Noise considerations in wind turbine design

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Agenda

- Introduction
- Wind turbine design driving factors
- Design choices and sound power level
- Mitigation solutions

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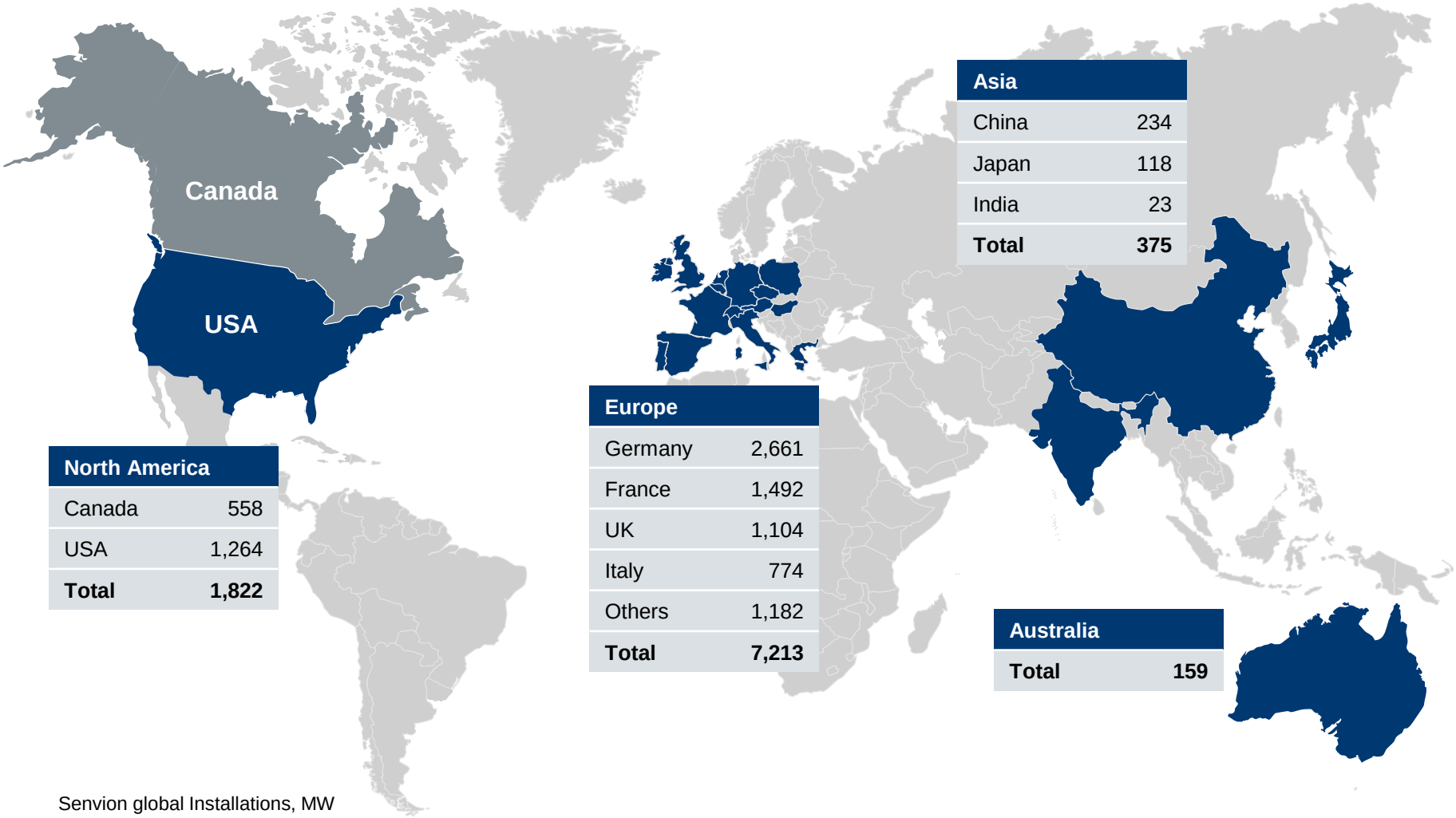
Senvion – Product portfolio

	Turbine Type	Rated power (MW)	Prototype installation
Offshore	6.2M126 6.2M152	6.15	2009/2014
Onshore turbines	3.4M104	3.40	2008
	3.2M114	3.20	2011
	3.0M122	3.00	2013
	MM92	2.05	2005
	MM82	2.05	2003
	MM100	1.80	2011
Sold in license	MM70	2.0	2002
	MD70	1.50	2001
	MD77	1.50	2001

Senvion – around 9.5 GW installed across the world...



North America	
Canada	558
USA	1,264
Total	**1,822**

Europe	
Germany	2,661
France	1,492
UK	1,104
Italy	774
Others	1,182
Total	**7,213**

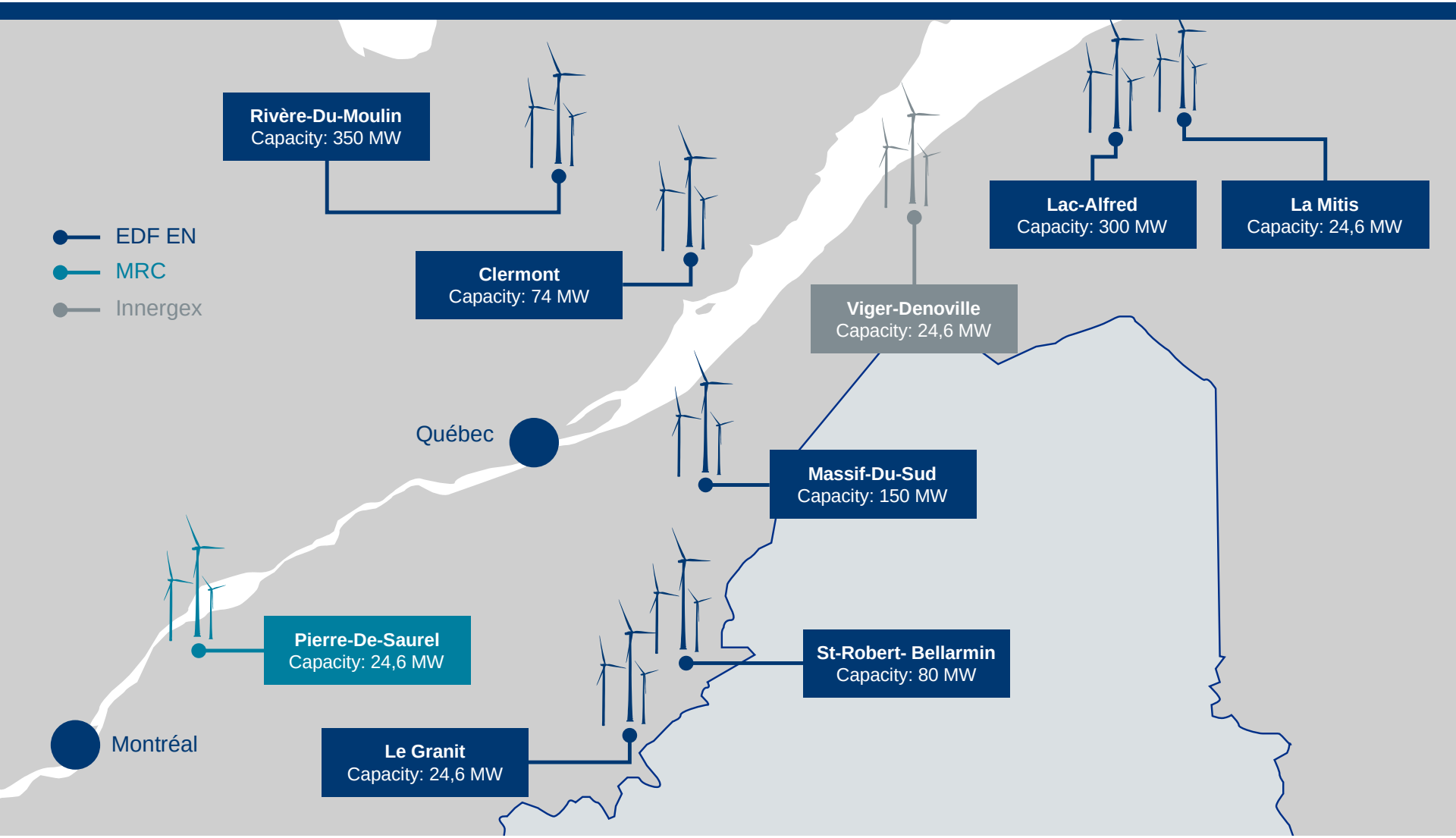
Asia	
China	234
Japan	118
India	23
Total	**375**

Australia	
Total	**159**

Senvion global Installations, MW

Source: Senvion · January 2014 · Includes all installed and SCADA connected systems · Senvion installations from 1987 onwards

Senvion in Québec – 1 GW



Senvion – More than 5 years of experience in Canada

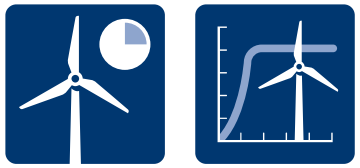
- Senvion Canada Inc. has been incorporated in Montreal, QC in 2007 as REpower Systems Inc. Today we supply projects across Canada and have own production capacities

- The first commercial projects started construction in 2011. Today, four commercial wind farms with an installed capacity of more than 550 MW are connected to the grid in Québec

Senvion – Value Proposition

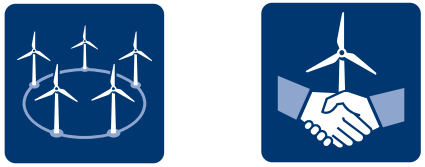
Most efficient transformation of wind power into electrical energy…over entire life-time of wind energy plants… with seamless integration

Efficient and reliable WEC design



Flexible WEC portfolio for optimal adaption to wind conditions

Support for optimal wind farm layout



Sophisticated operation and monitoring system

Service-friendly WEC design and flexible maintenance contracts

Flexible options to fulfill country-specific requirements (grid, climatic and environmental)

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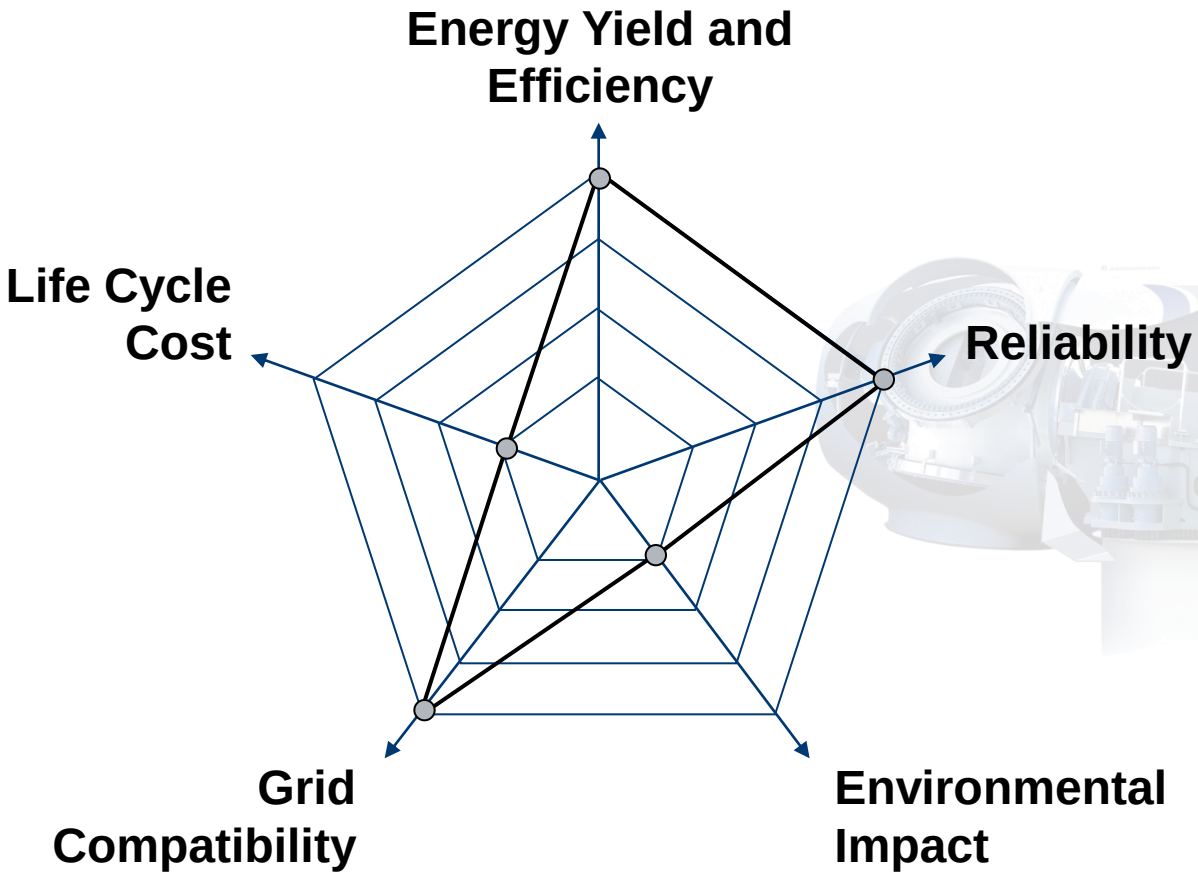
Wind turbine design driving factors



Technical evolutions to increase WEC efficiency

- Main trends on the wind turbine market:
  - Increase rotor diameters
  - Increase hub heights

- How can it be combined with low sound power levels?

Wind turbine: blades in the main source of noise

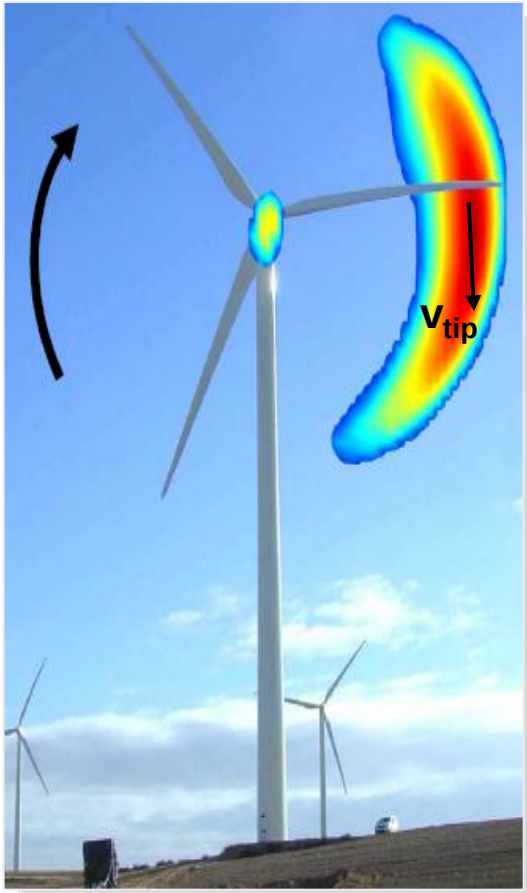
- The **Sound Power Level caused by the blades** is the most important factor, when evaluating the Sound Power Level of a wind turbine

- To reduce the Sound Power Level of a wind turbine it is important to **limit the blade tip speed** (depending on Rotor Diameter d and Rotor Speed ω)

$$v_{tip} = (\pi \times d) \times 60\ \omega$$

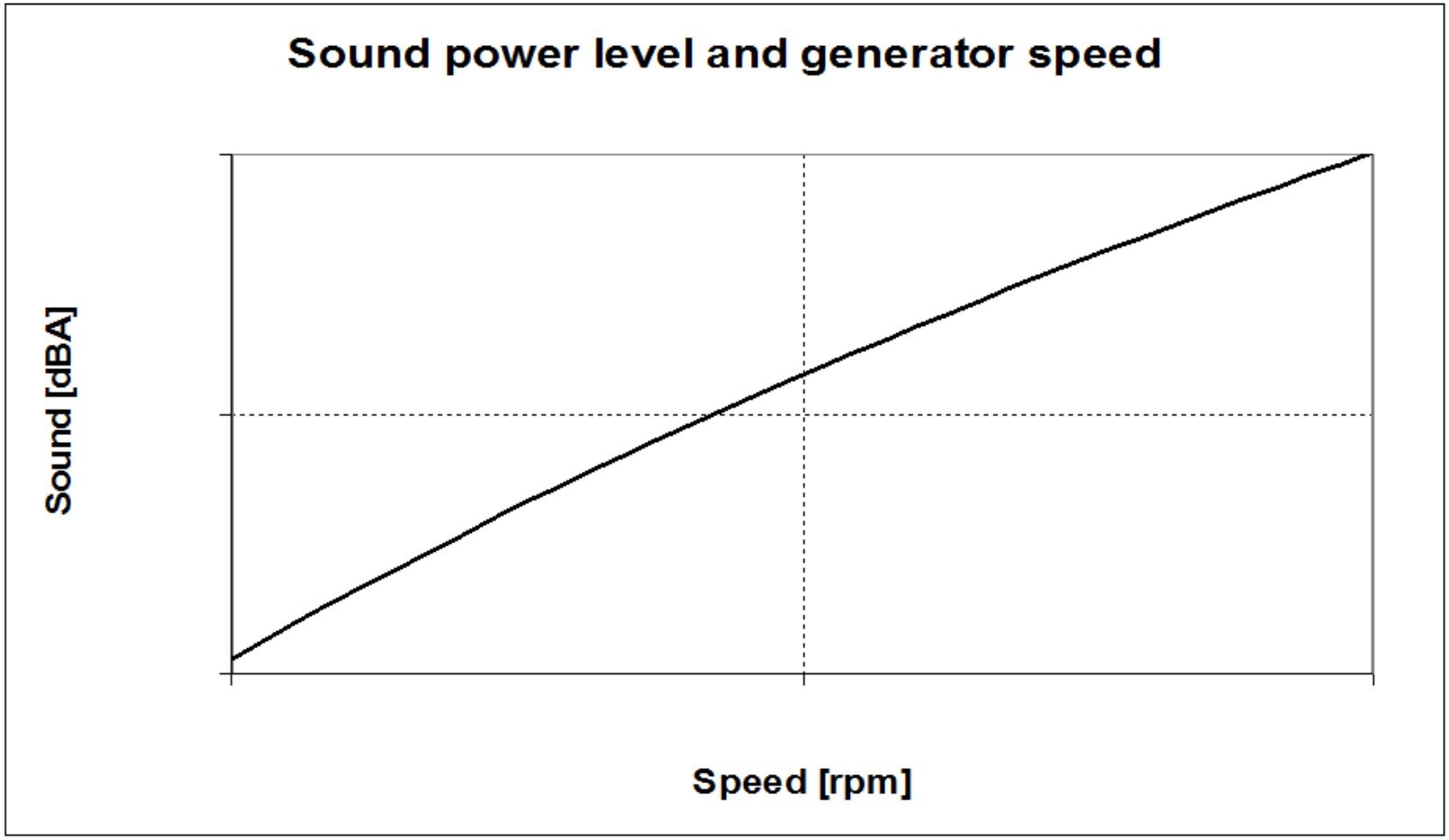
- Close to residential areas, it can be necessary to operate WEC in a **sound reduced manner** at certain times of the day or in specific wind conditions

- If regulation of the sound emissions is required, sound mitigation solutions exist: **Sound Management** can be used to control the WEC



Source: Predictiction of Wind Turbine Noise and Comparison to Experiment (Oerlemans/Schepers 2007)

Sound power level is directly linked to rotational speed



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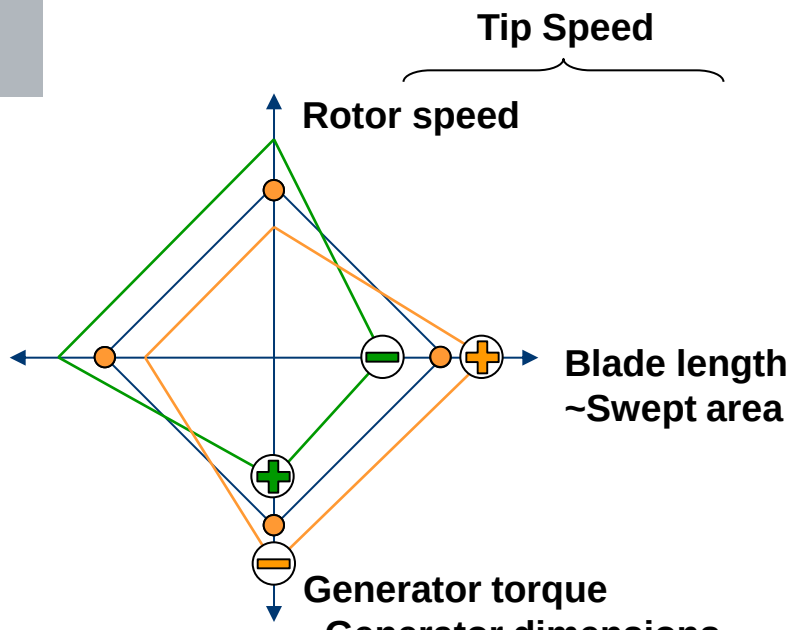
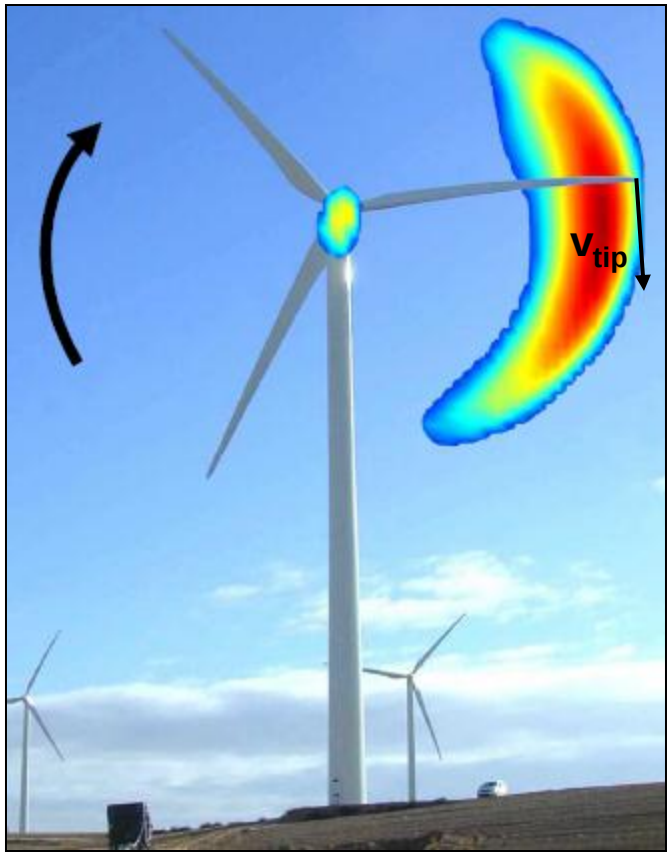
Sound power level & design choice: direct drive

Direct drive concepts: difficulty to combine wide swept area, cost-efficient electrical system and low sound power level

Direct Drive



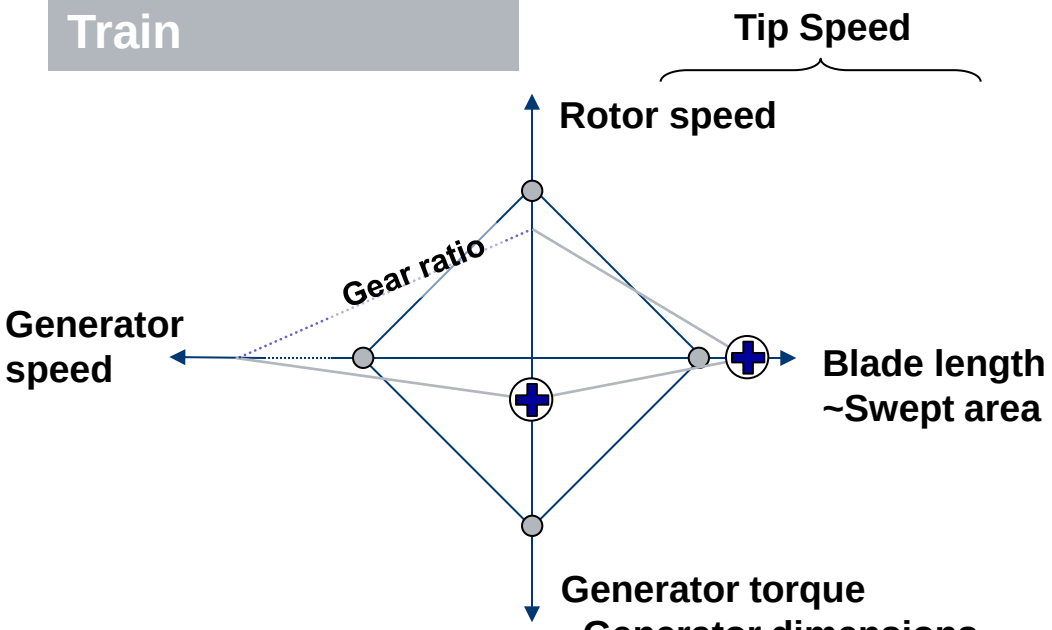


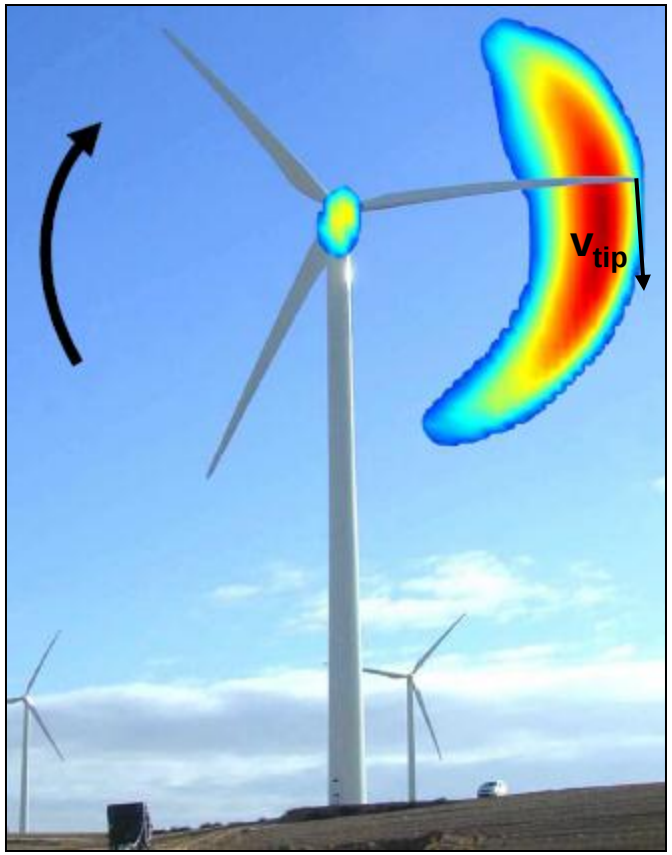
Source: Predictiction of Wind Turbine Noise and Comparison to Experiment (Oerlemans/Schepers 2007)

Sound power level & design choice: gear-based concept

Gearbox shields generator: Small generator size due to low generator torque

Gear-based Drive Train





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Mitigation solutions to limit sound emissions

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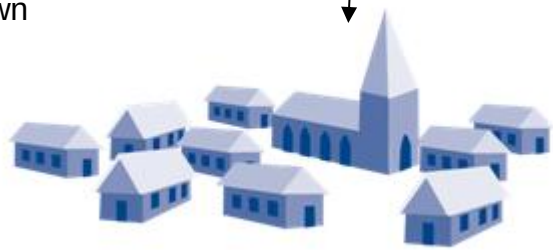
Restricted Noise Rating Level **L_r** [dB(A)]

Sound Power Level L_{SP} [dB(A)]

The Sound Power of the distant wind turbine leads to a certain **Noise Rating Level** in this town

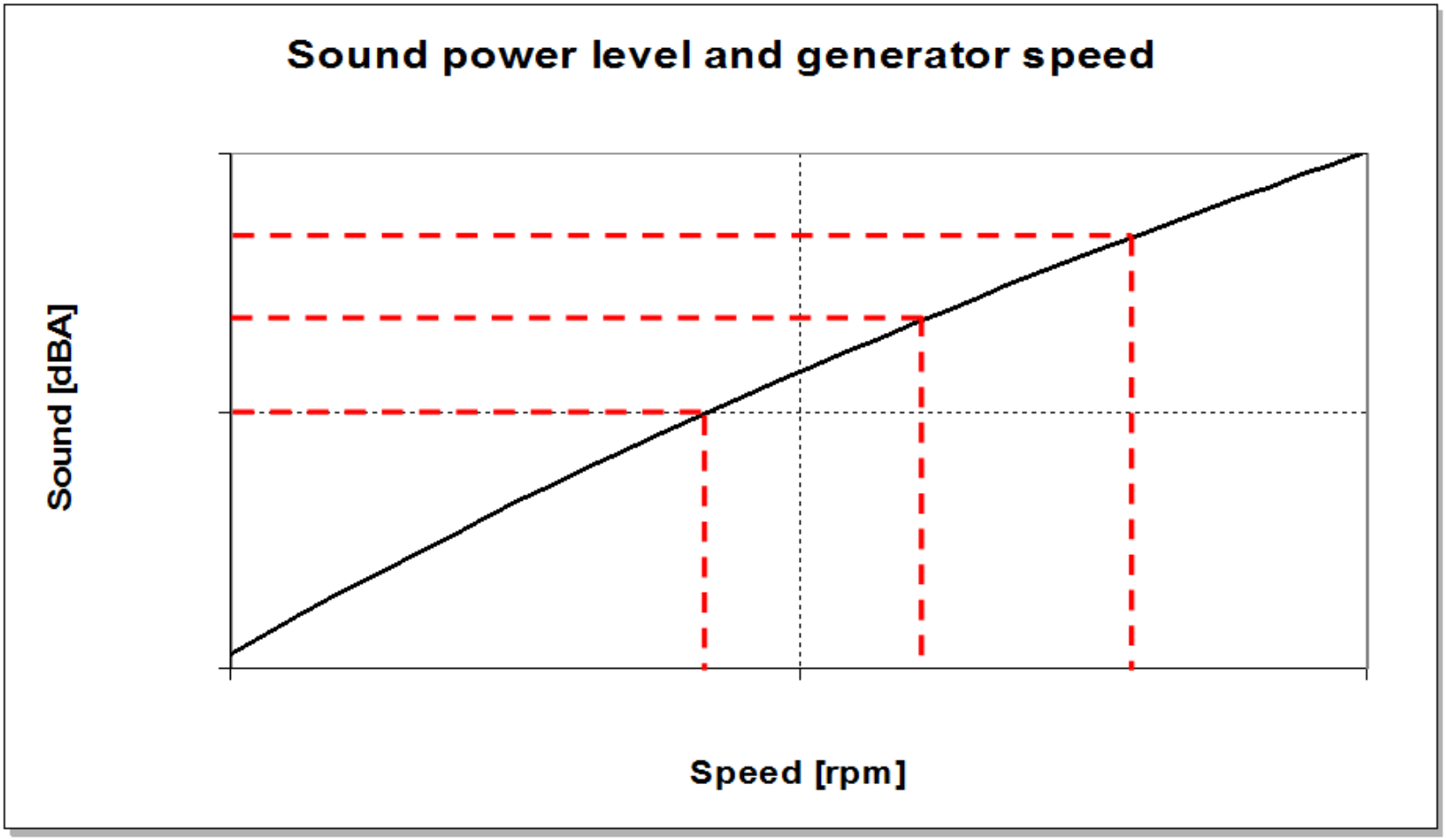


To limit the acoustic impact on residential areas the Noise Rating Level is regulated by law (resp. building permits)

→Limitation of **maximum** sound pressure level:
Senvion solution: **Sound Management I**

→Limitation of sound pressure level **depending on background noise**:
Senvion solution: **Sound Management II**

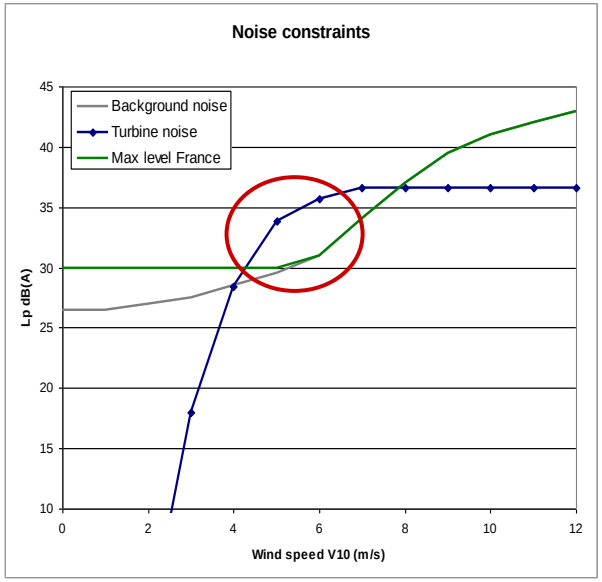
Sound Management I: technical concept



Reduction of sound power level (SPL) is achieved by reducing generator speed.

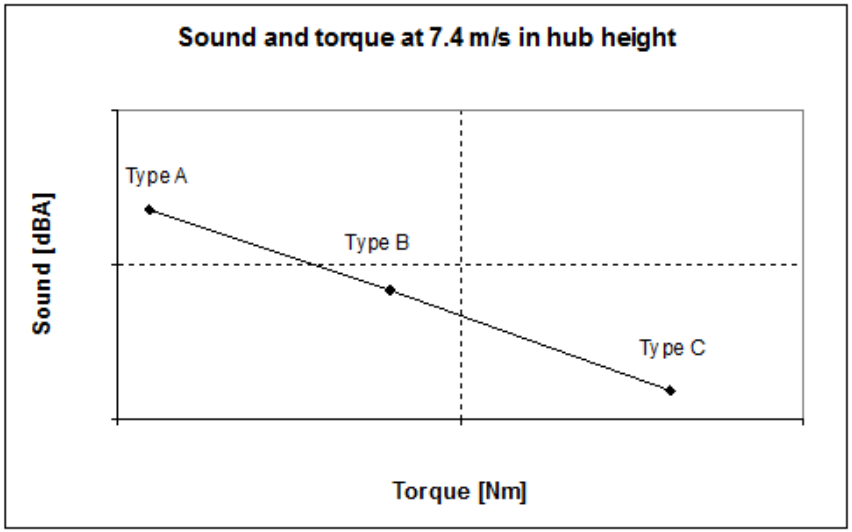
Sound Management II: context

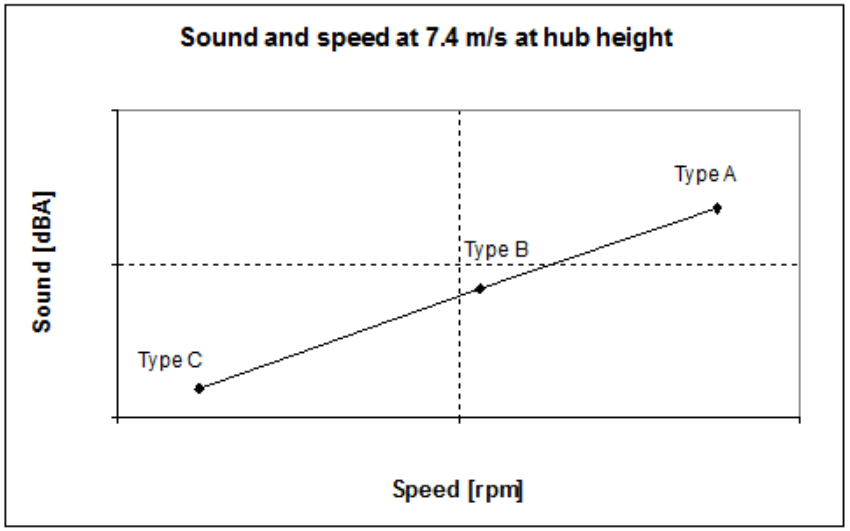
- For countries with a law defining a maximum noise above background noise caused by WEC (e.g.: maximum of 3 dB above background noise at night)
- Reduction of sound power level depending on the background noise.
- Background noise is low at low & medium wind speeds.
- Therefore reduction of sound power level in low and medium wind speeds.



Sound Management II: technical concept

Reducing sound by reduction of speed and increasing torque





Thank you for your attention

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