

# The impact of wind turbine noise on health



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Installed capacity of wind power in the world.

*World Wind Energy Association, Report 2009.*

How do residents close to a wind turbine perceive the noise?

Does wind turbine noise pose a risk for lowered well-being or even impaired health?

If so, what factors moderate the adverse effects?

Also, what is so special with wind turbine noise?



## Methods

Are people who live close to wind turbines annoyed by the sound and are there indications of health effects?

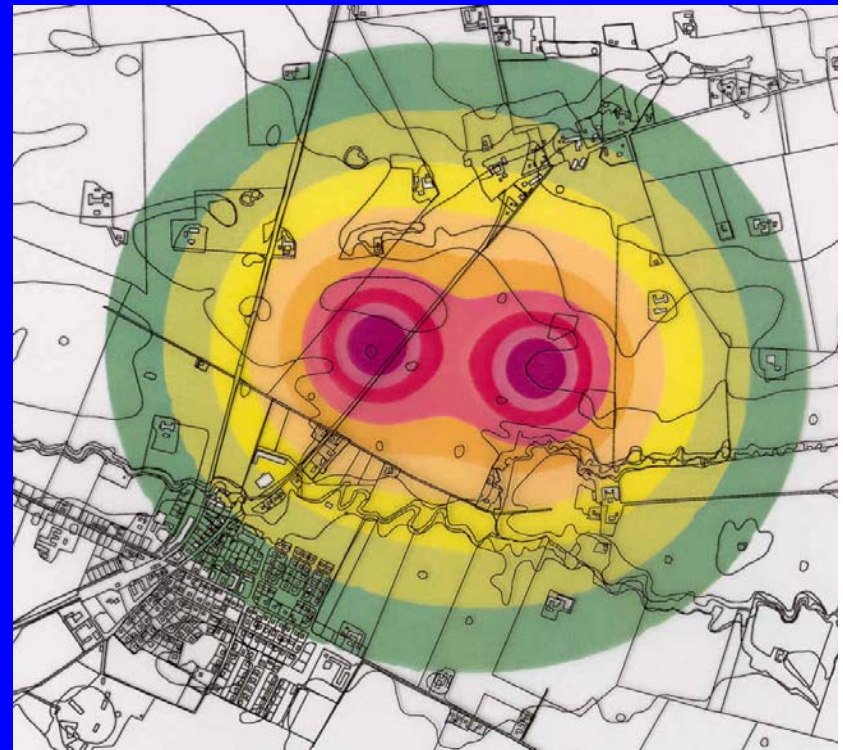
Epidemiological studies in Sweden and the Netherlands

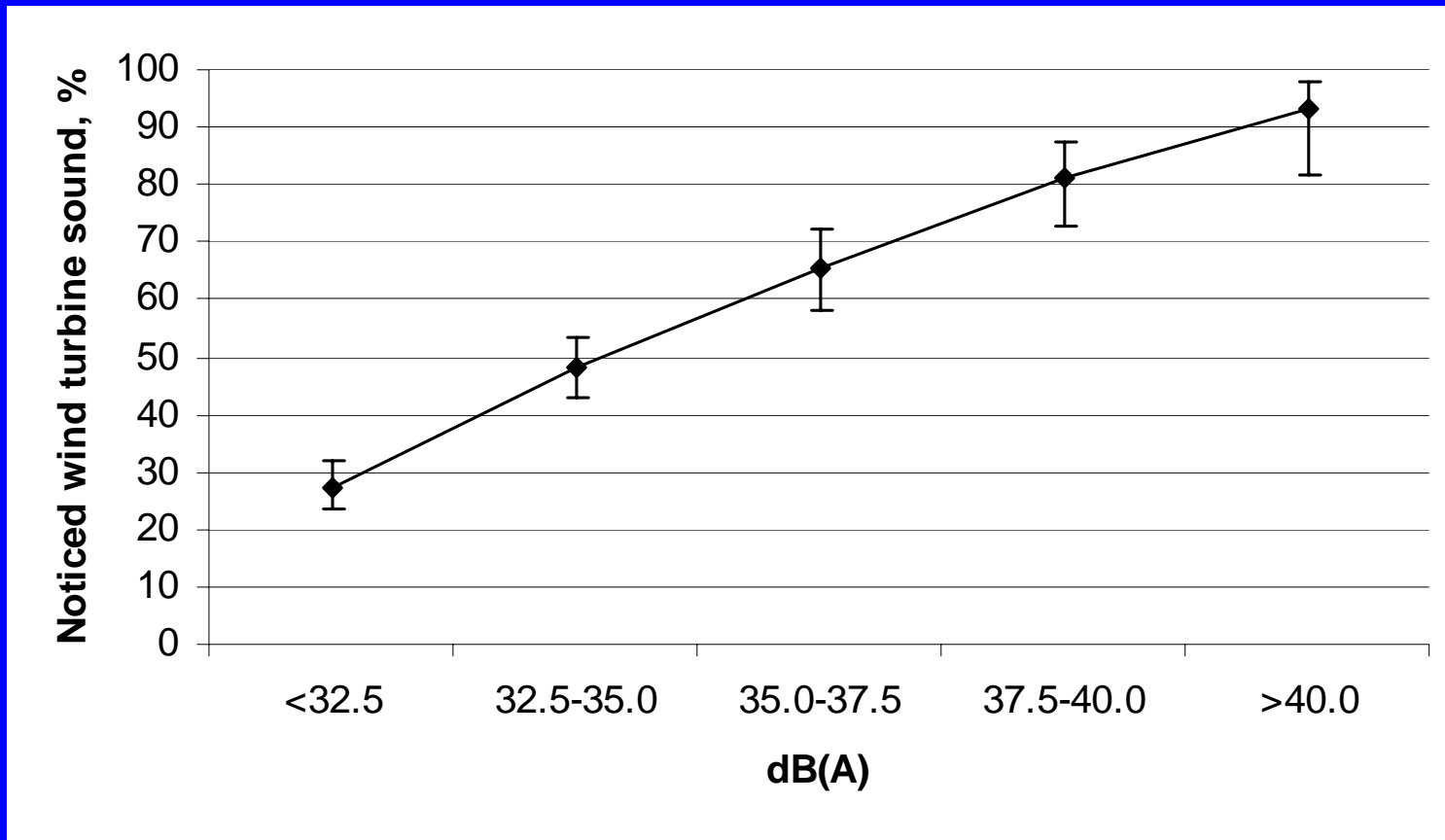
Calculated A-weighted sound pressure levels from wind turbines at the dwelling were related to response measured by masked questionnaires

*Pedersen E and Persson Waye K. Perception and annoyance due to wind turbine noise - a dose- response relationship. J Acou Soc Am 2004, 116, 3460-3470.*

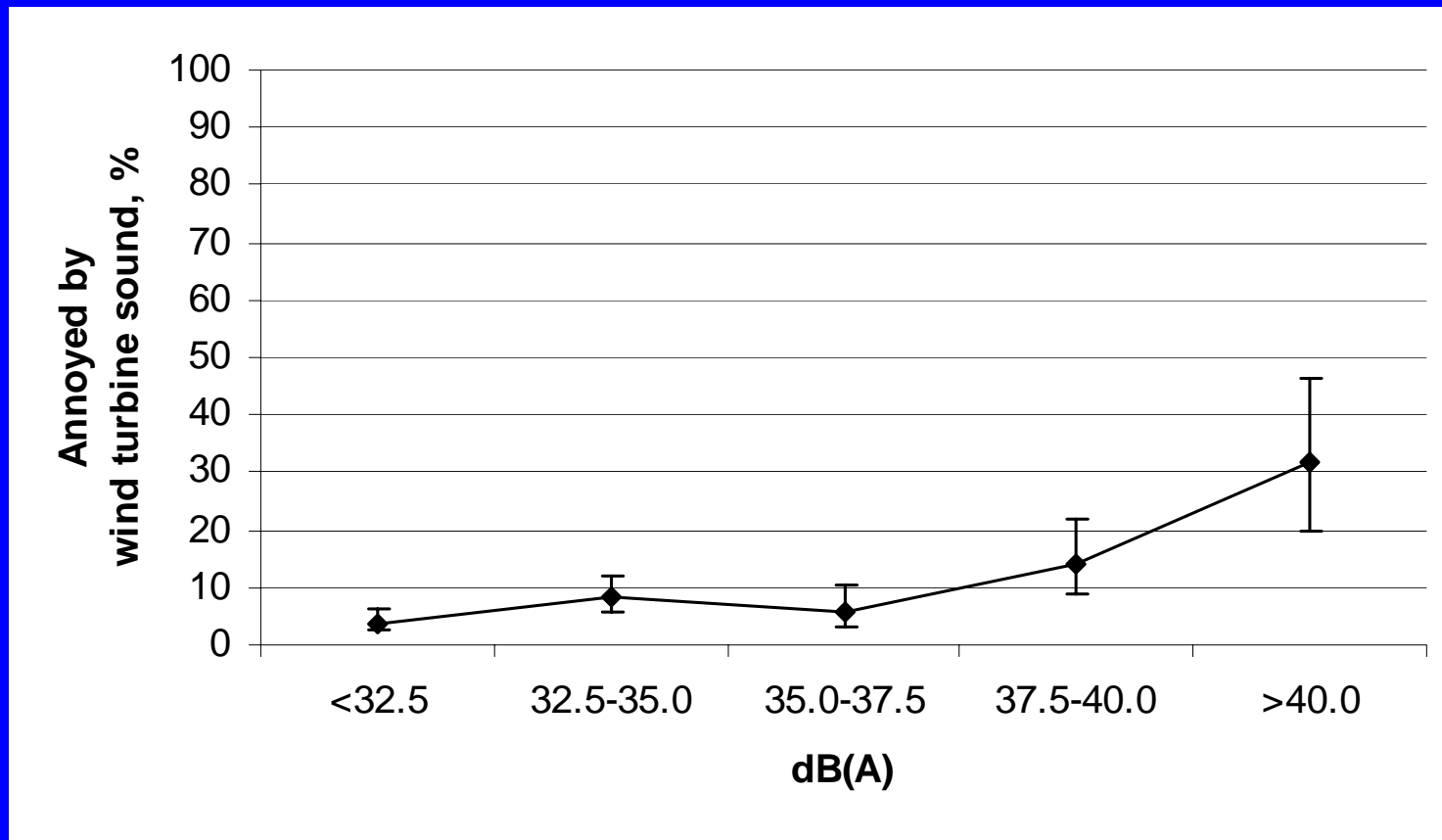
*Pedersen E and Persson Waye K. Wind turbine noise, annoyance and self-reported health and well-being in different living environments. Occup Env Med, 2007, 64, 480-486.*

*Pedersen E, Van den Berg F, Bakker R and Bouma J. Response to noise from modern wind farms in the Netherlands. J Acou Soc Am 2009, 126, 634-643.*





The percentages of respondents who noticed wind turbine sound at their dwelling (with 95% confidence intervals) related to A-weighted sound pressure levels; Swedish studies (n = 1095).



The percentages of respondents who were annoyed (rather or very) by wind turbine sound at their dwelling (with 95% confidence intervals) related to A-weighted sound pressure levels; Swedish studies (n = 1095).

<b>Notice sound from wind turbines</b>	<b>OR</b>	<b>95 % CI</b>
Sound level, 5 dB(A)-intervals	2.08	1.81–2.40
Visibility (do not see/see)	2.40	1.67–3.45
Topography (flat/hilly)	0.78	0.57–1.07
Urbanization (built-up/rural)	1.45	1.06–1.99

Respondents who could see at least one wind turbine from their dwelling and lived in a rural area were more likely to hear the wind turbine sound; Swedish studies (n = 1095).

<b>Annoyed by sound from wind turbines</b>	<b>OR</b>	<b>95 % CI</b>
Sound level, 5 dB(A)-intervals	1.46	1.22–1.75
Visibility (do not see/see)	13.97*	1.90–102.83
Topography (flat/hilly)	0.99	0.53 –1.87
Urbanization (built-up/rural)	2.90	1.78 –4.74

\*Exaggerated value due to the strong relationship between annoyance and visibility

Respondents who could see at least one wind turbine from their dwelling and lived in a rural area were also more likely to be annoyed by the wind turbine sound; Swedish studies (n = 1095).



<b>Annoyed by sound from wind turbines</b>	<b>OR</b>	<b>95 % CI</b>
Sound level, 5 dB(A)-intervals	1.70	1.42–2.04
Noise sensitivity* (4-point scale from "not at all sensitive" to "very sensitive")	1.73	1.32–2.27

\*Also adjusted for gender.

<b>Annoyed by sound from wind turbines</b>	<b>OR</b>	<b>95 % CI</b>
Sound level, 5 dB(A)-intervals	1.67	1.39–2.01
Attitude to wind turbines (5-point scale from "very positive" to "very negative")	2.24	1.80–2.79

<b>Annoyed by sound from wind turbines</b>	<b>OR</b>	<b>95 % CI</b>
Sound level, 5 dB(A)-intervals	1.53	1.25–1.88
Attitude to the impact of wind turbines on the landscape (5-point scale from "very positive" to "very negative")	5.24	3.86–7.10

Self-reported noise sensitivity and attitude towards the source moderated annoyance due to wind turbine noise; Swedish studies (n = 1095).



No relationship between  
levels of wind turbine sound  
and self-reported:

Long term disease

Diabetes

High blood pressure

Cardiovascular disease

Tinnitus

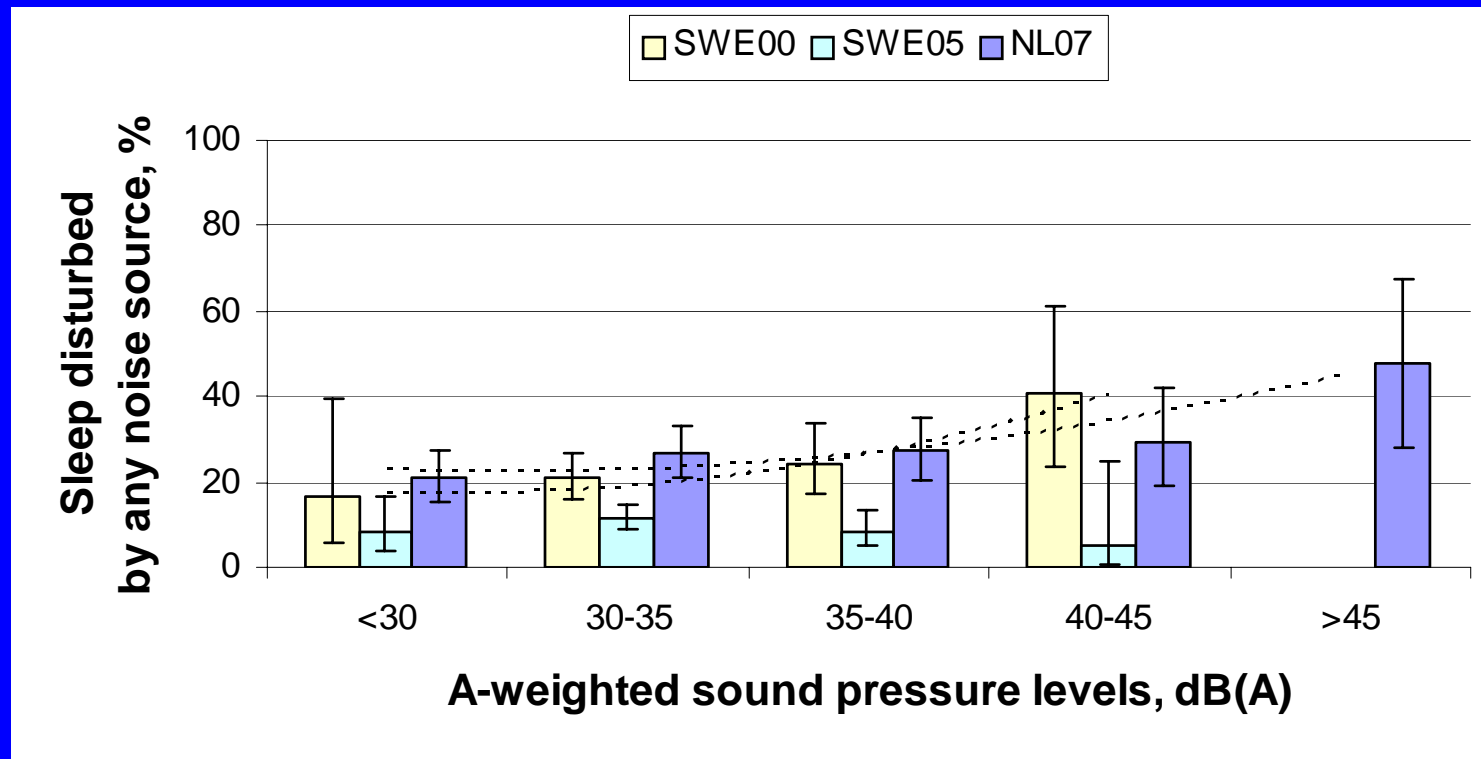
Impaired hearing

Headache

Undue tiredness

Stress symptoms

However....

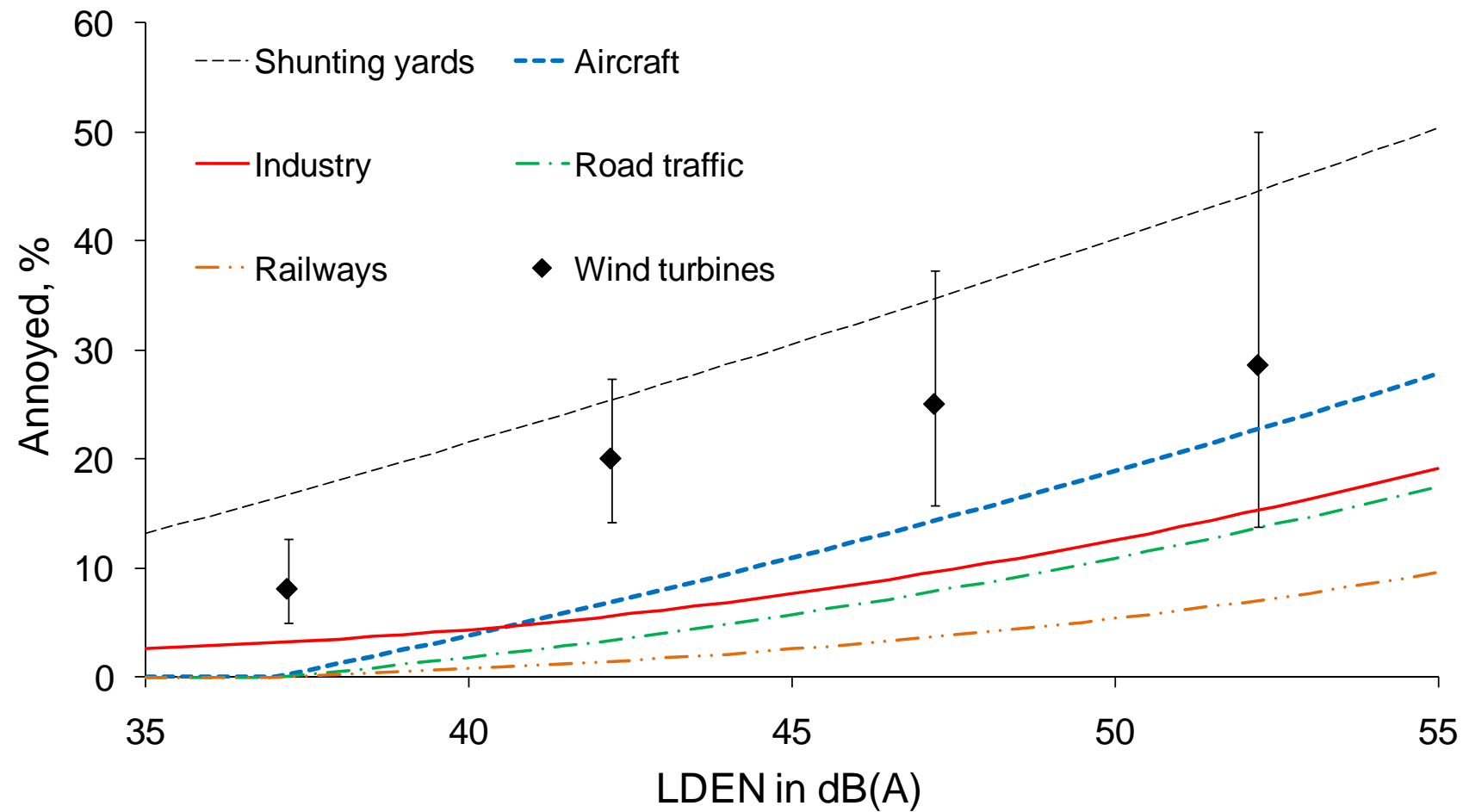


The percentages (with 95% confidence intervals) of respondents who reported that they were disturbed in their sleep by any noise source; SWE-00 (n = 341), SWE-05 (n = 746), NL-07 (only respondents who did not benefit economically from wind turbines; n = 593).

	<b>N</b>	<b>OR*</b>	<b>95% CI*</b>
<b>Headache</b>			
SWE-00	320	<b>1.24</b>	<b>1.01 – 1.51</b>
SWE-05	720	1.04	0.86 – 1.26
NL-07	650	<b>1.24</b>	<b>1.04 – 1.48</b>
NL-07**	630	<b>1.25</b>	<b>1.04 – 1.50</b>
<b>Undue tiredness</b>			
SWE-00	319	<b>1.22</b>	<b>1.00 – 1.49</b>
SWE-05	725	1.12	0.93 – 1.35
NL-07	652	1.15	0.98 – 1.35
NL-07**	630	1.10	0.93 – 1.31
<b>Tense and stressed</b>			
SWE-00	319	<b>1.25</b>	<b>1.00 – 1.56</b>
SWE-05	721	<b>1.22</b>	<b>1.00 – 1.50</b>
NL-07	652	<b>1.28</b>	<b>1.08 – 1.50</b>
NL-07**	631	<b>1.27</b>	<b>1.07 – 1.50</b>
<b>Irritable</b>			
SWE-00	319	<b>1.36</b>	<b>1.10 – 1.69</b>
SWE-05	724	<b>1.22</b>	<b>1.00 – 1.49</b>
NL-07	666	<b>1.23</b>	<b>1.05 – 1.45</b>
NL-07**	644	<b>1.27</b>	<b>1.07 – 1.50</b>

\*Adjusted for age, sex and A-weighted sound pressure levels.  
\*\*Adjusted also for economical benefits.

Associations between annoyance due to wind turbine noise and stress related variables.



Annoyance due to wind turbine noise in comparison to noise from traffic (*Miedema and Oudshoorn, 2001*) and industry (*Miedema and Voss, 2004*); Dutch study (n = 725).

# Why is wind turbine noise more annoying than other environmental sounds?

Amplitude modulated

Unpredictable

A technical sound in areas with natural background sound

Difficulties in estimations of sound levels



*Oerlemann et al. 2007*

## Methods

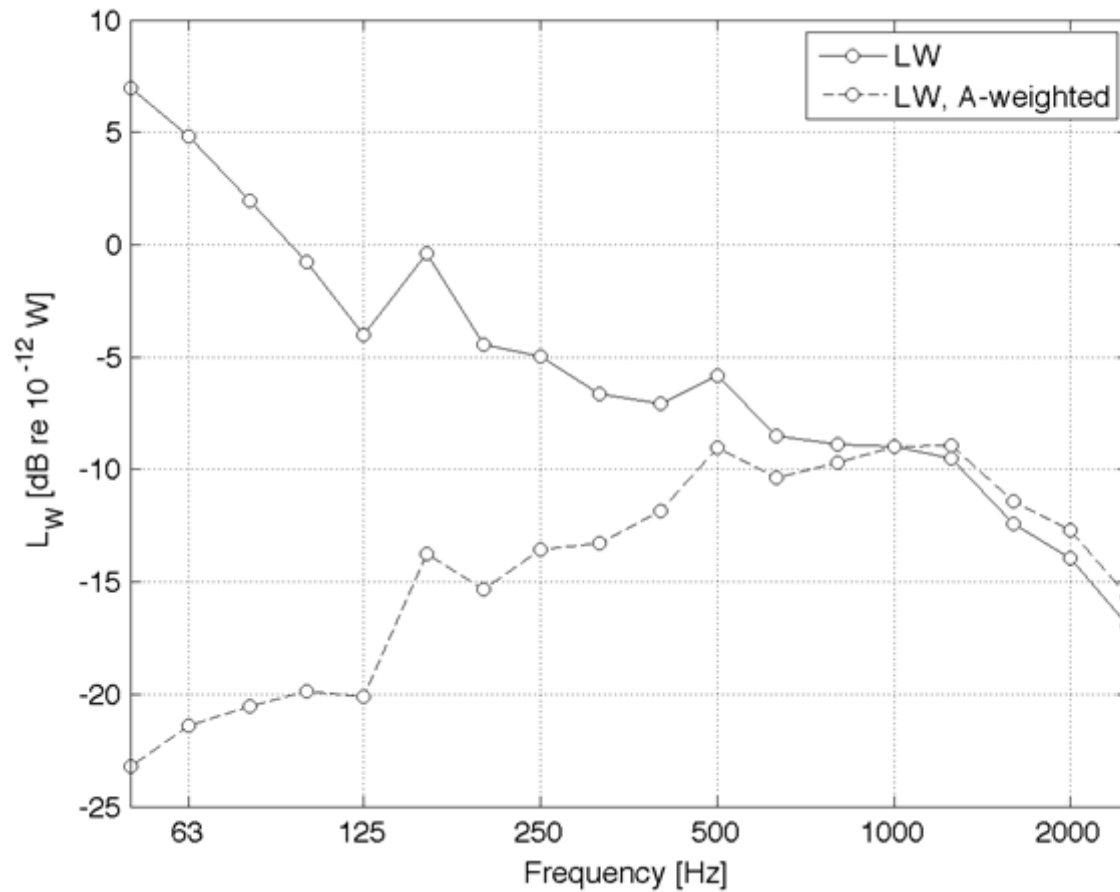
What is the sound like and how well do calculated immission levels correspond to measured levels?

Measured immission A-weighted sound pressure levels at 500 meter from a 1.5 MW wind turbine were related to calculated sound levels based on measured sound pressure levels at the wind turbine

Different sound propagation models were tested

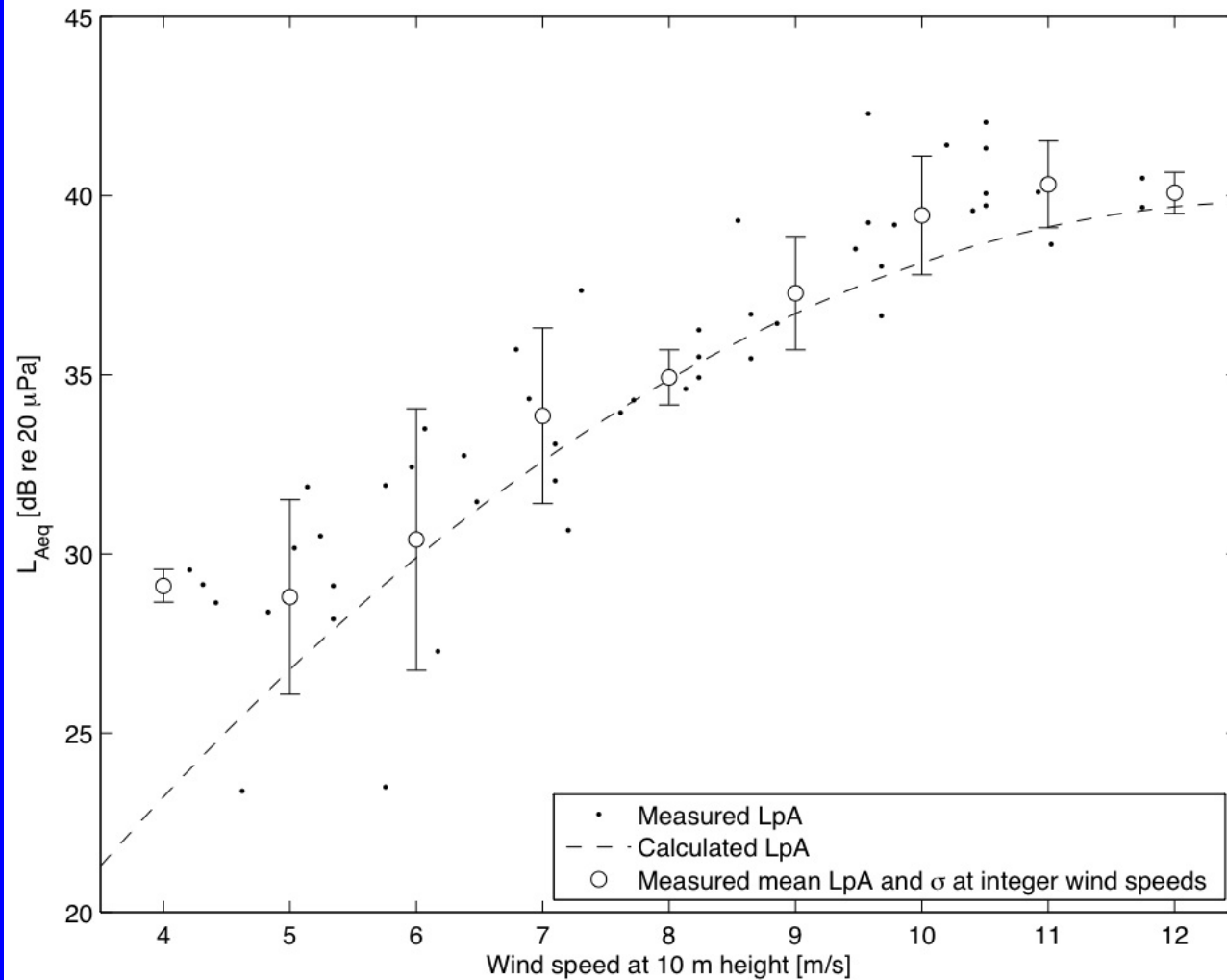
*Forssén J, Schiff M, Pedersen E and Persson Wayne K.  
Wind turbine noise propagation over flat ground:  
measurements and prediction. Acta Acustica, 2010, 96.*





Source spectrum from emission measurement at wind speeds around 12 m/s (at 10 m height), shown both as A-weighted and un-weighted, normalized to 0 dB(A).





Measured immission levels for downwind cases and calculations according to Swedish standard. Measured levels grouped to integer wind speeds are shown as mean value and standard deviation.

How can the large variations in measured immission levels at the same wind speed be explained?

Meteorological factors only have minor influence on sound propagation at shorter distances such as 500 m (and hence simplified models can be used)

However...

The uncertainty at the source (i.e. the emission level) is the main factor influencing the uncertainty in the calculations of sound levels at the receiver (i.e. immission levels); the turbine speed does not instantly adjust to the wind speed.



## Methods

How do people who live close to wind turbines perceive the sound?

Interviews with people that were very annoyed by the noise and those that were not at all annoyed

Analyzed with a Grounded Theory approach

*Pedersen E, Hallberg L R-M and Persson Wayne K. Living in the vicinity of wind turbines – a Grounded Theory study. Qualitative Research in Psychology, 2007, 4, 49-63.*



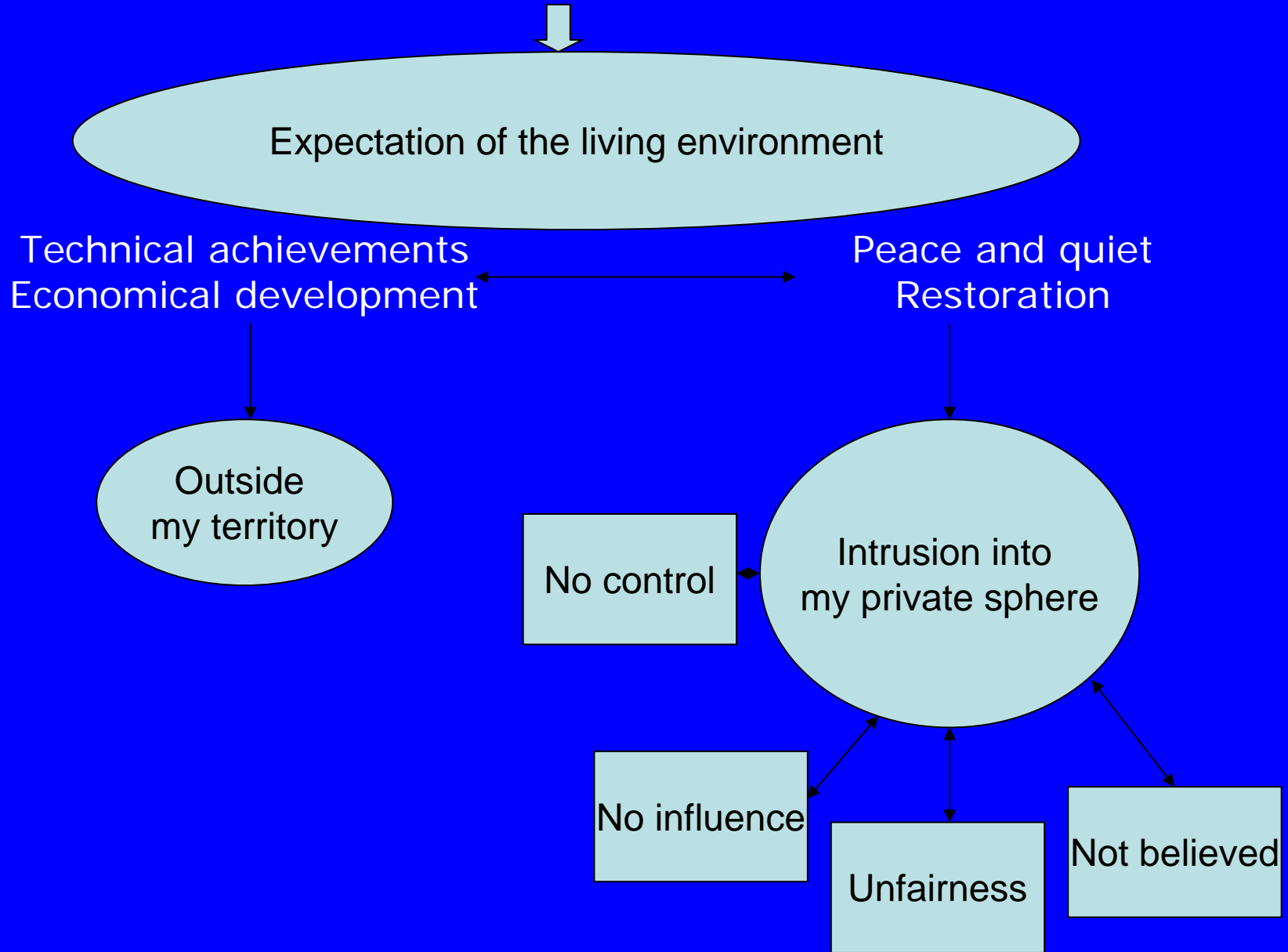
*“I saw it as a positive development. We didn’t have any wind turbines here, and because of that we didn’t know what they were. Then we got to know that it meant that every time you went in the garden or looked in that direction, it was spinning. It just spins and spins. It gets irritating.”*

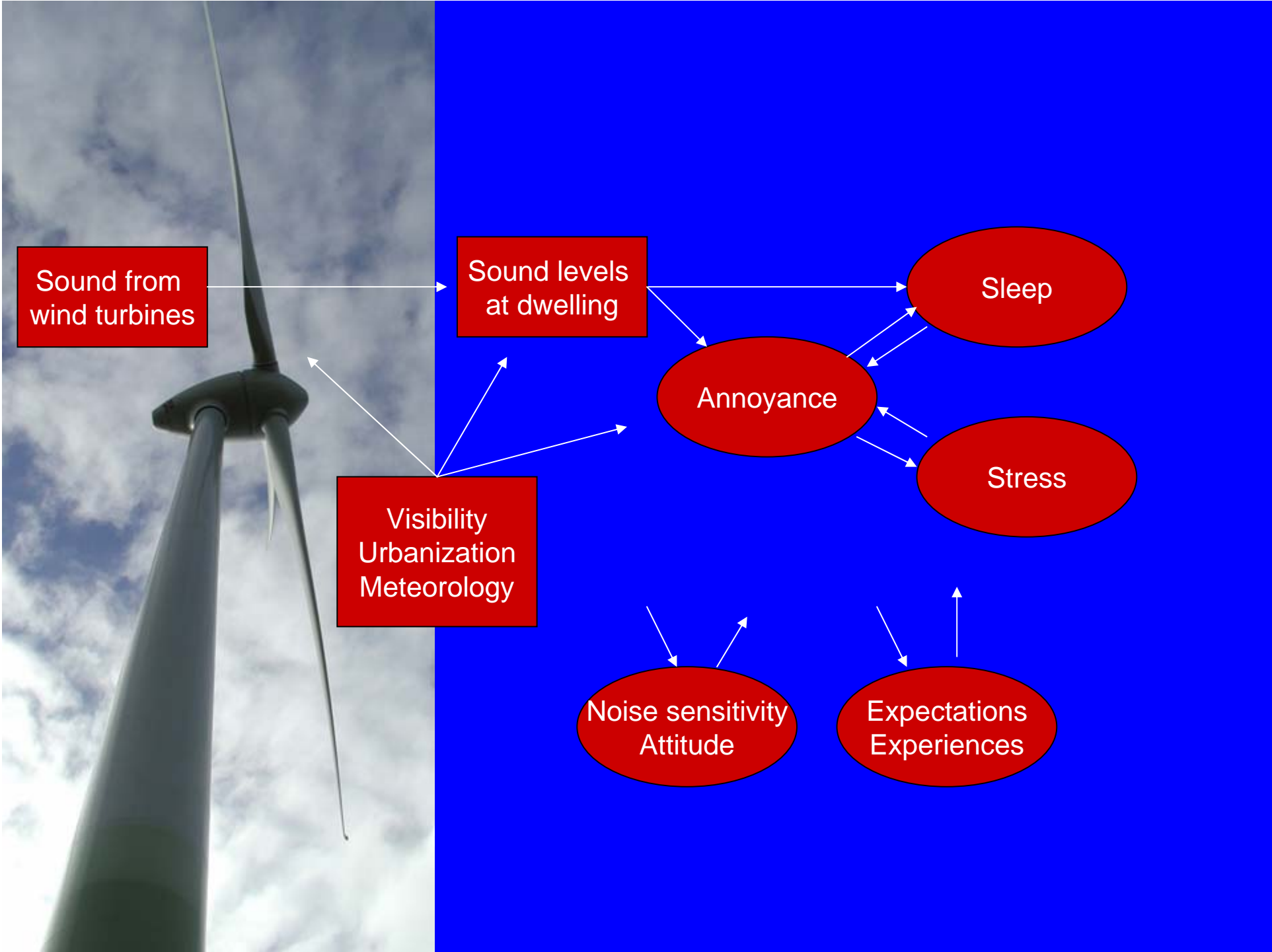
*“I drive wheel loaders and trucks. There’s plenty of bang and bonk all day long. You know, a garage. When I turn everything off for the night and hear that wind turbine, it’s enough to drive you crazy. It never goes away ... You go mad, it’s sort of like that. It’s always there. You get used to it, to some degree. But when you go out in your garden on a Saturday, and you hear it. You get so angry at that sound that you end up being angry at everything. Do you understand what I’m saying? It’ll drive you crazy.”*

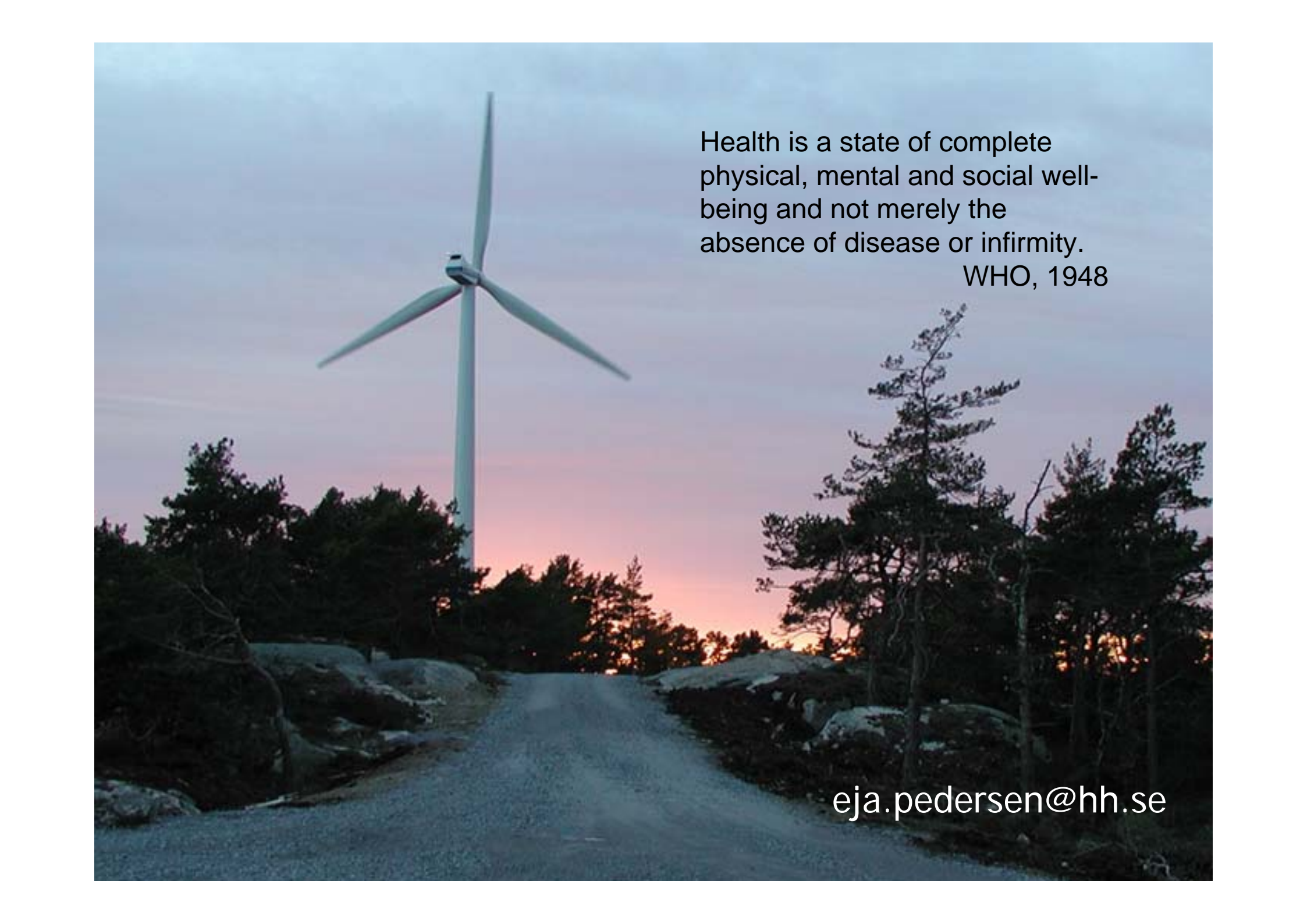
**Intrusion!**



# Sound from wind turbines







Health is a state of complete  
physical, mental and social well-  
being and not merely the  
absence of disease or infirmity.

WHO, 1948

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