The Wind Energy Center at UMASS

The Science of Wind Energy

Town of Harwich and the
Cape and Vineyard Electric Cooperative
Community Wind Forum

June 17 and 24th, 2009

Patrick Quinlan
Associate Director
UMass Wind Energy Center
Amherst, Massachusetts

University of Massachusetts

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Topics

About myself
About the UMass Wind Energy Center
Wind turbine technical features
Common terminology
Assessing the wind resource
Siting Issues--technical and economic overview
Siting Issues--environmental overview
Visual Issues
Sound Issues
Setback
Where to get good, detailed information

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About the Wind Energy Center

- The oldest wind energy engineering graduate program in the U.S.
- 4 faculty, 12 graduate students, and 5 staff.
- Assist the Commonwealth in wind siting, feasibility assessments, and technical studies.
- Technical support to the Hull wind turbine projects.
- Original prospectors of the wind energy resources in the Cape and Islands.
- www.umass.edu/windenergy

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About Me

- Associate Director of the UMass Wind Energy Center
- Over 25 years experience in renewable energy technology policy
- Former science fellow--White House Office of Science and Technology Policy
- Former staffer to the Ranking Member of the House Science Committee
- Former Senior Analyst at the National Renewable Energy Laboratory

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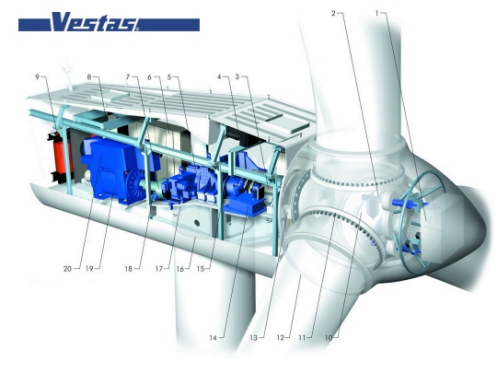
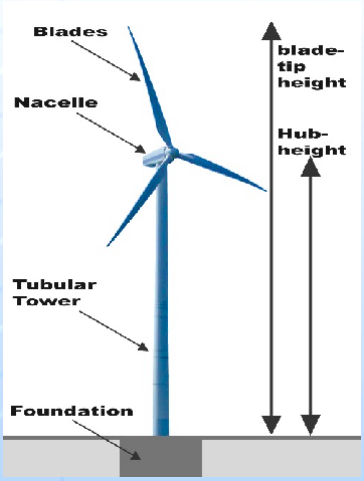
Design of wind turbines and wind facilities





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Wind turbine technical features

- Wind turbines consist of four main components—the **rotor**, transmission (**gearbox**), **generator**, **yaw system**, and **control systems**. Turbines can be direct drive (no gearbox) as well.
- The **nacelle** rotates (or yaws) according to the wind direction.
- Turbines can vary rotational **speed**, blade **pitch**, or both.
- Turbines deployed in multiple groups, called **arrays**, are arranged to avoid shadowing the wind from turbine to turbine.
- Turbines can be turned on and off remotely by an operator at a central control station.
- Turbines don't spin unless the winds are sufficient to generate electricity, or in extreme winds associated with severe storms.

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Other important wind power terminology

- **Turbine power rating** --the maximum instantaneous power output of the wind turbine, quoted in Watts. Typical value is 1.5 Megawatts (1.5 million Watts).
- **Turbine energy production** --a cumulative amount of energy produced by the wind turbine for a given period, usually a year. Quoted in kilowatt-hours (kWh) or megawatt-hours (MWh).
- **Capacity factor** --the average power output of the wind turbine, as a fraction of its power rating. A typical value is 28 percent. This reflects both the variability of the wind at a site and the efficiency of the turbine.
- **Average wind speed** --the long-term average speed of the wind, usually quoted in meters per second. (1 m/s = 2.24 mph). Typical value is 6 m/s.
- **Tower height** --the height of the turbine to the hub of the rotor, usually quoted in meters (1 meter = 3.28 feet). Typical values are 80 meters.
- **Wind shear** --the speed-up of wind with height, given as the exponent of a power-law equation. Typical low value--.15; high value--.30.
- **Turbulence intensity** --the roughness of the wind at a site. This is a dominant criteria for specifying a wind turbine. Typical low value--.15; high value--.30.

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Assessing the wind resource

- Understand potential benefits
  - Energy production
  - Environmental benefit
  - Economic benefit
- i.e Reduce risk
- Community focus
- Spec & order equipment

Anemometer

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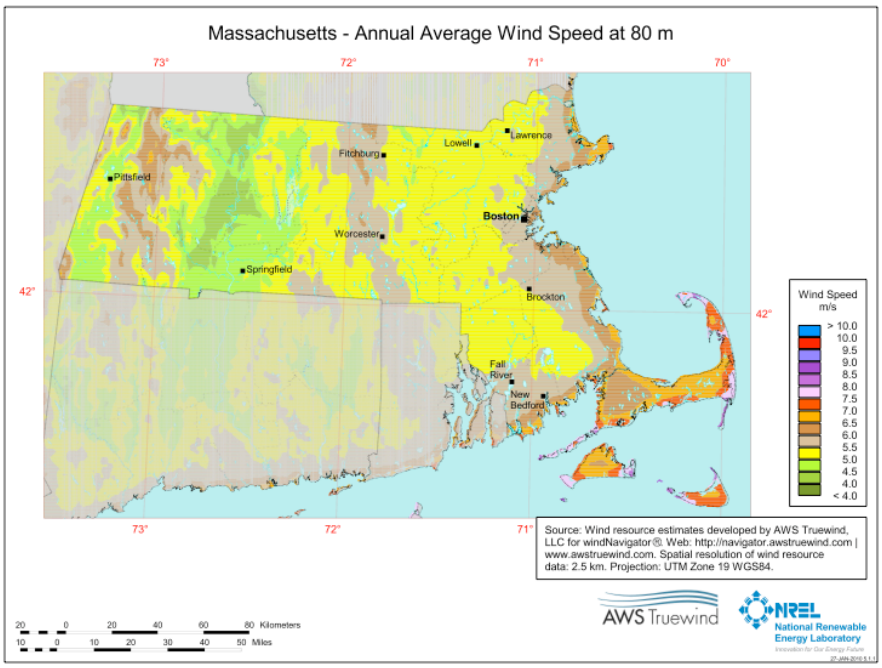

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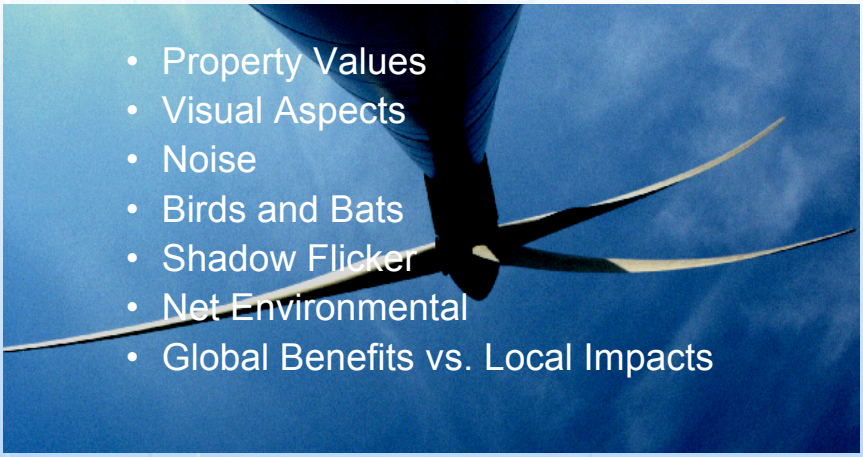
Siting issues--environmental overview



- Property Values
- Visual Aspects
- Noise
- Birds and Bats
- Shadow Flicker
- Net Environmental
- Global Benefits vs. Local Impacts

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Technical attributes of an attractive site

1. High average wind speed. High wind speeds are associated with:
   1. Site elevation above sea-level--this provides good exposure. But not too high--there's less air up there!
   2. Tower height--this provides good clearance from local trees and buildings. And less turbulence, too.
   3. The ocean--far fewer impediments to wind flow.
2. Low turbulence--this permits use of larger rotors on given turbines--better energy per dollar.
3. Good site access--good roads with few bends
4. Adequate utility interconnection for the site.
5. Low noise estimates to local residential locations
6. Low potential for visual flicker to local residential locations

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Environmental attributes of an attractive site

The UMass Wind Energy Center performs "fatal flaw" analyses for state project siting. Items considered are:

1. Wind map readings for first estimate of wind speed
2. FAA height restrictions in the area
3. Wetlands designations
4. Electric utility service and interconnection potential
5. Visual simulations from sensitive locations
6. Possibility of shadow flicker
7. Sound estimates for local residences
8. Zoning setbacks for various reasons
9. Sensitivity to ice shedding
10. Habitat sensitivities--both during construction and operation
11. Bird and bat sensitivities
12. Other…

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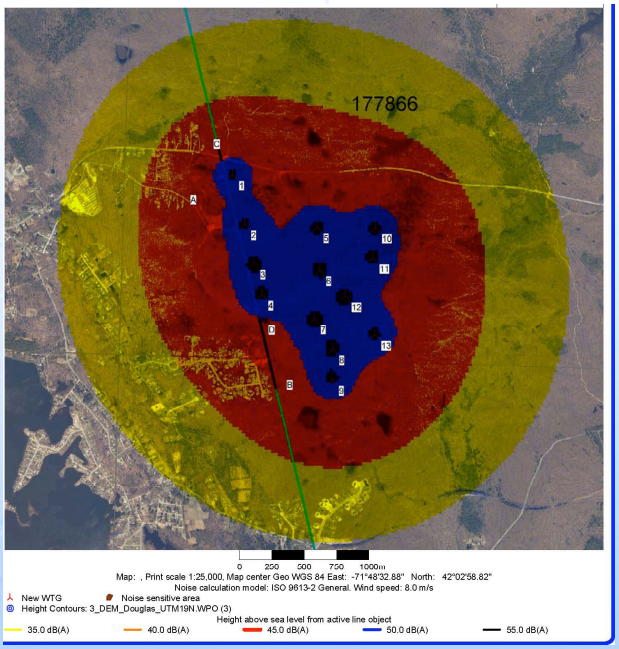
Example Sound Study Map



Example Visual Flicker Report

WindPRO version 2.6.1.252 Jan 2009

Printed/Page
04/28/2009 8:08 PM / 2

Licensed user:
Renewable Energy Research Lab, University of Massachusetts at Amherst
160 Governors Drive Amherst
MA 01003 USA
413 545 3914

Calculated:
04/28/2009 8:07 PM/2.6.1.252

Renewable Energy Research Lab
Mechanical and Engineering Dept
University of Massachusetts

SHADOW - Main Result

Calculation:

Calculation Results

Shadow receptor

No.	Name	Shadow, worst case: Shadow hours per year [h/year]	Shadow days per year [days/year]	Max shadow hours per day [h/day]	Shadow, expected values: Shadow hours per year [h/year]
A	Neighbor A 1	139:56	150	1:21	37:28
B	Neighbor B 1	73:01	147	0:45	20:21
C	Neighbor C 1	215:09	281	1:30	71:32
D	Neighbor D 1	66:44	127	0:50	23:30

Total amount of flickering on the shadow receptors caused by each WTG

No.	Name	Worst case [h/year]
1	NORDEX N100 2500 99.8 IO! hub: 100.0 m (18)	139:56
2	NORDEX N100 2500 99.8 IO! hub: 100.0 m (19)	33:01
3	NORDEX N100 2500 99.8 IO! hub: 100.0 m (20)	39:13
4	NORDEX N100 2500 99.8 IO! hub: 100.0 m (21)	0:47
5	NORDEX N100 2500 99.8 IO! hub: 100.0 m (22)	0:00
6	NORDEX N100 2500 99.8 IO! hub: 100.0 m (23)	0:00
7	NORDEX N100 2500 99.8 IO! hub: 100.0 m (24)	98:36
8	NORDEX N100 2500 99.8 IO! hub: 100.0 m (25)	28:03
9	NORDEX N100 2500 99.8 IO! hub: 100.0 m (26)	97:33
10	NORDEX N100 2500 99.8 IO! hub: 100.0 m (27)	0:00
11	NORDEX N100 2500 99.8 IO! hub: 100.0 m (28)	0:00
12	NORDEX N100 2500 99.8 IO! hub: 100.0 m (29)	39:48
13	NORDEX N100 2500 99.8 IO! hub: 100.0 m (30)	18:31

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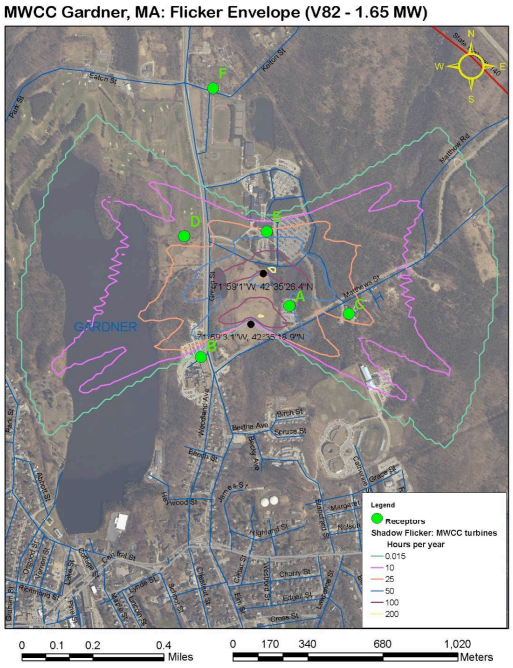
Example Visual Flicker Map



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Example Visual Simulation

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Where to get good, detailed information

- Wind Energy Center
  - Community Wind Fact sheets: www.umass.edu/windenergy/
  - 413-545-4359
- www.windpower.org
  - Lots of accessible, technical information
- Others:
  - AWEA: www.awea.org
  - Wind Power America: www. windpoweringamerica.gov
  - Utility Wind Interest Group : www.uwig.org
  - Links: www.fresh-energy.org
  - Database of State Incentives for R.E.: www.dsireusa.org
  - NREL Publications Database: http://www.nrel.gov/publications

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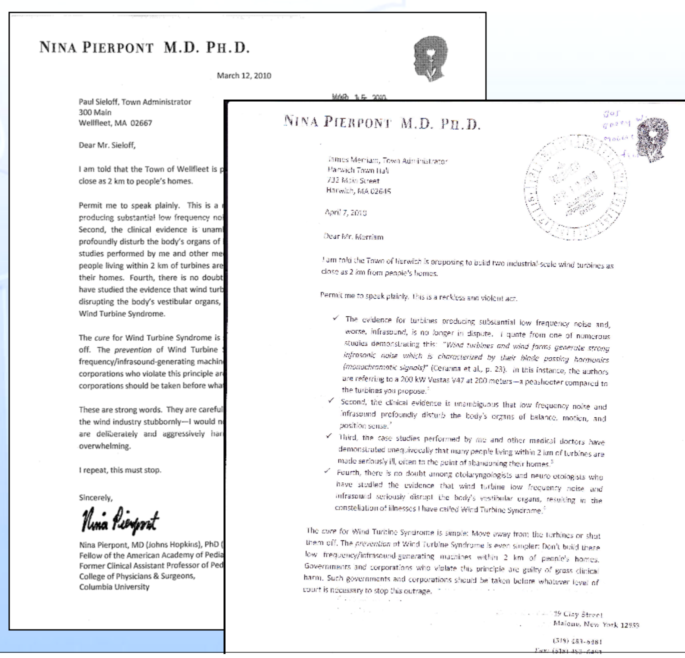
"Wind Turbine Syndrome"



NINA PIERPONT M.D. PH.D.

March 12, 2010

Paul Sieloff, Town Administrator
300 Main
Wellfleet, MA 02667

Dear Mr. Sieloff,

I am told that the Town of Wellfleet is p
close as 2 km to people's homes.

Permit me to speak plainly. This is a
producing substantial low frequency no
Second, the clinical evidence is unam
profoundly disturb the body's organs of
studies performed by me and other me
people living within 2 km of turbines are
their homes. Fourth, there is no doubt
have studied the evidence that wind turb
disrupting the body's vestibular organs,
Wind Turbine Syndrome.

The *cure* for Wind Turbine Syndrome is
off. The *prevention* of Wind Turbine
frequency/infrasound-generating machin
corporations who violate this principle ar
corporations should be taken before wha

These are strong words. They are careful
the wind industry stubbornly—I would n
are deliberately and aggressively har
overwhelming.

I repeat, this must stop.

Sincerely,

Nina Pierpont

Nina Pierpont, MD (Johns Hopkins), PhD (
Fellow of the American Academy of Pedia
Former Clinical Assistant Professor of Ped
College of Physicians & Surgeons,
Columbia University

NINA PIERPONT M.D. PH.D.

James Merriam, Town Administrator
Harwich Town Hall
732 Main Street
Harwich, MA 02645

April 7, 2010

Dear Mr. Merriam

I am told the Town of Harwich is proposing to build two industrial-scale wind turbines as close as 2 km from people's homes.

Permit me to speak plainly. This is a reckless and violent act.

- ✓ The evidence for turbines producing substantial low frequency noise and, worse, infrasound, is no longer in dispute. I quote from one of numerous studies demonstrating this: *"Wind turbines and wind farms generate strong infrasonic noise which is characterized by their blade passing harmonics (monochromatic signals)!"* (Ceranna et al., p. 23). In this instance, the authors are referring to a 200 kW Vestas V47 at 200 meters—a peashooter compared to the turbines you propose.[1]
- ✓ Second, the clinical evidence is unambiguous that low frequency noise and infrasound profoundly disturb the body's organs of balance, motion, and position sense.[2]
- ✓ Third, the case studies performed by me and other medical doctors have demonstrated unequivocally that many people living within 2 km of turbines are made seriously ill, often to the point of abandoning their homes.[3]
- ✓ Fourth, there is no doubt among otolaryngologists and neuro-otologists who have studied the evidence that wind turbine low frequency noise and infrasound seriously disrupt the body's vestibular organs, resulting in the constellation of illnesses I have called Wind Turbine Syndrome.[4]

The *cure* for Wind Turbine Syndrome is simple: Move away from the turbines or shut them off. The *prevention* of Wind Turbine Syndrome is even simpler: Don't build these low frequency/infrasound-generating machines within 2 km of people's homes. Governments and corporations who violate this principle are guilty of gross clinical harm. Such governments and corporations should be taken before whatever level of court is necessary to stop this outrage.

19 Clay Street
Malone, New York 12953

(518) 483-6481

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"Wind Turbine Syndrome"

- **Dr. Pierpont:** low frequency noise and infrasound profoundly disturb the body's organs of balance, motion, and position sense. Case studies performed by me and other medical doctors have demonstrated that many people living within 2 km of turbines are made seriously ill, often to the point of abandoning their homes. There is no doubt among otalaryngololigsts and neuro-otologists who have studied the evidence that wind turbine low frequency noise and infrasound seriously disrupt the body's vestibular organs, resulting in the constellation of illnesses I have called Wind Turbine Syndrome.
- **Peer Reviewed Epidemiological Study by Acoustic Ecology Institute:** "…it is also clear that wind farm noise is truly not that bothersome to most people who hear it or live near it, and that the vast majority of wind farms never generate any substantial ongoing noise issues. Concerns that dominate public discourse and activist web sites can seem to accentuate the hardest to quantify issues (such as direct health effects, especially of low-frequency noise), while magnifying the extent of problems as communities consider new wind developments.

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Noise

- The Acoustic Ecology Institute (www.acousticecology.org):
  - independent, non profit
  - tracking public concerns about wind farm noise,
  - while also studying new research, trade journals & reports
  - AEI's approach has been the same as we've taken to ocean noise issues since 2004: to do our best to
  - cut through the rhetoric and hyperbole from advocates on both sides of the issue
  - get a clearer sense of the state of understanding of these noise impacts, in order to help inform emerging public policy choices.

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Noise (continued)

- With wind farm noise, as with ocean noise, the more we learn, the more obvious it is that:

  - there is much we still do not know.

  - it's not nearly as simple as either side in this increasingly rancorous debate appears to think it is.

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AEI's Key Messages:

First, it is clear that many people, in all parts of the country, have been dramatically impacted by the noise of wind farms near their homes.

- To dismiss all these people as cranks, or as hyper-sensitive social outliers, does a disservice to constructive public discourse, and short-circuits our opportunities to learn from their experiences as we continue to develop new wind farms.

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AEI's Key Messages, con't:

Second, it is also clear that wind farm noise is truly not that bothersome to most people who hear it or live near it, and that the vast majority of wind farms never generate any substantial ongoing noise issues.

- Concerns that dominate public discourse and activist web sites can seem to accentuate the hardest to quantify issues (such as direct health effects, especially of low-frequency noise), while magnifying the extent of problems as communities consider new wind developments.

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AEI's Key Messages, con't:

Third, the nature of the sounds made by wind turbines make it especially difficult to rely on reassuring "noise limits" as proposed by states, counties, or townships.

Several factors contribute to this dilemma:

Noise propagation varies greatly with changing wind and atmospheric conditions;

Many different ways to average noise recordings, some of which can lead to noise levels much higher than local officials may think they are allowing;

The pulsing nature of turbine noise is inherently more attention-grabbing and more easily disruptive than road or industrial noises; and finally,

There is much we have yet to learn about the factors that create the most troublesome turbine noises, including pulses and low-frequency sound.

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AEI's Key Messages, con't:

And fourth, and perhaps most important yet least appreciated: we are facing some social choices that may be difficult to make.

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AEI's key conclusions:

- Broad-brush studies report no simple cause-effect between wind farm noise and various measures of impact (health, annoyance, property values),
  - But, it is also clear that a minority of those nearby do often experience dramatic, negative impacts.
  - How many such affected neighbors are we willing to accept? 5%? 20%?
- We can no longer pretend this more affected minority doesn't exist
- it's time to choose how much to adapt wind farm planning — or operations — in response to these impacts.

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In Europe: Standard regulations for wind turbine noise levels in effect in 2010

- standard regulations governing the maximum noise levels for wind turbines
- in line with European requirements
- will prescribe only a single standard with which wind farms must comply
- the regulations will be straightforward, simplifying local decision-making
- The new standard for maximum noise levels ('L-den-Norm') are unambiguous.
- Specify limits of yearly average noise levels during the day, evening and night.
- Separate standard for nighttime noise levels, the 'Lnight', specifically targeting levels that interfere with sleep
- Uniform and clear