Session III
Cause and Effect

Abstract and bio on slide 2 is reproduced from the Symposium Program
THE TORMENT OF SLEEP DISTURBANCE

Abstract: The most common complaint of those exposed to industrial wind turbine noise (WTN) is sleep disturbance. Many of the other symptoms, fatigue, headache, nausea, memory problems and tiredness are probably secondary to sleep disturbance. Sleep is by the brain and for the brain. It’s principal purpose seems to be the consolidation of memory. Loss of sleep, in the short term, causes daytime sleepiness, fatigue, problems with memory and thought processes and, in the longer term an increased risk of obesity, diabetes, high blood pressure and heart disease. There is now a large body of evidence proving beyond any reasonable doubt that sleep is disturbed and health impaired by wind turbines at distances up to 2km, at noise levels claimed to be safe by the industry.

Bio: Dr. Hanning is Honorary Consultant in Sleep Disorders Medicine to the University Hospitals of Leicester NHS Trust, UK. He retired in September 2007 as Consultant in Sleep Disorders Medicine. After initial training in anaesthesia, he developed an interest in Sleep Medicine. He founded and ran the Leicester Sleep Disorders Service, one of the longest standing and largest services in the UK. He was a founder member and President of the British Sleep Society. His expertise in this field has been accepted by the civil, criminal and family courts. He chairs the Advisory panel of the SOMNIA study, a major project investigating sleep quality in the elderly, and sits on Advisory panels for several companies with interests in sleep medicine.
Wind Turbine Noise and Sleep: The Torment of Sleep Disturbance

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Names will be taken!
Wind turbine noise and sleep

• Four Questions
  – How does noise affect sleep and health?
  – Why does WTN affect sleep so much?
  – How far away should they be?
  – What do we need to do next?
How does noise affect sleep?

• Sleep is essential for human health
  – Adequate duration
  – Adequate quality
• Inadequate sleep leads to:
  – Sleepiness
  – Poor concentration and memory
  – Fatigue, weariness
  – Increased risk of heart disease, obesity, diabetes etc
How does noise affect sleep?

Typical Sleep Staging in a Young Adult

Awake
Stage 1
Stage 2
Stage 3
Stage 4

REM

Hours
How does noise affect sleep?

• Sleep can be disturbed by:
  – Internal disturbances
    • Snoring and breath holding
    • Leg fidgets
    • Pain
    • Coughing etc., etc.
  – External disturbances
    • Noise (partner, traffic, machinery, aircraft, trains, teenagers, drunks, wind turbines etc., etc.)
    • Light
    • Touch
How does noise affect sleep?

• Stops you getting to sleep
  – Anger, frustration, loss of control, invasion of home, torment

• Stops you getting back to sleep
  – Everybody wakes during the night
  – Remember wakening if more than 30secs
  – Older people – more and longer

• Arousals
How does noise affect sleep?

• Arousals
  – Brief shift from deep sleep to light sleep
  – Lower sound levels than awakening (<30dBA)
  – Not recalled
  – Accompanied by short È in blood pressure
  – Elderly more spontaneous arousals
  – Some people aroused more easily
How does noise affect sleep?

- Arousals
  - Arousals more likely than awakenings
  - Fragment sleep
  - Unrefreshing sleep, fatigue etc., etc.
  - È risk high blood pressure
  - Subject only knows sleep is unrefreshing not why! That’s the torment
How does noise affect sleep?

• WTN “research” looks at remembered awakenings

• Awakenings are the tip of the iceberg

• Arousals are far more likely than remembered awakenings
Why does WTN affect sleep so much?

• Noise character
• Frequency spectrum
• Diurnal variation
Why does WTN affect sleep so much?

- Noise character
  - Swishing, thumping, pulsing (impulsive) noise
  - Varies, especially if two or more turbines
  - “In your face noise”
  - Fire alarm type of noise
  - Not masked by background noise (traffic, wind noise)
Why does WTN affect sleep so much?
Why does WTN affect sleep so much?

• **Excess Amplitude Modulation**
  – Thumping, pulsing (impulsive) noise
  – Turbine interaction
  – More likely with big turbines
  – More likely with wind shear
Why does WTN affect sleep so much?

- Frequency spectrum
  - Low Frequency Noise
    - Travels further
    - Penetrates buildings
    - Threatening
    - ? Disturbs sleep more easily
Why does WTN affect sleep so much?

- Diurnal variation
  - Louder at night
    - Atmospheric stability (wind shear)
    - Thermal inversion
  - Reduced background noise
Why does WTN affect sleep so much?

• How annoying are they?
  – Worse than traffic
  – Worse than aircraft
  – Worse than almost every industrial sound
  – Only beaten by:
    • The teenager next door’s boom box
    • A railway shunting yard
Why does WTN affect sleep so much?

![Graph showing the relationship between sound exposure and % highly annoyed for wind turbines, aircraft, road traffic, and railways.]

Sound exposure is for wind turbines calculated A-weighted $L_{eq}$ for a hypothetical time period and for transportation DNL.
How big a setback?

1. Calculate “safe” external noise
   - Theoretical assumptions
   - Industry response
   - Dose-response relationship
   - Scientific response

2. Calculate “safe” setback distance
   - What is “safe”? 
   - Which windfarms do you survey?
Dose-response relationship

Graph showing the relationship between spindle rate and probability of stable sleep at different sound levels (dB). The graph indicates that high spindle rate is associated with a higher probability of stable sleep compared to low spindle rate as the sound level increases.
Dose-response relationship

Spindle rate predicts sleep stability

Probability of stable sleep

Low spindle rate

High spindle rate

Sound level (dB)
How big a setback?

• Present “guidance”
  – Outdated assumptions on noise effects
  – Ignoring modern research
  – Inappropriate averaging of sound
  – Inappropriate assumptions on background masking
  – Exclusion of low frequency contribution
  – No involvement of appropriate experts
How big a setback?

• Too much evidence to review today, see my updated paper at www.windvigilance.com

• At least 1.5km, probably 2km.

• External noise level $<35$dB $L_{A90}$
What do we need to do next?

• Encourage or force governments to use properly determined dose-response relationships in determining truly safe setback distances.

• In the meantime, apply the precautionary principle.
What do we do next?

• Choose a Dose-response relationship
  – External noise v “Annoyance”
  – External noise v “Sleep Disturbance”
    • Reported awakenings
    • Measured arousals
    • Measured outcome (PSQI, ESS, BFI)
• RIVM (Dutch Environmental Health)
• External noise <35dBA \left( L_{DEN} 40dB \right)
Questions?