



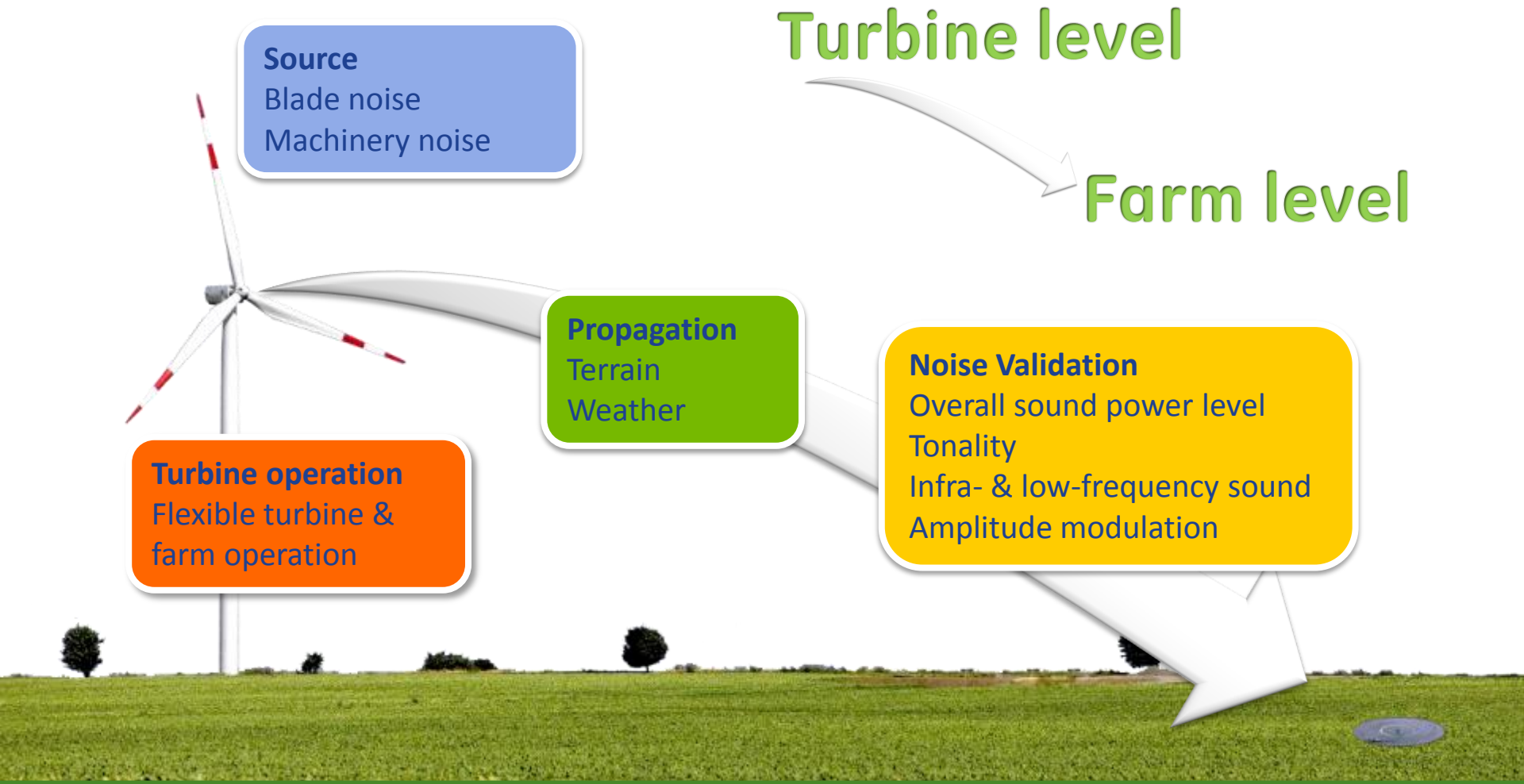
## Improved Aeroacoustics and Noise Management Options

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imagination at work

# From turbine to receptor



# Wind turbine noise today

Although wind turbines are relatively low level sources they can cause annoyance for residents near wind farms

Wind farm developers have to comply with regional noise regulations – Clear trends to lower noise limits

Lower noise limits and bigger rotor diameters require low noise designs



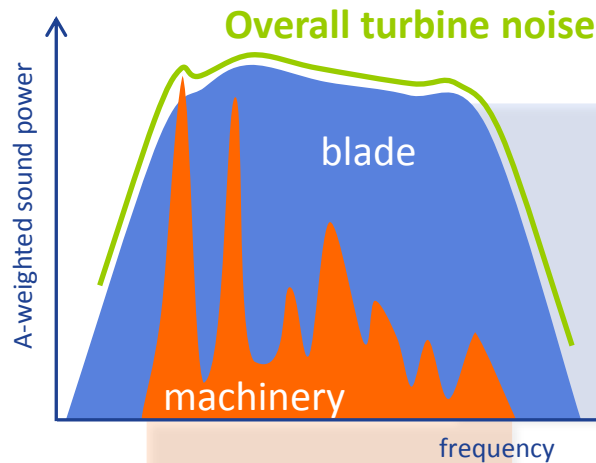
The “easy” solution

Innovation



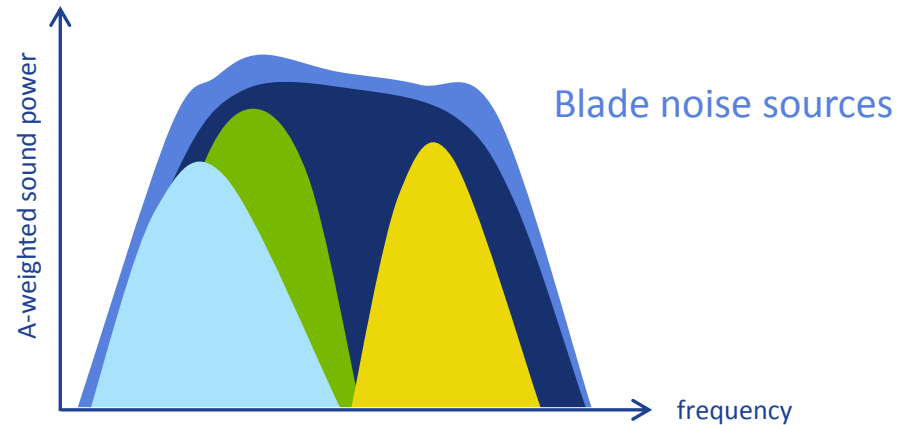
# Turbine level Sound Source Mitigation & Operation

# Wind turbine noise source: Overview



## Machinery noise

- Noise from gearbox at meshing frequency
- Cooling fans
- Brake systems



**Trailing edge noise:** Pressure fluctuations in the boundary layer scattered by the sharp trailing edge

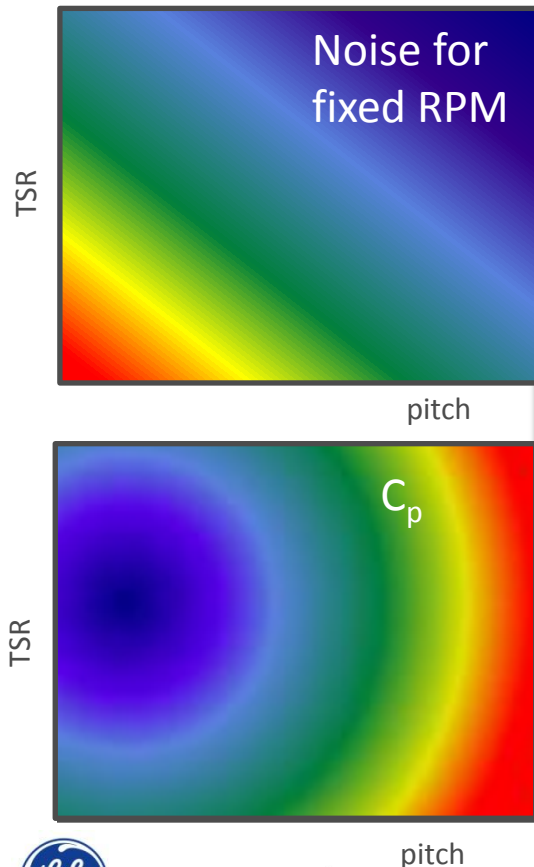
**Tip noise:** Vortex structures at the tip interacting with the blade edges & surfaces

**Inflow turbulence noise:** Inflow turbulence interacting with blade leading edge

**Flow separation noise:** Large turbulent structures interacting with blade trailing edge and surface

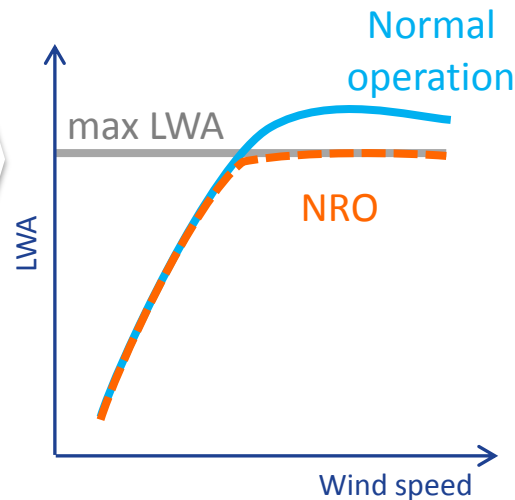
# Noise reduced operation

Understand noise & turbine performance based on TSR & pitch

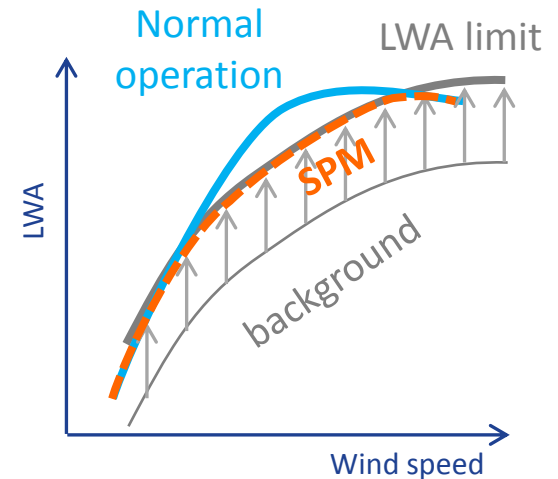


Control TSR & pitch for optimum AEP with noise constraint

**Noise Reduced Operation**  
Constrain max noise



**Sound Power Management**  
Noise limit as a function of wind speed



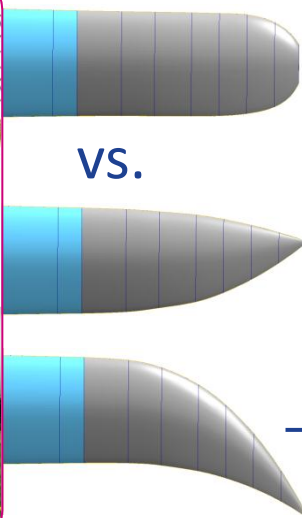


# Low noise tip design

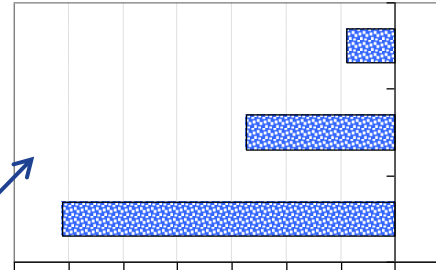


On-blade installation

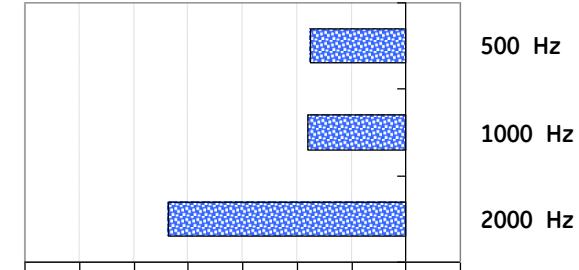
VS.



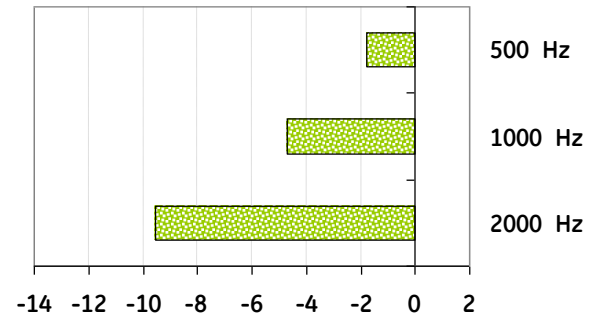
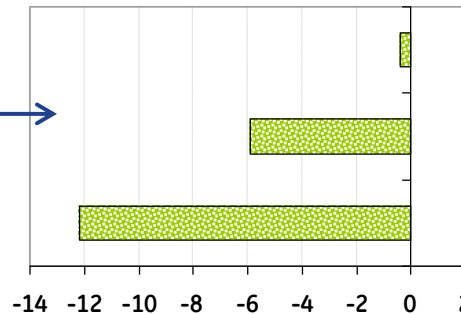
60% Rated Power



95% Rated Power



Difference in 1/3-octave SPL, [dBA]



2.5-100: 3<sup>rd</sup>-oct levels ref. 'blunt' tip shape

- Clear noise benefits from 0.5–2 kHz for 40–95% rated power – Most significant at 2kHz
- No tip noise contribution to overall noise spectrum with GE low noise tip

Let's hear the difference!



Sound recordings from baseline & redesigned tips, played back-to-back

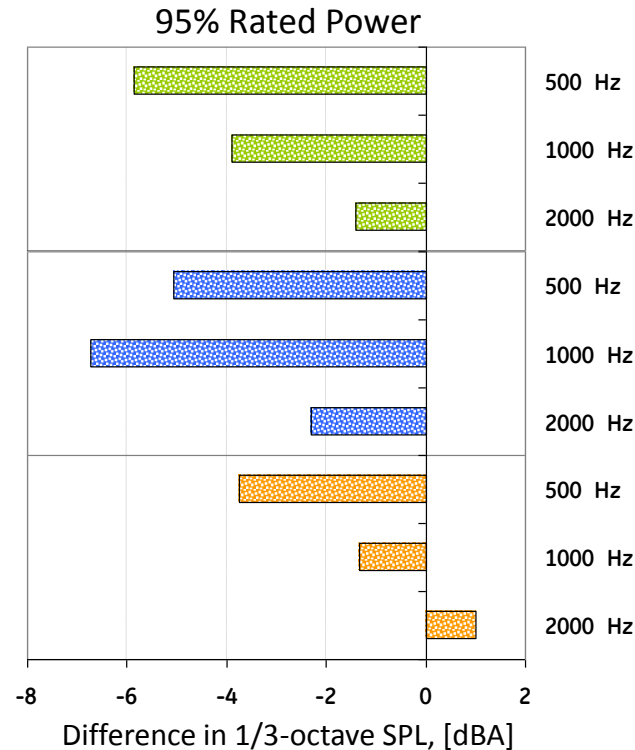
# Serration field test results

Third-octave band levels referenced to un-serrated blades

**1.5 MW  
with 77m rotor  
diameter**

**2.5 MW  
with 110m  
rotor diameter**

**2.75 MW  
with 103m  
rotor diameter**



- Clear noise benefits in frequency range 0.5–1 kHz
- Overall, Lwa's decreased by 2–4 dBA with serrations



# Farm level Sound Source Mitigation & Operation

# Farm interactions

... key in developing wind energy!

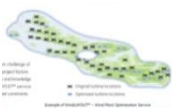
## Turbine centric view

Design



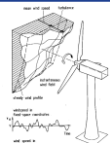
Design as  
*standalone unit*

Micrositing



Optimize layout for  
max AEP/min COE

Loads



Turbine Suitability  
Analysis, Mechanical  
Loads analysis

Operation



Operate as  
independent units  
in wind farm

Services

99%

Focus on  
availability

Noise



Microphone at IEC  
location

Adv. prediction  
capabilities

Learning from  
data

New technology  
developments

## Farm level approach



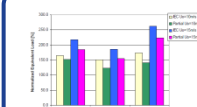
Design for op. in  
*wind farm*

-DM\$  
+AEP  
-Risk



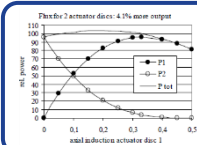
Very large farms  
Terrain interaction  
Farm interactions

+AEP  
-Risk



Remove excess  
margins

-DM\$  
+AEP  
-Risk



Cooperative  
operation, park  
level control

+AEP  
-Risk

MWhrs

Focus on energy  
capture

+AEP  
-Risk



Homes near the  
wind farm

+AEP  
-Risk

# Summary

# Summary

Noise control technologies allow to run high tip speeds with low noise – customer value

Flexible turbine operation & Sound Power Management enable customized solutions

Low Noise technologies, smart wind turbine control and wind farm control support meeting noise regulations at low cost of energy

GE will continue to invest into technology for better solutions





Thank you for your attention  
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