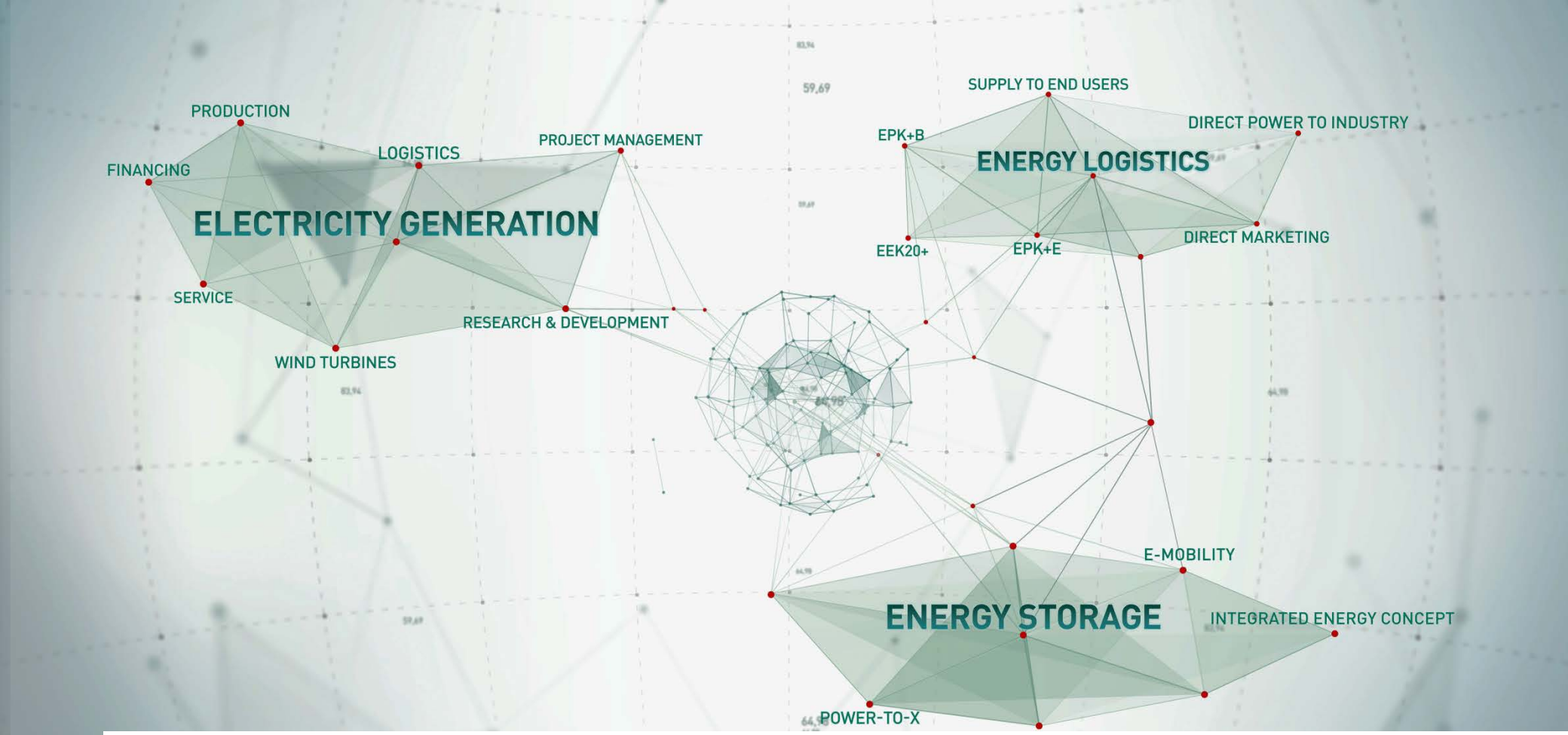


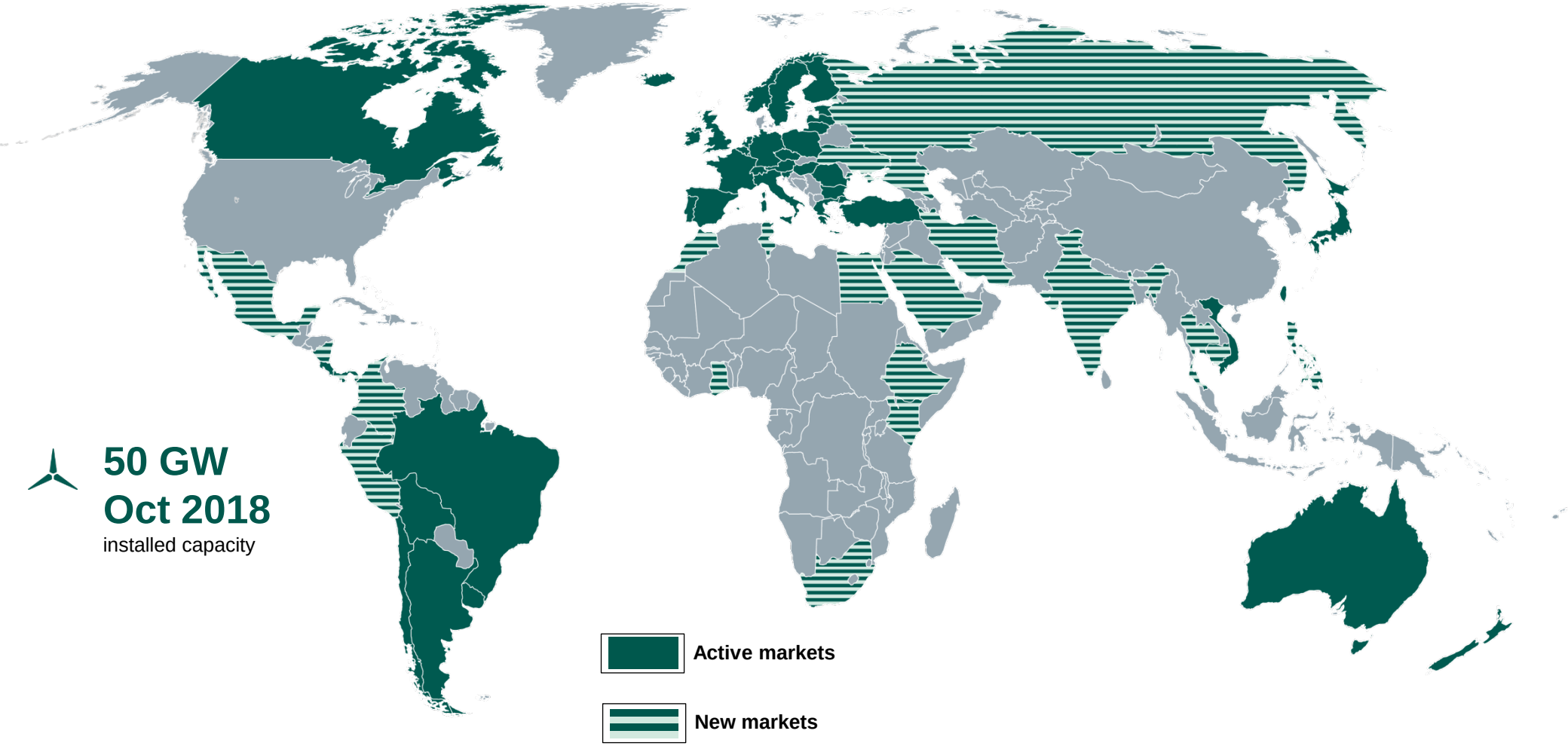
Strategies for minimizing and assessing icing losses

Winterwind Umeå, February 6th, 2019

Julian Schödler

ENERCON
ENERGY FOR THE WORLD

ACTIVE & NEW MARKETS

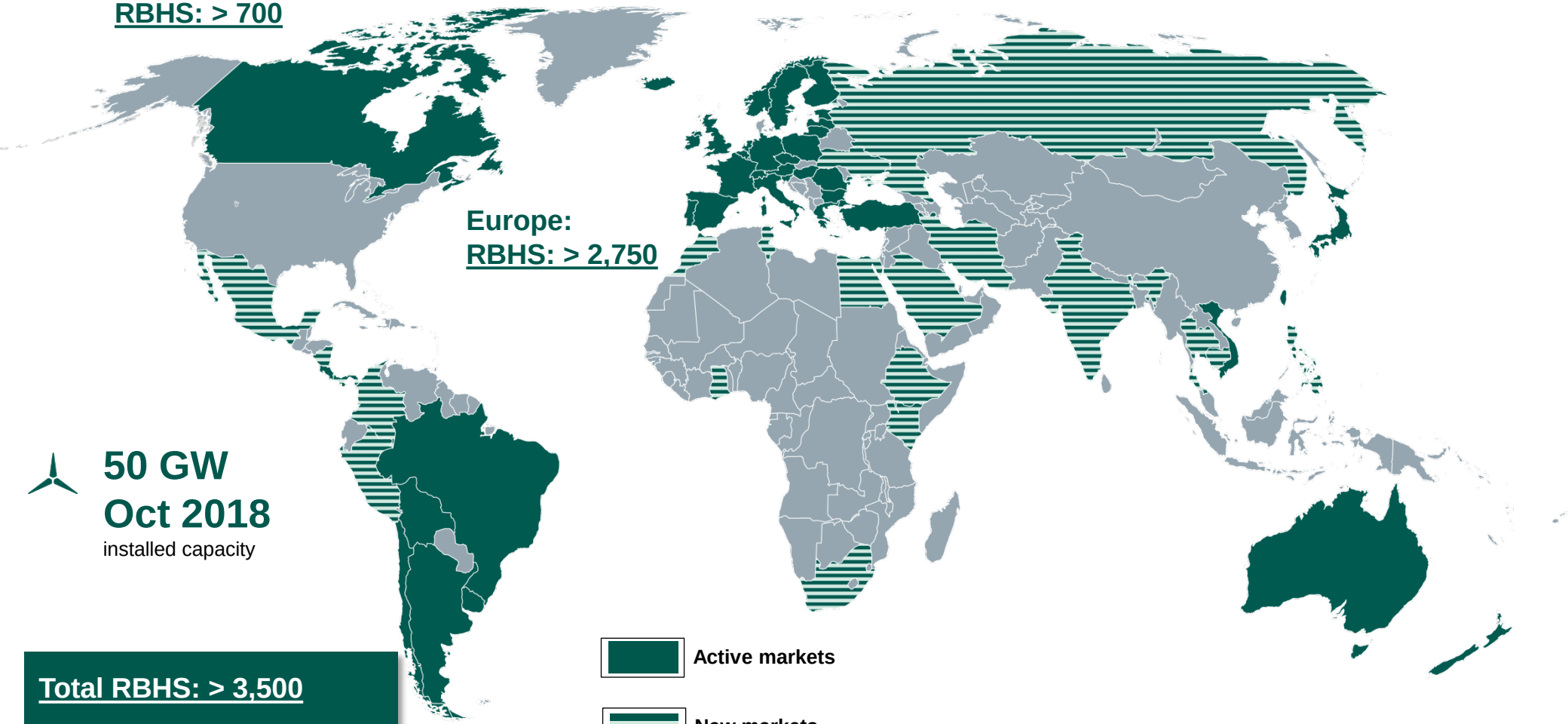


50 GW
Oct 2018
installed capacity

ACTIVE & NEW MARKETS

Canada:
RBHS: > 700

Europe:
RBHS: > 2,750



50 GW
Oct 2018
installed capacity

Total RBHS: > 3,500

in more than 20 countries

Active markets

New markets

AGENDA

1. Minimizing icing losses

1.1 Rotor blade heating system

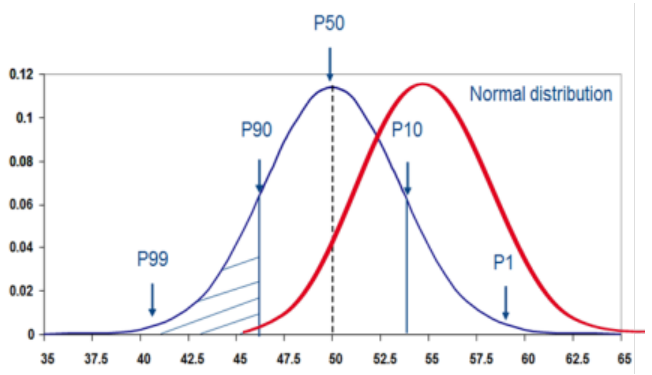
1.2 Ice detection systems

1.3 Cold climate package

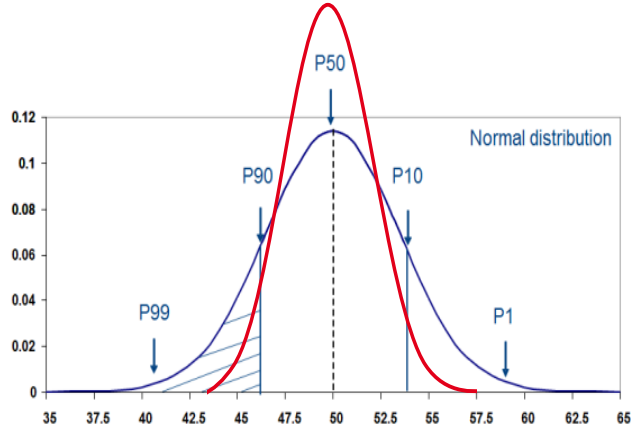
2. Site assessment

2.1 Site specific icing losses

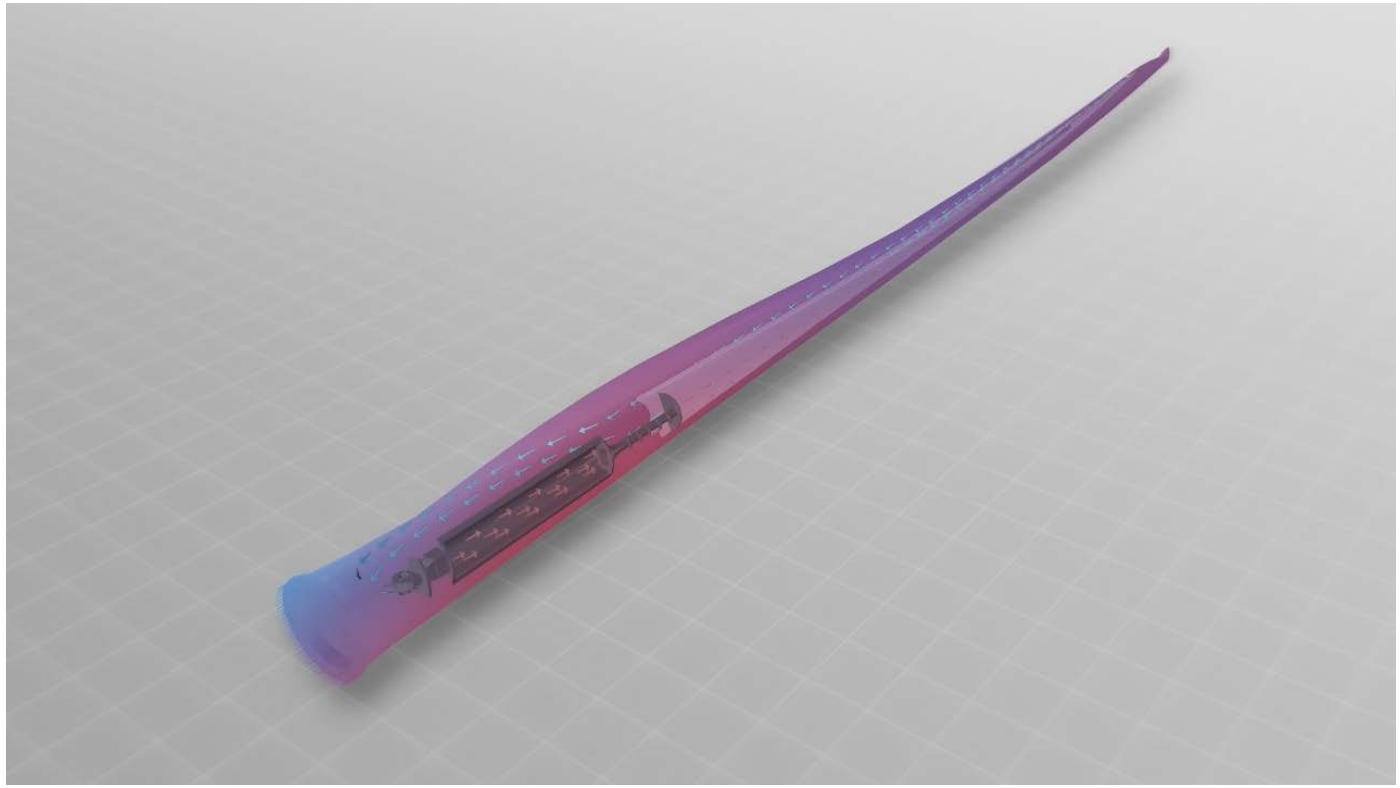
AEP increase



Uncertainty decrease



ROTOR BLADE HEATING SYSTEM



Principle
A fan heater installed on the blade root heats up the air in the rotor blade using the recirculating air method.

MINIMIZING ICING LOSSES

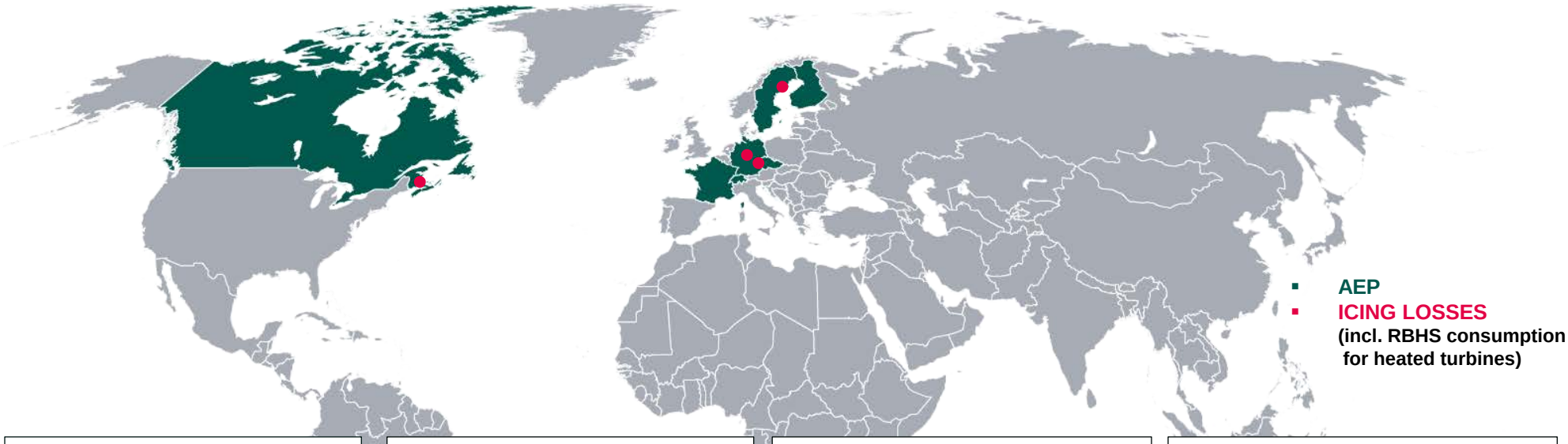
ROTOR BLADE HEATING SYSTEM

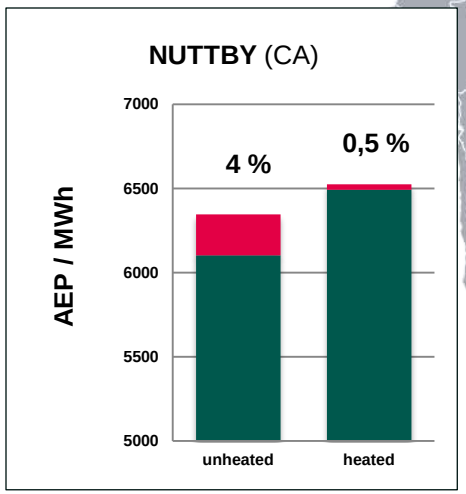
Properties

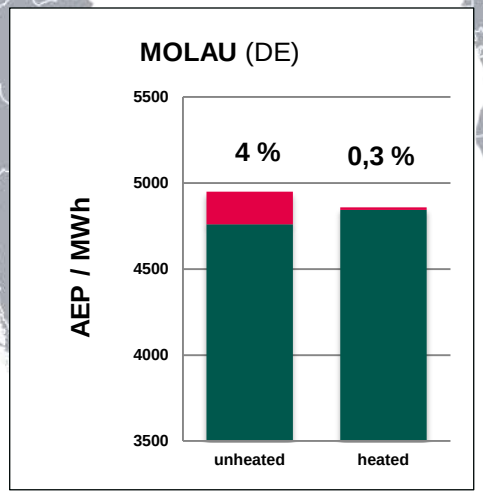
- Significant yield increase at Cold Climate sites
- Easy, low-cost maintenance
- No increased risk of lightning strikes
- Energy consumption between 46 kW and 225 kW (E-44 to E-141 EP4)
- Over 20 years' experience (first prototype in 1996)
- Validated by external consultants (Deutsche Wind Guard and Meteotest)

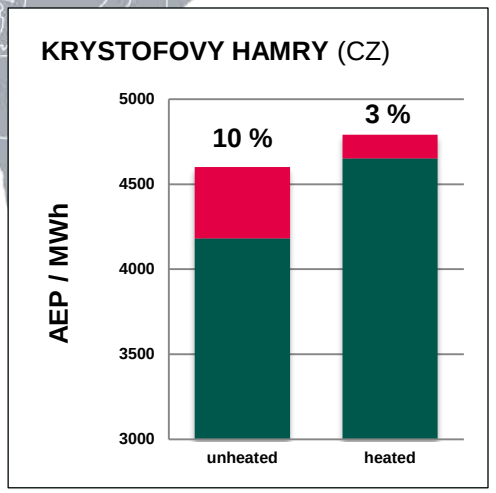
MINIMIZING ICING LOSSES

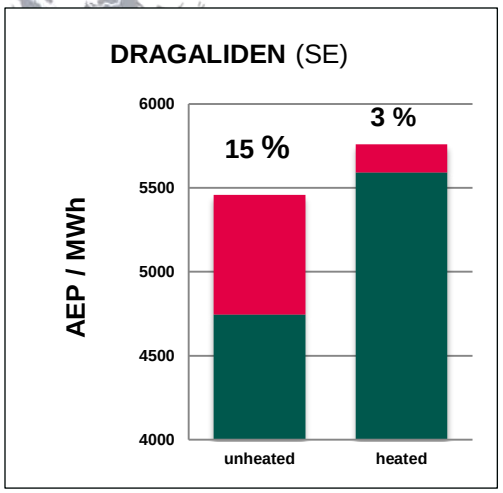
ROTOR BLADE HEATING SYSTEM









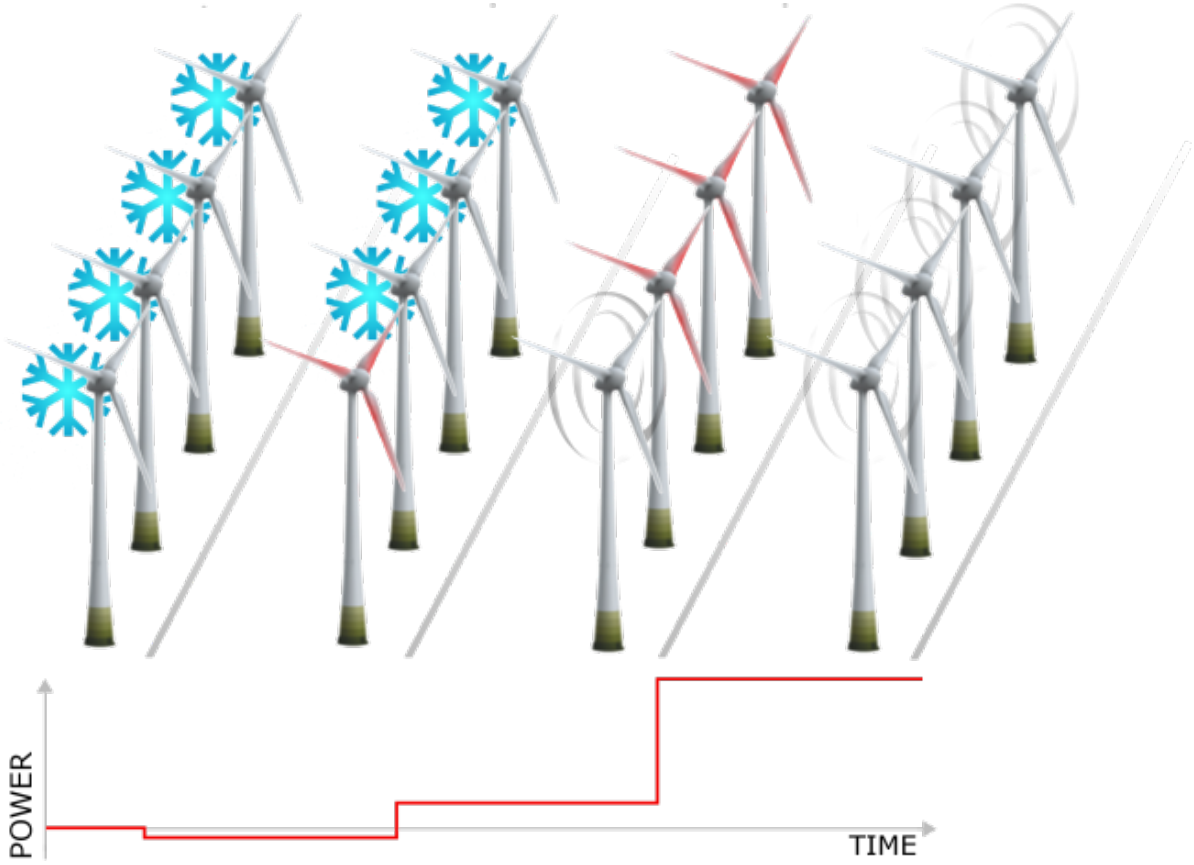


ROTOR BLADE HEATING SYSTEM

ENERCON POWER CONSUMPTION MANAGEMENT SYSTEM

Limit power consumption from grid

- Predefine maximum power
- Sequential heating
- Avoid grid penalties
- Grid stability



ICE DETECTION SYSTEMS

DETECTING ICING USING CHARACTERISTIC CURVES

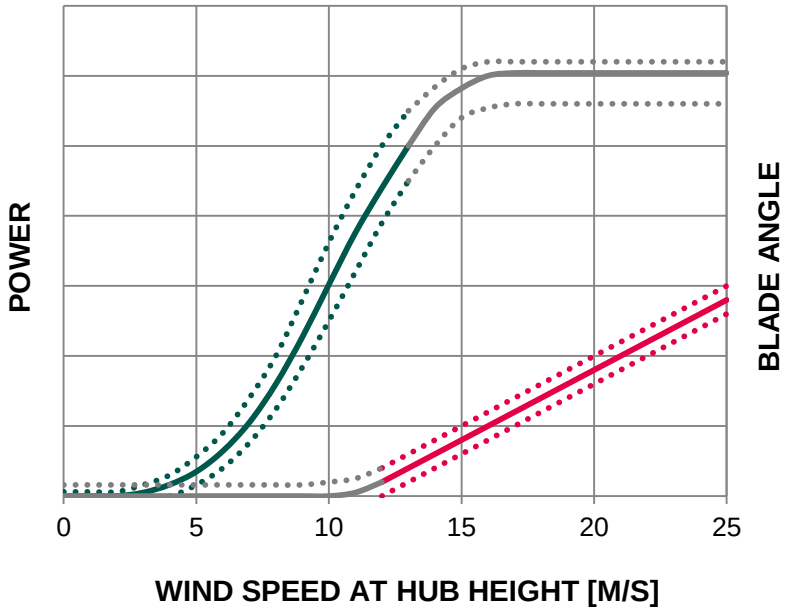
For detecting ice on ENERCON turbines, deviations from characteristic curves are monitored for temperatures below 2°C.

GREEN GRAPH – POWER CURVE METHOD

Deviations from the power curve compared to the current wind speed are detected and registered as ice on the rotor blades.

MAGENTA GRAPH – BLADE ANGLE METHOD

Deviations from the blade angle curve compared to the current wind speed are detected and registered as ice on the rotor blades.



Standard for all ENERCON WECs

European patent specification
EP 1 642 026 B1
© 2004 - 2024

ICE DETECTION SYSTEMS

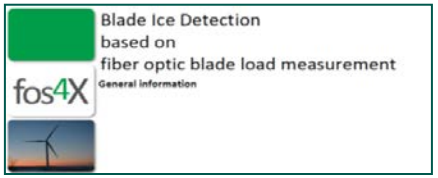
LABKOTEC
ULTRASONIC
MEASUREMENT

- Experience since 2006
- Measuring on hub height
- Increases working range
- Measures meteorological icing
- No control about the RBHS
- Increased functional safety

EOLOGIX
IMPEDANCE
MEASUREMENT

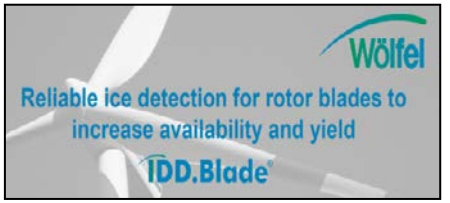
- Bonding of tags on blade
- Impedance measurement with a planar capacitor
- Self support by solar panel
- Two configurations under development:
  1) Ice detection during operation
  2) Automatic restart

FOS4X
EIGENFREQUENCY
MEASUREMENT



- Measurement with acceleration sensor in the blade
- Transmission via fiber-optic cables
- *Warnings* and *Alarms* with site specific ice mass thresholds optimize the turbine operation under icing conditions

WÖLFEL
EIGENFREQUENCY
MEASUREMENT

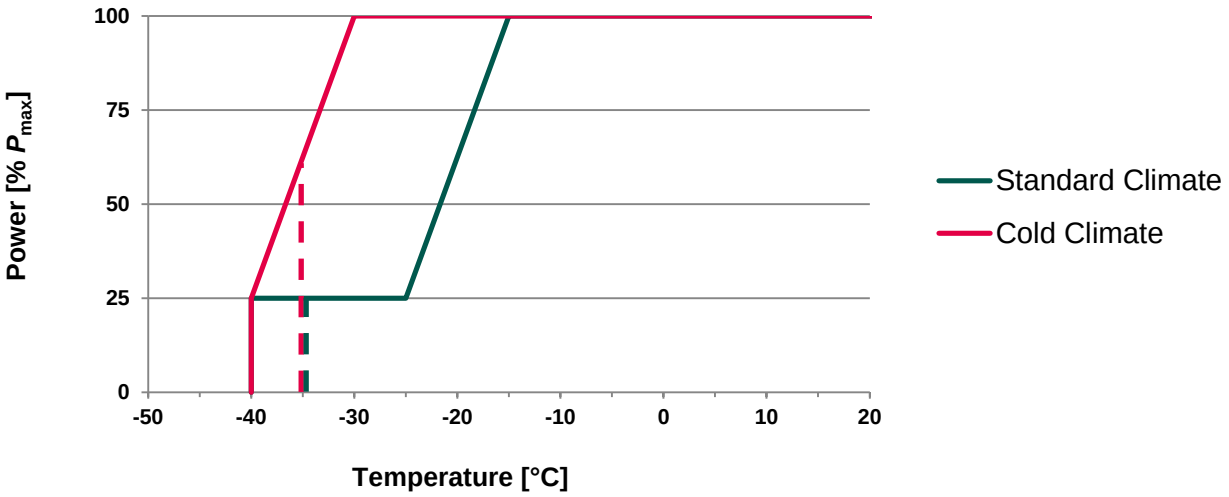


- Installation of a structural noise sensor in the blade
- Transmission via screened electric cables
- *Warnings* and *Alarms* with site specific ice mass thresholds optimize the turbine operation under icing conditions

- Proved by external consultant
- Measuring on blades
- Possibility of RBHS control & turbine restart
- Aim: Minimize losses and/or safety increase

COLD CLIMATE PACKAGE

- For low temperature climates
- ENERCON turbines are able to produce energy down to temperatures of -40°C
- Turbines in **“Standard Climate”** version have a decreased maximum power *P* for temperatures below -15°C.
- With **“Cold Climate”** adjustments the rated power P_{max} can be reached until -30°C.



COLD CLIMATE SITE

Site with more than nine days per year with temperatures below -20°C for at least one hour

or

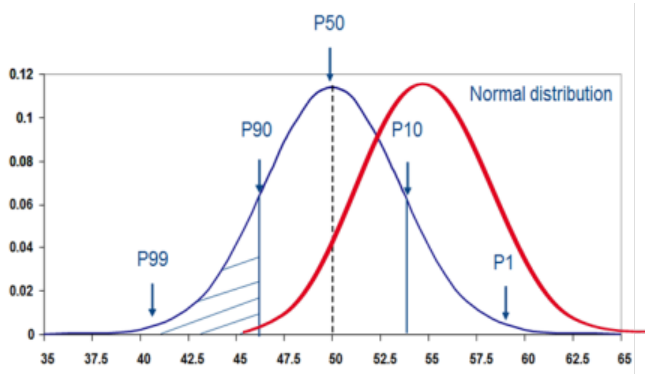
yearly average temperature below 0°C.

AGENDA

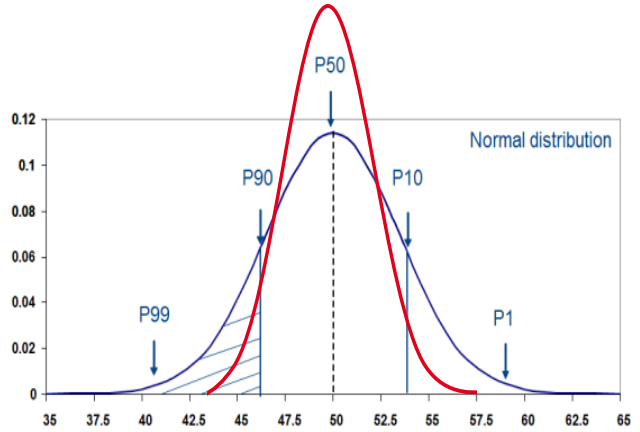
1. **Minimizing icing losses**
   - 1.1 Rotor blade heating system
   - 1.2 Ice detection systems
   - 1.3 Cold climate package

2. **Site assessment**
   - 2.1 Site specific icing losses

AEP increase



Uncertainty decrease



AEP [a.u.]

SITE SPECIFIC ICING LOSSES

- Why is the assessment of icing losses important?
  - Better financing conditions
  - Helps to estimate the gain of a de-icing system
- 3 Scenarios
  1. ENERCON turbines available
     → use turbine data to calculate losses
  2. Wind measurement campaign done
     → use measurement data
  3. No on-site data available
     → reanalysis data from nearby node

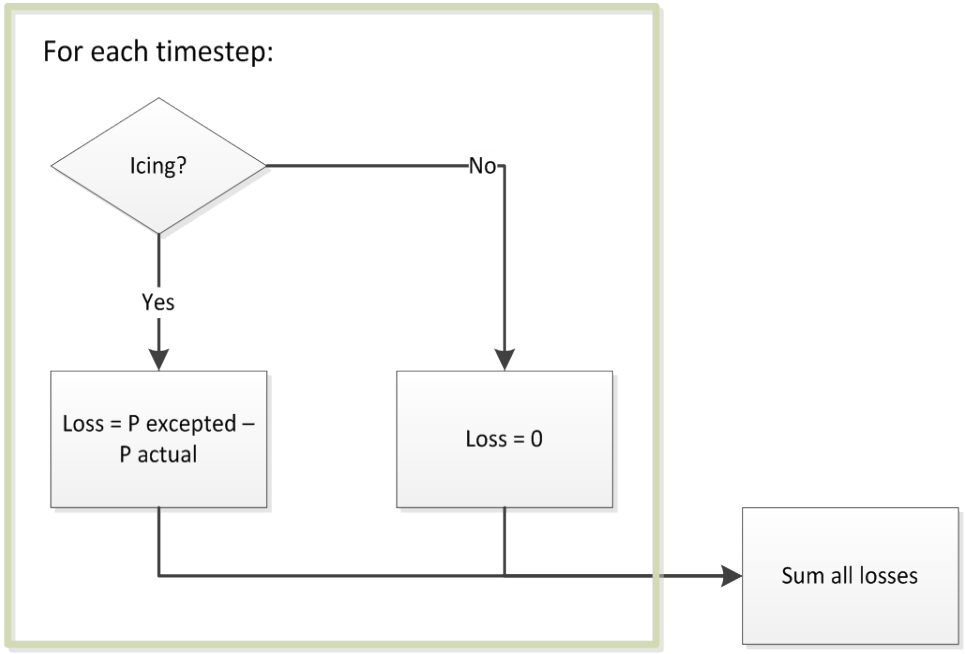
IEA ICE CLASS (no.)	**MET. ICING** (% of year)	**INSTR. ICING** (% of year)	**PRODUCTION LOSS (WITHOUT RBHS)** (% of AEP)	**PRODUCTION LOSS (WITH RBHS, CONSUMPTION INCL.)** (% of AEP)	**VALIDATION** (Site)
5	> 10	> 20	> 20	> 4	-
4	5 - 10	10 - 30	10 - 25	1.5 - 5	Krystofovy Hamry (CZ)* Dragaliden (SE)* Gabrielsberget (SE)
3	3 - 5	6 - 15	3 - 12	0.5 - 3	St. Brais (CH) Nuttby (CA)
2	0,5 - 3	1 - 9	0.5 - 5	0 - 1.5	Molau (DE)*
1	0 - 0.5	< 1.5	0 - 0.5	< 0.5	-

*** Proved by Meteotest, external consultant from Switzerland**

First four columns taken from: IEA Wind Task 19 [2016]: Available Technologie of Wind Energy in Cold Climates

SITE SPECIFIC ICING LOSSES

1. ICING LOSSES FROM TURBINE DATA



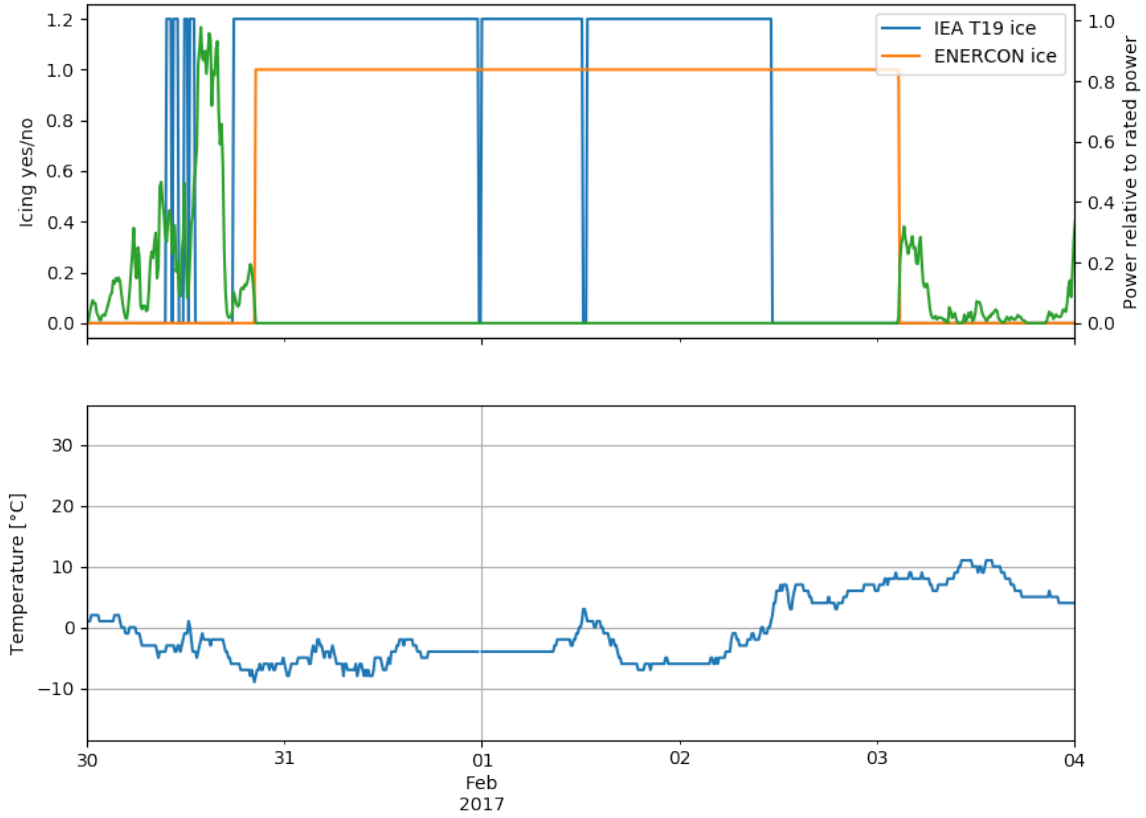
How to derive an icing time series from turbine data?

- **From turbine control system**
- Turbine generates continuous status and information messages, e.g. for
  - Normal operation, storm or lack of wind
  - Maintenence
  - Ice detection & blade heating
  - Noise & shadow curtailment
  - Major failures

SITE SPECIFIC ICING LOSSES

ICING LOSSES FROM TURBINE DATA – Comparison to IEA T19IceLossMethod

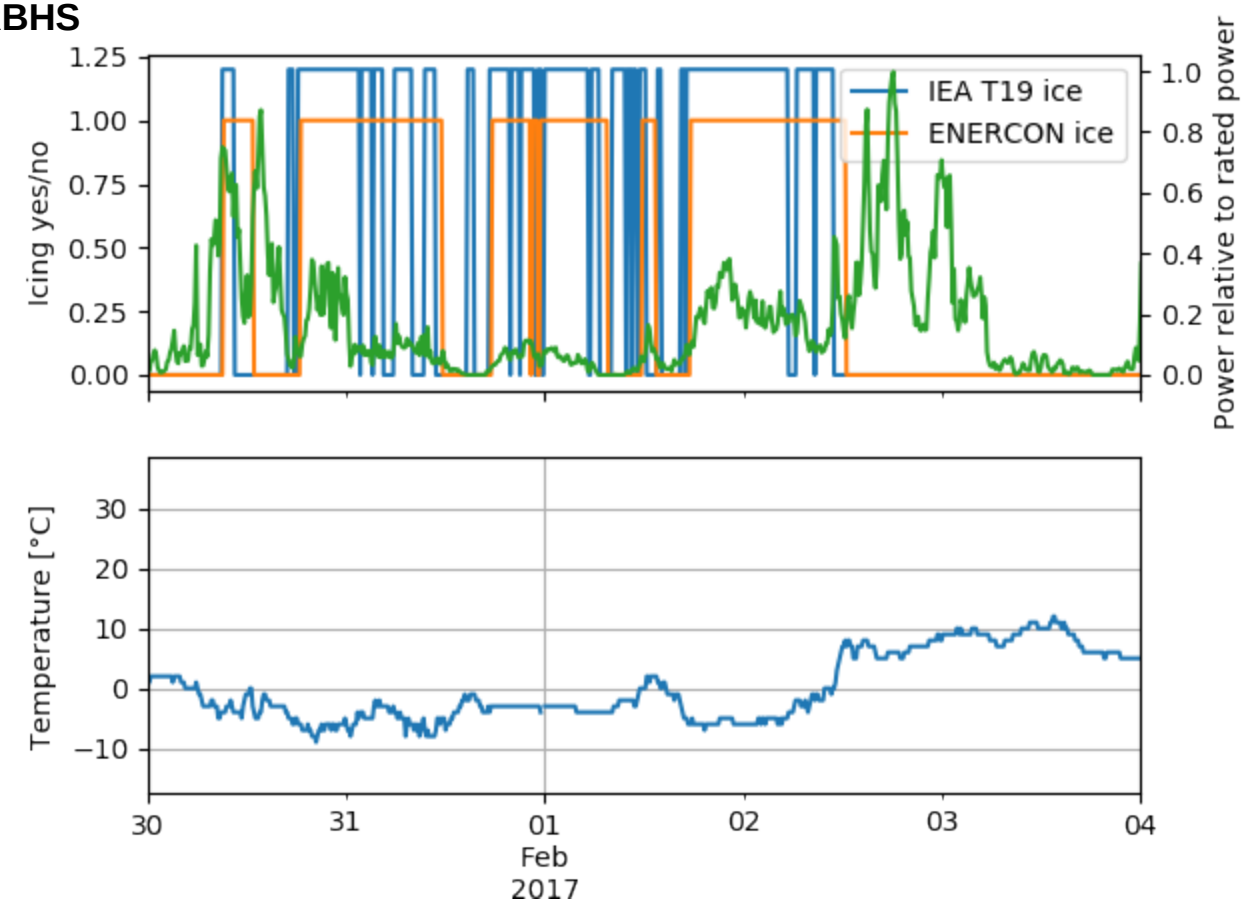
Turbine without RBHS



SITE SPECIFIC ICING LOSSES

ICING LOSSES FROM TURBINE DATA – Comparison to IEA T19IceLossMethod

Turbine with RBHS



LESSONS LEARNED

- Rotor blade heating system
  - Over 20 years experience, > 3.500 systems installed
  - Significant decrease of icing losses
  - Externally validated
- Proven ENERCON ice detection system using operating characteristics
- External ice detection systems integrated – externally validated
- Cold climate package – increase power output between -15 °C and -40 °C
- In-house loss estimation tool developed
  - Comparable to IEA T19 Ice Loss Tool
  - Optimized for ENERCON turbines

THANK YOU FOR YOUR ATTENTION!

ENERCON
ENERGY FOR THE WORLD

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IMPRINT

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