Wind Turbine Sound
Just the FACTS

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TECH environmental
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

Wind Turbine Sound - Topics

- *Acoustics 101*

  Sound Pressure vs Power Levels, Decibels, A-weighting, L_{EQ}, Defining "loud"

- *Are wind turbines loud?*

  How is turbine sound measured?

  How is turbine sound modeled?

  Low frequency sound (infrasound)

- *Turbine Noise Complaints: Health Impacts or Annoyance?*

- *Shadow Flicker*

  Criteria needed for flicker to occur

  Limits? Controls?

Acoustics 101

Sound Pressure Levels are distance dependent, can be measured

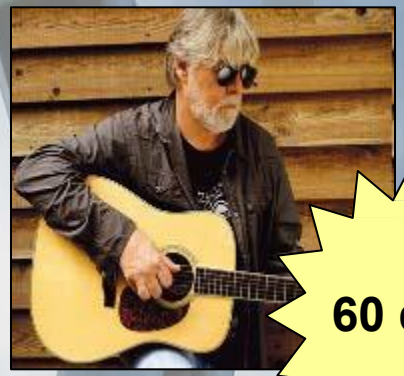
Sound Power Levels are calculated, not measured – represent the total power emitted by a source in all directions

Both typically expressed as A-weighted decibels (dBA)

Sound Pressure Levels are Measured in Decibels...

65 dBA

100 dBA



60 dBA

80 dBA

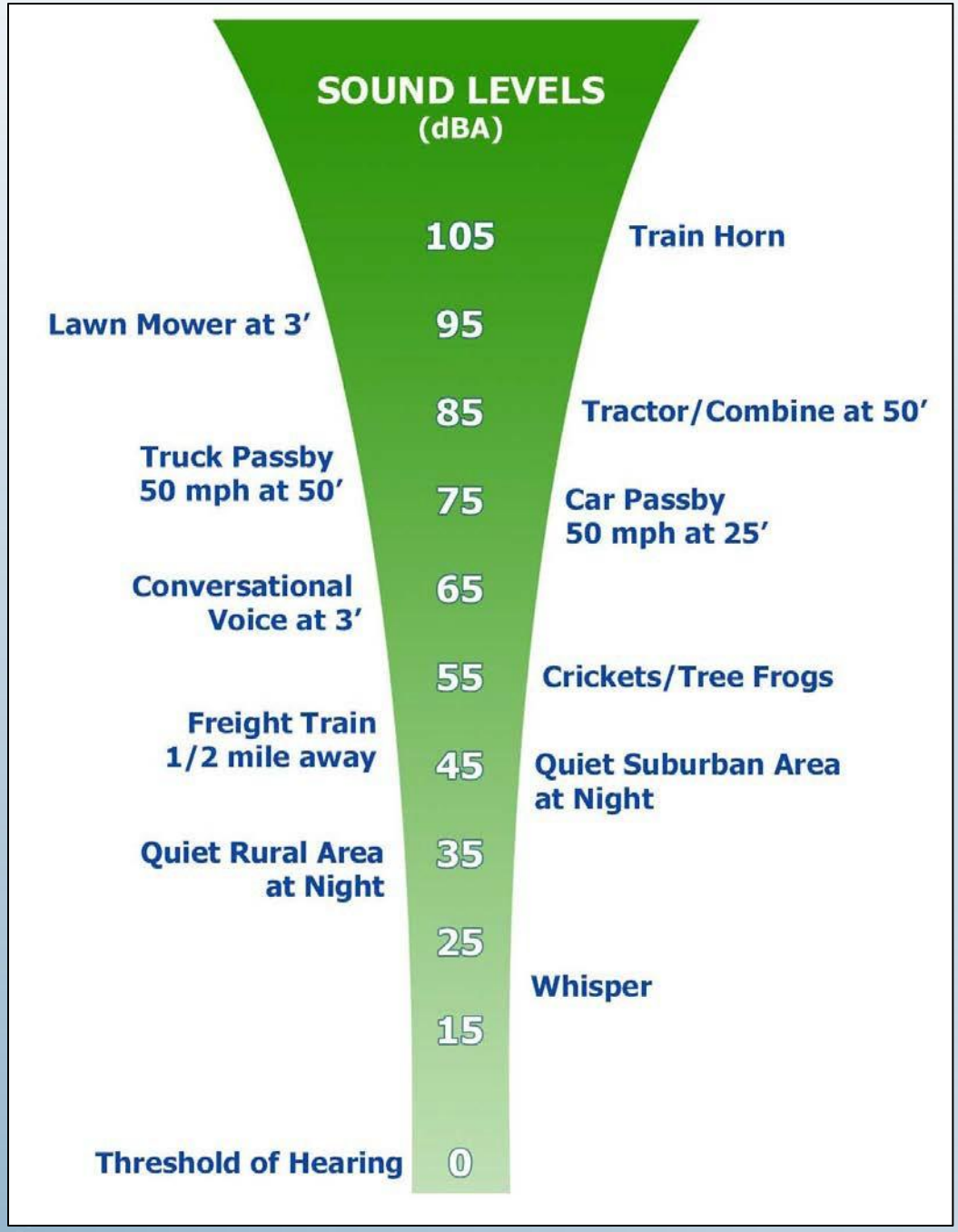
85 dBA

Acoustics 101

LEQ sound level – Most commonly used/preferred sound metric to describe sound levels "Equivalent Continuous Sound Level"

Can be thought of as the average sound level

Takes into account the total sound energy of the source over a period of time



Every 10-dBA Change is a Doubling (or halving) of Loudness

Acoustics 101

What does it mean for a sound to be "loud"?

Synonyms:

Blaring, booming, deafening, roaring, thunderous, ear-splitting

Are wind turbines loud?

Typical sound pressure levels produced by wind turbines at nearby homes range from 35-45 dBA

Are wind turbines loud?

No

Holy Name CCHS

Located 200 feet from Classrooms and Athletic Fields

How is wind turbine sound measured?

Measure Existing Sound Levels Pre-Construction

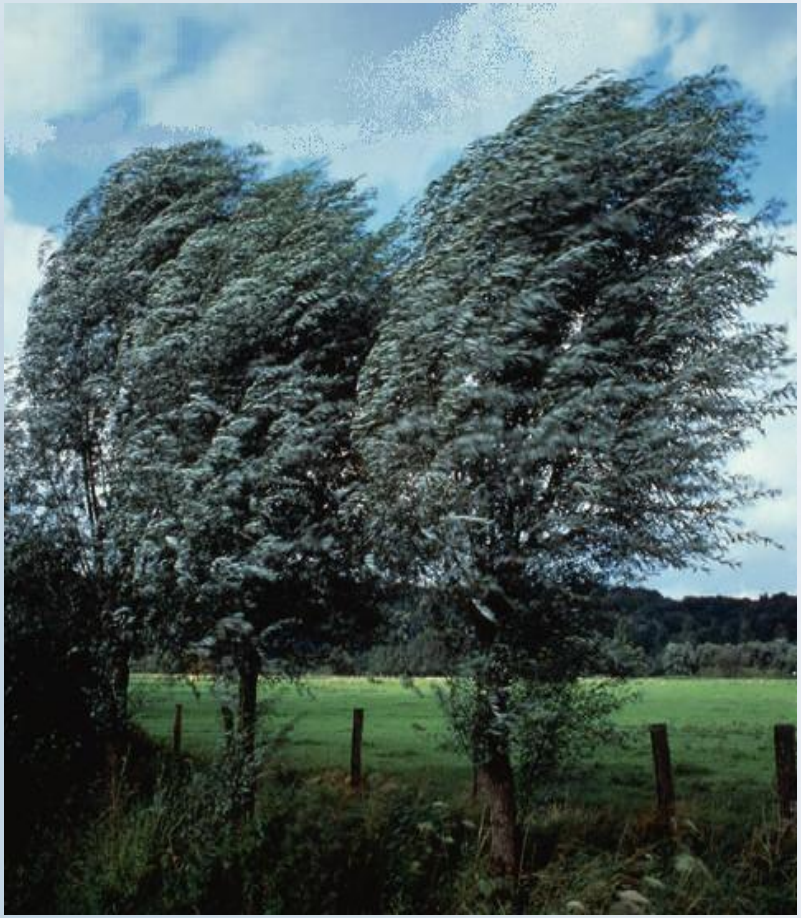
EPA states the equivalent L_{eq} sound level correlates best with how people perceive and react to sound

Measure Turbine Sound Levels Post-Construction

Must be done during full power (high wind conditions)
Sound meter operator notes times when noises interfere with measurements - wind gusts, traffic, airplanes, dogs barking, tractors, birds chirping, etc…
As a result, these measurements usually performed during nighttime hours

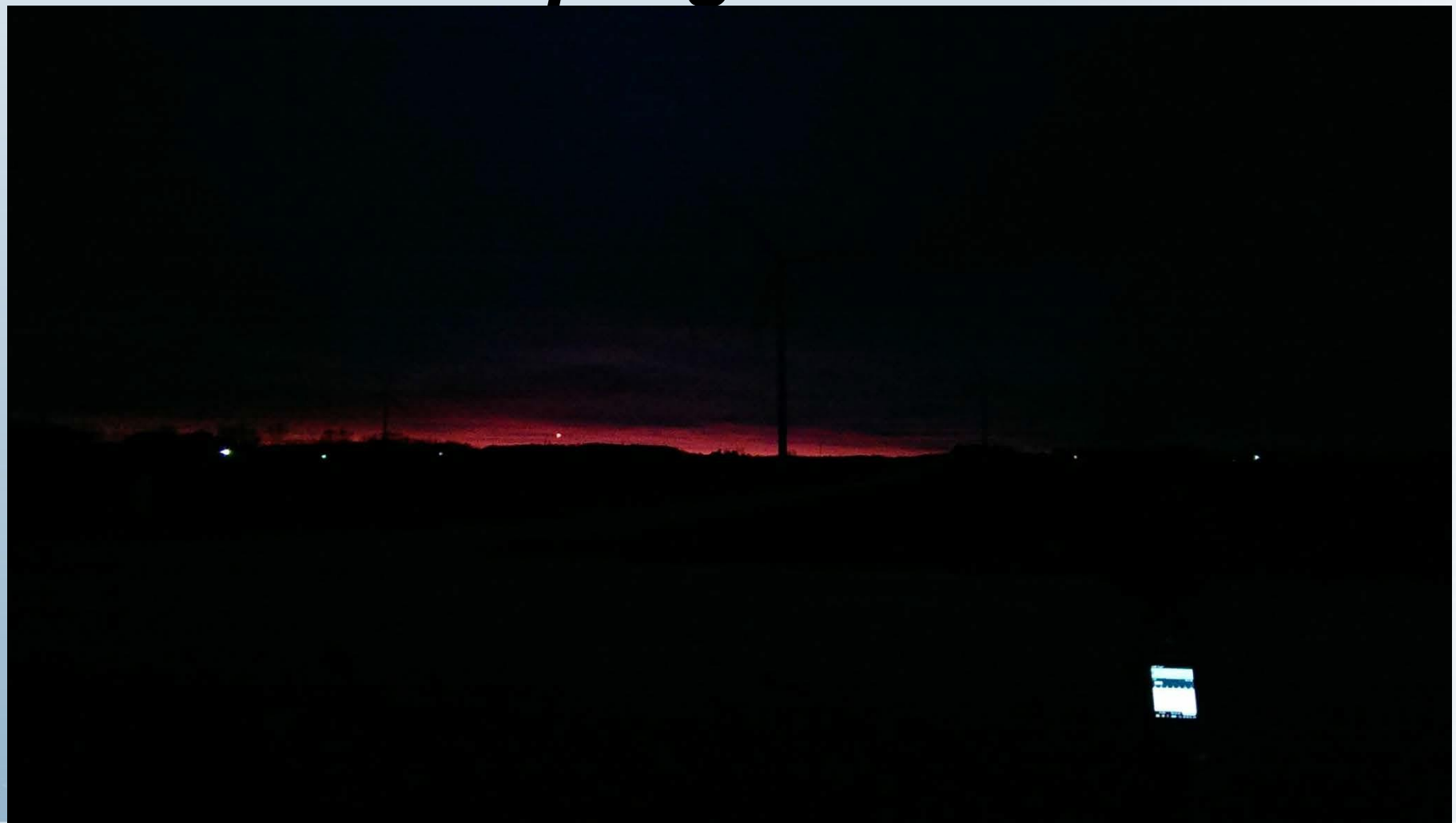
Turbines at Full Power Means Lots of Natural Wind Noise

… noise from wind turbulence, wind in trees, crops, around farm buildings and terrain can be substantial



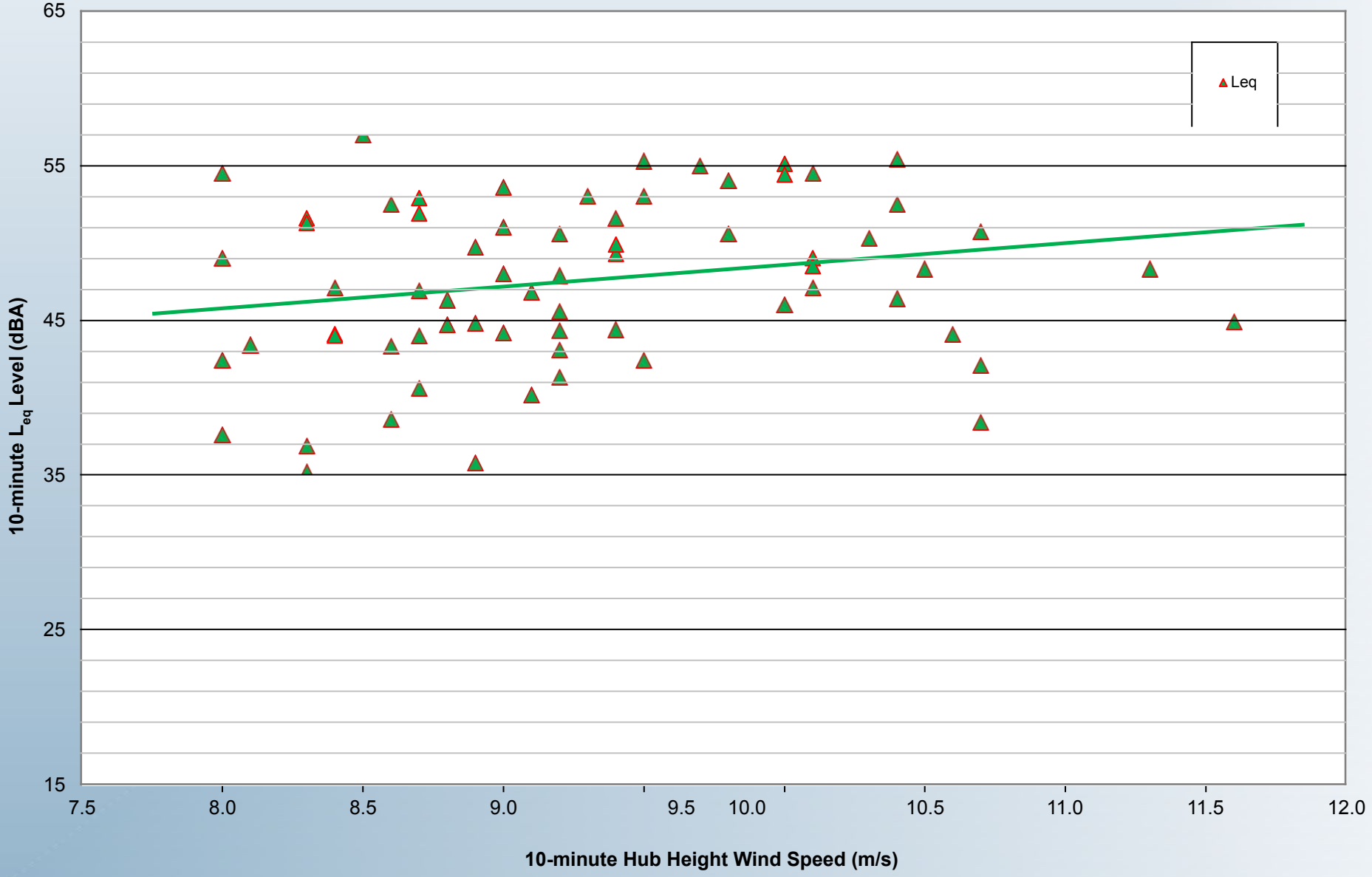
SHHHHHHH!

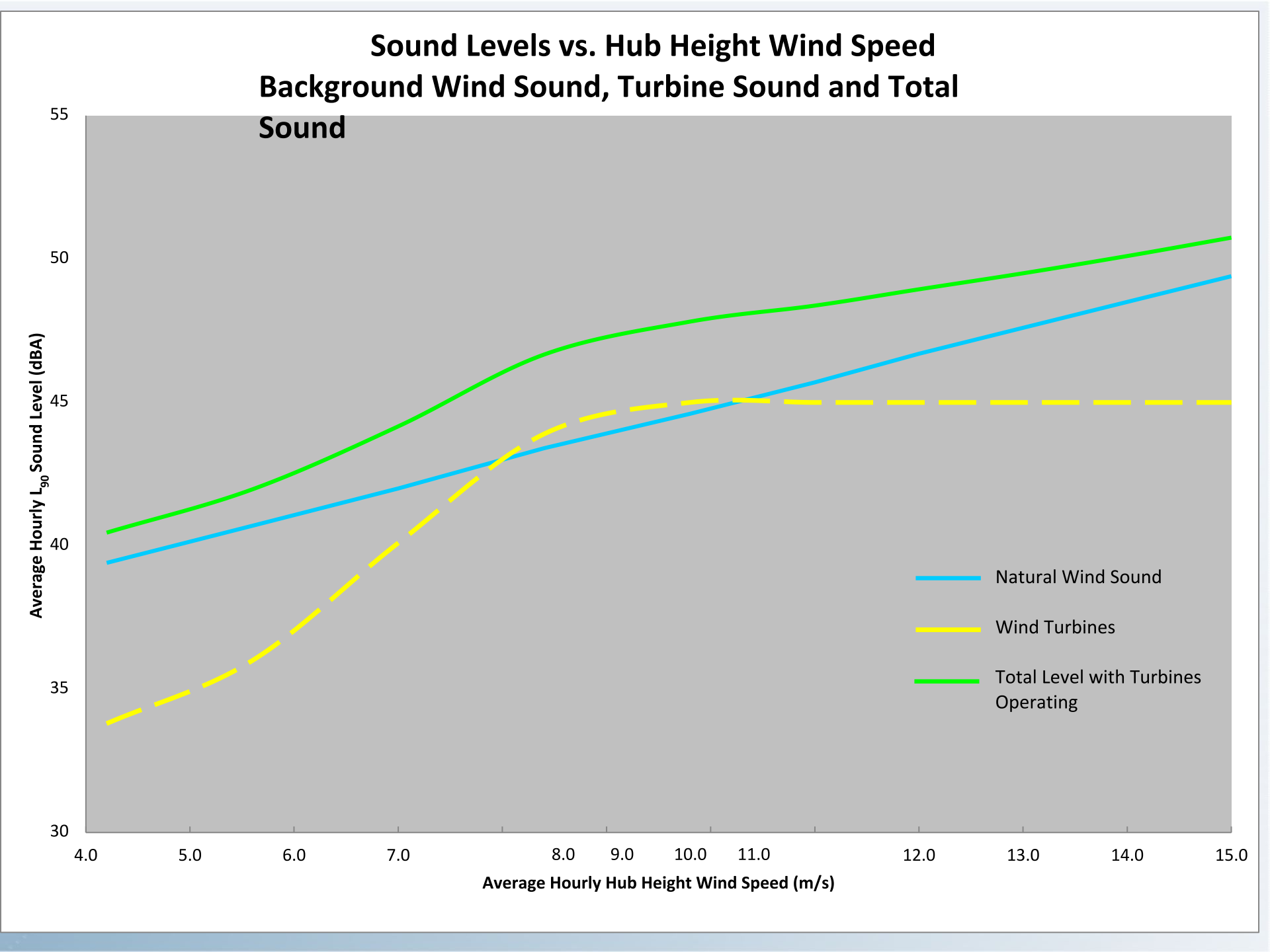
Nighttime monitoring in progress

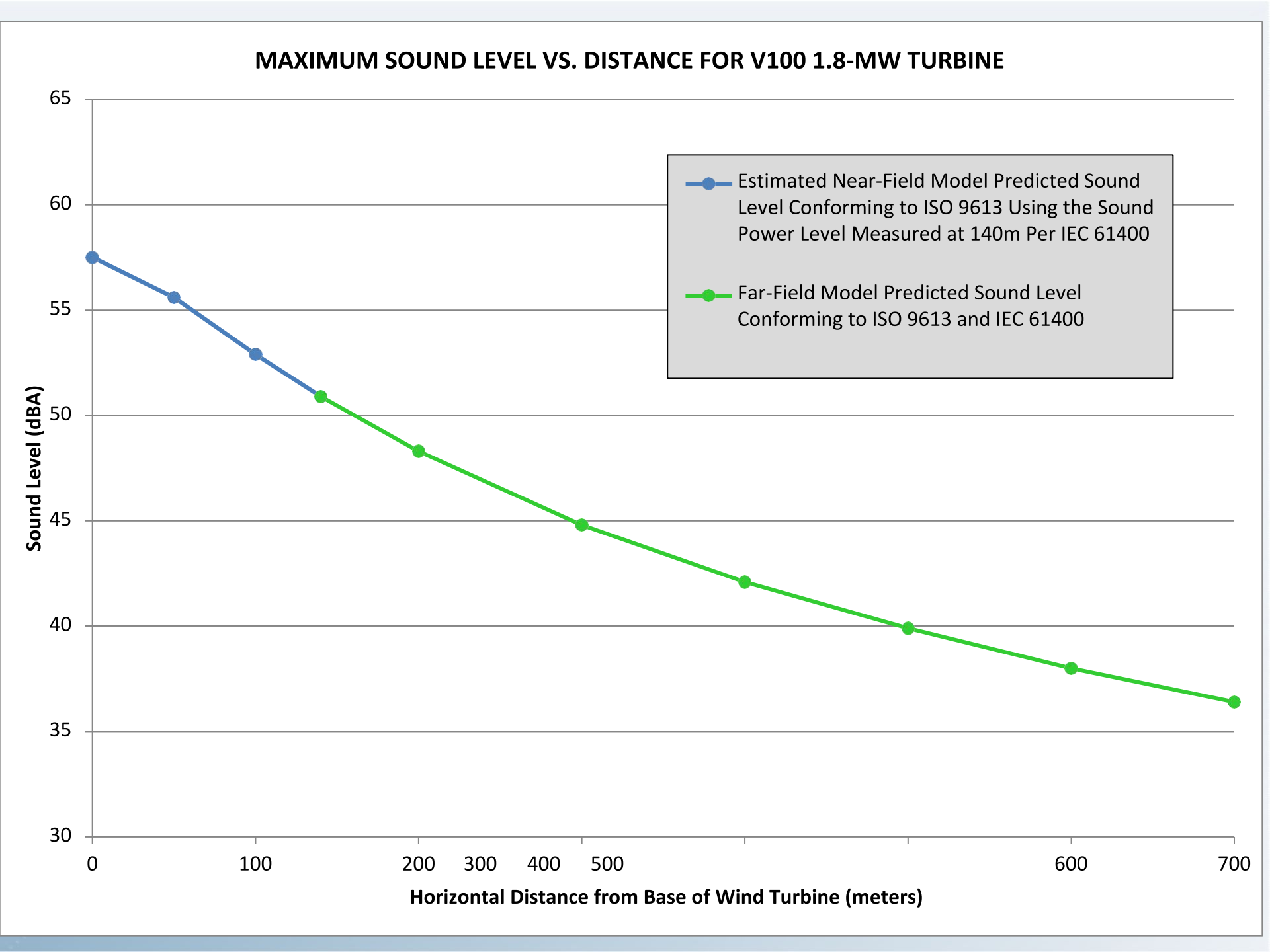


Post-Construction Sound Monitoring

Pre-Construction Nighttime L_{eq} Sound Levels Measured for HH Wind Speeds 8-12 m/s

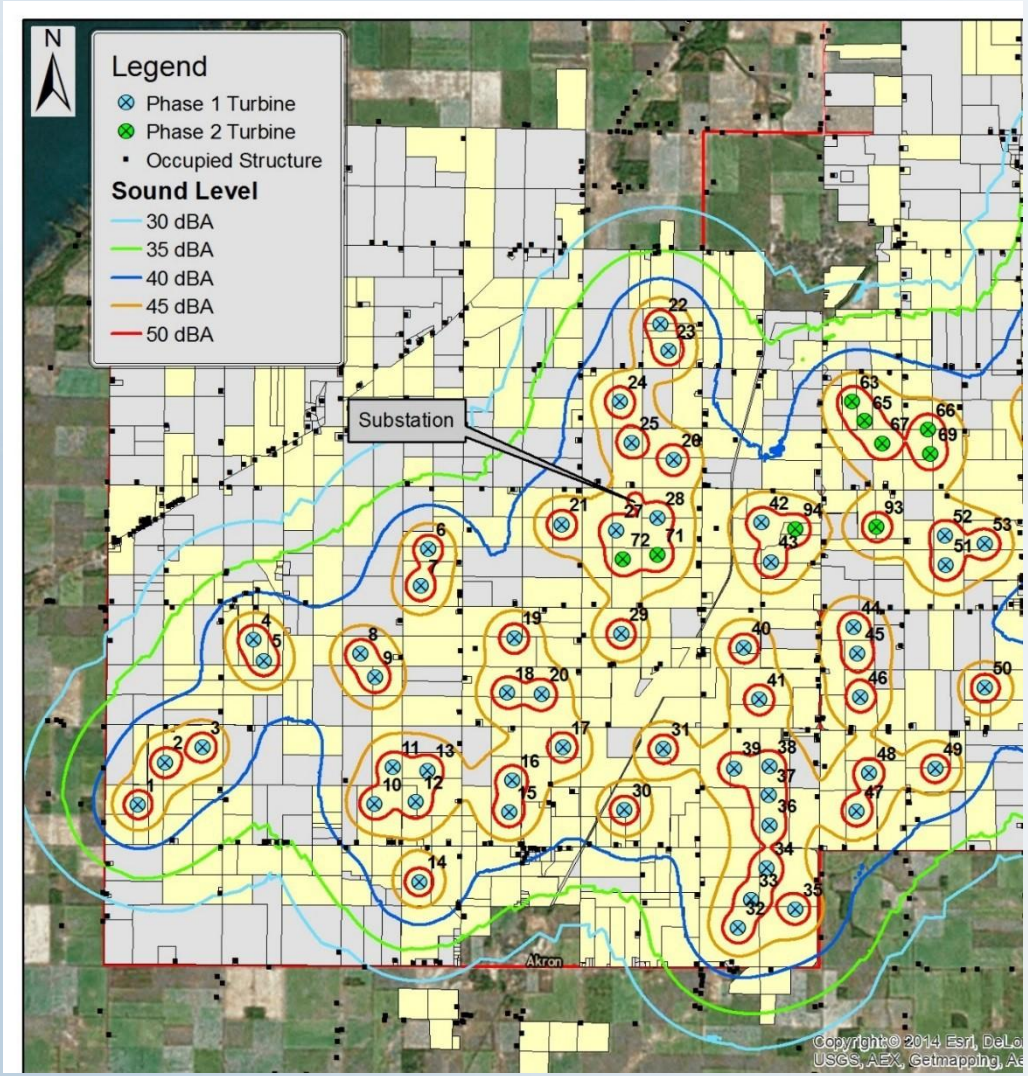



Sound Levels vs. Hub Height Wind Speed
Background Wind Sound, Turbine Sound and Total Sound
Average Hourly L_{90} Sound Level (dBA)
55
50
45
40
35
30
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
Average Hourly Hub Height Wind Speed (m/s)
Natural Wind Sound
Wind Turbines
Total Level with Turbines Operating


MAXIMUM SOUND LEVEL VS. DISTANCE FOR V100 1.8-MW TURBINE
65
60
55
50
45
40
35
30
Sound Level (dBA)
0
100
200
300
400
500
600
700
Horizontal Distance from Base of Wind Turbine (meters)
Estimated Near-Field Model Predicted Sound Level Conforming to ISO 9613 Using the Sound Power Level Measured at 140m Per IEC 61400
Far-Field Model Predicted Sound Level Conforming to ISO 9613 and IEC 61400

How is wind turbine sound modeled?

Sophisticated 3D modeling software calculates how sound levels propagate across site specific terrain.



A Range of Nighttime Community Sound Standards

- ***State of Texas: none***
- ***State of Maryland: 55 dBA***
- ***West Lafayette, Indiana: 55 dBA***
- ***State of Minnesota: 50 dBA***
- ***Cohocton, New York: 50 dBA***
- ***Columbia, Michigan: 50 dBA***
- ***Mason County, Michigan: 45 dBA***
- ***State of Maine: 42 dBA***

Options to Meet Sound Limit

- *Revise layout – move turbines*
- *Verify pitch-regulated turbine. Use a lower L_w turbine*
- *Apply a range of NRO to nighttime operation of certain turbines*

What about Low-Frequency and Infrasound?

- ***Human voice is 500 – 2,000 Hz***
- ***LF Sound is <200 Hz***
- ***Infrasound is <20 Hz***

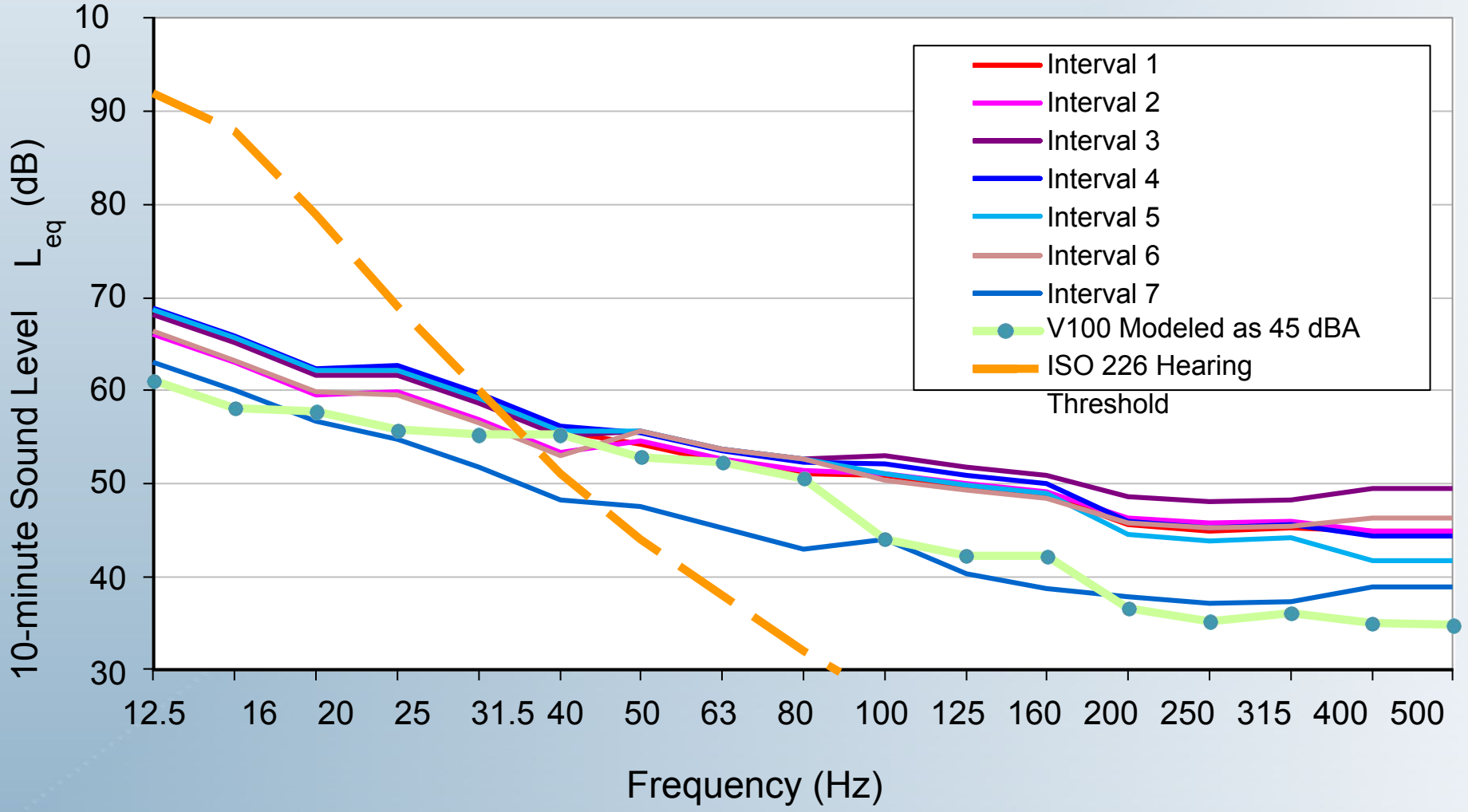
Low-Frequency and Infrasound are Always Present Outdoors

- *Natural air turbulence*
- *Thunderstorms*
- *Distant traffic noise*
- *Aircraft overhead*
- *Waves at the shore*

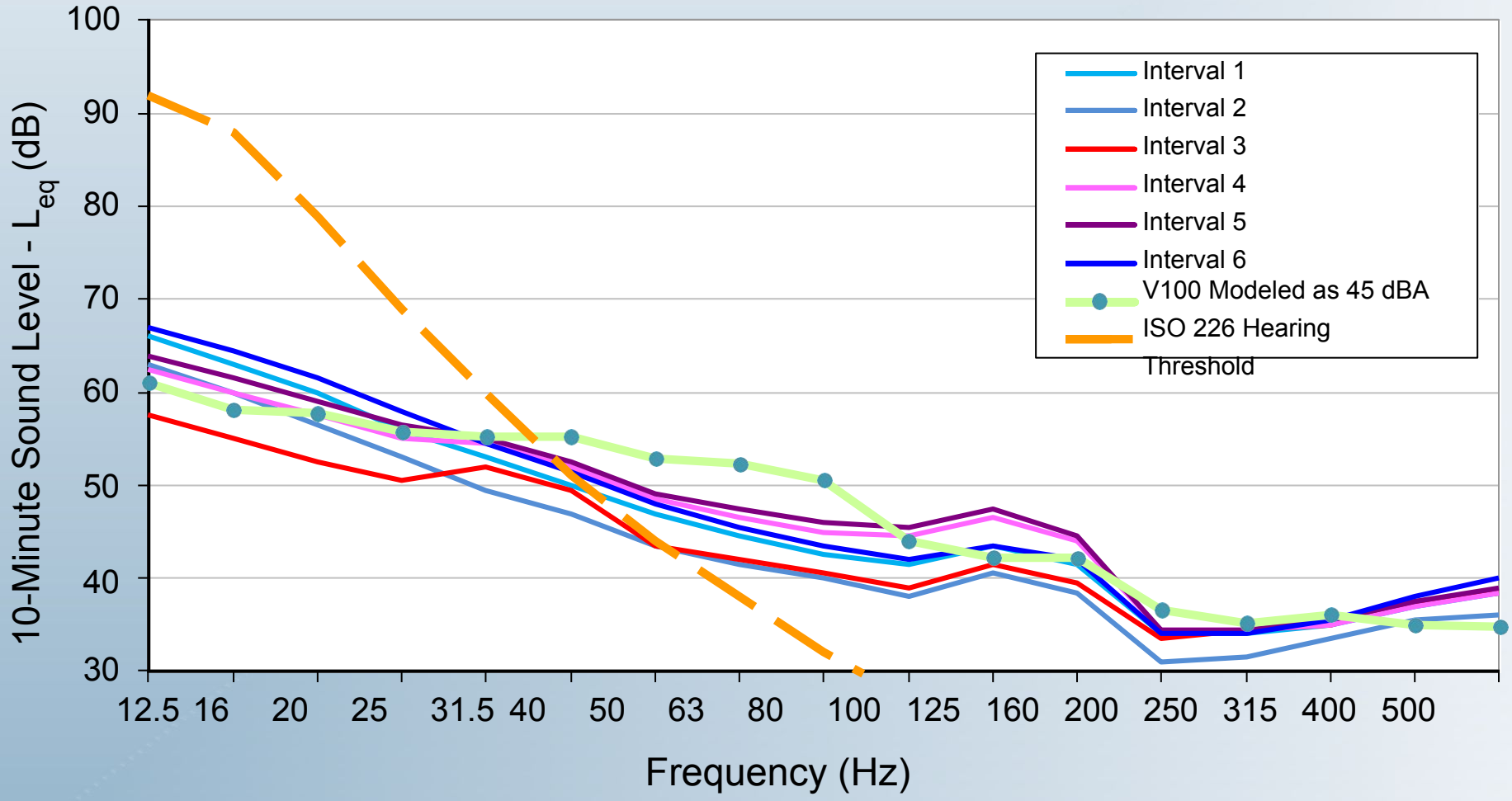
Facts about LF and Infrasound

- *LF spectrum of turbine sound is similar to that for natural background LF/IS*
- *Turbine sound < 40Hz is inaudible*
- *At 16 Hz (Infrasound), wind turbulence produces 60-65 dB, waves 70-75 dB, turbine is 60 dB, hearing threshold is 90 dB*
- *Turbine is 30 dB < hearing threshold*

LF Spectrum of Night Background (A) Sound Compared to 1.8-MW Turbine



LF Spectrum of Night Background (B) Sound Compared to 1.8-MW Turbine



Conclusions: Infrasound

- ***Wind turbine infrasound is typically 30 dB below the ISO 226 hearing threshold, below which no adverse health effects have been documented.[1,2]***
- ***Natural background levels of infrasound are often higher than those from turbines.***

1. 1. Leventhall, G., "Infrasound from Wind Turbines – Fact, Fiction or Deception," *Canadian Acoustics*, 34(2), 2006.
2. 2. US EPA, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, EPA-550/9-74-004, p.G-11.

HEALTH EFFECTS OR ANNOYANCE?

Studies, Facts and Expert Panel Reviews

Mass. Dept. of Public Health Independent Expert Panel (2012)

- ***Commissioned a panel of experts in public health, epidemiology, toxicology, neurology, sleep medicine, neuroscience, and mechanical engineering.***
- ***Analyzed "the biological plausibility or basis for health effects of turbines (noise, vibration, flicker)"***

Mass. Dept. of Public Health Independent Expert Panel (2012) Key Findings

- *There is no evidence for a set of health effects characterized as "Wind Turbine Syndrome".*
- *Available evidence shows infrasound near wind turbines cannot impact the vestibular system.*
- *There is insufficient evidence to determine whether there is an association between noise from wind turbines and annoyance independent from the effects of seeing a wind turbine.*

Journal of Occ. And Env. Medicine
Critical Review of Scientific Literature
Wind Turbines and Health (2014)

- ***No clear association between turbine noise and any reported disease or other health indicator.***
- ***Self-reported annoyance correlates with the person's attitude toward wind turbines, turbine visibility and whether individuals benefit financially. Annoyance does not correlate well with measured sound levels.***
- ***Infrasound does not present health risks.***

Other Peer-Reviewed Studies and Government Reports

- ***Ontario's Chief Medical Officer of Health***
- ***Australia's National Health and Medical Research Council***

All arrive at same conclusion:

Sound from wind turbines does not cause negative health impacts

"Other Studies"

- ***Rely on self-reported symptoms and claims of health problems. Self-selection bias is substantial.***
- ***No control group.***
- ***No control for confounding factors, e.g. do not account for natural LF sound.***
- ***Do not account for the Nocebo Effect: a worsening of mental or physical health based on fear or belief in adverse effects.***

Fatal Flaws of the Cooper Study

- ***Substantial self-selection bias. Six participants admitted anti-wind attitudes.***
- ***No control group.***
- ***No control for confounding factors.***
- ***No control for Nocebo Effect. In fact, the author highlights the Nocebo Effect.***
- ***Non-objective measure: "Sensations".***
- ***Not peer-reviewed.***

Fatal Flaws of the Cooper Study

- ***Info to Lancaster County Wind Energy Working Group: "Cooper found that these six subjects are able to sense attributes of the wind turbine emissions without there being an audible or visual stimulus present".***
- ***Cooper concludes (ES page ii): "For one resident, sensation, noise and vibration were observed with the wind farm shutdown".***

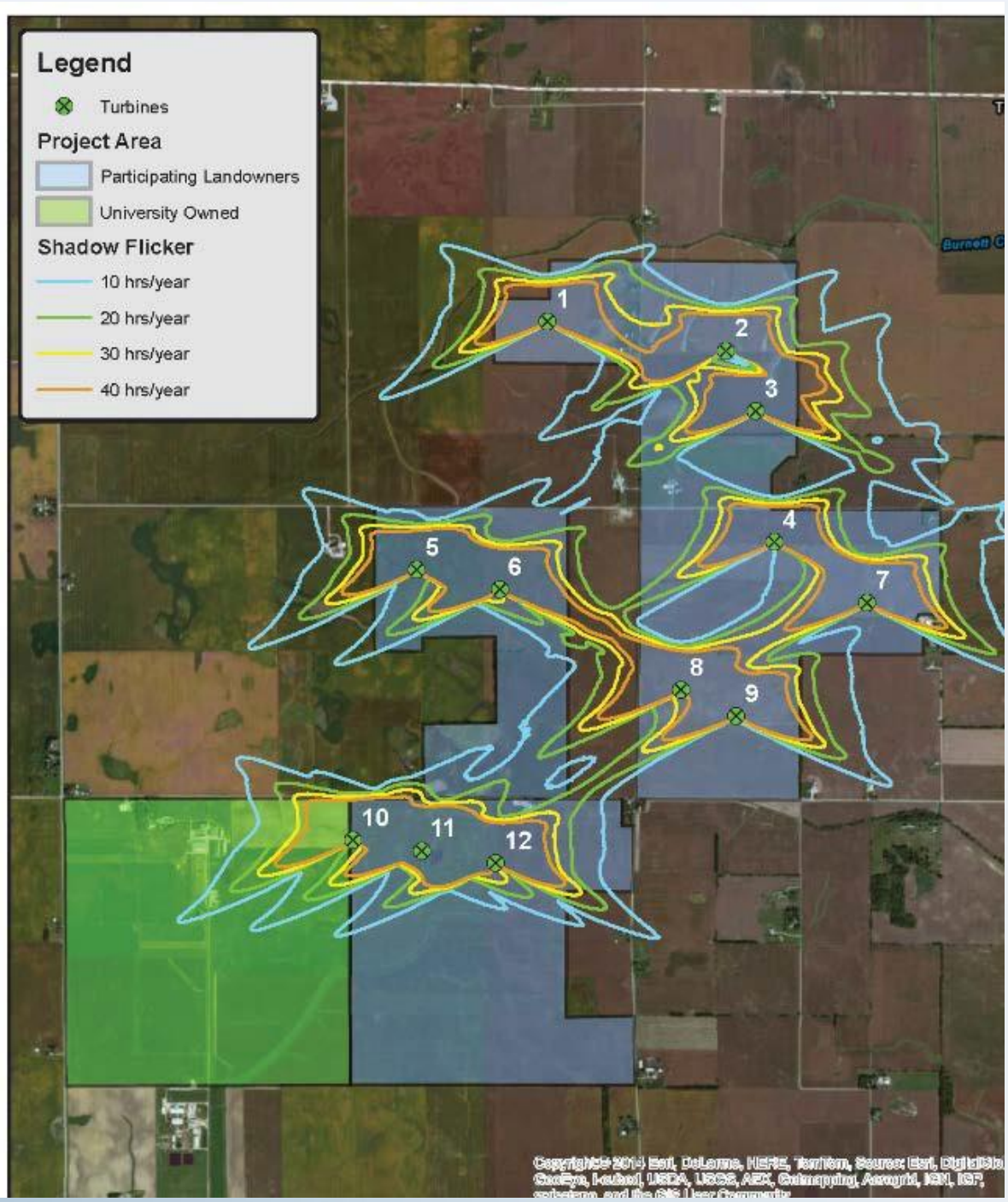
SHADOW FLICKER

Alternating changes in light intensity caused by the moving blade of a wind turbine casting shadows on the ground and structures

Shadow Flicker Does Not Occur

- *Unless sun, turbine and viewer line up perfectly*
- *On cloudy days*
- *Winds < cut-in speed*
- *Beyond 10 rotor diameters, or approx. 1,000 meters (3,200 feet) for a 2-MW turbine*

Annual Shadow Pattern



Flicker Impacts

- ***Frequency is below the 3 Hz safety threshold for epileptics (no seizure risk)***
- ***Annoyance only, not a health concern***
- ***Rarely regulated. Guideline is 30 hr/yr (German court case ruled this acceptable to the homeowner)***

Mitigation Options

- ***Revise turbine layout***
- ***Curtailment programs based on date, time of day, solar insolation and winds***
- ***Vegetative screening***

Conclusions

- *Wind turbines are not "loud"*
- *Sound from wind turbines is not a health concern*
- *Infrasound from wind turbines is inaudible*
- *Variety of methods and new technologies to design and control wind turbine sound, and shadow flicker*

Questions?

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