IEA Wind TCP

Task 54

Cold Climate Wind

Methodology to assess production losses due to ice based on power curve analysis

Timo Karlsson, Jennifer Pettersson, Charles Godreau, Patrice Roberge

Webinar - Svensk Vindkraft and Winterwind workshop

2025-02-03

Agenda

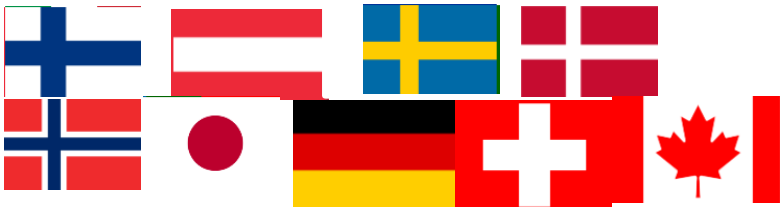
IEA Wind TCP

- Introduction to IEA Wind TCP Task 54
- Work plan 2021-2024
- Work plan 2025-2029
- Background – T19 Ice Loss method
- Methodology – T19 Ice Loss method
- User experience
- Break
- Workshop - discussion in smaller groups

IEA Wind TCP Task 54 – (previously known as Task 19)

IEA Wind TCP

- IEA – International Energy Agency
- Purpose of Task 54 is to bring expertise from different countries and gather information and provide guidelines, recommended practices and state-of-the-art industry standards within the topic of wind in cold climate
- Operating Agent: Timo Karlsson (FI), Task Manager: Charles Godreau (CA)
- Participating countries:



T54 – Work set-up

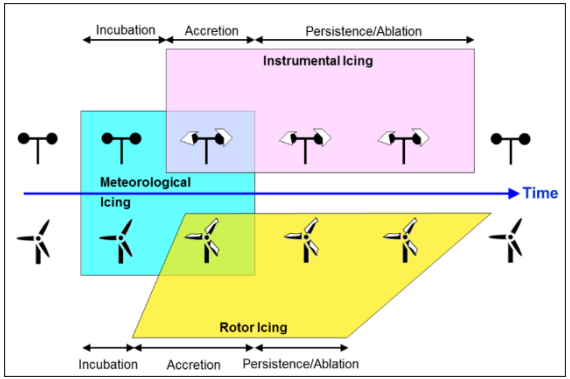
IEA Wind TCP

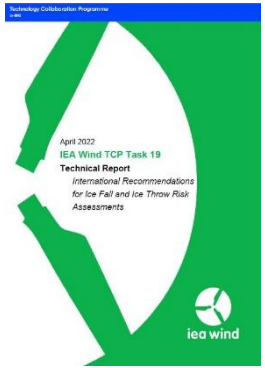
- The Task has regular meetings to coordinate activities within the group
- Work is done in subtasks where an assigned subtask leader coordinates the work for a specific subject
- Over the years, T54 participated in conferences to disseminate the work
- Dissemination is done throughout the years by publishing reports, presentations, etc.
- Annual physical meetings hosted by one of the participating countries

Publications

IEA Wind TCP

- Ice Loss Methodology – IEA Task 19 Ice Loss tool to assess production losses due to icing
- International Recommendations for Ice Fall and Ice Throw Risk Assessments (2nd edition)
- Performance warranty guidelines
- Site classification
- IEA Wind TCP Recommended Practice 13 2nd Edition: Wind Energy in Cold Climates (iea-wind.org)

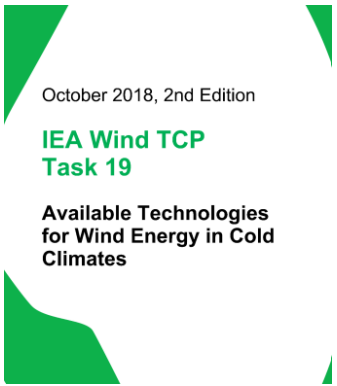


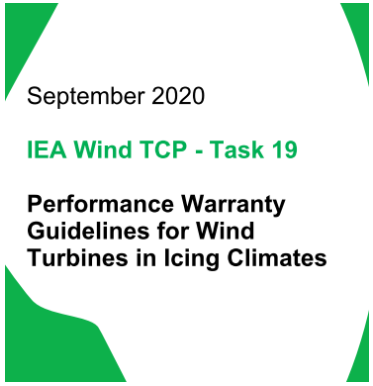


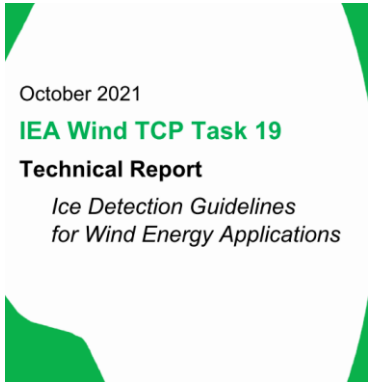
IEA Ice Class	Duration of Meteorological Icing [% of Year]	Duration of Instrumental Icing [% of Year]	Production Loss [% of AEP]
5	>10	>20	>20
4	5-10	10-30	10-25
3	3-5	6-15	3-12
2	0.5-3	1-9	0.5-5
1	0-0.5	<1.5	0-0.5

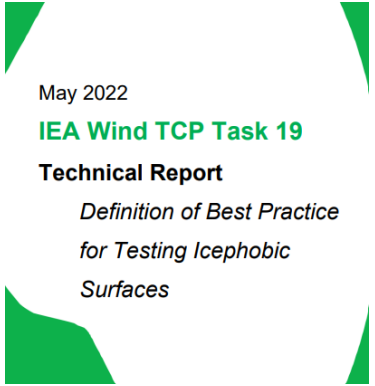
Task 19/54 – Public references

IEA Wind TCP









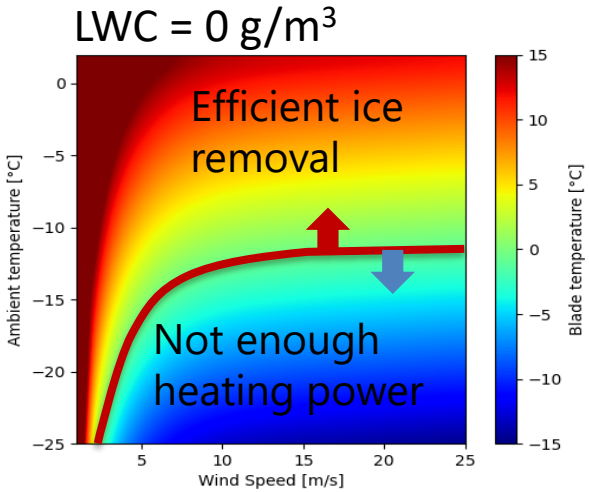
- International Recommendations for Ice Fall and Ice Throw Risk Assessments (2nd edition)
- Ice Detection Guidelines for Wind Energy Applications
- IEA Wind TCP Recommended Practice 13 2nd Edition: Wind Energy in Cold Climates (iea-wind.org)
- Available Technologies for Wind Energy in Cold Climates
- Definition of Best Practice for Testing Icephobic Surfaces

Available at: https://iea-wind.org/iea-publications/

T54 – Work plan 2021-2024

IEA Wind TCP

- Performance Envelopes
  - Under what conditions are the blade heating systems efficient?
  - A first release of an open source blade heating model
  - Icing events database – Call for contributions!!



- Operating wind turbines in very cold temperatures

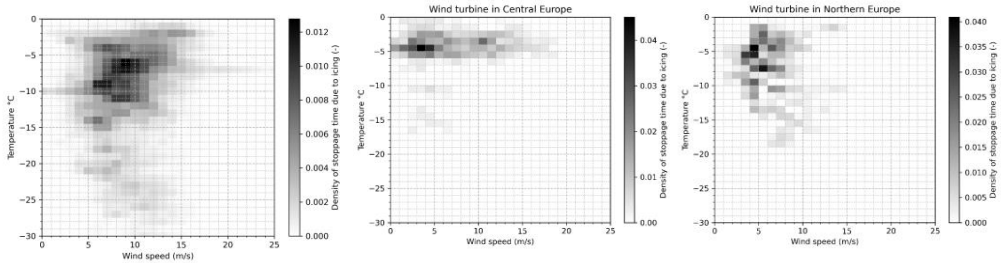
T54 – Work plan 2021-2024

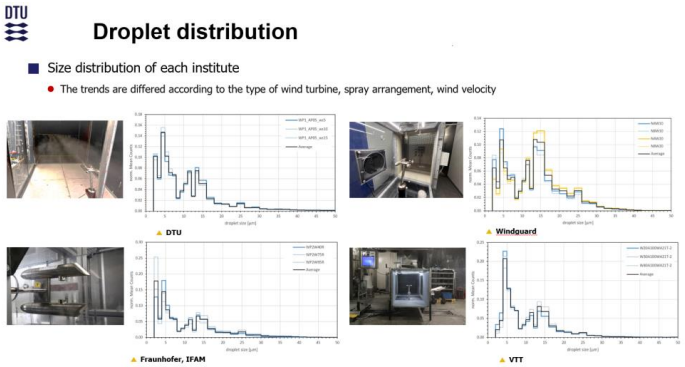
IEA Wind TCP

- Development of ice throw tool – will be released soon

- Uncertainty - Pre-construction icing uncertainty
  - Differences in ice loading in different climates

- Icing Wind tunnel
  - Round robin validation study





T54 work plan 2025-2029

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Title	Deliverable
Operational strategies	1 - Review of operational strategies of wind turbines in cold climates
Managing the ice throw risk	1 - Management of ice throw and ice fall risks during operation 2 - Pre-construction ice throw risk assessment
Offshore wind	1 - State-of-the-art of offshore icing assessment

T54 work plan 2025-2029

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Wind turbine and blade heating performance	1 - **Task 19 IceLossMethodology** 2 - IEA Ice Class 2.0 3 - Framework for field validation of blade heating systems performance
Icing events complexity	1 - Review of current knowledge 2 - Future research needs
Uncertainty	1 - Review of uncertainty in cold climate wind projects
Dissemination	1 - Industry awareness 2 - Recommended practices update

Assessment of production losses due to ice based on power curve analysis

Background and purpose

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- T19 (now T54) launched a method to assess production losses due to ice back in 2017, and later on with a few updates
- The purpose was because there was a need of an accurate and standardized methodology for calculating production losses due to ice for comparability

- The tool is Open source and accessible on GitHub
  GitHub - IEAWind-Task19/T19IceLossMethod: Method for estimating icing losses from wind turbine SCADA data

What is production losses due to ice?

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- Change in aerodynamic characteristics reduces production – reduced lift, increased drag
- Stops due to H&S (ice throw risk)
- Stops due to preventive structural integrity (vibrations etc)

From a power curve perspective

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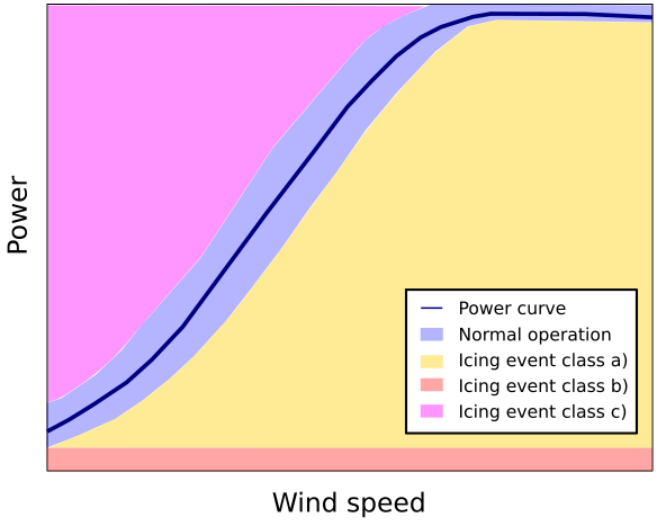

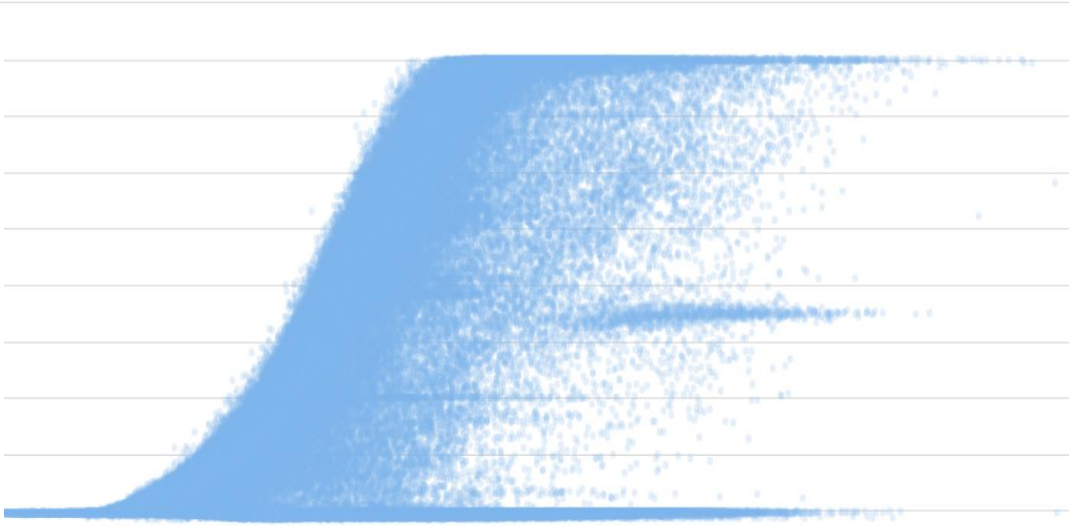

Mentimeter

Scan the QR code →
or
go to menti.com on your phone and
enter the code **7653 9791**

Task 19 Ice loss method

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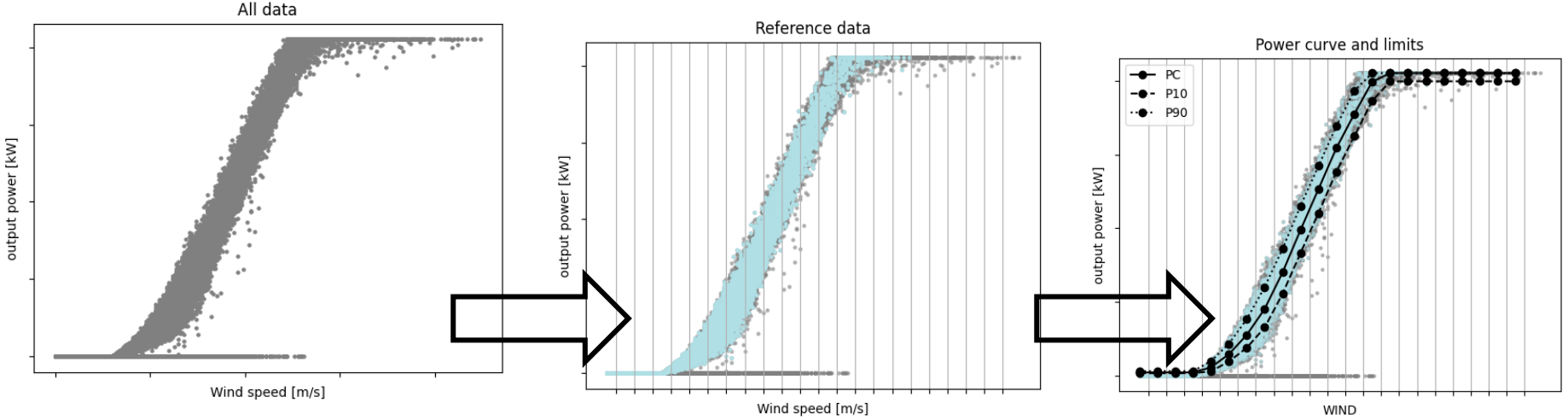
- Data needed:
  - Active Power [kW]
  - Wind speed [m/s]
  - Wind direction [°]
  - Temperature [°C]
  - Turbine status and information about alarms, stops, faults
  - IPS and Ice detection if available
- Preprocessing of data needed for all the steps
  - Curtailment, maintenance and other stops could be mistaken as production loss if not filtered out

Task 19 Ice loss method

IEA Wind TCP

- Generating reference power curve from historical data with binning method
  - Filter data based on temperature and turbine status to create a "safe" reference dataset. Site power curve and limits used for ice detection from this dataset



Task 19 Ice loss method

IEA Wind TCP

- Define start and end of icing events (default)
  - Operational production loss: active power below P10 for 30 consecutive minutes
  - Standstill production loss: active power below 0.05 *rated power for 20 consecutive minutes
- Calculate losses from start and end from icing events
  - Ice loss = Reference power – Active power

Detecting rotor icing from the power curve

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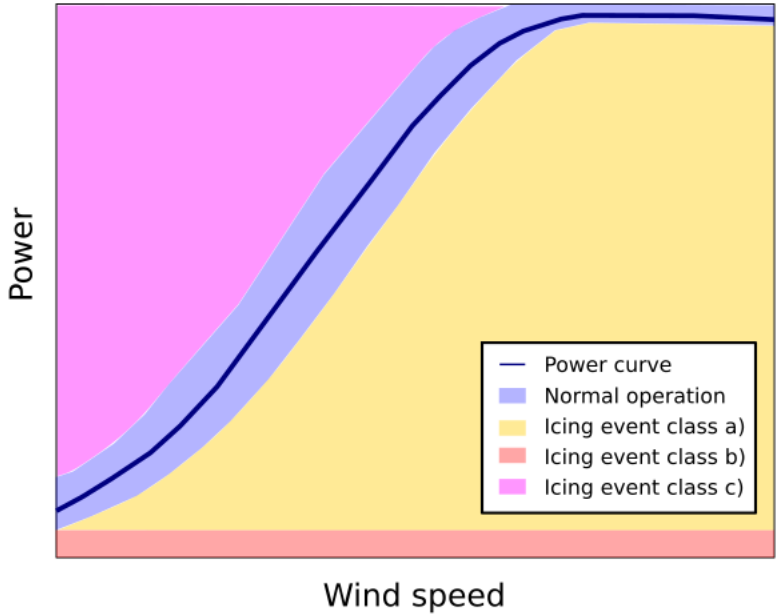
- Three main categories for icing:
- Icing event class a) - Operational icing loss
  - Still producing but with decreased production
- Icing event class b) – Standstill icing loss
  - No production or in idling
- Icing event class c) – Overproduction
  - Iced anemometer with lower windspeed measurement than expected production



What can we get from T19 IceLossMethod?

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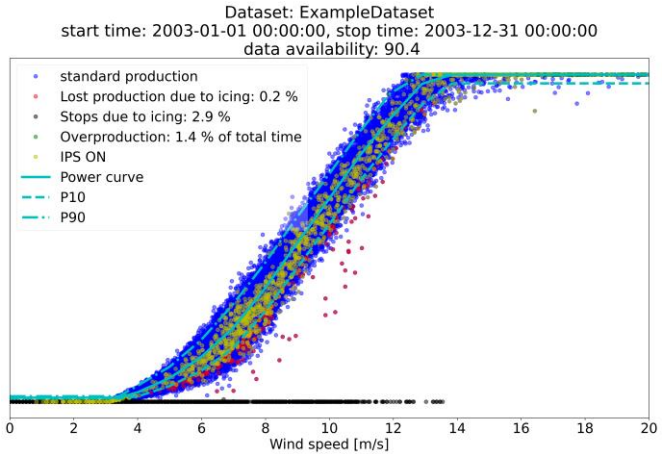
- Time series of icing losses categorised in operational, standstill loss.
- Summary of:
  - AEP ice loss MWh
  - Expected production
  - Available data
  - Other stops
  - Etc.

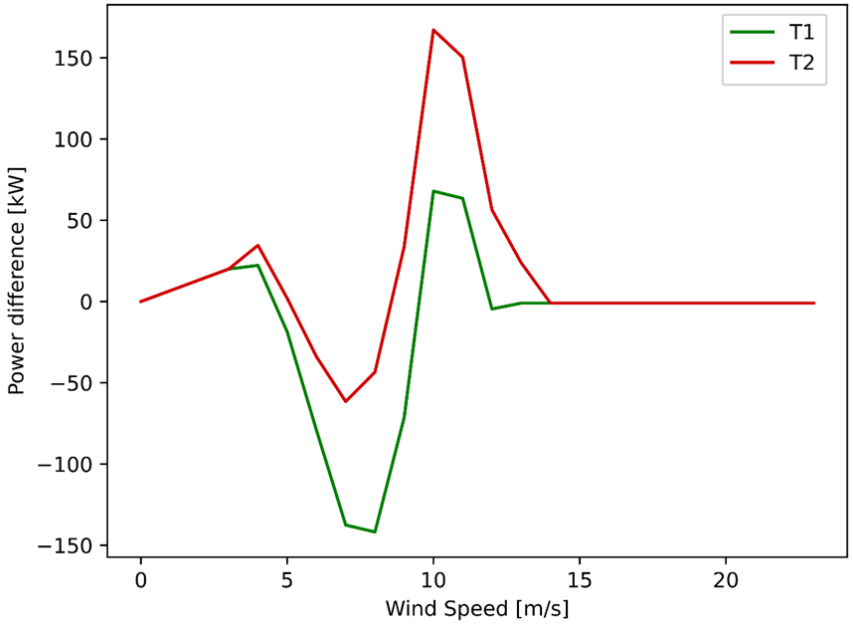


- Operational power curve (P50) with P10 and P90 curves
- Graph of the power curve with flagged events (icing loss, IPS, Ice detection)

Why bother to use the T19 Ice Loss Method?

IEA Wind TCP

- Standardize results
- More precise results
- An operational power curve includes more site specific effects than using manufacturers power curve
  - Wake, terrain etc.

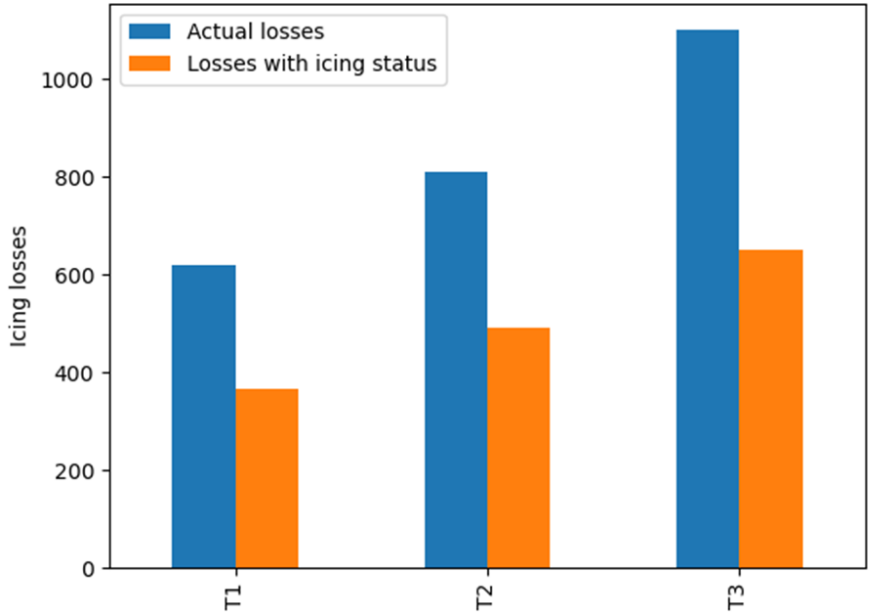


Fortin-Moreau & Roberge (2024), Icing Loss Estimation: Practical Insights for Accuracy. Winterwind 2024, Are, Sweden.

Why bother to use the T19 Ice Loss Method?

IEA Wind TCP

- Standardize results
- More precise results
- Cannot rely only on icing status from the turbine



Fortin-Moreau & Roberge (2024), Icing Loss Estimation: Practical Insights for Accuracy. Winterwind 2024, Are, Sweden.

Requirements

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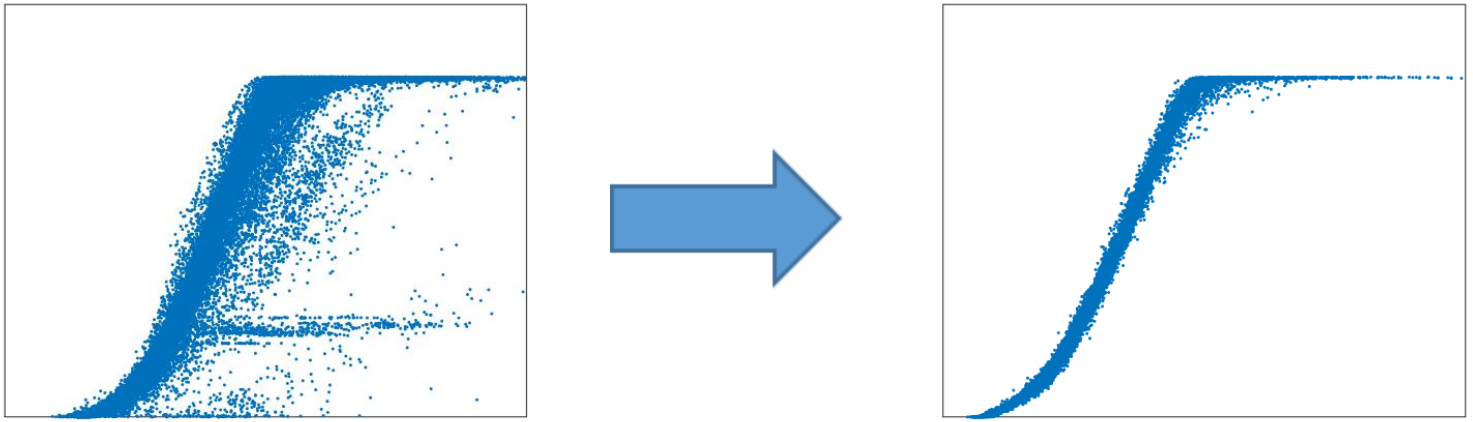
- Key: data clean up
- Untagged faults, maintenance and curtailment

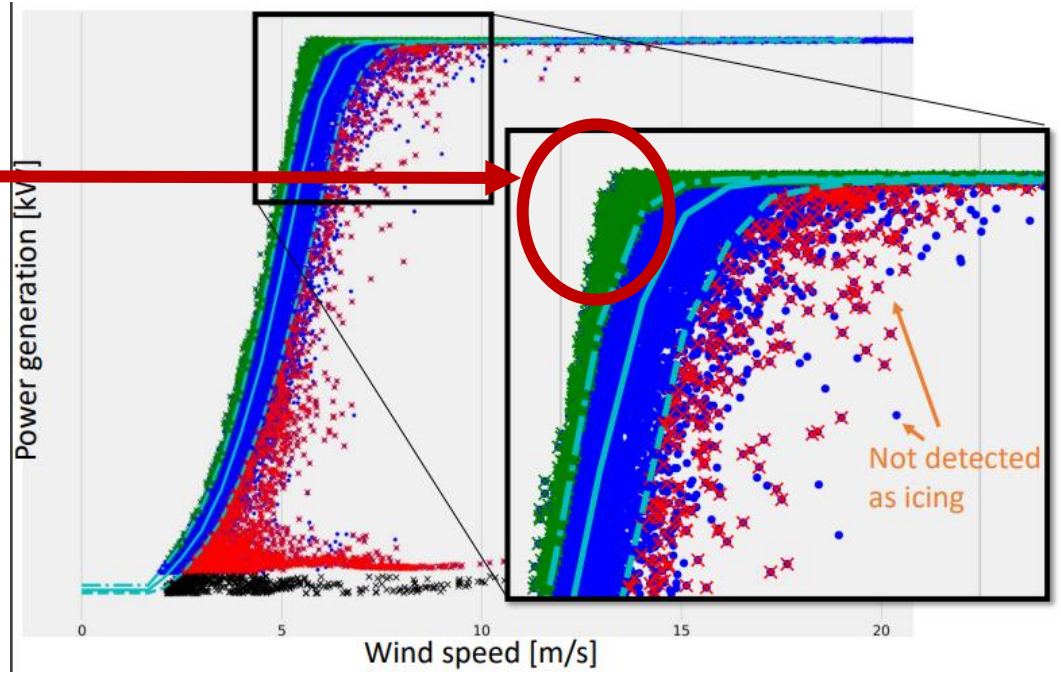


Fortin-Moreau & Roberge (2024), Icing Loss Estimation: Practical Insights for Accuracy. Winterwind 2024, Are, Sweden.

What happens if the data is not cleaned up properly?

IEA Wind TCP

- Skewed power curve
- Not icing event class c)

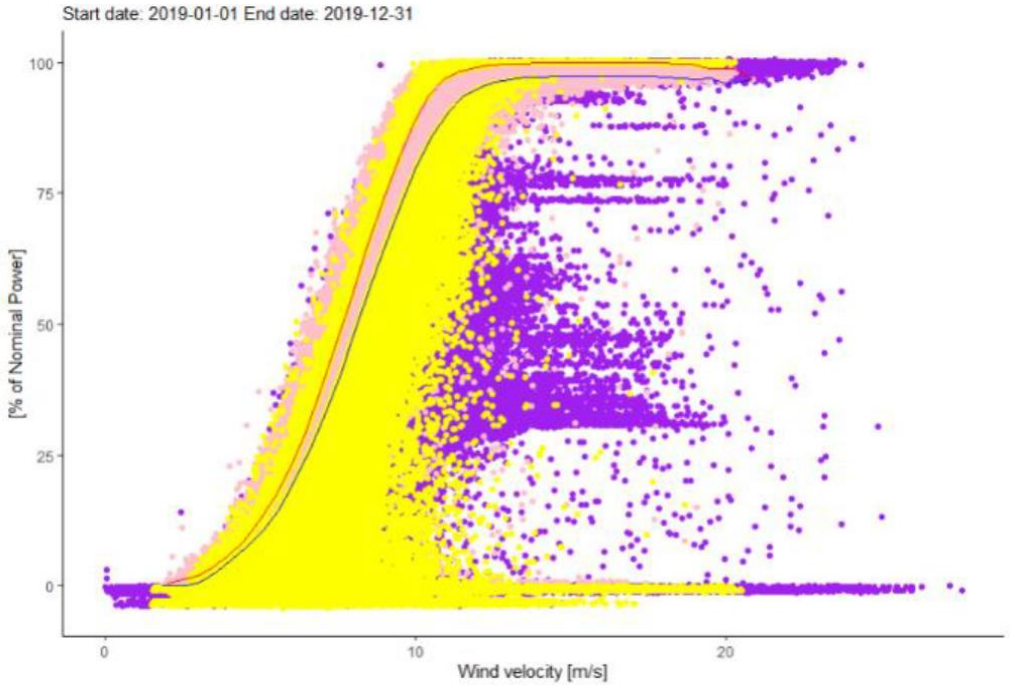


IGARASHI et al. (2022), Improvement of ILM calculation by pre-processing of the acquired data. Winterwind 2022, Skelleftea, Sweden.

Computing losses without filtering

IEA Wind TCP

- Lots of curtailment
- Narrow band of "normal production"
- Overestimation of losses



Canovas Lotthagen, Z. (2020). Defining, analyzing and determining power losses-due to icing on wind turbine blades.

Good example of filtering

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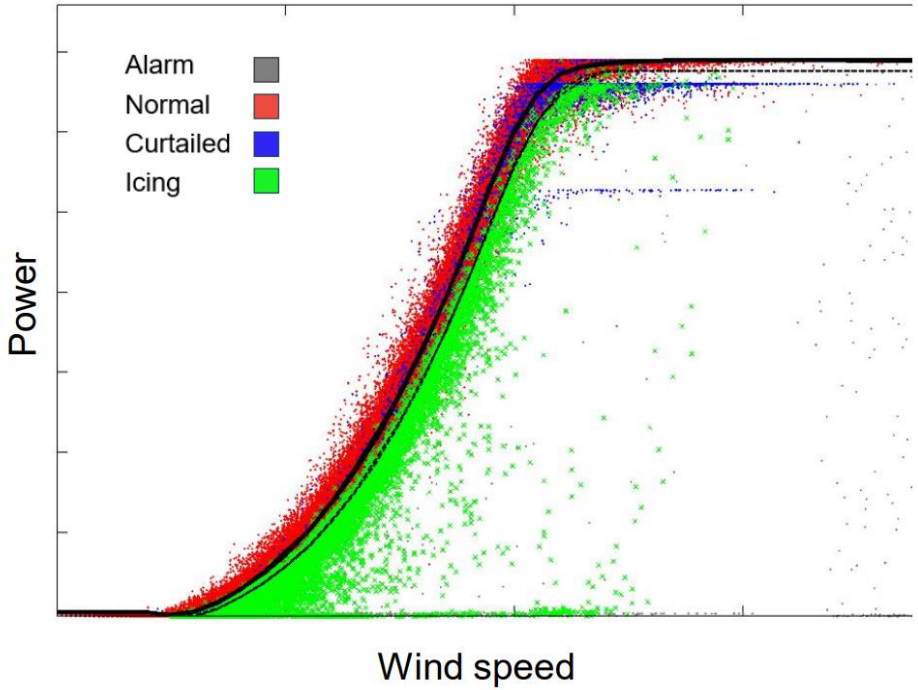
- Beyond the SCADA status



Molinder & Turkyilmaz (2023), Experiences analysing operational wind farms in cold climate . Winterwind 2023, Are, Sweden.

Summary

IEA Wind TCP

- Having a standardised way to assess production losses due to icing is important for comparability
- We have a well-established methodology to assess production losses and will gather input from the industry on how to improve it following this presentation during the workshop
- Pre-processing and filtering of data is key to a successful assessement
- We’re using the power curve as a detector of rotor icing resulting in production loss
- The operational power curve is used as a reference, to account for site variabilities
- We’re planning for a release of an updated version of the T19 Ice loss methodology – *stay tuned*

Thank you for your participation!

OA: Timo Karlsson, VTT (FI), timo.karlsson@vtt.fi

TM: Charles Godreau, Nergica (CA), cgodreau@nergica.com

IEA Wind TCP

How can we improve the methodology of assessing production losses?

Discuss in groups ~25 min + share highlights ~20min

Discussion points

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- Are you using power curve analysis to assess icing losses?
  - Are you using the T19 tool?
- Are you doing adaptations to the method specified in T19?
  - Like changing thresholds, adding new features etc
- **Are you missing some information from the methodology or want specific adaptations or added features?**
- **What are your use cases when you're using the tool?**
- **Have you had any issues with the tool?**
  - Somewhere specific where it fails or have obvious flaws?
- What are the challenges associated with assessing ice losses in general?

How can we improve the methodology of assessing production losses?

How can we distinguish between ”normal” performance loss and production loss?

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- Ice loss
- Wake loss
- Electrical loss
- Curtailment
- Temperature
- Other?

Temperature correction

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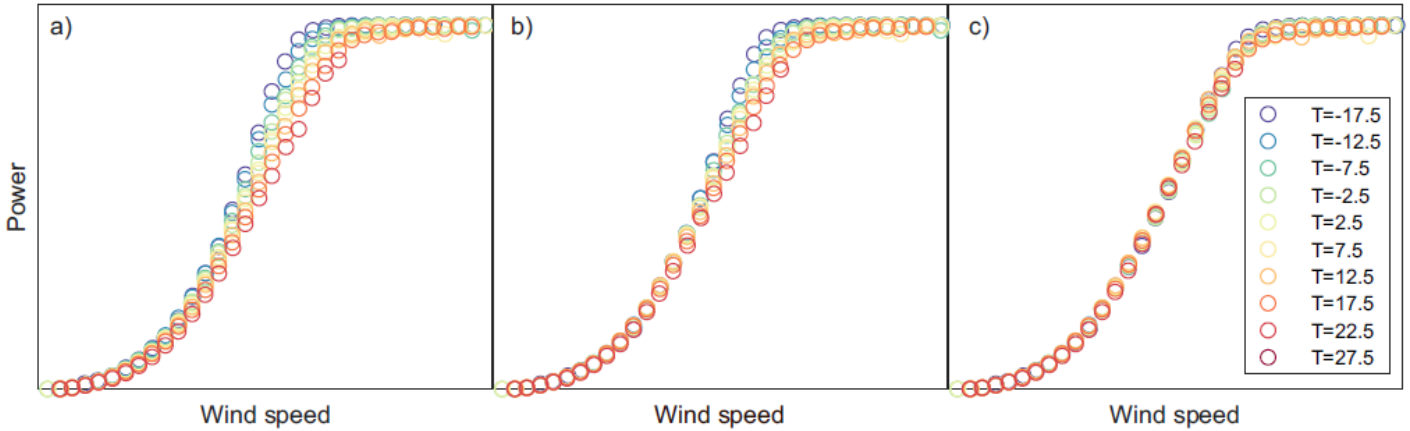
- T19 ice loss tool allows to correct the wind speed for air density
- For some sites this is not enough

a) Without correction

b) Air density

c) Air density +

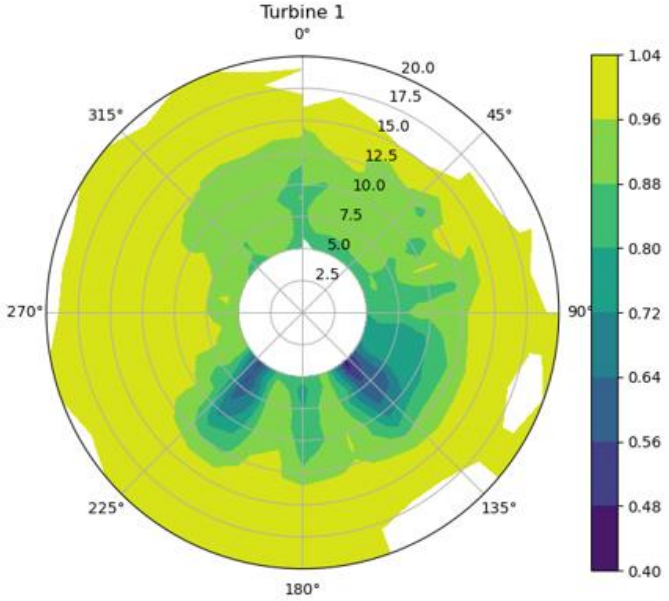


Roberge, P., Lemay, J., Ruel, J., & Bégin-Drolet, A. (2022). Towards standards in the analysis of wind turbines operating in cold climate–Part A: Power curve modeling and rotor icing detection. *Cold regions science and technology*, *196*, 103436.

Wind orientation dependance

IEA Wind TCP

- Wake effect: Extent of the effect more important offshore
- Topography effects onshore, small effect on the power curve
- Requires LOTS of data to correct



Temperature and wind orientation corrections

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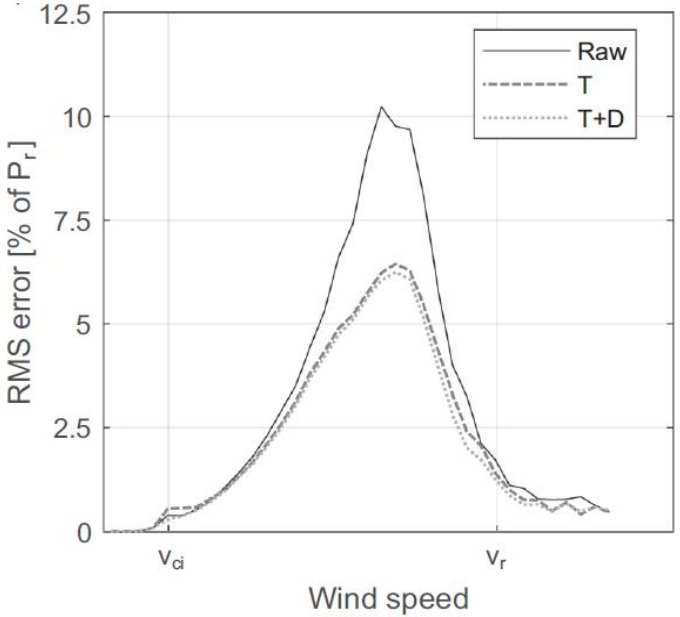
- How does correcting for those factors improve the expected power estimation?
- RMS error for each wind speed bin (cleaned data)
- Raw = no correction
- T = Temperature correction
- T + D = Temperature + wind orientation correction



Roberge, P., Lemay, J., Ruel, J., & Bégin-Drolet, A. (2022). Towards standards in the analysis of wind turbines operating in cold climate–Part A: Power curve modeling and rotor icing detection. *Cold regions science and technology*, *196*, 103436.

Caveats

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- The "cleanliness" of summer data determines the sensitivity of icing event detection (P10)
- Using summer data to give an indication of the quality of the power curve?

Discuss – 25 min in groups + share conclusions 20 min

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Develop your own methodology in a smaller groups for doing an assessment of icing losses and document it:

- What data do you need?

- Describe the steps you take in order to perform the assessment
  - Filtering of data: requirements
  - Reference power
  - Thresholds and conditions for losses: ice loss, wake, electrical, other
  - Output from the method
  - Validation for all steps

- **Do you have any suggestions on how to improve the current methodology?**

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Thank you for your participation!

OA: Timo Karlsson, VTT (FI), timo.karlsson@vtt.fi

TM: Charles Godreau, Nergica (CA), cgodreau@nergica.com

Appendix

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T54 – Work plan 2025-2029

Content of work plan 2025-2029

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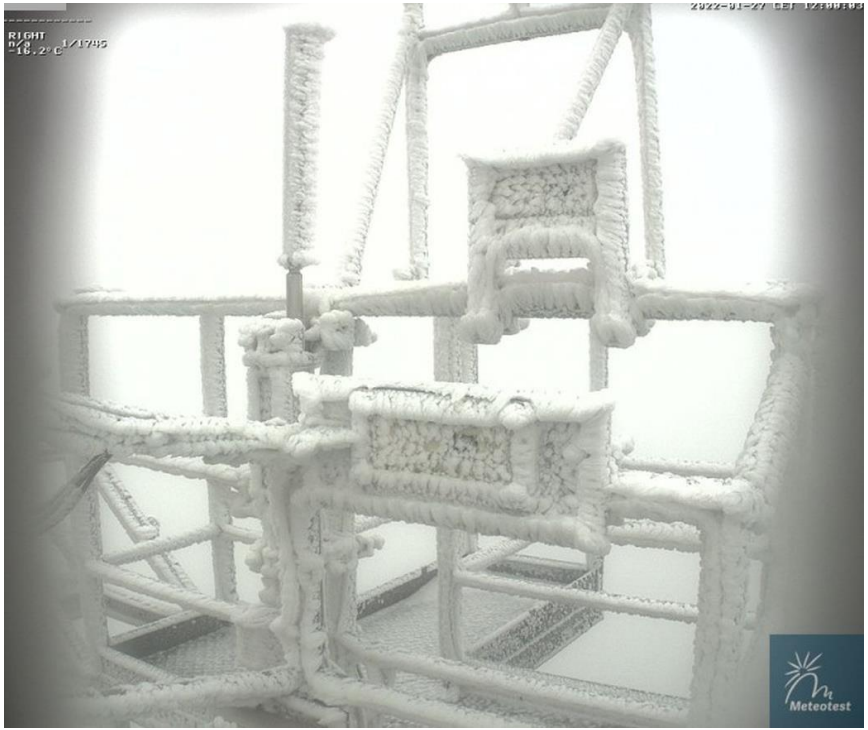
- Operational strategies
- Managing the ice throw risk
- Uncertainty
- Wind turbine and blade heating performance
- Offshore wind
- Icing events complexity
- Climatic wind tunnel validation
- Dissemination



Operational strategies

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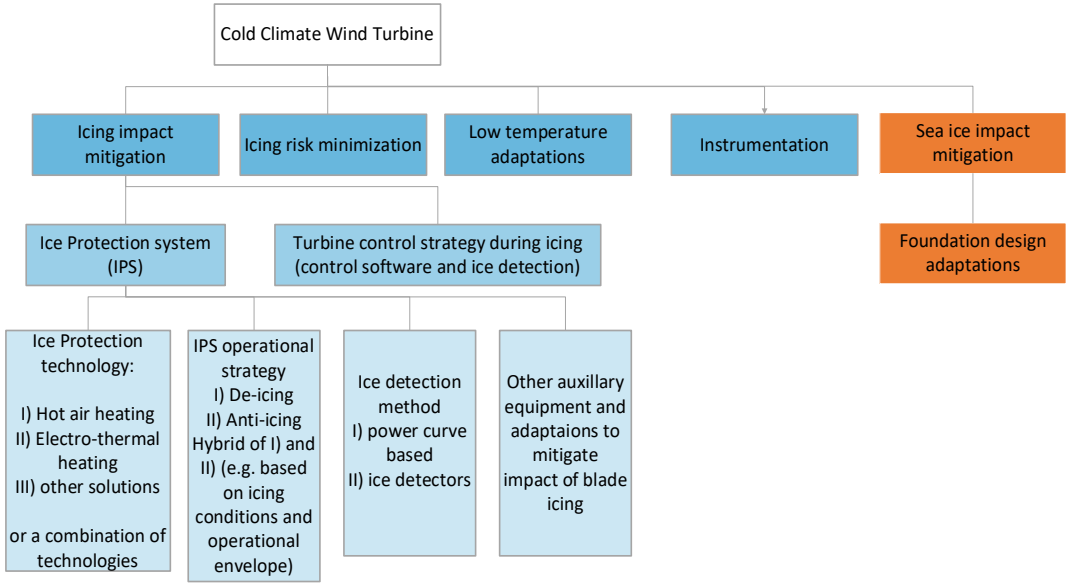
- Operating wind turbines in cold climate is a balancing act:
- Four objectives
  - Safety due to ice throw
  - Optimising production
  - Revenue based optimization
  - Lifetime preservation
- Collect industry experience based on that suggest KPIs to monitor in cold climates
- Recommended practices for operation



Ice throw risk management

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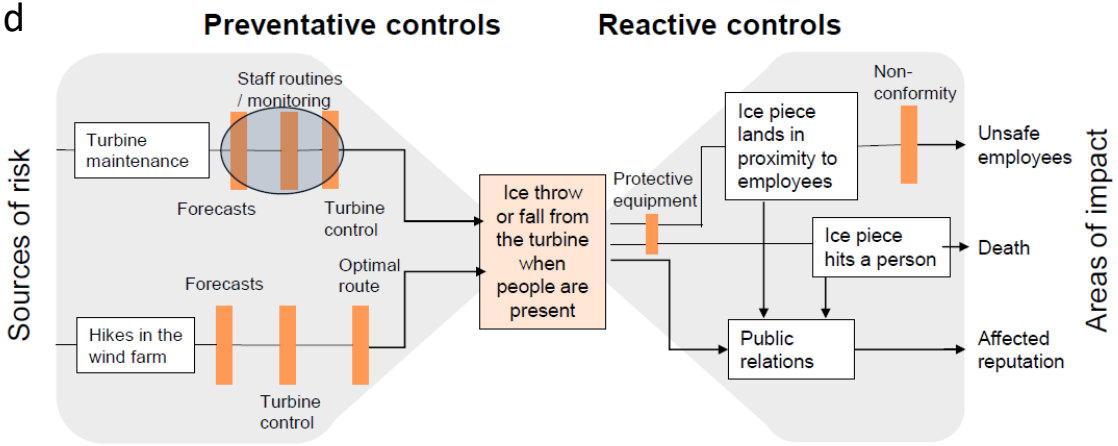
- Local laws/rules differ on how to deal with ice throw risk
- Collect risk management strategies and experiences from different countries, compile best practises
- Effect of annual variability on risk
- Effect of blade heating and other mitigation technologies on ice throw risk
- Other risk reduction technologies
- Feed into recommended practices



Uncertainty

IEA Wind TCP

- Icing includes uncertainty of many aspects of wind power production
  - pre-construction and short-term forecast uncertainties for icing occurrence
  - geographic variability
  - propagation of uncertainties through the model chain.
- Develop
  - uncertainty metrics for icing effects on wind resources, to update IEC standards
  - reporting framework to use such metrics for communicating pre-construction icing impacts
  - formulations based on these metrics for uncertainty estimates
    - Use these to improve ice throw risk estimation

Offshore

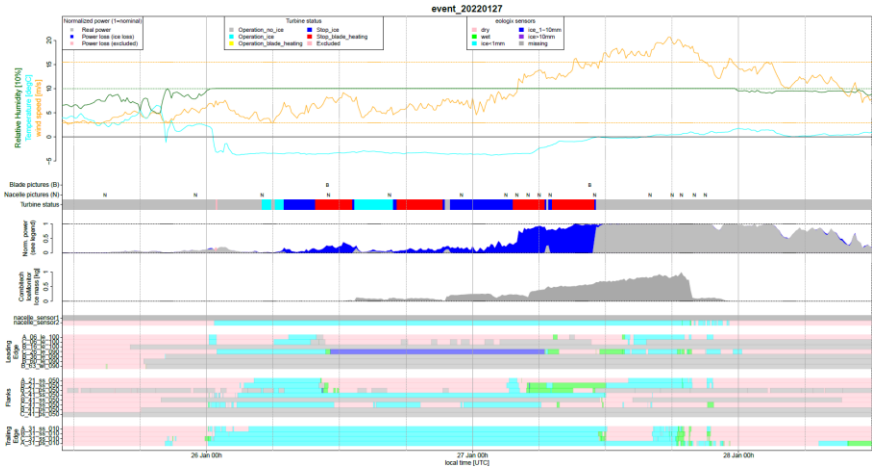
IEA Wind TCP

- Sea ice
  - Collect best practices from the industry and state-of-the-art from research
    - Assessment
    - Mitigation
- Atmospheric icing offshore?
  - Evaluation of weather models at sea, near-shore sites
- Sea spray icing
  - Effect on blades?

Icing events complexity

IEA Wind TCP

- Effect of icing on the blades varies
  - between different regions of the world,
  - between different icing events at one particular site and even
  - during a single icing event
- We aim at publishing a document containing:
  - review of the current knowledge about icing events complexity and variability
  - overview of the concrete applications in wind energy for which this complexity is most relevant
  - overview of future needs in terms of research and technical solutions
  - definition of “best practices” for dealing with icing events complexity in different concrete applications.

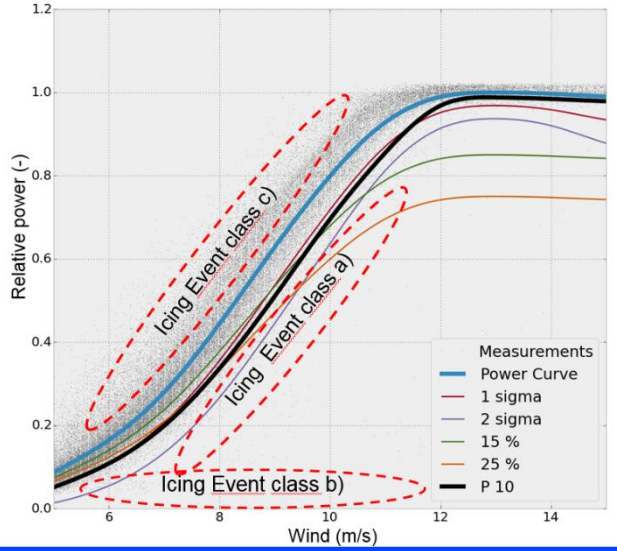


Wind turbine and blade heating performance

IEA Wind TCP

- Ice classification
  - Originally from 2011, revisit needed to take into acccount technical progress and available data
- Icing loss evaluation
  - Open source software tool
  - Industry workshop on topic to collect experience and requirements

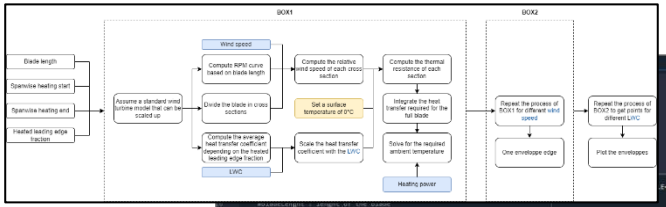
IEA Ice Class	Duration of Meteorological Icing [% of Year]	Duration of Instrumental Icing [% of Year]	Production Loss [% of AEP]
5	>10	>20	>20
4	5-10	10-30	10-25
3	3-5	6-15	3-12
2	0.5-3	1-9	0.5-5
1	0-0.5	<1.5	0-0.5

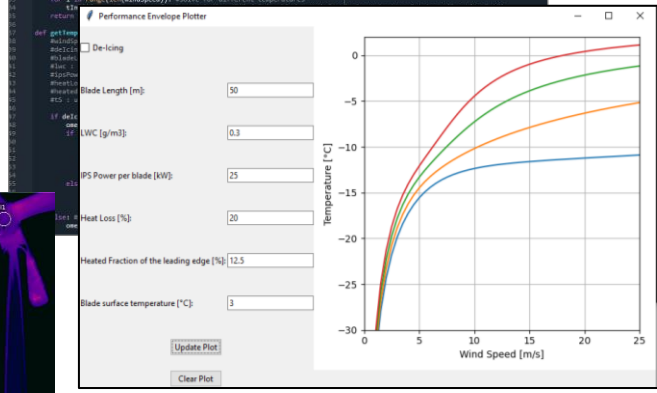


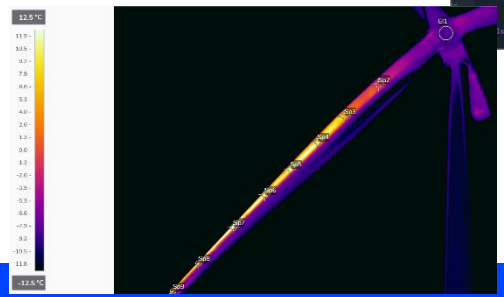
Wind turbine and blade heating performance cont.

IEA Wind TCP

- Blade heating performance
  - Improve on model released during phase 1
  - Additional validation with real-world data
  - Release as open source software
- Blade heating performance validation
  - Recommendations as a report
  - Framework for field validation of blade heating system performance



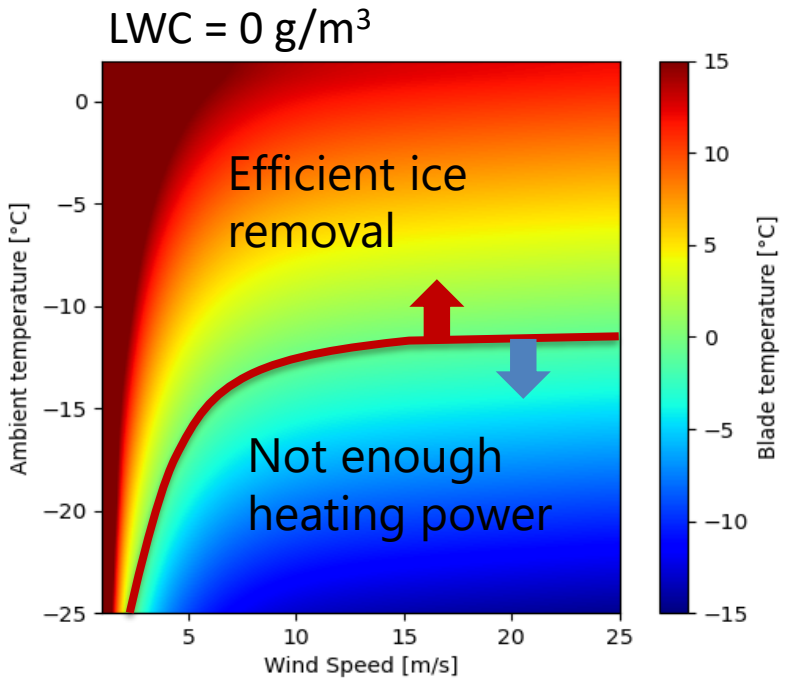




Some highlights from previous term

IEA Wind TCP

- Blade heating
  - Defined the operational envelope
  - First release of blade heating model (open source software)
  - Workshops at conferences to develop validation process together with industry
- Operating wind turbines in very cold temperatures
- Icing events database



Some highlights from previous term

- Uncertainty
  - Pre-construction icing uncertainty
    - Spatiotemporal variation in icing
    - Differences in ice loading in different climates
- Development of ice throw tool
- Icing Wind tunnel
  - Round robin validation study