Icing impacts on electricity grids and markets

IEA Wind Task 54

Winterwind 2024

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IEA Wind TCP

IEA Wind Technology collaboration platform

IEA Wind TCP

- Research collaboration platform operating under International Energy Agency (IEA)
- Platform for research collaboration
- Goal is to disseminate research in wind energy
- Promote international collaboration

IEA Wind TCP Contracting Parties

Research tasks at end of 2022

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- Task 11 - Wind Strategy, Collaboration & Outreach on Urgent Topics of Wind Energy Research (Wind SCOUT)
- Task 25 - Design and Operation of Energy Systems with Large Amounts of Variable Generation
- Task 28 - Social Acceptance of Wind Energy Projects
- Task 30 - Offshore Code Comparison Collaboration, Continuation, with Correlation and unCertainty (OC6)
- Task 34 - Working Together to Resolve Environmental Effects of Wind Energy (WREN)
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- Task 46 - Erosion of Wind Turbine Blades
- Task 47 - TURBulent INflow Innovative Aerodynamics (TURBINIA)
- Task 48 - Airborne Wind Energy
- Task 49 - Integrated Design on Floating wind Arrays (IDeA)
- Task 50 - Hybrid Power Plants
- Task 51 - Forecasting for the weather-driven Energy System
- Task 52 - Large-Scale Deployment of Wind Lidar
- Task 53 - Wind Energy Economics
- **Task 54 - Cold Climate Wind Power**

Task 54 – Cold climate wind

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- *Mission:*
  - *Improve large scale deployment of cold climate wind power in a safe and economically feasible manner*
- Methods:
  - Focus on standardization, reference solutions, gathering and disseminating information
  - Provide tools to better understand and estimate the risks involved in cold climate wind

- Particpating countries
- Current term ends at end of 2024

Motivation

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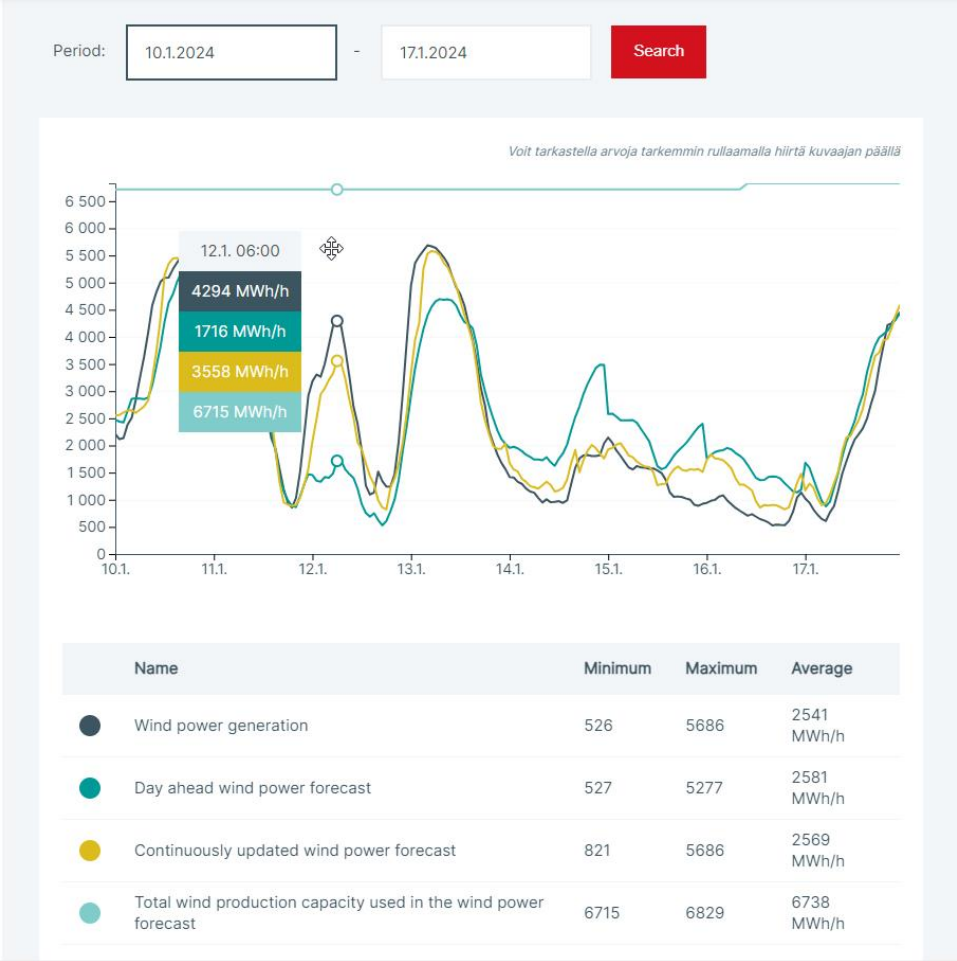
- Increase in wind power share in cold climate markets
- High profile incidents with winter storms
- High electricity prices in winter
- Increase in balancing costs
- Cut off of Russian imports

➔Increased interest in efficiency of wind power production in cold climate

System overview

- Icing events often geographically large
- Impact large number of wind power sites at the same time
- Growing wind power share ↑↑ these impacts
- Limited balancing capacity
- Icing loss > balancing capacity ?



Data source: Fingrid, https://www.fingrid.fi/en/electricity-market-information/wind-power-generation/

Icing overview

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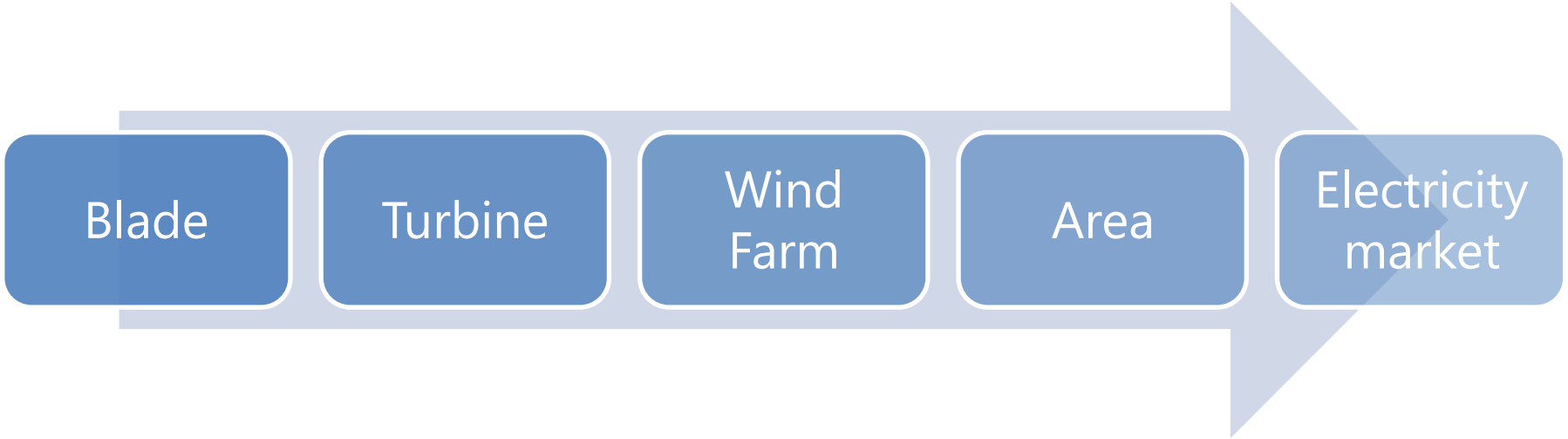
- Needed
  - A vertical look at icing how it impacts the entire chain of operations in wind power
- From individual turbine blade all the way to electricity market



Icing overview - Turbine

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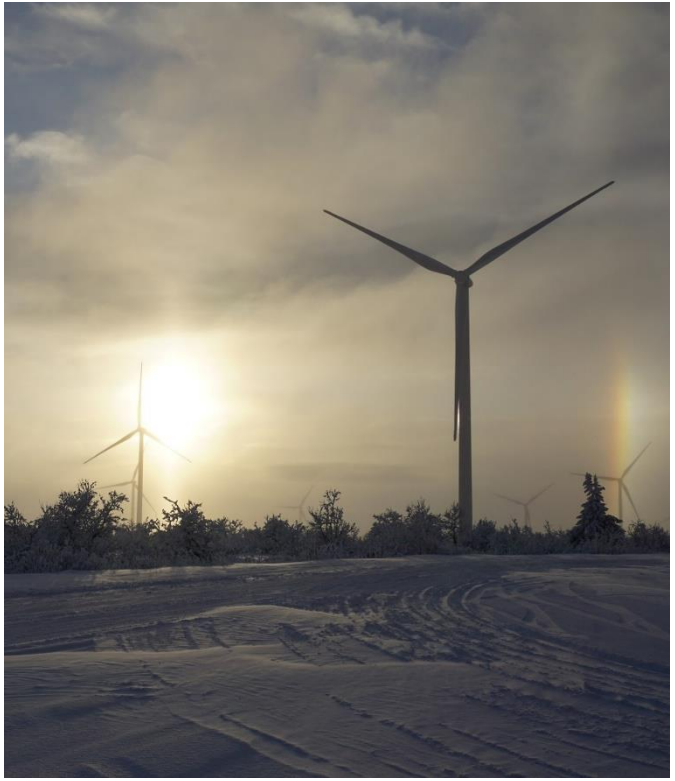
- Turbine loses power due to icing – aerodynamic losses
- Turbine icing is quite well studied
- Mitigations at turbine level
  - Heating
  - Detection
  - Control adjustments
- Mitigations not perfect, increased uncertainty of output



Mitigations

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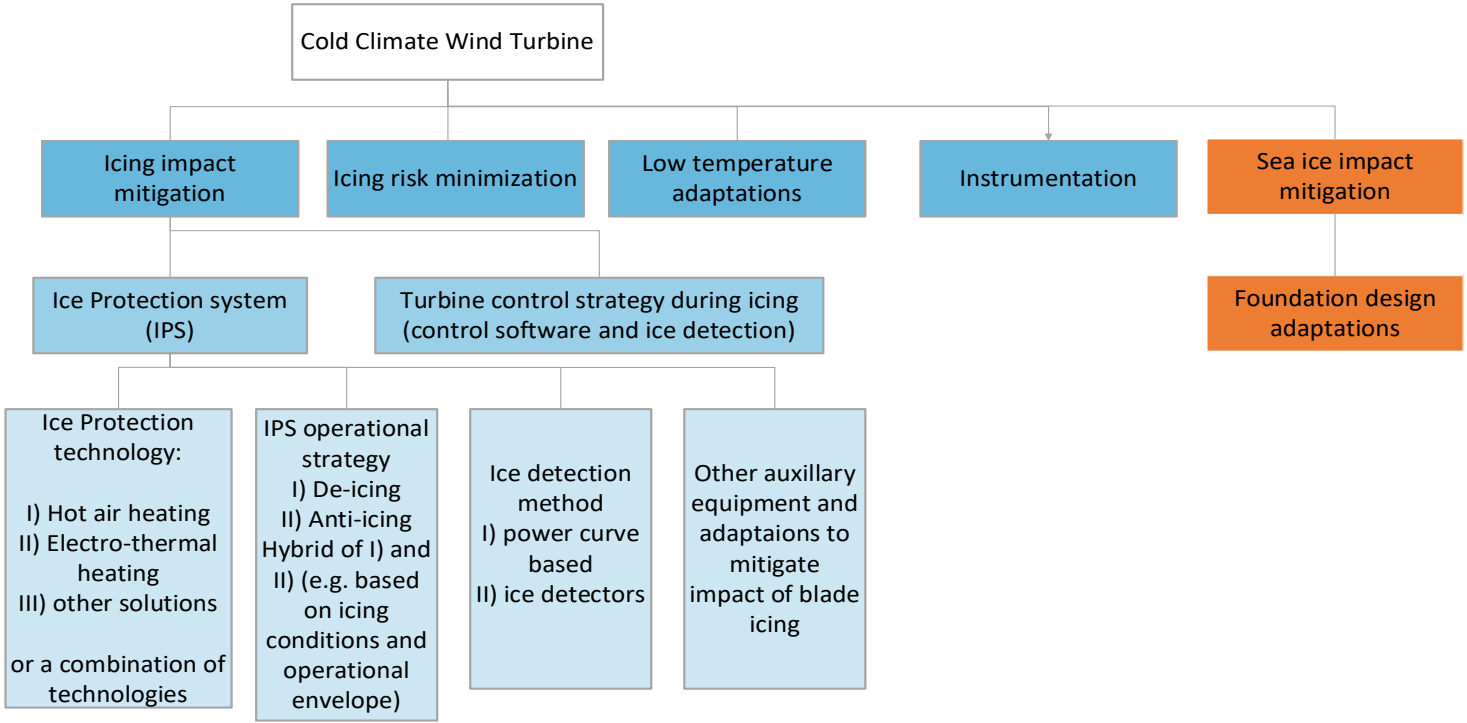
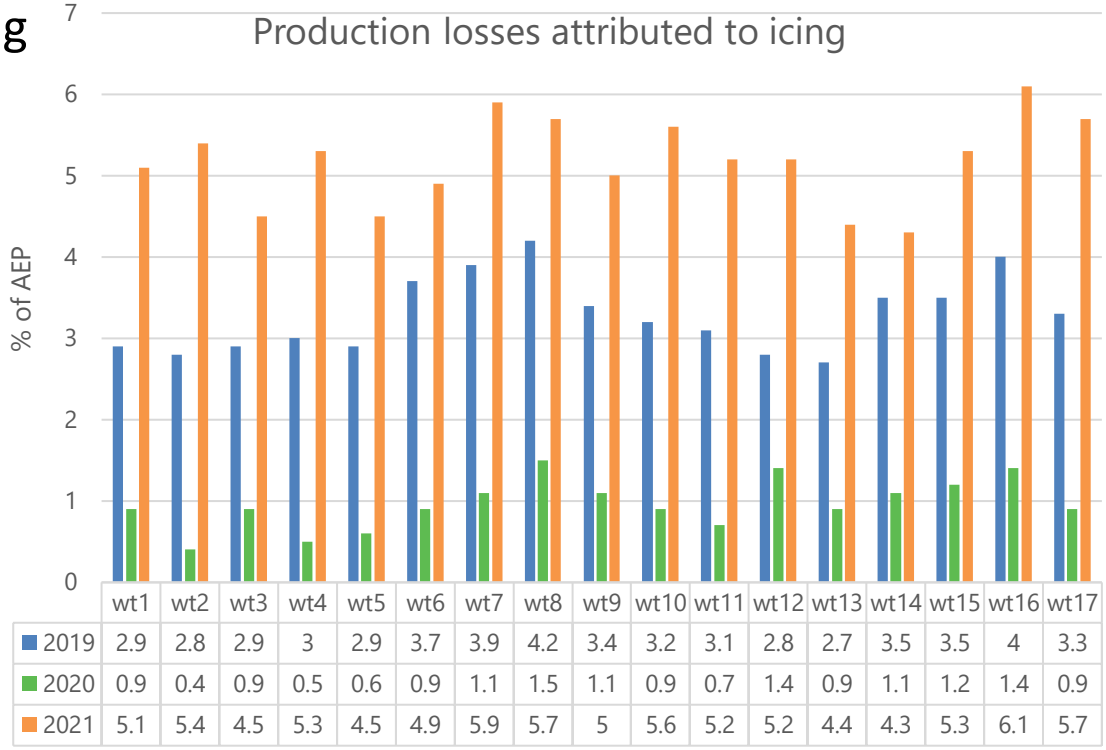


Icing overview – site

- Turbine output affected by icing
- Different impact at different turbines
- Compounding uncertainty



	wt1	wt2	wt3	wt4	wt5	wt6	wt7	wt8	wt9	wt10	wt11	wt12	wt13	wt14	wt15	wt16	wt17
2019	2.9	2.8	2.9	3	2.9	3.7	3.9	4.2	3.4	3.2	3.1	2.8	2.7	3.5	3.5	4	3.3
2020	0.9	0.4	0.9	0.5	0.6	0.9	1.1	1.5	1.1	0.9	0.7	1.4	0.9	1.1	1.2	1.4	0.9
2021	5.1	5.4	4.5	5.3	4.5	4.9	5.9	5.7	5	5.6	5.2	5.2	4.4	4.3	5.3	6.1	5.7

Cost of icing

- Transeferring losses to revenue
- Using actual electricity prices from the market
- The cost is of icing is amplified by increased electricity price in winter time
- Balancing costs can be avoided, this is worst case

Year	Balancing cost %	Icing loss cost %	Production loss %
2019	4.9 %	6.1 %	5.3 %
2020	2.4 %	3.8 %	2.6 %
2021	7.8 %	9.7 %	6.6 %
2022	9.1 %	10.8 %	6.3 %
Average	**6.4 %**	**8.0 %**	**4.9 %**

System level

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- Consequence
  - Large scale losses for regional icing events
  - Unprepared for losses increase balancing requirements
  - Limit on the largest allowable icing loss

- Wind resource, icing events
  - forecasting
  - similarity to low wind effects
  - uncertainty of the forecast, complexity of the turbine response in real time

Wind turbine icing impact on electricity market

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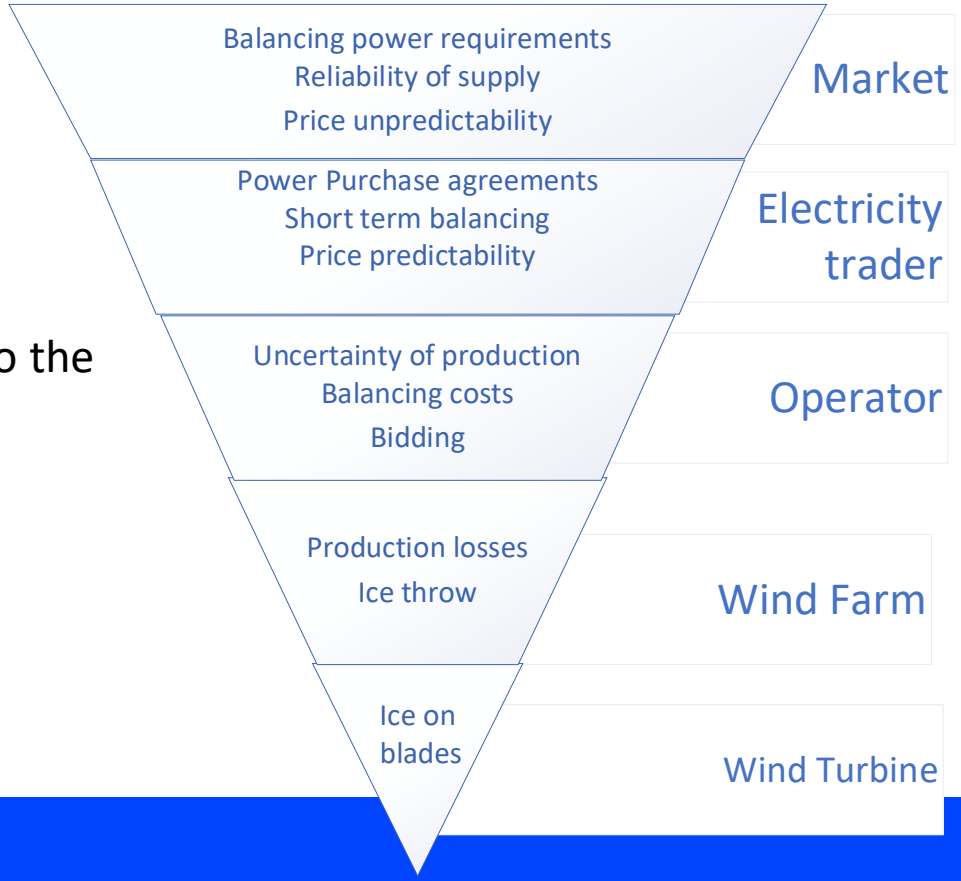
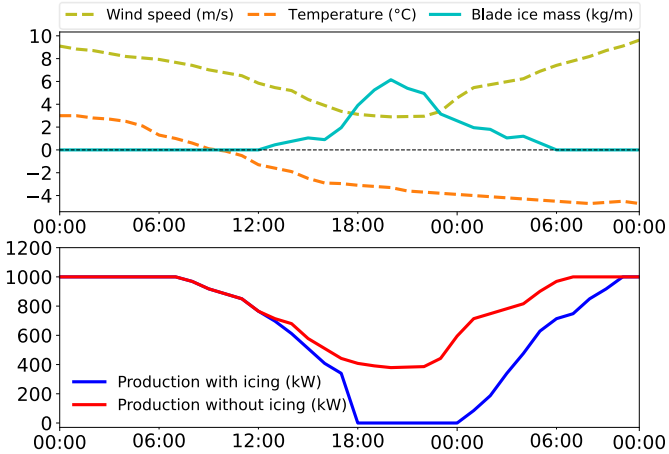
- Icing impact operations at all levels
  - Icing
    - happens at turbine level
    - compounding uncertainty into the electricity system
  - Solutions
    - Technological solutions,
    - turbine level modifications



Mitigations

- Forecasting
  - Icing
    - Safety
      - Notifying public
      - Work place safety
    - Production
      - Decrease power production uncertainty
  - Iced turbine behaviour
    - Control blade heating
- Integration of forecasting into operations



*Example of **production forecasts** accounting for the effect of blade ice (lower figure). In this case, the blade ice mass (light blue color in the upper figure) causes a complete shutdown of the turbine.*

System level

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- Research requirements
  - Forecasting
    - Capability exists
    - Metorological icing → Rotor icing → production losses
  - Need a comprehensive view on all of this
- Uncertainty
  - Reduction of uncertainty of the power curve
  - Reduction of uncertainty of next day production estimate
  - Integration of this into production systems.

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