Potential Health Impacts of
WIND TURBINES

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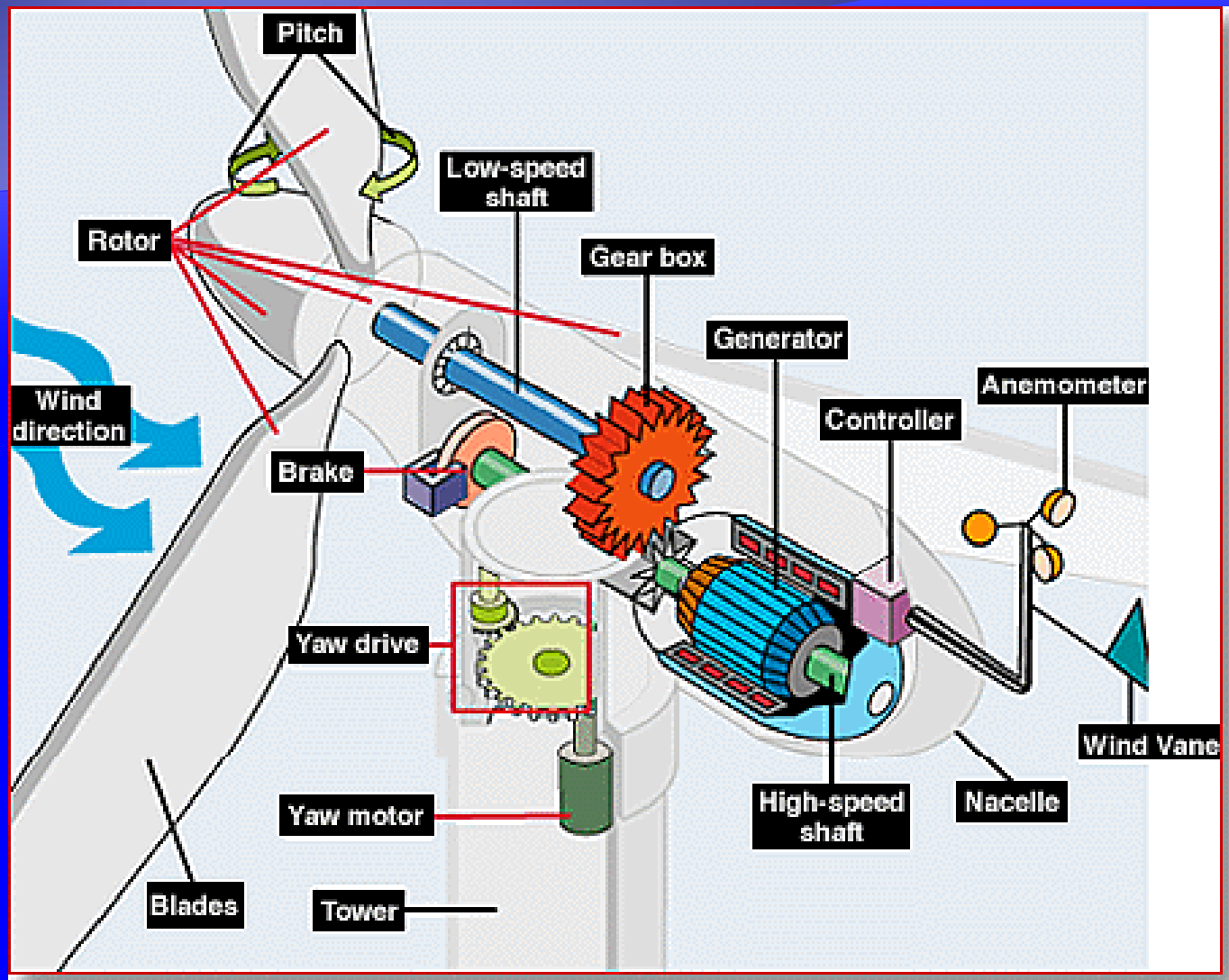
Wind Turbines

Source: Minnesota White Paper 2009

How It Works

- **Wind turbines are mounted on a tower**
  - Tower height: up to 328 feet (100 meters)
  - Total height: up to 492 feet (to the tip of the blade)
  - Wind speed increases with increasing height
  - At heights above 100 feet, there is more wind and less turbulence
- **Propeller-like blades catch the wind's energy**
  - Three blades are mounted on a shaft to form a rotor
  - Rotor diameter: up to 328 feet
  - Blade length: up to 164 feet
- **The rotor is connected to the main shaft, which spins a generator to create electricity**

Inside the Wind Turbine



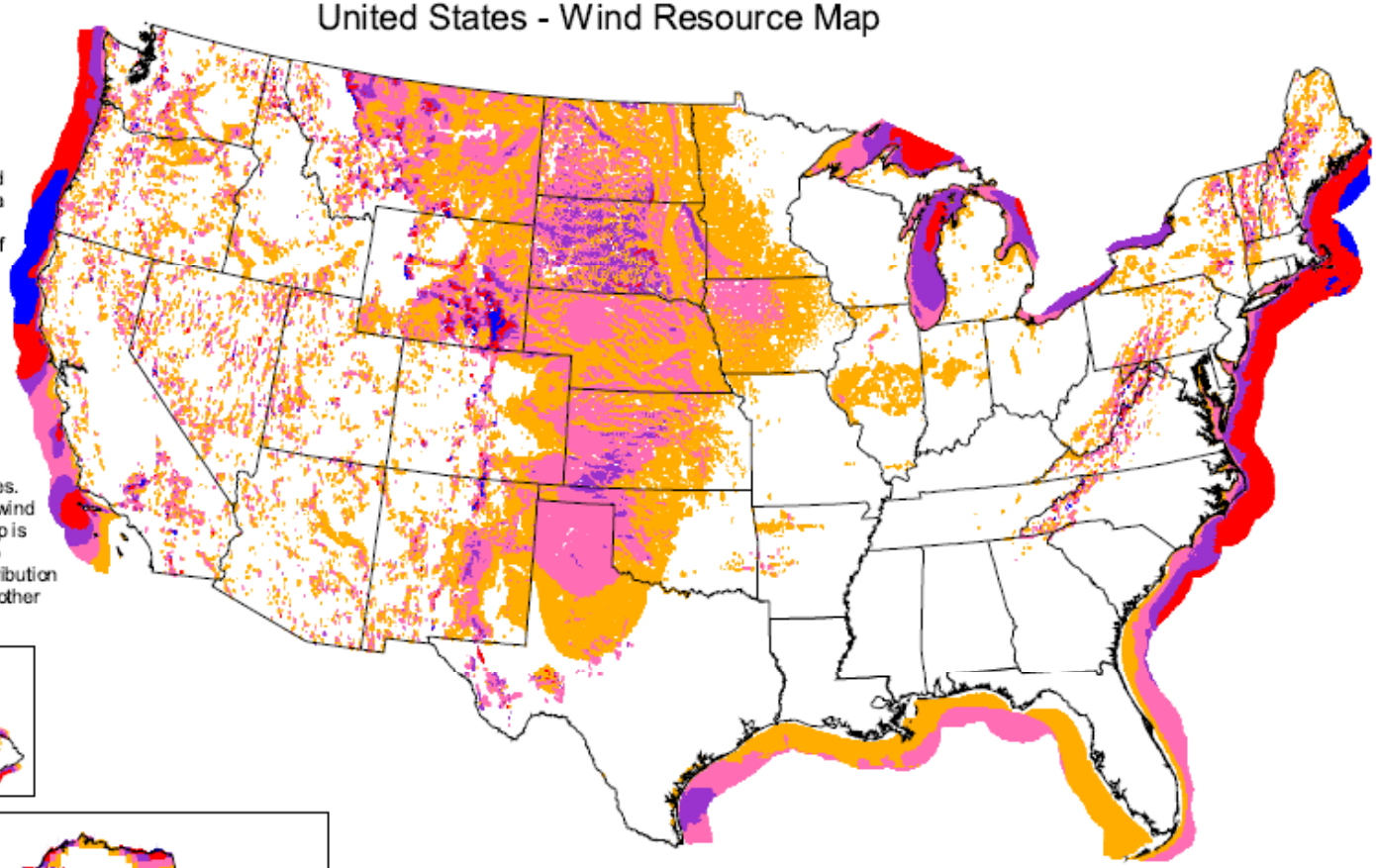
Source: U.S. Department of Energy- Energy Efficiency and Renewable Energy

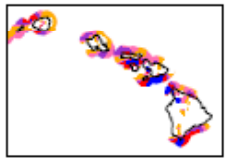
Wind Speeds and Energy

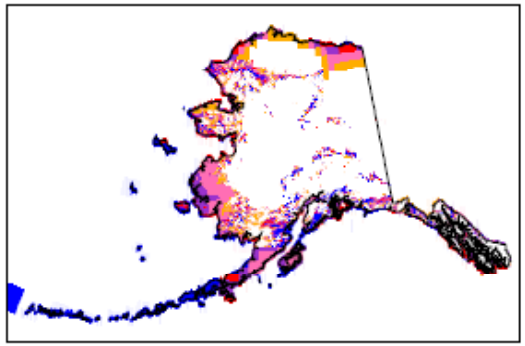
- **The importance of good wind speeds**
  - The energy that the wind contains is a function of the **cube (V^3)** of the wind speed
  - A site with 12-mph average winds has >70% more energy than a site with 10-mph average winds
- **Energy generation in megawatts (MW)**
  - A 2 MW wind turbine can power about 500 average Ohio homes
  - A 200 MW project (100 2 MW turbines) could power 50,000 homes annually

United States - Wind Resource Map

This map shows the annual average wind power estimates at a height of 50 meters. It is a combination of high resolution and low resolution datasets produced by NREL and other organizations. The data was screened to eliminate areas unlikely to be developed onshore due to land use or environmental issues. In many states, the wind resource on this map is visually enhanced to better show the distribution on ridge crests and other features.







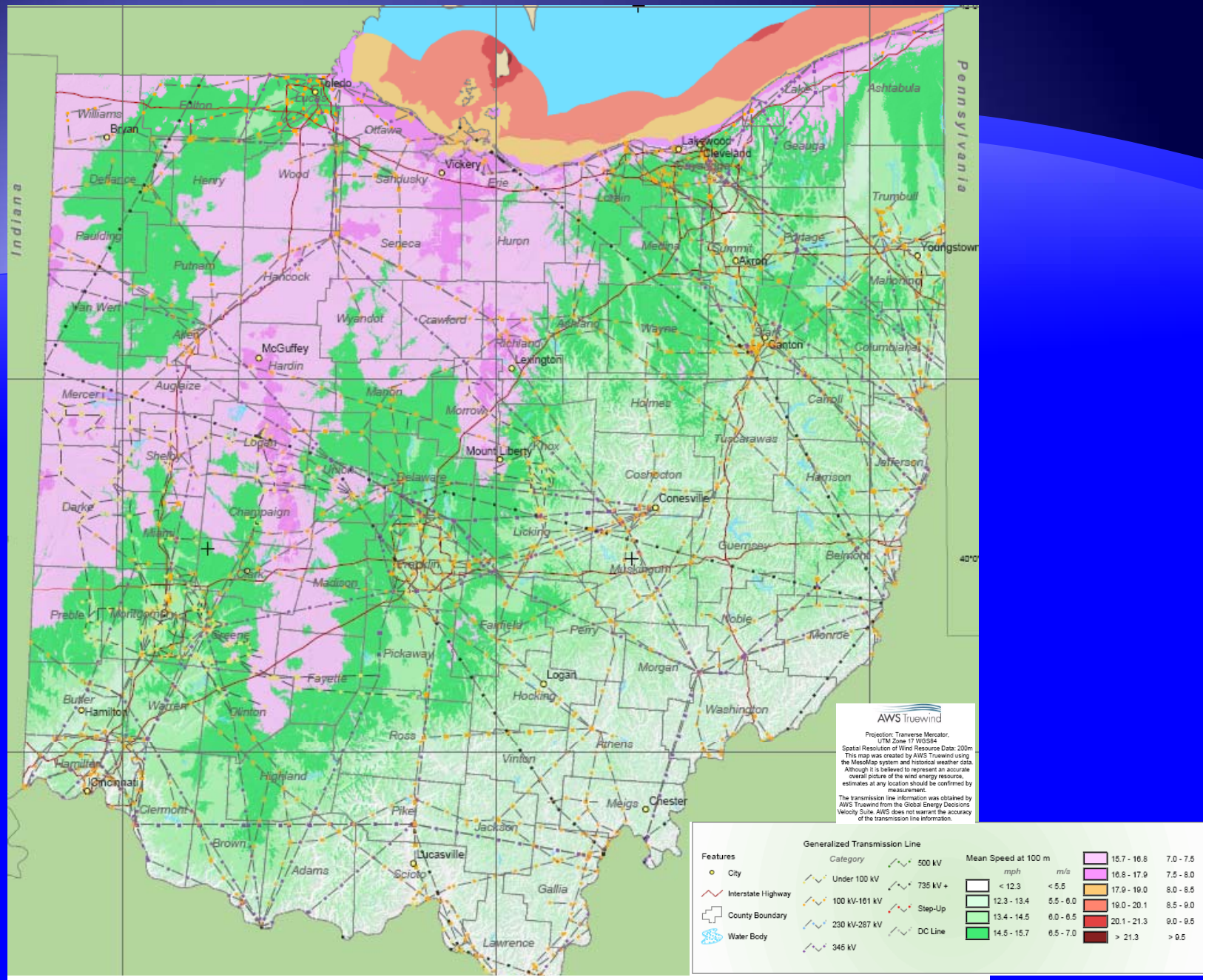
Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m^2	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
7	Superb	800 - 1600	8.8 - 11.1	19.7 - 24.8

[a] Wind speeds are based on a Weibull k value of 2.0

U.S. Department of Energy
National Renewable Energy Laboratory

06-MAY-2009 1.1.9



Wind Resource of Ohio

Mean Annual Wind Speed at 100 Meters

Ohio Wind Farm Applications

Project	County	#Turbines
Buckeye Wind Project	Champaign	70
Hardin Wind Farm	Hardin	200
Hardin County North Wind Farm	Hardin	19- 27
Black Fork Wind Project	Richland & Crawford	112
Blue Creek Wind Farm	Van Wert & Paulding	175
Timber Road Wind Farm	Paulding	35

Power Siting in Ohio

- A certificate of environmental compatibility and public need must be obtained from the Ohio Power Siting Board (OPSB)
  - The Board has 7 voting and 4 non-voting members
  - Voting Members:
    - Public Utilities Commission of Ohio (PUCO)
    - Ohio Environmental Protection Agency
    - Ohio Department of Agriculture
    - Ohio Department of Development
    - Ohio Department of Health
    - Ohio Department of Natural Resources
    - A public member (an engineer)

Siting Process in Ohio

- Pre-Application Conference
  - Opportunity to clarify rules and regulations
- Public Informational Meeting
  - To advise affected persons of the upcoming project
- The Application
  - The Board's staff has 60 days to complete a review
- Staff Report
  - Findings and recommendations
  - Prepared by the Staff of the PUCO
  - In coordination with other state agencies

Siting Process in Ohio

- Public Hearings
  - Citizens, interest groups, and governmental entities present sworn testimony
- Adjudicatory or formal legal hearings
  - A hearing officer (attorney) presides over the hearings in the capacity of a judge
  - A court reporter records all proceedings and testimony
  - Hearing officer recommends an action to the Board
- Board makes a Decision

Application Filing Requirements

- OAC, Chapter 4906-17 Application Filing Requirements for Wind-Powered Electric Generation Facilities
  - Became effective on May 7, 2009
  - Affects any wind farm of 5 MW or more
  - Application to include:
    - Project summary
    - Detailed project description and schedule
    - Project area analyses
    - Technical data
    - Financial data
    - Environmental data
    - Social and ecological data

Wind Farm Application

Setbacks

- Minimum setbacks established in 4906-17:
- **From the property line:**
  - **1.1 times the total height** of the turbine structure as measured from its tower's base to the tip of its highest blade
  - Example: 541 feet for a 492-foot turbine
- **From the residence:**
  - **750 feet** in horizontal distance from the tip of the turbine's nearest blade at 90 degrees to the exterior of the nearest habitable residential structure
  - Example: 914 feet for turbine with a 164 foot blade

Turbine Near Residence

This Michigan home is about 1,500 feet away from a wind turbine

Health & Safety Requirements

4906-17-08 (A)

- Noise
  - Evaluate & describe operational noise levels at adjacent properties under day and nighttime conditions
  - Evaluate & describe the cumulative operational noise levels for the wind facility
  - Use computer modeling software
- Ice throw
- Blade shear
- Shadow flicker

Sound

- Sound: pressure variation that can be heard
- Noise: unwanted sound
- Expressed as a sound pressure level, measured in decibels (dBA)
- Decibel scale is logarithmic - covers the wide range of sound pressures
- Frequency: pressure variations per second – hertz (Hz)

Noise Levels in Decibels

Source	dBA
Civil Defense Siren	140-130
Jet Takeoff at 200 feet	120
Rock Music Concert	110
Pile Driver at 50 feet	100
Lawn Mower at 3 feet	95
Ambulance Siren at 100 feet	90
Freight Cars at 50 feet	90
Vacuum Cleaner at 3 feet	85
Pneumatic Drill at 50 feet	80
Freeway at 100 feet	70
Light Traffic at 100 feet	50
Speech Range	50-70
Large Transformer at 200 feet	40
Wind Turbine at 1,000 feet	40-50
Rural Background at Night	20-40
Soft Whisper at 5 feet	30

Sound Properties

- Sound intensity deceases with the square of the distance from the source (inverse-square law)
- Rules of thumb:
  - Sound pressure level drops 6 dBA as you double the distance
  - Two equal noise sources will produce a noise level that is 3 dBA greater than the single source

Frequencies and Hearing

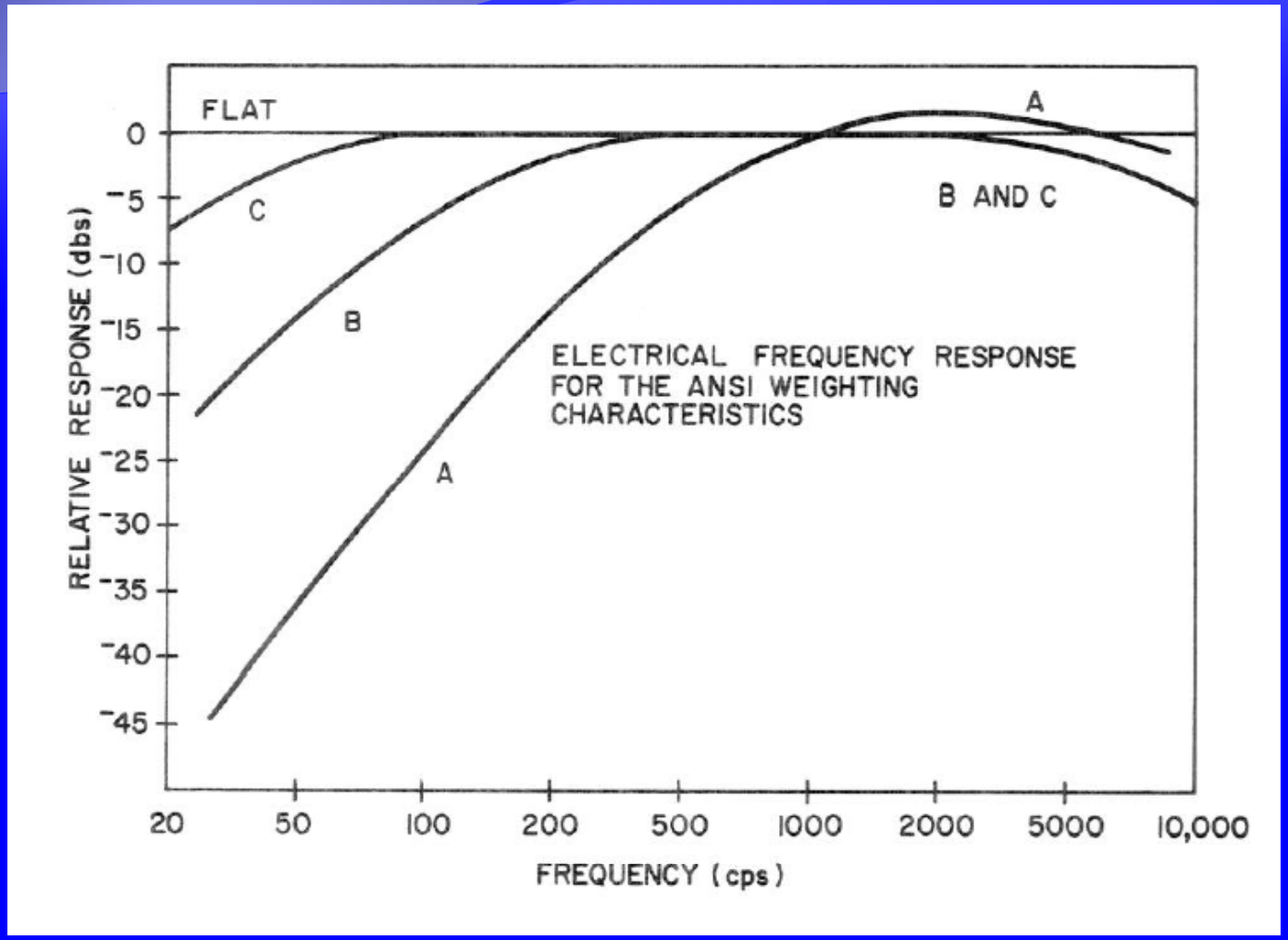
- Audible Range: 20 - 20,000 Hz
- Speech frequency: 500- 4,000Hz
- Low Frequency Sound: 10 - 200 Hz
- Infrasound (inaudible or barely audible): < 20 Hz
  - Low frequency sound can travel longer distances and pass through walls and windows with little attenuation due to their longer wavelengths

Frequency Weighting

- A-weighting
  - Approximates the human ear's response to sound
  - The very low frequencies are discriminated against, attenuated, or filtered out quite severely
  - Popular in the assessment of overall noise hazard
- C-weighting
  - Corresponds to the ear's response for loud environments
    - If the measured sound level is much higher on the C-weighting than on A-weighting, much of the noise is low frequency

Sound Measurements

Frequency-Response Attenuation for the A-, B-, and C-Weighting Networks



Source: NIOSH 1973. Frequency-Response Characteristics for Sound Level Meters

Noise from Wind Turbines

- Two major sources of wind turbine noise:
  - 1) **Mechanical noise** caused by the gearbox, generator, yaw drives, cooling fans, and hydraulics and
  - 2) **Aerodynamic noise** caused by the interaction of the turbine blades and the wind
    - Dependent on wind speed
    - Increases with rotor speed

Wind Turbine Noise

- Sound Power Level: acoustic power output
- Not to be confused with sound pressure level, also in dB
- 98 -108 dBA, depending on the wind speed
- The sound pressure level at a given distance from the source can be calculated from the sound power level

Wind Turbine Noise

Three types of noise are emitted by wind turbines:

- *Broadband noise* from the swishing or whooshing sound from the wind turbine blades at frequencies > 100 Hz
- *Tonal noise* consists of a "hum" or "pitch" occurring at distinct frequencies due to rotating machinery
- *Low-frequency noise* in the range of 10 to 200 Hz.
  - This range includes *infrasound* which is inaudible or barely audible sound at frequencies below 20 Hz

Infrasound

- Older "downwind" turbines emitted infrasound
  - Blades passed through the tower's wind shadow
  - Not an issue with newer "upwind" turbines
- Modern wind turbines create levels of infrasound comparable to ambient levels in the natural environment due to wind (HGC Engineering 2006)
- Infrasound from wind turbines typically is below 70 dB (below the audible threshold)
- Noise produced by wind turbines generally is not a major concern for humans beyond a half-mile or so (NAS 2007)

Noise Standards

- No federal or state laws that would specifically limit noise from a wind project
  - In the 1970s, the EPA developed standards for noise
  - In 1981, the EPA concluded that noise issues were best handled at the State or local government level
- Community Noise Levels and Guidelines
  - Other countries
  - World Health Organization (WHO)

Occupational Noise Regulations

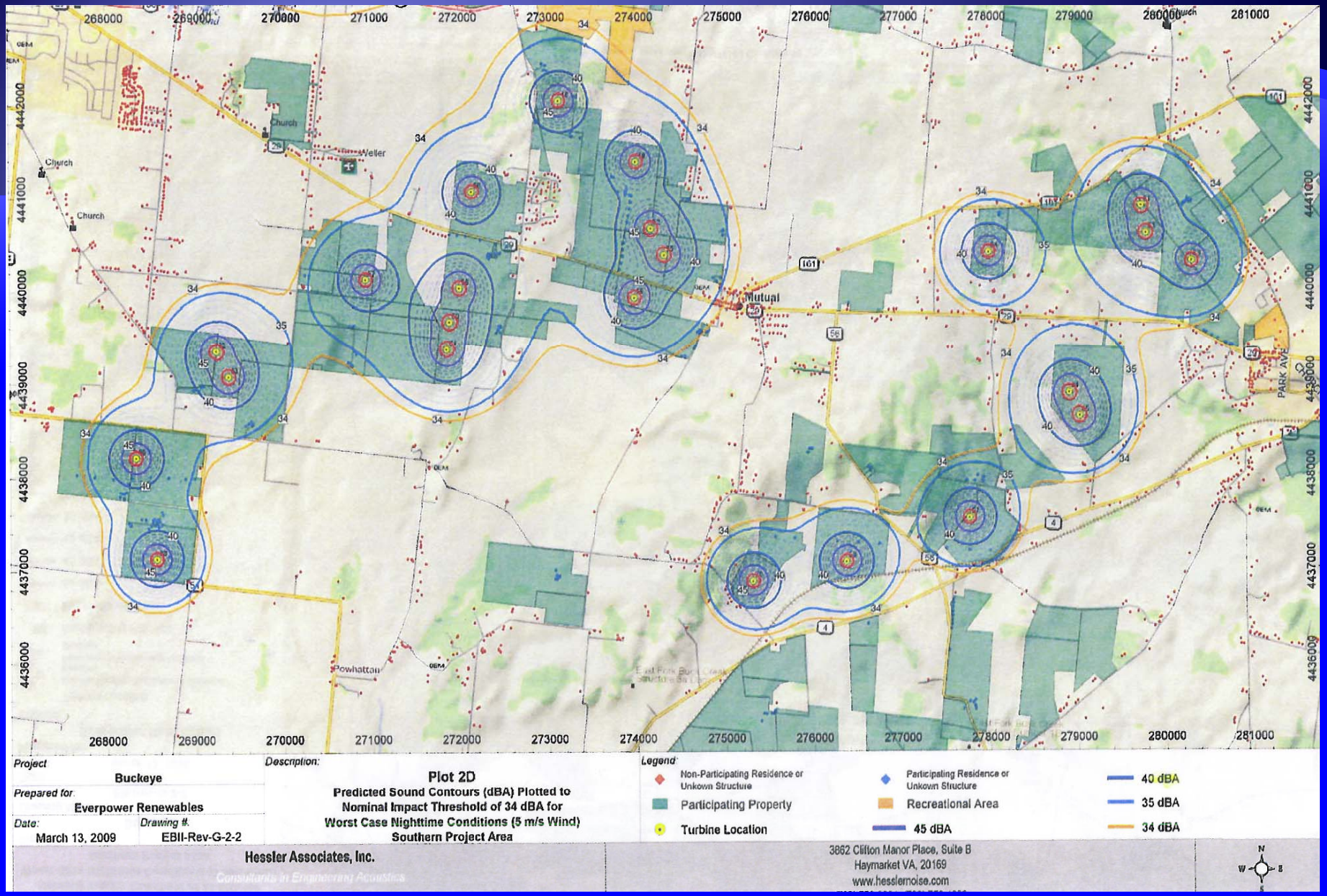
- For the prevention of noise-induced hearing loss
- Occupational Safety and Health Administration (OSHA) requires:
  - Control of noise exposures
    - 90 dBA limit as an 8-hour time-weighted average (TWA)
  - Employee protection
  - Comprehensive hearing conservation program
    - 85 dBA action level

Permissible Noise Levels and Guidelines

Country/ Organization	Type	Day	Night
Germany	Exclusively residential area Rural area	50 40	35 30
Netherlands	Exclusively residential area Rural area	45 ---	35 45
Denmark	Exclusively residential area	---	40
WHO	Night noise guideline for Europe ($L_{night, outside}$)	---	40

Sources: Hau 2006 , WHO 2009

Predicted Sound Contours



Shadow Flicker

- Moving shadow
  - Most pronounced during the morning and evening
  - Less of an issue in the U.S. than in Northern Europe
- Not likely to cause epileptic seizures
  - Flicker frequency is 0.6 - 1.0 Hz
  - Seizures not expected if < 5 Hz
- No regulations for shadow flicker
  - 30 hours per year is used as a guideline
  - Applicant is required to evaluate & describe impact from shadow flicker - typically use a computer model

Ice Throw

- Ice may build up on the rotor blades and shed or be thrown off an operating turbine
  - Ice fragments typically land within 328 feet (100 meters) from the base of the turbine (EU WECO)
  - Negligible risk at 722 feet (220 meters) [Garrad Hassan 2007]
  - Safety issues to service personnel and to local infrastructure within 500 feet of the turbine (NWCC 2006)

Blade Shear

- *Blade Shear* is the possibility of a rotor blade dropping or being thrown
  - Extremely rare
  - Blade will tumble due to the position of the center of gravity (Hau 2006)
  - Documented blade failures and maximum distances:
    - Entire blade - 492 feet (150 meters)
    - Blade fragment - 1,640 feet (Garrad Hassan 2007)
- Safety features
  - Braking systems allow for automatic shutdown at high wind speeds
  - Vibration monitoring systems

Visual Impact

- Information on the proposed layout is required by OAC 4906-17, and includes:
  - Photographic interpretation or artist's pictorial sketches of the proposed facility…

View from US Route 36 - Town of Urbana, Champaign County, OH
Facing Northeast, 1.0 Miles from Nearest Visible Turbine

Studies

- **Three studies of people living near wind turbines:**

  Pedersen & Waye 2004 & 2007, Pedersen et. al. 2009

  - Cross-sectional studies in Sweden and The Netherlands
  - People were more annoyed by wind turbine noise than transportation or industrial noise at comparable levels
  - Annoyance was related to attitudes toward the visual impact of wind turbines
  - People who benefited economically from the wind turbines were less annoyed

Results

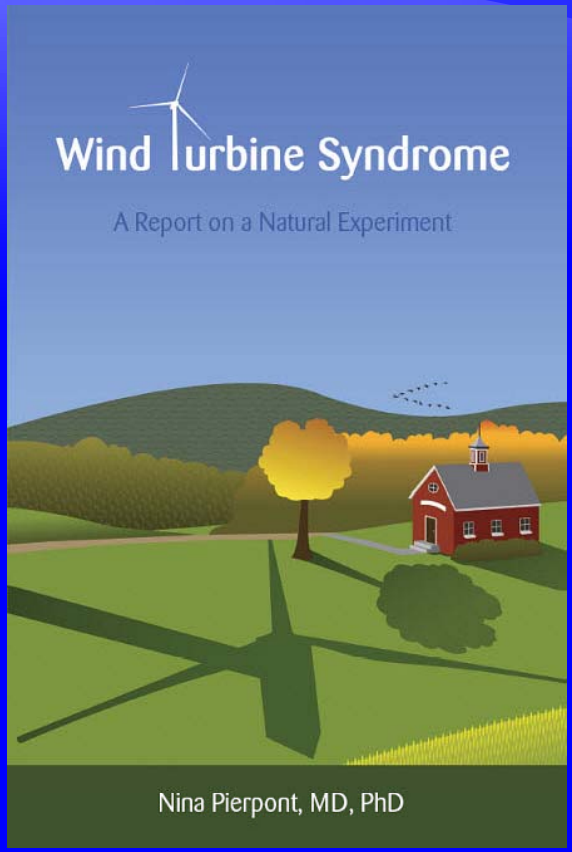
Pedersen et. al.

- ~5% of all respondents reported annoyance
- ~15 % at >40 dBA reported annoyance (2007)
- ~25% at 40-45 dBA who did not benefit economically reported being rather or very annoyed (2009)
- Annoyance increased with increasing sound pressure levels (a dose-response relationship)
- Annoyance was more likely in areas that were rated as quiet and in areas where turbines were visible

Case Reports

Wind Turbine Syndrome

- Nina Pierpont, M.D., Ph.D. (2009)
- Symptoms include:
  - Sleep disturbance
  - Headache
  - Tinnitus
  - Ear pressure
  - Dizziness
  - Vertigo
  - Nausea
  - Visual blurring
  - Tachycardia
  - Irritability
  - Problems with concentration and memory
  - Panic episodes associated with sensations of internal pulsation or quivering, which arise while awake or asleep



Pierpont Study

- Case series
- Studied 38 people in 10 families
  - Based on telephone interviews of people from North America (mostly Canada) and Europe
  - Families lived between 1,000 feet and 1 mile from newer wind turbines (most left their homes)
  - Older people, especially those with a past history of migraines, motion sickness, or inner ear damage seemed to be most affected
  - Proposes that wind turbine low frequency noise is the main cause of symptoms

Wind Turbine Syndrome

Proposed Mechanisms:

- Low frequency noise (LFN) from wind turbines may send false signals to the vestibular system:
  - Proposes that low frequency noise and vibration from turbines deceives the body into thinking it's moving
- Visceral vibratory vestibular disturbance (VVVD)
  - Proposes that wind turbine sound in the 4-8 Hz range causes vibrations of the diaphragm and the abdominal viscera (internal organs)

Limitations

- Based on a **case series** study
  - Observational study - a series of case reports
  - Cannot determine a dose-response relationship
  - Cannot show cause and effect
- Selection bias
  - Sampled the most severely affected
  - Limited to English-speaking subjects
- Symptoms were self-reported
    - Medical records were provided for only 5 subjects
    - Proxies interviewed for 15 out of 37 subjects
- Recall bias

Pierpont's Recommendations

- Recommends a well controlled prospective study
  - Study a group of people before and after the installation of a wind farm
  - Find out who is affected and at what distance
- Wind farms should not be sited closer than 1.25 miles (2 km) from people's homes or where people congregate
  - Noise level criteria: Kamperman and James

Vibroacoustic Disease

- Research in Portugal by Dr. Mariana Aves-Pereira et. al. suggests that long-term exposure to high intensity low frequency noise can damage the body:
  - Thickening of cardiovascular structures
  - Mutagenic changes in cell structure
  - Link to epilepsy and cancer suggested
- Based on case reports of aircraft and airport occupations
- No control groups
- Significantly greater sound levels associated with airport operations than with wind turbine operations

American Wind Energy Association

- **AWEA Position Paper:** *Wind Turbine Sound and Health Effects* *An Expert Panel Review*
  - December 2009
- **Conclusions**

1. Sound from wind turbines does not pose a risk of hearing loss or any other adverse health effect in humans.
2. Subaudible, low frequency sound and infrasound from wind turbines do not present a risk to human health.

Position Paper

Conclusions continued:

3. Some people may be annoyed at the presence of sound from wind turbines

   Annoyance is not a pathological entity

4. A major cause of concern about wind turbine sound is its fluctuating nature

   Some may find this sound annoying, a reaction that depends primarily on personal characteristics as opposed to the intensity of the sound level

ODH Recommendations

- Greater setbacks for non-participating residents than the required minimum distance
  - Based on a reduction to 40 dBA at night - WHO guideline for night noise exposure
  - Distance: 1,500 to 2,000 feet from a residence, depending on acoustic output of wind turbine model
- A turbine/turbine layout that produces the least amount of noise, including low frequency noise
- Shadow flicker: less than 30 hours per year
- An effective complaint collection and investigation process

Resources

ODH Summary Report

http://odh./ohio.gov (see Health Assessment Section Fact Sheets)

Minnesota White Paper

http://www.health.state.mn.us/divs/eh/hazardous/topics/windturbines.pdf

Ohio Wind Working Group

http://www.ohiowind.org/

National Renewable Energy Laboratory

http://www.nrel.gov/wind/

American Wind Energy Association

http://www.awea.org/

Ohio Power Siting Board

http://www.opsb.ohio.gov/

Questions

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