

**DRAFT FOR REVIEW PURPOSES ONLY**

15 March 2012

Town of Falmouth Board of Selectmen  
59 Town Hall Square  
Falmouth, MA 02540.

via email: [selectmen@falmouthmass.us](mailto:selectmen@falmouthmass.us)

Subject: Acoustical Consulting Services  
Falmouth Wind I and Wind II  
Sound Mitigation Options Review and Recommendations  
Acentech Project No. 621707

Attention: Town of Falmouth Board of Selectmen

**1. Introduction**

The Town of Falmouth has installed at their waste-water treatment plant two Vestas model V82 wind turbine generators each rated at 1.65 MWe. Wind I started operation in March 2010 and Wind II started operation in February 2012. A range of concerns by certain nearby residents have been raised including sound, shadow flicker, and ice throw associated with Wind I operation and future operation of Wind II. To address these concerns, a wide range of mitigation options have been proposed for consideration by the Falmouth Board of Selectman. For example, operation of Wind I was curtailed during nighttime periods to reduce sound and was recently removed from service until further notice. Wind II is now operating for a 30-day trial period without curtailment to be followed by a period of limited operation during specific wind speeds.

The Town retained Weston & Sampson (W&S), an environmental and infrastructure consulting firm, to evaluate Wind I and II mitigation options. Their report, *Wind Energy Facility Mitigation Alternatives Analysis*, was submitted to the Board in December 2011. Acentech and DNV Renewables have reviewed the portions of that report related to options for mitigating sound associated with the wind turbines. This letter<sup>1</sup> and the two attached tables document the results of Acentech's review and also identifies various mitigation methods that could be

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<sup>1</sup> Both Acentech authors have more than 30 years of direct experience providing acoustical consulting services for electric-energy generation, transmission, and distribution projects ranging in size from less than 1 MW to more than 1000 MW. Clients have included government agencies, developers, owners and operators, neighbors, and trade associations.

considered in addition to those addressed in the W&S report. Acentech has not undertaken a review of those portions of the W&S report related to financial considerations, shadow flicker, and ice throw. Preparation of this report was funded by the Massachusetts Clean Energy Center.

The numbers of people living within earshot of industrial facilities, energy plants, and transportation routes such as rail lines and well-traveled highways have increased substantially during the past decades. Most people are accepting of the wide range of environmental sounds heard in their neighborhoods. However, when sound from a new facility is introduced into the environment it can be expected that some neighbors might report finding it to be intrusive, annoying, and difficult to accommodate.

Adverse health effects including temporary or permanent hearing loss are well documented for long-term exposure to the loud noises such as within some factories or the brief loud noise from firearms. An extensive review of possible health impacts associated with wind turbine environmental sound is provided in the recent report<sup>2</sup> prepared for the Massachusetts Department of Environmental Protection and Massachusetts Department of Public Health. The expert panel authors report that “Most epidemiologic literature on human response to wind turbines relates to self-reported “annoyance,” and this response appears to be a function of some combination of the sound itself, the sight of the turbine, and attitude towards the wind turbine project.” Conclusions provided by the panel include “... the weight of the evidence suggests no association between noise from wind turbines and measures of psychological distress or mental health problems. None of the limited epidemiological evidence reviewed suggests an association between noise from wind turbines and pain and stiffness, diabetes, high blood pressure, tinnitus, hearing impairment, cardiovascular disease, and headache/migraine.” The panel does recommend that additional measurements and studies are warranted. The panel also considered German and Danish guidelines for villages with mixed usages and residential areas and recommends that nighttime sound limits of 37 to 45 dBA should be considered as “promising practices” for wind turbine sound in Massachusetts. That is the approximate range of wind turbine sound levels at adjacent residents reported by HMMH for Wind I and II.

## **2. Acentech recommendations for consideration by the Falmouth Board of Selectman**

These recommendations are discussed in greater detail in later sections of this letter report.

### ***Near term recommendations***

- a) Decide if the Town chooses to select and adopt sound criteria different from the Massachusetts DEP noise guidelines.
- b) Increase the hub-height (HH) cut-in wind speed from 3.5 to 8.0 m/s during early morning hours between midnight and 3 am with low wind speeds aimed at compliance with the Massachusetts DEP noise guidelines.

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<sup>2</sup> Wind Turbine Health Impact Study: Report of Independent Expert Panel, January 2012

- c) Consider shutting down the wind turbines during summer nighttime periods with selected wind conditions when the wind turbine sound is probably most intrusive to some adjacent neighbors and when the wind resource is lowest.
- d) Consider wind direction when forming curtailment plans. Sound from the wind turbines can be expected to be somewhat greater in downwind directions than in upwind directions.
- e) Offer to purchase at full fair-market value properties within a selected distance from the site that were owned by the current owner before Wind I was installed and then resell the properties with an appropriate easement.
- f) Determine if frequent curtailments damage the wind turbine generators.

***Longer term recommendations***

- a) Perform additional measurements to check if the wind turbine sound power levels comply with the Vestas reference values.
- b) Meet with Vestas engineering representatives for an update on assistance they can offer to reduce the sound produced by their wind turbines. This would include consideration of physical modifications to the wind turbines and operational adjustments.
- c) Conduct continuous measurements of the wind turbine sound at selected locations during a full range of weather and operating conditions for an extended period, such as six months to a year. These measurements would include documentation of amplitude-modulated sound, low-frequency-sound, and infrasound with and without wind turbine operation.
- d) Consider the application of sound masking or active noise control at the wind turbines or at selected nearby residences.
- e) Offer to upgrade the outdoor-to-indoor sound insulation of selected nearby residences.

### **3. Review of sound mitigation options addressed and evaluated in the W&S report**

#### ***Remove wind turbines from the current sites***

It has been suggested that the wind turbines could be decommissioned, dismantled, removed from the current sites at the waste-water treatment facility, and relocated to another site. The turbines might be relocated by the Town or sold to others for reuse elsewhere. W&S estimates that the cost associated with relocating both turbines would be about \$4,480,000 plus the cost, if any, for use of the new site. W&S indicates that there appears to be little or no salvage value for the turbines.

Relocating the wind turbines away from the current site should, of course, eliminate all future concerns about operating sound at the neighbors located near the current site.

#### ***Curtail wind turbine operation during early morning hours with low wind speeds***

The analysis performed by Harris Miller Miller Hanson (HMMH) and reported by W&S provides that the sound produced by Wind I and Wind II is expected to comply with the MassDEP noise guidelines during nearly all operating conditions. The exception, when the MassDEP noise guidelines might be exceeded with both wind turbines operating, is during early morning hours between about midnight and 3 am. It is during this time period that HMMH found background sound levels to be lowest when there was little or no wind.

To avoid exceeding the MassDEP noise guidelines, it has been suggested that one or both turbines not operate during early morning hours unless wind speeds are high and background sound levels are elevated. This is accomplished by increasing the hub-height cut-in wind speed from 3.5 to 8 m/s for one or both turbines during early morning hours.

W&S estimates annual revenue losses of about \$38,500 associated with curtailment of both Wind I and Wind II during the three early morning hours when wind speeds are low. Estimated annual revenue losses increase to about \$77,000 for curtailments extended to six nighttime/early-morning hours from 11 pm to 5 am for both Wind I and Wind II.

It is the authors' opinion that nighttime curtailment of the wind turbines during specific conditions represents a reasonable option aimed at achieving compliance with the MassDEP noise guidelines and should be helpful to adjacent neighbors who are concerned about the wind turbine sound. If or when steps can be implemented to reduce sound generation at the wind turbines, curtailment might no longer be necessary.

It is noted above that the Town should decide if it might be appropriate to adopt sound criteria that are different than the Massachusetts DEP noise guidelines.

It is also noted that an analysis of local wind-shear conditions performed by DNV indicate that during early morning hours with moderate to high wind speeds the estimated background sound levels (without wind turbine operation) might be lower than were reported by HMMH. Sound

measurements being performed by others during March 2012 might help to clarify actual typical background sound levels.

***Curtail wind turbine operation during high wind speeds***

W&S estimates annual revenue losses of about \$500,000 per turbine associated with curtailment during periods when hub-height wind speeds are 10 m/s or greater.

***Upgrade the outdoor-to-indoor sound reduction at selected nearby residences.***

Acentech has been providing acoustical consulting services to MassPort and other airport operators during more than three decades in support of their Residential Sound Insulation Programs (RSIPs) to reduce airplane noise inside thousands of neighbor's homes. Our in-home test results demonstrate that upgrading sound insulation typically reduces the interior sounds from aircraft over-flights by the order of 6 to 9 dBA. The HMMH analysis reported by W&S indicates that the expected reductions of interior sounds from the wind turbines are less, the order of about 3 to 8 dBA with installation of upgraded windows and exterior doors.

The W&S report provides estimated costs for residential sound insulation to be the order of \$30,000 to \$45,000 per house. This estimated cost is in-line with our experience for other Residential Sound Insulation Programs.

It is the authors' opinion that improving the sound insulation of nearby homes could be helpful to nearby neighbors when they are inside their homes. It is important to recognize that residential sound insulation would provide no reduction of the wind turbine sound heard in the yard outside a neighbor's house or inside the house when windows and/or doors are open. It is noted that upgraded sound insulation improves energy efficiency during the heating season and can incur cooling costs if windows are closed during summer months.

***Installation of a sound barrier wall between turbines and adjacent neighbors.***

Sound barrier walls are often used to interrupt or deflect the propagation of sound from a source to a nearby receiver. The barrier walls installed during the past few decades along sections of our highways represent just one example. They are often about 10 to 20-ft high.

To be effective in reducing sound, barrier walls must fully interrupt the line-of-sight between the sound source and receiver. And they should be located relatively close to the source or close to the receiver. The sound reduction provided by a barrier wall is diminished when the receiver is downwind of the source.

Most of the aerodynamic sound from the wind turbines is produced by the outer portion of the blades where the blade speed is greatest. At this installation, the tips of the rotating blades reach a height of approximately 397-ft above local grade elevation.

W&S and HMMH examined the sound reduction performance of a 900-ft long barrier wall as high as 40 to 50 ft and located along the north side of Blacksmith Shop Road to protect four adjacent homes to the south of the road. This is significantly greater than the height of typical barrier walls (installed without supporting earth berms) as are commonly seen along interstate highways.

The HMMH analysis reported by W&S indicates that the 41-ft high barrier wall could be expected to reduce wind turbine sound by 7 to 9 dBA outside the first floor of the nearest few residences and by about 1 dBA outside the second floor windows. The W&S report provides estimated costs for a barrier wall 900-ft long by 41-ft high to be the order of \$1,000,000 to \$2,000,000.

It is the authors' opinion that such a barrier wall does not represent a reasonable mitigation option because of the high costs and negligible sound reduction expected at second floor windows.

***Replace the existing blades with blades that generate less sound, if and when available.***

Vestas does not yet offer upgraded blades that generate less aerodynamic sound than do the currently installed blades. If quieter blades become available from Vestas, W&S estimates the "replacement" costs would be the order of \$1,558,000 per turbine.

It is the authors' opinion that it might be possible at a lower cost to "modify" the existing blades to generate less sound. The results of research published by GE show that a) modifications to wind turbine blade tips and b) installation of serrated trailing edges along the outer portion of wind turbine blades can be expected to achieve modest reductions in the aerodynamic sound generation and sound received at neighboring locations. Recent in-field measurements indicate that sound was reduced by approximately 2 dBA with the installation of serrated trailing edges at the three 1.5 MWe wind turbines operating on Vinalhaven Island.

***Install software from Vestas allowing the Town additional control of wind turbine operations.***

Software available from Vestas could be installed allowing the Town additional local control of wind turbine operations. It is not yet known if this option would be helpful in reducing sound from the wind turbines. W&S estimates that this would cost approximately \$275,000.

It is the authors' opinion that additional local control of the turbine operations might be useful in reducing sounds during specific wind conditions.

#### **4. Additional sound mitigation options that could be considered**

Listed below are additional sound mitigation options suggested by Acentech for consideration by the Falmouth Board of Selectman. These options were not addressed in the W&S report.

##### ***Compensation***

There are a limited number of residences directly adjacent to the wind turbines where neighbors have objected to the sound from the wind turbines. The Town could offer to purchase from owners of selected properties easements associated with wind turbine operation. Or the Town could offer to purchase at full fair-market-value selected adjacent properties. The Town could then resell the purchased properties (with an easement) to people less sensitive to wind turbines.

This would help to compensate selected adjacent neighbors and could reduce potential concerns they might have about residential property values. It is our experience that this approach has been successfully applied at other energy development projects in New England. The costs for the Town to compensate selected adjacent neighbors have not been estimated.

##### ***Define the problem better***

The following three steps are suggested to better define the sound produced by the wind turbines and why some neighbors find the sound to be objectionable.

- 1) Perform additional measurements to check if the sound power levels produced by the wind turbines are in compliance with Vestas reference values, particularly at higher hub-level wind speeds.
- 2) Monitor sound continuously for an extended period at selected locations to better document and quantify operating and weather conditions when wind turbine sound is most intrusive for neighbors. This would include documentation of amplitude-modulated sound, low-frequency-sound, and infrasound with and without wind turbine operation.
- 3) Compare the sounds produced by Wind I with the sounds produced by Wind II and the sounds produced by other wind turbine designs.

##### ***Design changes aimed at reduced sound generation***

It is suggested that the following design changes could be considered.

- 1) Meet with Vestas engineering representatives to explore their experience and investigate the following potential modifications aimed at reduced sound generation from the wind turbines.
- 2) Install serrated trailing edges and/or reduced-noise tip designs at the existing wind turbine blades to reduce aerodynamic sound generation. Serrated trailing edges installed on another wind turbine have been shown to provide a modest reduction in sound generation and would reduce sound at neighboring locations.
- 3) DNV discussions with Vestas indicate that modifications to the blade pitch controller and/or installation of serrated trailing edges should be investigated.

### ***Active control of wind turbine sound***

Initial investigations of active noise control to attenuate wind turbine sound inside nearby houses for another project site have been performed by Conquest Innovations, LLC with assistance from Acentech. Simultaneous digital audio recordings were made at locations inside and outside a neighbor's house about 2000 ft from the site when sound from both operating wind turbines could be heard. The measured data were analyzed, control algorithms and software codes were developed, and simulations were performed by Conquest Innovations, LLC. Based on those findings and past corporate experience, they concluded, with a high level of confidence, that an active noise control system could be developed to reduce low-frequency wind turbine sound within nearby residential structures. The possibility of using active noise control directly at the wind turbine to reduce low-frequency sound was also evaluated.

Cost estimates to develop, install, and demonstrate active noise control systems can be prepared.

### ***Sound masking***

Sound masking introduces low-level steady background sound. It is installed to improve acoustic environments such as in office spaces and libraries. It helps to reduce the intrusiveness of unsteady sounds. Sound masking could be offered to adjacent neighbors to reduce the noticeability of the amplitude-modulated sounds that some neighbors characterize as whoosh – whoosh sounds. Sound masking could also be considered at the wind turbines during times with noticeable amplitude-modulated sounds.

Costs associated with sound masking would be modest.

### ***Further options for consideration***

Apply the health-related conclusions provided in the January 2012 DEP report “Wind Turbine Health Impact Study: Report of Independent Expert Panel”.

Consideration could be given to shutting down the wind turbines during summer nighttime periods with selected wind conditions when the wind turbine sound is probably most intrusive to some adjacent neighbors and when the wind resource is probably lowest.

Perform a cost-benefit analysis of the mitigation options.

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Please contact us if you have questions regarding this letter report or need additional information at this time. The direct dial telephone number for Eric Wood is 617.499.8034, and for Jim Barnes is 617.499.8018.

Sincerely yours,



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**Summary of Sound Mitigation Options Addressed in the  
 December 2011 Report by Weston & Sampson**

<b>Sound Mitigation Options</b>	<b>Estimated Costs</b>	<b>Comments</b>
Remove both wind turbines away from current site	One-time \$4,480,000.	Eliminates future concerns about sound at this site
Curtail operation both turbines during midnight to 3 am with low wind speeds (increase cut-in speed at HH from 3.5 to 8 m/s)	Ongoing annual \$38,500.	Achieves compliance with MassDEP noise guidelines
Curtail operation both turbines during 11 pm to 5 am with low wind speeds (increase cut-in speed at HH from 3.5 to 8 m/s)	Ongoing annual \$77,000.	Achieves compliance with MassDEP noise guidelines
Curtail operation both turbines during HH wind speeds of 10 m/s or greater	Ongoing annual \$500,000. per turbine	Should help to reduce some neighbor's concerns
Upgrade sound insulation of selected nearby residences	One-time \$30,000. to \$45,000. per residence	Modest sound reduction inside neighboring homes
Construct a sound barrier wall 900-ft long by 41-ft high	One-time \$1,000,000. to \$2,000,000.	Not considered a reasonable option
Replace blades with new blades from Vestas that generate less sound	One-time \$1,558,000.	Probably not available from Vestas at this time
Install software from Vestas allowing more local control	One-time \$275,000.	Not yet know if this would contribute to reduced sound operation

**Additional Sound Mitigation Options Not Addressed in the  
 December 2011 Report by Weston & Sampson**

<b>Mitigation Options</b>	<b>Estimated Costs</b>	<b>Comments</b>
Offer to purchase noise easements from selected neighbors	Costs not estimated	Compensates selected adjacent neighbors
Offer to purchase selected neighboring properties	Costs not estimated	Reduce potential concerns about property values
Additional measurements to check if sound complies with Vestas reference values	Modest	A check on Vestas responsibilities
Monitor sound continuously for an extended period	Modest	Document better the range of wind and operating conditions when sound is most intrusive
Additional measurements to define the source and level of infrasound	Modest	Document better the source and level of infrasound
Meet with Vestas to explore sound reduction options	Modest	Update on what Vestas has to offer
Blade modifications such as serrated trailing edges or reduced-noise tips	Costs not estimated	Modest additional sound reduction
Active sound control at selected residences or directly at wind turbines	Costs can be provided	Address low-frequency sound mentioned by some neighbors
Sound masking at selected residences or directly at wind turbines	Modest	Address amplitude-modulated sound “whoosh – whoosh” mentioned by some neighbors
Determine criteria to be used for judging wind turbine sound	Modest	Quantify reasonable expectations
Consider conclusions of the January 2012 DEP report	Modest	Understand potential health effects
Shut down operations during specific summer nighttime periods	Costs not estimated	Time period when sound might be most intrusive to certain neighbors
Perform cost-benefit analysis of mitigation options	Modest	Provide rank ordering of mitigation options