Retrofit of IPS – can we estimate the potential gain based on SCADA and model data?

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Introduction

- Icing losses cause large costs, especially in combination with often high imbalance costs during major icing events.
- **Objective**: Assess the expected icing losses with a **retrofitted** Ice Protection System (IPS) based on historical operational data and model data for a specific wind farm in Sweden.

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- **Pre-construction** – KVT IceLoss assessment

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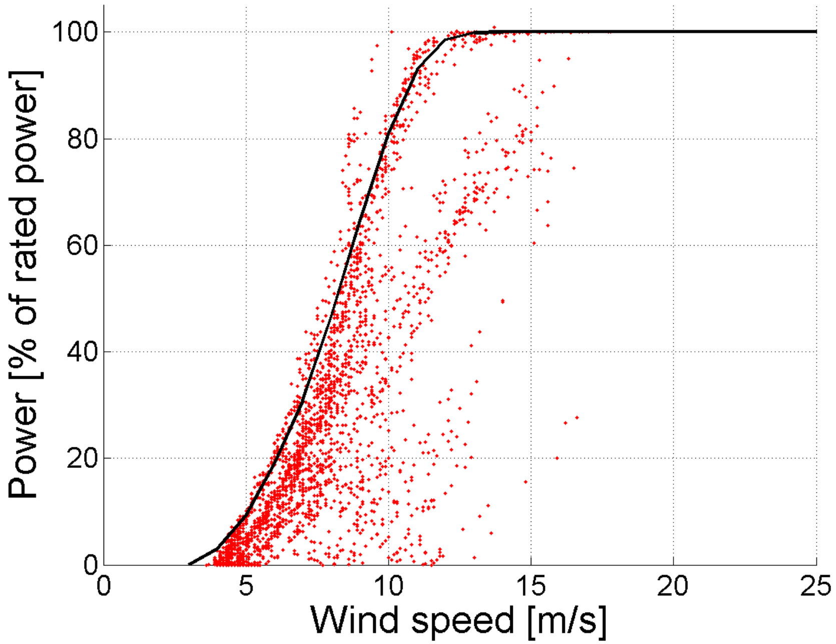
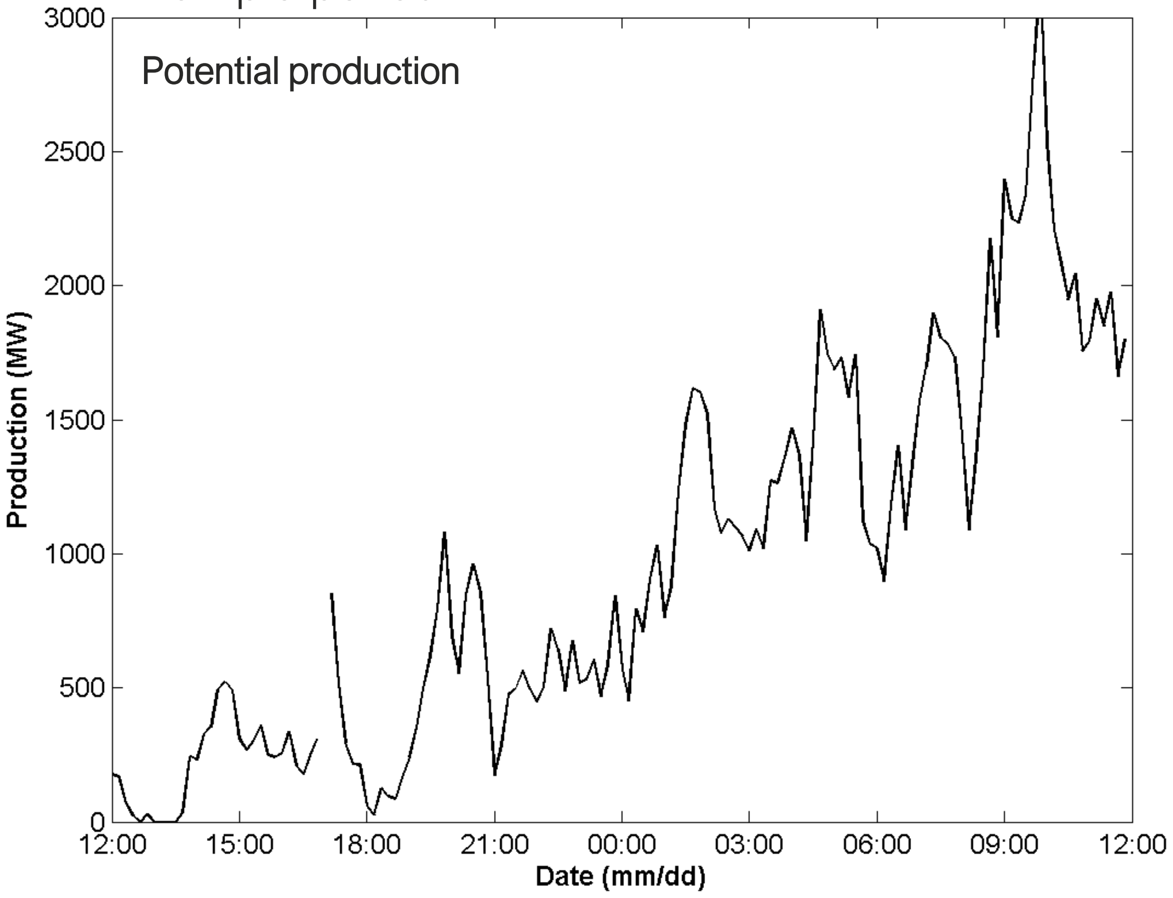
- **Pre-construction** – KVT IceLoss assessment
- **Post-construction** – SCADA data + KVT IceLoss model, *assuming an automatic system*



SCADA Data Analysis – estimating experienced icing losses

- **Determine potential production**:
  - **Reference power curve:** Periods when turbines are not in full performance are filtered out.
  - **Potential production:** Based on nacelle wind speeds and reference power curve

Example period



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SCADA Data Analysis – estimating experienced icing losses

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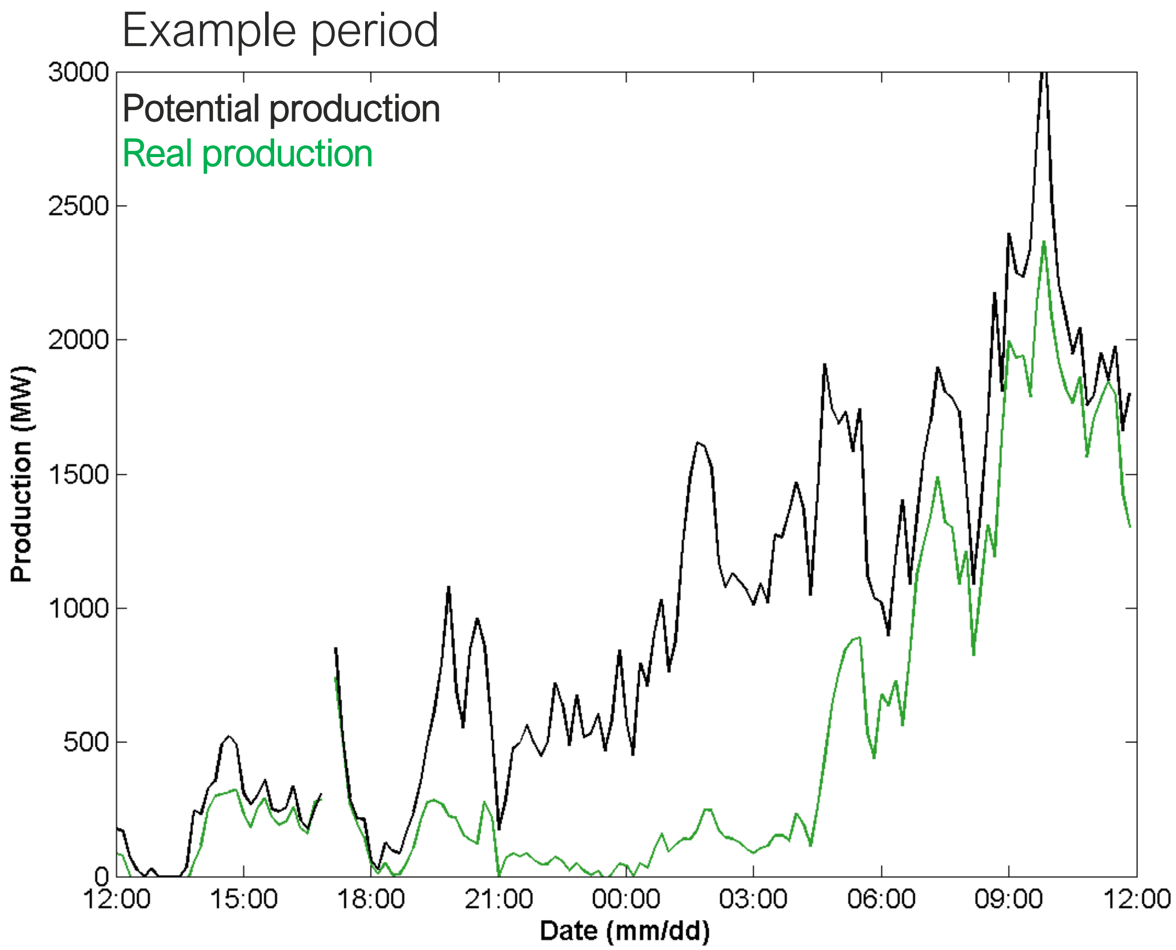
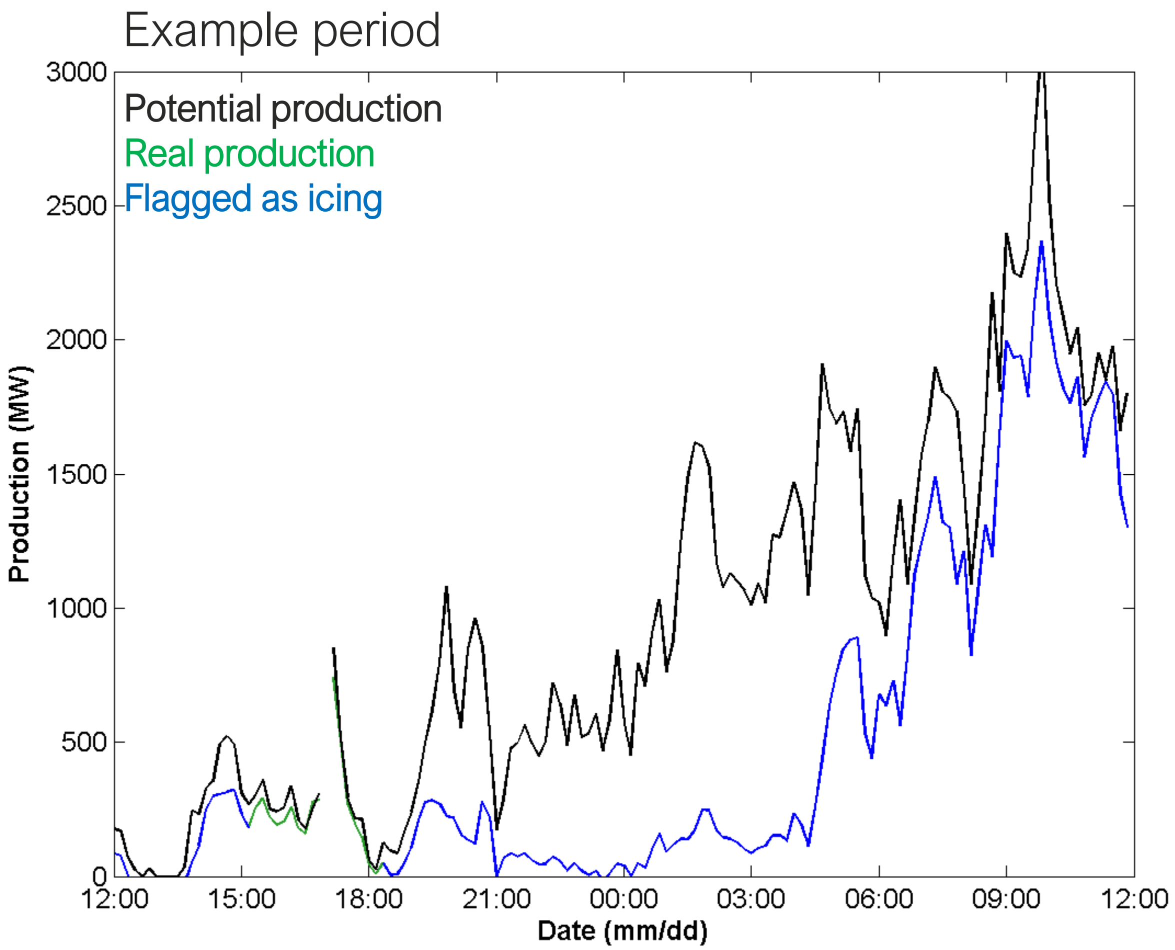


SCADA Data Analysis – estimating experienced icing losses

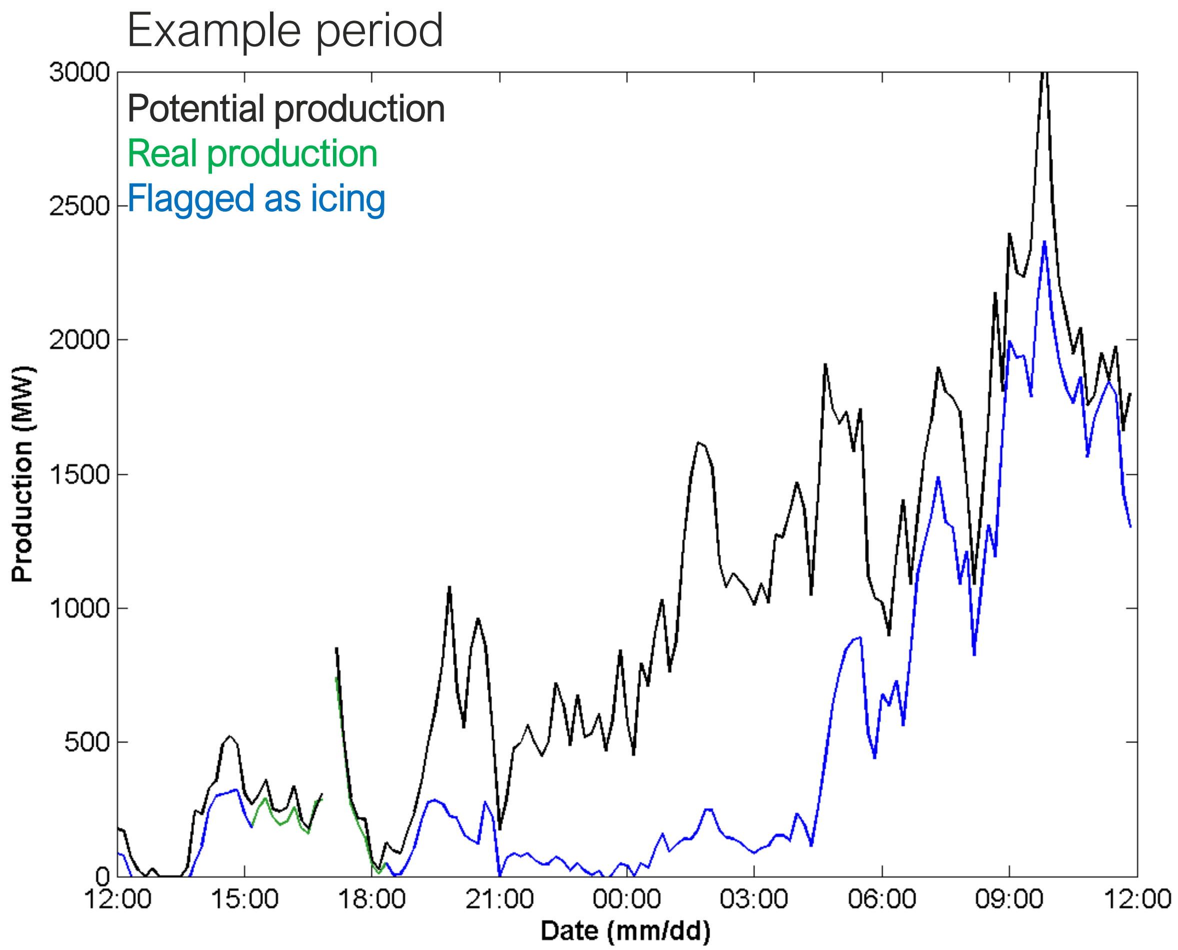
- **Determine potential production**:
  - **Reference power curve:** Periods when turbines are not in full performance are filtered out.
  - **Potential production:** Based on nacelle wind speeds and reference power curve
  - **Real production:** From SCADA observations
- **Finding Icing Periods**:
  - Alarm codes associated with icing.
  - Task 19 method: Periods influenced by icing using the reference power curve and temperature below 2°C.
  - Manual inspection of data.



SCADA Data Analysis – estimating experienced icing losses

Experienced loss at the wind farm 2023-2024:

- 11.8% of AEP

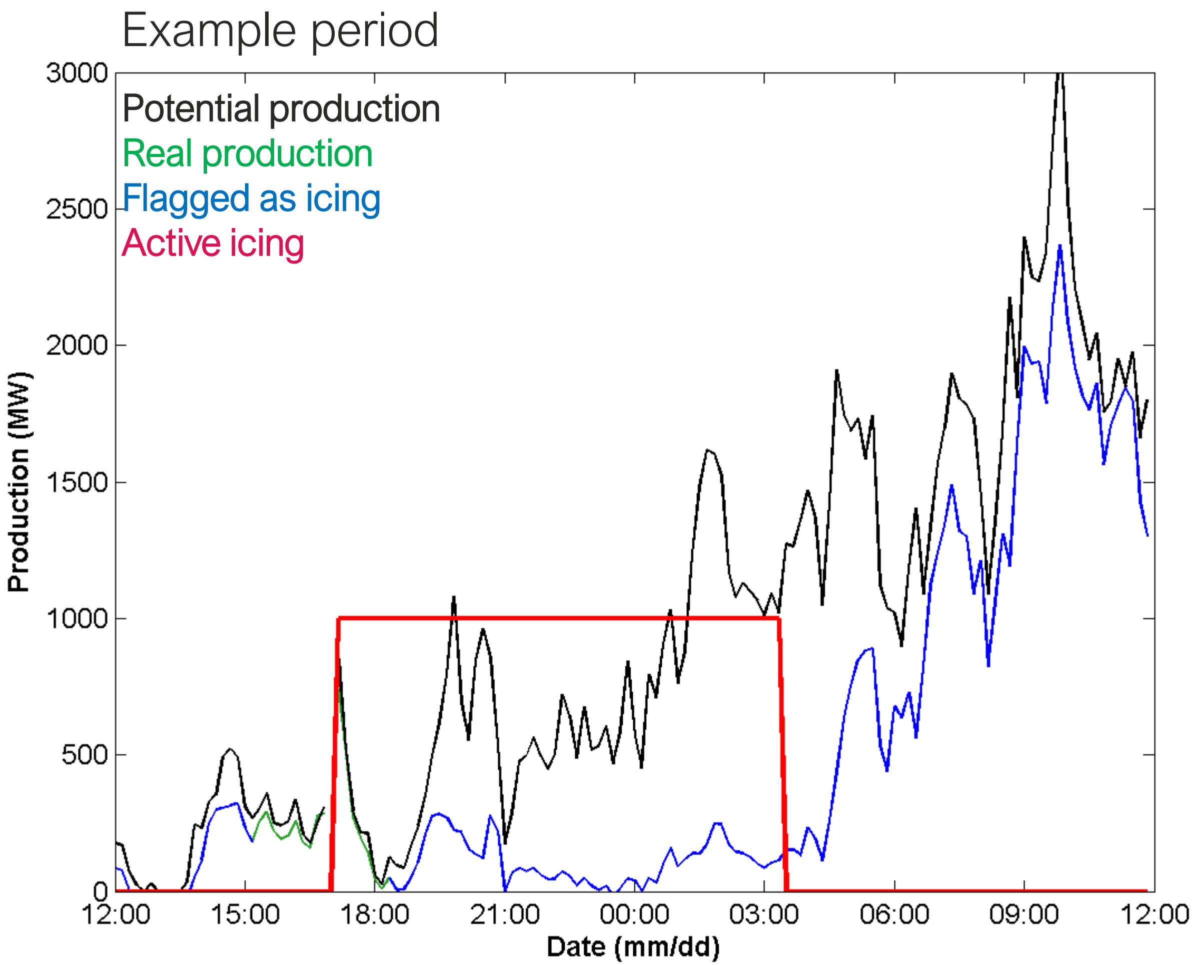


Modelling the IPS - Methodology

- **Heating cycle Assumptions**:
  - **De-Icing**: Turbine stopped during cycle.
  - **Anti-Icing**: Turbine operate with reduced production during cycle.
  - Anti-Icing applied if within IPS envelope (depend on wind speed and temperature)
  - Cycle length, recovery rate ….

Modelling the IPS - Methodology

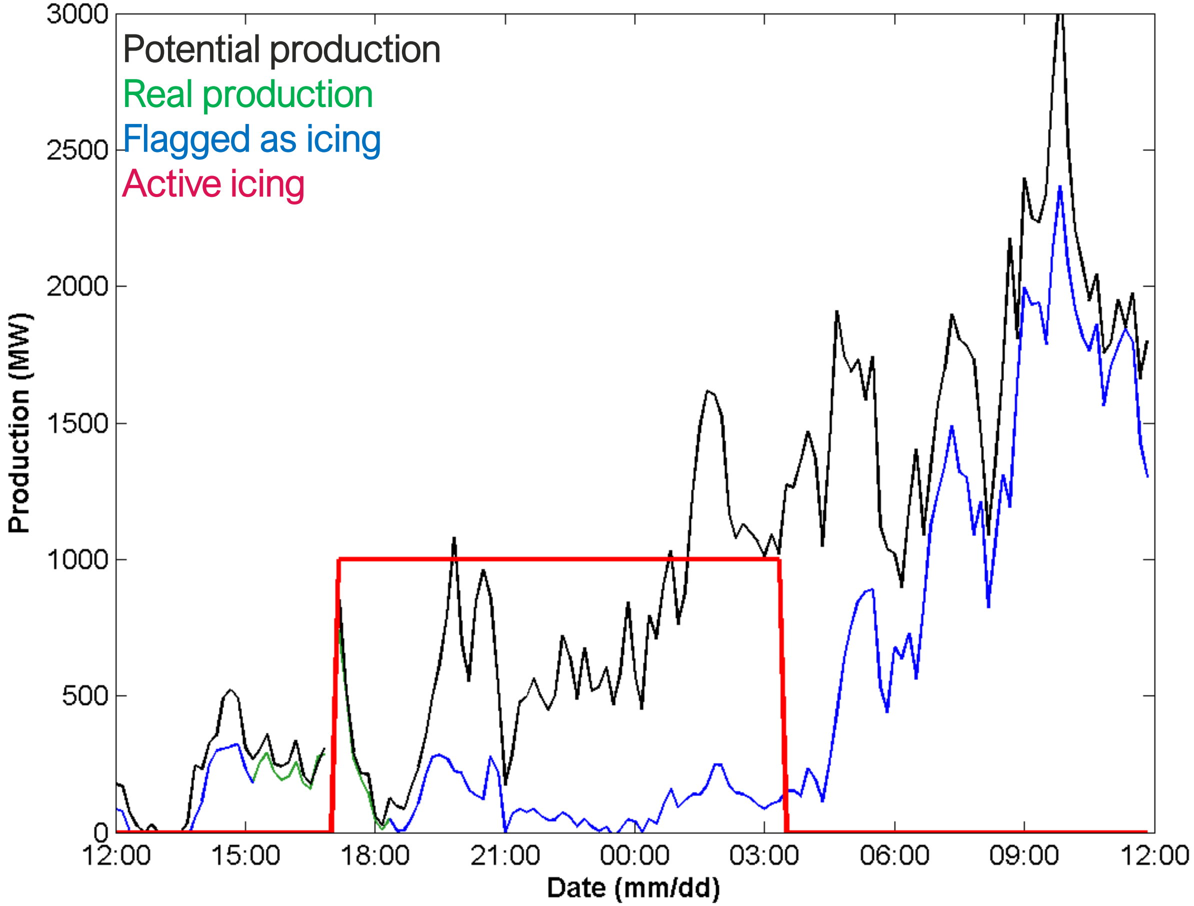
- **Determine icing build-up periods:**
  - Need to be considered to assess the success of an IPS each icing period
  - KVT IceLoss model used to find periods with ice build up



Modelling the IPS - Methodology

- **Success of a heating cycle depends on:**
    - Temperature and wind speed conditions (IPS envelope)
    - Icing conditions

Example period



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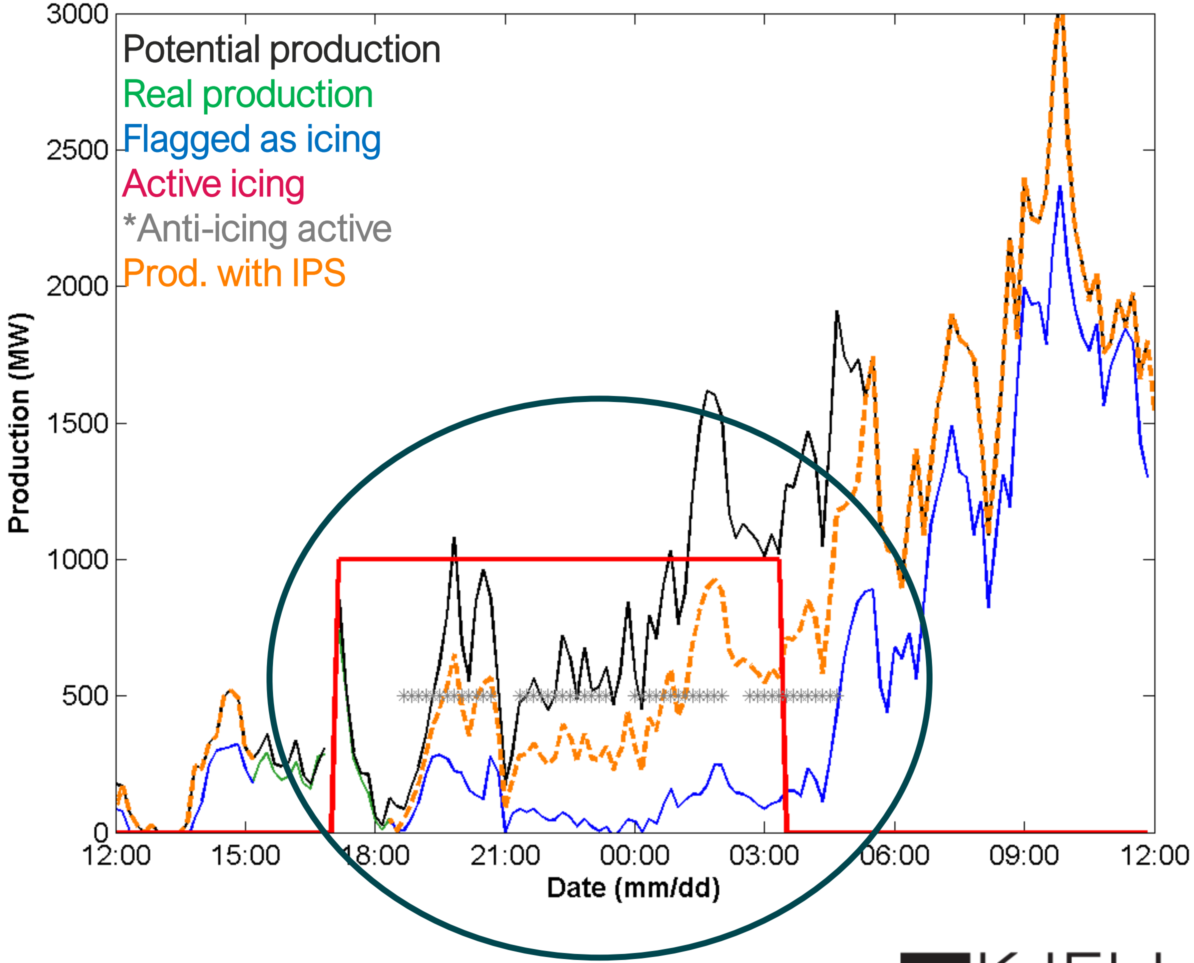
Modelling the IPS - Methodology

- **Success of a heating cycle depends on:**
  - Temperature and wind speed conditions (IPS envelope)
  - Icing conditions
  - **If not fully successful** – cycle restart

Example period



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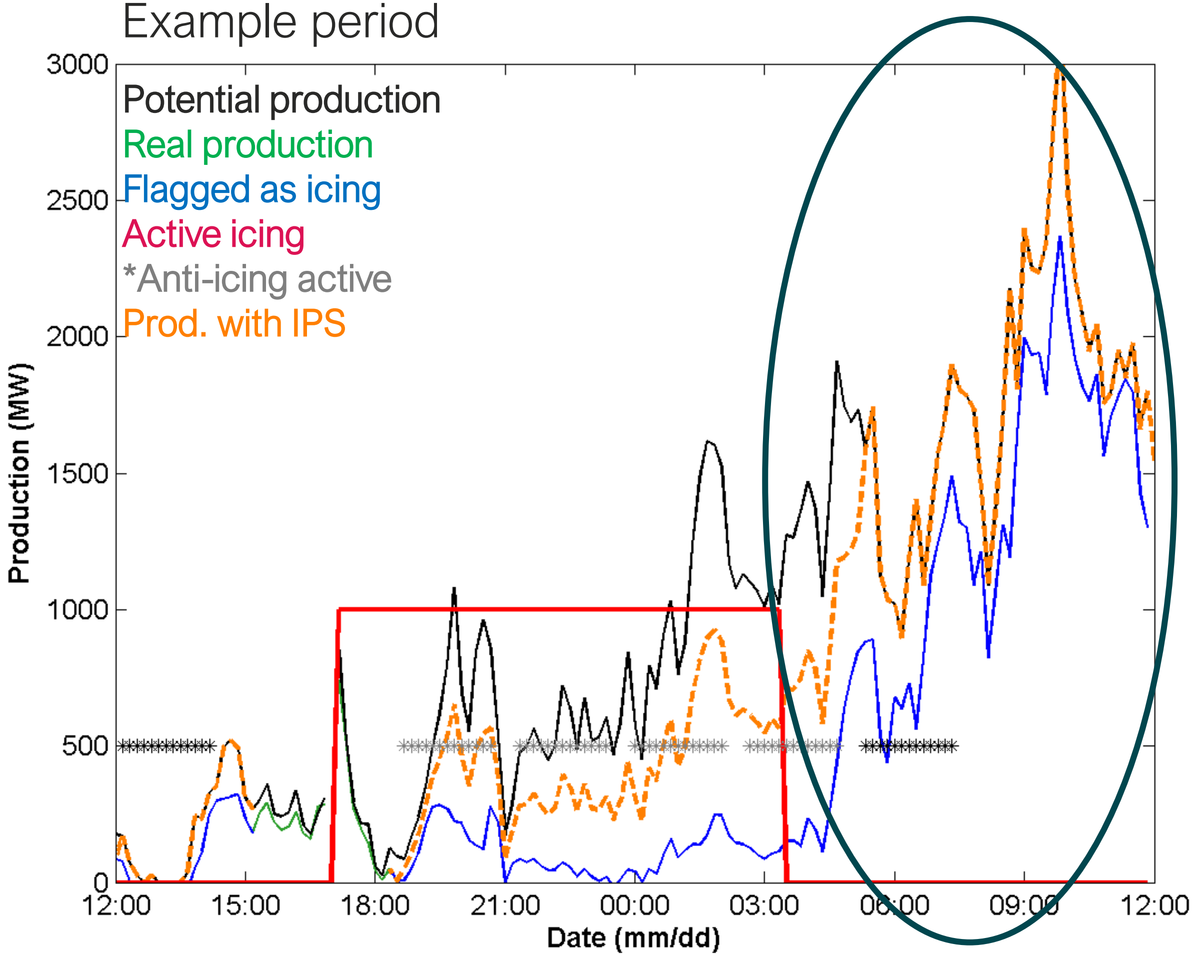
Modelling the IPS - Methodology

- **Success of a heating cycle depends on:**
  - Temperature and wind speed conditions (IPS envelope)
  - Icing conditions
  - If not fully successful – cycle restart
  - **If successful** – production is set to potential production

Example period



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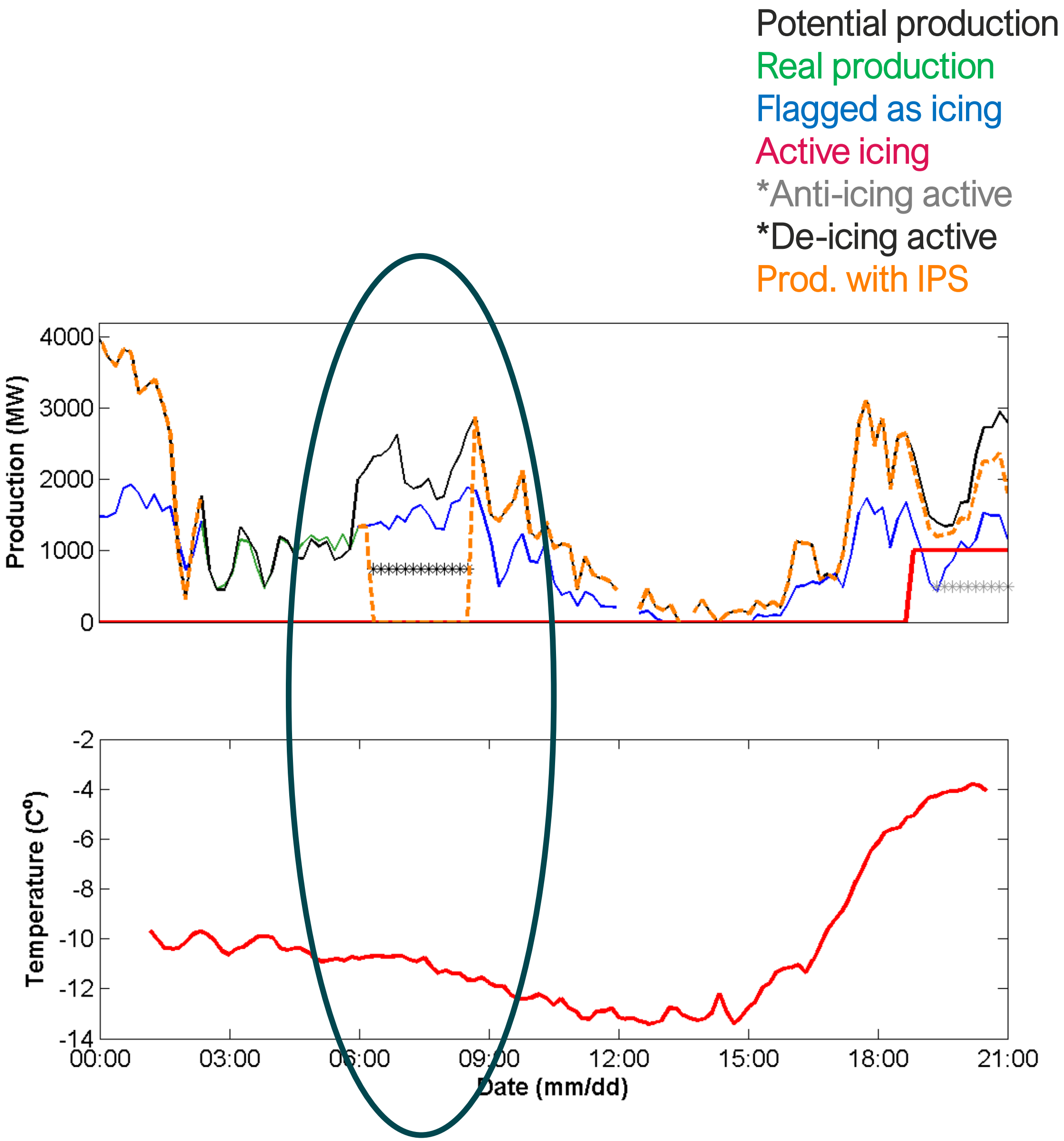
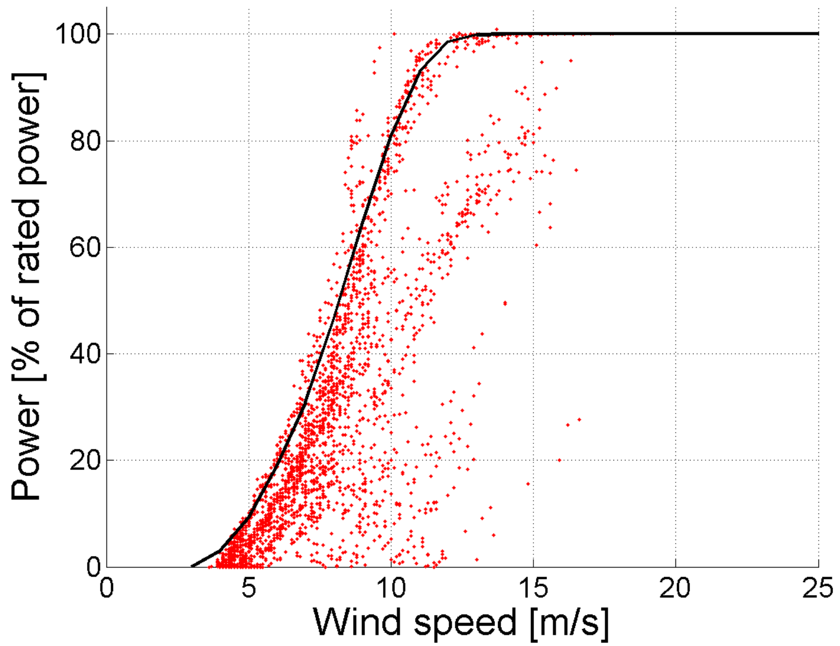
Modelling the IPS - Methodology

- **Another example:**
  - Cold temperatures – outside Anti-icing envelope –> **De-icing applied**
  - Turbine is assumed to be stopped during De-icing



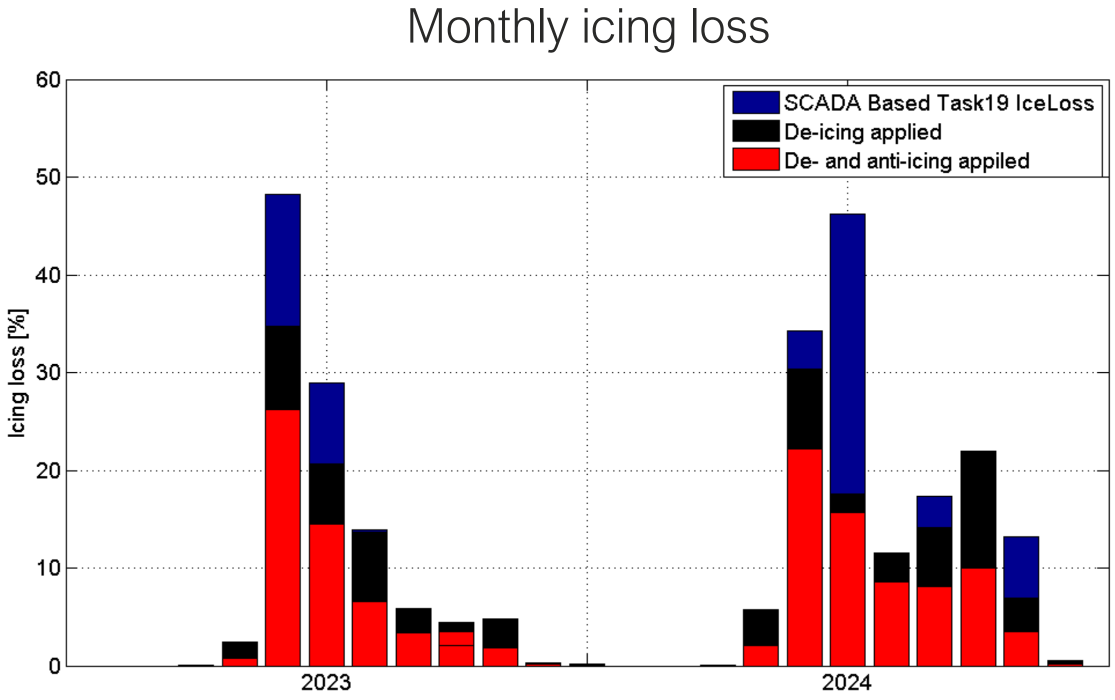
Results: Short-term historical losses

- **Experienced loss without IPS based on SCADA 2023-2024**: 11.8 % of AEP.



Results: Short-term historical losses

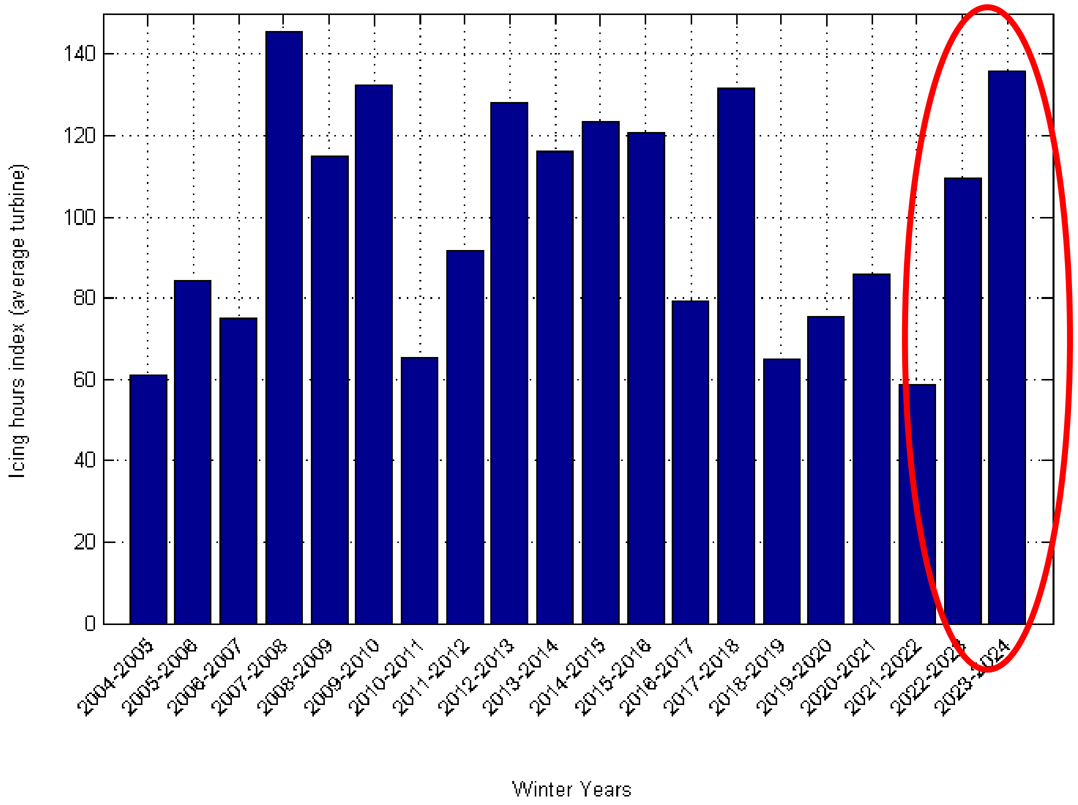
- **Experienced loss without IPS**: 11.8 % of AEP.
- **With modelled IPS**: 7.1% (5.4 – 9.1) of AEP.



Long-term correction of losses

- **Icing varies from year to year** – important to long-term correct the result
  - Expected to have lower losses on average at the site compared to short-term

Modelled icing hour index at the site



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Historical and long term corrected estimated Icing Losses

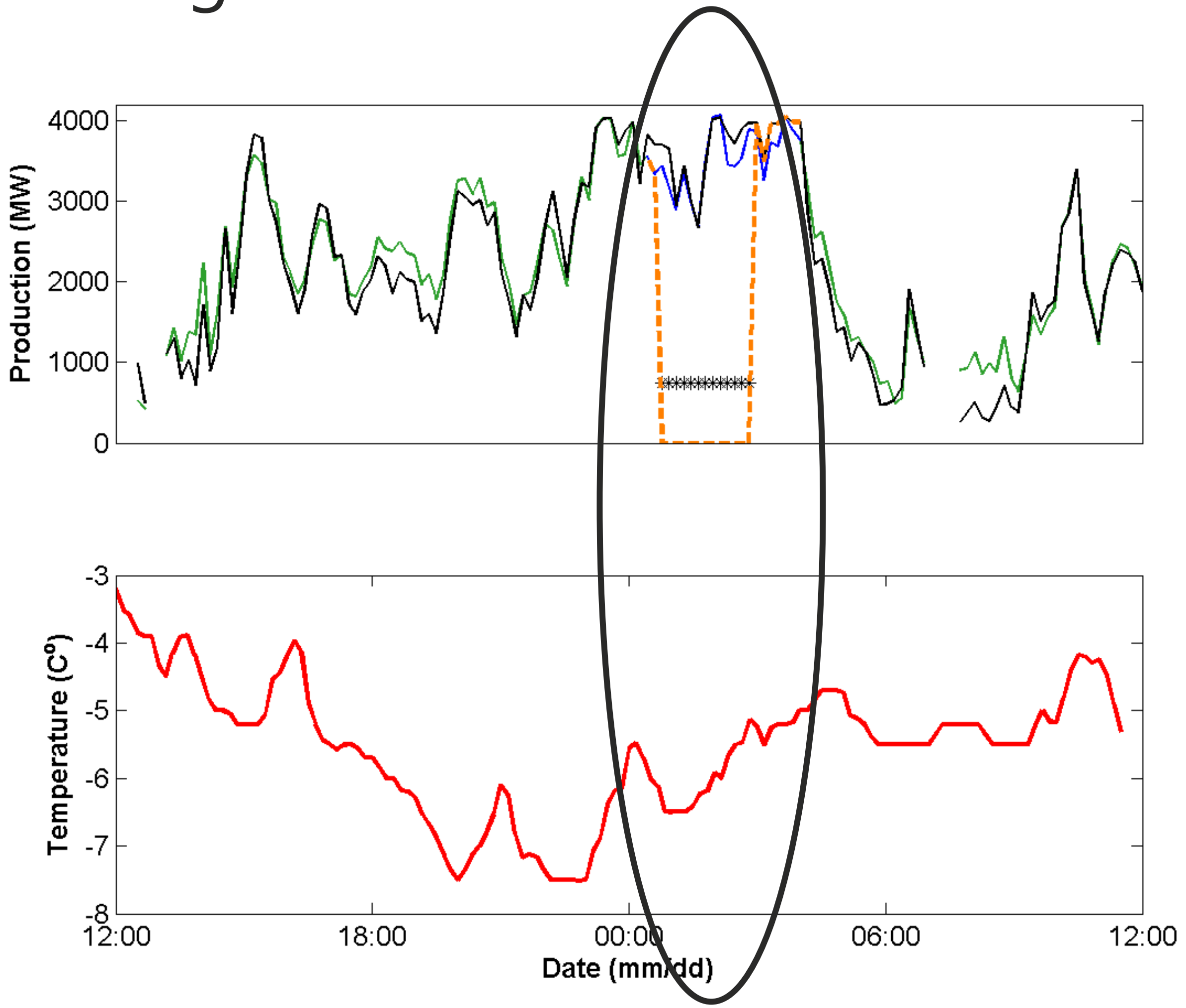
- **Historical Losses**:
  - Experienced loss without IPS: 11.8% of AEP.
  - With modelled IPS: 7.1% (5.4 – 9.1) of AEP.

- **Expected Long-Term Losses**:
  - Without IPS: **9.3%** ± 2.0% of AEP.
  - With modelled IPS: **5.7%** ± 2.7% of AEP.

Estimated recovery for this specific wind farm

Further work: What would be the result if we assume a system that also consider forecasted icing and icing losses?

- Optimally, de-icing should not have been switched on?
- Would an icing forecast have been beneficial?



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Summary

- Estimated recovery of icing losses with a **retrofitted** Ice Protection System (IPS) was modelled based on operational data
- Icing model needed to find active icing periods and for long-term correction
- Uncertain, require several assumptions

Thank you!

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