Wind turbine noise

An ECN perspective

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www.ecn.nl

Motivation

- How can the perceived noise problem be tackled?

- Noise means different things to different people!

- Considering noise from different perspectives:

– Blade designer

– Turbine manufacturer

– Project developer (general public)

→ Practical approach

Contents

- Brief introduction to ECN Wind
- Wind turbine noise
  - Sources, where does it come from
  - Propagation, how does it travel
- ECN noise modeling tool – SILANT
  - Predicting and visualising complex noise phenomenon.
  - Validation of the model
- Noise case studies, from the perspective of:
  - Blade designers
  - Turbine manufacturers
  - Project developers and owners
- Conclusions and recommendations

ECN a (very) brief introduction

ECN – The Energy Research Centre of the Netherlands

With and for the industry, ECN develops knowledge and technology that enable the transition to a sustainable energy system.

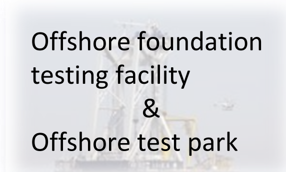
ECN Wind Energy

Pioneers in wind energy technology and systems with more than 35 years experience

Core competencies

- Rotor and wind farm aerodynamics
- Integrated farm / turbine design
- Operations and Maintenance
- Measurements & Experiments (with unique field facilities)

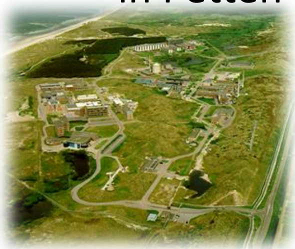
ECN Wind in the Netherlands



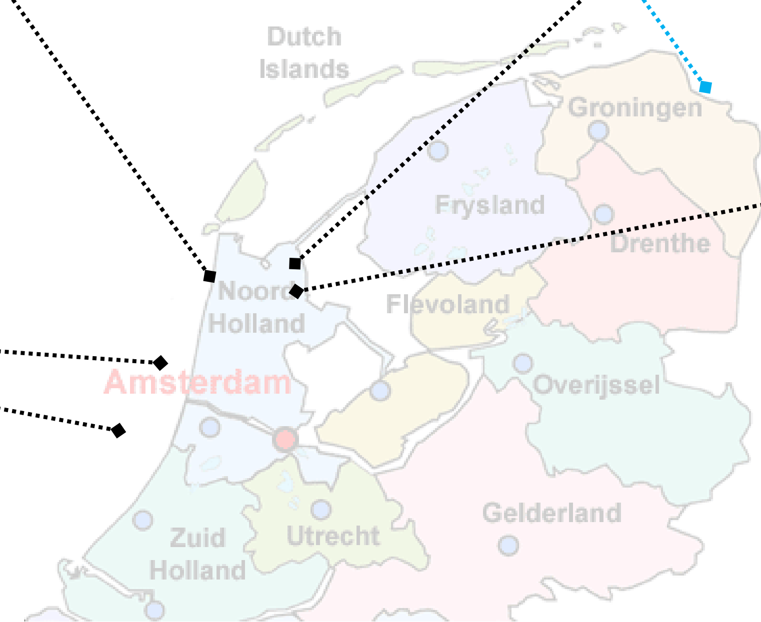
Offshore foundation testing facility
&
Offshore test park

Planned

Head Office
in Petten



Offshore parks
& metmasts



Blade & material testing

Test Site
Up to 7.5MW

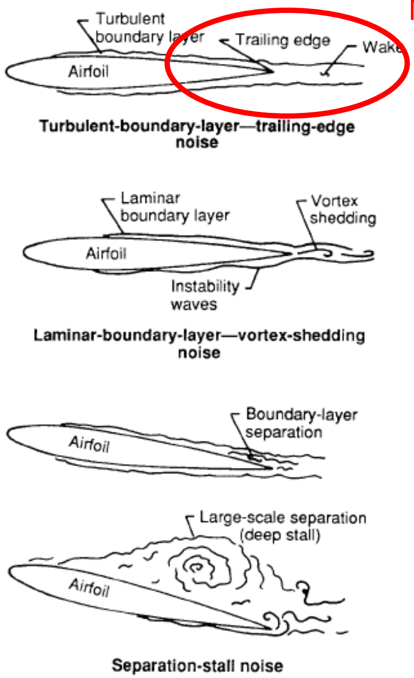
5 x R&D turbines
5 x Prototypes

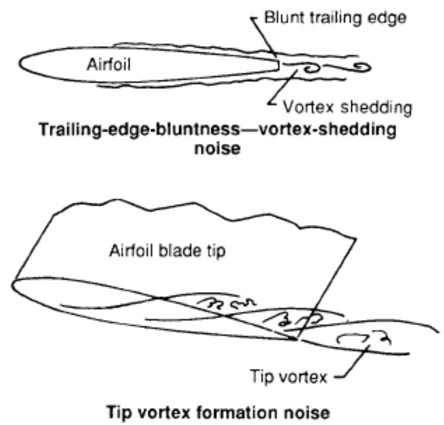
Scaled wind farm

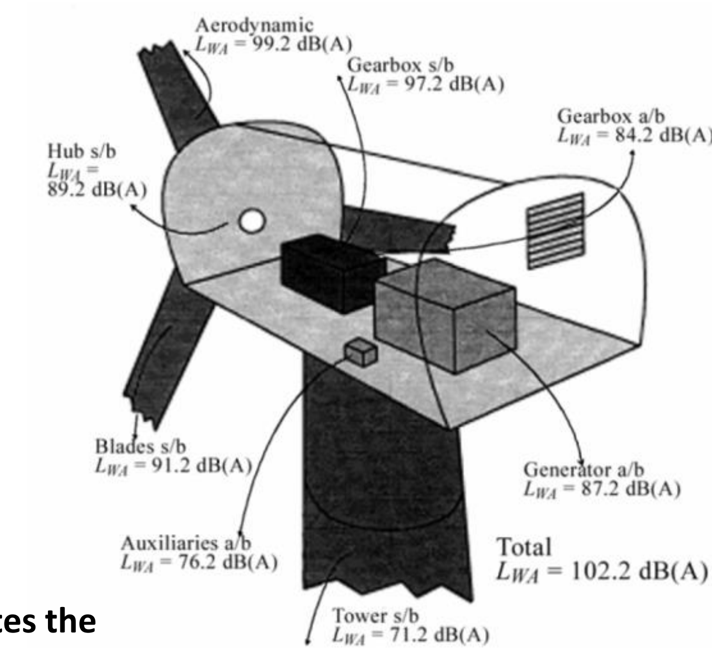
Noise sources

- Aerodynamic noise
- Mechanical noise

Most significant source for perception







Aerodynamic noise most often dominates the perceived noise problem within the public

Noise propagation

- Propagation effects are very complex:

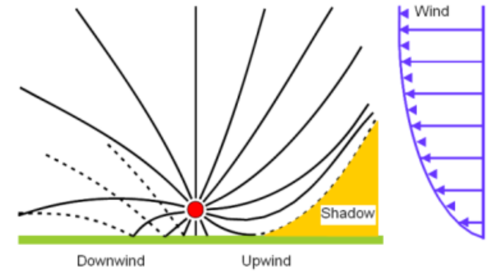
- Refraction (bending) by wind and temperature gradients (e.g. upwind bend up, downwind bend down)

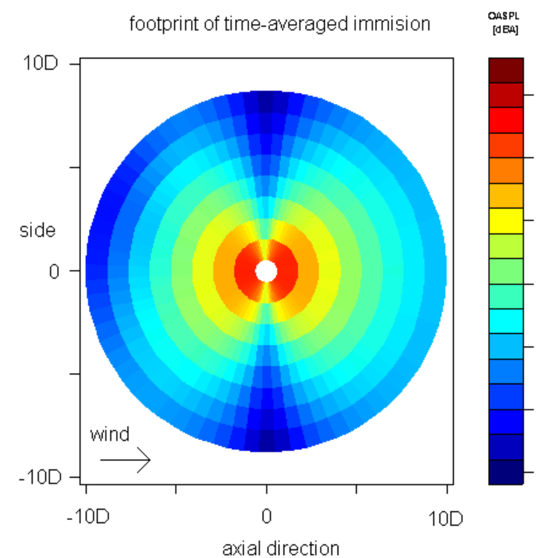
- Reflection/absorption from the ground. Effect very dependent on noise frequency / angle & ground conditions

- Highly directional and moving sources (rotor)

- Flat or hilly/mountainous terrain

- Interaction of sound waves with rotor wake and atmospheric turbulence

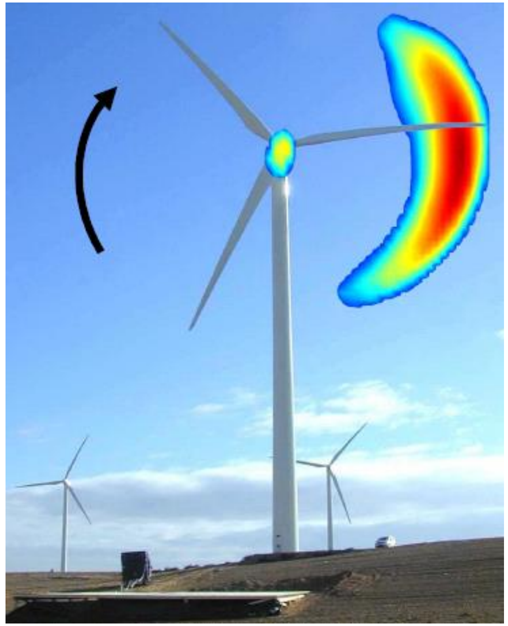




Noise perception

What do people hear? (or think they hear)

- Trailing edge noise (70%-95% span) dominant
- Swish: downward blade movement most noisy
- On going debate on low frequency. Below 20Hz cannot be heard, but are there other effects?



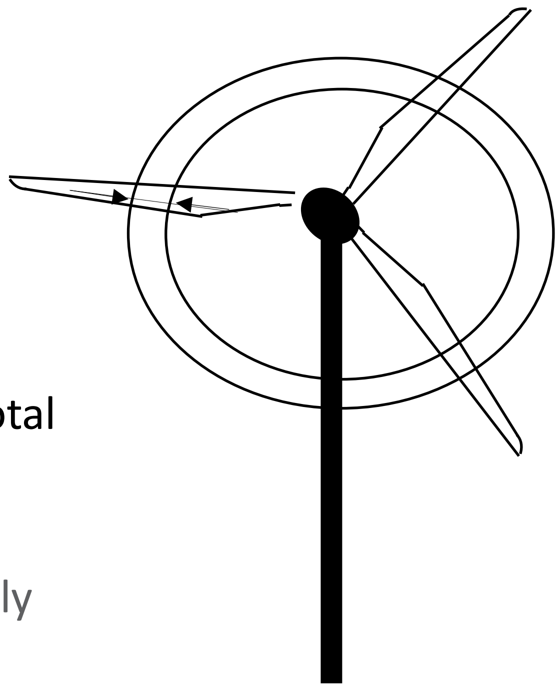
SILANT – modeling approach

- Divide wind turbine blades into elements (usually order of 10 to 20)
- For every blade element two noise sources are calculated:

  1. Trailing edge noise using the model of Brooks, Pope and Marcolini[1]

  2. Inflow noise using the model of Amiet[2] and Lowson[3]
- Separately calculate tip noise for each blade[1]
- Sum noise sources ('acoustically') over elements yielding total blade and turbine sound power level.
- Optionally calculate immission for specified receiver(s)

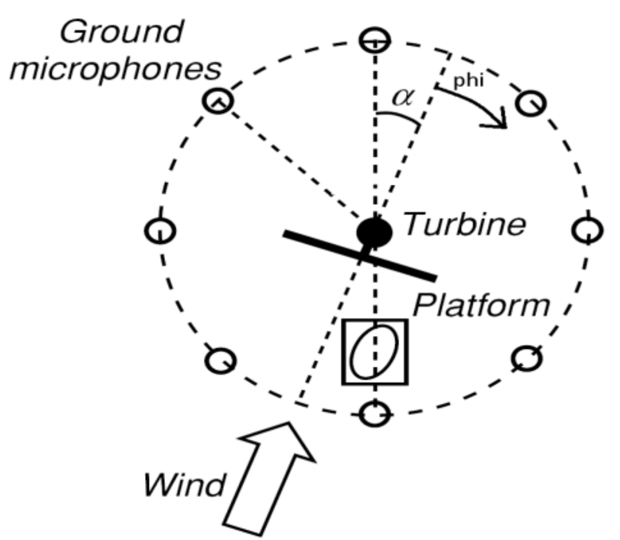
\- Treat each element source receiver combination individually and sum acoustically



[1] T.F. Brooks, D.S. Pope and M.A. Marcolini (1989): "Airfoil self noise and prediction". Reference publication 1218, NASA.
[2] R.K Amiet (1975): "Acoustic radiation from an airfoil in a turbulent stream". Journal Sound Vib., 41(4):page 407-420
[3] M.V. Lowson (1993): "Assessment and prediction of wind turbine noise ". ETSU W/13/00248/REP, Dept of Trade and Industry.

SILANT – validation

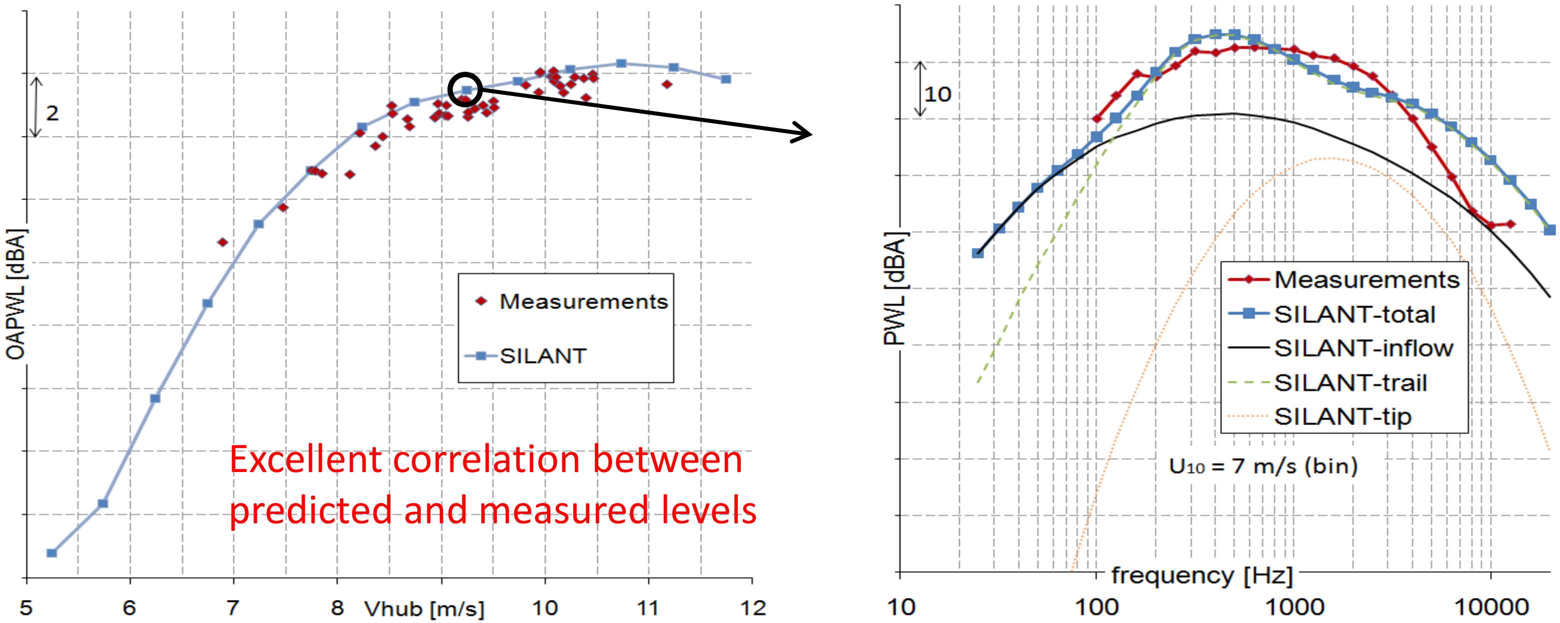
- Comparison using 2.3MW turbine at ECN test field (NLR measurements)



- Polar ground microphones located around turbine

ECN

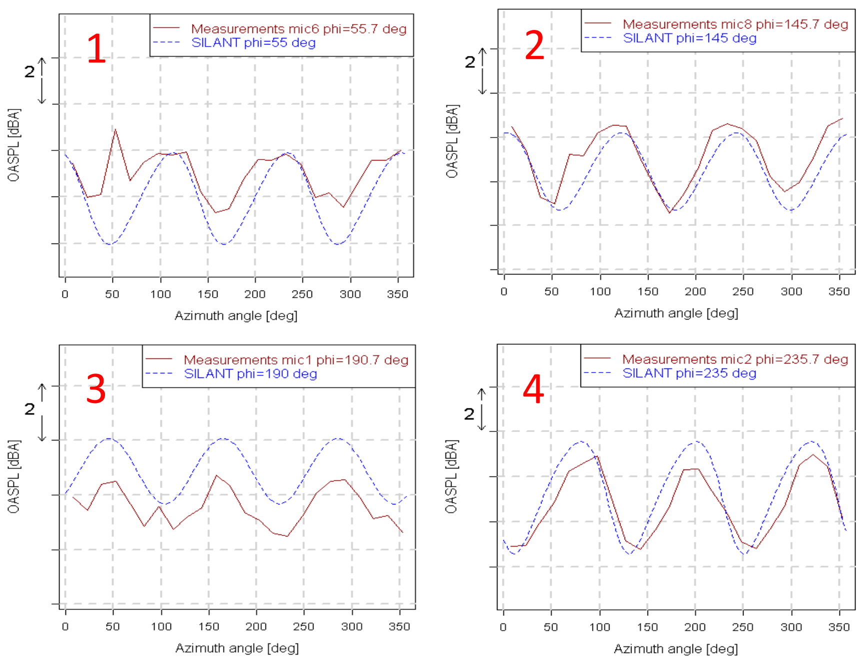
SILANT – validation (emission)

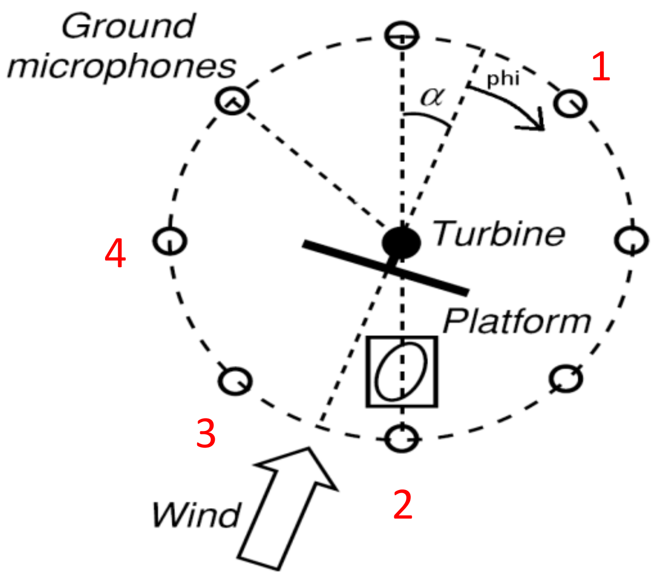


Measured and computed OAPWL (left) and PWL spectrum (right)

OAPWL = overall power watt level

SILANT – validation (immission)





Variation of OASPL with rotor azimuth angle of 4 polar positions for a single datapoint

OASPL = overall sound pressure level

Case study: Blade designer

- Multi-disciplinary

-Aerodynamics
-Aero-elasticity
-Acoustics
-Control (pitch angle, rpm)
-Materials and structures

- Things to consider

-Power production
-Blade mass
-Noise
-Loads
-Manufacturability and transport
-Operation & maintenance
etc…

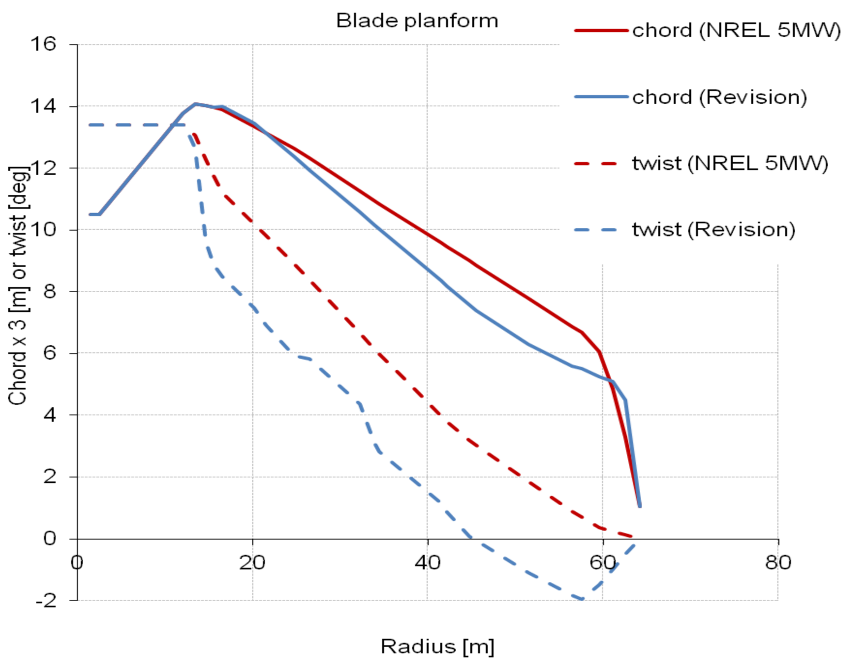
End goal minimum Cost of Energy (CoE)

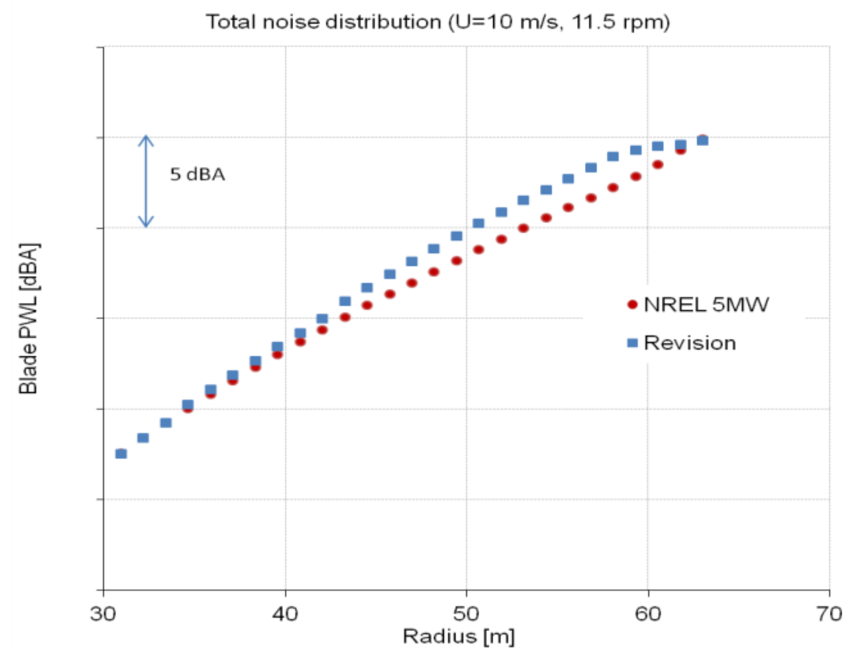
Noise is just one piece of the puzzle!

- **Integral design is the most beneficial but unfortunately not usually practiced**

Case study: Blade designer

- Influence of blade planform





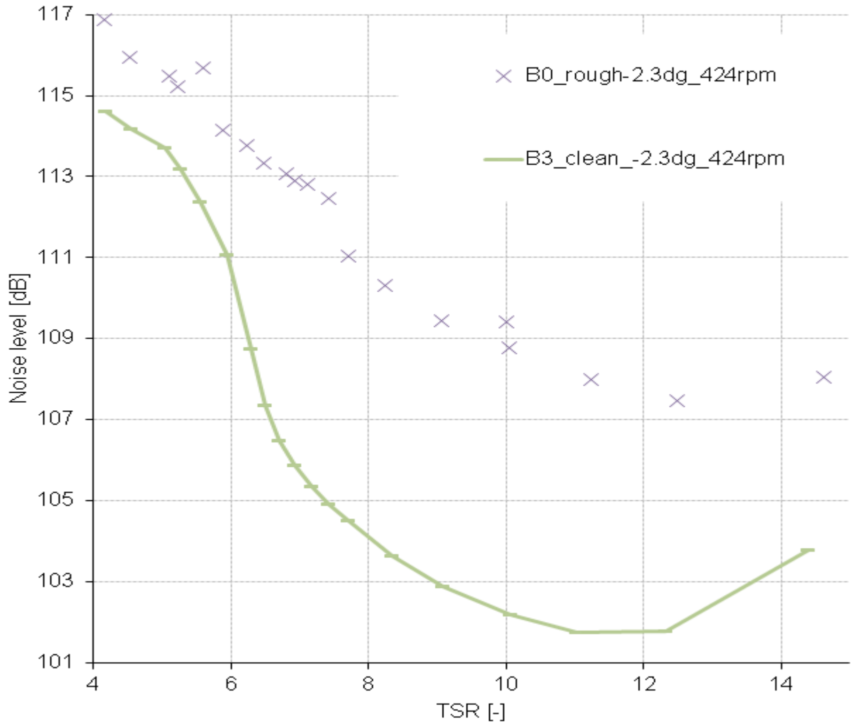
Key message : noise can be signifnicantly reduced by taking a multidisciplinary approach in blade design

Case study: Blade designer

- Latest experimental results: New MEXICO in DNW

Case study: Blade designer

- New MEXICO: Roughness

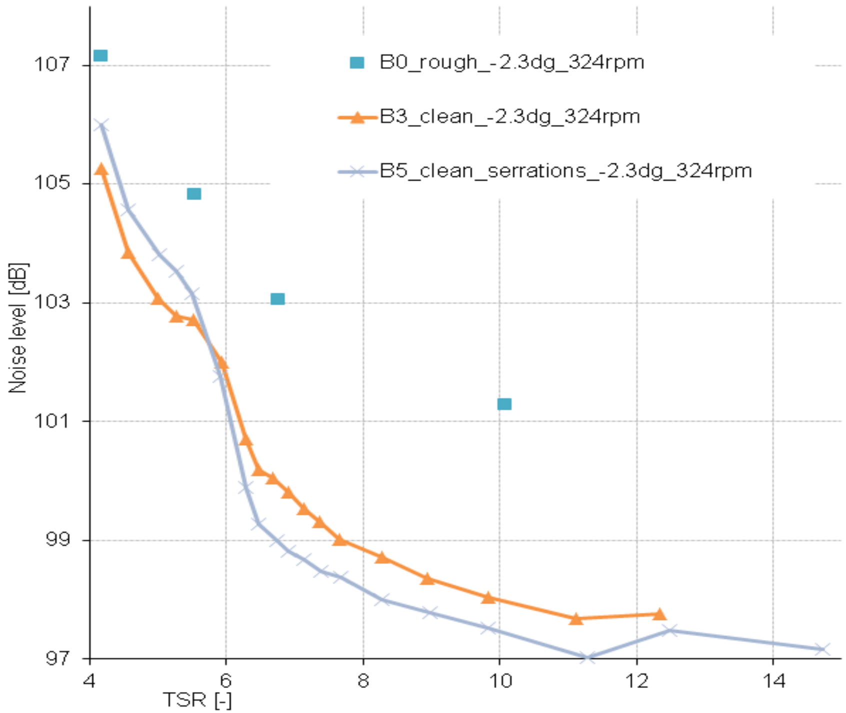


Rotor noise variation with tip speed ratio (TSR) for 424 rpm

Effect of roughness

Case study: Blade designer

- New MEXICO: Noise mitigation devices

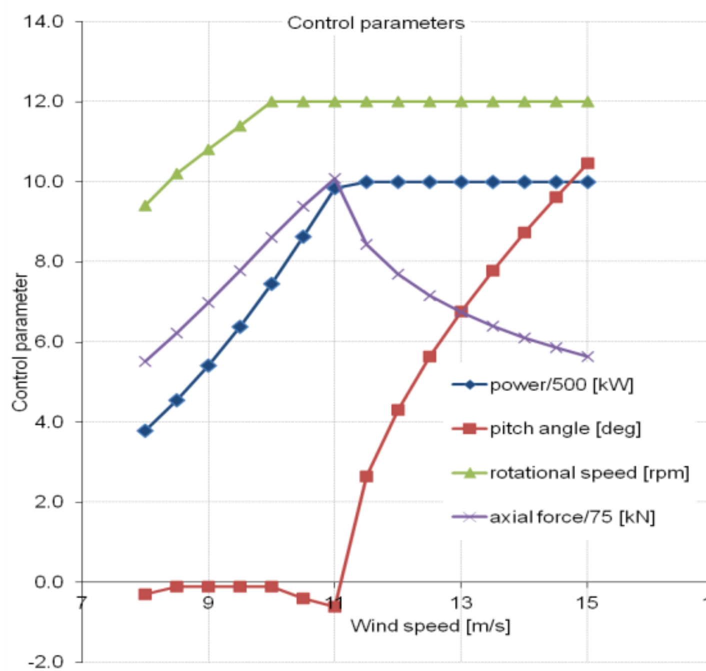


Rotor noise variation with tip speed ratio (TSR) for 324 rpm

Effect of serrations (only 10%R covered)

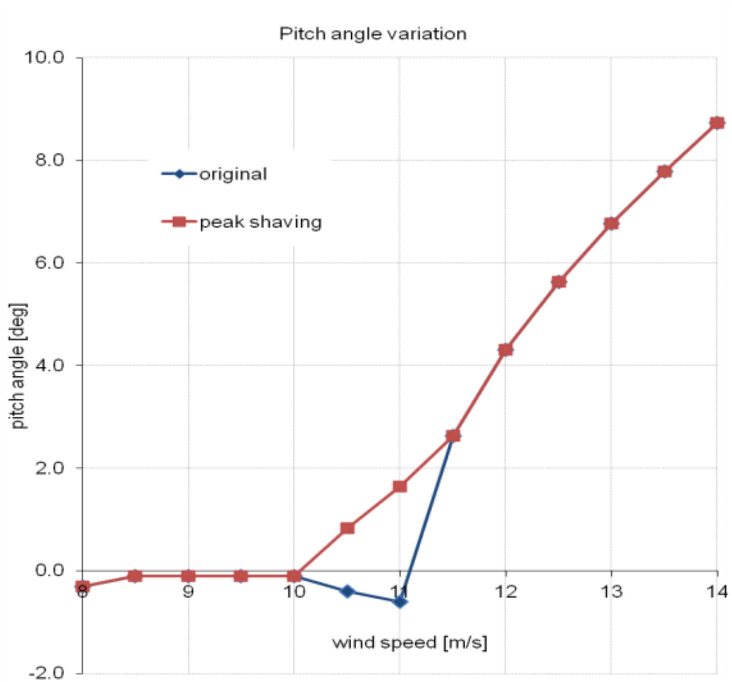
Case study: Turbine manufacturer

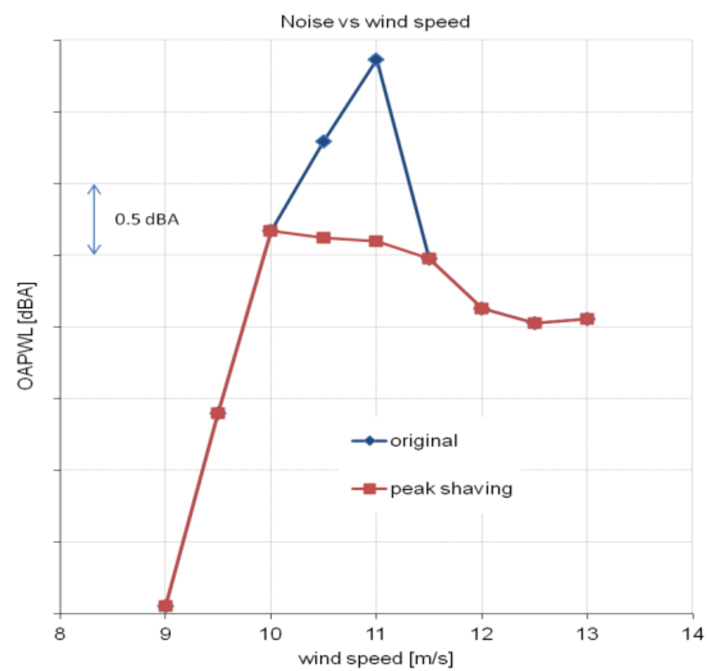
- Active pitch to vane turbines: control by means of rpm and pitch angle



Case study: Turbine manufacturer

- Influence of control parameters on noise





Key message:
Decrease noise by modifying
the wind turbine controller

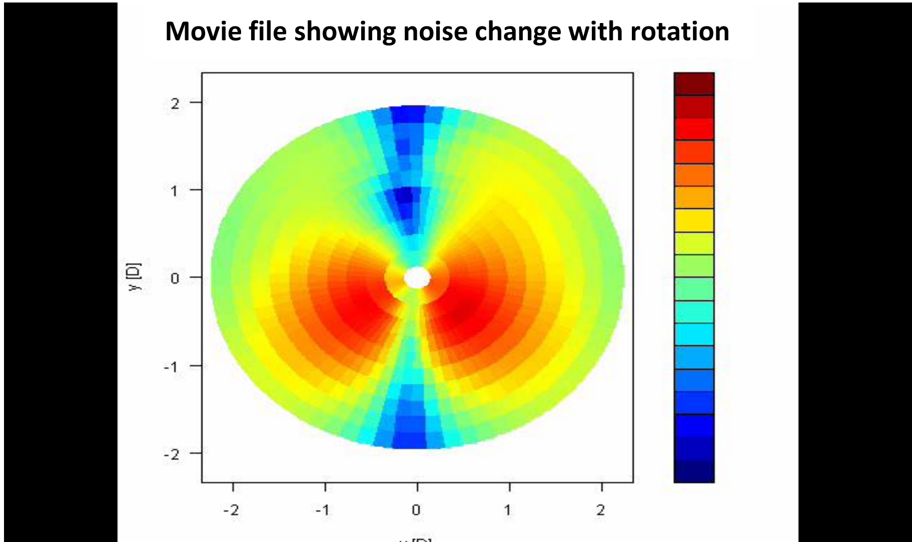
- Cost: 0.65% annual yield reduction for 5MW turbine

Case study: Project developer

- Regulations vary per country

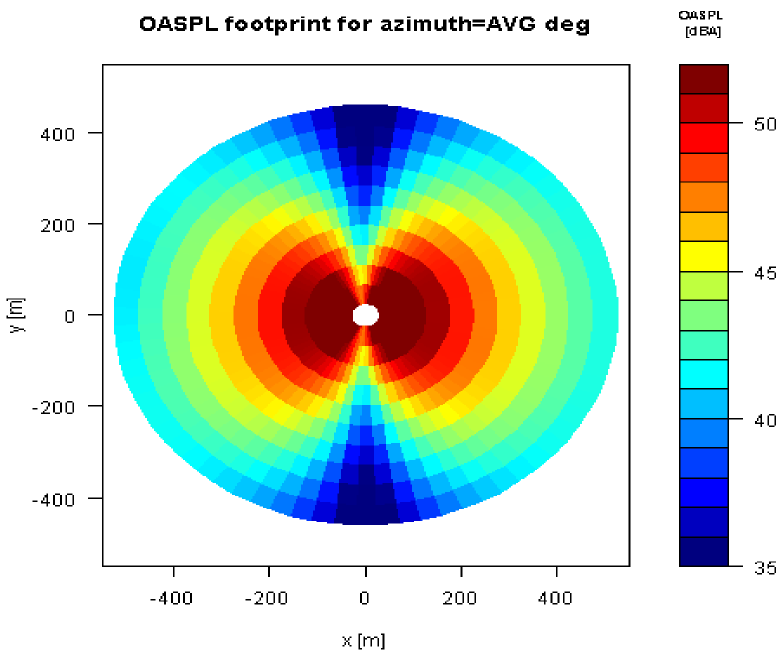
- absolute noise level vs difference with background
- area distinction (rural/residential/commercial/indoor/outdoor)
- time (day/night)
- compliance based on measurements or calculations
- tonal noise penalties
- A-weighting
- usually based on averaged OASPL, but..

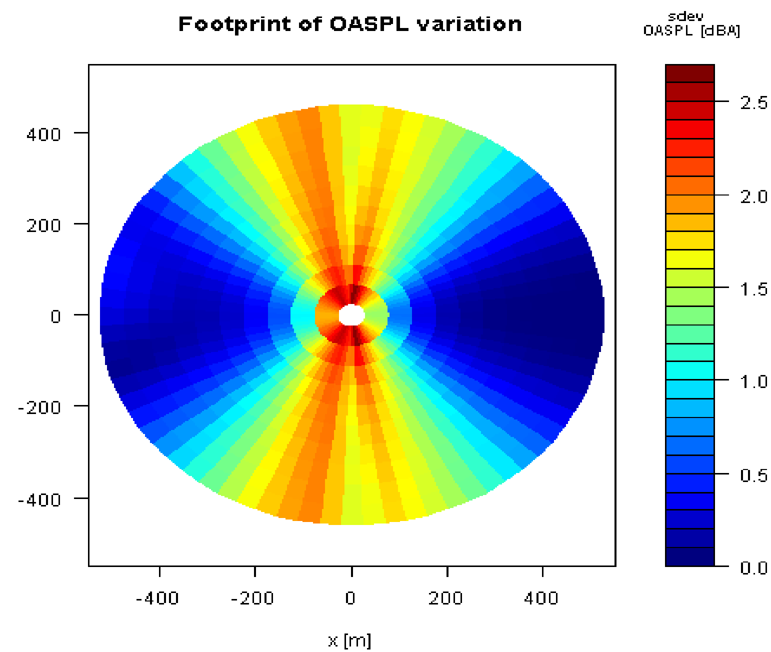
- Noise levels vary in space and time:



Case study: Project developer

- Planning (and regulation) could benefit from considering directivity and temporal variation of noise on **farm** level

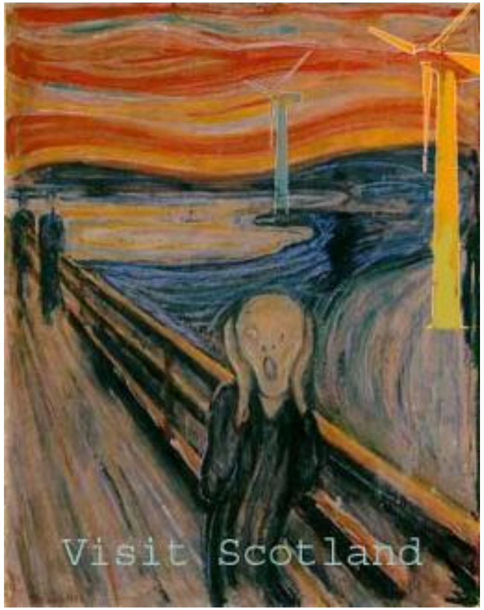




Conclusions

- How can perceived noise problem be tackled?
- Several openings are given from the viewpoint of
  – Blade designer
  – Turbine manufacturer
  – Project developer (general public)
- Let's not forget the most important audience..

- Acknowledgement: EU SIROCCO, NLR



Source: www.tw312.org.uk

Questions ?

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