Consensus report

Panel made of individuals with expertise in different, yet relevant areas.

There was overlap in the literature that was reviewed by the panel members.

Panel members formed individual opinions, discussions were based on need to share expertise in order to develop completely informed set of findings and best practices.

All panel members reviewed the data and came to consensus.

Overview of

Wind Turbine Health Impact Study: Report of Independent Expert Panel

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Scope of review

Peer reviewed articles
- Epidemiological studies
- Biological research associated with vestibular system
- Mechanical design and operation of wind turbines
- Acoustic and vibration (related)
- Animal studies of IFLN

Technical reports
- NASA
- National Academy of Science

Gray literature
- Non peer reviewed epidemiological studies
- Books
- Other state, country, national reviews related to wind turbines

Public comment
- Docket
- Web pages, blogs, youtube

- 100 items cited
- More than 100 more articles read

Today's overview

Noise and vibration – Sheryl Grace

Ice Throw – Jim Manwell

Shadow Flicker – Jim Manwell

Health Impact – Wendy Heiger-Bernays

Noise and Vibration

Noise and Vibration -

Pressure is measured in Pascals (Newton/m^2)

To get to dB : sound pressure level:

$$SPL = 10 \log_{10} [p^2/p^2_{ref}] = 20 \log_{10}(p/p_{ref})$$

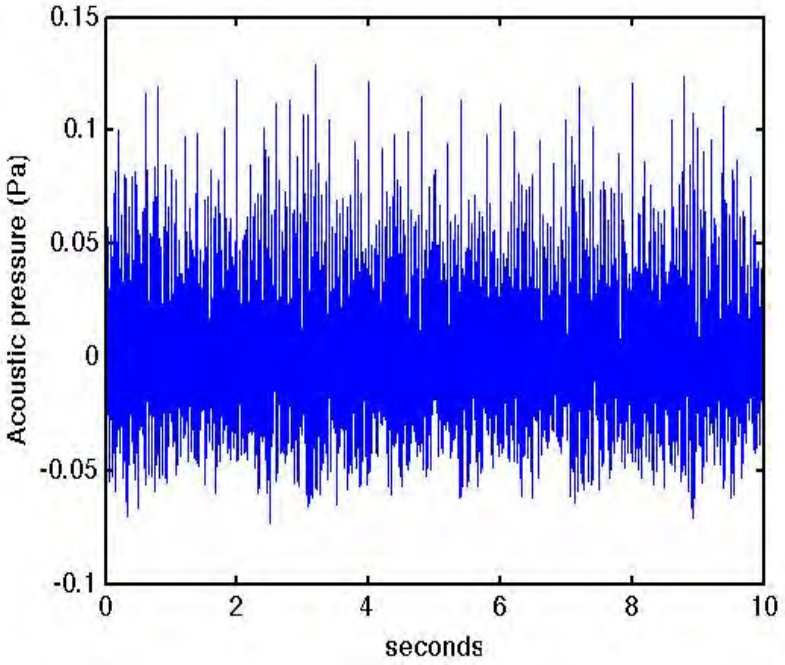
$$p_{ref} = 20 \text{ X } 10^{-6} \text{ Pa} = 20\mu\text{Pa}$$

Some characteristics of human response to sound include

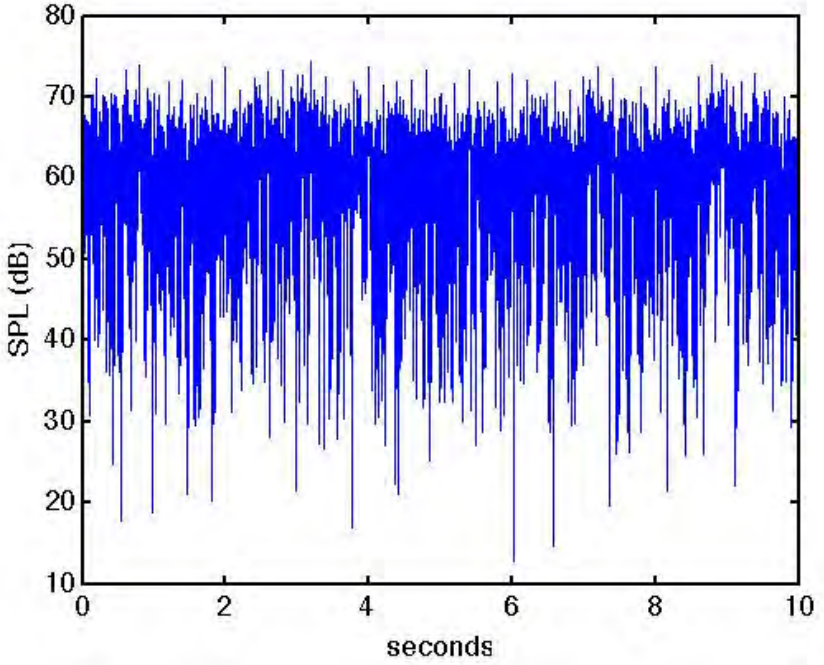
- Changes in sound level < 1 dB cannot be perceived
- Doubling the magnitude of the acoustic pressure leads to a 6 dB increase in SPL
- A 5 dB SPL change will result in a noticeable community response
- A 10 dB SPL change is subjectively heard as an approximate doubling in loudness.

Noise and Vibration -

Start with pressure is measured in Pascals (N/m^2)



Change to SPL

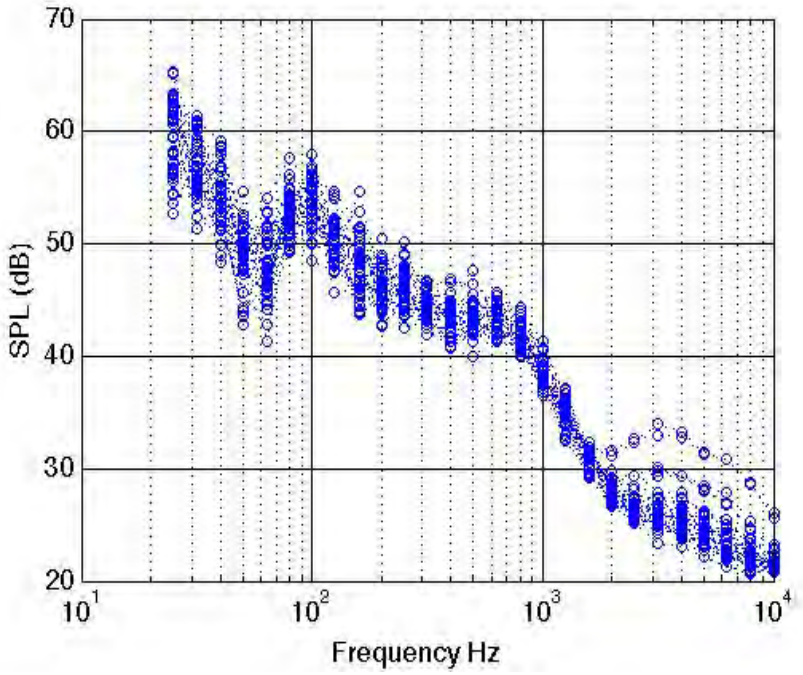


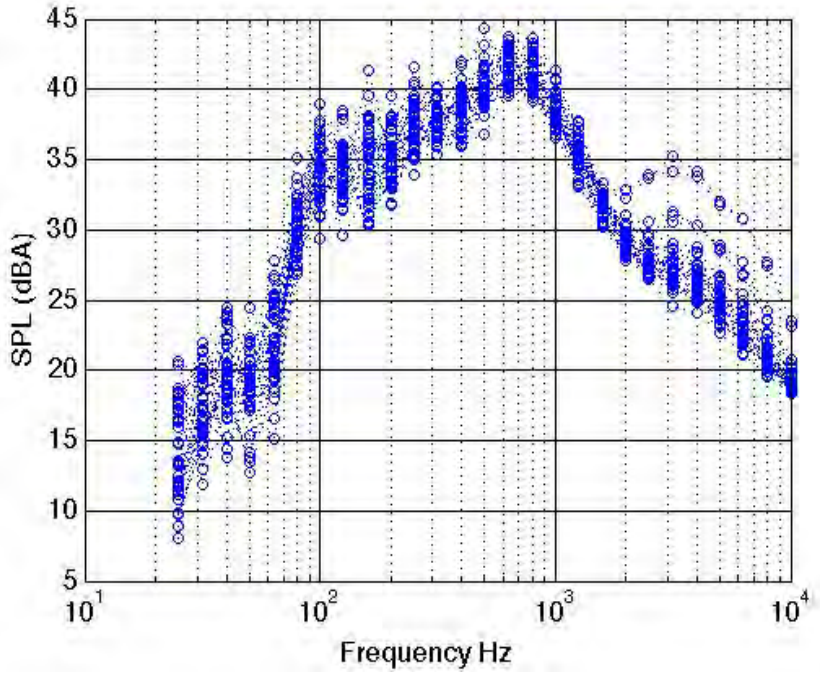
Data from German wind farm

Noise and Vibration -

Move to frequency domain, put in 1/3 octave bands. Used fast averaging method.

Apply A-weighting

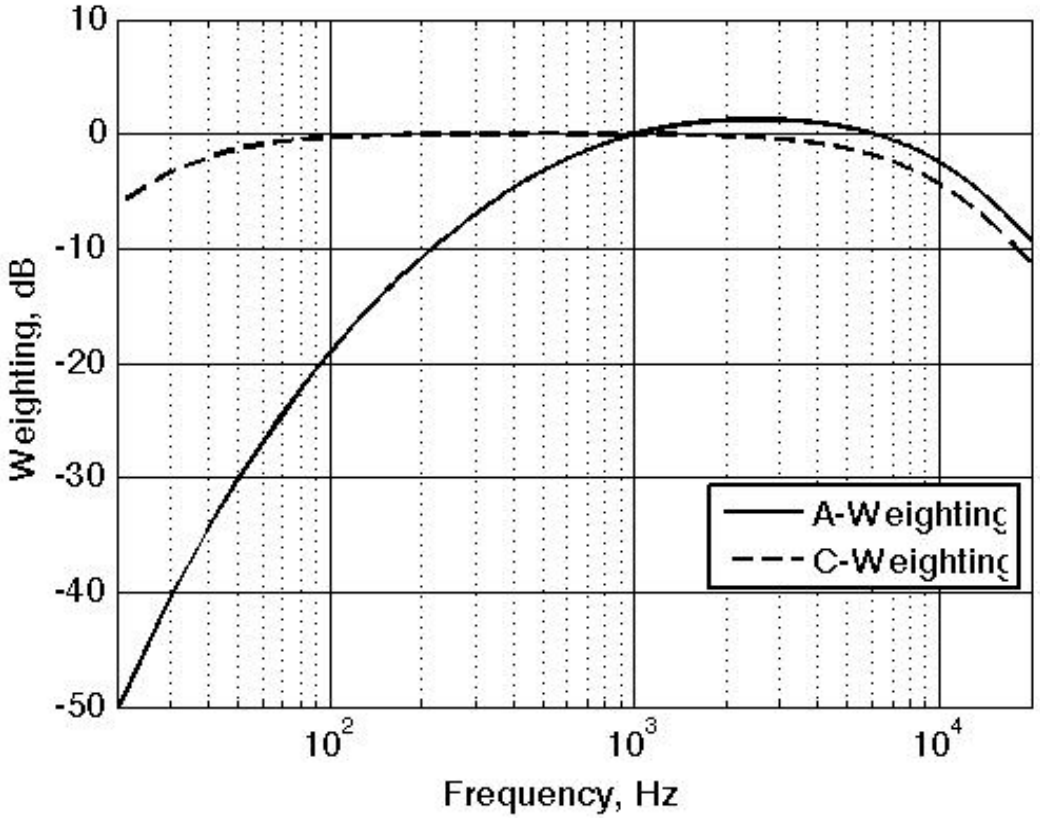




Average over all frequencies – get overall sound pressure level reported

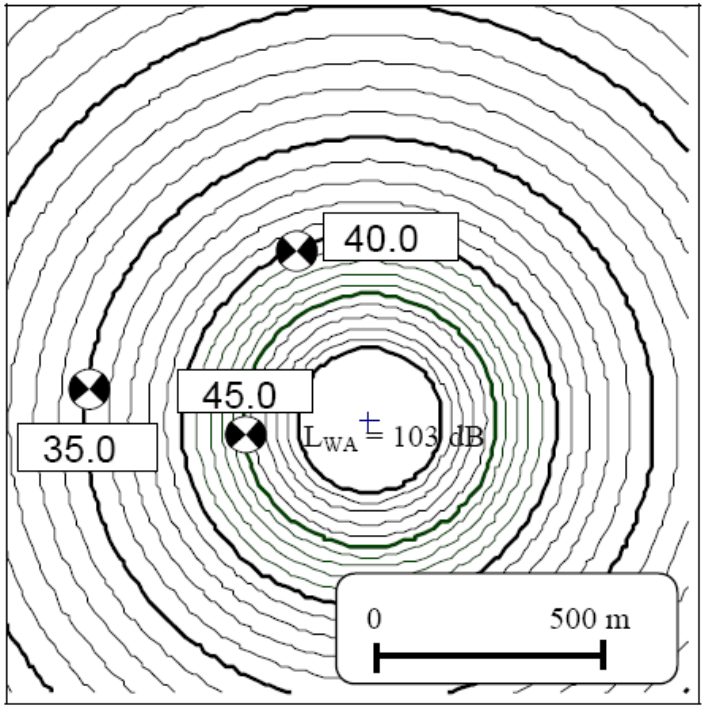
Noise and Vibration -

Weighting curves – A-weighting reflects human perception curve



Noise and Vibration -

Typical sound pressure level vs. distance from single wind turbine

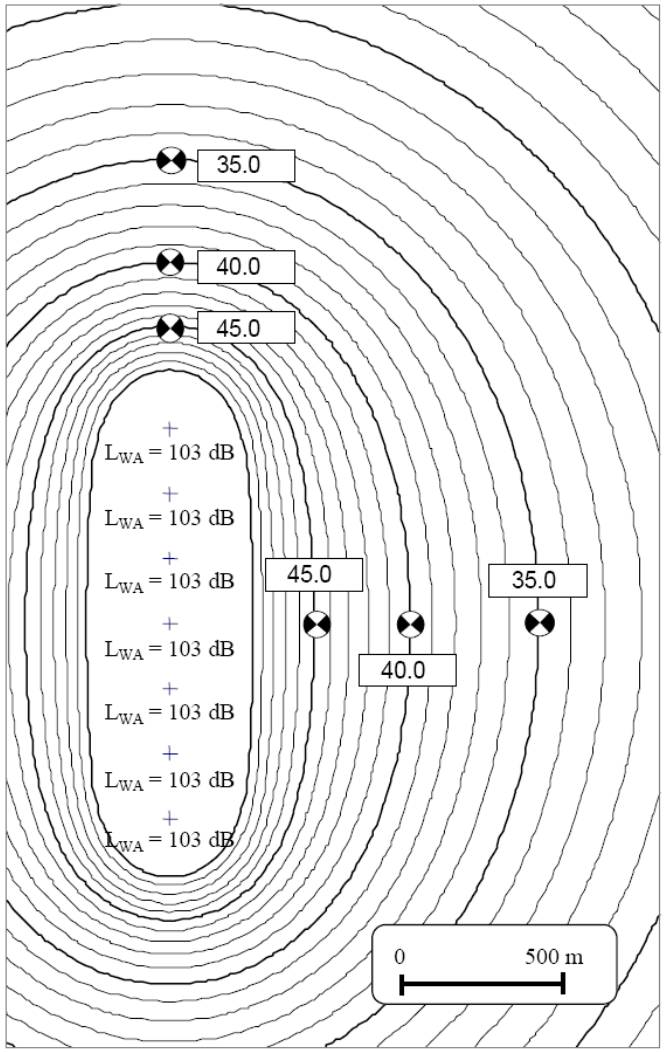


Sound pressure, dB(A)	Distance, m
45	280
40	410
35	620

Noise and Vibration -

Typical sound pressure level vs. distance from multiple wind turbines

Sound pressure, dB(A)	Distance, m
45	440
40	740
35	1100



Noise and Vibration -

Propagation of noise from wind turbines depends on many things

- speed of sound gradients (temperature profile)
- reflection from hillsides
- atmospheric absorption

Audible : “wooshing”, “swish-swish”

- due to amplitude modulation of broadband noise generated because of aerodynamic effects on the blades
- pulsates at blade passage frequency (~1 Hz)
- affected by wind shear (difference from wind at bottom and top of blade disk)
- perceived as louder at night (stable atmosphere, quiet background)

Noise and Vibration -

Infrasound (less than 20 Hz) –

- can be heard if at very high level (> 110 dB)
- can be felt (chest pound) if at very high level (> 110 dB)

- most coupling mechanisms hypothesized in gray literature are not substantiated by levels measured near wind turbines

- recent attention on a part of the inner ear called the Outer Hair Cells that are known to be responsive to infrasound (at lower levels) -- however, evidence does not exist to demonstrate the influence of wind turbine-generated infrasound on vestibular mediated effects in the brain.

Noise and Vibration -

Vibration

- Seismic (ground-carried) measurements recorded near wind turbines and wind turbine farms are unlikely to couple into structures.
- high amplitude impulses that focus due to topography or refraction had been shown to couple into homes near an older downwind turbines (10 out of 1000) (downwind turbine)
- haunted space effect – room vibrations due to HVAC or other fan coupled to building

If infrasound [or audible pulses] couples into structures, then people inside the structure could feel a vibration. Such structural vibrations have been shown in other applications to lead to feelings of uneasiness and general annoyance.

[Trusted, reproducible] measurements have not proven such coupling from modern upwind turbines.

Ice Throw

Ice Throw

Ice can fall or be thrown from a wind turbine during or after an event when ice forms or accumulates on the blades.

There is sufficient evidence that falling ice is physically harmful and measures should be taken to ensure that the public is not likely to encounter such ice.

Can calculate safe distance using first principles.

Ice Throw

Falling ice can be carried by wind→

Distance can be predicted from wind speed, typical size and shape of pieces of ice

Ice can be released from blade during rotation→

Distance can predicted from Newton's 2nd Law, also considering typical size and shape of ice and effect of atmospheric drag

Maximum expected ice throw distances→

1.5 x (Rotor diameter + Tower Height)

Example: 80 m rotor and 80 m tower→ 240 m max likely ice throw

Distance can be minimized by suitable control measures

Shadow Flicker

Shadow flicker

Shadow flicker results from the passage of the blades of a rotating wind turbine between the sun and the observer.

1. Depends on the location of the observer relative to the turbine and the time of day and year.

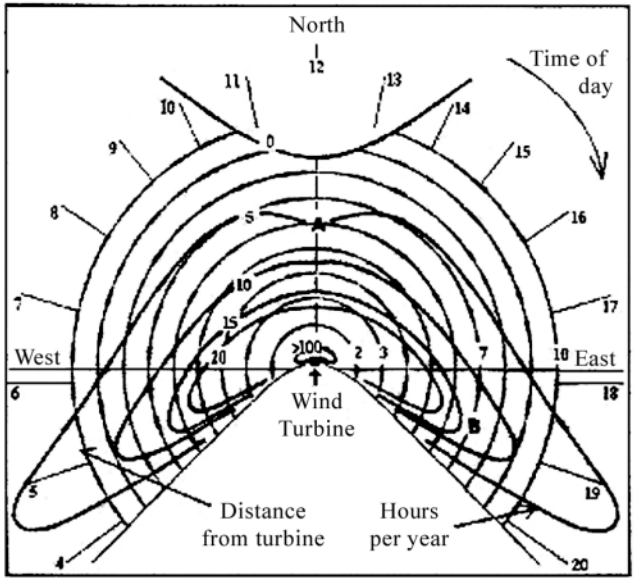
2. Frequency is proportional blade passage frequency and is generally between 0.5 and 1.1 Hz for typical larger turbines.

3. Shadow flicker is only present at distances of less than 1400 m from the turbine.

Video illustrating shadow flicker→

Shadow flicker

Shadows are shorter in summer, longer in winter
Shadows appear to the west of a turbine before noon, to the east after noon.



Typical path of sun
http://oikos.com/library/solar_site_design/index.html

Typical shadow flicker diagram
European Wind Energy Assoc.

Shadow flicker

Scientific evidence suggests that shadow flicker does not pose a risk for eliciting seizures as a result of photic stimulation.

There is limited scientific evidence of an association between annoyance from prolonged shadow flicker (exceeding 30 minutes per day) and potential transitory cognitive and physical health effects.

Best practice:

1. Limit maximum flicker time to less than 30 min/day
2. Limit total flicker time to less than 30 hr/yr (assuming clear sky)

Minimize flicker effect by:

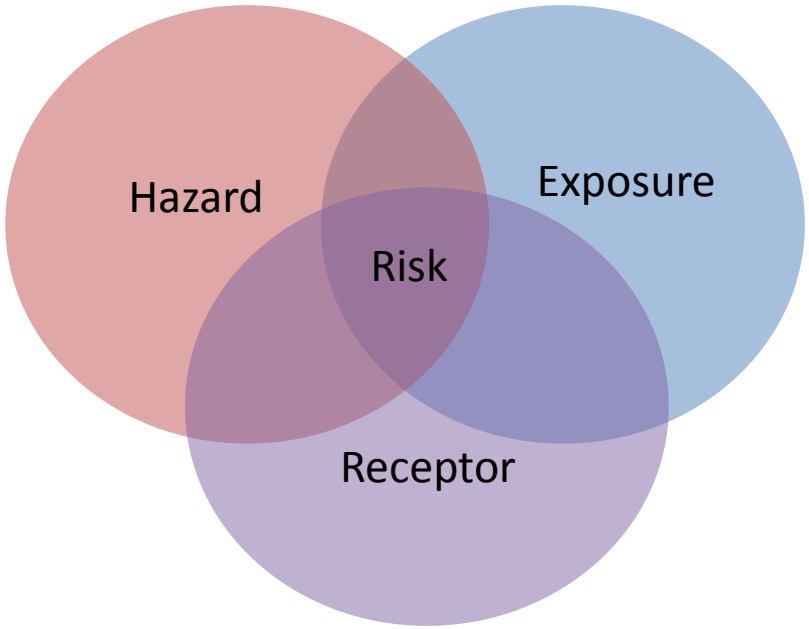
1. Choice of location (distance and direction)
2. Limiting rotor speed at certain times

Risks to Human Health and Safety

Associations between exposure and health are based on the evidence.

Evidence (data that support or refute)

Data/Studies (information/results)



Health impact of noise and vibration

Public Health Impact = Wide ranging; physical and/or psychological

Population response to stimuli

Noise and Vibration

We draw conclusions from the science. Associations between exposure and health are based on the weight of the evidence.

- Evidence (data that support or refute)
- Data/Studies (information/results)

Few epidemiological studies of human health effects from exposures to ***turbine noise & vibration*** have been conducted.

- Self-reported effects
- Lack of robust sound pressure measurements

Hazard-free status cannot be assumed from the weak studies that showed no strong associations between these exposures and illness.

Health impact of noise and vibration-

Most epidemiologic studies on human response to ***wind turbines*** relates to self-reported "annoyance,"

- limited epidemiologic evidence suggesting an association between exposure to wind turbines and annoyance.
- Cannot determine whether there is an association between noise from wind turbines and annoyance independent from the effects of seeing a wind turbine and vice versa.

Self-reported "annoyance"

Health impact of noise and vibration-

- Limited evidence from epidemiological studies suggesting an association between noise from wind turbines and sleep disruption…. ***it is possible that noise from some wind turbines can cause sleep disruption*****.**

- There is not enough evidence to provide particular sound-pressure thresholds at which wind turbines cause sleep disruption. Further study would provide these levels.

- Whether annoyance from wind turbines leads to sleep issues or stress has not been sufficiently quantified. While not based on evidence of wind turbines, ***there is evidence that sleep disruption can adversely affect mood, cognitive functioning, and overall sense of health and well-being.***

Sleep disruption

Sleep disruption DOES adversely affect health

Health impact of noise and vibration-

- Insufficient evidence that the noise from wind turbines is ***directly (i.e., independent from an effect on annoyance or sleep) causing health problems or disease.***

- The weight of the evidence suggests no association between noise from wind turbines and measures of psychological distress or mental health problems

- Insufficient ***data*** to suggest an association between noise from wind turbines and pain and stiffness, diabetes, high blood pressure, tinnitus, hearing impairment, cardiovascular disease, and headache/migraine.

Not enough data to suggest an association between wind turbine noise and a multitude of *other* health effects

Health impact of noise and vibration-

Syndrome – essential characteristics that appear together

There is no evidence (for the explanation provided) for a set of health effects, from exposure to wind turbines that could be characterized as a "Wind Turbine Syndrome."

Health Risks of Wind Turbines

- **Shadow flicker** does not cause epileptic seizures, yet can be disruptive;
- **Ice**, if thrown and hits people, can cause physical harm;
- **Audible noise**, especially at night may disrupt **sensitive** receptors' sleep.
  - May occur directly (if close enough) or indirectly (if annoyed)
  - Sleep disruption can result in headaches, loss of cognition, exhaustion and poor quality of life.
- **Infrasound** may be sensed by **sensitive** individuals, likely not directly from the turbine, but by coupling into homes, attributed to self-reported disorientation, dizziness, nausea.

Best Practices

Best Practices for Moving Forward

The best practices exist because it has been shown that self-reported annoyance, sleep deprivation, and health effects are greatly reduced when certain considerations are given

The best practices could inform policy

The best practices could be useful to municipalities

Use calculation method available for ice throw distances

Adhere to < 30 min/day, 30 hrs/year for shadow flicker

Best Practices for Moving Forward

Consider noise limits used in other countries

Land Use	**Sound pressure level, dB(A) nighttime limits**
Industrial	70
Commercial	50
Villages, mixed usage	45
Sparsely populated areas, 8 m/s wind*	44
Sparsely populated areas, 6 m/s wind*	42
Residential areas, 8 m/s wind*	39
Residential areas, 6 m/s wind*	37

Must define averaging window

Best Practices for Moving Forward

Know type of turbine and noise specs for turbine

Ongoing program of monitoring and evaluation of sound produced by wind turbines is suggested

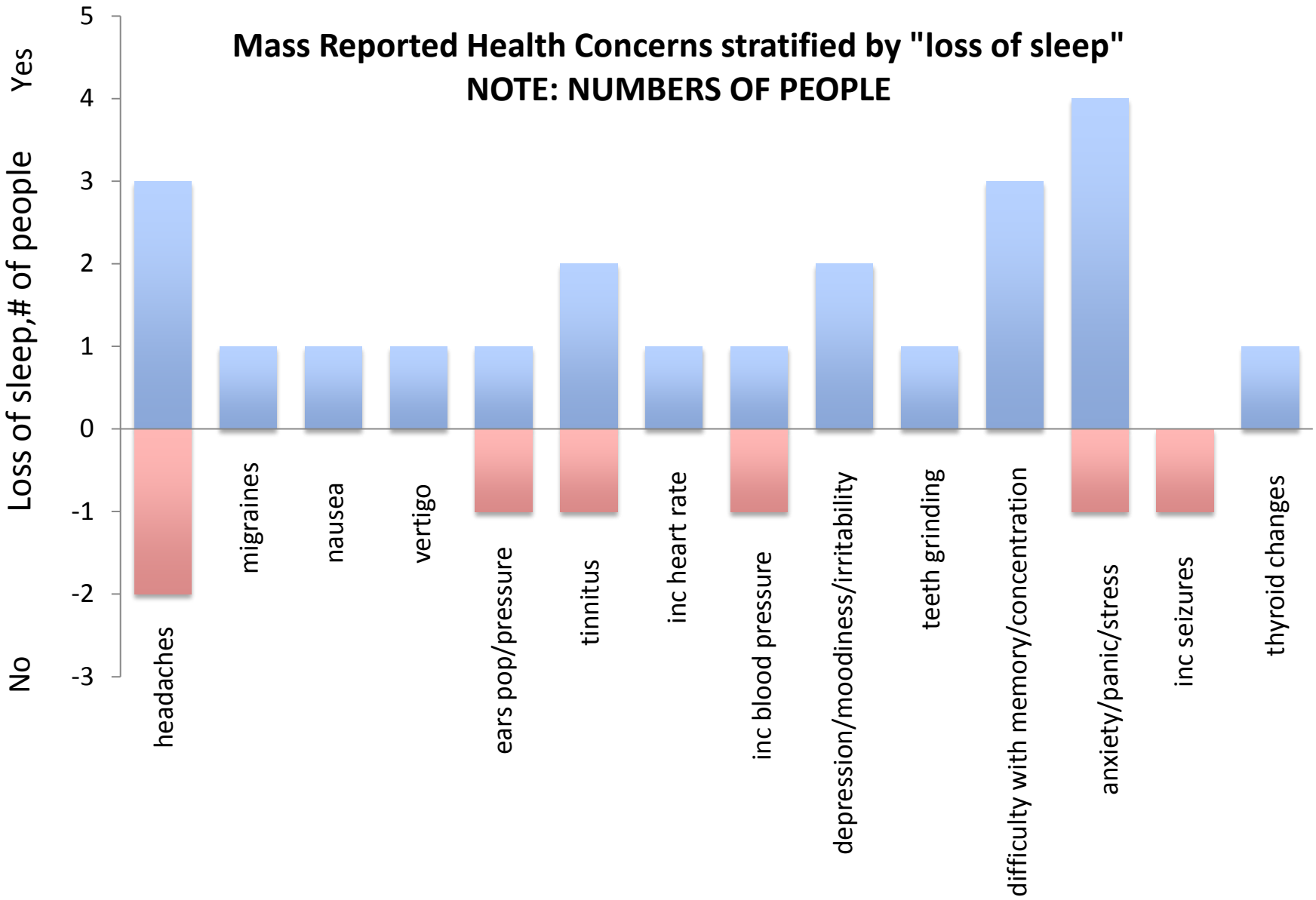
Closer investigation of homes where A and C weighting noise measurements outside differ by 15 dB or more

Direct involvement of neighbors in wind turbine development and economic plan is suggested

Continued public engagement

Questions

Vestas V82
1.65 MW



Comments/Concerns Reported to MassDEP (2011)