Performance assessment of ice protection systems for wind turbines

Winterwind 2015, Piteå

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- Introduction
- Wind turbine ice protection markets
- Approaches to blade ice protection
- Ice protection performance assessment
- Conclusion

VTT Services for stakeholders in the whole wind power value chain

Technology and Innovations

Investment Feasibilty

Construction and Installation

System design and asset planning

Products and solutions for wind power cost parity

Operation and Maintenance

Total level of activity in wind energy R&D at VTT 35-40 person years

VTT in wind turbine ice protection

R&D

Demonstration and upscaling

Commercialisation

1990 - 1997

- Ice accretion TURBICE, coatings
- Basic approach to blade heating system

1996-1997

- 450 kW 1996, 600 kW 1998, 1 MW 1999
- Most units, still in operation

1997 - 2001

- VTT, Kemijoki Oy, Bonus
- Spin-off Kemijoki Arctic Technology Oy (KAT) 1998 - 2001

2001 –

- follow-up campaigns, performance assessment
- wind and ice measurments and sensor development
- Ice risk assessment

2009 - 2014

- Development process
- Upscaling, licensing 90 – 100 - 128 m dia, 2,5 – 3 – 4,5 MW
- Winwind, Nordex, Gamesa and others

2014 -

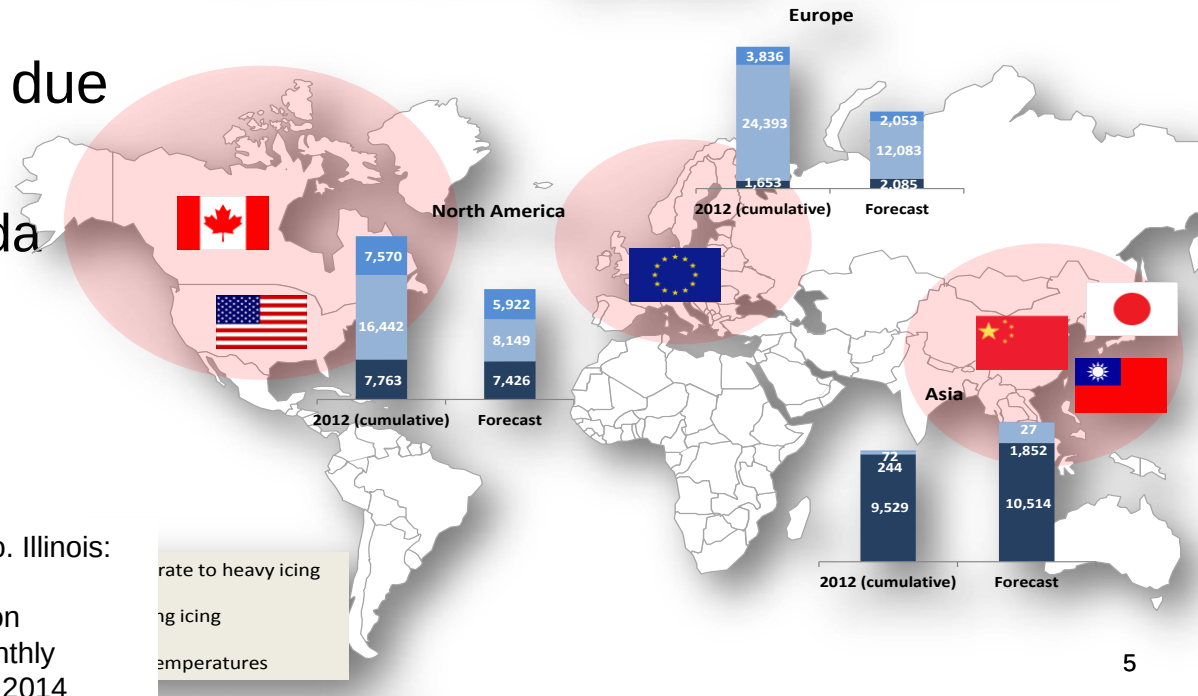
- Spin-off Wicetec Oy
- Commercial collaboration
- Performance assessment
- About 500 MW in operation

Need for ice protection

- Wind turbine investments
  - IEA IceClass 3-5: 8 GW in 2013-17
  - IEA IceClass 1-2: 20 GW
  - in 2013-17 [1]
- Significant financial losses due to icing, in existing fleet
  - estimated value in Canada only is 200 M$/a [2]

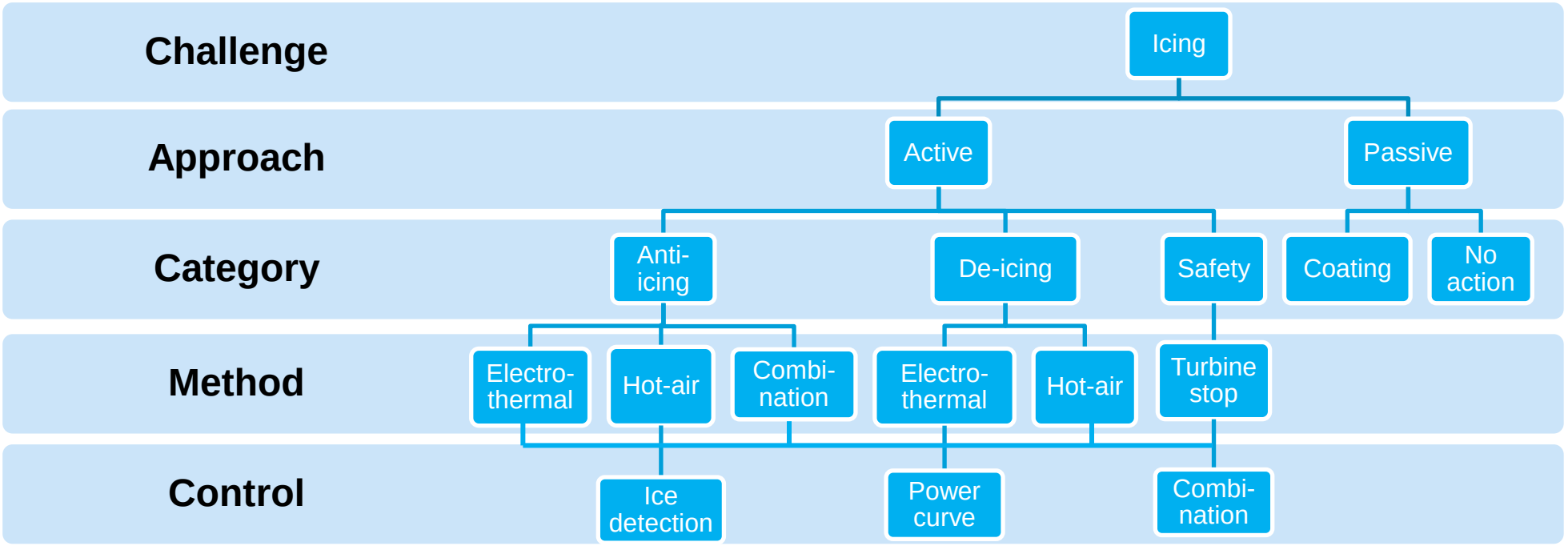
IEA Ice class	Meteorological icing	Instrumental icing	Production loss
	% of year	% of year	% of annual production
5	>10	>20	> 20
4	5-10	10-30	10-25
3	3-5	6-15	3-12
2	0.5-3	1-9	0.5-5
1	0-0.5	<1.5	0 - 0.5

Capacity in CC (up to end 2012) and forecasted (2013-2017) in MW
View of World



[1]: Navigant Research, 2013. World Market Update 2012, Chicago. Illinois: Navigant Research, ISBN: 978-87-994438-4-0
[2]: Wadham-Cagnon et al, 2014. Smartly Investing In Ice Protection Systems To Effectively Reduce Financial Loss. In Wind Power Monthly forum Optimising Wind Farms in Cold Climate, Helsinki Nov 26-27 2014

Different ice protection principles and approaches



Based on Lehtomäki & Peltola: Optimising wind farms in cold climates
Wind Power Monthly Forum on Wind Power In Cold Climates. Helsinki 26-27.11.2014

Ice protection performance assessment relevance

Technology and Innovations

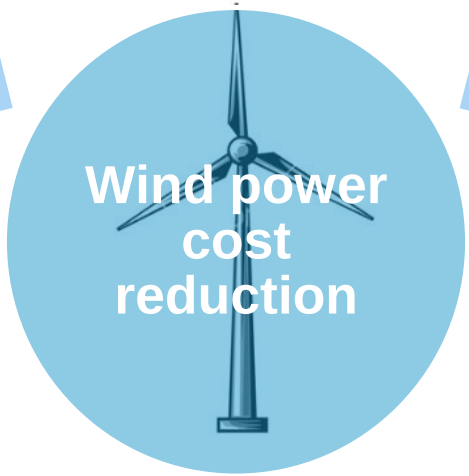
- Ice protection design and optimization
- Power performance curve in icing conditions

Investment Feasibilty

- Business case for ice protection

Construction and Installation

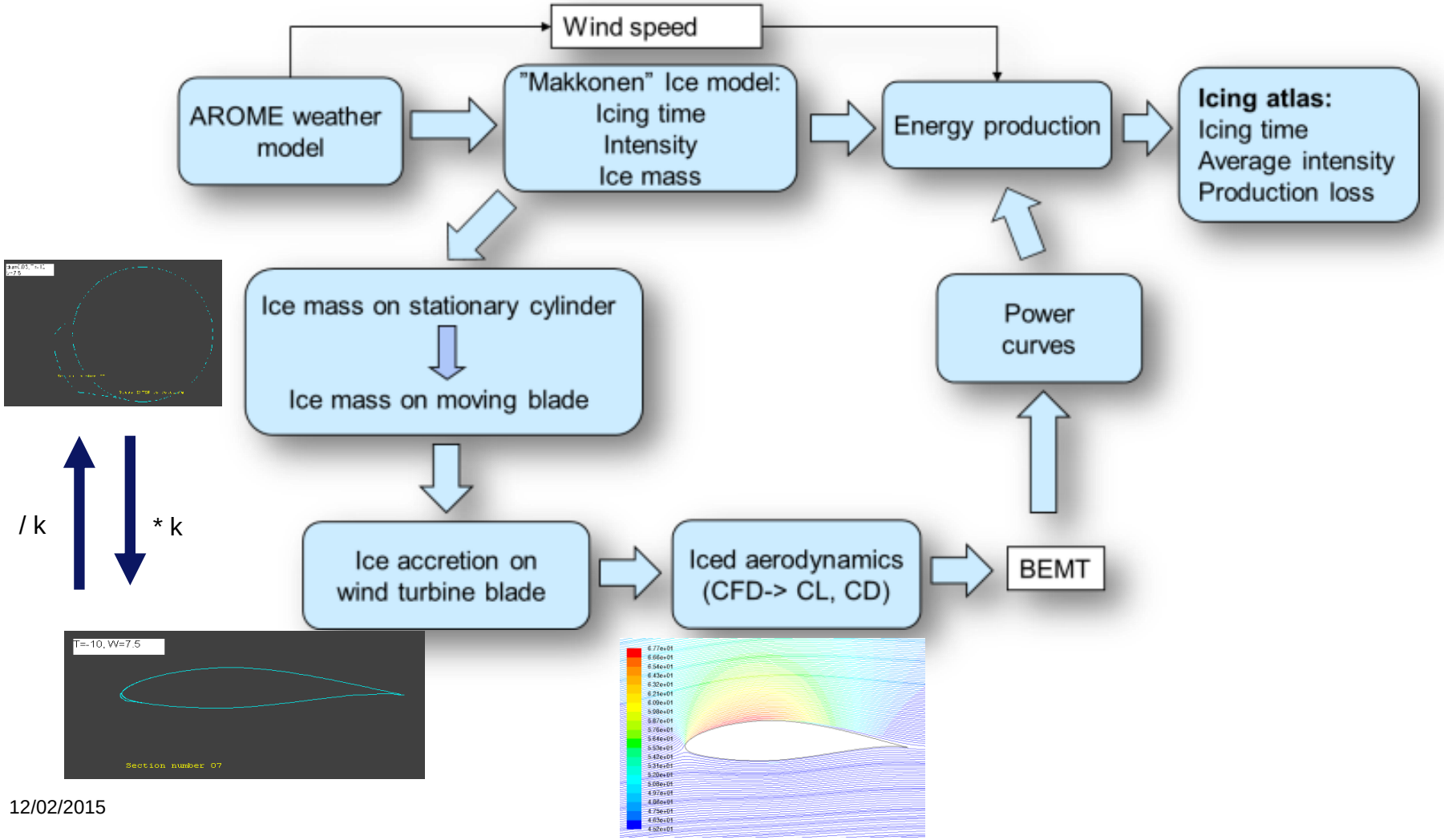
System design and asset Planning



Operation and Maintenance

- Power production forecasting
- Power performance in icing conditions

Production loss assessment
- modeling based, SCADA based



Ice protection of blades

- Maintain wind turbine performance in icing conditions
  - Reduce aerodynamic penalty (loss of AEP)
  - Avoid forced stops (loss of AEP)
  - Avoid adverse turbine loading (loss of lifetime)
  - Reduce risk of ice throw (loss of acceptance)

Business case for ice protection – pre-design

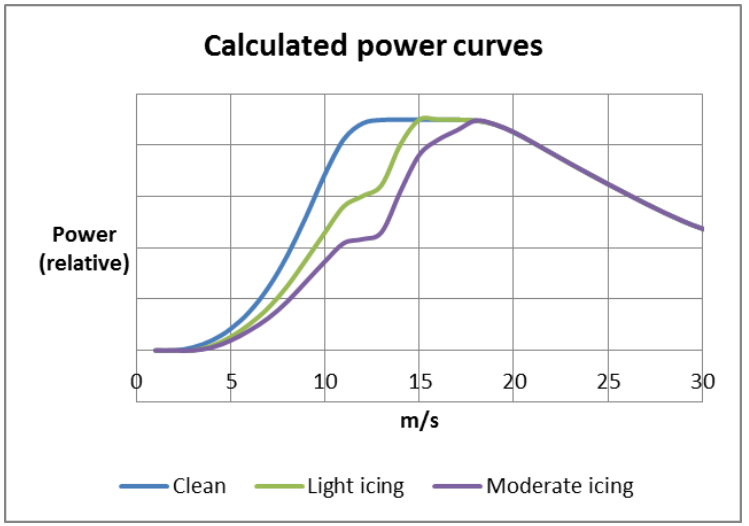
Site and meteorological data
- Wind conditions
- Icing conditions
- Site data

Turbine data
- Turbine power curve
- Turbine operation
- Blade data

Ice prevention design
- Options
- Limitations
- Main design parameters

Options comparison
- Performance recovery
- Own consumption
- Value
- Cost and complexity

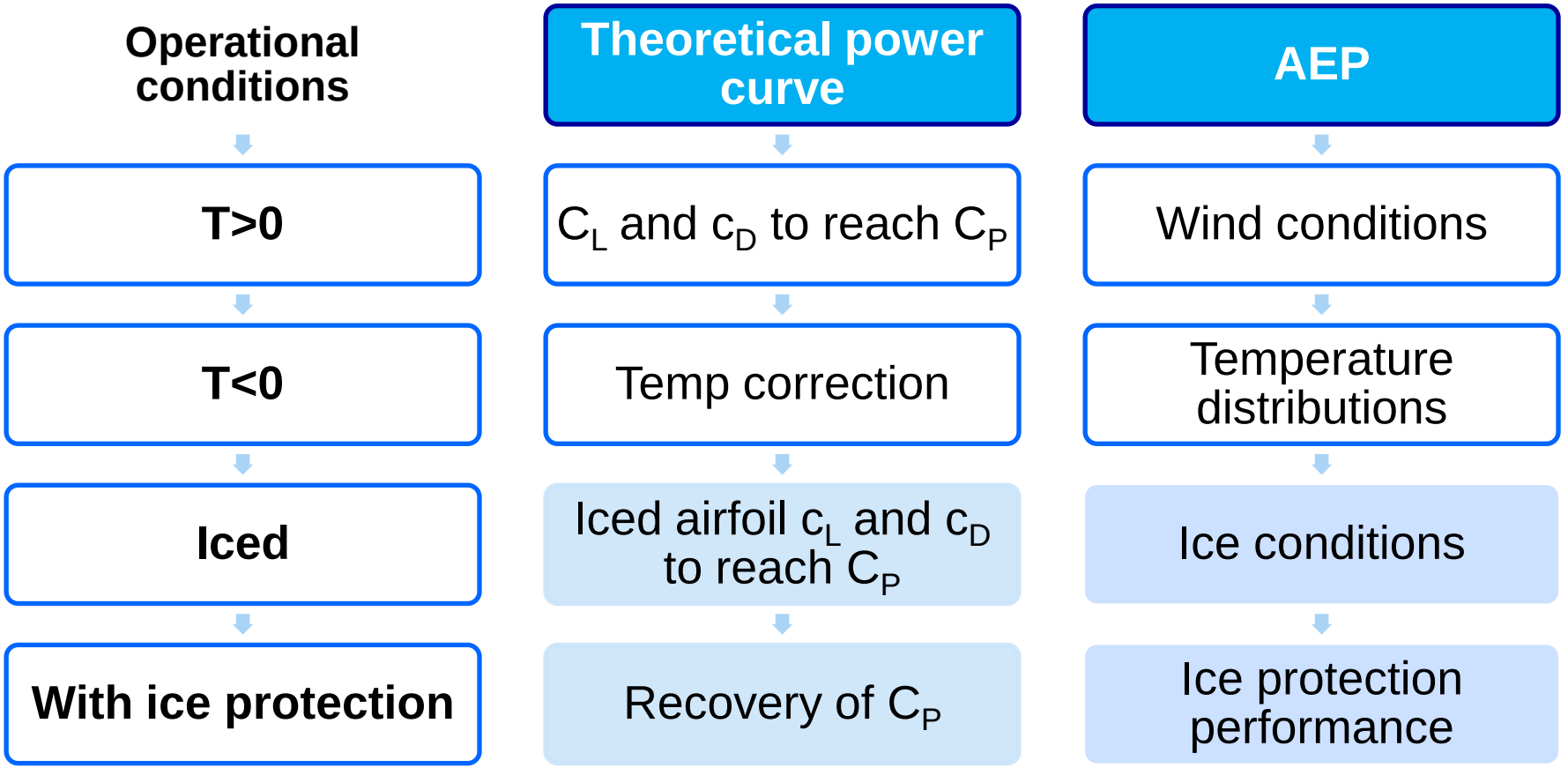
Recommendations
- Design
- Next steps



Ice protection design requirements

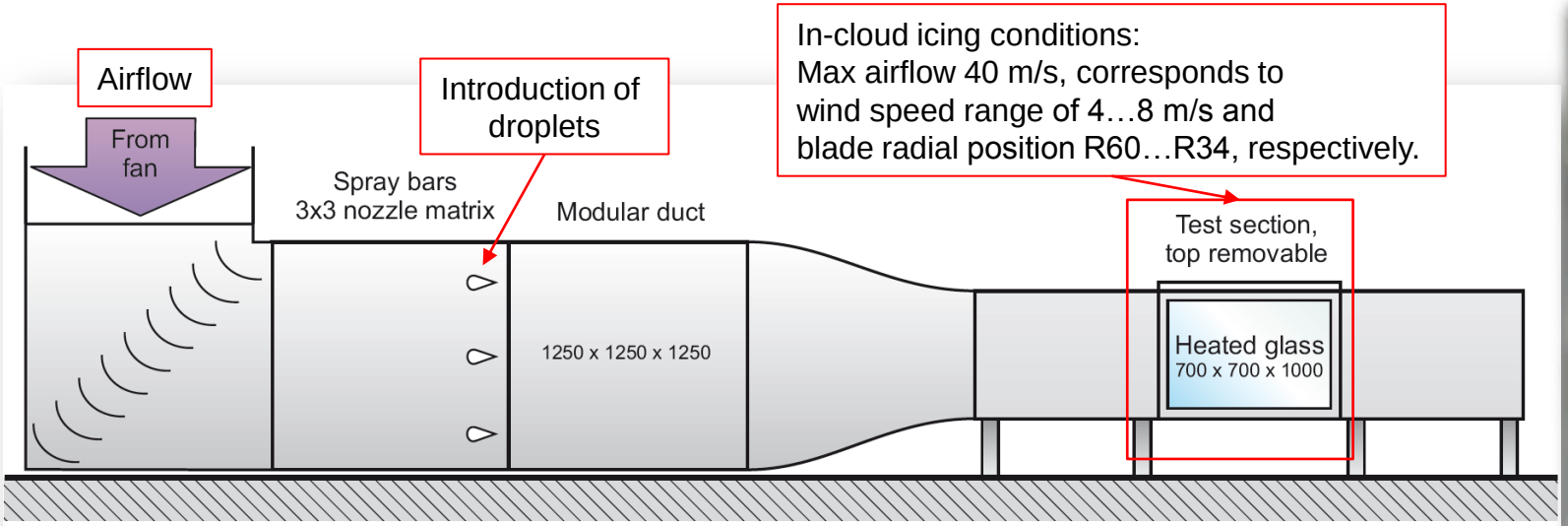
- May include e.g.
  - Design for an IEA Ice Class or equivalent requirement
  - Operational in specified condition envelope
  - Mechanical endurance and lifetime – like extreme, fatigue and transport accelerations, as well as vibration and dynamics requirements
  - Certification requirements – e.g. lightning
  - Electrical design – supply voltage, power available, etc
  - Electrical protection – overvoltages, personnel, lightning

Power performance of wind turbine in icing conditions – design

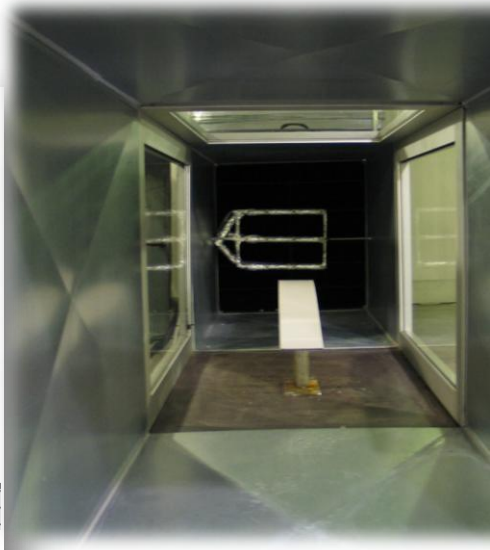


Design verification in an icing wind tunnel

- To verify anti- or de-icing functionality and design limits
  - Electrothermal heating, hot-air system, coating, combination
  - Not a system level assessment, scale model
- Controlled conditions
- Relatively cheap and fast



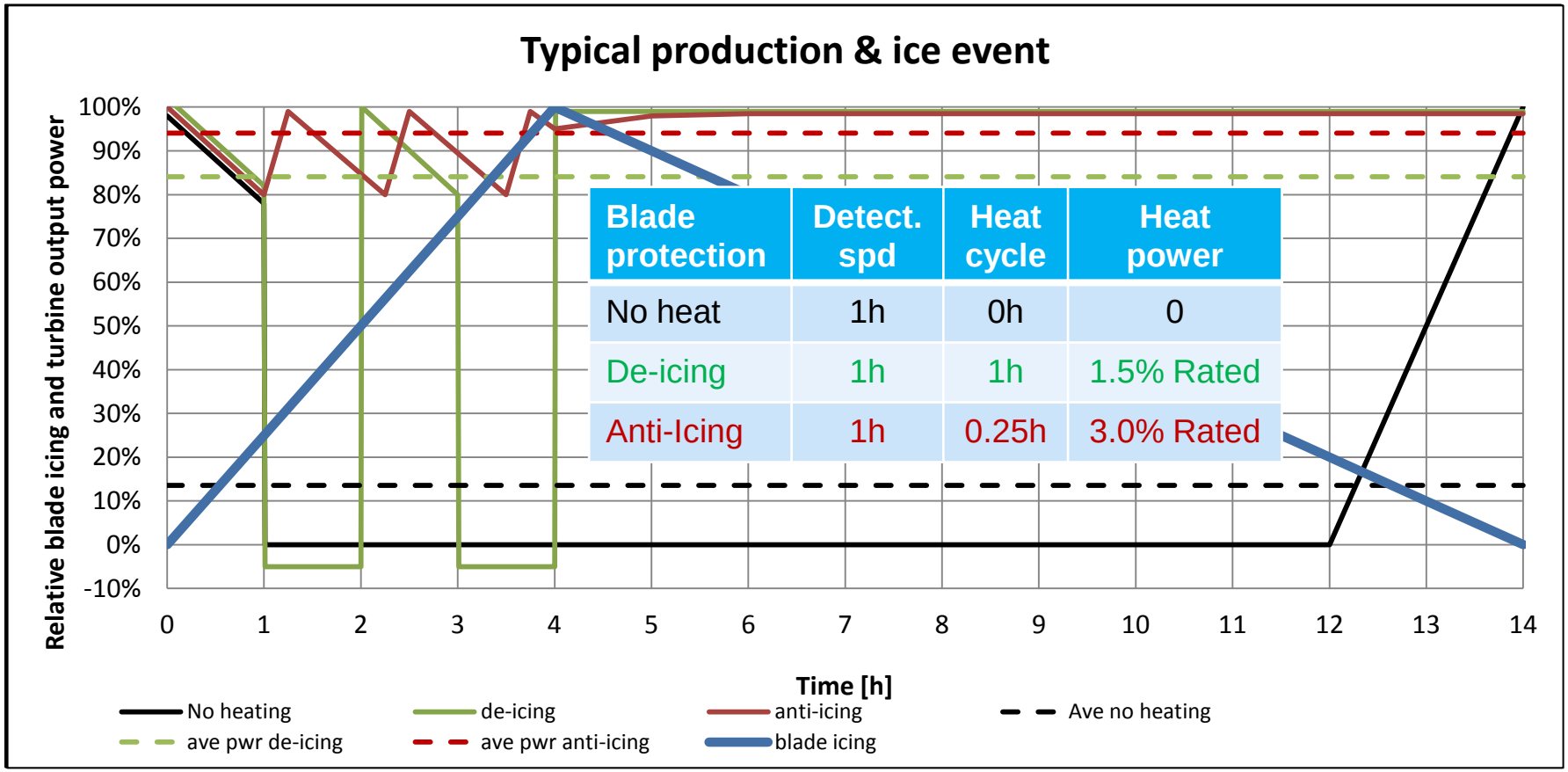
Icing wind tunnel layout, side view.



Power performance of wind turbine with ice protection – ”type certification”

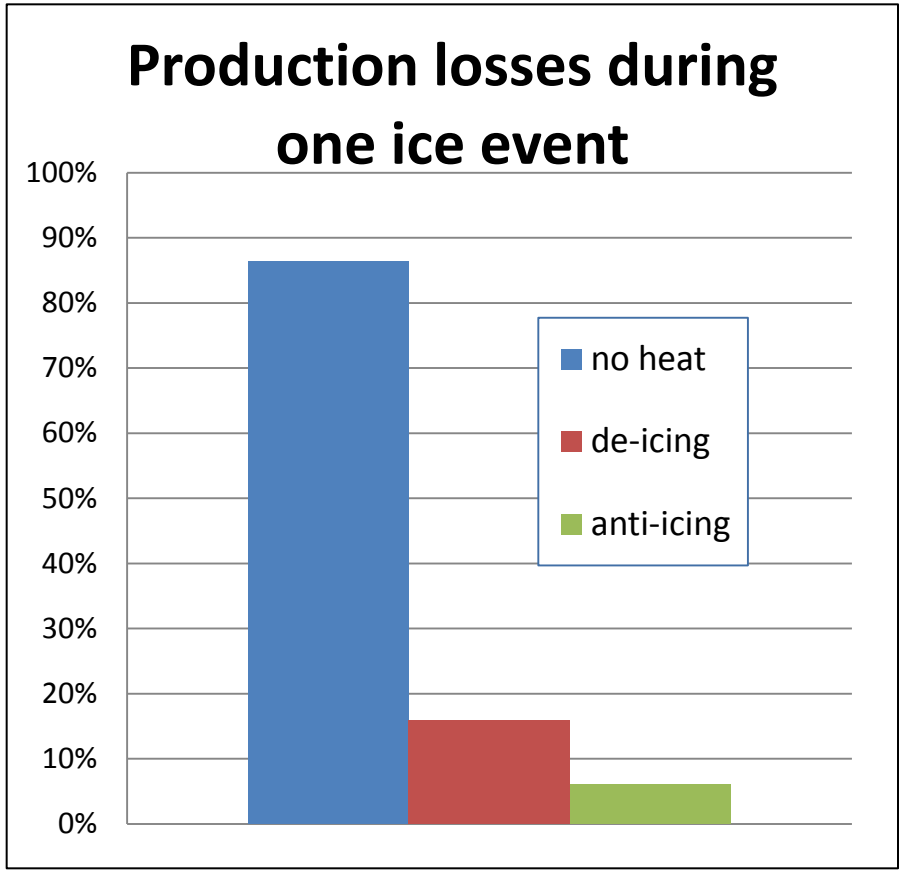
Operational conditions	(Type) Power performance curve	Annual energy production AEP
T>0	IEC 61400-12-1, @ 15 C	Wind conditions
T<0	Class 1 anemometry for T <0	Temp correction and distribution
Iced	Class 1 anemometry for icing conditions	AEP-loss, e.g. T19 approach from SCADA
With ice protection	Turbine and ice protection specific	As above?

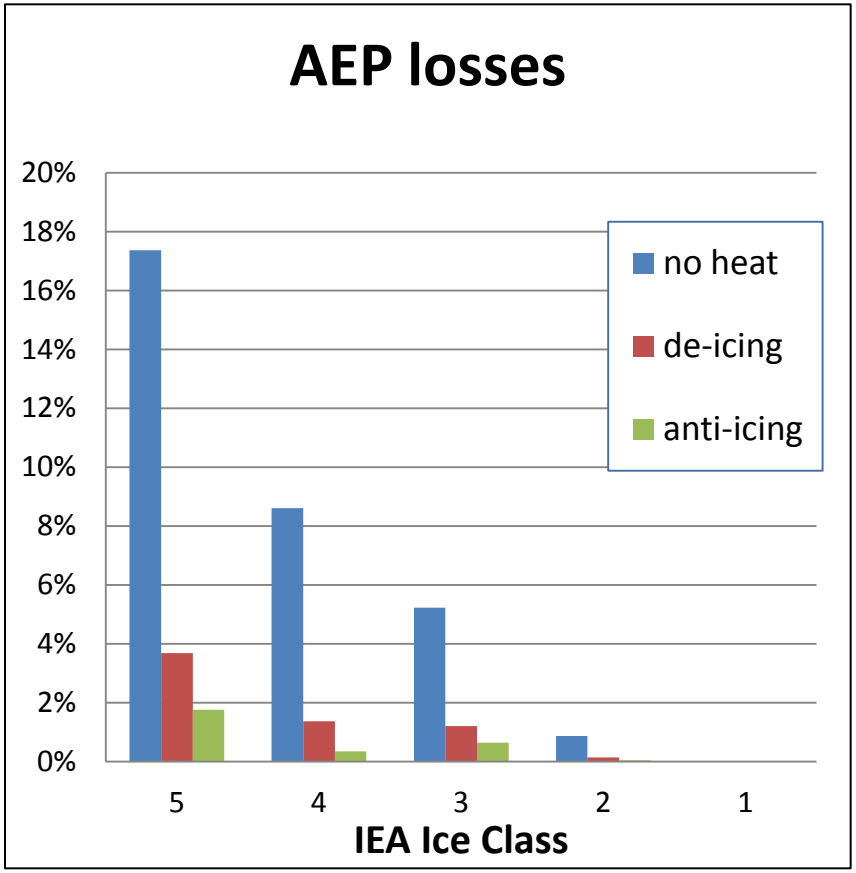
Example: Assessing system performance and financial benefits



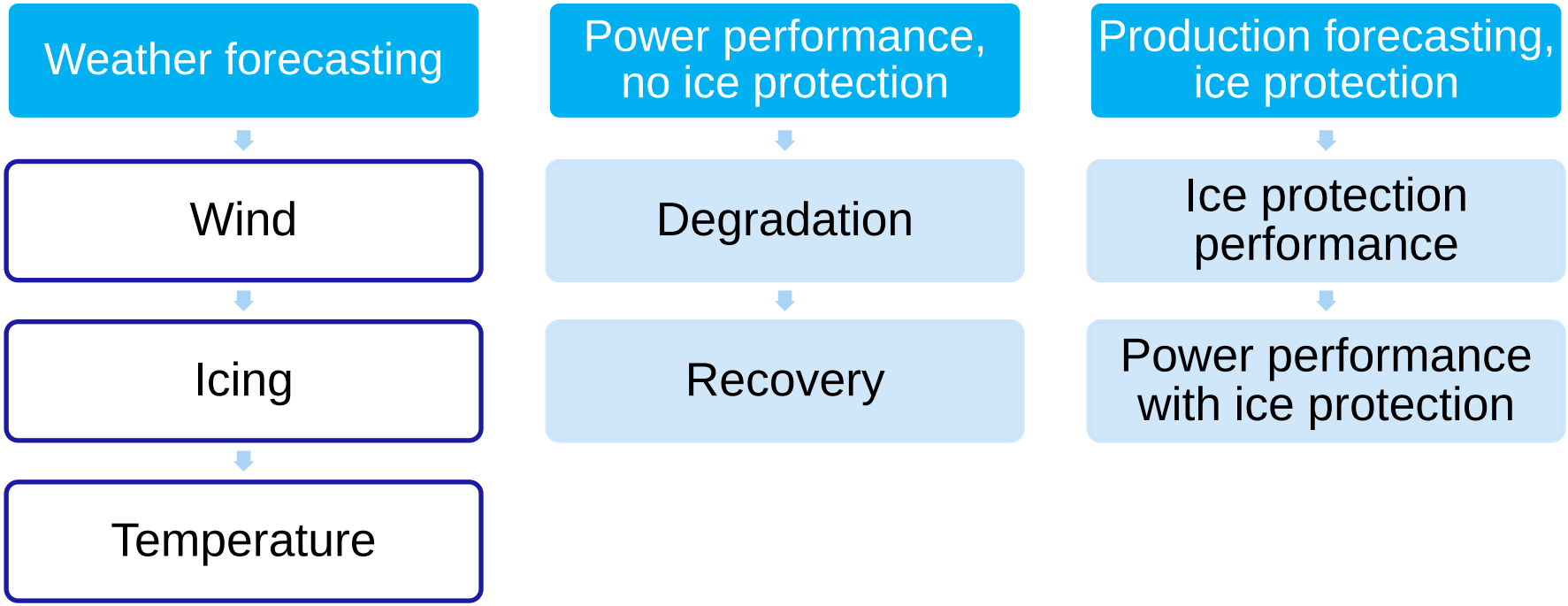
Blade protection	Detect. spd	Heat cycle	Heat power
No heat	1h	0h	0
De-icing	1h	1h	1.5% Rated
Anti-Icing	1h	0.25h	3.0% Rated

Example: Assessing system performance and financial benefits





Production forecasting



Ice protection performance assessment

- To reduce financial risks
  - Pre-design to support business case
  - Design to compare alternative aproaches and optimize design
  - Design verification
  - System performance for financing and risk assessment
  - System performance for production forecasting
- Standards/practices to assess ice protection performance missing
  - Power performance curve for T<0, icing and both
  - Design and verification conditions
  - Need and scope for R&D cooperation
  - Activity for international arenas
    - Eg. IEA Wind Task19, EU Horizon 2020

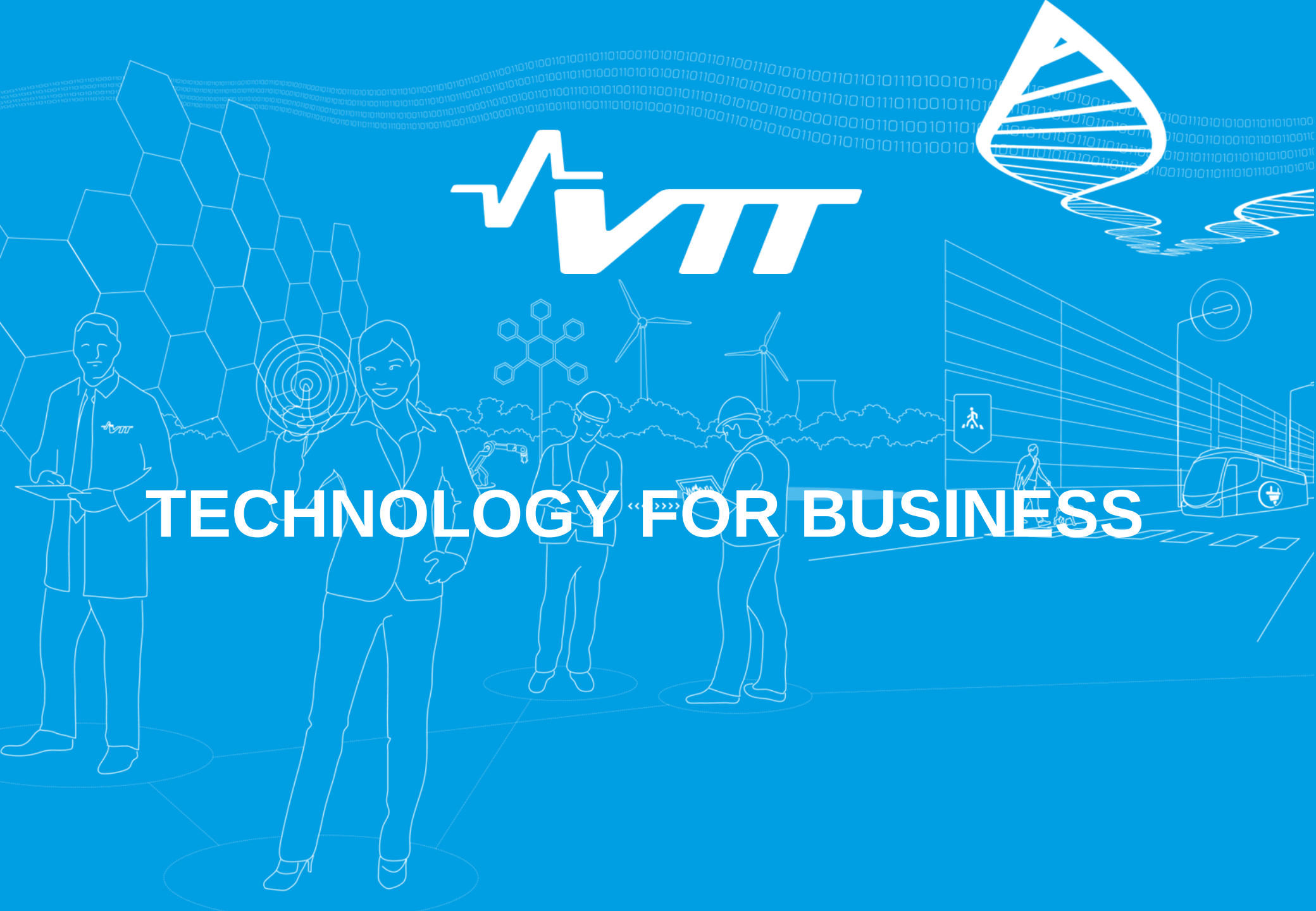
Heating makes the difference – just quantify it

Nos 1 and 3 heating on No 2, heating off

Olos wind farm.

- **Bonus turbines with blade heating**
- **Built 1998-99, in operation**

Video: Raimo Huuhtanen, Vapo


TECHNOLOGY FOR BUSINESS