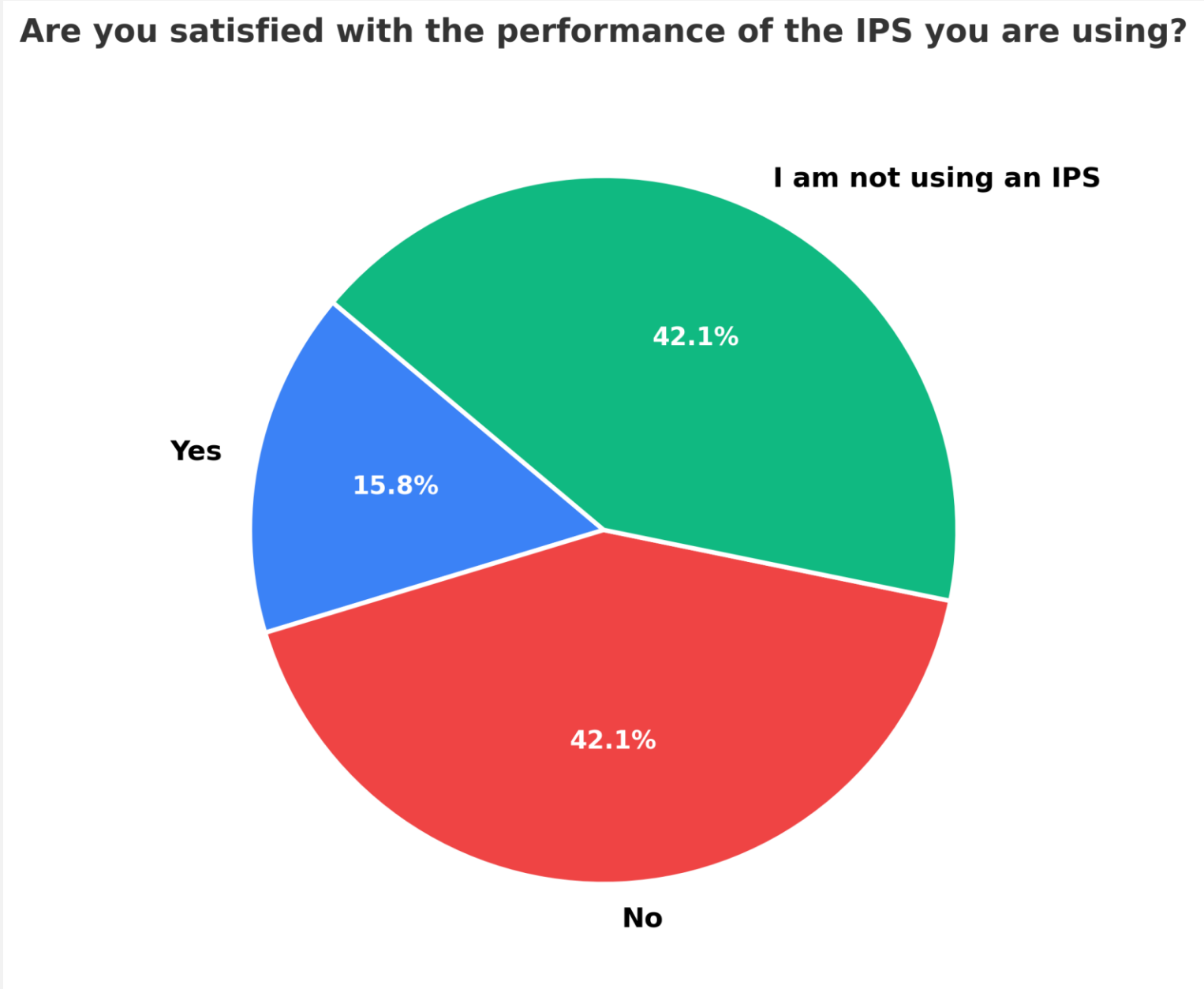
The Missing Piece

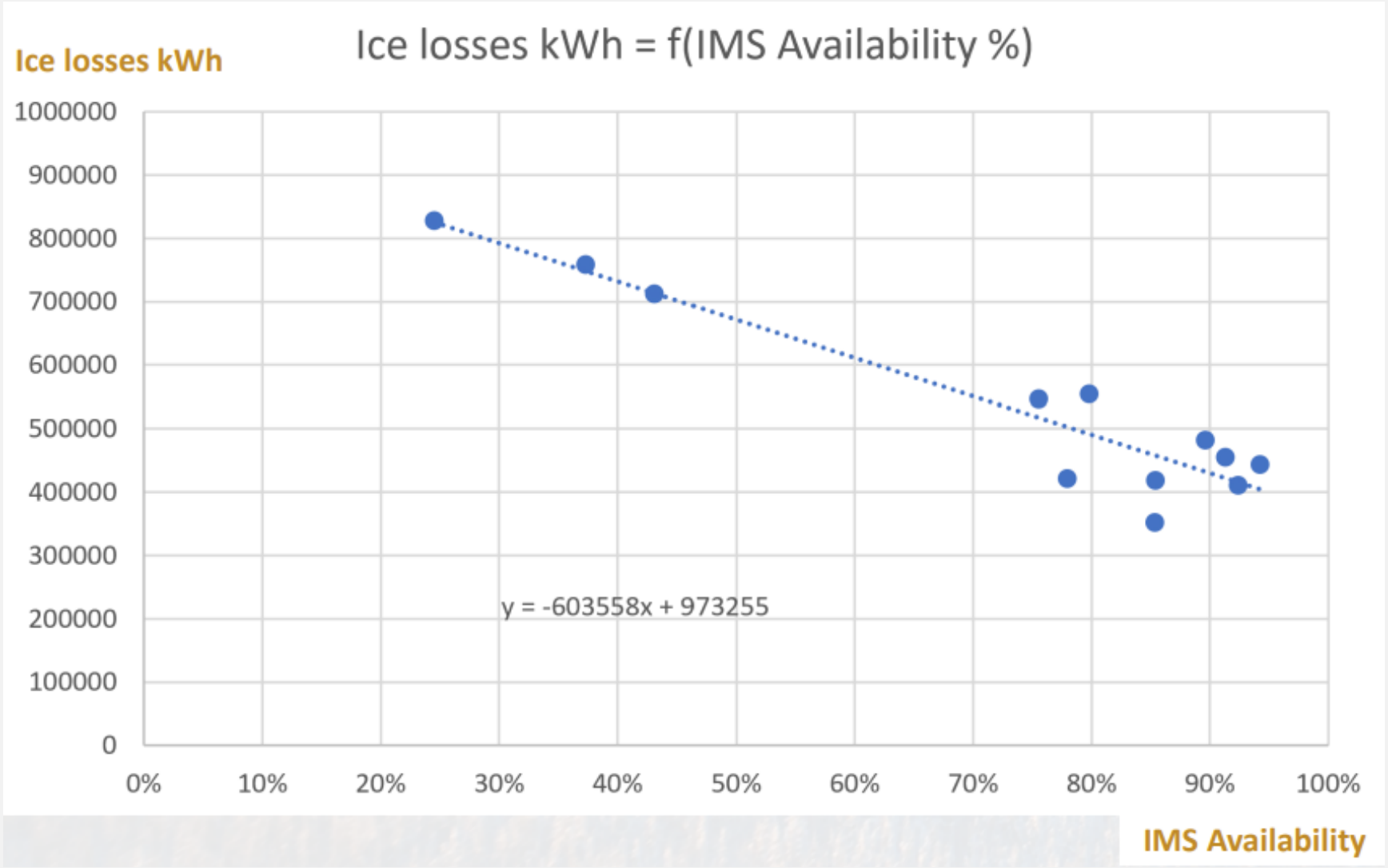
Solving the Puzzle of Ice Protection System Performance

Patrice Roberge, ing., Ph.D.
Instrumentation Icetek

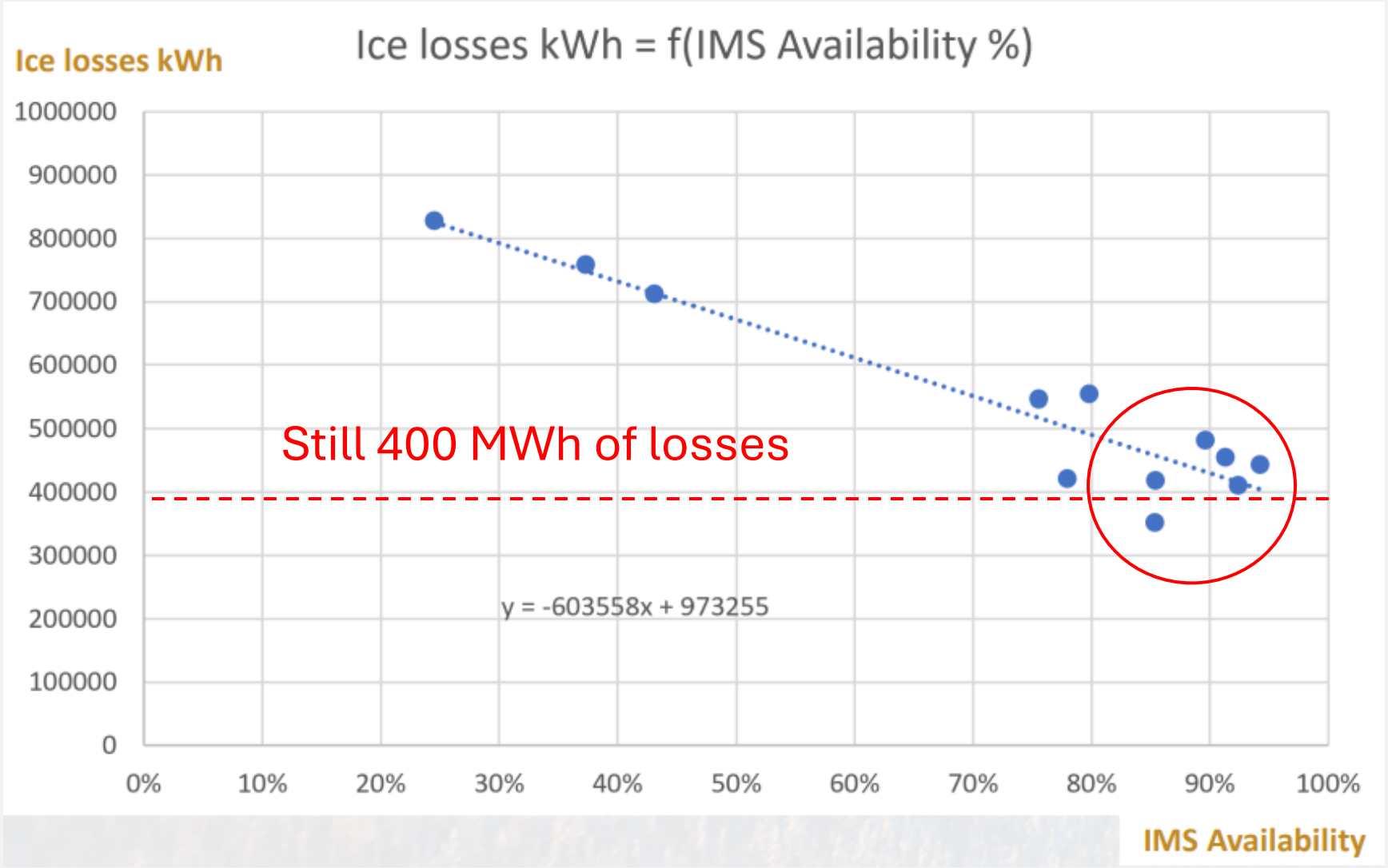
Why are people not satisfied?



Godreau, C., 2020. Ice Protection Systems and Retrofits: Performance and Experiences. Winterwind 2020, Åre, Sweden, 3-5 Febuary 2020.



Grenholm, S., 2024. Strategies and tools for designing and optimizing wind farms for prosperous operation in cold climates, Åre, Sweden, 2024



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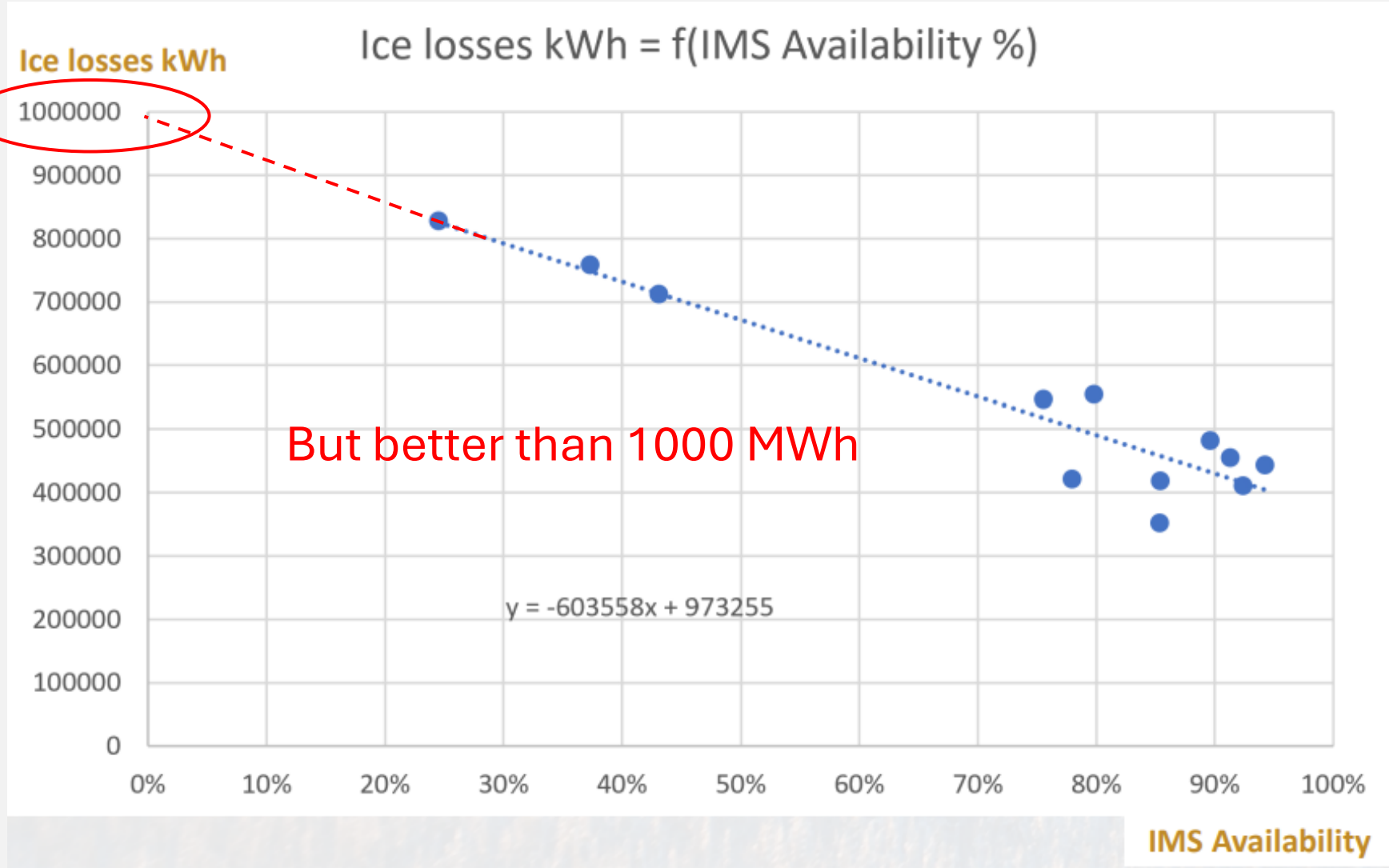
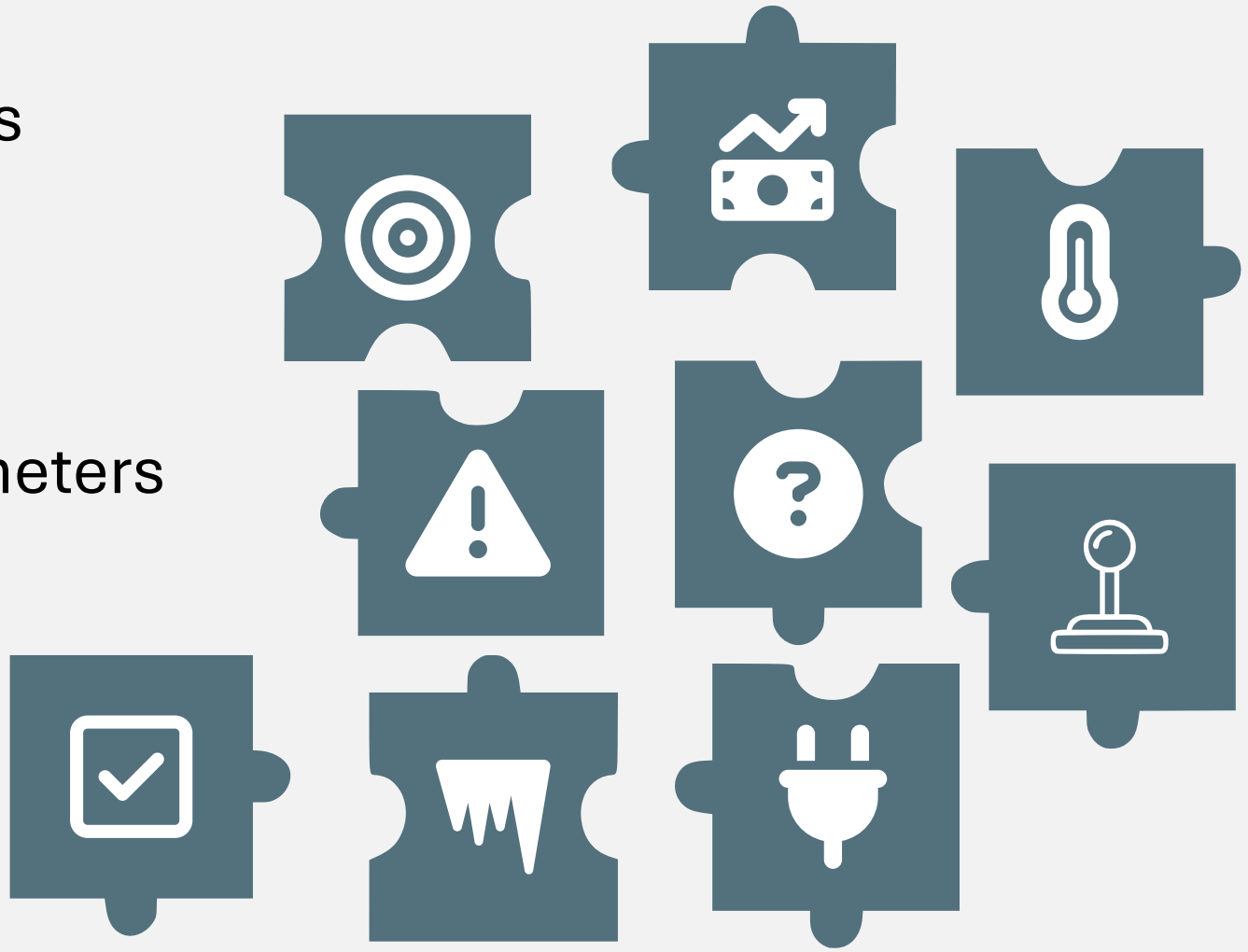


Grenholm, S., 2024. Strategies and tools for designing and optimizing wind farms for prosperous operation in cold climates, Åre, Sweden, 2024

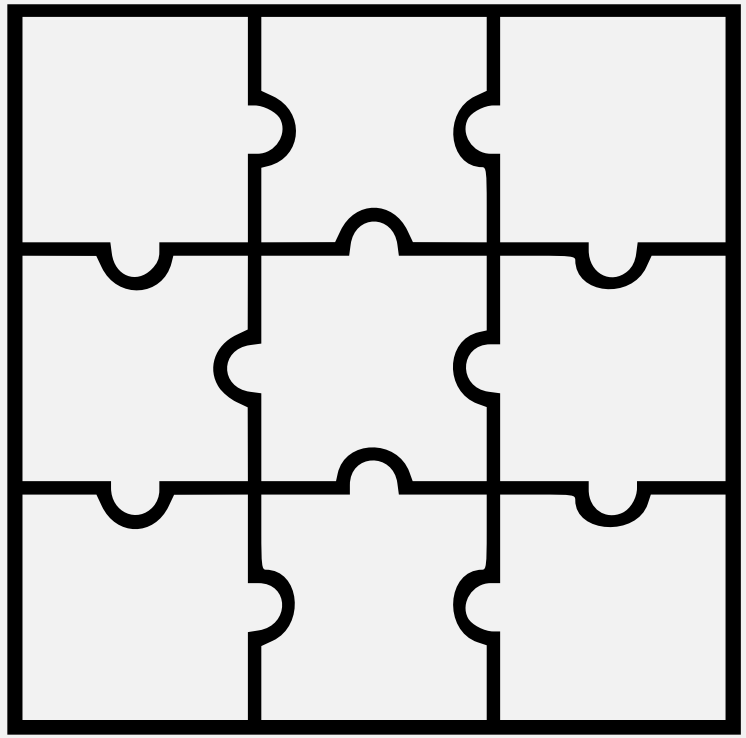
Ice Protection Systems (IPS)

- Numerous factors
- Understand fixed limitations
  - Plan ahead
- Actionable parameters
  - Take control



IPS Availability

IPS availability



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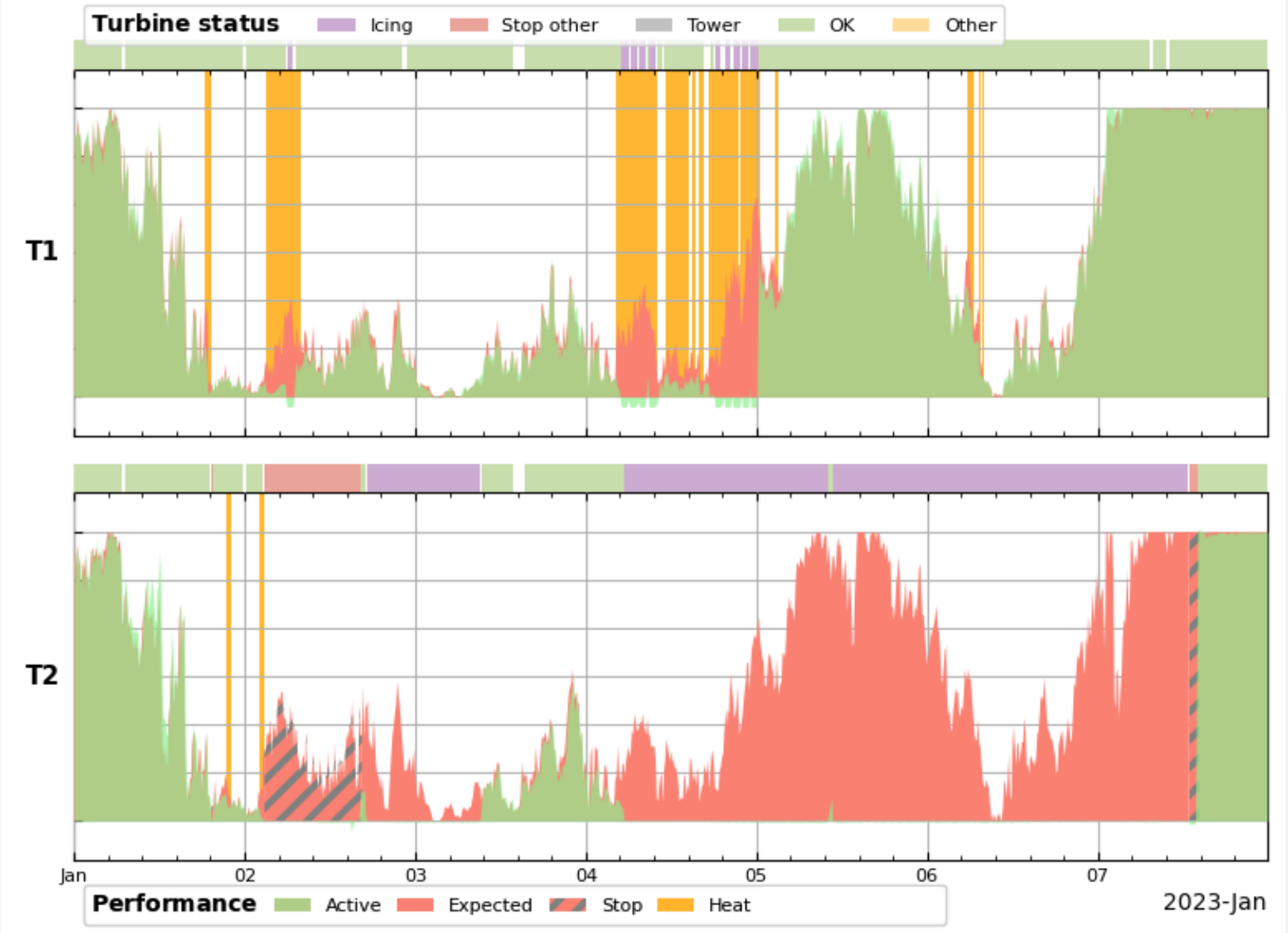

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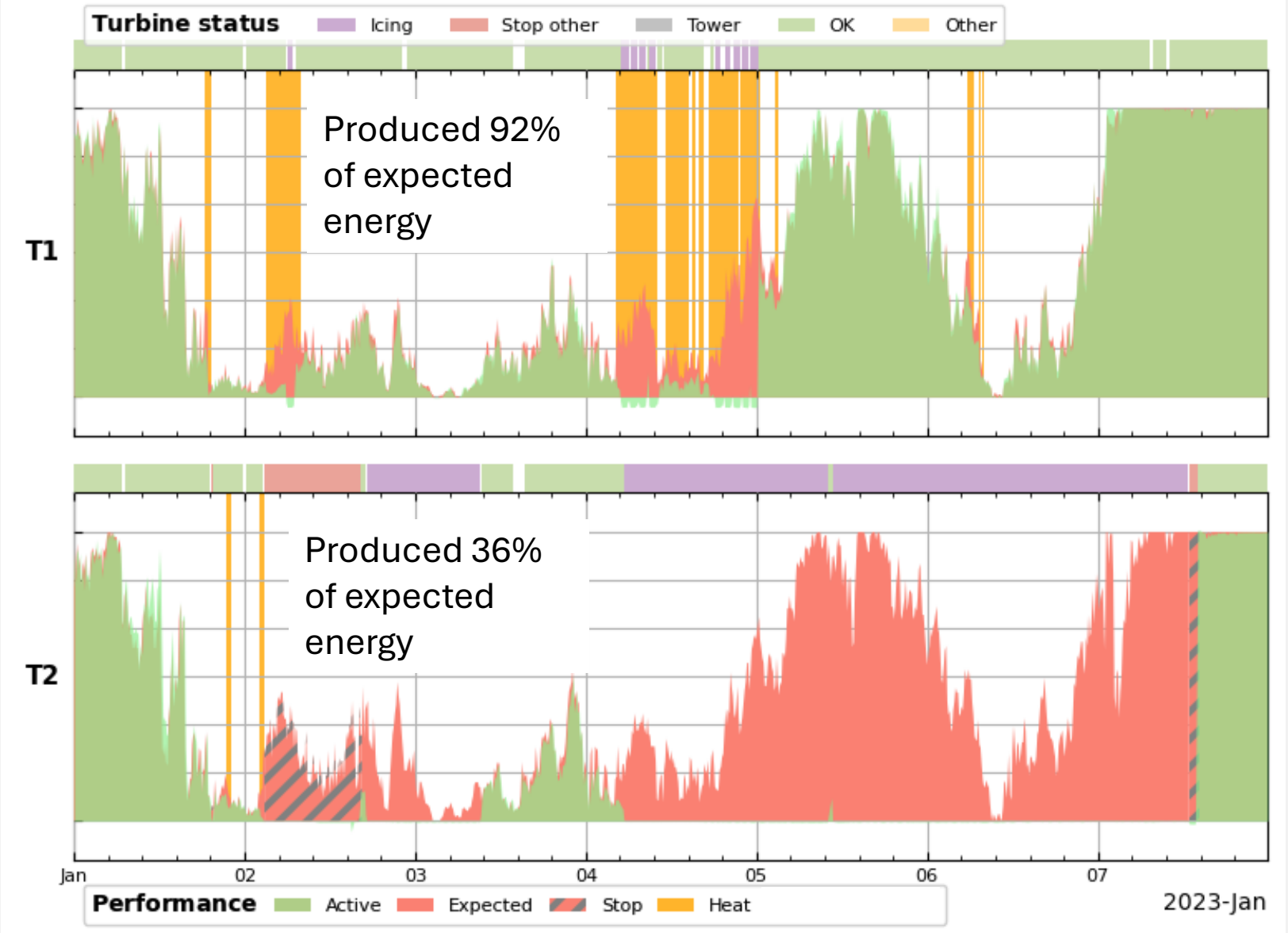

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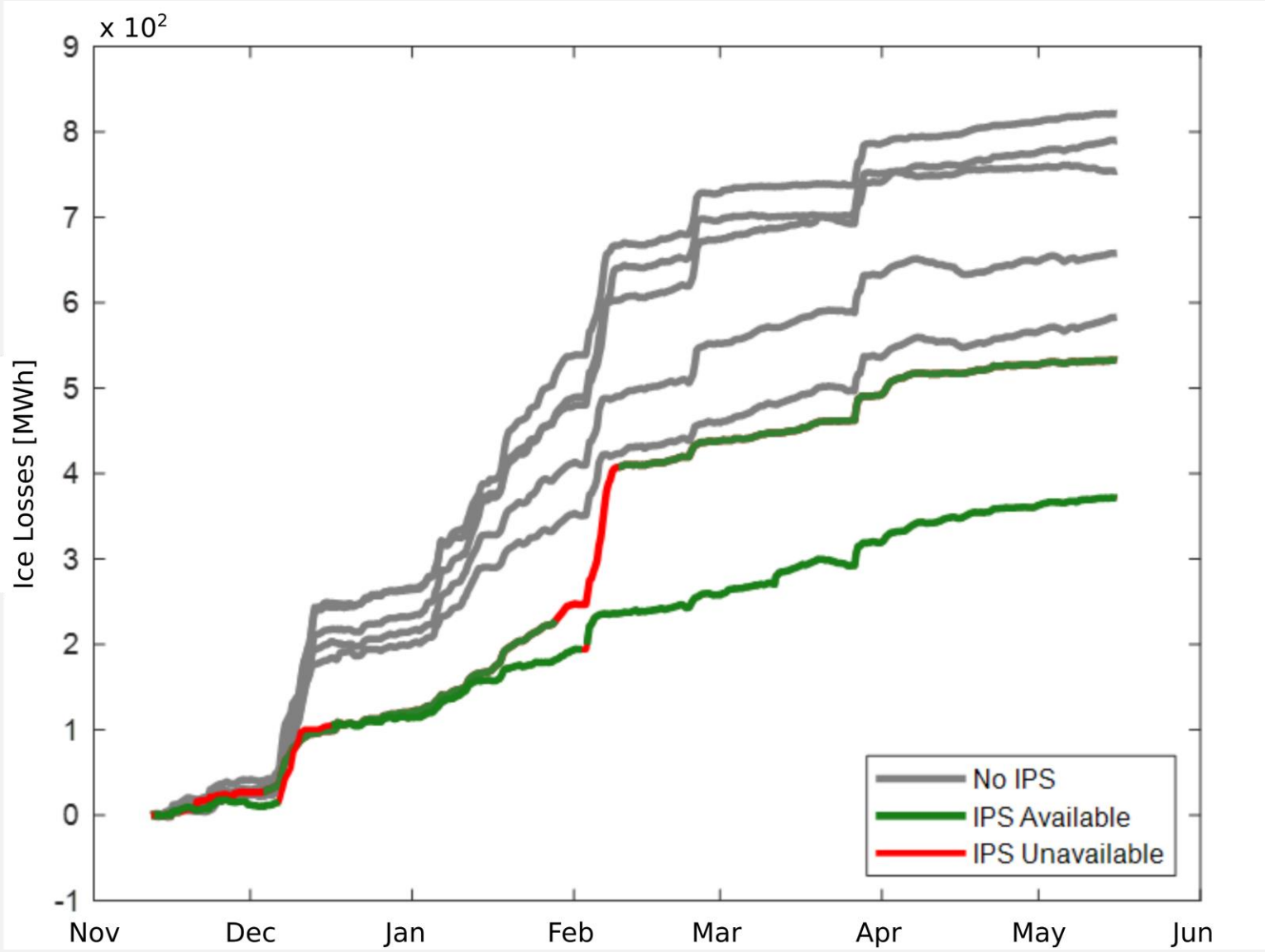


IPS Availability

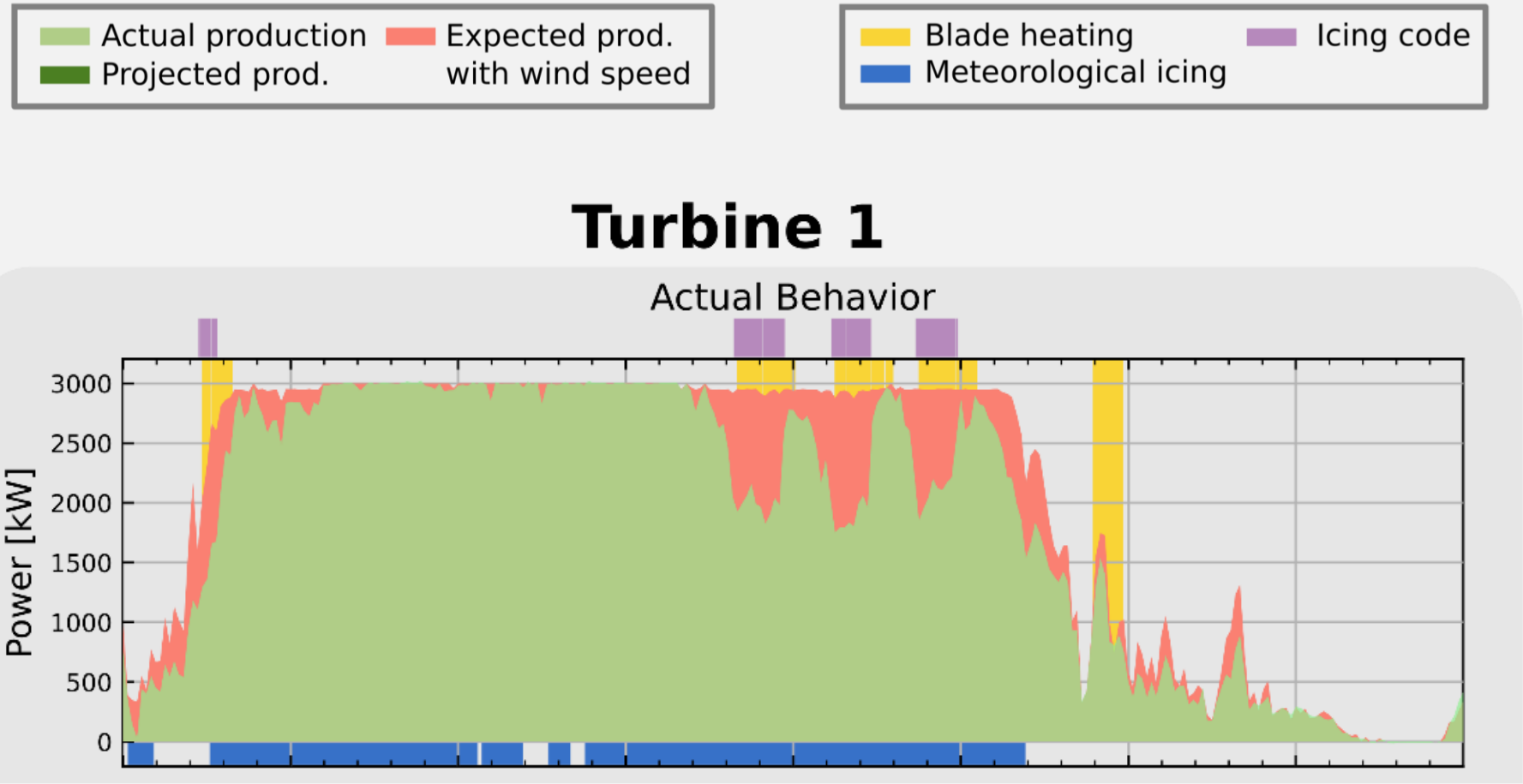
How to quantify?

- Easy KPIs to identify quickly unavailability

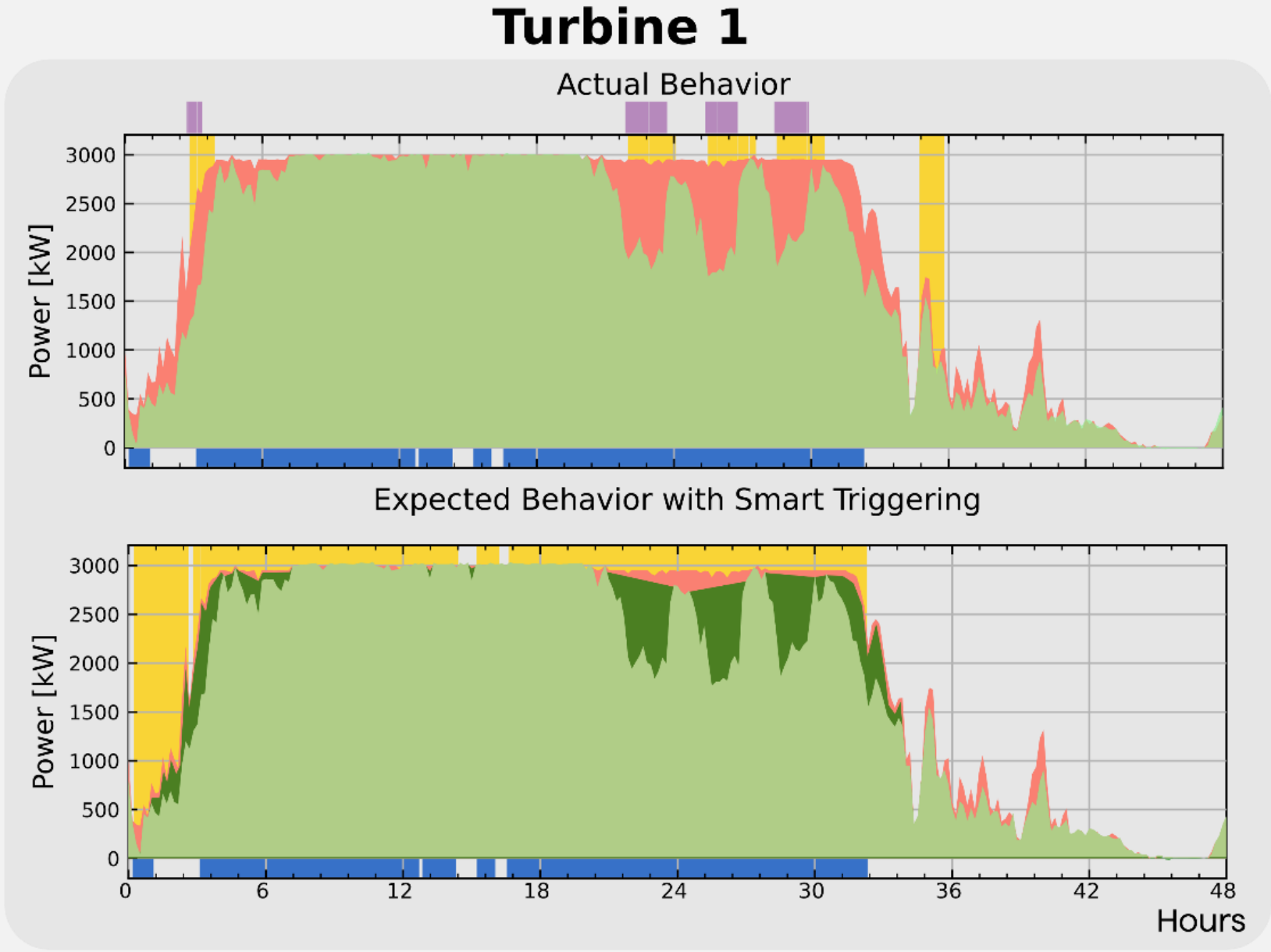
    1. Was it activated when supposed to?
    2. When activated, did it heat?

Triggering strategy

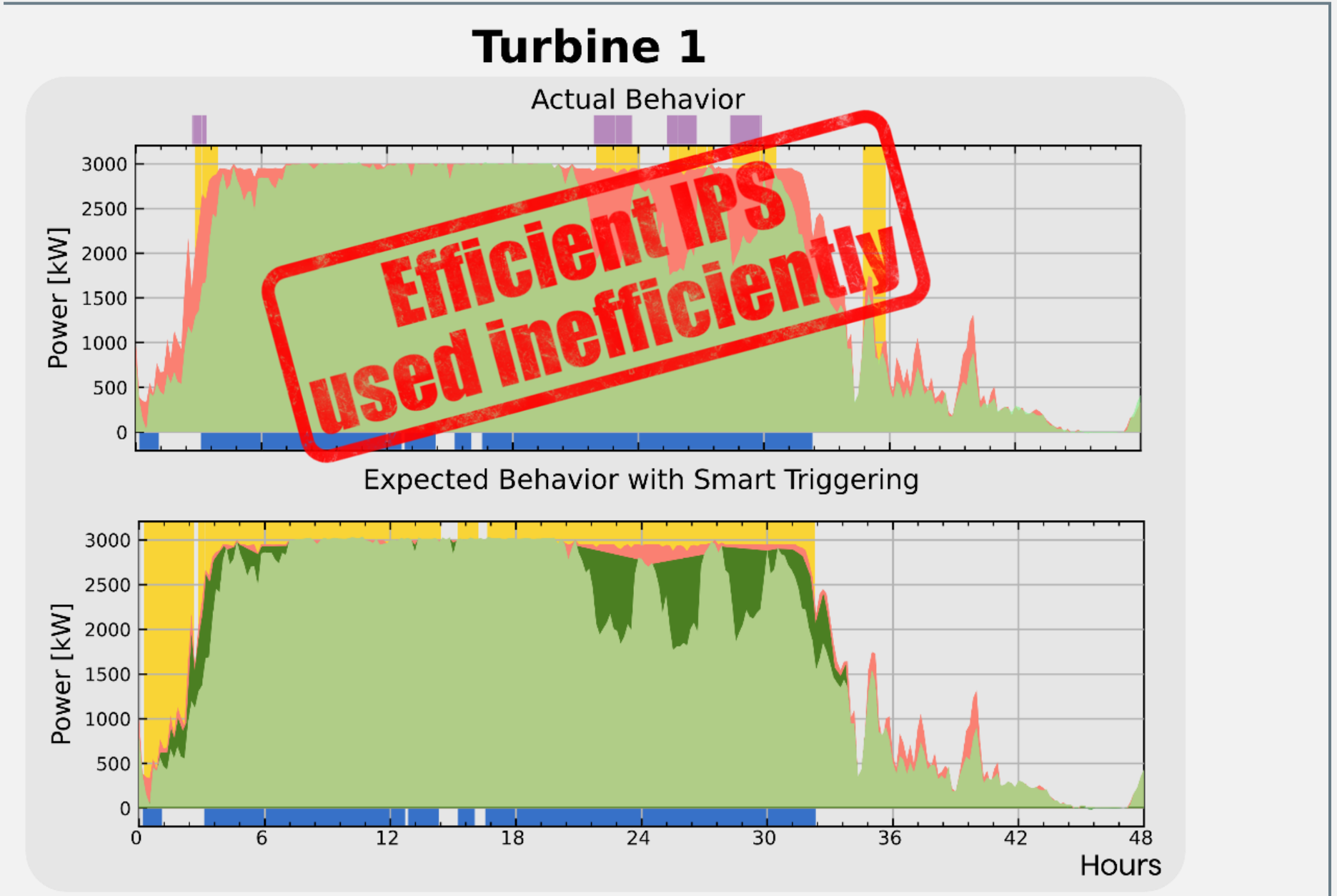
Reactive vs. proactive approach



Triggering strategy

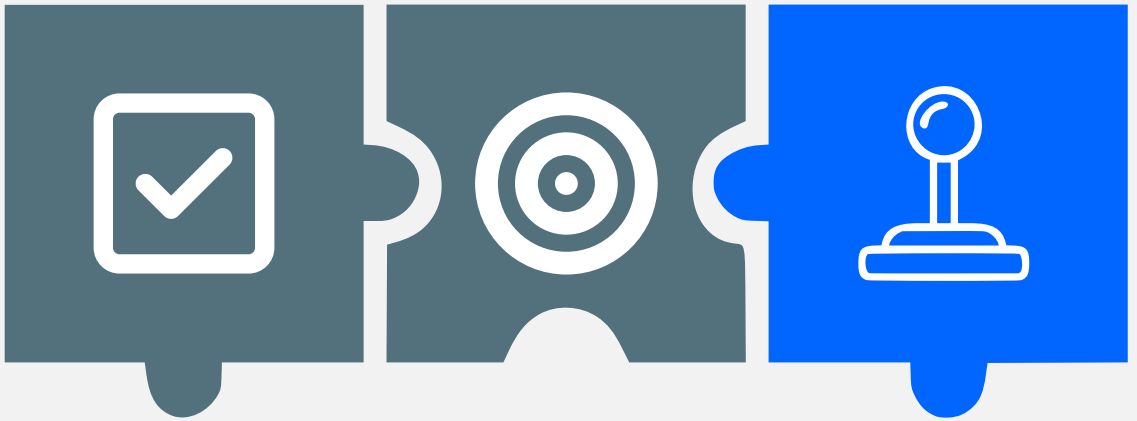


Triggering strategy

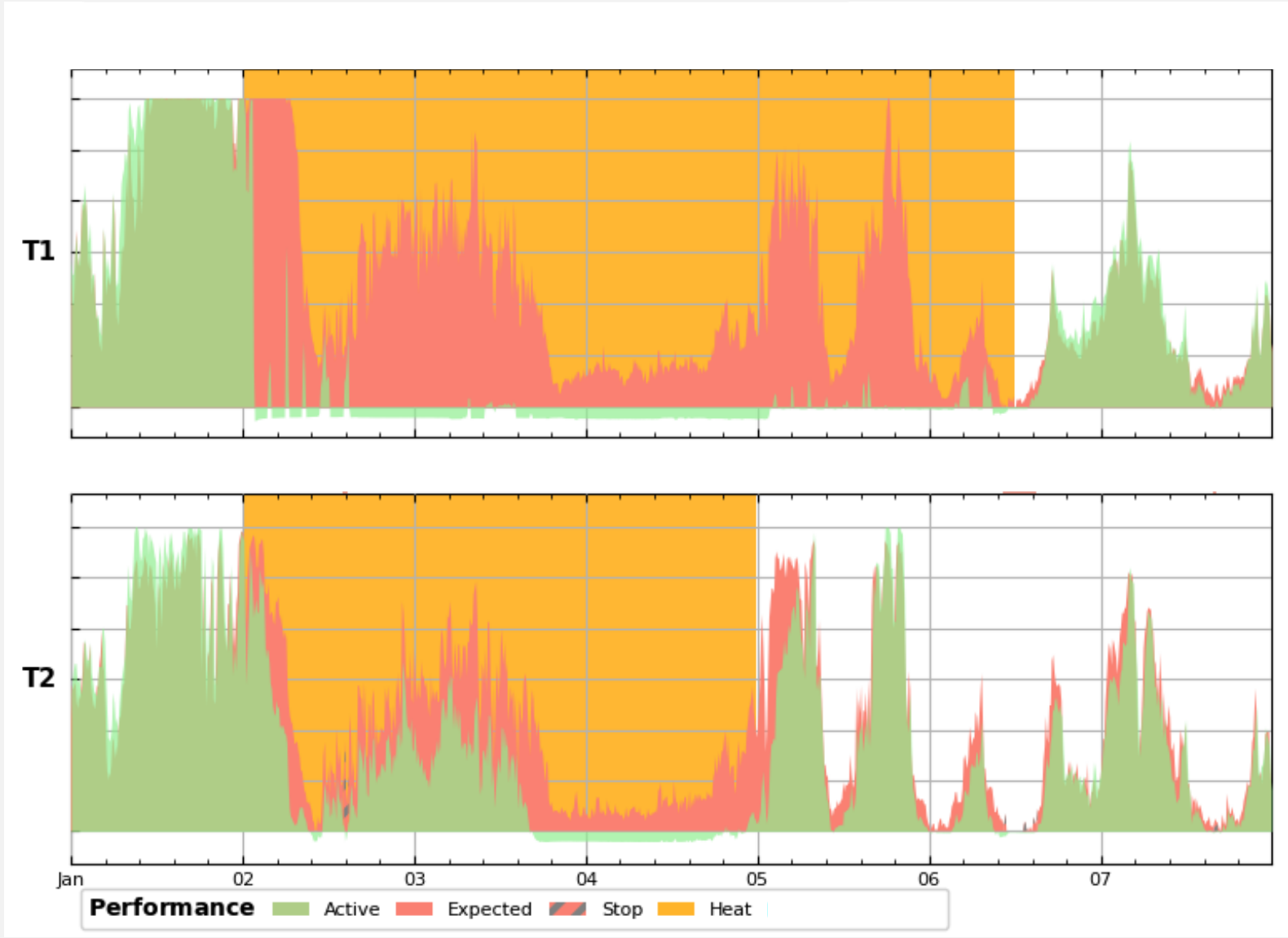


Turbine control strategy

Turbine control stategy



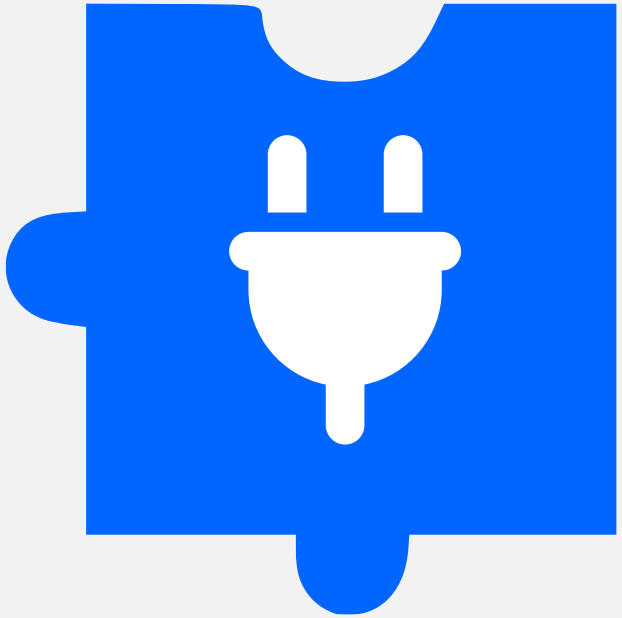
Turbine control strategy

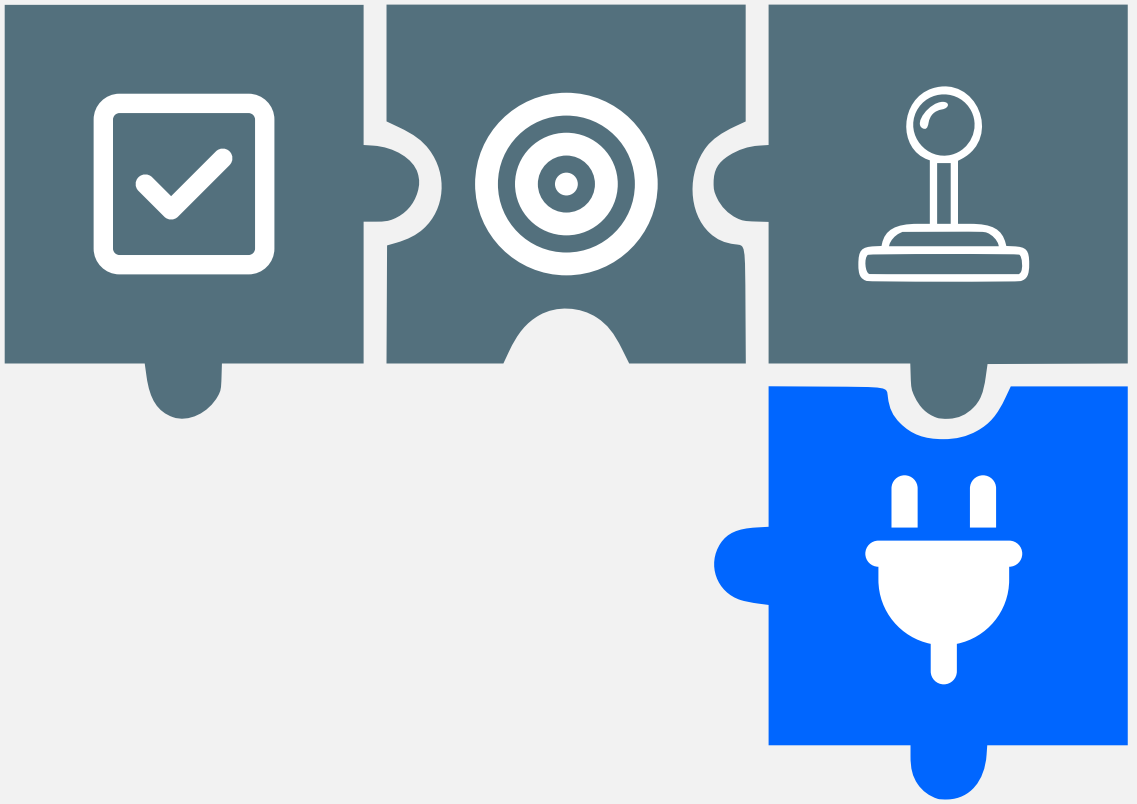


Turbine control strategy

Same heating system, different sensitivity

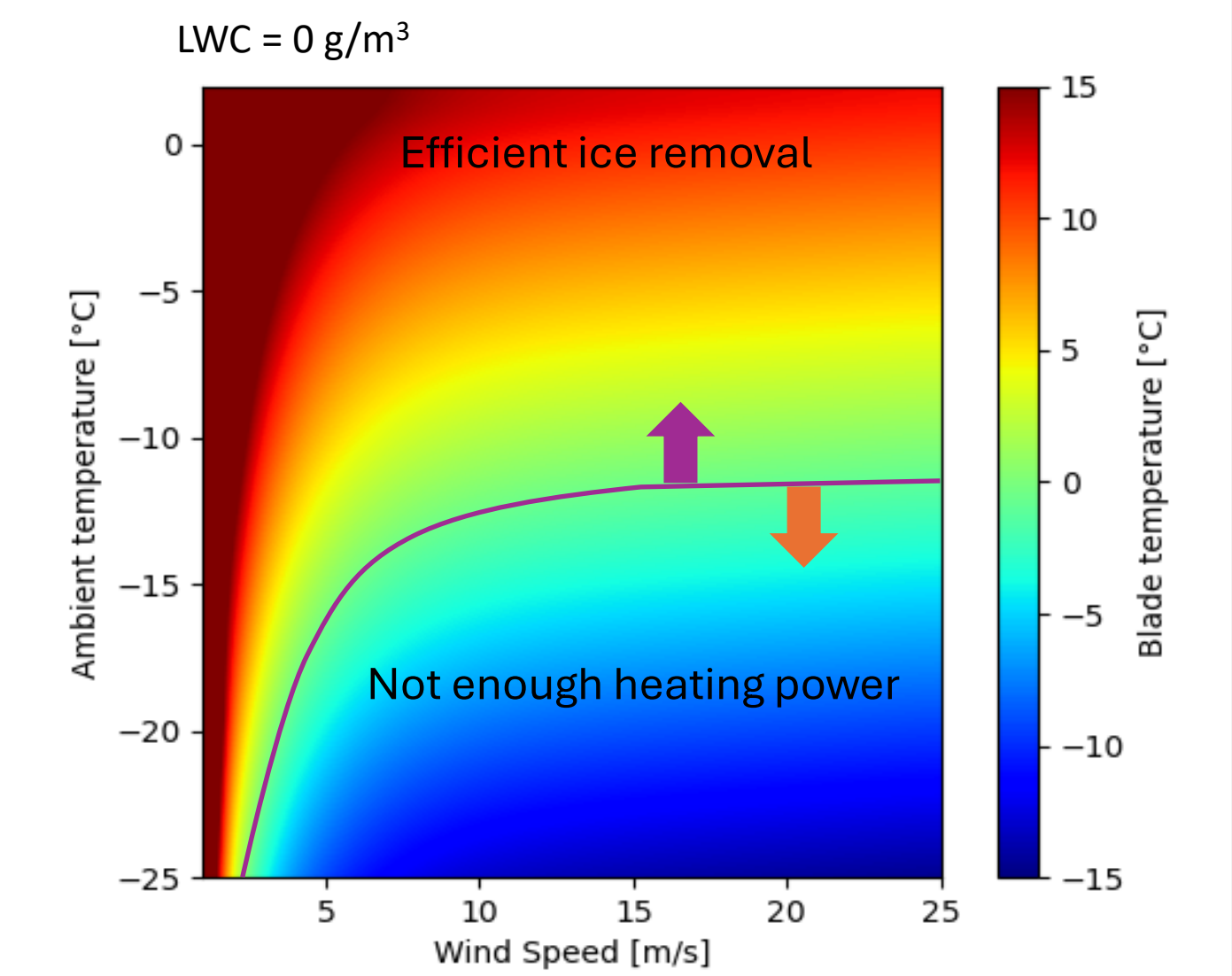
Appropriate power





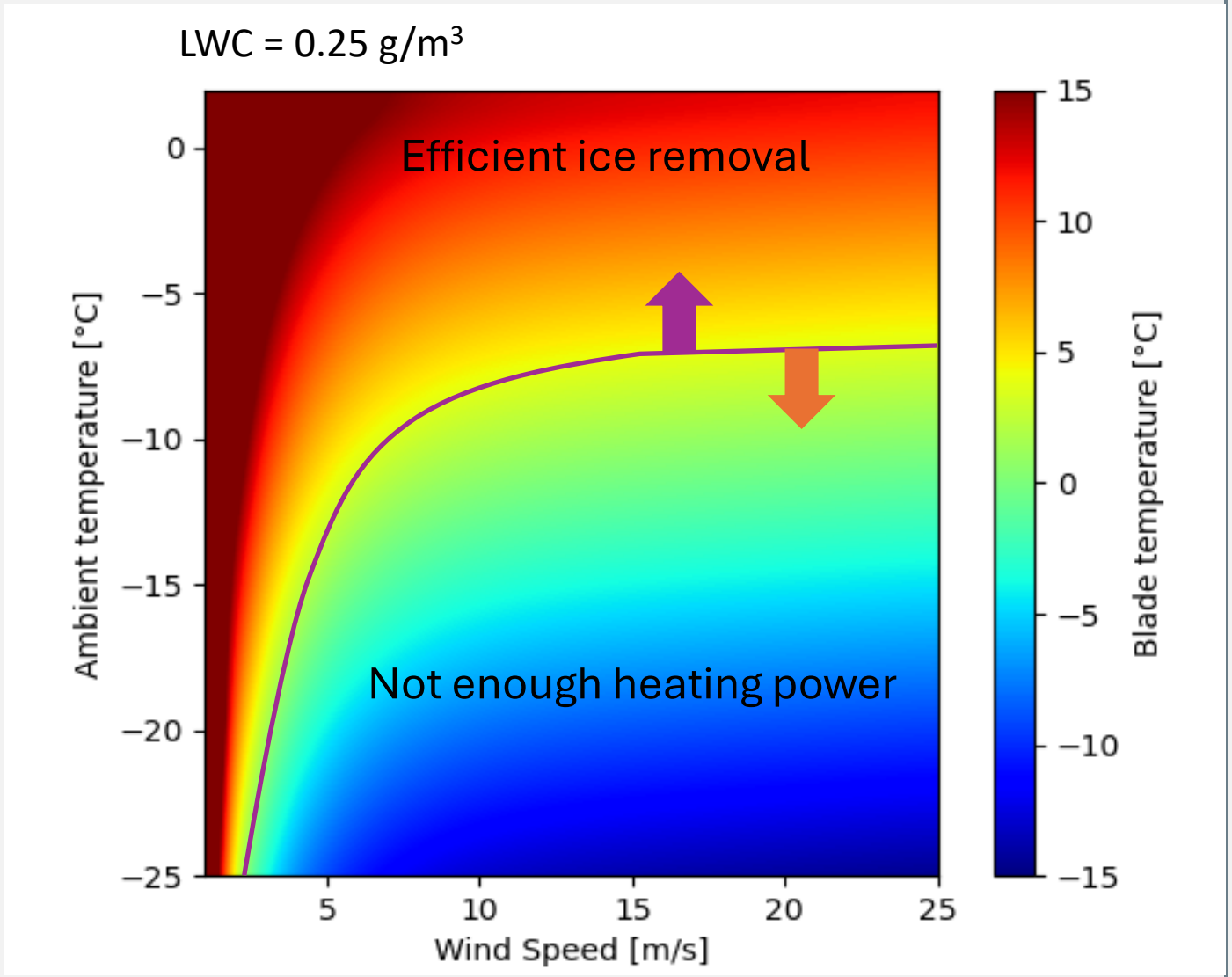
Appropriate power

- Performance envelope (Task 54)
- You will never prevent 100% of the icing losses



Appropriate power

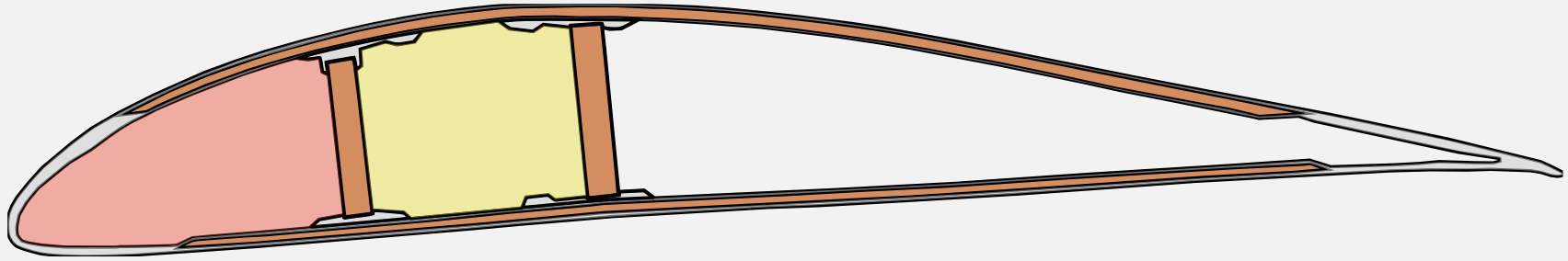
- LWC is important



Blade limitations

Blade limitations

- Often not 100% of the available heat can be used
- Maximum temperature of the fiberglass



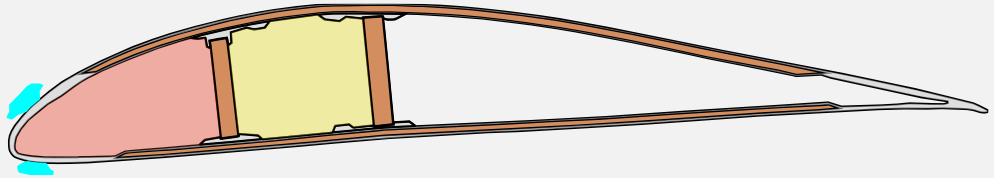
Anti-icing vs. De-icing

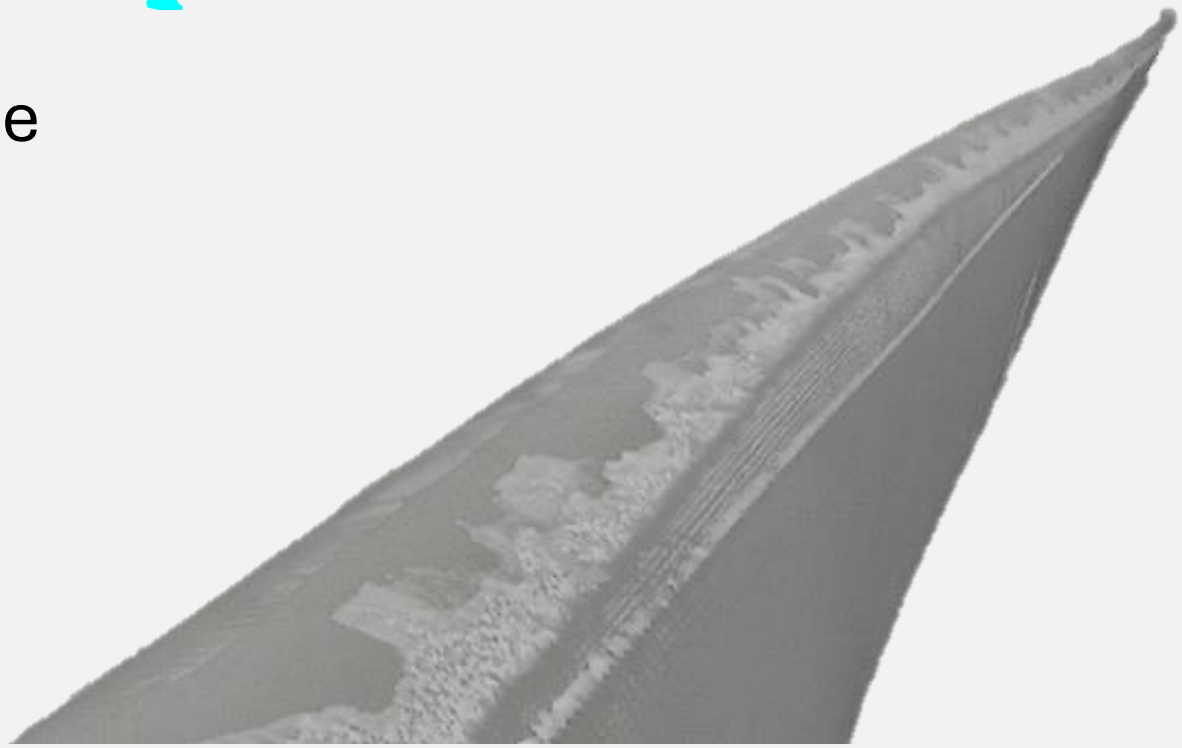
Anti-icing vs. De-icing

- Turbine stopped
- = lower relative wind speed
- = better efficiency?
- Not always the case

Anti-icing vs. De-icing

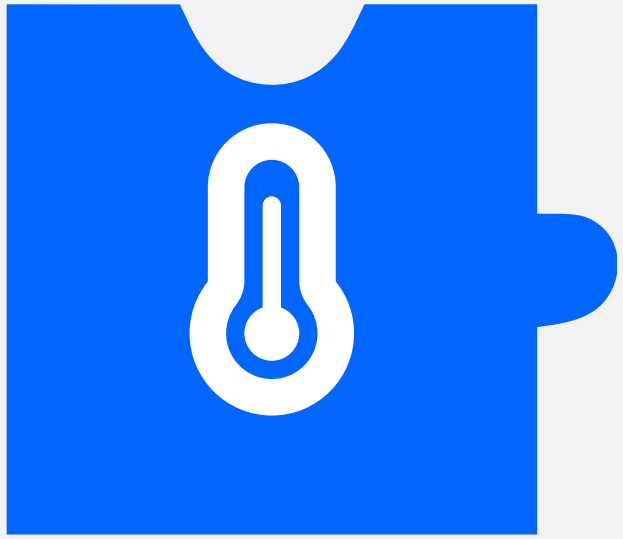
- Cold spots need an extra kick
- Centrifugal forces + blade bending helps ice removal





Heated area

Heated area



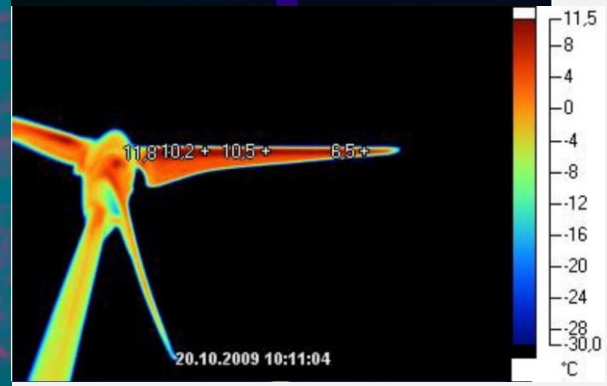
Heated area

- What part of the blade should be heated?
- Leading edge? Trailing edge? All?


Nordex, 2022

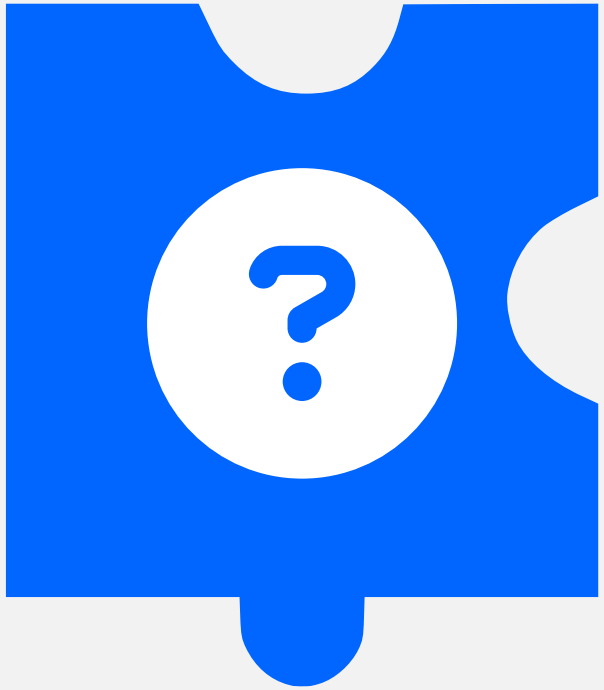

Borealis Wind, 2022


Wicetec Oy., 2021



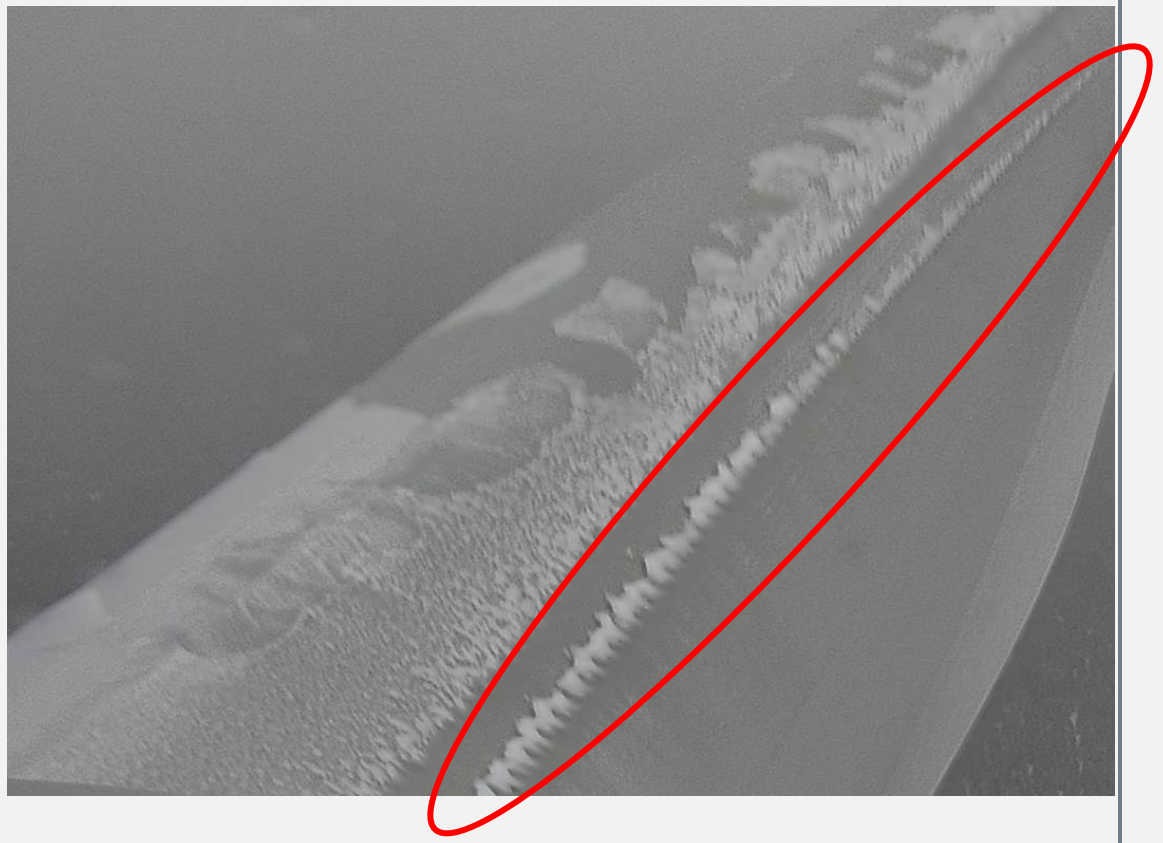
Enercon, 2011

Other Considerations

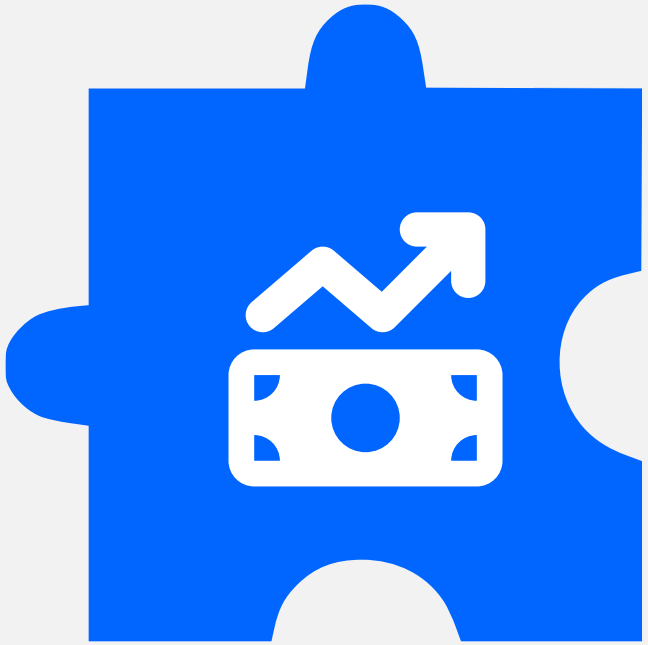


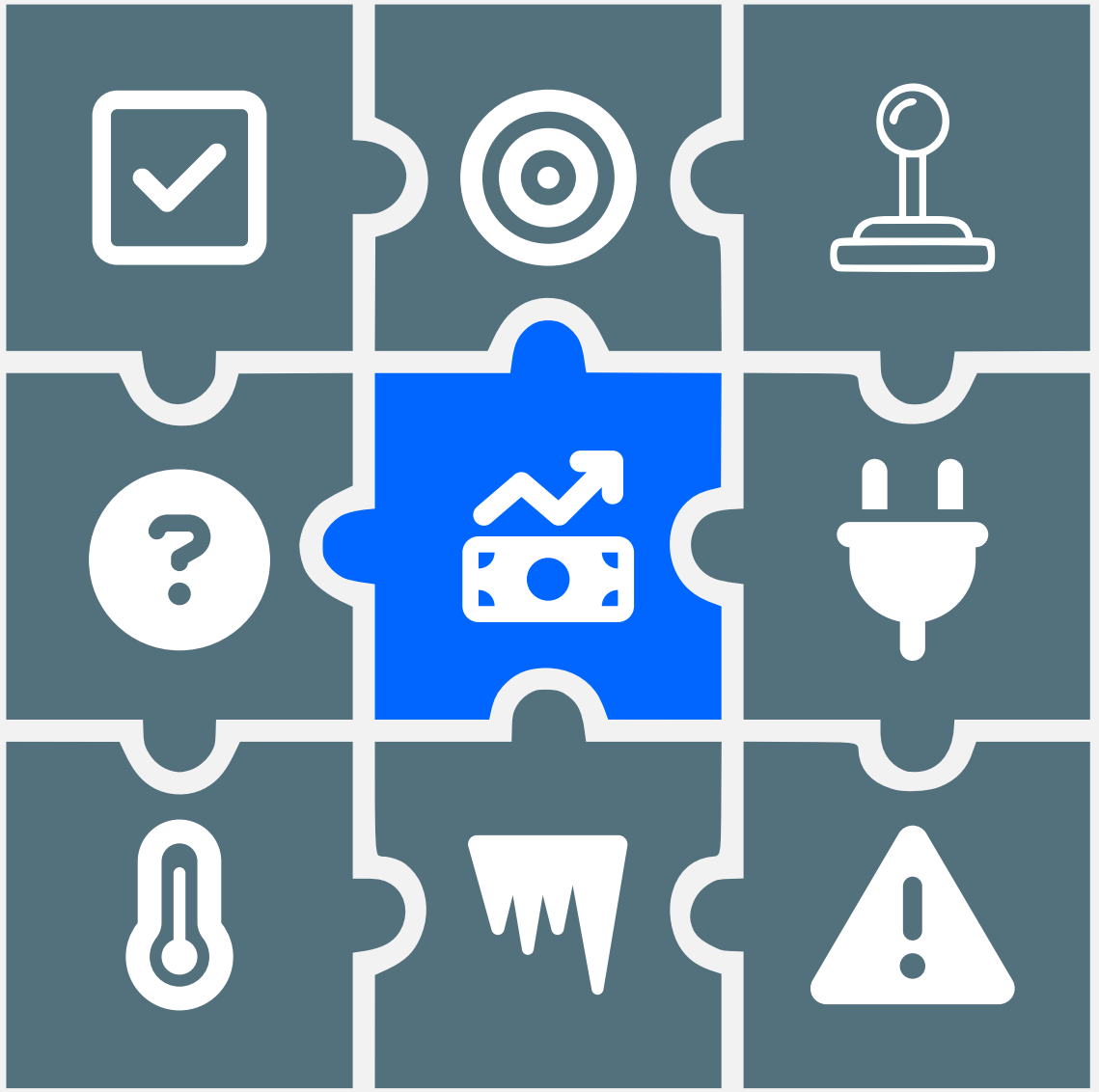
Other Considerations

- Iced up blade add-ons
  - Vortex generators
  - Blade cerrations
- Not heated, can hinder performance
- Collateral damages
  - Heating limitations
  - Cost of heating

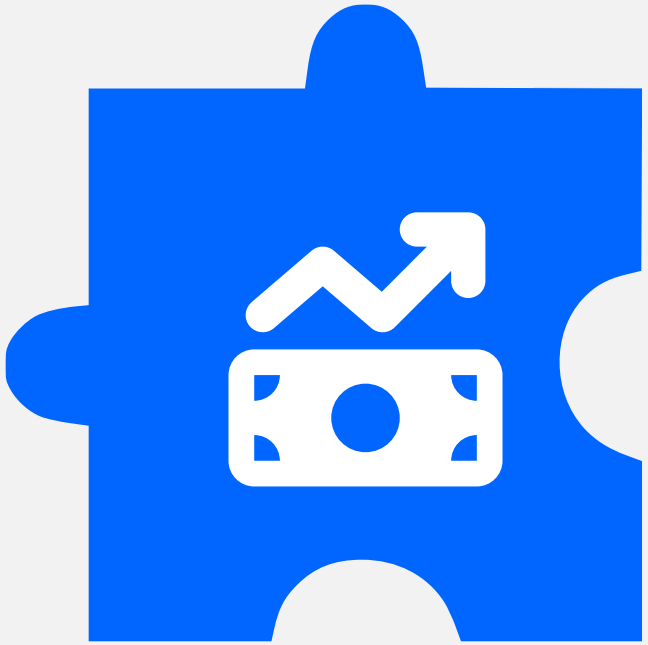


IPS Performance



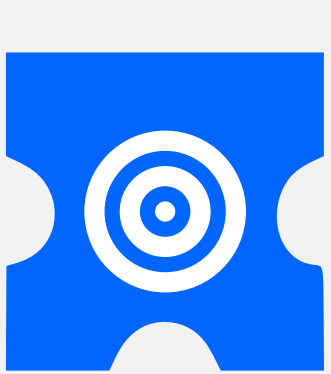


IPS Performance



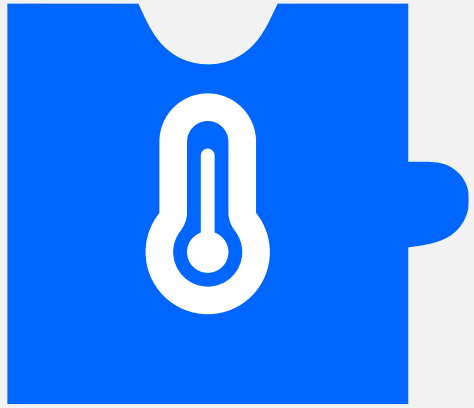
Triggering strategy

Anti-icing vs. De-icing



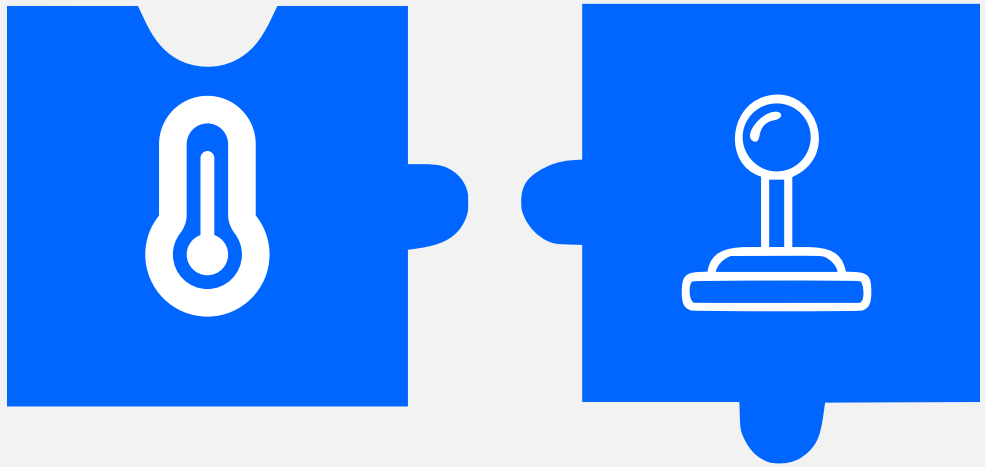
IPS Performance

Heated Area



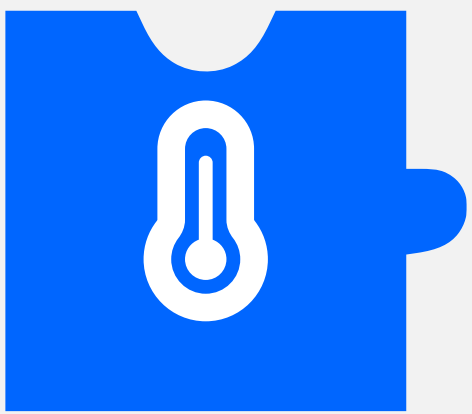
Turbine control strategy

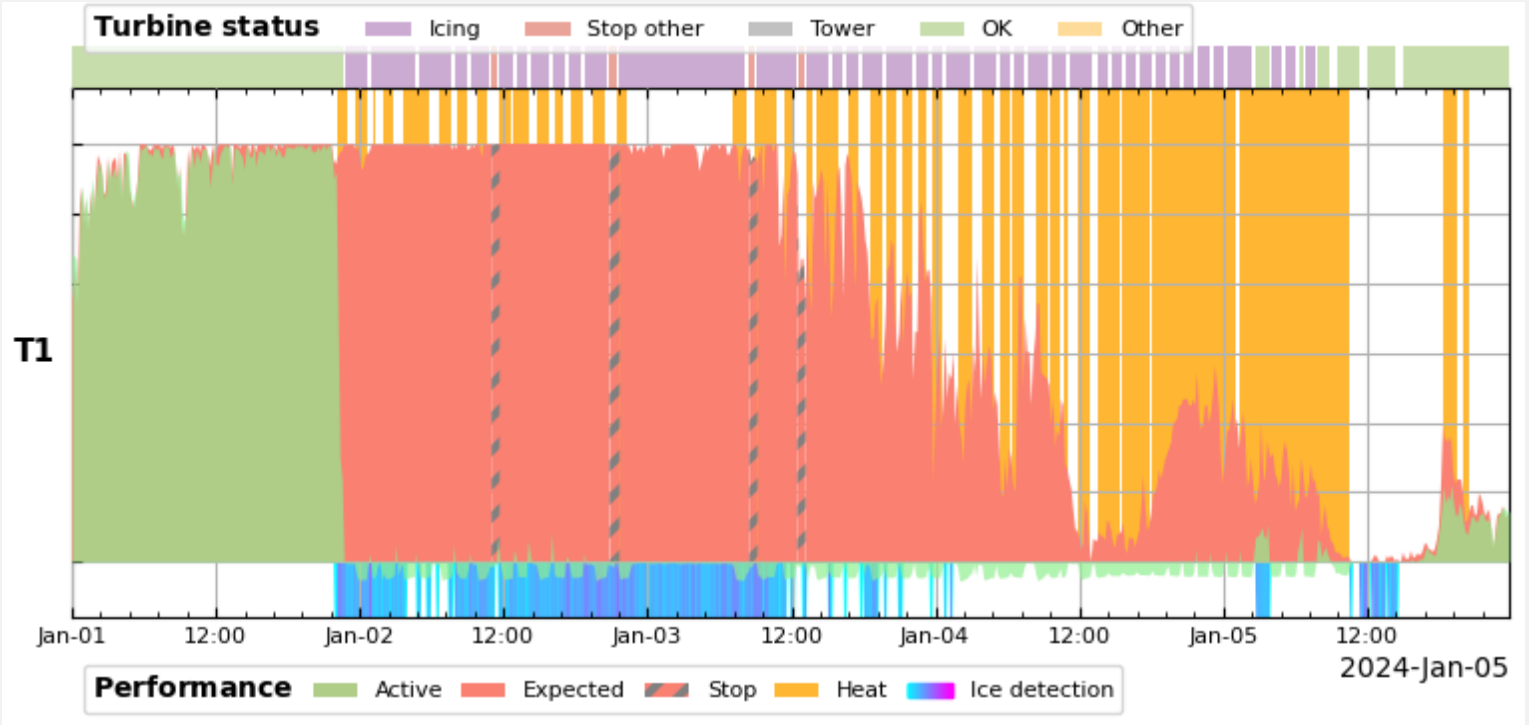
A small heated area will rarely remove 100% of the ice and requires a more lenient turbine control strategy



Is the IPS efficient?

IPS Performance





Now what?

- How do I put all of these puzzle pieces together?
- IceBrain
- Generate IPS availability KPIs
- Trigger IPS based on the IC-1
- Live monitoring for icing

Thank you

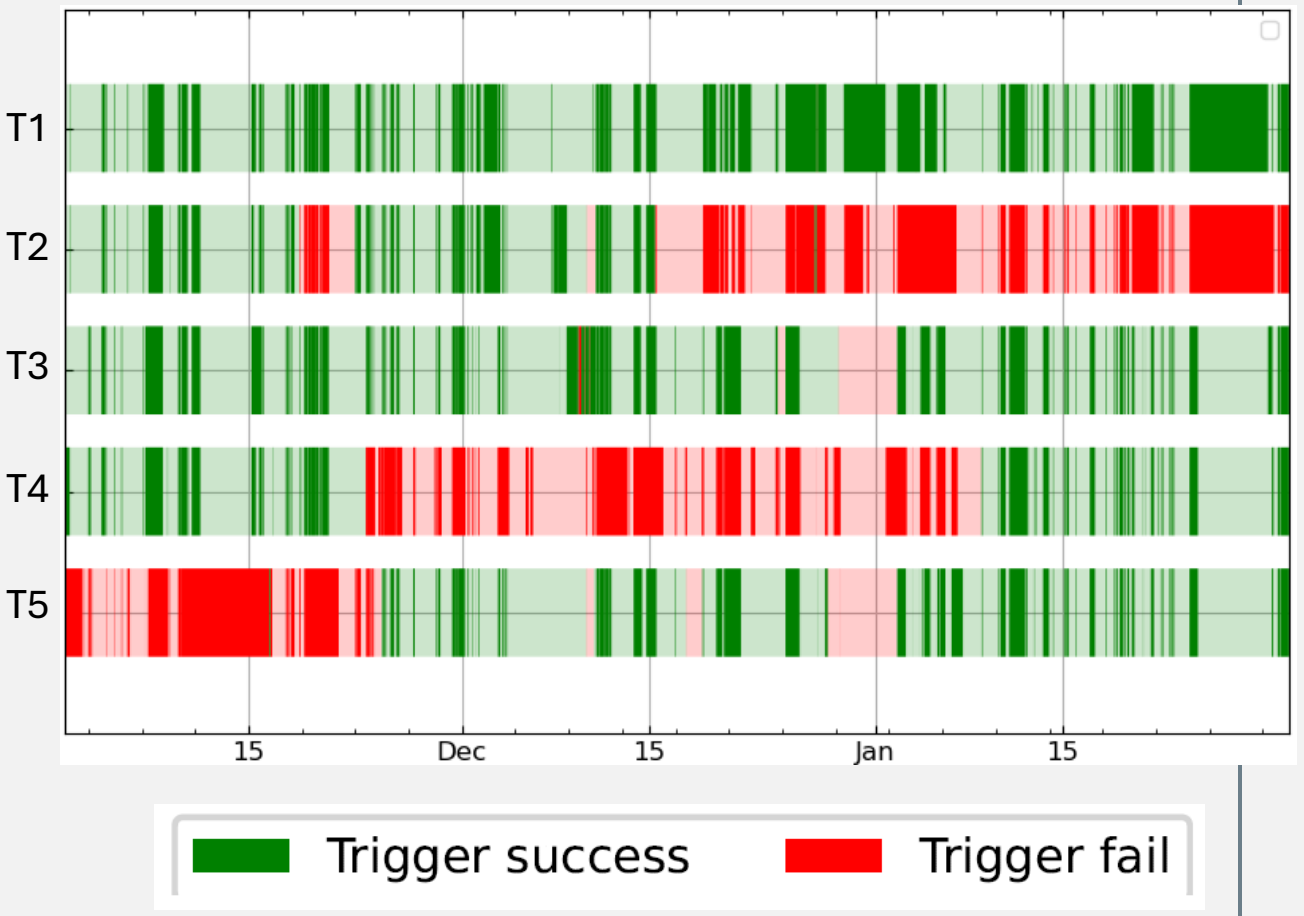
Synergy

- Project planning phase
- One missing piece can make the difference

IPS availability

- Easy KPIs to identify quickly unavailability

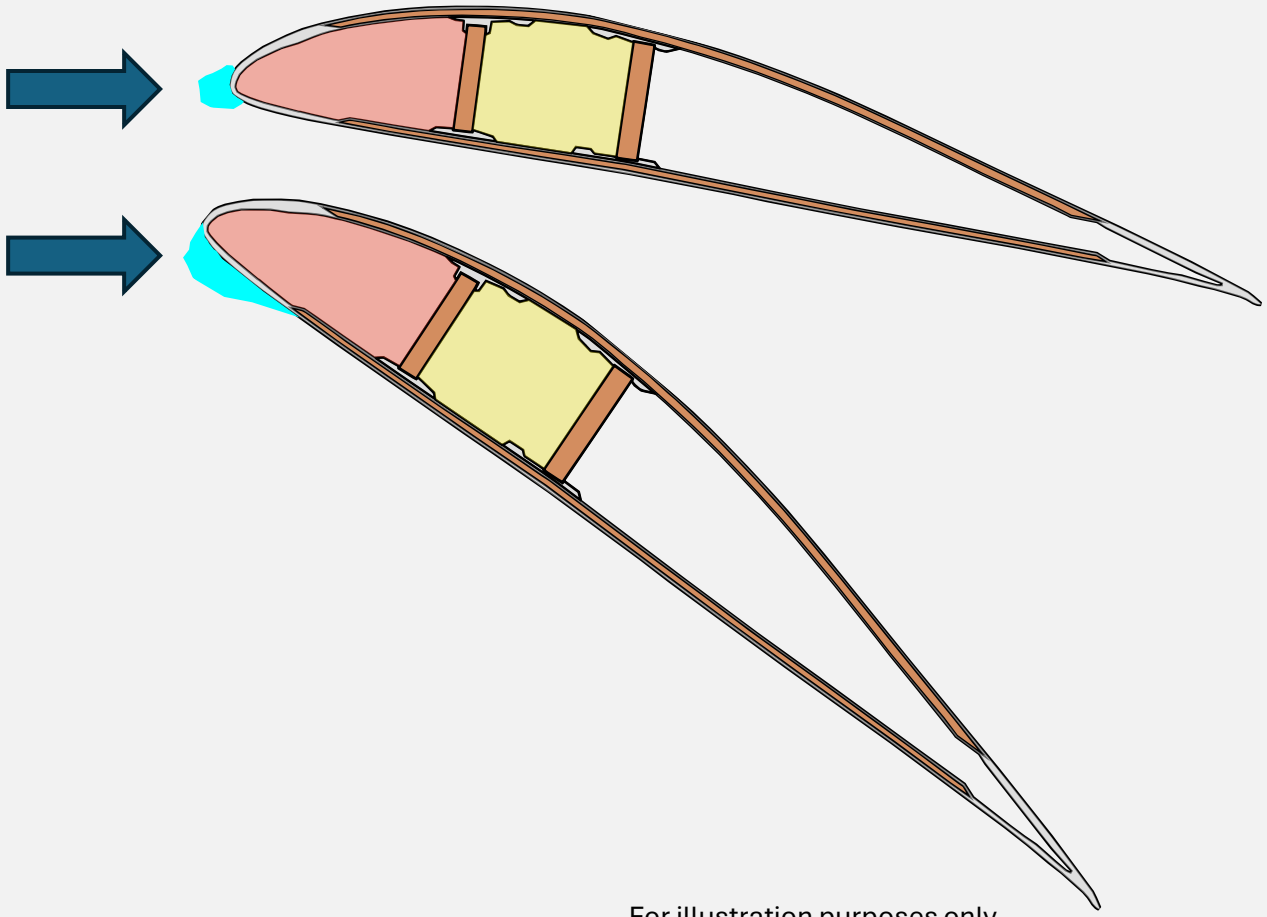
1. Was it activated when supposed to?
2. When activated, did it heat?



Anti-icing vs. De-icing

Anti-icing vs. De-icing

- Accretion zone in anti-icing vs de-icing
- Ice accretion outside the main heating zone
- Harder to remove



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