5 x total turbine height from the closest point of property lines, public or private ways, and occupied buildings, or manufacturer's specifications, whichever is largest.
Community Impacts	Noise	Option 1 relies on existing municipal maximum sound levels Option 2 is based on measured levels of ambient noise (see Noise section).
	Shadow Flicker	No more than 30 hours per year at occupied structures or sites permitted for occupied structure construction at time of wind project permitting (using worst-case scenario modeling).
	Other Impacts (Visual & Signal Interference)	Require a viewshed analysis and photographic renderings. Also require turbine developers to notify nearby communication towers prior to construction. If communication issues arise additional transmitter masts should be installed at the wind developer's expense or the developer should be responsible for finding another, mutually agreeable solution.
Environmental Impacts	Environmental Impacts	Require pre- and potentially post-construction site characterization visits and/or surveys as outlined by the USFWS's voluntary guidelines. Also engage with RI DEM, USFWS, and other appropriate environmental groups for comments and recommendations.

As municipalities set standards for the following wind siting impacts, the following considerations should be kept in mind:

- Recommended standards should be applied at the time of project permitting.
- It is recommended that municipalities consider options for less stringent standards for community impacts where applicable and appropriate. Specifically, municipalities may choose to propose less stringent standards for community impacts in zones with fewer sensitive receptors, for example—commercial or industrial zones.

- It is recommended that municipalities do not propose less stringent standards for public and environmental safety impacts within their ordinances.
- It is recommended that municipalities measure most standards with respect to abutting property lines, not just at occupied buildings, as a property owner may wish to develop an undeveloped part of his/her lot in the future. Shadow flicker standards are a critical exception to this rule.
- Expert reviewers or consultants may be needed by a municipality to evaluate the technical aspects of a wind turbine project proposal. It is recommended that municipalities set a limit or negotiate a maximum cost to the wind developer for these services prior to a proposal review. OER is able and willing to provide assistance to municipalities as they navigate issues related to hiring third party consultants.
- Projects with impacts reaching across town lines should be required to work with each town. The developer should comply with the siting standards of each impacted area's governing municipality.
- Providing flexibility in siting standards is an essential part of any wind siting ordinance. Blanket standards do not allow regulations to be molded to the needs of different sites and different project neighbors. If landowners are willing to assume greater risk or exposure to siting impacts, they should be allowed to do so within reason. Other states such as Connecticut use waivers to provide this flexibility within their siting standards (See Appendix D for Connecticut's waiver language). However, Rhode Island's Zoning Enabling Act differs from Connecticut's zoning laws and the use of waivers in Rhode Island may be legally prohibited. We recommend that municipalities obtain legal counsel with expertise in zoning prior to finalizing their wind siting ordinances. As an alternative to waivers, it is recommended that Rhode Island municipalities create two types of special use permits for terrestrial wind turbine projects. The first type of permit or special use permit should be granted for wind turbine projects meeting a municipality's specified siting standards and located within a wind-permitting zone (i.e. within a zone that allows wind turbines as a 'permitted' or 'special' use). The second type of special use permit should be granted if a project exceeds the impact levels allowed by the municipality but the municipality's Zoning Board still wishes to permit the development after having heard the opinions of all landowners who will experience the increased impacts. In order to differentiate between special use permits granted for projects meeting siting standards versus those granted due to a lack of opposition/individual Zoning Board decisions, this document will refer to them as 'special use permits' and 'increased impact special use permits' (IISUPs) respectively.
- Clearly written IISUPs and IISUP notification letters are an essential part of wind siting guidelines as they allow regulations to be better molded to the needs of different sites. However, reviewing these types of special use permit requests can require extensive technical expertise and a comprehensive understanding of site details. Therefore, it is encouraged that municipalities reach out to appropriate departments and agencies during IISUP reviews. In general, the Rhode Island Office of Energy Resources is well equipped to provide IISUP guidance and decision-making support. Please see Appendix E for a sample review procedure.

* * * * *

Setbacks

<u>Description of Impacts</u>

There are three main safety concerns associated with proximity to large scale wind turbines: turbine collapse/topple, blade throw, and ice shedding/throw. These concerns are usually tied to extreme weather events[3][4]. Although both tower collapse/topple and blade throw events are rare, they have the potential to be catastrophic due to the size and location of the equipment.

Turbine collapse or topple describes the failure of a turbine's support structures, such as the foundation or tower. The failure of such support structures can result in the turbine tumbling to the ground. In this situation, setbacks slightly larger than the total turbine height are likely sufficient to protect the public from turbine collapse or topple.

Blade throw describes a failure scenario in which a blade or section of a blade becomes detached from the turbine structure. Due to the rotation of the blades, these detached pieces can be thrown away from the turbine base. The distance thrown can vary significantly depending on variables such as turbine rotor speed, blade release angle, wind velocity, mass of detached piece, and turbine height [5].

A final safety concern is ice throw or shedding. During certain weather conditions, it is possible for ice to accumulate on the blades and tower of a turbine. If the turbine rotor is not rotating, ice fall risk is similar to that of other tall stationary structures such as communication towers and buildings. However, if turbines continue to operate during icing conditions, spinning blades may throw ice debris a significant distance from the tower base. An empirically derived equation presented in the 2000 Wind Energy in Cold Climate Final Report, defines a maximum throwing distance as 1.5 times the sum of the turbine's hub height and rotor diameter [6]. This equation only provides a rough estimate of a risk zone, but when coupled with conservative operation protocols and/or modern ice-sensing technologies it can actively prevent dangerous ice throw scenarios.

Proper siting and operational practices can effectively mitigate all three of these safety concerns. Connecticut and Maine have set a precedent for using 1.5 times the total turbine height as a public safety setback. Massachusetts also calls for this setback value in their model zoning ordinances created by the Massachusetts Department of Energy Resources and the Massachusetts Executive Office of Environmental Affairs.

<u>Recommended Standards</u>

	Minimum Setback to Private or Public Ways not located on the property being developed	**Minimum Setback to Property Lines**	**Minimum Setback to Any Occupied Building not located on the property being developed**	**Include Language for IISUPs**
Recommended for Rhode Island	1.5 x Total Turbine Height	1.5 x Total Turbine Height	1.5 x Total Turbine Height	Yes

- Total turbine height is defined as the distance from the base of the turbine to the tip of a turbine blade when the blade is pointed at the 12 o'clock position.
- Setback distances should be measured from the closest edge of the turbine base to the closest point of the occupied building, property line, or private or public way.
- If a private or public way or occupied building located on the property being developed will not have a 1.5x setback, the developer should notify the land owner and submit an acknowledgement of the lessor setback signed by the land owner to the municipality.
- If a manufacturer's setback recommendations are larger than the minimums listed above, the manufacturer setback values should be applied to the installation.

- Only turbines meeting International Electrotechnical Commission (IEC) or similar certifications should be permitted.
- Signage should be considered as a means of providing extreme weather warnings to the public. Phrases such as "stay clear if wind is over ## mph or if ice is visible on blades or towers" may be advisable along the outer perimeter of a wind development's setback distance.
- Temporary shutdown or idling procedures should be required for turbines during ice shedding conditions unless proven de-icing technologies, larger than minimum setbacks, or limited human access to surrounding areas can be demonstrated.
- Increased impact special use permits (IISUPs) for lesser setback distances should be granted if all landowners who will experience smaller setback distances do not object.

FAQ's

1. What setbacks do other states recommend?

Below is a summary table of wind turbine setbacks employed by other New England states in 2015.

	Setback Min. to Private or Public Ways	Setback Min. to Property Lines	Setback Min. to Wind Site Structures (buildings, critical electric infrastructure)	Setback Min. to Residential or Commercial Structures	Includes Language for Setback Waivers
CT[7]	Not Mentioned	1.5 (for WT facility < 65MW) 2.5 (for WT facility > 65MW) Or manufacturer recommendations, whichever is larger	Not Mentioned	1.5 ("occupied residential structure")	Yes
MA[8]	1.5	1.5	1.5	3.0	Yes
VT[9]	None	None	None	None	None
NH[10]	Not established	Not established	Not established	Not established	Not established
ME[11]	Not Mentioned	1.5 Or setback requirements for local zoning classification, whichever is larger	Not Mentioned	Not Mentioned	Yes
RI 2012[12]	1.25-1.5	1.5 (2.0 for residential property lines)	None	None	Yes

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[7] http://www.cga.ct.gov/aspx/CGARegulations/CGARegulations.aspx?Yr=2014&Reg=2012-054&Amd=E http://www.ct.gov/csc/lib/csc/regulations/final_clean_copy_wind_regs.pdf

[8] http://www.mass.gov/eea/docs/doer/gca/wind-not-by-right-bylaw-june13-2011.pdf and http://www.mass.gov/eea/docs/doer/gca/as-of-right-wind-bylaw-june-2011.pdf and http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/wind/wind-energy-model-zoning-by-law.html

[9] http://psc.wi.gov/renewables/documents/windSitingReport2014.pdf (summary of all state guidelines from Oct 2014)

[10] http://www.nh.gov/oep/energy/programs/documents/sb99-rulemaking-final-deliverable.pdf

[11] http://www.maine.gov/dep/land/sitelaw/windpower/ and http://www.maine.gov/dep/land/sitelaw/application_text.pdf

[12] http://www.planning.ri.gov/documents/LU/energy/Wind_Energy_FacilityGuidelines_June-2012_.pdf

2. **Why should a turbine be certified by the IEC or other certification body?**

   Third party certification can help to verify a turbine's capabilities and safety. For example, international standards such as the IEC 61400-23 and IEC 61400-5 are available for wind turbine blades. If a turbine meets these blade-specific standard**s**, the blade is certified to operate for a 20 year lifespan under testing conditions. Meeting these standards can help to lessen blade throw risks, especially when paired with redundant systems to stop turbine operation during severe weather or wind events. These types of certifications are intended to provide for public safety while ensuring manufacturers meet design, performance and reliability standards. It is important that wind developments meet the most current standards at the time of construction.

3. **Is there failure rate data for modern, U.S. wind turbines?**

   Unfortunately, U.S. turbine failure data is very limited. There are no requirements or incentives for U.S. turbine manufacturers or operators to publicly report turbine failures. The U.S. also lacks a regulatory body charged with compiling and verifying failure events. Therefore, failure risk data specific to U.S. turbines and climate conditions is not currently available.

4. **How far away can a blade or piece of a blade be thrown?**

   Due to the lack of U.S. turbine failure data, there is little empirical evidence to define how far a turbine blade, or part of a blade, could be thrown. A 2005 study of German and Denmark wind turbine failures occurring between the years of 1984 to 2001, identified a maximum throw distance of 500 meters. However, this data is unlikely to reflect modern turbine blade throw risks [3].

5. **Why are increased impact special use permits (IISUPs) important for setback requirements?**

   Special use permits provide flexibility in the siting standards. They allow the standards to be molded on a case-by-case basis. For example, consider the following scenario: a developer wishes to build a turbine closer to a neighbor's property line than allowed by the setback standards. However, the property within the required setback contains wetlands where development can't occur. In this case, the property owner might encourage the Zoning Board to accept the increased risk on his wetlands by not objecting to issuance of an IISUP. IISUPs may play an important role in turbine siting, especially in more densely developed areas.

6. **How often do icing weather conditions occur in Rhode Island?**

   According to the 2012 Rhode Island Renewable Energy Siting Partnership report, Rhode Island usually experiences wind turbine icing conditions 0-2 times per year.

7. **What are mitigation strategies for ice throw?**

   If icing is expected to be a problem, operation protocols can be established to prevent blade rotation during icing conditions. Sensors and visual observations can help identify when operation should be halted due to ice buildup. Multiple blade de-icing technologies are also in different stages of research and development. In the future, there will likely be viable technologies to prevent the buildup of ice on wind turbine blades.

* * * * *

Noise

Description of Impact

Noise is generally considered the point at which sound becomes bothersome due to intensity (loudness) or tonal quality (frequency). Reducing the noise emanating from wind turbines that will negatively impact people in the surrounding area should be the objective of siting standards.

There are several critical sound parameters to bear in mind in developing ordinances:

- Sound pressure level (dB) at the source.
- Distance from the sound source to the impacted parties.
- Sound propagation from source to impacted parties. Sound propagation varies depending on wind direction and speed, wind shear, turbulence, terrain vegetation, atmospheric conditions (humidity, rain, snow, etc.). For example, the impact can vary significantly going “with the wind” vs. “against the wind.”
- Ambient noise levels in the area surrounding the wind turbine. Ambient noise levels vary throughout the day and can likewise change the perception of noise emanating from a wind turbine.

When operating, wind turbines produce both mechanical and aerodynamic sound. Mechanical sound is largely generated by turbine components, such as the generator or gearbox, located in the turbine nacelle. This sound is relatively easy to mitigate via nacelle sound insulation.

Aerodynamic sound, on the other hand, comes from the interaction between the air, the rotating turbine blades and the tower. This sound is often complex and can vary with weather, wind speed, blade angle and other parameters. Together, both sound sources radiate sound away from the turbine and can increase the sound levels of the surrounding area.

Recommended Standards

Municipalities are encouraged to choose between two recommended options for establishing noise standards for wind turbine development. Option 1 is based on existing municipal maximum sound levels; Option 2 is based on levels of ambient sound. Both options consider sound levels at abutting property lines. Both options should also include language for increased impact special use permits (IISUPs); should require complaint collection, disclosure, and investigation procedures; and should establish a pre-set limit on the frequency and/or total number of times compliance testing can be required. It is recommended that municipalities begin with Option 1 as it is the easiest to implement and the least burdensome to wind turbine developers. However, if zones are expected to be sensitive to changes in sound levels, Option 2 can provide a more conservative standard.

Option 1: This approach uses existing municipal maximum sound levels (dB(A)) set for each zone – these values are often described in municipal noise ordinances.

The turbine developer will need to predict the turbine’s sound pressure level via modeling at the points of interest. It is recommended that the most up-to-date IEC standards for sound power levels (IEC 61400-11 ed 3 as of 2015) be used for the proposed turbines and any additional anticipated sound emitting equipment (for example, substation transformers). These sound power levels should then be used in the most current ISO outdoor sound pressure propagation methods (ISO 9613-2 as of 2015) to develop a sound contour map of the project and to predict turbine sound at surrounding property lines. Other accurate sound modeling options, such as NORD200 software, should also be accepted. All efforts to be reasonably conservative in this modeling should be taken. The predicted sound levels should include one scenario that is based on the maximum turbine sound power level with a typical vendor uncertainty (e.g. +2 dB(A)) using mixed or hard ground conditions (i.e., ISO 9613-2 Ground Absorption factor (G) for fully absorptive ground (G=1) should not be relied on).

The predicted project sound levels or sound contours are representative of project-only sound levels. The total sound level that one would hear or measure after project completion is the acoustic sum of the project sound level and the existing, background sound level. Therefore, L_{EQ} values in dB(A) should be predicted by the modeling efforts for each abutting property line. The L_{EQ} metric is a common way to describe sound levels that vary over time. It is a single A-weighted decibel value which takes into account the total sound energy over the period of time of interest (please see the Glossary of Terms for an explanation of A-weighted decibel level). All efforts to be conservative in modeling this L_{EQ} value for wind developments should be taken—i.e. worst case scenarios should be applied where appropriate.

The resulting conservative L_{EQ} value(s) that represent project-only sound levels, should be compared to the municipal maximum sound limits (MMSL). If the logarithmic sum of MMSL + L_{EQ} is less than or equal to 1 dB(A) above MMSL, then the turbine should be permitted with respect to noise. If the logarithmic sum of MMSL + L_{EQ} is greater than 1dB(A) above MMSL, then the turbine would be considered too loud for the abutting property(ies) unless increased impact special use permits (IISUPs) are obtained.

> PROs of Option 1: The time, costs, and uncertainties associated with measuring ambient sound can be avoided.
>
> CONs of Option 1: If noise complaints are received, this method can add a layer of difficulty to post-construction compliance monitoring. If post-construction monitoring shows sound levels greater than 1 dB(A) above the MMSL, the turbine will need to be shut-down for ambient sound measurements. Without knowing the ambient sound levels, it is impossible to determine if the turbine is at fault for increasing the sound level above the permitted level.

Option 1 is based on the fact that sound levels add logarithmically, not linearly. For example, 50 dB(A) + 46 dB(A) ≠ 96 dB(A). Rather, 50 dB(A) + 46 dB(A) = 51.5 dB(A). The following chart can be used to approximate the logarithmic addition of sound levels.

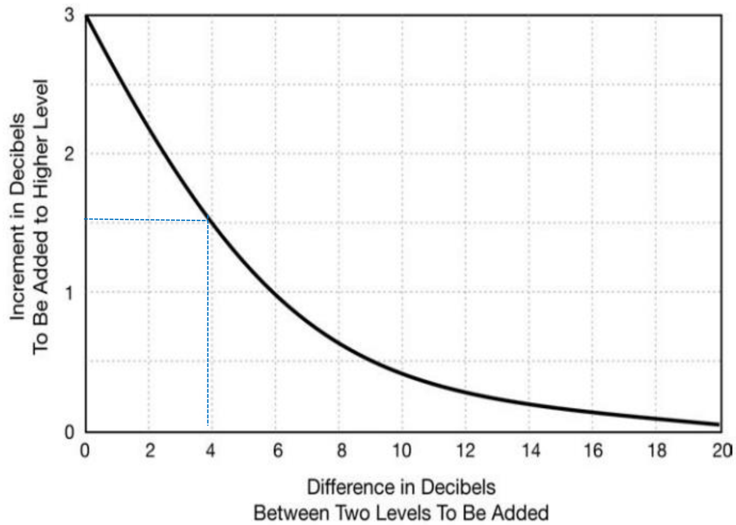


Figure 4: Approximate Decibel Addition Graph[7]

Option 2: This method requires the measurement of a site's pre-construction ambient sound. It is common to define ambient as a L_{A90} value. L_{A90} is the A-weighted decibel level (dB(A)) that is exceeded 90% of the time (please see the Glossary of Terms for an explanation of A-weighted decibel level). Often, the lowest ambient sound levels are measured at night during the winter. A pre-defined, technically detailed method for measuring sound should be selected by the municipality. See Maine's No Adverse Environmental Effect Standard of the Site Location Law, Section I: Sound Level Standards for Wind Energy Developments[13] or the MassCEC Acoustic Study Methodology for Wind Turbine Projects[14] for example sampling methods. Often, a wind developer will need to fund a third party with acoustic expertise to conduct this pre-construction sound monitoring.

After quantifying the ambient sound levels at the abutting property lines, the turbine developer will need to predict the turbine's sound via modeling. It is recommended that the most up-to-date IEC standards for sound power levels (IEC 61400-11 ed 3 as of 2015) be used in conjunction with the most current ISO sound pressure propagation methods (ISO 9613-2 as of 2015) to predict turbine sound at surrounding property lines. Other accurate sound modeling options, such as NORD200 software, should also be accepted. L_{EQ} values in dB(A) should be predicted by the modeling efforts for each abutting property line. L_{EQ} is a single A-weighted decibel value that represents the total sound energy over the period of time of interest. It is a common means of representing a time-averaged sound level for sounds that vary.

The logarithmic summation of the L_{EQ} values plus the corresponding pre-construction ambient sound levels is the resulting noise level (RNL) at each property line. The RNL values should not exceed zone-specific A-weighted decibel increases over ambient. In other words, the non-logarithmic difference between RNL and ambient must be less than or equal to the allowed dB(A) increase over ambient.

[13] http://www.maine.gov/sos/cec/rules/06/096/096c375.doc

[14] http://images.masscec.com/uploads/attachments/MassCEC_Acoustic_Study_Methodology_for_Wind_Turbine_Projects_12-9-11.pdf

Increases over ambient should be limited based on zone. For example, a residential zone may only allow a 10 dB(A) increase while an industrial zone could allow for a 15 dB(A) increase. A municipality may also set maximum dB(A) values for each zone type. Some municipalities may already have such maximum dB(A) sound levels defined in their noise ordinances. If this is done, it is recommended that the more restrictive limit (maximum limit versus increase over ambient limit) be applied for permitting.

PROs of Option 2: This method prevents turbine neighbors from experiencing a large increase in ambient sound levels. There will not be a large change in sound levels for the surrounding properties.

CONs of Option 2: A method must be chosen for measuring ambient sound. Requiring the measurement of ambient sound levels may increase siting costs and the time needed for site analyses. Ambient sound levels can also vary depending on season, time of day, weather, and other factors. For this reason, ambient sound is often very difficult to accurately quantify.

Similar to Option 1, if noise complaints are received, this method can add a layer of difficulty to post-construction compliance monitoring. If post-construction monitoring shows sound levels greater than the allowed dB(A) above documented ambient levels, the turbine will need to be shut-down for further ambient sound measurements. Without knowing if the ambient sound levels have changed since the original measurements, it is impossible to determine if the turbine is at fault for increasing the sound level above the permitted level.

Both Options: To make either option more conservative a L_{DEN} value with dB(A) penalties for pure tones or short duration repetitive sounds can be predicted via modeling (instead of a L_{EQ} value). L_{DEN} refers to a day-evening-night A-weighted decibel value. Similar to an L_{EQ} value, a L_{DEN} value is a time-averaged value used to represent variable sound. However, it is more conservative than L_{EQ} values because it penalizes sound levels that occur between certain hours. Specifically, the sound measurement occurs over 24 hours with 10 dB penalties added to the sound levels between 23:00 and 7:00 and 5 dB penalties added to the sound levels between 19:00 and 23:00. The penalties are meant to reflect people's extra sensitivity to sound during night and evening hours. See the Glossary of Terms for the definitions of pure tones and short duration repetitive sounds. Both standards should include language for increased impact special use permits (IISUPs); should require a complaint collection, disclosure and investigation procedure; and should establish a pre-set limit on the frequency and/or total number of times compliance testing can be required.

FAQ's

1. How can compliance be enforced?

To accurately measure complex sounds and sound levels, specialized equipment is required. The costs of procuring, maintaining, calibrating, and deploying this equipment is often a barrier to municipal compliance testing. Therefore, it is common for a third party acoustics expert to be hired if noise complaints are submitted. Often, the turbine operator will be required to fund the third party noise analysis. Detailed sound sampling procedures, such as the ones described in Maine's No Adverse Environmental Effect Standard of the Site Location Law, Section I: Sound Level Standards for Wind

Energy Developments[15] or the MassCEC Acoustic Study Methodology for Wind Turbine Projects[16], should be specified to ensure the comparability of measurements. A municipality should also establish a pre-set limit on the number of times compliance testing can be required.

2. What are potential mitigation strategies for noise?

Mechanical noise emitted from the nacelle can often be controlled by additional nacelle insulation or the selection of quieter mechanical devices. However, aerodynamic noise is less easily mitigated. If a turbine is noncompliant with respect to its noise production, operational modification and/or curtailment during weather conditions that cause excessive noise generation may be required.

3. Why are increased impact special use permits (IISUPs) important for noise requirements?

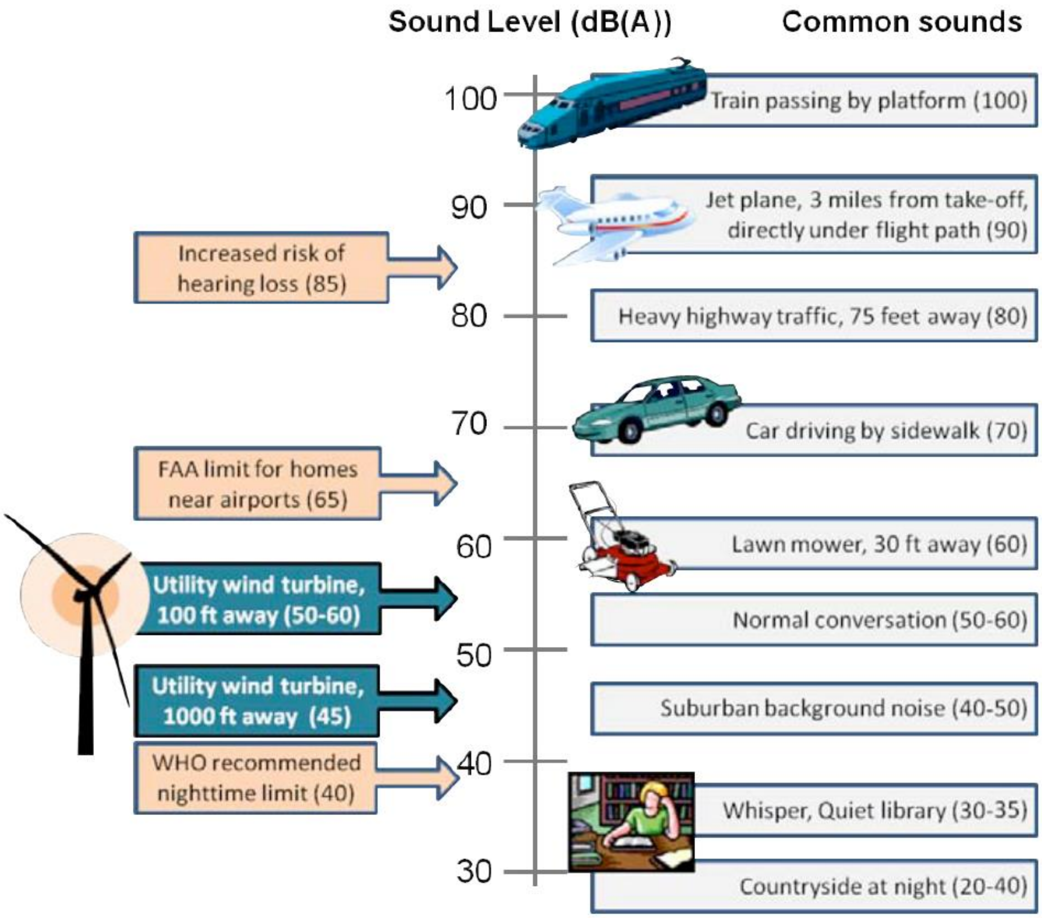
In general, special use permits can allow siting standards to be better molded to the needs of a specific site. For example, consider a scenario of a wind turbine located near a farm with sold development rights. Although the noise at the farm property line may exceed the limits chosen by the municipality, the farmer's house may be located some distance away. If the farmer feels that the potential for increased noise over his/her fields will not disturb his/her operation and he/she cannot develop the land near the turbine, then the benefits of the turbine's development may outweigh any increased noise impacts. By allowing the Zoning Board to consider the desire of nearby property owners to accept differing levels of noise on their property, the standards become adaptable on a case-by-case basis.

4. What does 45 dB(A) or 50 dB(A) equate to?

The graphic below was used in a 2010 West Michigan Wind Assessment Issue Brief. [8]

[15] http://www.maine.gov/sos/cec/rules/06/096/096c375.doc

[16] http://images.masscec.com/uploads/attachments/MassCEC_Acoustic_Study_Methodology_for_Wind_Turbine_Projects_12-9-11.pdf



5. What noise level is appropriate for sleeping?

According to the World Health Organization (WHO), a $L_{night,outside}$ of 40 dB should be the target limit for night noise guidelines. This value protects the general public, including vulnerable groups such as children, the chronically ill, and the elderly. L_{night} is defined according to the European Union (EU) definition in Directive 2002/49/EC: "L_{night} is the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the night periods of a year."[9]

6. What is infrasound? Is it generated by wind turbines and does it pose a health concern?

Infrasound (IS), often interchanged with the term low frequency noise (LFN), is defined by the Webster-Merriam online dictionary as "a wave phenomenon of the same physical nature as sound but with frequencies below the range of human hearing." The threshold for human hearing is 20 Hz. Any sound wave with a frequency below this level is classified as infrasound.

Both natural and man-made sources of infrasound exist in our environment. Ocean waves are a common example of a natural source, wind turbines are an example of a man-made source. At this time there is no evidence of physiological effects caused by the levels of infrasound emitted from wind turbines. [10][11]

Moreover, a 2015 Frontiers in Public Health article states "…the results from the current investigation indicate that increases in LFN associated with wind turbine operation are correlated with increases in overall sound levels. These results, in conjunction with those of previous reports, suggest that controlling for overall sound levels produced by normally operating wind turbines will inherently control for LFN. The results reported here are in agreement with a recent report issued by Health Canada, which concluded that following over 4,000 h [hours] of wind turbine noise measurements, there was "*no additional benefit in assessing LFN as C- and A-weighted levels were so highly correlated (r=.94) that they essentially provided the same information*". Given the low levels of IS and the correlation between LFN and overall sound levels from wind turbines, the development and enforcement of suitable outdoor guidelines and limits, based on dB(A), provide an effective means to evaluate, monitor, and protect potential receptors."[12]

7. **What are the general health impacts of sound?**

Different levels of sound exposure have been linked with certain physiological effects in humans. Loud, impulse sounds such as a close proximity gun shot, and long-term sound levels greater than 75-85 dB(A) can induce hearing loss. In addition, studies have linked noise exposure with annoyance, sleep disturbance, decreased patient and staff performance in hospitals, decreased cognitive performance in schoolchildren, and higher occurrence of hypertension and cardiovascular disease. The scientific literature has only connected wind turbine noise with increased self-reported annoyance and sleep disturbance [13]. The World Health Organization (WHO) suggests an average night-time outside noise level of 40 dB(A) to prevent all noise-induced health effects.[14][15]

* * * * *

Shadow Flicker

Description of Impact

When an operating wind turbine is positioned between the sun and an observer, the rotating blades can cast moving shadows on an observer's location. This phenomenon is called shadow flicker and it is widely recognized as a potential annoyance factor for people living and working near large scale wind turbines. Fortunately, shadow flicker is relatively easy to model and predict as it is based on the sun's daily and seasonal pathways across the sky. Therefore, appropriate site selection should be able to control for shadow flicker effects. It should be noted that shadow flicker only occurs on sunny days when a turbine is spinning. In stormy, overcast, or cloudy conditions, if the sun is not bright enough to cast shadows, it will not bright enough to cause shadow flicker.

Recommended Standard

Shadow flicker should be limited to no more than 30 hours per year at occupied structures or sites permitted for occupied structure construction at the time of wind project permitting. This limit should be based on worst-case scenario modeling, which assumes flat, open land, constant sunshine during the day and constant wind turbine operation. Appropriate modeling software such as WindPro should be used for these analyses. This standard should only be applied to occupied structures not located on the wind development property. If an occupied structure located on the property being developed will experience shadow flicker in excess of the standard, the developer should notify the land owner and submit an acknowledgement of the higher shadow flicker impact signed by the land owner to the municipality. Increased impact special use permits (IISUPs) for higher shadow flicker exposure on occupied structures located outside of the wind development property should be allowed. In addition, a standard should require complaint collection, disclosure, and investigation procedures, and should establish a pre-set limit on the frequency and/or total number of times compliance testing can be required.

A realistic modeling standard that accounts for topology, obstacles, and normal weather and wind patterns could be used by a municipality to lessen the shadow flicker requirement on occupied structures in non-residential zones. Figure 3 on page 12 of this document provides an example of how realistic versus worst-case scenario modeling can be applied to adjust the conservativeness of the shadow flicker standard. It is recommended that a municipality work with a developer to determine which variables and data should or should not be used in a realistic model. All assumptions made in a realistic model should be carefully reviewed by a municipality.

FAQ's

1. What are the potential health impacts of shadow flicker?

Previously, the main concern regarding health and shadow flicker has been the risk of inducing seizures in individuals with photosensitive epilepsy. However, seminal studies published in the peer-reviewed medical journal Epilepsia[16][17] have investigated this relationship and have found that rotation frequencies of 3 Hz or greater are needed for wind turbines to pose a risk to the photosensitive population. A 3 Hz frequency translates into a 60 rotations per minute (rpm) speed for a three-bladed wind turbine. This rpm is well above the rotation speeds of most modern, large-scale wind turbines. Common rpms range from 6 to 17 rpm for today's large-scale turbines. Other health concerns are tied to annoyance. At this time, further studies are needed to determine the exact relationship between shadow flicker and annoyance.[18]

2. What are some mitigation strategies for flicker?

If shadow flicker limits are exceeded, operational curtailment during flicker-producing conditions is a potential mitigation strategy. The installation of blinds, the planting of vegetation, and/or the installation of other screening measures by the turbine operator/developer can also help to decrease the effects of shadow flicker. It is important that the mitigation strategy most acceptable to the affected property owner be selected.

3. Why are increased impact special use permits (IISUPs) important for flicker requirements?

Special use permits are an important part of adapting standards on a case-by-case basis. In the case of shadow flicker, certain sites may only experience shadow flicker during limited periods of the day and only during certain times of the year. For example, flicker may only occur in the early morning hours for a particular household during the winter. If members of this household are rarely awake during these hours or are already at work, the property owner and Zoning Board may feel the benefits of the turbine's development outweigh the shadow flicker nuisance. In such a scenario, IISUPs allow the siting standards to be better molded to the needs of a specific site.

* * * * *

Environmental Impacts

Description of Impact

There are several environmental impacts that are specific to large scale wind turbines. These include avian and bat fatalities and wildlife displacement and/or behavioral change due to turbine operation and maintenance activities.

Birds & Bats: Today's wind turbines can pose a risk to birds and bats though the exact impact has yet to be accurately quantified [19][20][21]. In comparison to other U.S. human activities and structures, current total avian mortality due to wind turbines has been shown to be relatively low [20].

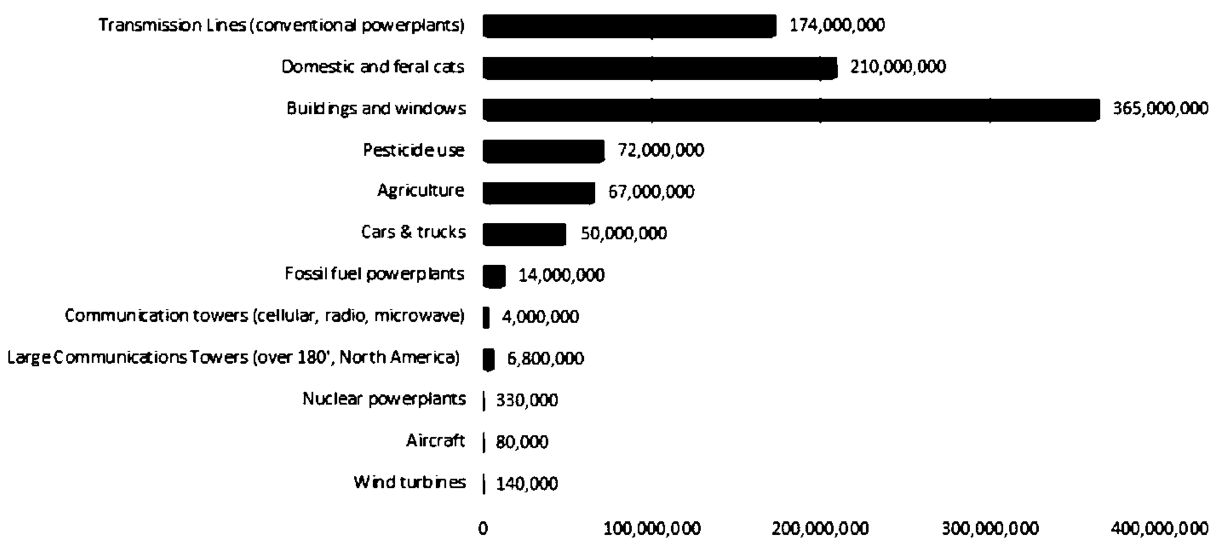


Fig. 1. Annual avian mortality in the USA [8–11]. Numbers show the lowest values when a range of estimates is given.

Figure 5: Annual avian mortality in the USA [20].

However, the relatively small number of documented avian deaths from wind turbines does not mean that the mortality rates should be ignored. It is important to note that the number of wind turbines compared to the number of domestic cats, transmission lines, buildings and windows, and other categories shown in the above figure is extremely low. In addition, low reported mortality rates could be due to a lack of consistent or standardized monitoring or reporting and/or various factors affecting fatality detection rates. As the number of turbines increases, negative avian and bat effects will likely increase. Of particular importance are the type of birds represented by the mortality rates and the potential for effective mitigation strategies. Even a small increase in mortality rates can be harmful to some populations, especially for long-lived species such as bats, with slow maturity and low reproductive rates [6][7]. More research is also needed to determine if bats are disproportionately affected by wind turbines compared to birds.

Several species likely impacted by wind turbine development are also protected by the U.S. Fish and Wildlife Service. Specifically, Bald and Golden Eagles are federally protected under the Bald and Golden Eagle Protection Act (16 USC 668-668d); many migratory bird species are protected under the Migratory Bird Treaty Act (16 USC 703-712); and endangered or threatened species are protected by the

Endangered Species Act (16 U.S.C. 1531–1544; ESA). The April 2015 addition of the Northern Long-Eared Bat to the federal list of threatened species should be of particular concern to Rhode Island wind developers.

All Fauna: Questions remain regarding wind turbines and their effects on all types of surrounding fauna. Further studies regarding species displacement and predator-prey balances are needed to explain species-specific effects [22][23][24].

Recommended Standard

Due to the current, limited scientific understanding, it is recommended that the scale of a proposed project be considered in regards to potential environmental impacts. All project proposals should consider the available literature and history, current habitat types, and potential presence and activities of fauna near the proposed site. This may require both pre- and post-construction monitoring via visual, acoustic, netting, and/or other appropriate surveying methods. Mitigation strategies may also need to be identified if significant potential for adverse environmental effects exists. The costs of environmental surveys and monitoring activities should be weighed against the usefulness of the data to be collected, the severity of potential environmental impacts, and the need for further information.

In general, it is recommended that areas that serve as important migratory layovers, pathways, or concentration points be avoided, as should endangered or protected species nesting, breeding, or feeding sites. At minimum, a literature review should be conducted as well as a basic site characterization visit. During a site characterization visit, an expert will identify surrounding habitat types and their potential for attracting or supporting species of concern. The potential for a project to displace or attract enough fauna to significantly affect local predator-prey balances should also be considered.

The level of consideration for these environmental affects should reflect the scale of potential impact. Detailed analyses should be reserved for wind farms sited near important wildlife habitats, within migratory pathways, or where endangered or protected species are present. For a more in depth decision making process, the U.S. Fish and Wildlife Service (U.S. FWS) has put together voluntary guidelines that can be accessed online.[17] To accompany these wind siting guidelines, an eagle conservation guide was released in 2013.[18] The Rhode Island Natural Heritage Program, overseen by the Rhode Island Department of Environmental Management (RI DEM), is also a good resource regarding Rhode Island's rarest and most vulnerable natural landscapes.[19] This program has created Geographic Information Systems (GIS) layers based on observation densities of rare, threatened, and endangered species that can be found on the RIGIS website.[20]

Another source of peer-reviewed wind and environmental impact studies is the American Wind and Wildlife Institute (AWWI).[21] AWWI maintains a website with a mapping tool for impacted species identification.[22] The tool also has links to mapped information such as The Nature Conservancy Priority Areas and Audubon Important Bird Areas.

[17] http://www.fws.gov/ecological-services/es-library/pdfs/WEG_final.pdf
[18] http://www.fws.gov/migratorybirds/Eagle_Conservation_Plan_Guidance-Module%201.pdf
[19] http://www.dem.ri.gov/programs/bpoladm/plandev/heritage/
[20] http://www.edc.uri.edu/rigis/data/data.aspx?ISO=biota
[21] https://awwi.org/
[22] http://www.wind.tnc.org/#app=1db9&5362-selectedIndex=1&509c-selectedIndex=0

Wind turbine developers should be required to engage the U.S. FWS, the RI DEM, and other appropriate environmental advisory groups as early in the proposal process as possible. In general, the environmental impacts of wind turbines are best handled at the state and federal levels. Therefore, project guidance from the U.S. FWS, and when possible RI DEM and other appropriate environmental advisory groups, should be obtained prior to a municipality's project review. All relevant recommendations and comments from these environmental groups/agencies should be addressed in a project proposal and considered by a municipality during the permitting process. Mitigation strategies should be identified and included in plans prior to construction approval in case post-construction monitoring indicates an unacceptable level of environmental impact. Post-construction monitoring data, if deemed necessary to collect, should be shared with the municipality. If federal (and state, if received) environmental recommendations are met by a proposal, a municipality should not retain the right to reject a proposal for environmental reasons.

FAQ's

1. **How many important migratory bird/bat pathways are in Rhode Island? Where are they? And are wind turbines likely to adversely affect them?**

   In general, birds and bats do not tend to follow a particular line or pathway until they encounter the ocean. However, particularly in the fall, they tend to concentrate near the coastline and follow the coast south. Most migrate at night with the timing of their migratory movements coinciding with certain weather events. Unfortunately, little more is well understood about migratory pathways. Many questions regarding how and when they are used remain unanswered. A lack of information regarding current population levels can also prevent an accurate understanding of the effects of turbine-caused mortalities. Therefore, post-construction monitoring is important to ensure the real-life impacts are close to those predicted by the pre-construction survey(s). In addition, known concentration areas and ground resting or roosting places along the coast should generally be avoided by wind turbine development.

2. **Who can help to identify if an area is an important bird/bat habitat or if there are endangered or protected species present?**

   It is recommended that a developer engage the U.S. Fish and Wildlife Service and the Rhode Island Department of Environmental Management as early in the development process as possible. Both of these agencies can offer expertise in floral and faunal identification and site evaluations.

3. **What are potential mitigation strategies for birds/bats?**

   If significant adverse avian impacts are likely to occur, another site should be considered. Mitigation strategies such as tubular tower construction, operation curtailment, limited lighting (must be in compliance with the Federal Aviation Agency (FAA), see Code of Federal Regulations here: http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&SID=61302bd90d79271a583474ad2f9dcd7e&rgn=div5&view=text&node=14:2.0.1.2.9&idno=14#14:2.0.1.2.9.2.1.3), and/or avian detection technologies can also be incorporated into construction and operation plans [25]. To specifically reduce mortality risks for the threatened Northern Long-Eared Bat, it is recommended that increased wind turbine cut-in speeds be considered. Since these bats are thought to be less active during high winds, increased cut-in speeds can significantly reduce the risk to this species. This may be an important operation restriction if a turbine is likely to affect Northern Long-Eared Bats [26].

4. What costs are associated with pre- and post-construction environmental surveys?

In general, environmental studies can be relatively expensive for wind farms consisting of only one or a few wind turbines. Due to equipment, expert time, and analysis costs, most environmental surveying techniques such as radar, acoustic studies, raptor surveys, and mist netting with radio transmitter placement, require investments well above $10,000 per study. These costs must be weighed against the usefulness of the data collected and the need for further information. In general, collecting pre- and post-construction data, though costly, is likely the best way to improve and simplify future environmental impact standards.

* * * * *

Other Impacts

Description of Impacts

Visual Impacts: Due to the height and siting needs of large scale wind turbines, they may have significant visual impacts on the surrounding landscape. Whether they improve or detract from the landscape is highly subjective. In either case, it is important to understand the change that will result from turbine construction. To get a sense as to the visual impact, a viewshed/sightline or other visual impact analysis should be included in a project proposal. In addition, accurately-scaled, photographic renderings should be produced for areas with the greatest expected visual impact(s). Daytime and nighttime renderings should be submitted if lighting requirements are likely to impact the nighttime scenery. It is advisable that visual impacts to recognized historic, cultural, archeological, or scenic sites be minimized.

In general, unless pre-existing visual impact standards are violated, a turbine project proposal should not be rejected on the basis of visual impacts. Wind development should not be treated differently from other types of development with respect to visual impacts. If a municipality has pre-existing visual impact standards, wind development should be required to abide by those standards. However, if no visual impact standards exist in a municipality at the time of an application submittal, none should be applied to the review of a wind development proposal.

Signal Interference: Previously, when wind turbines were predominately made with metal, they had the potential to cause signal variations due to signal deflection. However, modern turbines are now made with synthetic materials that have minimal impacts on broadcast signal transmission [26][27]. If broadcast issues do arise after turbine installation, additional transmitter masts can be installed at relatively low cost to the wind turbine developer [26]. Prior to construction, it is recommended that wind turbine developers notify any nearby communications towers.

References

[1] R. M. Downie, “This Week in Block Island’s History: 124 years of electric power on Block Island,” *The Block Island Times*, 29-Aug-2012.

[2] C. Atkinson-Palombo and B. Hoen, “Relationship between Wind Turbines and Residential Property Values in Massachusetts: A Joint Report of University of Connecticut and Lawrence Berkeley National Laboratory,” Boston, MA, 2014.

[3] L. W. M. M. Rademakers and H. Braam, “ANALYSIS OF RISK-INVOLVED INCIDENTS OF WIND TURBINES,” *Energy Res. Cent. Netherlands Publ. as Append. A Guid. Risk- Based Zo. Wind Turbines (handb. Risicozonering Wind.*, 2005.

[4] AWEA and ASCE, “Recommended Practice for Compliance of Large Land-based Wind Turbine Support Structures,” Washington, DC & Reston, Virginia, 2011.

[5] G. Carbone and L. Afferrante, “A novel probabilistic approach to assess the blade throw hazard of wind turbines,” *Renew. Energy*, vol. 51, pp. 474–481, 2013.

[6] H. Seifert, A. Westerhellweg, and J. Kröning, “Risk analysis of ice throw from wind turbines,” *Pap. Present. Boreas VI*, no. April 2003, 2003.

[7] C. E. Hanson, D. A. Towers, and L. D. Meister, “Transit Noise and Vibration Impact Assessment,” 2006.

[8] E. (Grand V. S. U. Nordman, “Wind Power and Human Health: Flicker, Noise and Air Quality,” 2010.

[9] World Health Organization, “Night Noise Guidelines for Europe,” Copenhagen, Denmark, 2009.

[10] Australia Department of Health, “Wind farms, sound and health,” Melbourne, Australia, 2013.

[11] T. Evans, J. Cooper, and V. Lenchine, “Infrasound levels near windfarms and in other environments,” 2013.

[12] R. G. Berger, P. Ashtiani, C. a. Ollson, M. Whitfield Aslund, L. C. McCallum, G. Leventhall, and L. D. Knopper, “Health-Based Audible Noise Guidelines Account for Infrasound and Low-Frequency Noise Produced by Wind Turbines,” *Front. Public Heal.*, vol. 3, no. February, pp. 1–14, 2015.

[13] J. H. Schmidt and M. Klokker, “Health Effects Related to Wind Turbine Noise Exposure: A Systematic Review,” *PLoS One*, vol. 9, no. 12, p. 28, 2014.

[14] M. Basner, W. Babisch, A. Davis, M. Brink, C. Clark, S. Janssen, and S. Stansfeld, “Auditory and non-auditory effects of noise on health,” *Lancet*, vol. 383, no. 9925, pp. 1325–1332, 2014.

[15] J. M. Ellenbogen, S. Grace, W. Heiger-Bernays, J. F. Manwell, D. A. Mills, K. A. Sullivan, M. G. Weisskopf, and S. L. Santos, “Wind Turbine Health Impact Study: Report of Independent Expert Panel January 2012,” 2012.

[16] G. Harding, P. Harding, and A. Wilkins, “Wind turbines, flicker, and photosensitive epilepsy: Characterizing the flashing that may precipitate seizures and optimizing guidelines to prevent them,” *Epilepsia*, vol. 49, no. 6, pp. 1095–1098, 2008.

[17] A. R. D. Smedley, A. R. Webb, and A. J. Wilkins, “Potential of wind turbines to elicit seizures under various meteorological conditions,” *Epilepsia*, vol. 51, no. 7, pp. 1146–1151, 2010.

[18] L. D. Knopper, C. a. Ollson, L. C. McCallum, M. L. Whitfield Aslund, R. G. Berger, K. Souweine, and M. McDaniel, “Wind Turbines and Human Health,” *Front. Public Heal.*, vol. 2, no. June, pp. 1–20, 2014.

[19] M. M. P. Huso and D. Dalthorp, “A comment on bats killed in large numbers at united states wind energy facilities,” *Bioscience*, vol. 64, no. 6, pp. 546–547, 2014.

[20] S. Wang, S. Wang, and P. Smith, “Ecological impacts of wind farms on birds: Questions, hypotheses, and research needs,” *Renew. Sustain. Energy Rev.*, vol. 44, pp. 599–607, 2015.

[21] a. Tabassum, M. Premalatha, T. Abbasi, and S. a. Abbasi, “Wind energy: Increasing deployment, rising environmental concerns,” *Renew. Sustain. Energy Rev.*, vol. 31, pp. 270–288, 2014.

[22] J. W. Pearce-Higgins, L. Stephen, A. Douse, and R. H. W. Langston, “Greater impacts of wind farms on bird populations during construction than subsequent operation: Results of a multi-site and multi-species

analysis," *J. Appl. Ecol.*, vol. 49, no. 2, pp. 386–394, 2012.

[23] T. K. Stevens, a. M. Hale, K. B. Karsten, and V. J. Bennett, "An analysis of displacement from wind turbines in a wintering grassland bird community," *Biodivers. Conserv.*, vol. 22, no. 8, pp. 1755–1767, 2013.

[24] V. L. Winder, L. B. Mcnew, A. J. Gregory, L. M. Hunt, S. M. Wisely, and B. K. Sandercock, "Effects of wind energy development on survival of female greater prairie-chickens," *J. Appl. Ecol.*, vol. 51, no. 2, pp. 395–405, 2014.

[25] R. Saidur, N. a. Rahim, M. R. Islam, and K. H. Solangi, "Environmental impact of wind energy," *Renew. Sustain. Energy Rev.*, vol. 15, no. 5, pp. 2423–2430, 2011.

[26] D. Al Katsaprakakis, "A review of the environmental and human impacts from wind parks. A case study for the Prefecture of Lasithi, Crete," *Renew. Sustain. Energy Rev.*, vol. 16, no. 5, pp. 2850–2863, 2012.

[27] K. Dai, A. Bergot, C. Liang, W.-N. Xiang, and Z. Huang, "Environmental issues associated with wind energy – A review," *Renew. Energy*, vol. 75, pp. 911–921, 2015.

APPENDICES

A. Municipal Development Proposal Checklist

The following checklist is meant to serve as a reference for municipalities as they draft their project proposal guidelines and zoning ordinances. The list is in no particular order.

All wind turbine proposals and/or ordinances should address the following topics:

1. Check if the development will meet safety, community, and environmental standards—setbacks, noise, shadow flicker, visual impacts, signal interference, and environmental impacts
2. Noise analysis(es)
3. Shadow flicker analysis
4. Visual impact study and photographic renderings
5. Copy of communication tower notification
6. Environmental literature review, results of site characterization visit(s), and comments from RI DEM, U.S. FWS and/or other environmental groups
7. Results of further environmental studies (if required)
8. Decommissioning plan, including funding considerations
9. Turbine visual appearance—such as advertising, color, lighting, and appropriate safety signage
10. Construction issues—such as erosion, water quality, noise, habitat loss and/or fragmentation, and component transportation. All applicable permits should be sought by the developer
11. Turbine certifications
12. Mitigation strategies applicable for potential project impacts
13. Compliance/enforcement protocols
14. Safety protocols—who operates the machine(s), how are different weather scenarios handled, are fire safety protocols in place?
15. Turbine specifications
16. Application fees
17. Grid interconnection documentation
18. Complaints—collection, disclosure and investigation procedures
19. Public hearings, public notices, and/or notifying neighbors
20. Professional Engineer (P.E.) certified foundation
21. Applicable local and state building codes
22. Compliance with the Federal Aviation Administration (FAA). See Code of Federal Regulations here: http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&SID=61302bd90d79271a583474ad2f9dcd7e&rgn=div5&view=text&node=14:2.0.1.2.9&idno=14#14:2.0.1.2.9.2.1.3. Or use their Notice Criteria Tool here: https://oeaaa.faa.gov/oeaaa/external/gisTools/gisAction.jsp?action=showNoNoticeRequiredToolForm
23. Compliance with the Department of Defense (DOD). Since radar systems can be affected by wind turbines as return signals may give the appearance of a moving aircraft on a 2-dimensional radar screen. The DOD has a preliminary “wind siting tool” that helps identify potential areas of interference: https://oeaaa.faa.gov/oeaaa/external/gisTools/gisAction.jsp?action=showLongRangeRadarToolForm
24. Bonding for owner/operator default or bankruptcy situations
25. Liability insurance

26. Signed acknowledgements from land owner(s) of the property to be developed if impacts greater than the standards set by the municipality are likely to occur
27. A description of tangible project benefits to the municipality

B. Rhode Island Wind Turbine Case Studies*

Wind turbine installation	Setback from homes (ratio of setback to turbine height)	Setback from public roads and right of ways (ratio of setback to turbine height)	Height of turbine (ft)	Setback from closest property line (ratio of setback to turbine height)	Closest property line type	Formal flicker complaints	Flicker study completed	Ice shedding events documented	Wildlife study(ies) completed	Total recorded bird or bat mortalities over all years of operation	Years in operation
Sandywoods	3.04	1.04	231	-	-	-	-	-	-	-	~3
Hodges Badge	2.85	1.49	158	1.1	Residential (Agriculture)	None	Yes	No	No	None	~4
Portsmouth High School	1.2	0.8	414	0.1	Open Space/School	None	Yes	No	No	-	~4 months
Portsmouth Abbey	1.66	2.66	240	3.1	Residential	None	Yes	No	Yes	2	~9
Aquidneck Corporate Park in Middletown	7.55	0.52	157	0.3	Traffic sensitive office business (OBA)-Commercial	None	No	No	No	1	~6
DEM Fishermen's Memorial State Park	2.05	1.82	157	-	Residential	None	Yes	No	Yes	1	~4
New England Tech	N/A	1.32	157	-	-	None	-	No	-	-	~6
Shalom Housing	N/A	1.31	157	0.1	-	1	No	No	No	None	~4
Narragansett Bay Commission #1 (A)	2.83	0.37	365	0.6	Industrial	None	Yes	No	No	~11	~3
Narragansett Bay Commission #2 (B)	5.10	0.37	365	0.6	Industrial	None	Yes	No	No	~11	~3
Narragansett Bay Commission #3 (C)	3.59	0.81	365	0.7	Industrial	None	Yes	No	No	~11	~3
North Kingstown Green	0.7	0.4	414	-	Residential	None	Yes	No	No	1	~4
WED Coventry 1	2.4	3.8	414	1.1	Residential	None	Yes	No	No	-	~6 Months
WED Coventry 2	4.5	2.6	414	1.1	Residential	None	Yes	No	No	-	~6 Months
WED Coventry 2A	3.7	1.2	414	0.6	Residential	None	Yes	No	No	-	~6 Months

WED Coventry 2B	3.5	1.3	414	0.4	Residential	None	Yes	No	No	-	~6 Months
WED Coventry 3	1.2	2.4	414	1.1	Residential	None	Yes	No	No	-	~6 Months
WED Coventry 4	3.2	5.7	414	1.1	Residential	None	Yes	No	No	-	~6 Months
WED Coventry 6	6.6	4.2	414	0.3	Residential	None	Yes	No	No	-	~6 Months
WED Coventry 6A	3.0	0.2	414	0.2	Residential	None	Yes	No	No	-	~6 Months
WED Coventry 6B	1.5	1.1	414	0.6	Residential	None	Yes	No	No	-	~6 Months

*All information was provided by persons knowledgeable of one or more listed turbines. All information is provided to the best of these persons' knowledge and is not guaranteed as accurate. "–" means data was not provided.

C. Sample Wind Ordinance

DISLCAIMER: Please note that this sample ordinance is governed by Massachusetts law which differs from Rhode Island law and should be used for informational purposes only. Municipal officials should obtain legal counsel with expertise in zoning before finalizing their wind ordinances.

Revised March 2012

Model As-of-Right Zoning Ordinance or Bylaw: Allowing Use of Wind Energy Facilities

Prepared by:
Department of Energy
Resources
Massachusetts Executive Office of Environmental
Affairs

This Model By-Law was prepared to assist cities and towns in establishing reasonable standards for wind power development. The by-law is developed as a model and not intended for adoption without specific review by municipal counsel.

1.0 Purpose

The purpose of this bylaw is to provide standards for the placement, design, construction, operation, monitoring, modification and removal of wind facilities that address public safety, minimize impacts on scenic, natural and historic resources and to provide adequate financial assurance for the eventual decommissioning of such facilities.

The provisions set forth in this bylaw shall take precedence over all other bylaws when considering applications related to the construction, operation, and/or repair of land- based wind energy facilities.

1.1 Applicability

This section applies to all utility-scale and on-site wind facilities proposed to be constructed after the effective date of this section. This section also pertains to physical modifications to existing wind facilities that materially alter the type, configuration, location or size of such facilities or related equipment.

This section does not apply to off-shore wind systems.

2.0 Definitions

As-of-Right Siting: As-of-Right Siting shall mean that development may proceed without the need for a special permit, variance, amendment, waiver, or other discretionary approval. As-of-right development may be subject to non-discretionary site plan review to determine conformance with local zoning bylaws as well as state and federal law. As-of-right development projects that are consistent with zoning bylaws and with state and federal law cannot be prohibited.

Building Inspector: the inspector of buildings, building commissioner, or local inspector charged with the enforcement of the state building code.

Building Permit: The permit issued in accordance with all applicable requirements of the Massachusetts State Building Code (780 CMR).

Critical Electric Infrastructure (CEI): electric utility transmission and distribution infrastructure, including but not limited to substations, transmission towers, transmission and distribution poles, supporting structures, guy-wires, cables, lines and conductors operating at voltages of 13.8 kV and above and associated telecommunications infrastructure. CEI also includes all infrastructure defined by any federal regulatory agency or body as transmission facilities on which faults or disturbances can have a significant adverse impact outside of the local area, and transmission lines and associated equipment generally operated at voltages of 100 kV or higher, and transmission facilities which are deemed critical for nuclear generating facilities.

Designated Location: The location[s] designated by [the community's local legislative body] in accordance with M.G.L. c. 40A, section 5, where wind energy facilities may be sited as-of right. Said location[s] [is/are] shown on a Zoning Map [insert title of map]. This map is hereby made a part of this Zoning Bylaw and is on file in the Office of the [Town/City] Clerk.

Note: *The "designated location" refers to the location within a community where wind power generation is permitted as-of-right. Establishment of a designated location for wind power generation is an integral part of the process of adopting an As-of-Right Wind Energy Facility Bylaw.*

Legal Requirements: *The process of designating the location must comport with the requirements of Section 5 of Chapter 40A of the Massachusetts General Laws which sets out the requirements for adopting and amending zoning bylaws.*

Communities should keep in mind the requirements of the Green Communities Program. To qualify for designation as a Green Community, the designated area must provide a realistic and practical opportunity for development of wind power generation. An average wind speed of six meters per second at 50 meters elevation is considered the minimum wind speed for *commercial scale wind generation, however, the potential for power generation increases exponentially with increased average wind speeds.*

To satisfy the as-of-right zoning requirement contained in the Green Communities Act, the as-of-right bylaw must allow for wind energy facilities that utilize at least one turbine with a rated nameplate capacity of 600 kW or more.

Methods of Designating a Location: *Communities may designate locations by reference to geographically specific zoning districts. In the alternative, communities may create an overlay district consisting of all or portions of multiple preexisting zoning districts, where wind power generation is permitted by right. In designating a location, it is important for the community implementing the zoning bylaw to consider the availability of wind and particular characteristics of the local community.*

Height: The height of a wind turbine measured from natural grade to the tip of the rotor blade at its highest point, or blade-tip height. This measure is also commonly referred to as the maximum tip height (MTH).

Note: *The height of the wind energy facility will have a direct impact on the amount of power it generates. While actual outputs vary, a wind turbine that is 250 feet tall will have an average nameplate capacity of roughly 660 kW, whereas a turbine that is 450 feet will have an average nameplate capacity of roughly 1.5 to 2.0 MW.*

As previously mentioned, to satisfy the as-of-right zoning requirement contained in the Green Communities Act, the as-of-right bylaw must allow for the construction and operation of wind generation facilities that utilize at least one turbine with a rated nameplate capacity of 600 kW or more.

Actual generating capacity must be considered not only in terms of tower height, but also in light of average wind speeds at a given location.

Rated Nameplate Capacity: The maximum rated output of electric power production equipment. This output is typically specified by the manufacturer with a –nameplate‖ on the equipment.

Site Plan Review Authority: Refers to the body of local government designated by the municipality to review site plans.

Utility-Scale Wind Energy Facility: A commercial wind energy facility, where the primary use of the facility is electrical generation to be sold to the wholesale electricity markets.

Wind Energy Facility: All of the equipment, machinery and structures together utilized to convert wind to electricity. This includes, but is not limited to, developer-owned electrical equipment, storage, collection and supply equipment, service and access roads, and one or more wind turbines.

Wind Monitoring or Meteorological Tower: A temporary tower equipped with devices to measure wind speed and direction, to determine how much electricity a wind energy facility can be expected to generate.

Wind Turbine: A device that converts kinetic wind energy into rotational energy to drive an electrical generator. A wind turbine typically consists of a tower, nacelle body, and a rotor with two or more blades.

Zoning Enforcement Authority: The person or board charged with enforcing the zoning bylaws.

Note: *By state statute, this may be the "inspector of buildings, building commissioner or local inspector, or if there are none, in a town, the board of selectmen, or person or board designated by local ordinance or by-law". MGL 40A § 7. In many communities, the building inspector is the person charged with enforcing both the state's building code and local zoning bylaws.*

3.0 General Requirements for all Wind Energy Facilities

The following requirements are common to all wind energy facilities to be sited in designated locations.

3.1 Compliance with Laws, Ordinances and Regulations

The construction and operation of all such proposed wind energy facilities shall be consistent with all applicable local, state and federal requirements, including but not limited to all applicable safety, construction, environmental, electrical, communications and aviation requirements.

3.2 Building Permit and Building Inspection

No wind energy system shall be erected, constructed, installed or modified as provided in this section without first obtaining a building permit.

Note: *Under the state building code, work must commence within six (6) months from the date a building permit is issued, however, a project proponent may request an extension of the permit and more than one extension may be granted.*

3.3 Fees

The application for a building permit for a wind energy system must be accompanied by the fee required for a building permit.

3.4 Site Plan Review

No wind energy facility shall be erected, constructed, installed or modified as provided in this section without first undergoing site plan review by the Site Plan Review Authority.

Purpose: *The purpose of the site plan review is to determine that the use complies with all requirements set forth in this zoning by-law and that the site design conforms to established standards regarding landscaping, access, noise and other zoning provisions.*

Additional Considerations: *As part of the implementation of an as-of-right wind energy bylaw, communities should consider amending their existing site plan review provisions in order to incorporate site plan review conditions that apply specifically to wind energy facilities.*

3.4.1 General

All plans and maps shall be prepared, stamped and signed by a professional engineer licensed to practice in Massachusetts.

Pursuant to the site plan review process, the project proponent shall provide the following documents:

(a) A site plan showing:

- **i.** Property lines and physical dimensions of the site parcel and adjacent parcels within 500 feet of the site parcel;
- **ii.** Outline of all existing buildings, including purpose (e.g. residence, garage, etc.) on site parcel and all adjacent parcels within 500 feet of the site parcel, including distances from the wind facility to each building shown;
- **iii.** Location of the proposed tower, foundations, guy anchors, access roads, and associated equipment;
- **iv.** Location of all existing and proposed roads, both public and private, and including temporary roads or driveways, on the site parcel and adjacent parcels within 500 feet of the site parcel;
- **v.** Location of all existing above ground or overhead gas or electric infrastructure, including Critical Electric Infrastructure, and utility rights of way (ROW) and easements, whether fully cleared of vegetation or only partially cleared, within 500 feet of the site parcel;
- **vi.** Existing areas of tree cover, including average height of trees, on the site parcel and any adjacent parcels within a distance, measured from the wind turbine foundation, of 3.0 times the MTH.;
- **vii.** Proposed changes to the landscape of the site, grading, vegetation clearing and planting, exterior lighting (other than FAA lights), screening vegetation or structures;
- **viii.** Tower foundation blueprints or drawings signed by a Professional Engineer licensed to practice in the Commonwealth of Massachusetts;
- **ix.** Tower blueprints or drawings signed by a Professional Engineer licensed to practice in the Commonwealth of Massachusetts;

x. One or three line electrical diagram detailing wind turbine, associated components, and electrical interconnection methods, with all National Electrical Code and National Electrical Safety Code compliant disconnects and overcurrent devices;
xi. Documentation of the wind energy facility's manufacturer and model, rotor diameter, tower height, tower type (freestanding or guyed), and foundation type/dimensions;
xii. Name, address, phone number and signature of the applicant, as well as all co-applicants or property owners, if any;
xiii. The name, contact information and signature of any agents representing the applicant; and
xiv. A maintenance plan for the wind energy facility;

(b) Documentation of actual or prospective access and control of the project site (see also Section 3.5), together with documentation of all applicable title encumbrances (e.g. utility ROW easements);
(c) An operation and maintenance plan (see also Section 3.6);
(d) A location map consisting of a copy of a portion of the most recent USGS Quadrangle Map, at a scale of 1:25,000, showing the proposed facility site, including turbine sites, and the area within at least two miles from the facility. Zoning district designation for the subject parcel should be included; submission of a copy of a zoning map with the parcel identified is suitable for this purpose;
(e) Proof of liability insurance, in amounts commensurate with the risks;
(f) Certification of height approval from the FAA;
(g) A statement that evidences the wind energy facility's conformance with Section 3.10.6, listing existing ambient sound levels at the site and maximum projected sound levels from the wind energy facility; and
(h) Description of financial surety that satisfies Section 3.12.3.
(i) A public outreach plan, including a project development timeline, which indicates how the project proponent will meet the required site plan review notification procedures and otherwise inform abutters and the community.

The Site Plan Review Authority may waive documentary requirements for good cause shown.

Additional Consideration (expedited site plan review for smaller wind energy facilities):
The extensive site plan review documentation set forth in Section 3.4.2 of this model bylaw may not be appropriate for smaller wind energy facilities, such as those utilizing turbines under 150 feet in height. Accordingly, communities should consider incorporating a provision in their bylaw that allows smaller wind energy projects to undergo a site plan review with fewer required documents. One of the key goals underpinning the Green Communities Program is the development of renewable and alternative energy capacity. Communities should shape their bylaws to enable both large and small wind energy projects to proceed without undue delay.

3.5 Site Control

The applicant shall submit documentation of actual or prospective access and control of the project site sufficient to allow for installation and operation of the proposed wind energy facility. Control shall include the legal authority to prevent the use or construction of any structure for human habitation, or inconsistent or interfering use, within the setback areas.

3.6 Operation & Maintenance Plan

The applicant shall submit a plan for maintenance of access roads and storm water controls, as well as detailed procedures for operational maintenance of the wind facility that are in accordance with manufacturer's recommendations for the period of expected operation of such facility. A facility that is not being maintained in accordance with the submitted plan and manufacturer's recommendations shall cease operation until such time as the facility is brought into compliance with the maintenance plan and manufacturer's recommendations.

3.7 Utility Notification

No site plan for the installation of a wind energy facility shall be approved until evidence has been given that the electric utility company that operates the electrical grid where the facility is to be located has been informed of the customer's intent to install an interconnected customer-owned generator, and copies of site plans showing the proposed location have been submitted to the utility for review. No installation of a wind energy facility should commence and no interconnection shall take place until an

–Interconnection Agreement pursuant to applicable tariff and consistent with the requirements for other generation has been executed with the utility. Off-grid systems shall be exempt from this requirement, unless they are proposed to be located within setback distance from the sideline of an existing utility ROW.

3.8 Temporary Meteorological Towers (Met Towers)

A building permit shall be required for stand-alone temporary met towers. No site plan review shall be required for met towers. Met towers shall not be located within setback distance from the sideline of any utility ROW.

Note: *Under the state building code, work must commence within six (6) months from the date a building permit is issued, however, a project proponent may request an extension of the permit and more than one extension may be granted.*

3.9 Design Standards

3.9.1 Appearance, Color and Finish

Color and appearance shall comply with Federal Aviation Administration (FAA) safety requirements.

3.9.2 Lighting

Wind turbines shall be lighted only if required by the FAA. Lighting of other parts of the wind energy facility, such as appurtenant structures, shall be limited to that required for safety and operational purposes, and shall be reasonably shielded from abutting properties. Except as required by the FAA, lighting of the wind energy facility shall be directed downward and shall incorporate full cut-off fixtures to reduce light pollution.

3.9.3 Signage

Signs on wind energy facilities shall comply with the Town's sign by-law. The following signs shall be required:

(a) Those necessary to identify the owner, provide a 24-hour emergency contact phone number, and warn of any danger.

(b) Educational signs providing information about the facility and the benefits of renewable energy.

Wind turbines shall not be used for displaying any advertising except for reasonable identification of the manufacturer or operator of the wind energy facility.

3.9.4 Utility Connections

Reasonable efforts, as determined by the Site Plan Review Authority, shall be made to place all developer-owned utility connections from the wind energy facility underground, depending on appropriate soil conditions, shape, and topography of the site and any requirements of the utility provider. Utility owned electrical equipment required for utility interconnections may be above ground, if required by the utility provider.

3.9.5 Appurtenant Structures

All appurtenant structures to wind energy facilities shall be subject to applicable regulations concerning the bulk and height of structures, lot area, setbacks, open space, parking and building coverage requirements. All such appurtenant structures, including but not limited to, equipment shelters, storage facilities, transformers, and substations, shall be architecturally compatible with each other and contained within the turbine tower whenever technically and economically feasible. Whenever reasonable, structures should be shaded from view by vegetation and/or located in an underground vault and joined or clustered to avoid adverse visual impacts.

> ***Note:*** *Regulations governing appurtenant structures are typically contained in a town's zoning bylaw.*

3.9.6 Height

The height (MTH) of wind energy facilities shall not exceed 450 feet in height.

Note: *A turbine height of 450 feet is used for illustration purposes only. Communities may set a height limit that is less than 450 feet, provided that the limit selected allows for the as-of-right construction and operation of turbines with a rated nameplate capacity of 600 kW or more.*

Currently, a land-based turbine that is 450 feet in height is considered a large turbine. Periodically, communities may wish to revisit their siting criteria to ensure that they reflect industry standards as well as Green Communities Act requirements.

3.10 Safety and Environmental Standards

3.10.1 Emergency Services

The applicant shall provide a copy of the project summary, electrical schematic, and site plan to the police and fire departments, and/or the local emergency services entity designated by the local government, as well as the local electrical utility company. Upon request the applicant shall cooperate with local emergency services in developing an emergency response plan. All means of disconnecting the wind energy facility shall be clearly marked. The applicant or facility owner shall identify a responsible person for public inquiries or complaints throughout the life of the project.

3.10.2 Unauthorized Access

Wind energy facilities shall be designed to prevent unauthorized access. For instance, the towers of wind turbines shall be designed and installed so that step bolts or other climbing features are not readily accessible to the public and so that step bolts or other climbing features are not installed below the level of 8 feet above the ground. Electrical equipment shall be locked where possible.

3.10.3 Setbacks

A wind turbine may not be sited within:
(a) a distance equal to one and one-half (1.5) times the maximum tip height (MTH) of the wind turbine from buildings, critical infrastructure—including Critical Electric Infrastructure and above-ground natural gas distribution infrastructure—or private or public ways that are not part of the wind energy facility;
(b) a distance equal to three (3.0) times the maximum tip height (MTH) of the turbine from the nearest existing residential or commercial structure; or
(c) a distance equal to one and one-half (1.5) times the maximum tip height (MTH) of the turbine from the nearest property line, and private or public way.

3.10.5 Shadow/Flicker

Wind energy facilities shall be sited in a manner that minimizes shadowing or flicker impacts. The applicant has the burden of proving that this effect does not have significant adverse impact on neighboring or adjacent uses.

Educational Note: Shadow flicker is caused by sunlight passing through the swept area of the wind turbine's blades. As sunlight passes through the spinning blades, it is possible to have a stroboscopic effect that can, under the right conditions, affect persons prone to epilepsy. In general, these conditions require varying light intensity at frequencies of 2.5-3 Hz. Large commercial turbines are typically limited to a frequency of less than 1.75 Hz. Furthermore, the impacts of shadow flicker diminish rapidly with distance and should be minimal at 10 or more rotor diameters. Though the RPM for smaller turbines is generally higher (up to 350 RPM, for some turbines), the small size of the rotor swept area, combined with the shorter tower heights, support a negligible shadow flicker impact from these types of facilities. In any case, the effects of shadow flicker are a seasonal and/or diurnal impact, requiring that the sun be at the right position in the sky to generate a line of sight with the affected building and the wind turbine rotor. As such, the impacts of shadow flicker will generally only be felt for a few hours per year.

3.10.6 Sound

The operation of the wind energy facility shall conform with the provisions of the Department of Environmental Protection's, Division of Air Quality Noise Regulations (310 CMR 7.10).

Educational Note: According to the Division of Air Quality Control Policy, a source of sound will be considered to be violating 310 CMR 7.10 if the source:

(a) Increases the broadband sound level by more than 10 dB(A) above ambient, or
(b) Produces a ―pure tone‖ condition – when an 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 structure. Ambient is defined as the background A-weighted sound level that is exceeded 90% of the time measured during equipment hours. The ambient may also be established by other means with consent from the DEP.

3.10.7 Land Clearing, Soil Erosion and Habitat Impacts

Clearing of natural vegetation shall be limited to that which is necessary for the construction, operation and maintenance of the wind energy facility or otherwise prescribed by applicable laws, regulations, and bylaws, and subject to existing easements, restrictions and conditions of record.

3.11 Monitoring and Maintenance

3.11.1 Wind Energy Facility Conditions

The applicant shall maintain the wind energy facility in good condition. Maintenance shall include, but not be limited to, painting, structural repairs, emergency braking (stopping) and integrity of security measures. Site access shall be maintained to a level acceptable to the local Fire Chief and Emergency Medical Services. The project owner shall be responsible for the cost of maintaining the wind energy facility and any access road(s), unless accepted as a public way.

3.11.2 Modifications

All material modifications to a wind energy facility made after issuance of the required building permit shall require approval by the Site Plan Review Authority.

3.12 Abandonment or Decommissioning

3.12.1 Removal Requirements

Any wind energy facility which has reached the end of its useful life or has been abandoned shall be removed by the licensee. The owner/operator shall physically remove the facility no more than 150 days after the date of discontinued operations. The applicant shall notify the Site Plan Review Authority by certified mail of the proposed date of discontinued operations and plans for removal. Decommissioning shall consist of:

(a) Physical removal of all wind turbines, structures, equipment, security barriers and transmission lines from the site.

(b) Disposal of all solid and hazardous waste in accordance with local, state, and federal waste disposal regulations.

(c) Stabilization or re-vegetation of the site as necessary to minimize erosion. The Site Plan Review Authority may allow the owner to leave landscaping or designated below-grade foundations in order to minimize erosion and disruption to vegetation.

3.12.2 Abandonment

Absent notice of a proposed date of decommissioning or written note of extenuating circumstances, the wind energy facility shall be considered abandoned when the facility fails to operate for more than one year without the written consent of the Site Plan Review Authority. If the applicant fails to remove the facility in accordance with the requirements of this section within 150 days of abandonment or the proposed date of decommissioning, the town may enter the property and physically remove the facility

3.12.3 Financial Surety

Applicants for utility-scale wind energy facilities shall provide a form of surety, either through escrow account, bond or otherwise, to cover the cost of removal or failure to maintain, in the event the town must maintain or remove the facility and remediate the landscape, in an amount and form determined to be reasonable by the Site Plan Review Authority, but in no event to exceed more than 125 percent of the cost of removal and compliance with the additional requirements set forth herein, as determined by the applicant. Such surety will not be required for municipally or state- owned facilities. The applicant shall submit a fully inclusive estimate of the costs associated with removal, prepared by a qualified engineer. The amount shall include a mechanism for calculating increased removal costs due to inflation.

D. Example Waiver Language

DISLCAIMER: Rhode Island's Zoning Enabling Act differs from Connecticut's zoning laws and the use of waivers in Rhode Island may be legally prohibited. Accordingly, the following is meant to illustrate the flexibility of wind siting standards accommodated by another New England state. Municipal officials should obtain legal counsel with expertise in zoning prior to finalizing their wind ordinances.

The Connecticut Siting Council uses the following language in their 2015 wind turbine waiver provisions.

"GENERAL WAIVER PROCEDURE

(j) Waivers.

(1) Agreements. Pursuant to Section 16-50o of the Connecticut General Statutes, the applicant or petitioner shall submit any agreements entered into with any abutting property owner of record to waive the requirements under subsections (a) and (c) of section 16-50j-95 of the Regulations of Connecticut State Agencies.

(2) Requests. The applicant or petitioner shall submit to the Council any request for a waiver of the requirements under subsections (a) and (c) of section 16-50j-95 of the Regulations of Connecticut State Agencies at the time an application or petition is filed with the Council. If the Council finds good cause for a waiver of the requirements under subsections (a) and (c) of section 16-50j-95 of the Regulations of Connecticut State Agencies during a public hearing, the applicant or petitioner shall provide notice by certified mail to the abutting property owner of record that includes, the following:

(A) notice of the requirements under subsections (a) and (c) of section 16-50j-95 of the Regulations of Connecticut State Agencies;
(B) notice of the criteria considered for a good cause determination to waive the requirements under subsections (a) and (c) of section 16-50j-95 of the Regulations of Connecticut State Agencies;
(C) notice of the wind turbine manufacturer's recommended setback distances; and
(D) notice that the abutting property owner of record is granted a 30-day period of time from the date notice by certified mail is sent to an abutting property owner of record to provide written comments on the proposed waiver of the requirements under subsections (a) and (c) of section 16-50j-95 of the Regulations of Connecticut State Agencies to the Council or to file a request for party or intervenor status with the Council pursuant to Sections 16-50j-13 to 16-50j-17, inclusive, of the Regulations of Connecticut State Agencies.

SPECIFIC TO SETBACKS

(2) Waiver of requirements. The minimum required setback distances for each of the proposed wind turbine locations and any alternative wind turbine locations at the proposed site and any alternative sites may be waived, but in no case shall the setback distance from the proposed wind turbines and any alternative wind turbines be less than the manufacturer's recommended setback distances from any occupied residential structure or less than 1.5 times the wind turbine height from any occupied residential structure, whichever is greater:

(A) by submission to the Council of a written agreement between the applicant or petitioner and abutting property owners of record stating that consent is granted to allow reduced setback distances; or

(B) by a vote of two-thirds of the Council members present and voting to waive the minimum required setback distances upon a showing of good cause, which includes consideration of:

(i) land uses and land use restrictions on abutting parcels;
(ii) public health and safety;
(iii) public benefit and reliability;
(iv) environmental impacts;
(v) policies of the state; and
(vi) wind turbine design and technology.

SPECIFIC TO SHADOW FLICKER

(2) Waiver of Requirements. The maximum total annual hours of shadow flicker generated by the operation of each of the proposed wind turbines and any alternative wind turbines at the proposed site and any alternative sites may be waived:

(A) by submission to the Council of a written agreement between the applicant or petitioner and property owners of record stating that consent is granted to allow excess total annual hours of shadow flicker; or

(B) by a vote of two-thirds of the Council members present and voting to waive the total annual hours of shadow flicker requirements upon a showing of good cause, which includes consideration of:

(i) land uses and land use restrictions on abutting parcels;
(ii) public health and safety;
(iii) public benefit and reliability;
(iv) environmental impacts;
(v) policies of the state; and
(vi) wind turbine design and technology."

E. Increased Impact Special Use Permit Language & Procedure

The following procedure is a modified version of the Town of South Kingstown's Liquor License Policies and Procedures[23]. It has been modified to support land-based wind turbine projects seeking increased impact special use permits (IISUPs). Municipal officials should obtain legal counsel with expertise in zoning prior to finalizing their wind special use permit procedures.

New Increased Impact Special Use Permit Applications

A. Application

1. An application form must be obtained from the Town Clerk, fully completed, and returned to the Town Clerk with the application processing fee and all required documentation to include:
    a. Site Plan
    b. Special Use Permit Application
    c. Master Plan Amendment Approval for locations in Special Management Districts (if applicable).
2. The application forms to be used are available in the Office of the Town Clerk and are specifically made part of these rules and regulations.
3. The non-refundable application processing fee is $##.
4. The application must contain a description of the project sufficient to identify the specific location, on the property and/or nearby properties, where increased impacts above zoning standards could occur. A site plan, drawn to an acceptable engineering scale and accurately presenting all required data must be submitted with, and as part of, the increased impact special use permit application. The site plan shall contain:

    Parcel identification (Tax Assessor's Map and Lot.)

    Property ownership.

    Zoning Classification.

    Identification of all special use permits, variances, and other legally authorized deviations from the Zoning Ordinance with dates of authorization, including special use permits granted for the expansion of existing uses.

    Identification of exact locations where increased impacts in excess of those permitted by zoning standards could occur.

    Identification of all property owners who may experience increased impacts in excess of those permitted by current zoning standards.

B. Notice

Notice of the application must be given by regular mail to all owners of property who may experience increased impacts in excess of those permitted by applicable zoning standards. The notice is to follow a standard format set by the Town, and will be reviewed and mailed by the Town. Costs shall be paid by the applicant. The notice must state that impacted residents have a right to be heard and state the time and place of the hearing. In addition, each notice must specify the impact(s) that will be in excess of the

[23] http://www.southkingstownri.com/town-government/policies-and-procedures/licenses/liquor-license-rules-and-regulations

Town’s siting standards, where the increased impact(s) will occur on an owner’s property, what land development restrictions could result from the wind turbine development, and how much greater the impact(s) will be compared to the Town’s siting standards.

C. Advertising

The Town must advertise the hearing once a week for two weeks in a newspaper of local circulation. The initial advertisement must appear 30 days or more before the scheduled hearing date.

D. Basis for Denial

1. All available increased impact special use permits authorized under the limits established by these rules and regulations have been issued and no increased impact special use permit is currently available.
2. Objection is made by at least one owner of a property likely to experience impacts in excess of the Town’s siting standards and the Zoning Board determines that the increased impact(s) pose(s) health, or safety concerns or are incompatible with Town zoning goals or plans.
3. The Zoning Board has general discretionary authority to deny an increased impact special use permit based upon criteria which it has established and fairly applies. The following criteria have been established by the Town Council:
    a. Compliance with all Town Ordinances;
    b. Impact on existing municipal services and requirement, if any, for new municipal services;
    c. Compliance with all wind siting requirements included in the Town’s wind siting ordinance except siting impact standards and zoning requirements;
    d. Such other health and safety factors as each individual application may present.
4. Failure of applicant to comply with the requirements of State law

E. Special Use Permit

Wind turbine impacts in excess of the Town’s wind siting standards are permitted under the Zoning Ordinance only by special use permit. Prior to filing the application for an increased impact special use permit, the applicant must demonstrate that an application for a special use permit has been filed with the Zoning Board.