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Availability of Ice Mitigation Systems

A key driver for performance and revenue

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Winterwind 2025

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Powerful design … Efficient … and Complicated

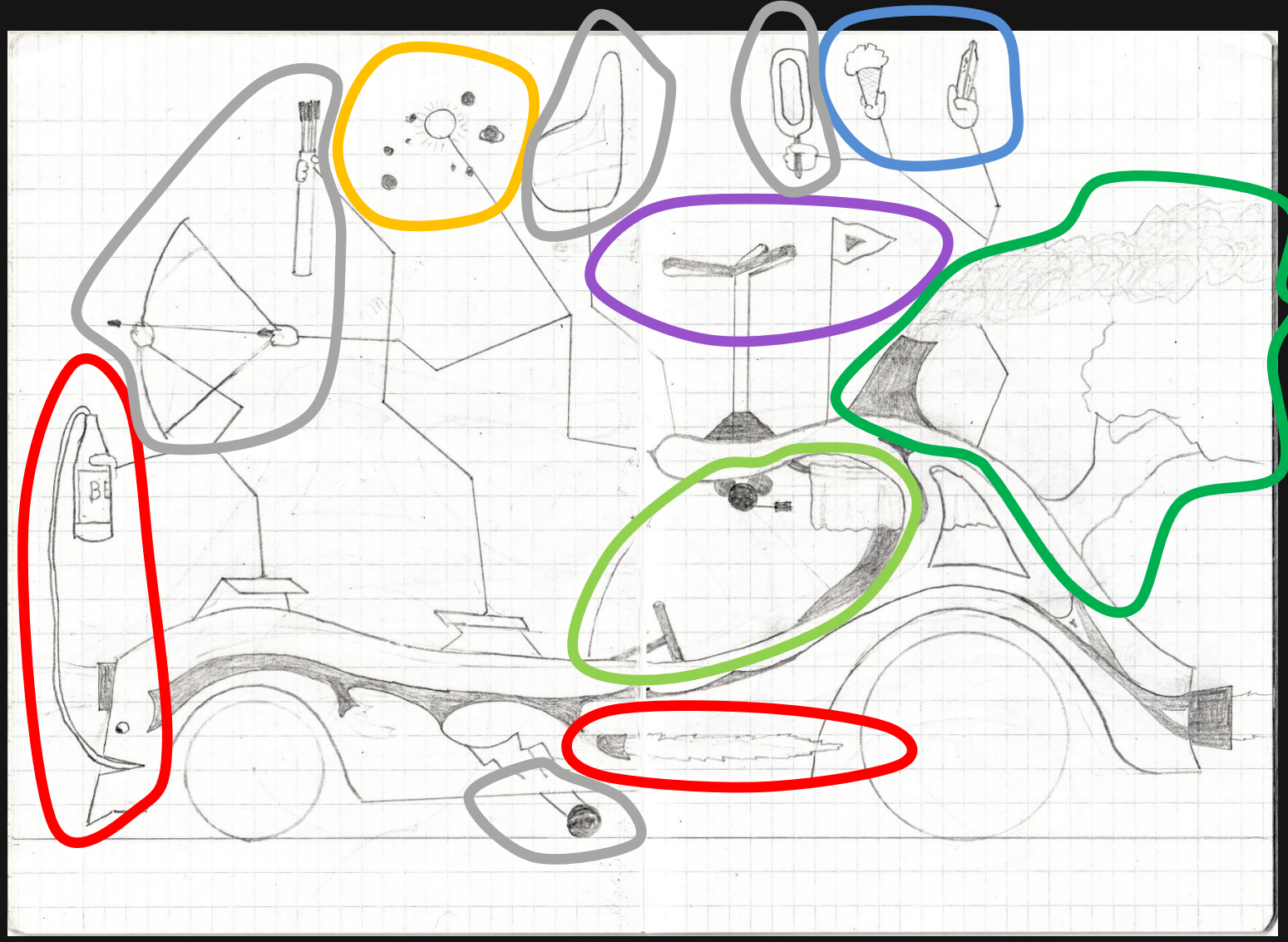
Communication with the world outside

Controller system

Internal energy consumption

Heating system

?? Unknown components



Temperature

Icing

Wind speed

Wind direction

Reducing carbon dioxide emissions

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Ice Mitigation Systems

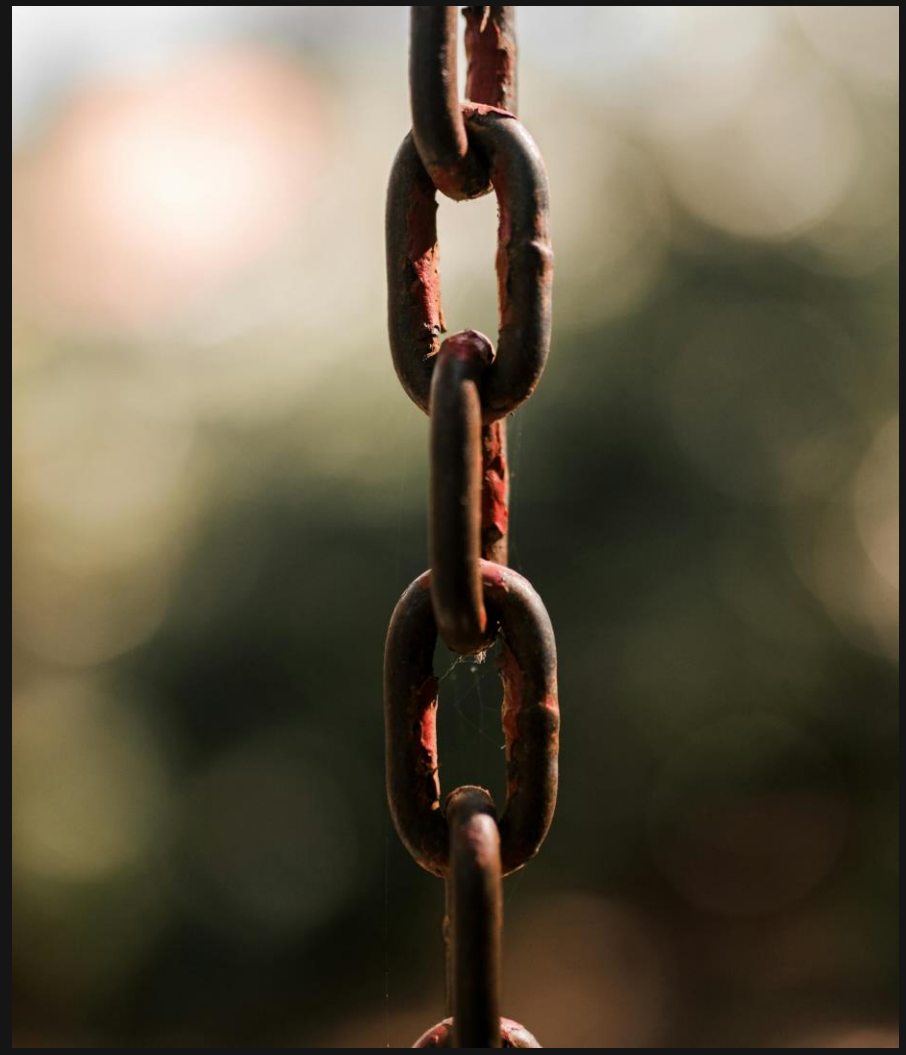
Efficient ... and Complicated

- Even the most powerful system is of now use if it is faulted
- Faults may be advanced, but also very simple

Ice Mitigation Systems

Chain of actions

- **Required functions**
  - Ice detection
  - Communication
  - Controller
  - Blade heating
  - Temperatures readings
  - Software
- **Missing redundancy**
- **Never more powerful than it´s weakest link**



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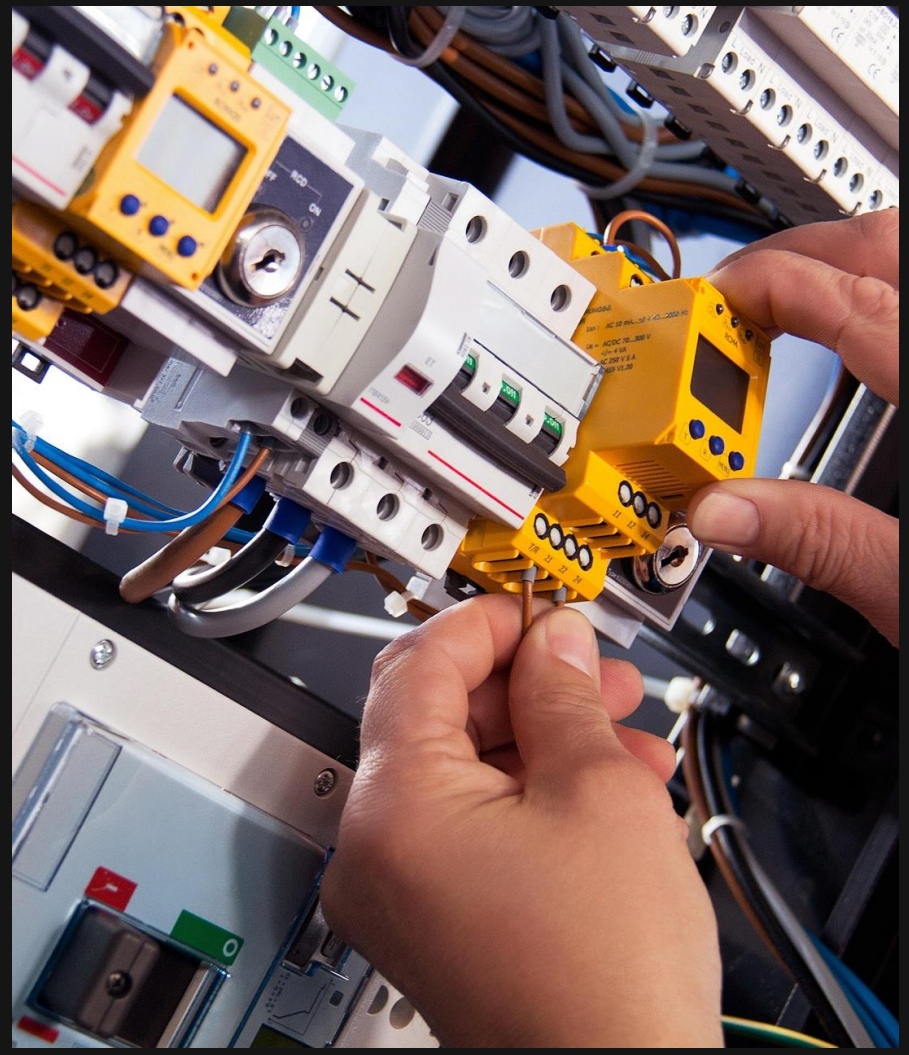
Reasons for IMS failures

Common causes

- Blown fuses
- Loose cables
- Communication issues
- False temperature readings
- Broken power supplies
- Over temperature failures

Requires

- Repair teams on site
- Spare parts stock holding
- Road access, snow, ice
- Safe weather and ice throw conditions
- Software and parameter settings



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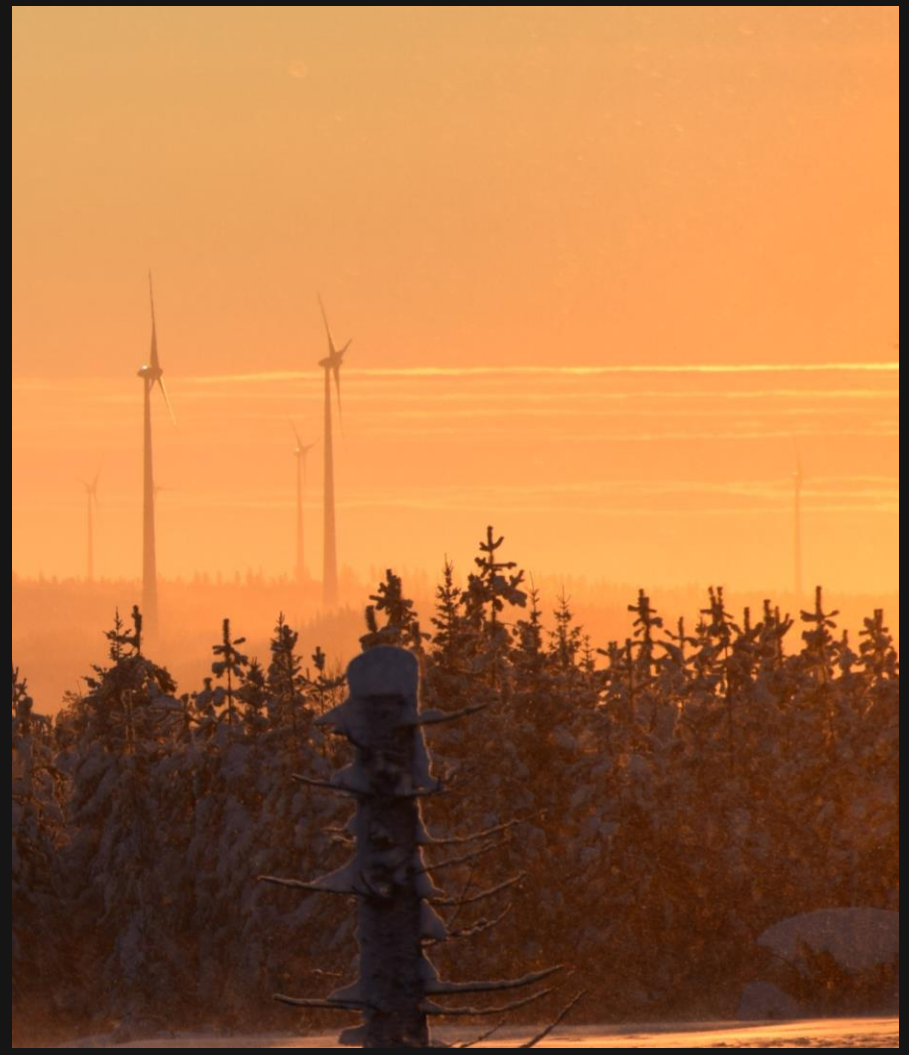
IMS availability

- IMS Availability – The ability to respond adequately to icing, usually by running blade heating
- Large impact on production and revenue
- Ice losses are frequent when spot prices are high



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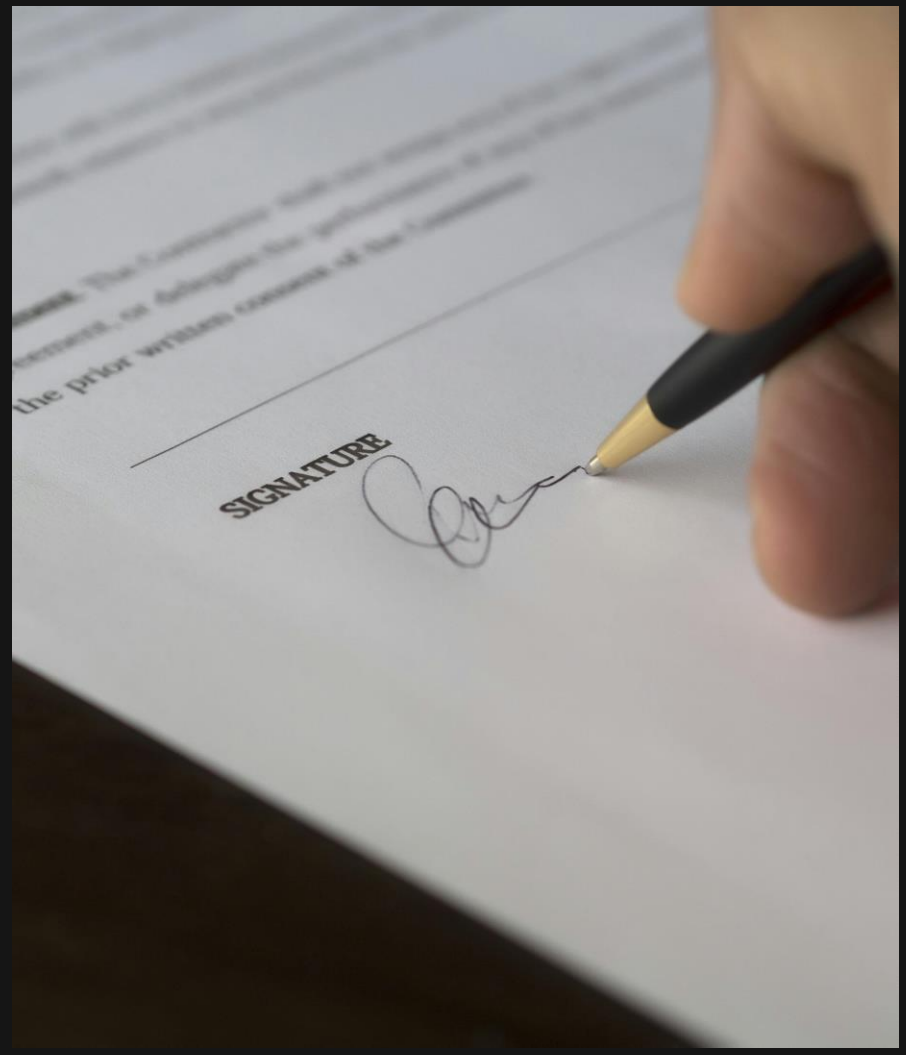
IMS availability

- Often forgotten or weakly regulated in contracts
- No industry standard for calculating IMS availability



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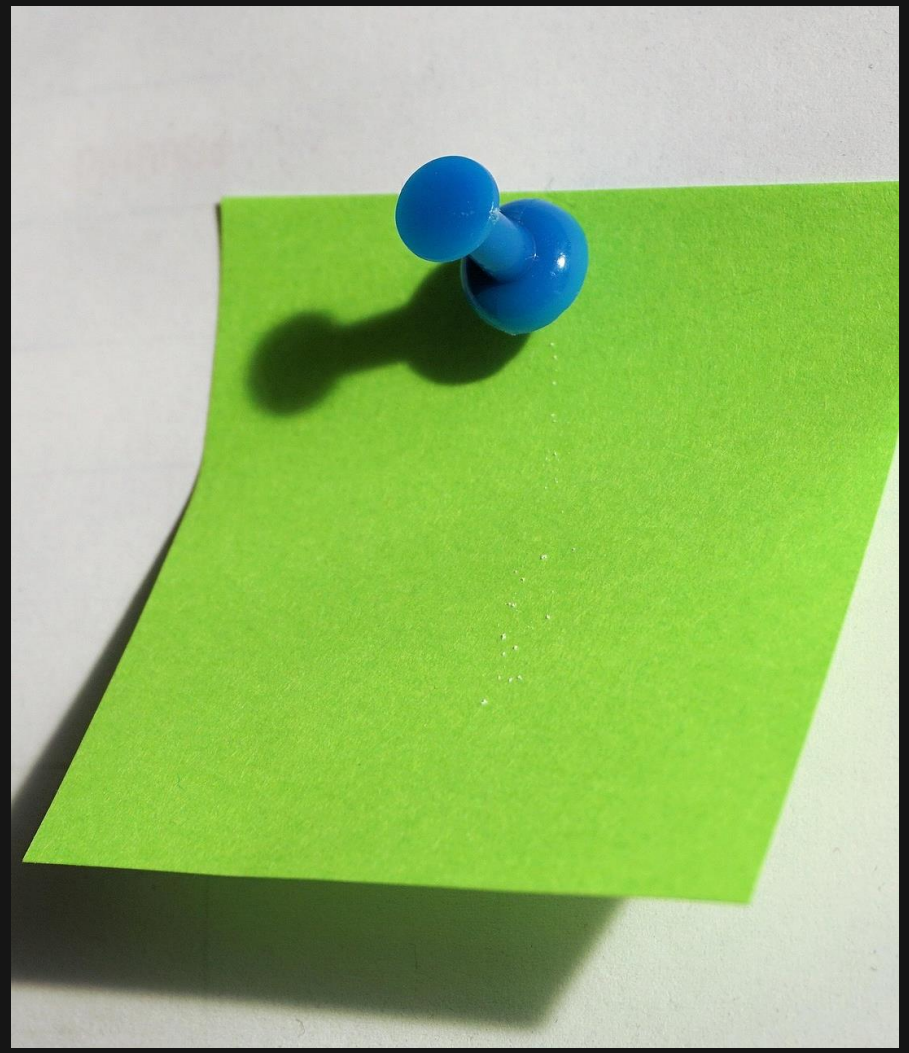
The task



- Find a standardized method to estimate IMS availability
- Use basic signals and messages
- Build on Task 19 methodology
- Results comparable between different turbine types and farms
- Add financial information

Skogberget wind farm

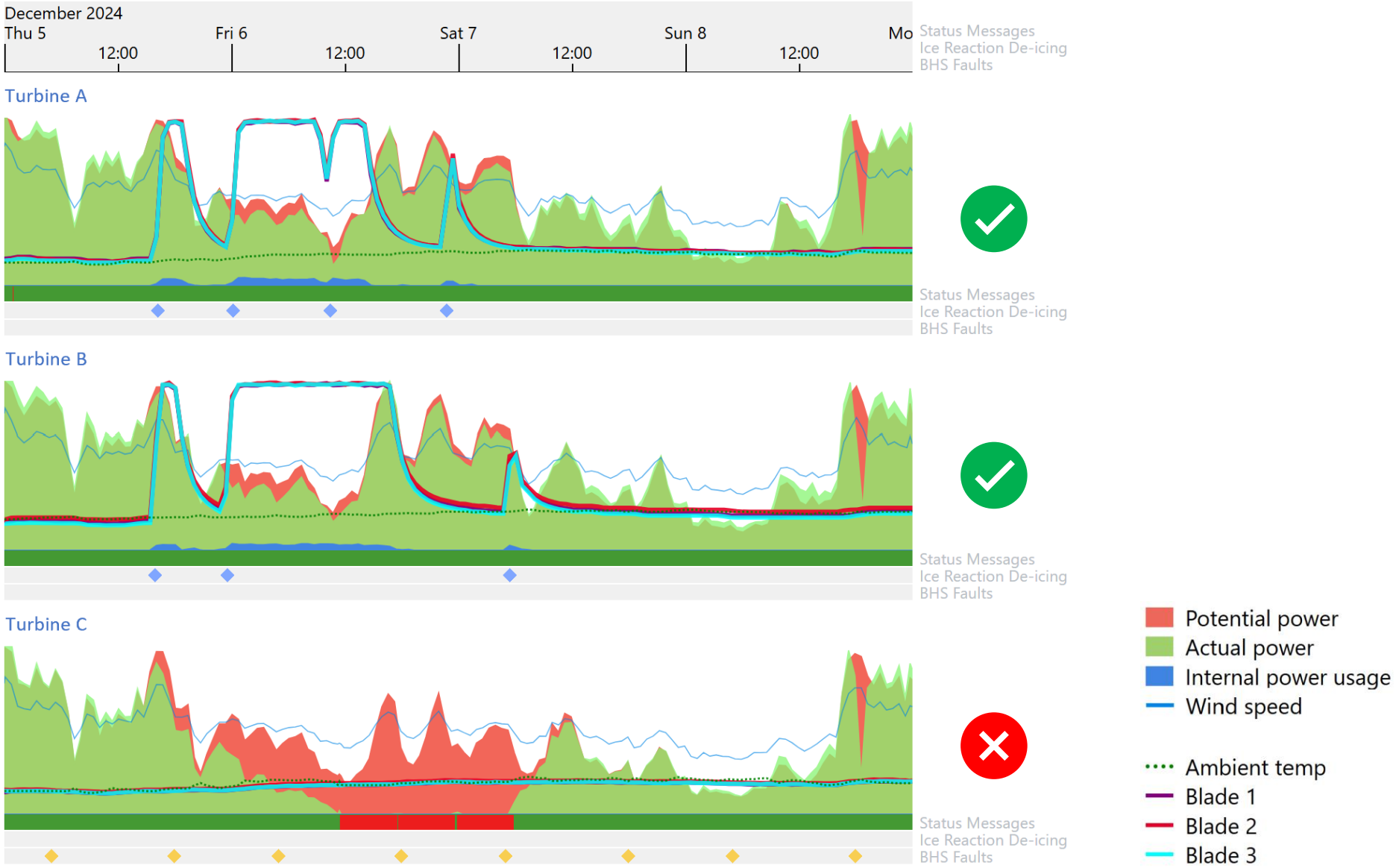
Markbygden, northern Sweden

36 turbines

Enercon E-92 E2 2.35MW

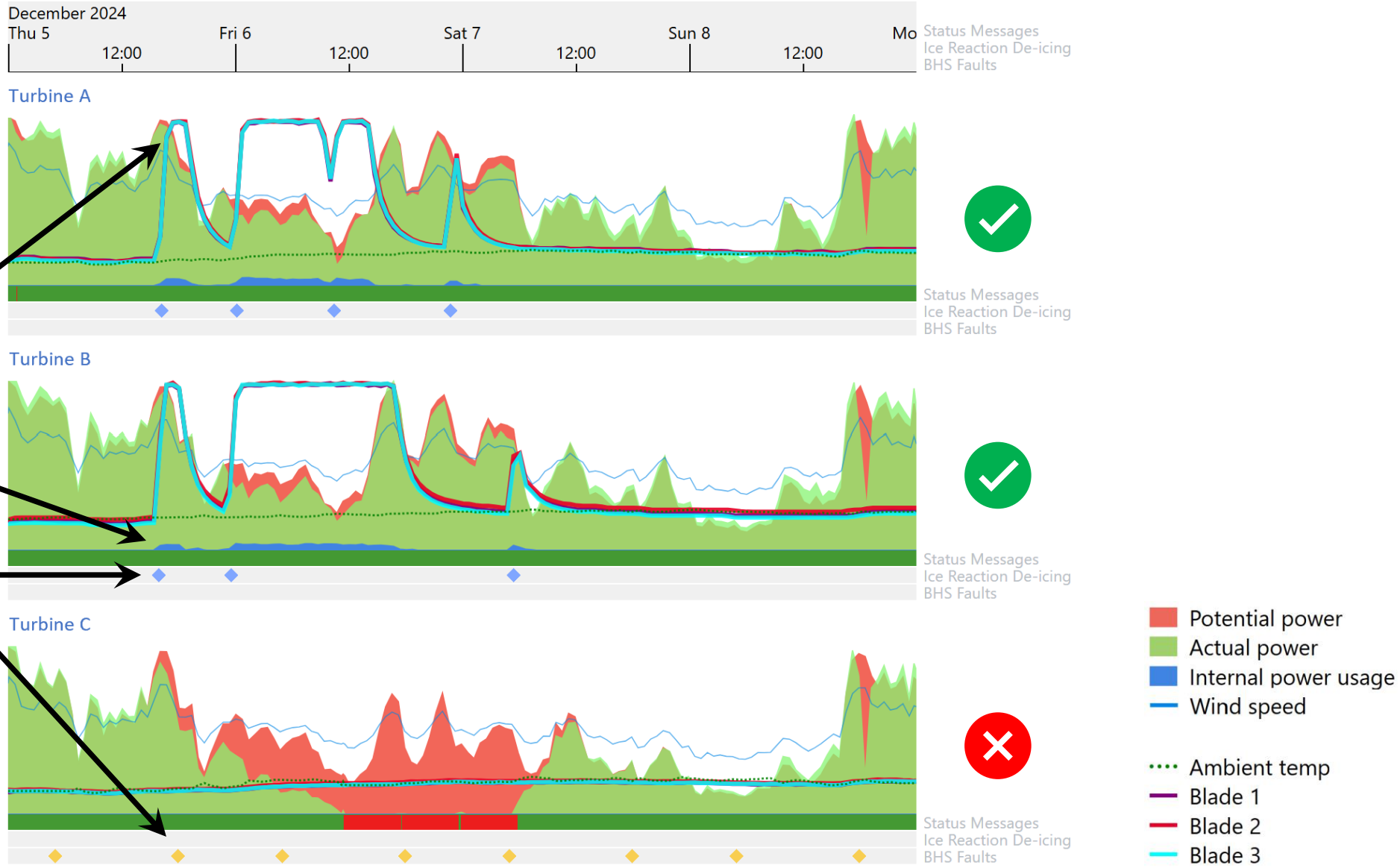
Hot air blade heating system

Importance of functional IMS



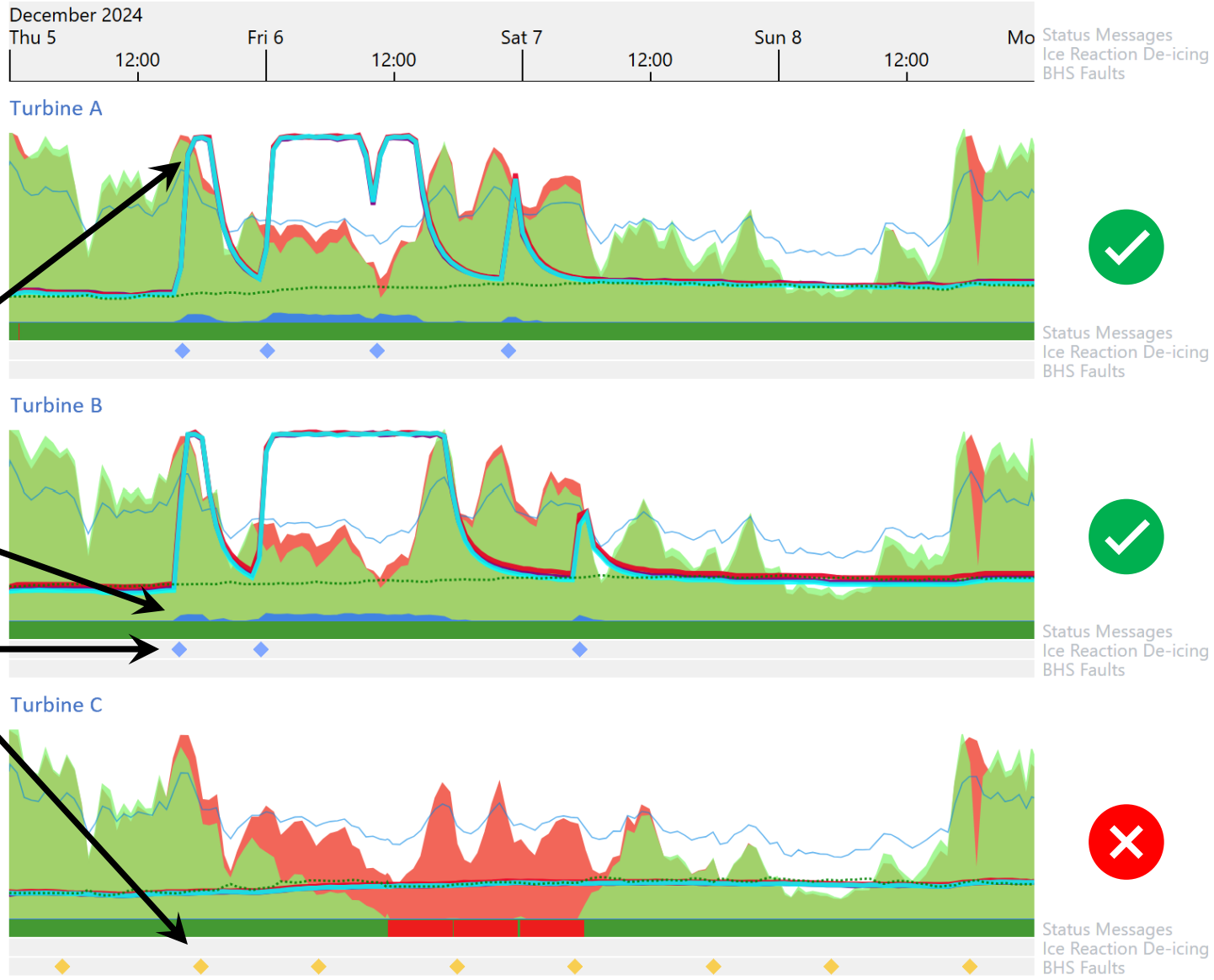
How to know if IMS is functional or faulted?

- **Blade temperatures**
- **Blade heating power usage**
- **Messages**



How to know if IMS is functional or faulted?

- **Blade temperatures**
- **(Blade heating power usage)**
- **((Messages))**

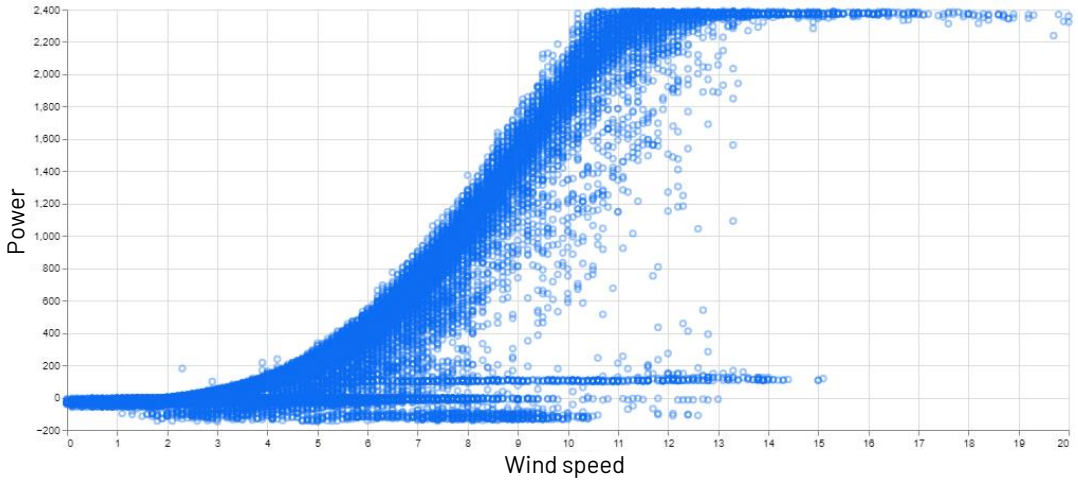


When IMS is faulted, false or missing turbine messages and signals may be part of the problem

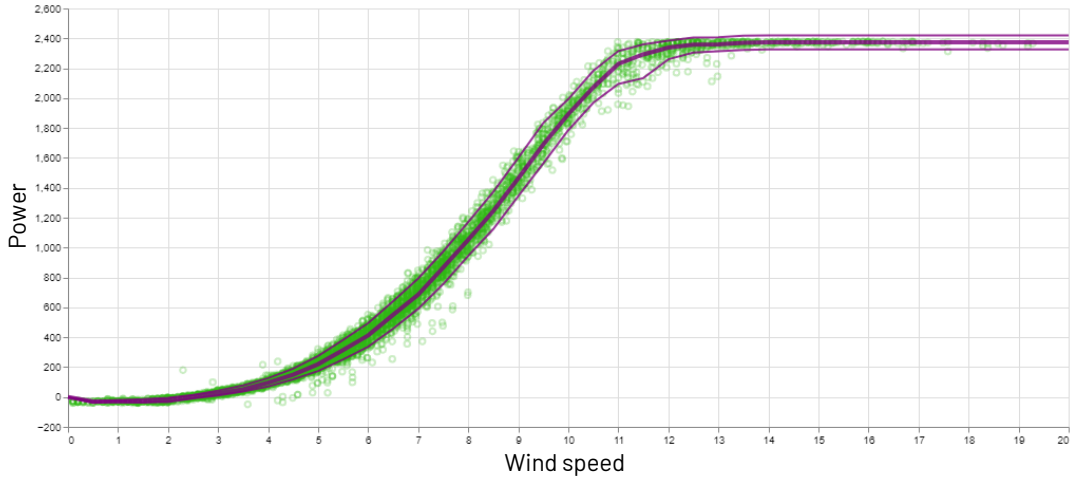
Use as basic information as possible

Basic ice loss calculation – Task 19

Reference power curve from none iced operation



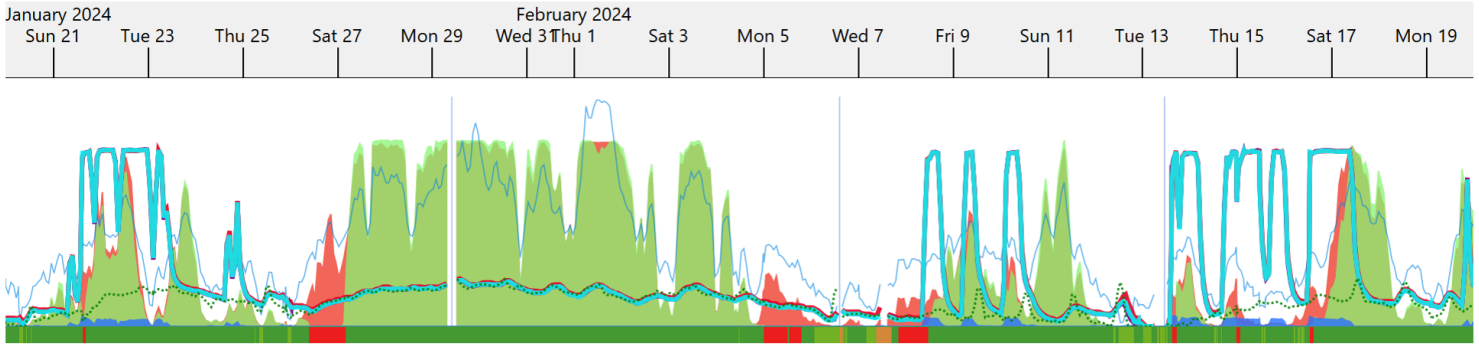
All 10-min data points



None iced reference data points and p90, median and p10 curves

Basic ice loss calculation – Task 19

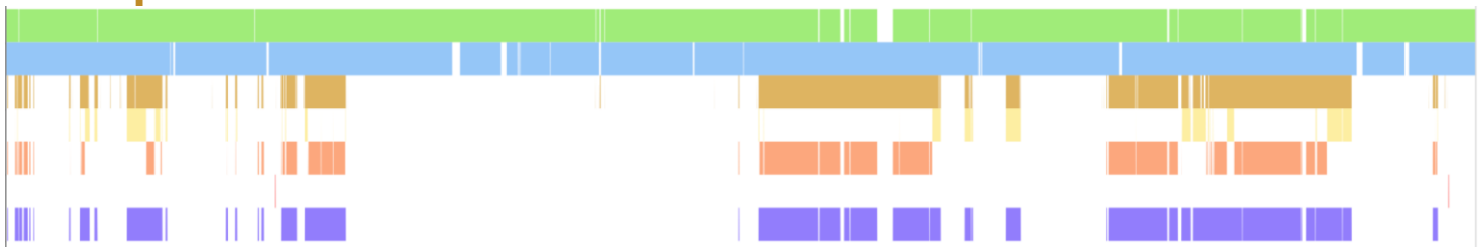
Production overview



Potential power
Actual power
Internal power usage
Wind speed

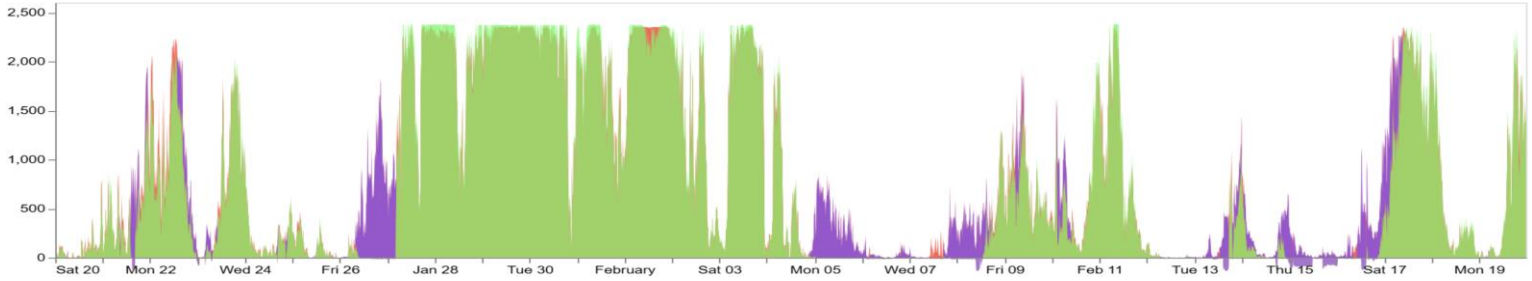
Ambient temp
Blade 1
Blade 2
Blade 3

Ice loss periods



Normal operating state and not curtailed (to remove none-iced related faults)
Ambient temperature is below 3 °C
Power below 10th percentile of own reference power
IEa (Production ice losses)
IEb (Standstill ice losses)
IEc (Overproduction, iced anemometer)
IEa + IEb (All ice losses)

Ice losses kWh



Ice losses
Other none-ice-related losses
Power (actual net power, exported)

Key events »» IMS functional or faulted

Key event “Blade heating is running” – Indicating IMS functional

- Blade temperatures – Much higher than ambient temperature (>= 20 °C, >= 30 minutes)
- (Blade heating power usage) – Useful for electro thermal heated blades
- ((Messages)) – Useful when reliable

Key event “Severe ice, no response” – Indicating IMS faulted

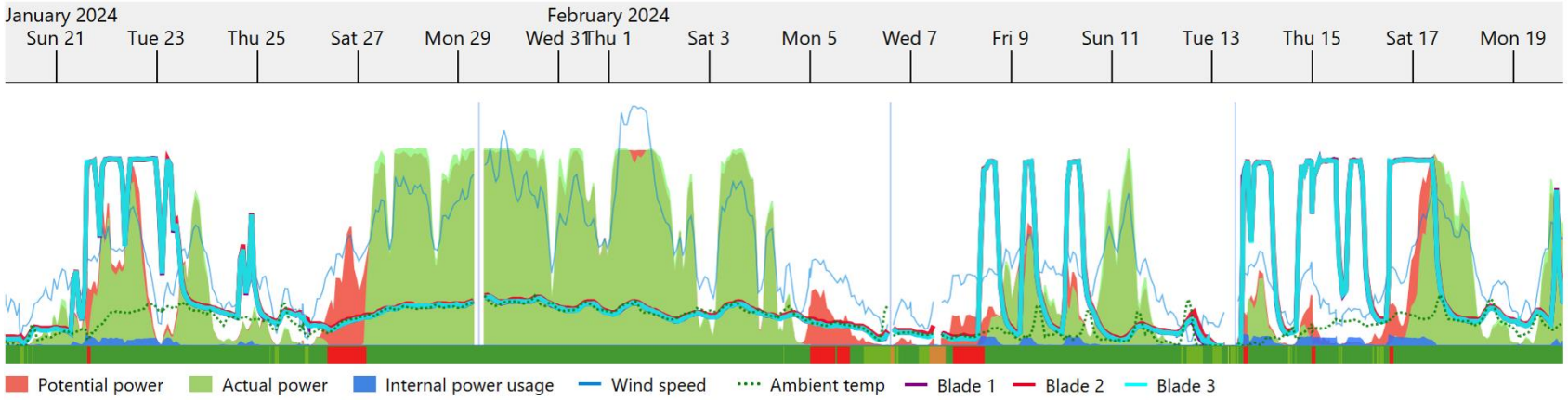
- Medium or high wind speed (reference power >= 15% of max capacity)
- Power output is two times below median vs p10 distance (two times Task 19 diff)
- Turbine fails to respond, does not run any blade heating
- Conditions valid for >= 60 minutes continuous (two times Task 19 time)

Times between key events

- Last key event state is still value, until otherwise is proven

Method example

Production overview



Real life

- Blade heating power usage is only approximal and including other consumption
- Warning messages (IMS faults) are missing in current data source

»» Use blade temperatures

Key events »» IMS functional or faulted

Evaluation time, only include time when IMS is needed »» IMS availability

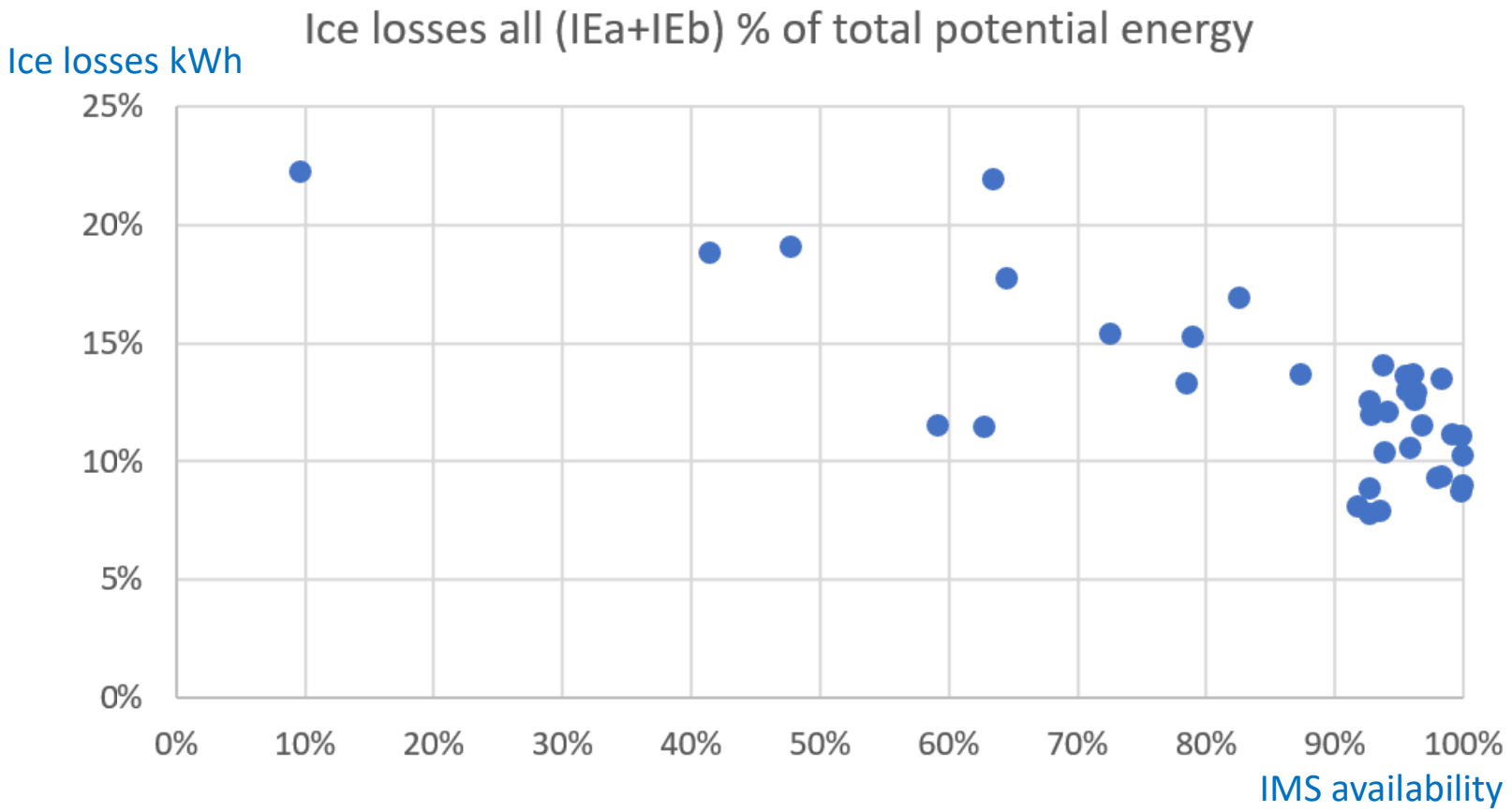
Ice affected = Task 19 ice losses & Power expected (reference power at current wind speed >= 0,5% of max power)

IMS availability (by demand) = IMS functional time % of ice affected time

IMS availability (time based) = IMS functional time % of all cold weather time

Ice losses = f (IMS availability)

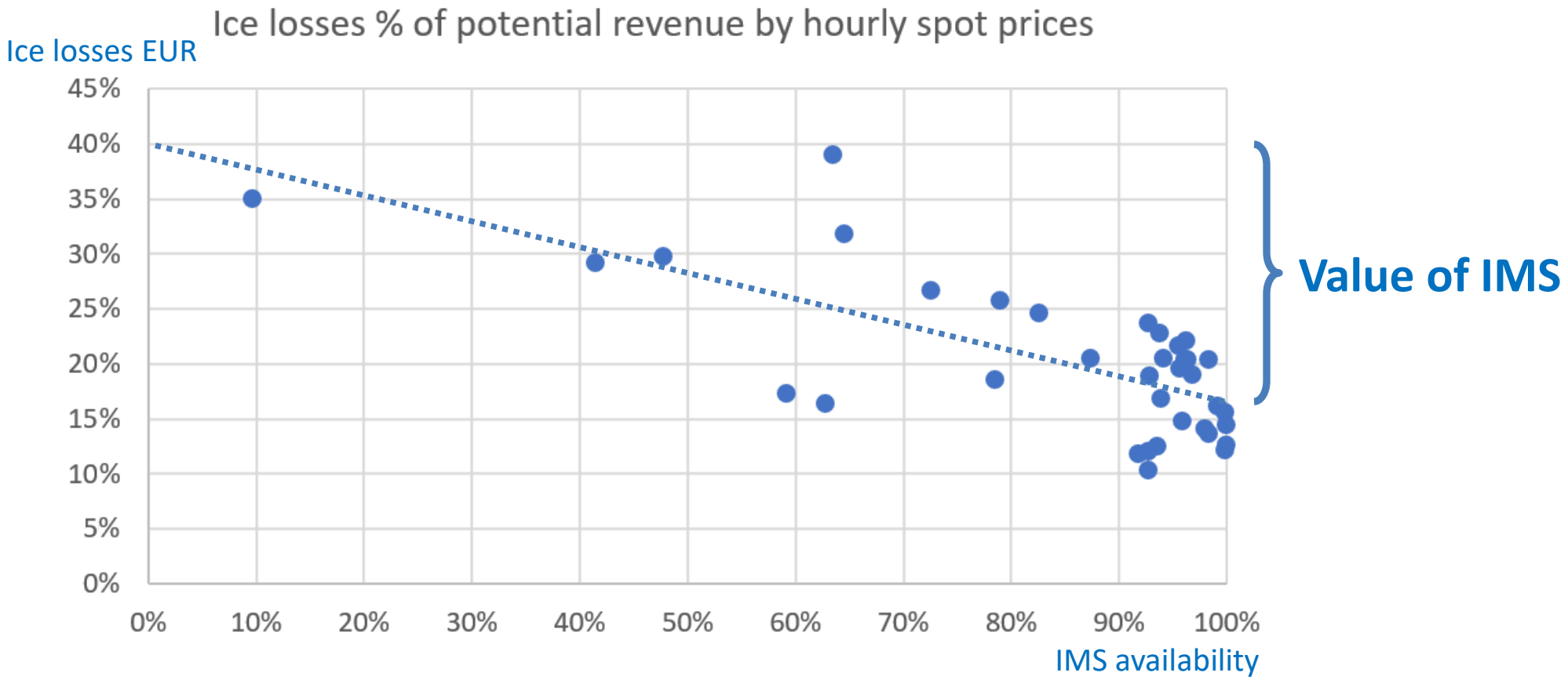
Ice losses energy (kWh) as function of IMS availability (by demand)



Skogberget wind farm, northern Sweden, winter year 23-24 (July 2023 – June 2024)

Ice losses = f (IMS availability)

Ice losses revenue (EUR) as function of IMS availability (by demand)



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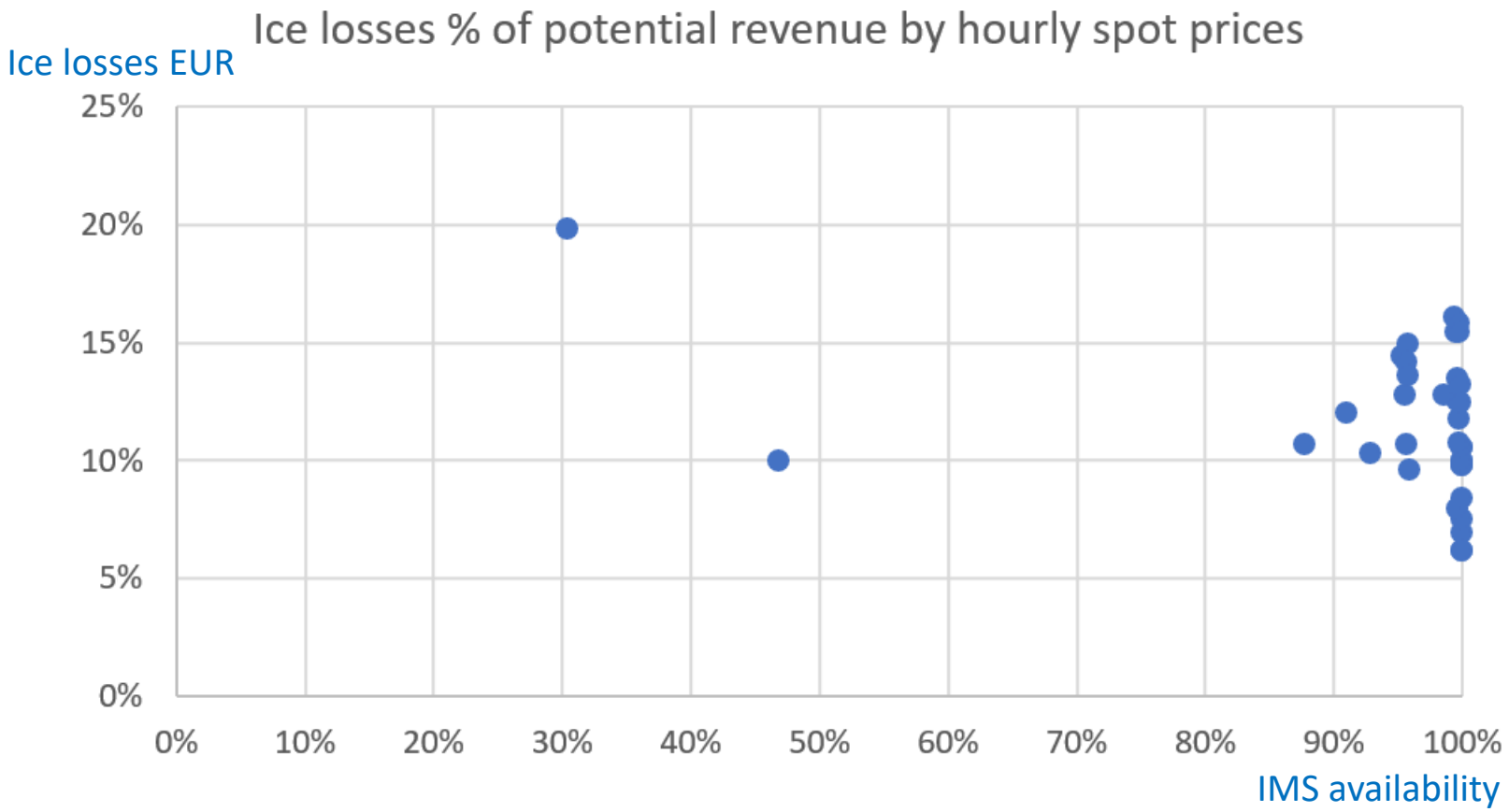

Value of IMS?

Regression not possible

Skogberget wind farm, northern Sweden, beginning of winter year 24-25 (July 2024 – January 2025)

Extra ice losses due to faulted IMS

Extra ice losses due to faulted IMS

- kWh & EUR
- Important for business decisions, to find sufficient levels of efforts

Reference functional IMS

- Post-process whole wind farm
- For each 10-minute period, build a reference (production, ice losses) including turbines with functional IMS and normal operating state

Extra ice losses, for each turbine each 10-minute...

- Turbine in normal operating mode (no other stops or curtailments)?
- IMS faulted?
- Extra ice losses = Difference between reference and actual ice losses

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IMS availability

Challenges

- Usage of messages as key events
- Turbines with short faults (coming/going)
- IMS restricted by farm consumption limits
- Out of IMS operating window
- Long times with only mild icing (no key events)
- Evaluation time: by demand, time based, farm demand, calendar time

Opportunities

- Common view on situation
- Contracts
- Compare different turbine types and wind farms
- Business decisions: sufficient repair efforts
- Stable renewable energy production

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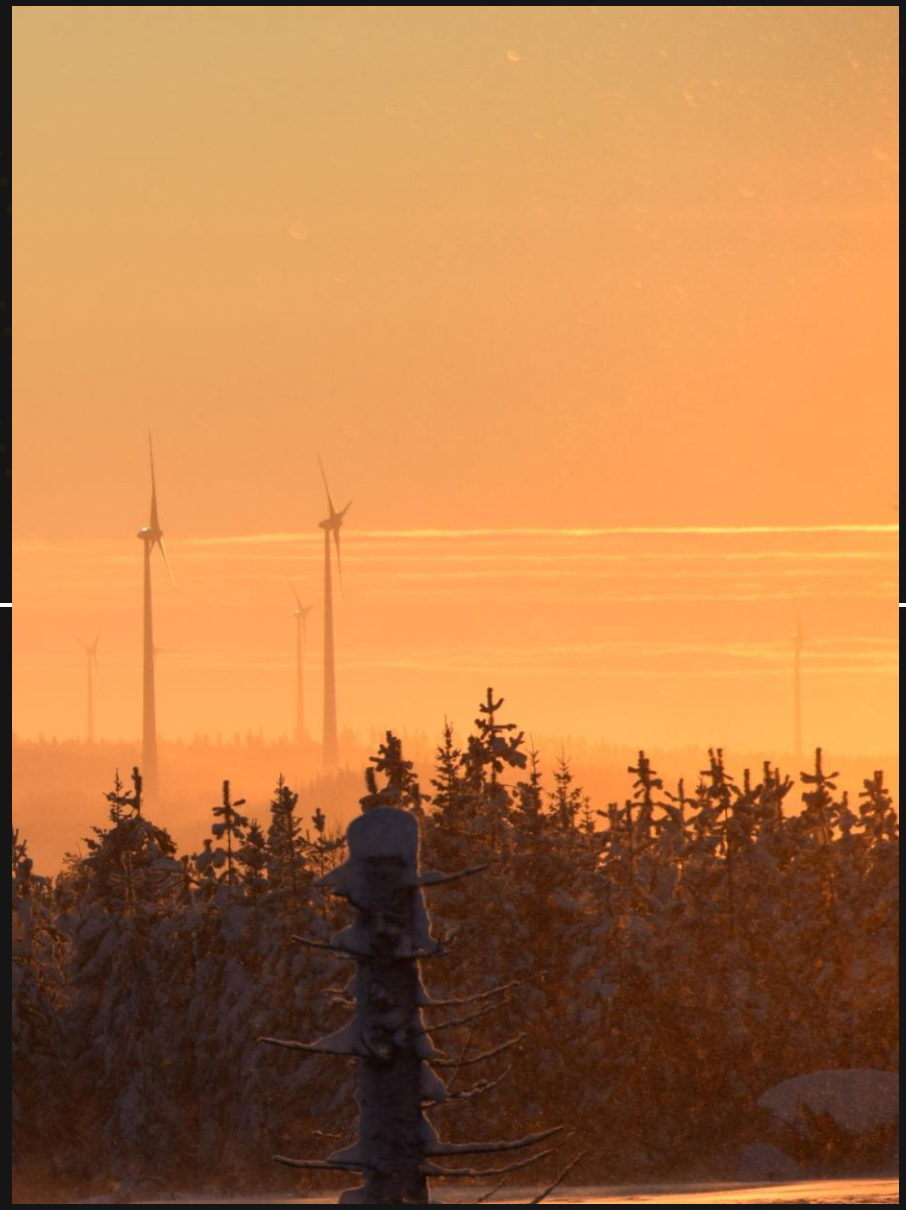
Thank you!



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