VTT TECHNICAL RESEARCH CENTRE OF FINLAND LTD

Benchmark analysis of ~~5~~ 4 different wind turbine Ice Protection Systems

Ville Lehtomäki, Timo Karlsson, Simo Rissanen
VTT Technical Research Centre of Finland Ltd

Winterwind INTERNATIONAL WIND ENERGY CONFERENCE 10th year ANNIVERSARY

5-7Feb2018 @ Åre, Sweden

Outline

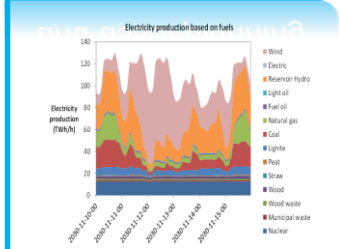
- VTT wind power & icing overview
- Icing basic
- Need for IPS benchmark
- Approach
- Results
- Summary & next steps

VTT Services for wind power value chain

30 % consultancy
70 % jointly funded

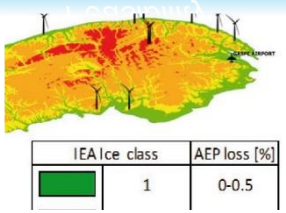
~40 person years/year

Power system design and asset planning



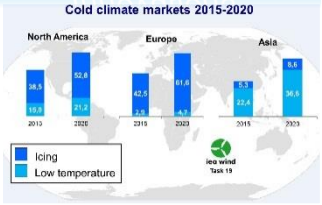
- *Value of wind power generation*
- *Electricity market impacts*
- *Capacity adequacy*
- *Grid electricity planning*
- *IEA and EERA activities*

Investment Feasibility



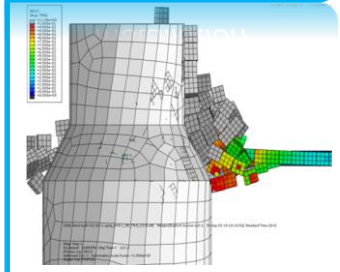
- *Wind Power Icing Atlas (WIceAtlas)*
- *Grid Code Compliance*
- *Noise Assessment Methodology*
- *Radar, TV and communications interference*

Technology and Innovations



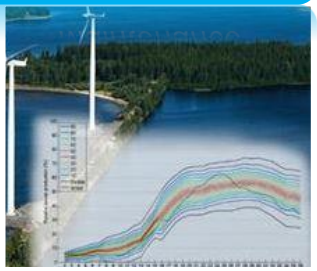
- *Technologies for Cold Climates*
- *Ice detection systems*
- *IEC standards, IEA & EERA activities*
- *Drivetrain solutions*
- *Technology and Markets Foresight*

Construction and Installation



- *Sea ice loads*
- *Off- and onshore foundation measurements and design*

Operation and Maintenance



- *Production forecasting methods*
- *Smart decision-making for wind turbine O&M*

International customers throughout the value chain

Related networks

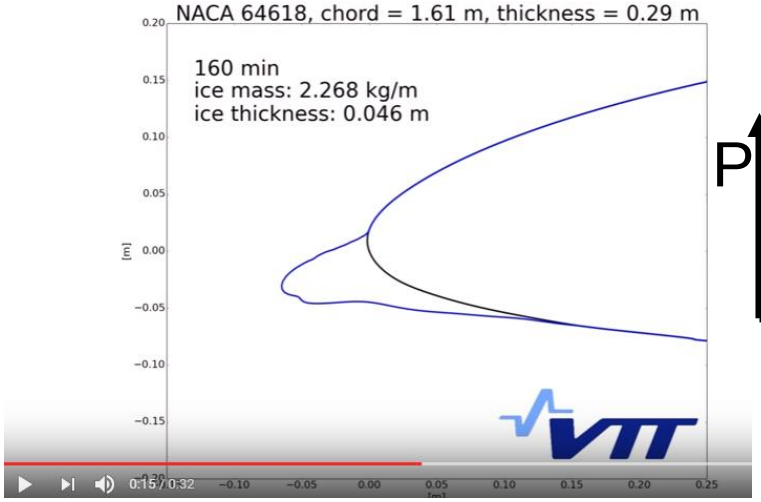
iea wind · IEC · EERA · EARTO IMPACT DELIVERED · EWEA THE EUROPEAN WIND ENERGY ASSOCIAT · The Federation of Finnish Technology Industries

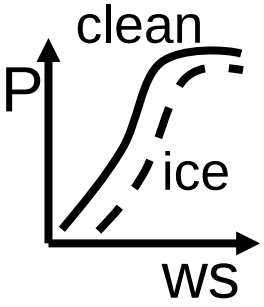
Contact: ville.lehtomaki@vtt.fi geert-jan.bluemink@vtt.fi

www.vttresearch.com\windpower

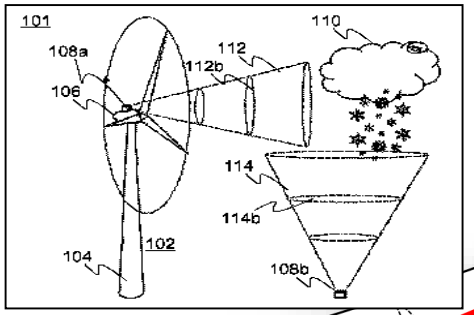
VTT Cold Climate Wind Power

Ice accretion theory 1990s ->





Patents

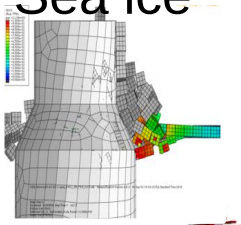


WICETEC
Ice Prevention Systems

Ice Prevention System
Commercial spin-off

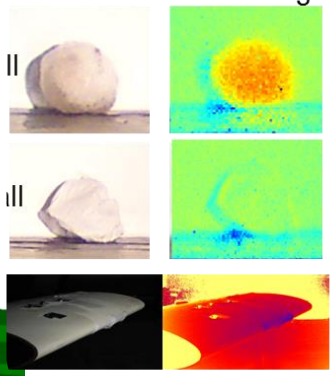
IEC International Electrotechnical Commission

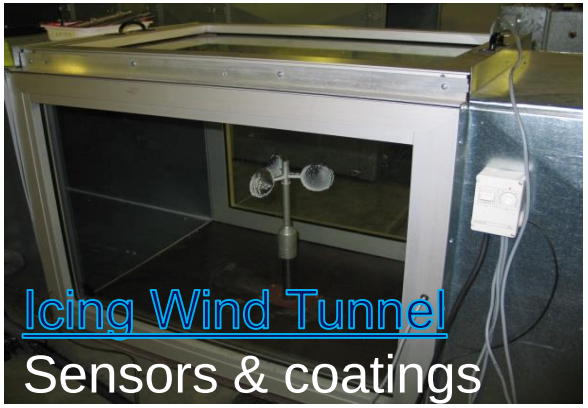
Sea ice



Ice imaging

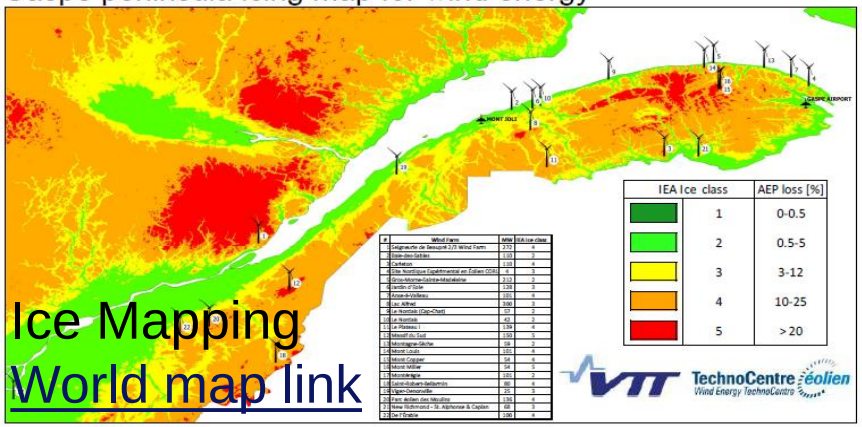
Picture VTT IceImage®





Icing Wind Tunnel
Sensors & coatings

Gaspé peninsula icing map for wind energy



Ice Mapping
World map link

Load simulations

vttresearch.com\windpower

Icing basics
Need for IPS benchmark

ICING

Cloud water droplets & T < 0°C

Makkonen model:

$$\frac{dM}{dt} = \alpha_1 \alpha_2 \alpha_3 \cdot w \cdot A \cdot V$$

Ice accretion on blades

Reduced aerodynamics

ICING

Cloud water droplets & T < 0°C

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ICING

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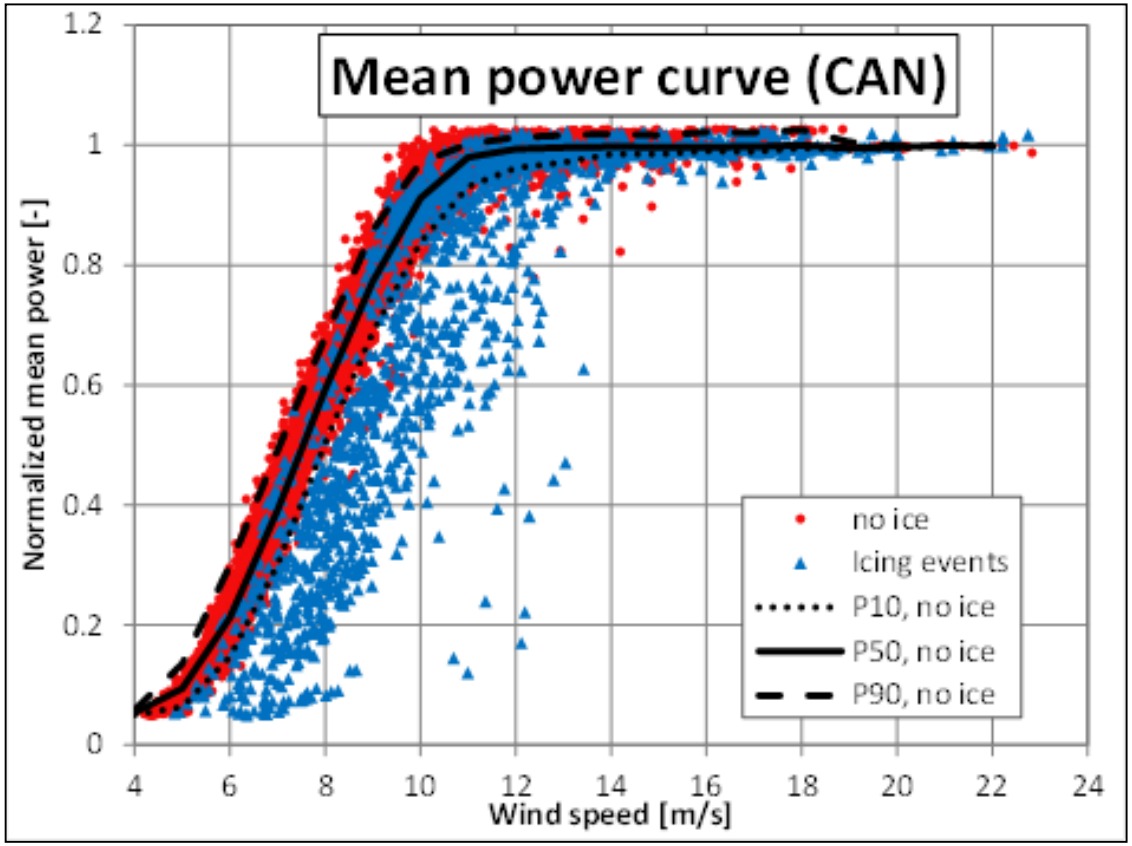


Market Need: Huge potential!

Cold climate markets 2015-2020

Cumulative installed capacity by end of 2015 [MW]		Forecasted capacity by end of 2020 [MW]	
Low temperature	Icing*	Low temperature	Icing*
40 500	86 500	62 500	123 000
Total 127 000		**Total 185 500**	

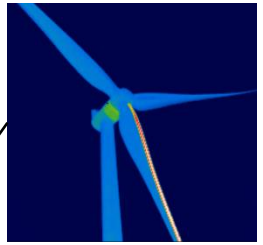
*: IEA Ice Classification ≥ 2 meaning > 44h/a of meteorological (in-cloud) icing

+12GW/a -> 59GW of new installations to cold climates by 2020!

➢ Compare: new offshore +4GW/a -> 20GW by 2020

http://www.windpowermonthly.com/article/1403504/emerging-cold

Industry need



ENERCON
ENERGY FOR THE WORLD

Gamesa
SIEMENS

NORDEX

acciona
Windpower

Vestas®

DEC 东方电气
DONGFANG ELECTRIC

How to choose the correct IPS & OEM?

What losses & gains do existing systems have?

Need to answer this question:

What is the performance and maturity of current state-of-the-art wind turbine Ice Protection System (IPS) solutions available on the markets?

Industry consortium project goals

Timeline:
Dec2017-Jun2018

- Anonymized, first-in-the-world & public benchmark analysis of Enercon, Vestas, Siemens-Gamesa, Nordex-Acciona and Dongfang state-of-the-art wind turbine Ice Protection Systems (blade heating, anti- and de-icing) using historical SCADA data
- Benchmark between different OEMs
  - icing losses with Ice Protection System (IPS),
  - production gains due to IPS and
  - IPS maturity level from O&M perspective
- Prepare public report of key findings, publish in June 2018

Project lead:

Project partners:

BLAIKENVIND
Owned by Skellefteå Kraft och Fortum

VATTENFALL

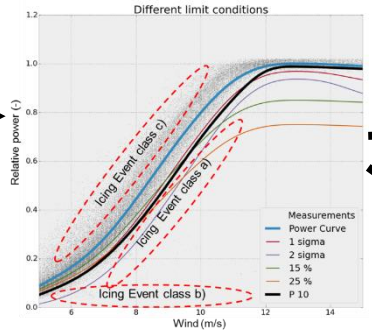
TAALERI

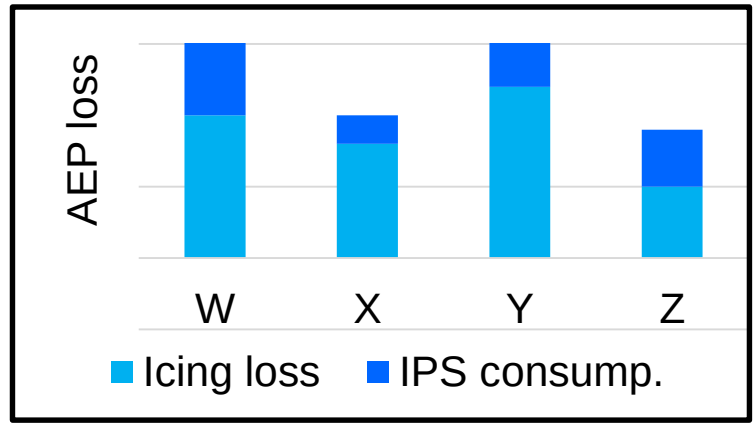
Approach

Approach – Use historical SCADA data

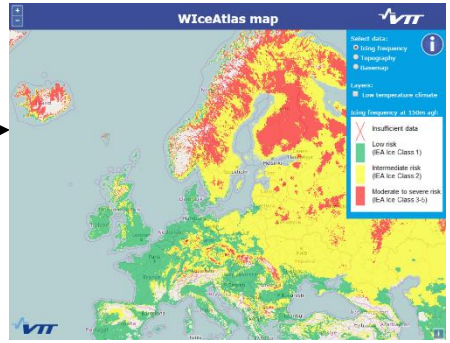
T19IceLossMethod

a) Icing loss

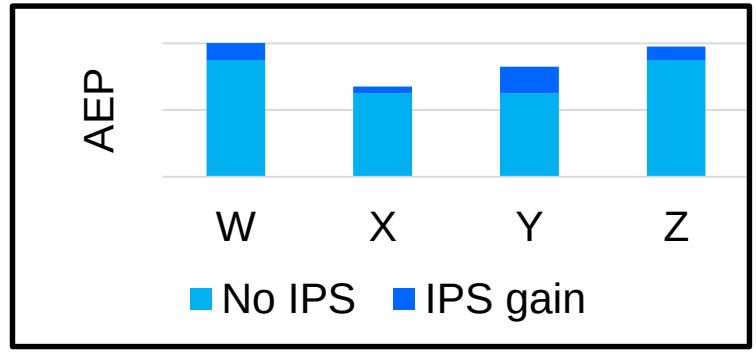




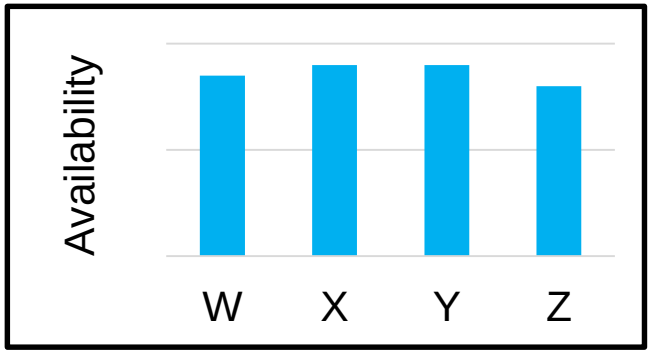
b) AEP gain



http://virtual.vtt.fi/virtual/wiceatla/



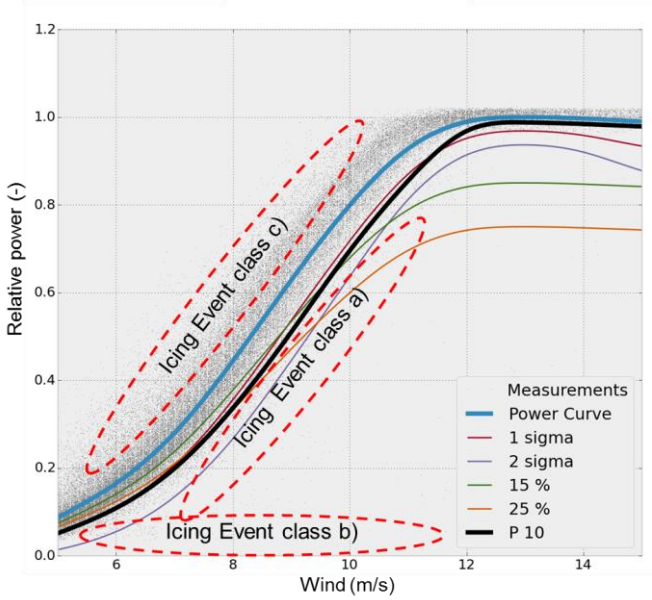
c) IPS maturity



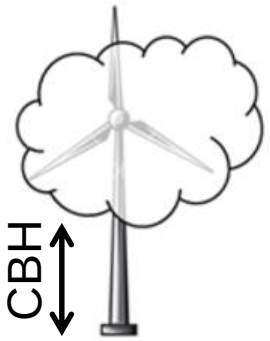
No results yet…

a) Icing loss
T19IceLossMethod

1. Publicly available free software for calculating icing losses from any SCADA dataset developed by IEA Wind Task 19
2. Method uses the rotor as an ice detector
3. Result robustness achieved by using 10th percentile (P10) of non-iced power curve
4. False alarms minimized by including the ”memory effect” of icing: more than one 10-min datapoints needed to trigger positive rotor ice detection

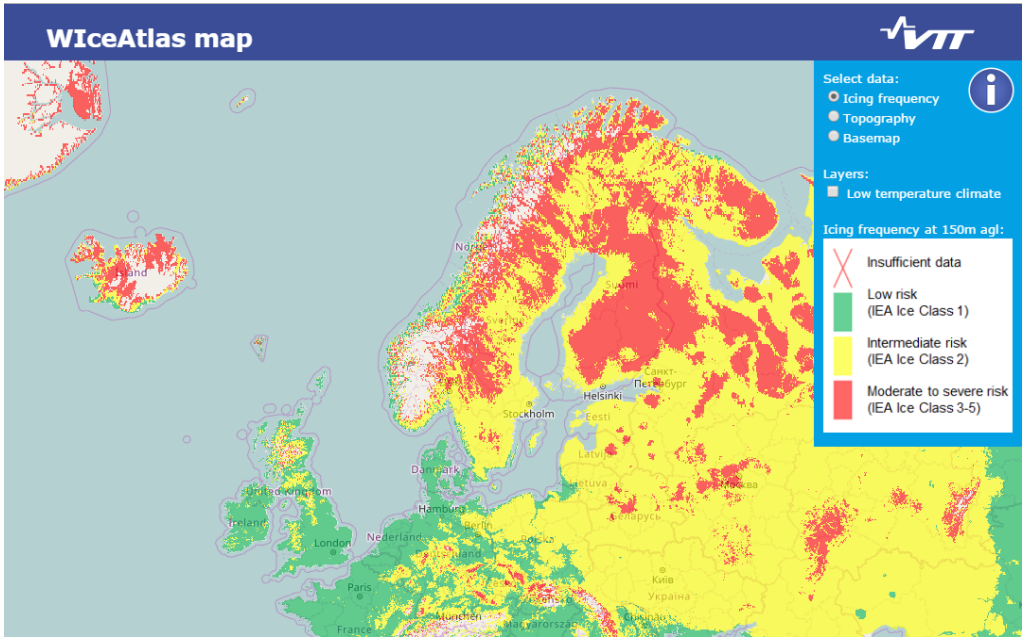


Download software here:
https://community.ieawind.org/task19/t19icelossmethod



b) AEP gain
WIceAtlas – Wind Power Icing Atlas

- Global icing atlas for icing loss assessment <u>for non-IPS WTs</u>!
- WIceAtlas is based on cloud base height <u>measurements</u>
- Data from 4500 meteorological stations, >20 yr/station
- Temperature from MERRA
- Criteria for icing: CBH <= 150 m and T < 0 **<u>(In-cloud icing only!)</u>**
- Validated* with several sites, successful hit rate 82%



Additional information and public map:
http://www.vtt.fi/sites/wiceatlas

*: http://windren.se/WW2017/7_2_09_Cattin_IEA_Task_19_-_Blind_icing_map_validation_Pub_v2.pdf

5 turbine OEMs all with IPS installed

All turbines are +2MW and +D80m

Vestas

SIEMENS Gamesa
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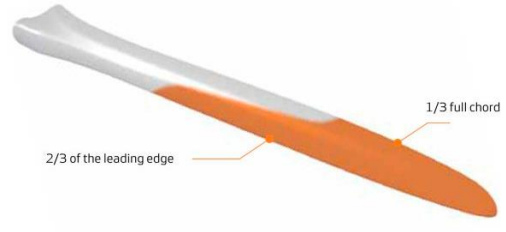
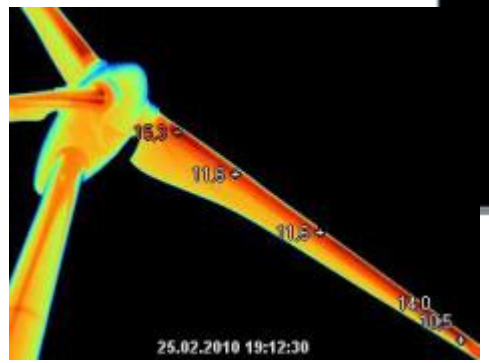
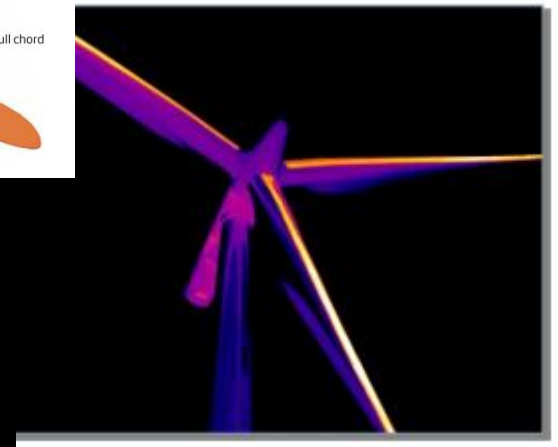
NORDEX

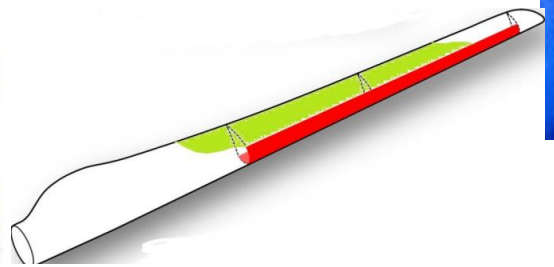
acciona
Windpower

DEC
东方电气
DONGFANG ELECTRIC









Overview of sites

OEM	Region	WIceAtlas IEA Ice Class	GWA wind	Years of data*
A	North EU	4	7.3 m/s	≥ 2
B	North EU	3	6.8 m/s	≥ 2
C	North EU	4	7.0 m/s	≥ 2
~~D~~	~~Central EU~~	~~2~~	~~6.5 m/s~~	~~≥ 2~~
E	North EU	4	7.2 m/s	≥ 2

*: by June 2018

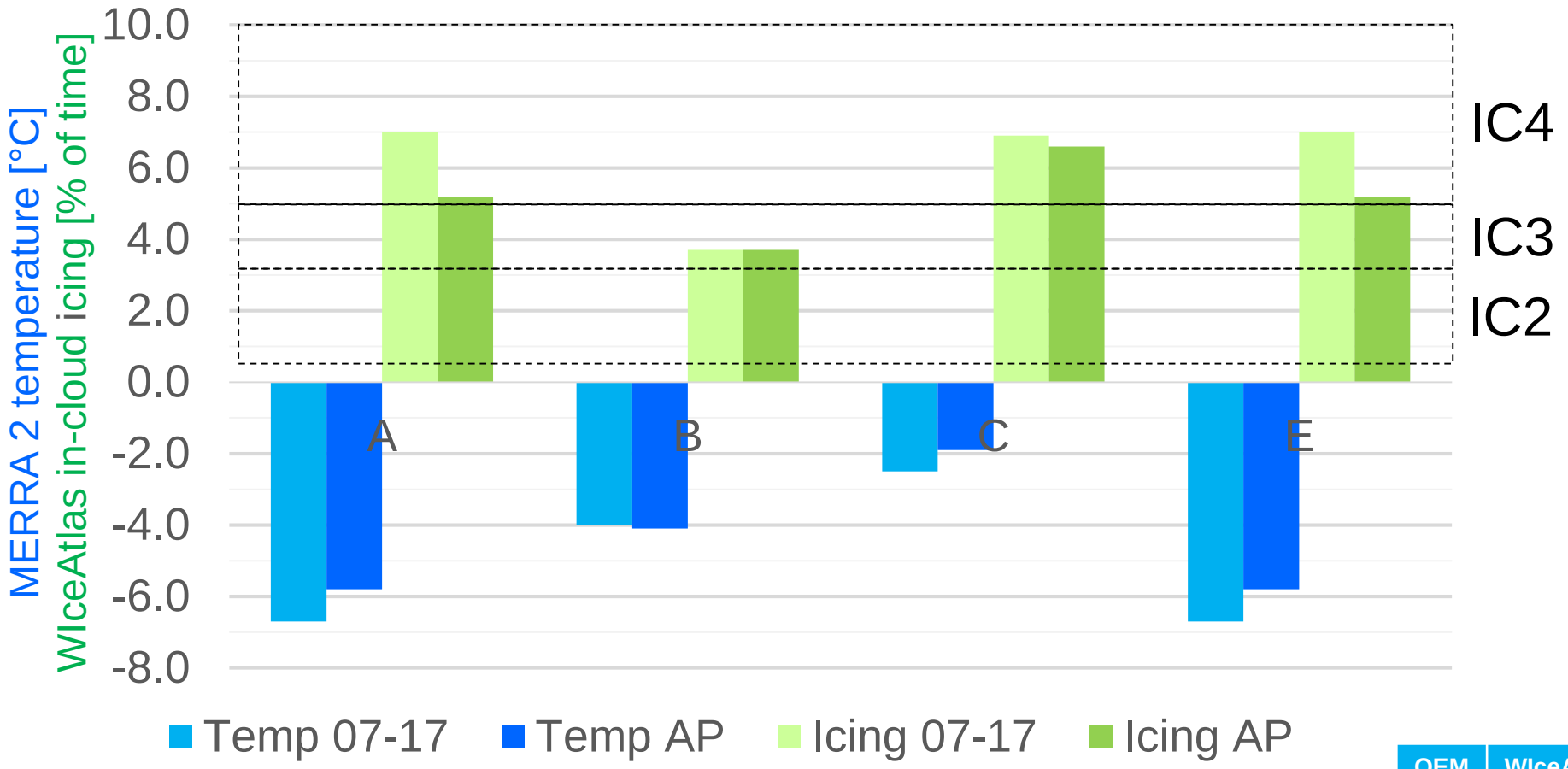
No results yet for D…

IEA Ice class	Meteorological icing	Instrumental icing	Icing loss
	% of year	% of year	% of gross 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

Results
Site assessment

WARNING:
PRELIMINARY!

Winter temperature and icing conditions



Reference temperature & icing from winter average (Nov-Apr)
Analysis Period from available SCADA time period

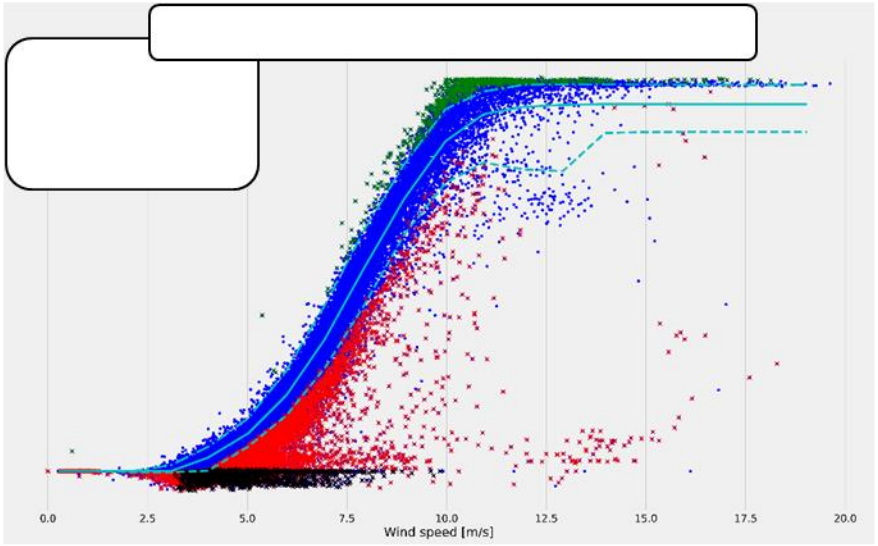
OEM	WIceAtlas 1979-2015
A	4
B	3
C	4
E	4

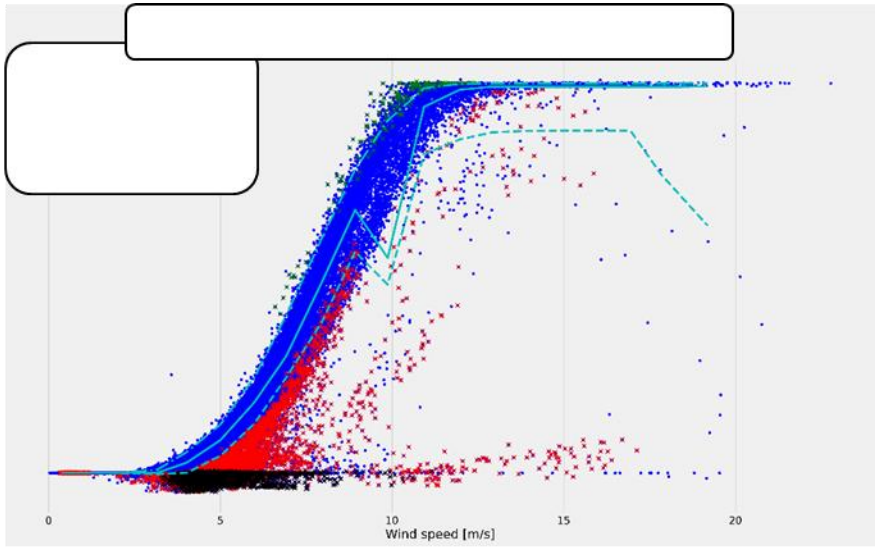
WARNING:
PRELIMINARY!

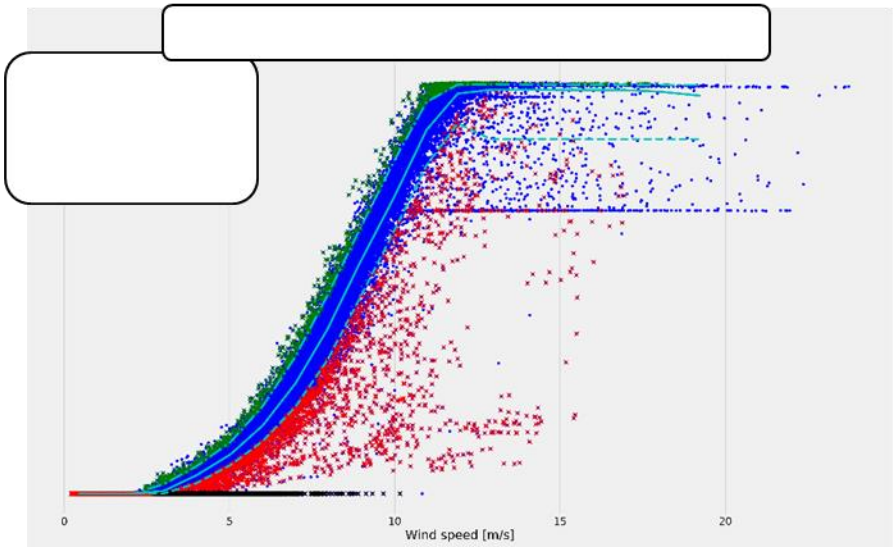
Results
SCADA analysis

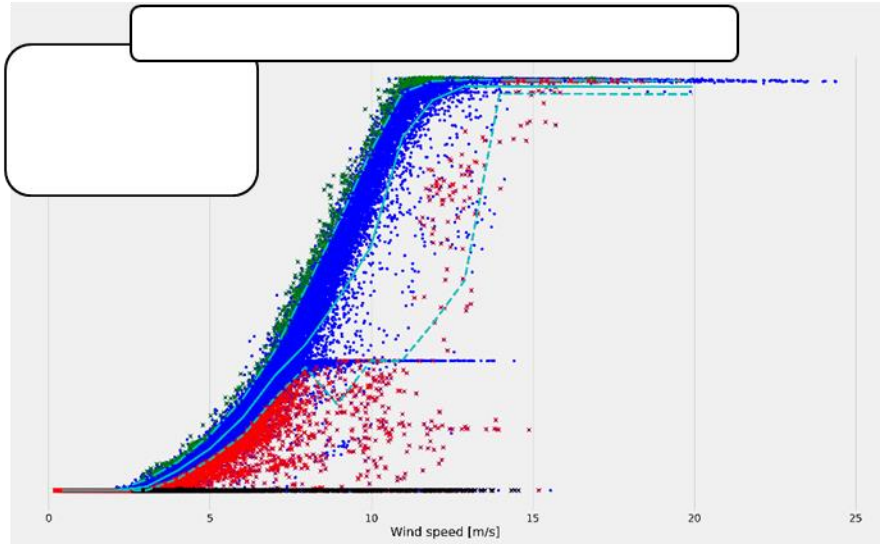
Power curve: general findings so far

- Do not trust turbine status code! Error code more reliable (now used)

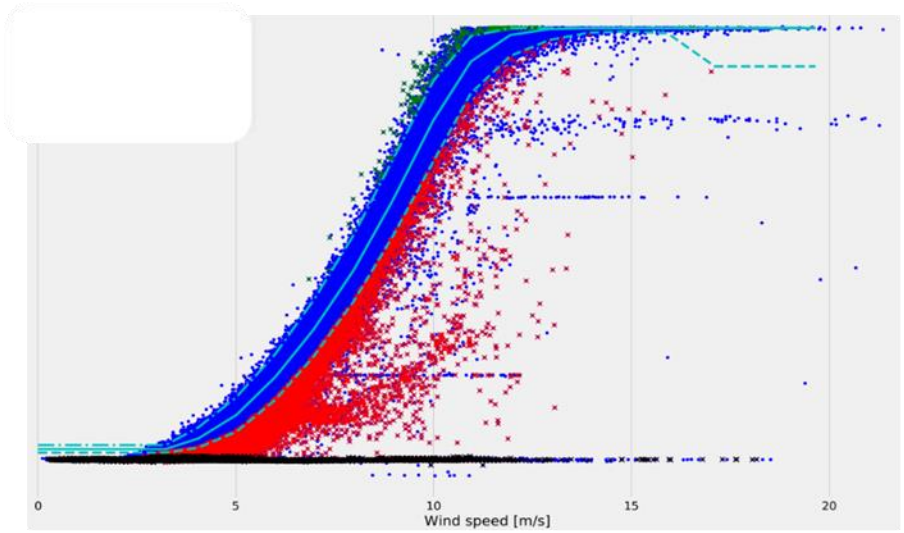


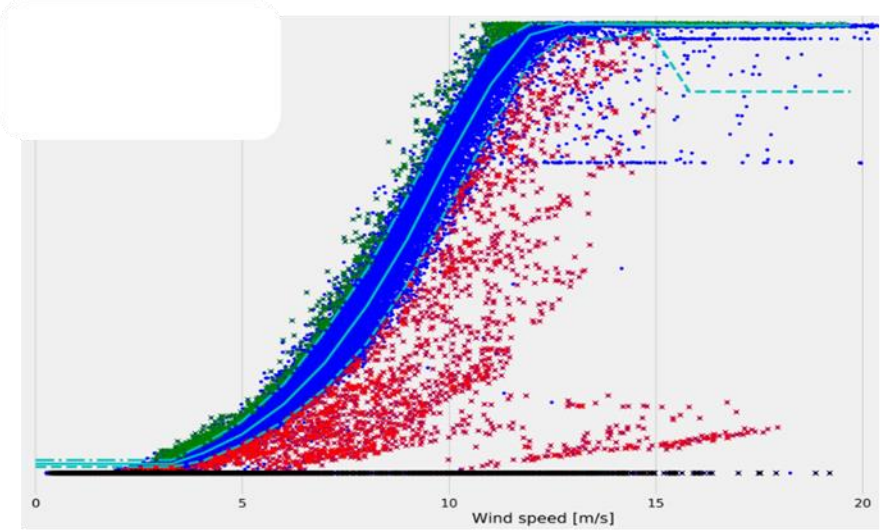


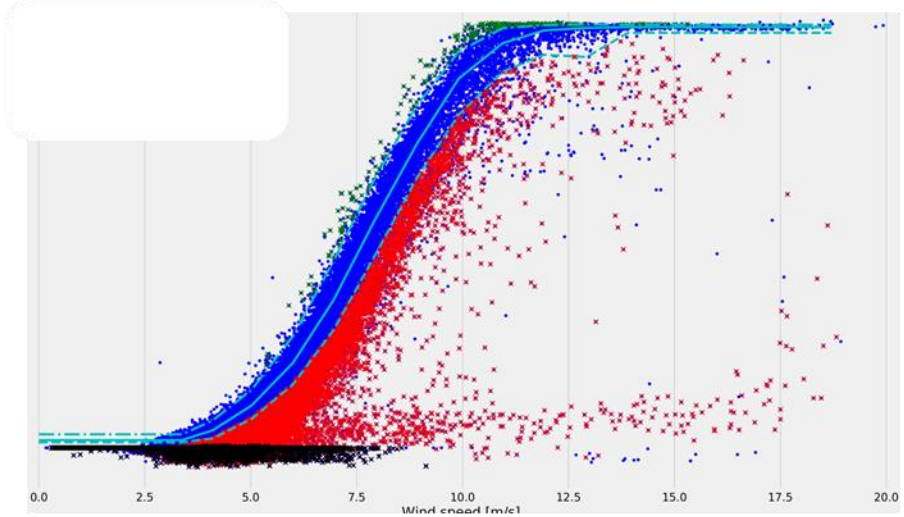


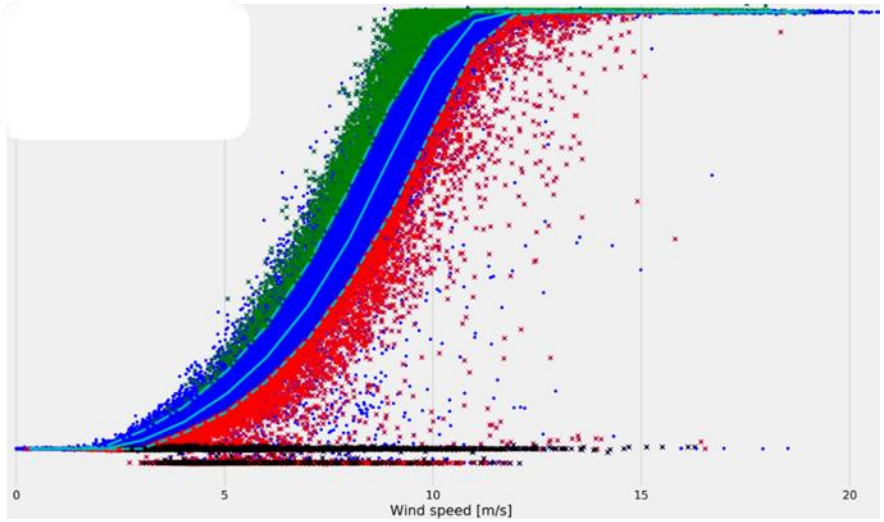


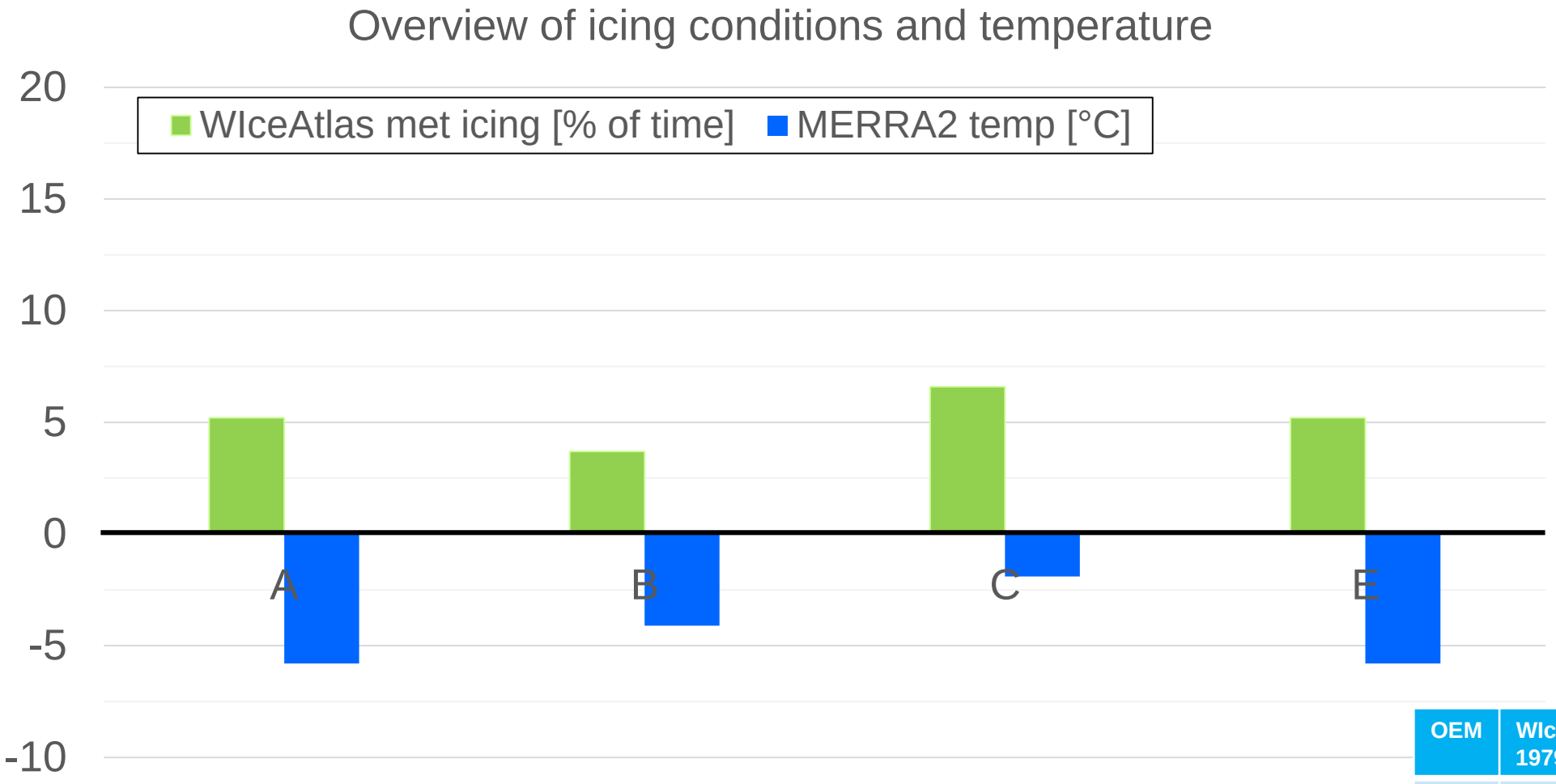
Error code filtered power curves, better!





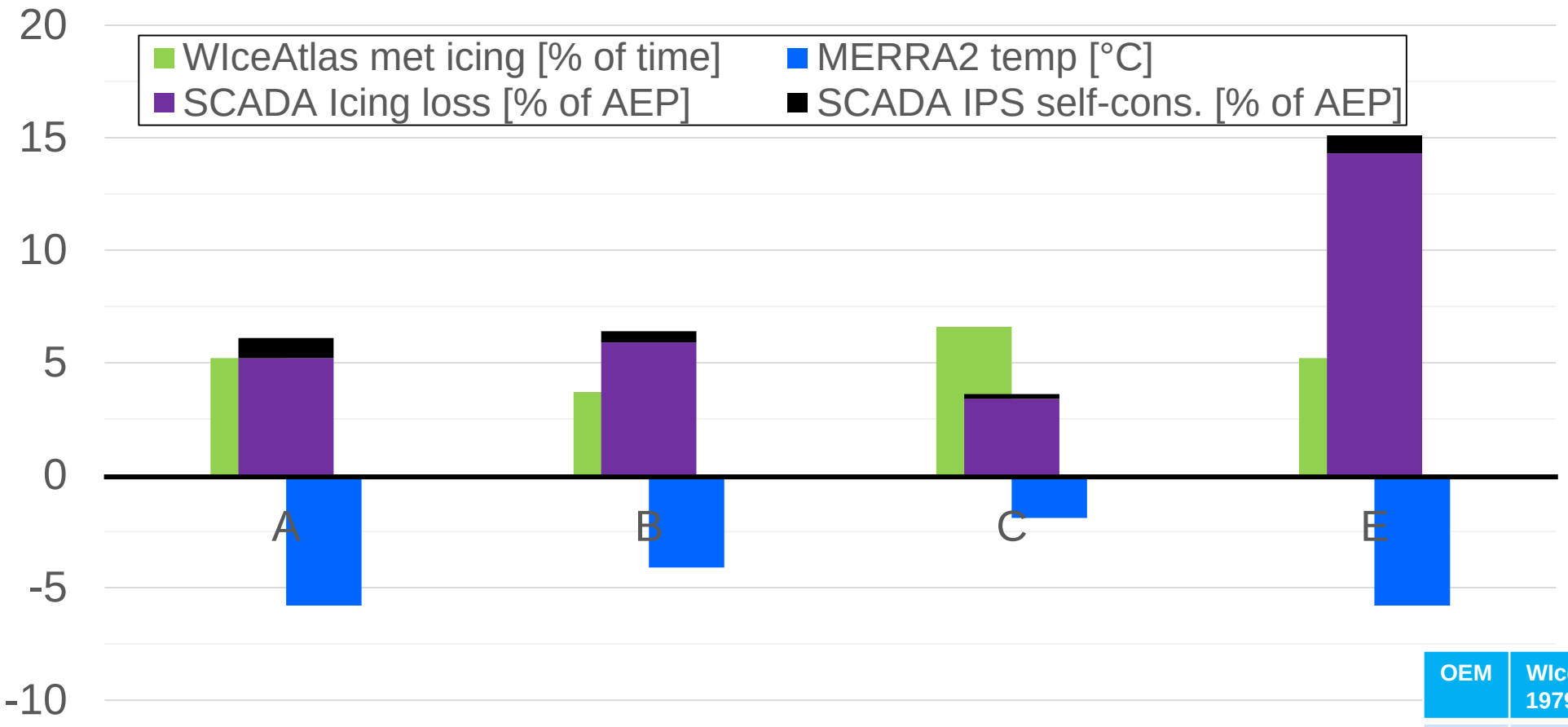




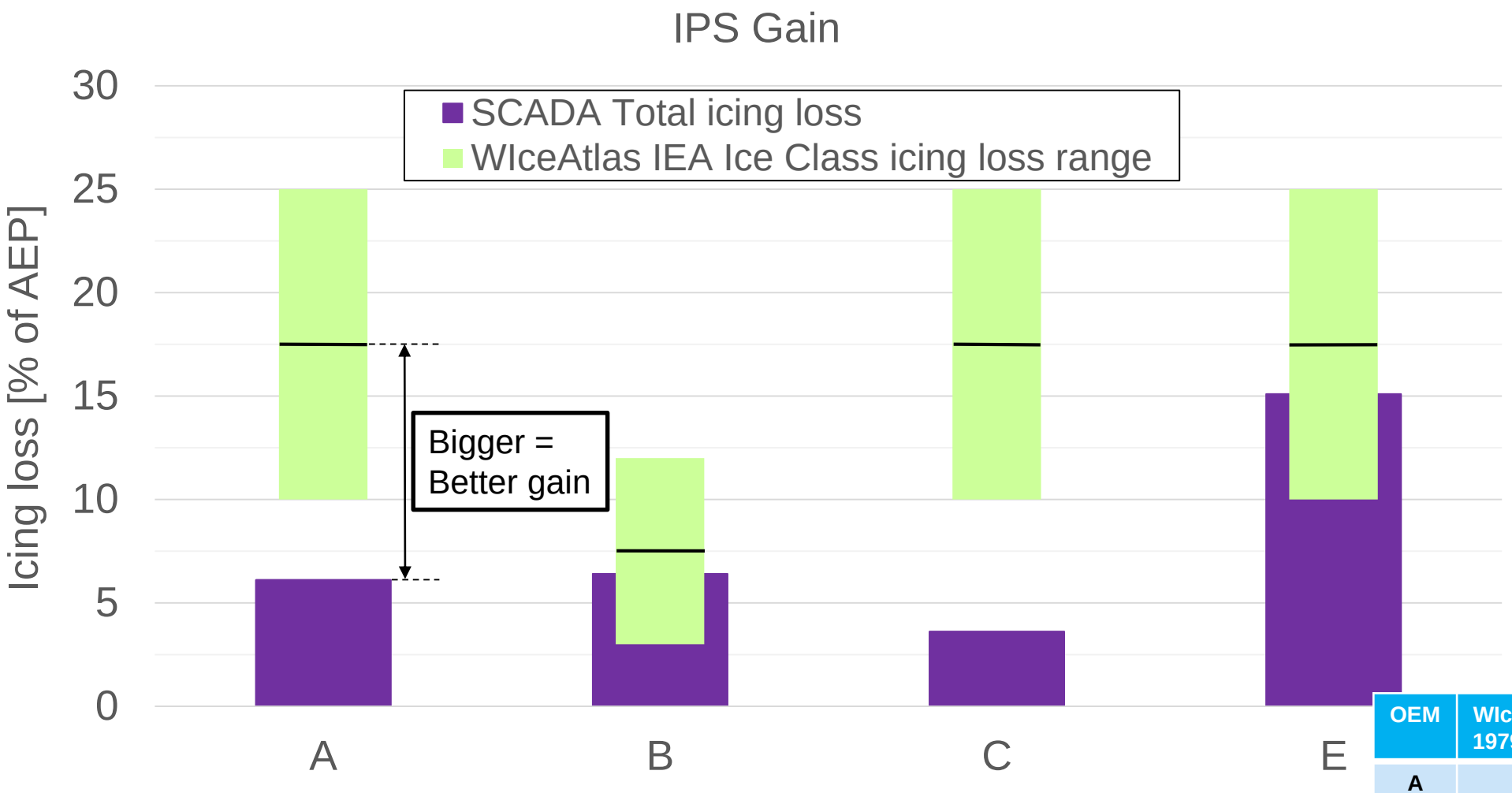


OEM	WIceAtlas 1979-2015
A	4
B	3
C	4
E	4

Overview of icing conditions, temperature and icing losses



OEM	WIceAtlas 1979-2015
A	4
B	3
C	4
E	4



OEM	WIceAtlas 1979-2015
A	4
B	3
C	4
E	4

Summary

- Presented preliminary results of 4 OEMs, final results of 5 OEMs in June 2018
  - Some sites have only one winter so far
- Do not trust SCADA status code, use error code for filtering!
- Icing losses range from 3.5-15 % of AEP
- IPS self-consumption below 1 % of AEP
- IPS theoretical gain varied quite much but more SCADA needed
  - OBS! Gain sensitive to non-IPS theoretical WIceAtlas results

Next steps

- Include winter 2017/18 to analysis
- Look also into interannual variation, turbine specific IPS analysis
- IPS maturity (technical availability)
- Public report out in June 2018

Thank you!

Ville Lehtomäki
Senior Scientist
ville.lehtomaki@vtt.fi
+358 50 370 7669