Blade heating system performance envelope field validation – practical experiences

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WICETEC
Ice Prevention Systems

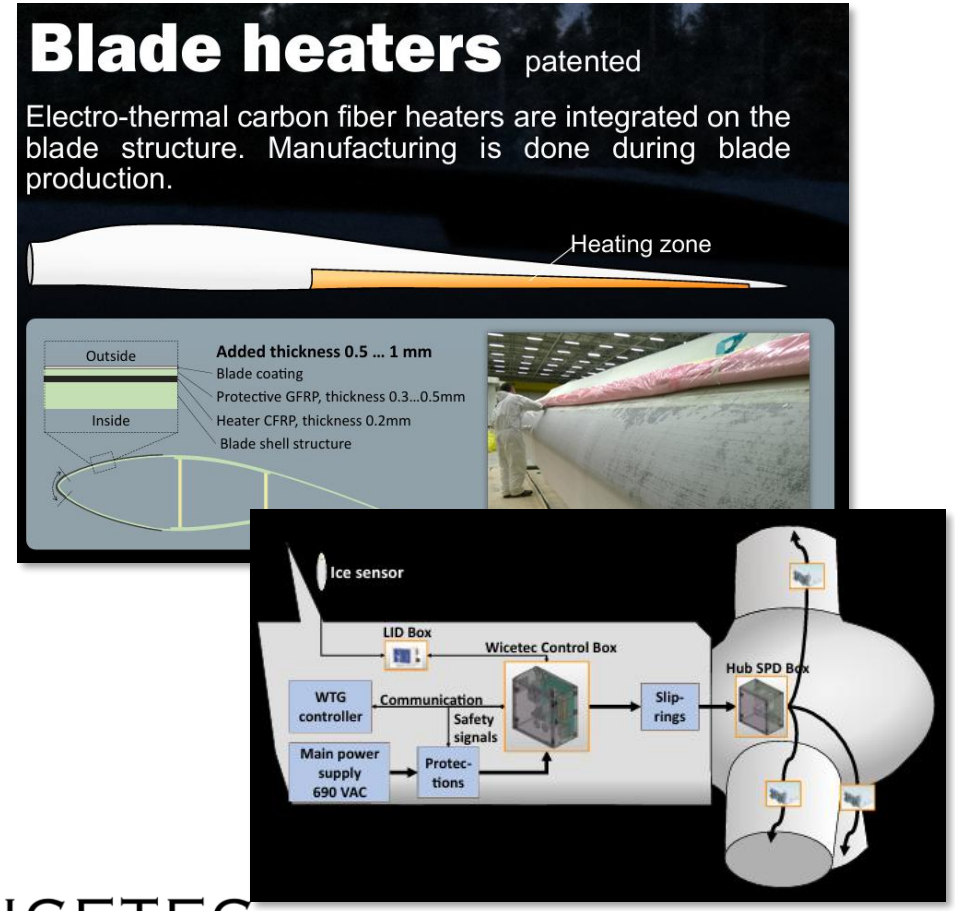
FabricAir

BorealisWind
Ice Protection System

Who we are?

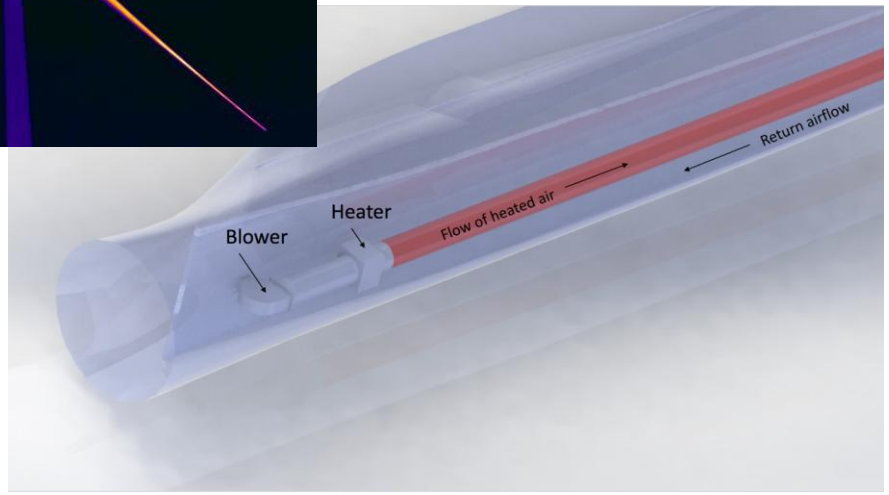
Wicetec, founded in 2014

- Main product: carbon fabric-based blade heating system for wind turbines



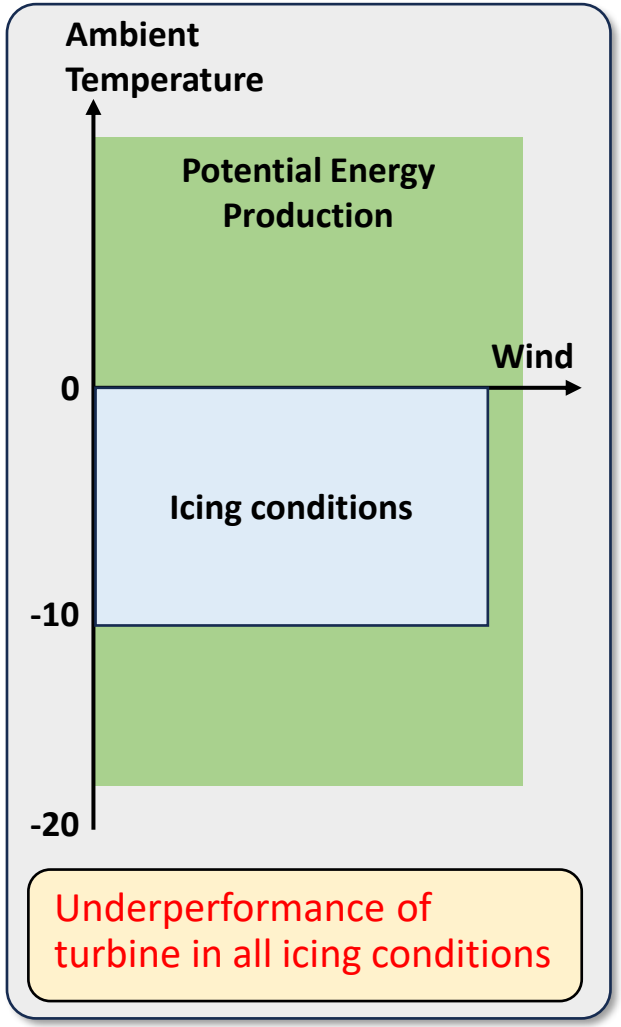
BorealisWind, founded in 2016

- Main product: internal hot-air blade heating retrofit

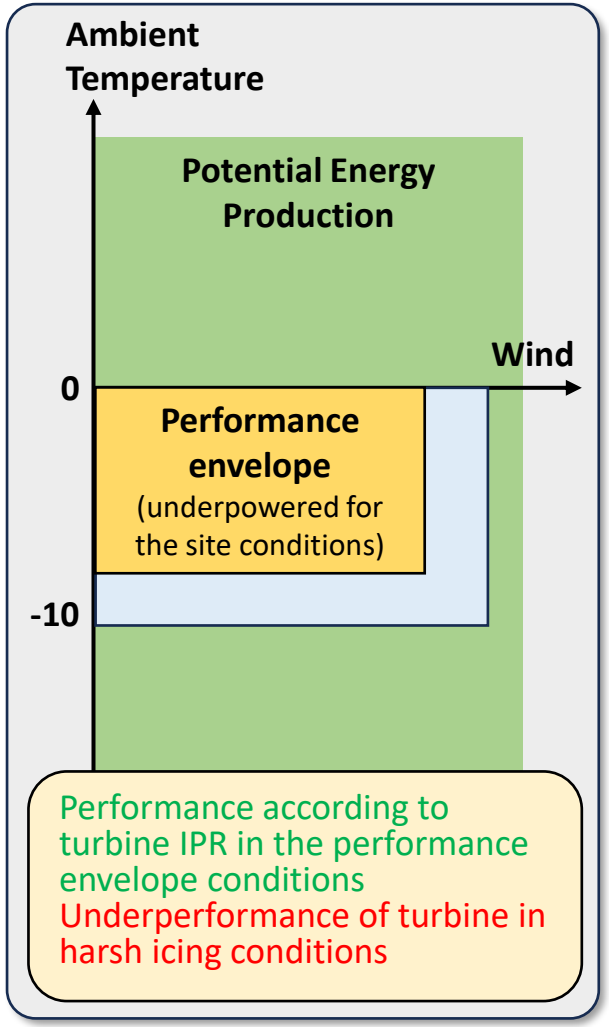


What does “performance envelope” mean?

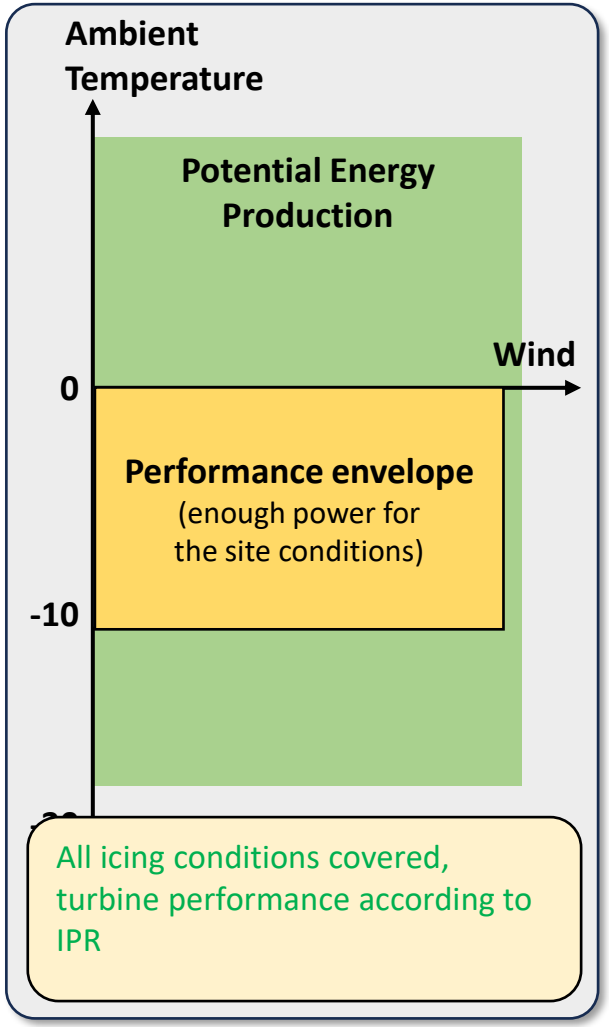
Ideal wind production, no icing



Underperformance of turbine in all icing conditions



Performance according to turbine IPR in the performance envelope conditions
Underperformance of turbine in harsh icing conditions



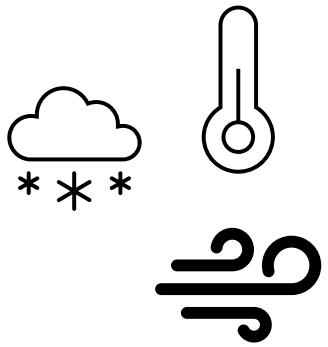
All icing conditions covered, turbine performance according to IPR

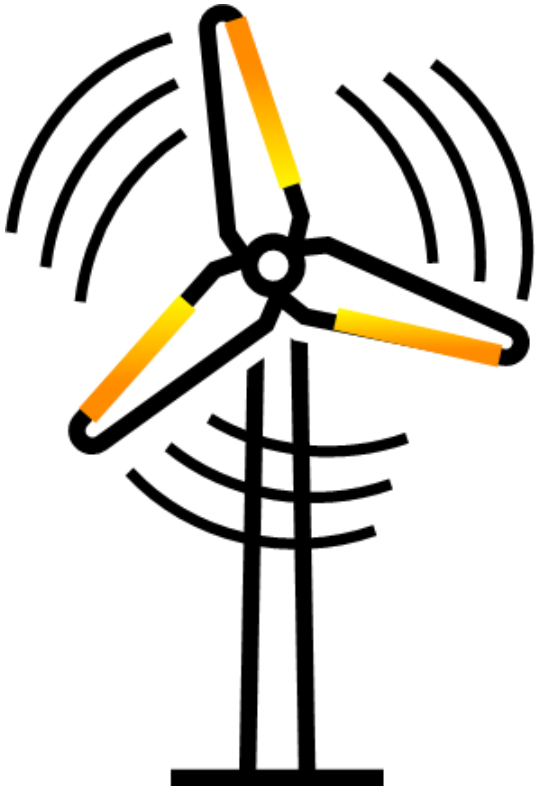
Performance envelope describes the **weather conditions,** where blade surface temperature can be raised above 0 °C.

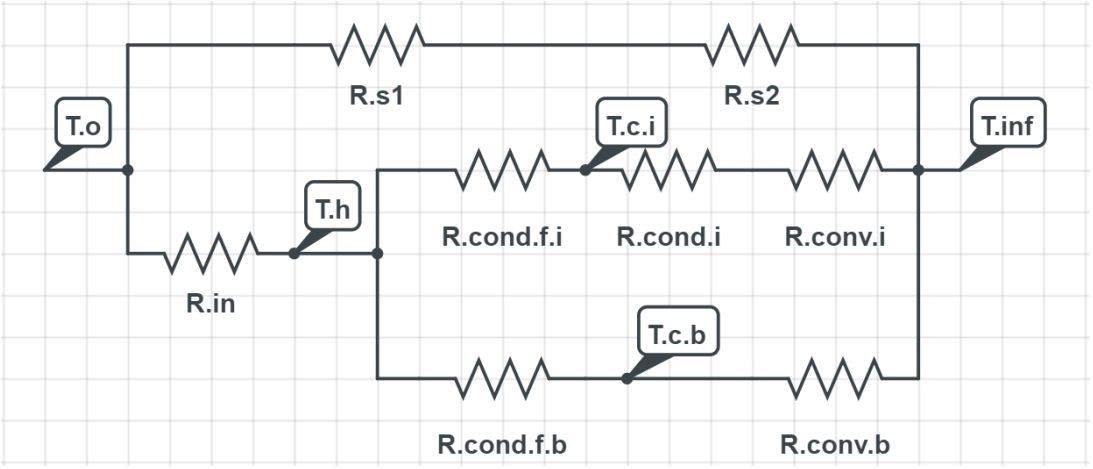
$$IPR = \frac{Actual\ Energy\ Production\ (during\ icing)}{Potential\ Energy\ Production\ (during\ icing)} * 100$$

What impacts IPS Performance Envelope?

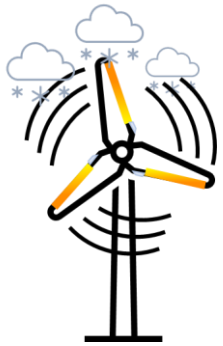
- Ambient conditions:
  - Wind speed
  - Temperature
  - Liquid water content
- Rotor RPM (anti-/de-icing)
- Heating power



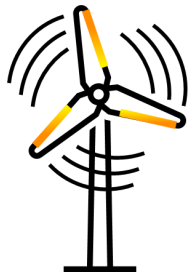




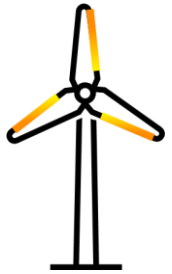
How the performance envelope can be validated?



Icing weather,
turbine in operation



Dry weather,
turbine in operation



Dry weather,
turbine standstill

IEA Wind Task 54 – Performance envelope sub task is developing the methodology

-wind speed
-ambient temperature
-icing
-blade surface temperatures
-turbine data
-pictures from blades (hub camera etc.)

Measurements depending on case

Measurements | Measurements | Measurements

Modelling

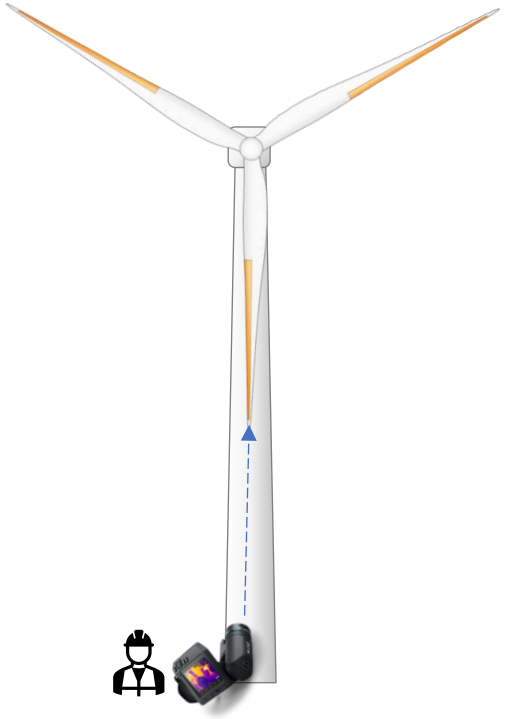
Transfer to "turbine in operation"

Transfer to "icing weather"

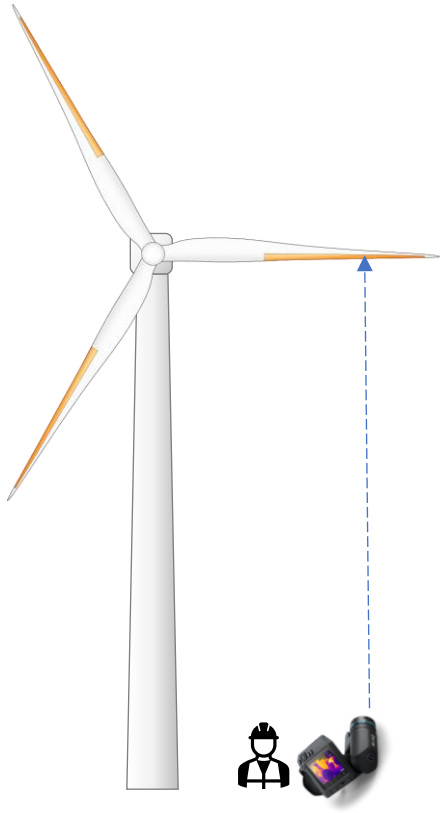
Post processing to
define the performance envelope

For example:
IPS Performance Envelope Model by Patrice Roberge

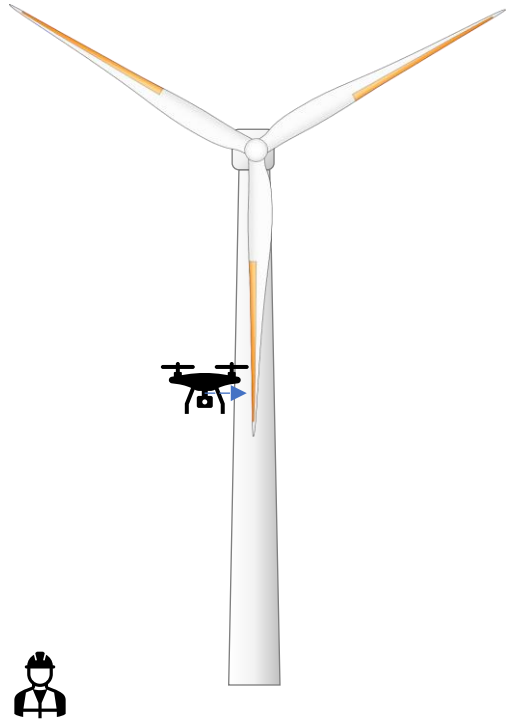
Thermal imaging of blade heaters



Bad angle, reflections

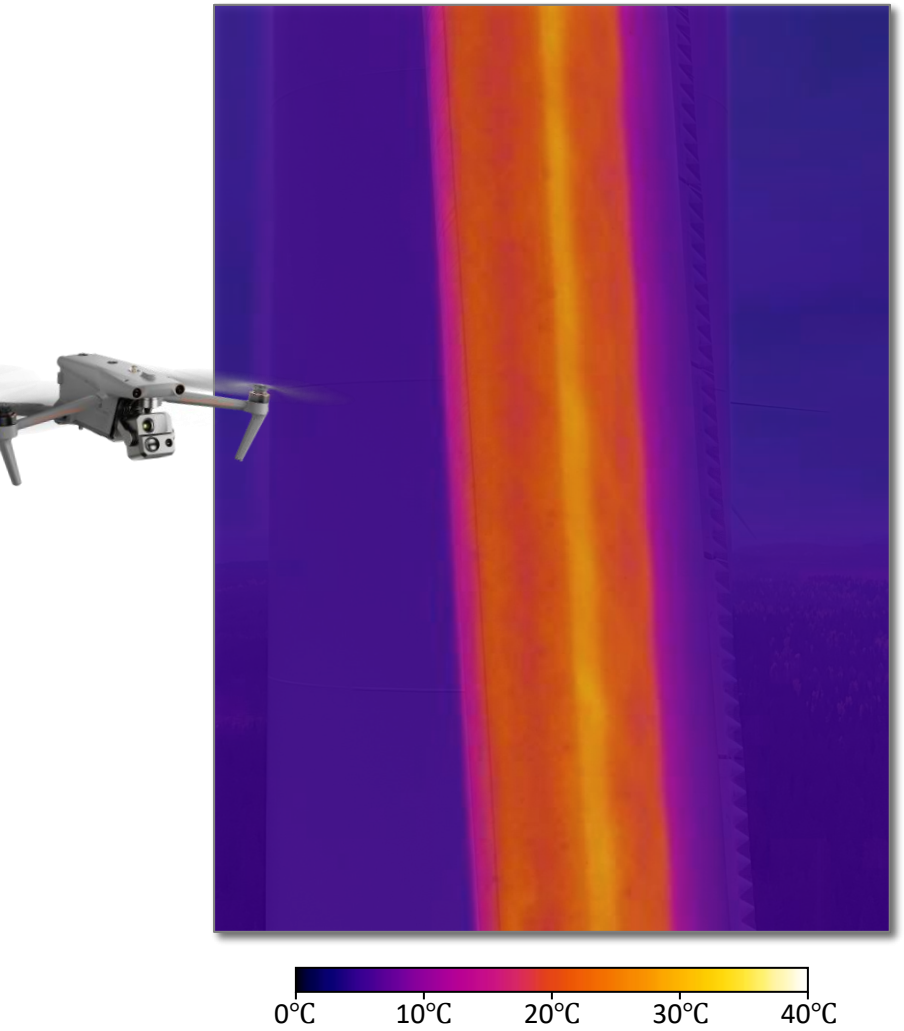


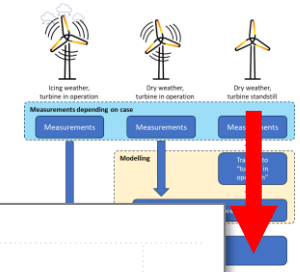
Acceptable viewing angle
Distance to target ≥ hub height
Limitation on camera & operator position

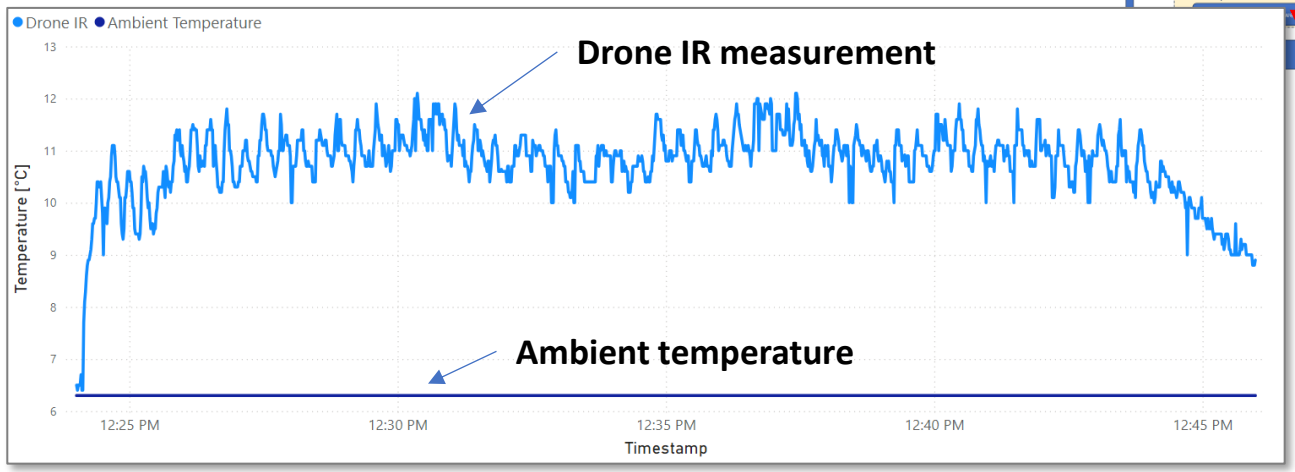


Optimal viewing angle
Short distance to target
No limitations on camera & operation position

Case example – Dry weather, turbine standstill

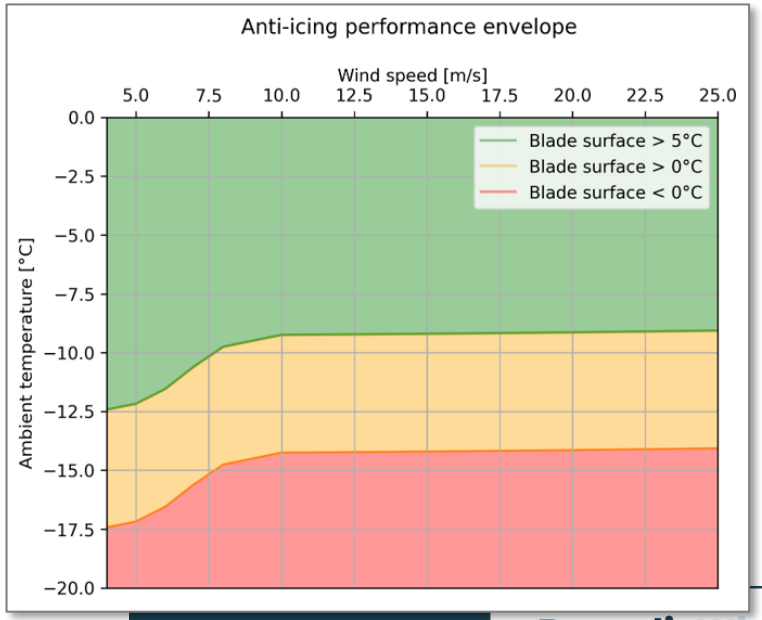






Wicetec's thermal model + TURBICE simulations

Transfer of "standstill & dry measurements" to operating and icing conditions

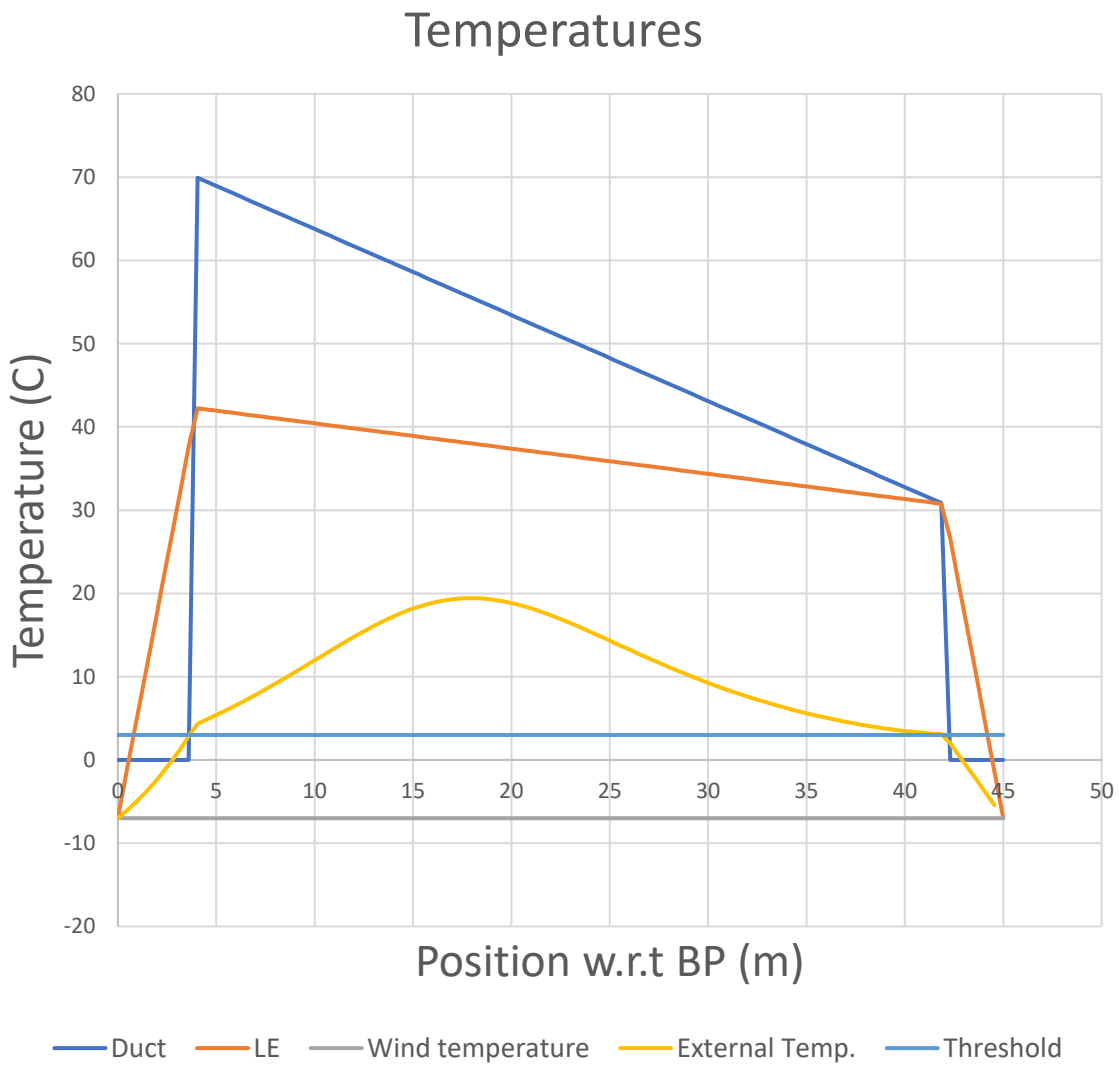


WICETEC Ice Prevention Systems

FabricAir

BorealisWind Ice Protection System

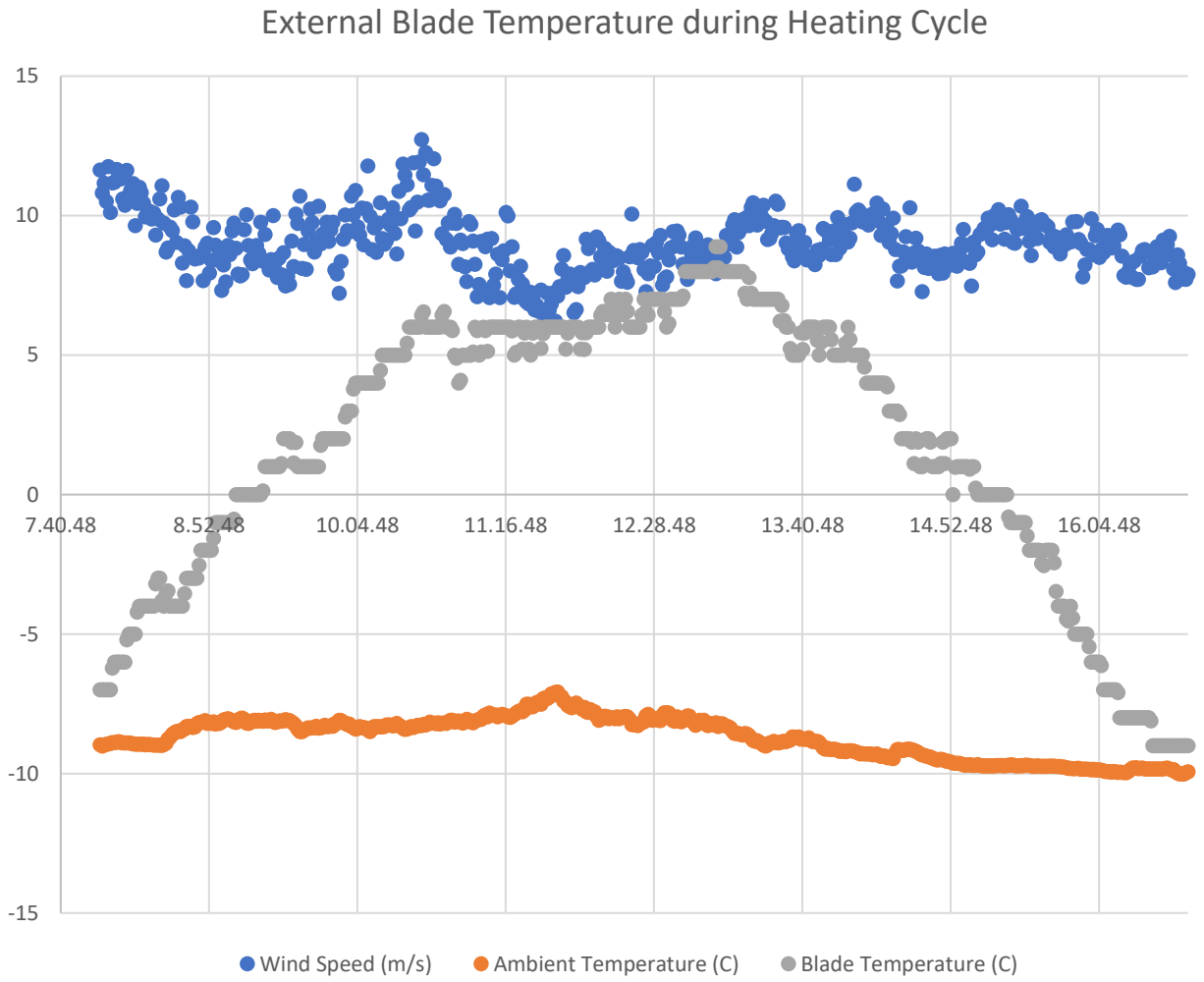
Case example – Ground based thermal camera measurements



Ambient Temperature	-7°C
Wind Speed	6 m/s
Blade Internal Temperature	32°C
Blade External Temperature	11°C

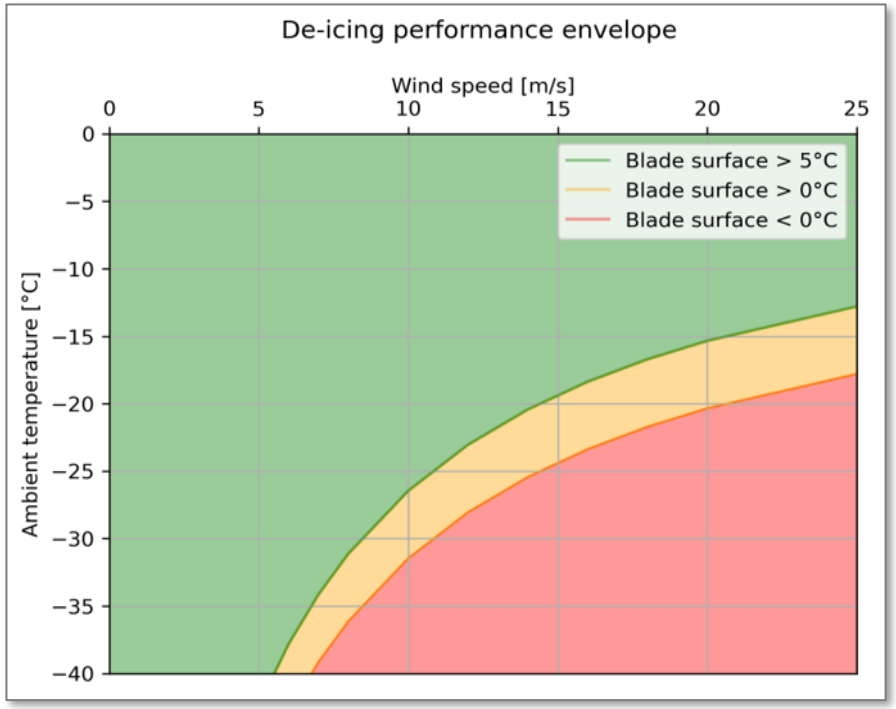
Case example – Surface Mounted Temperature Sensors

- External temperature measured on leading edge at 37m of 45m blade
  - Measured January 2021
- IPS is triggered and increases external blade temperature up to 9°C from -8°C
- Data used for validation

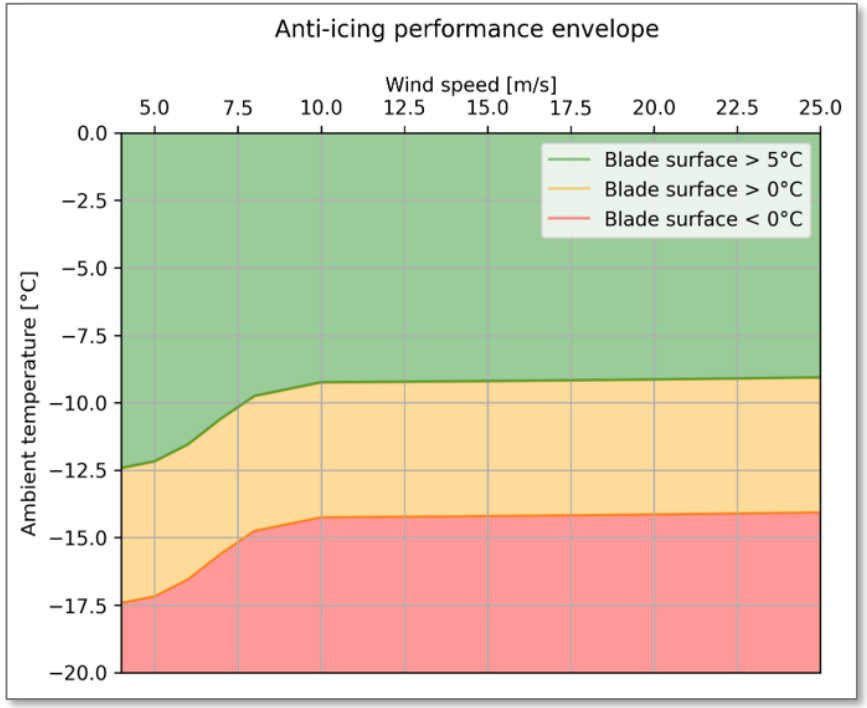


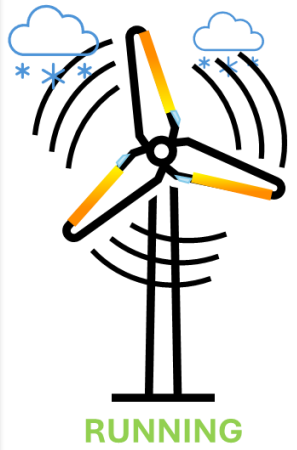
Effect of operational mode

De-icing



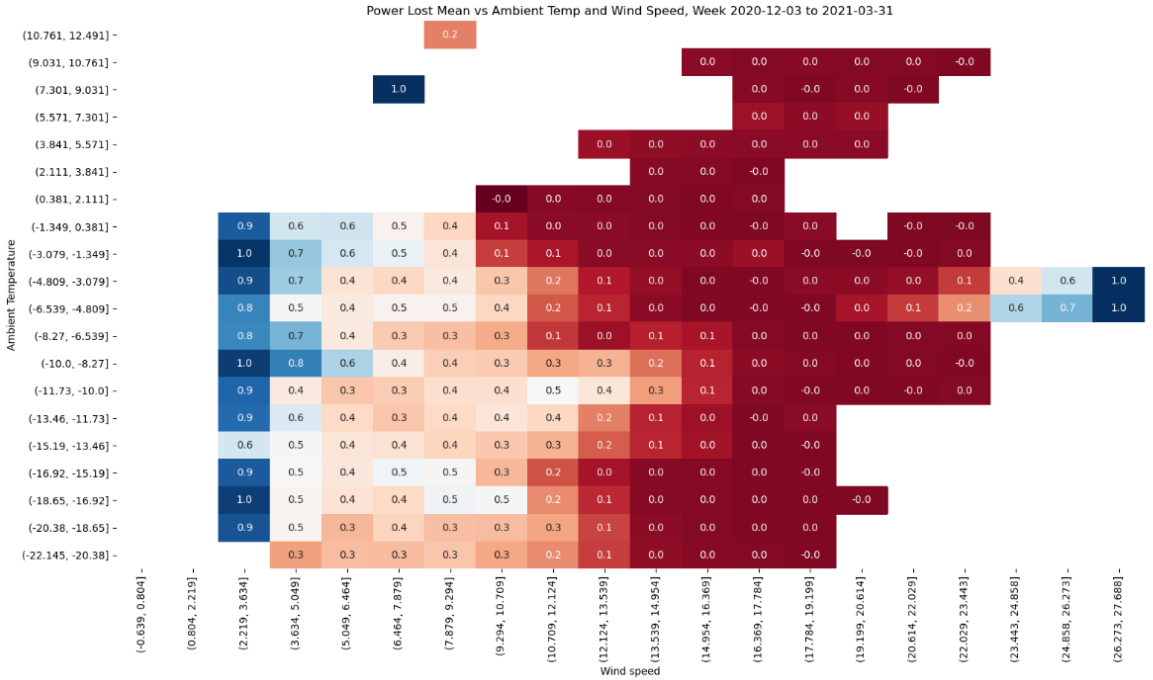
Anti-icing

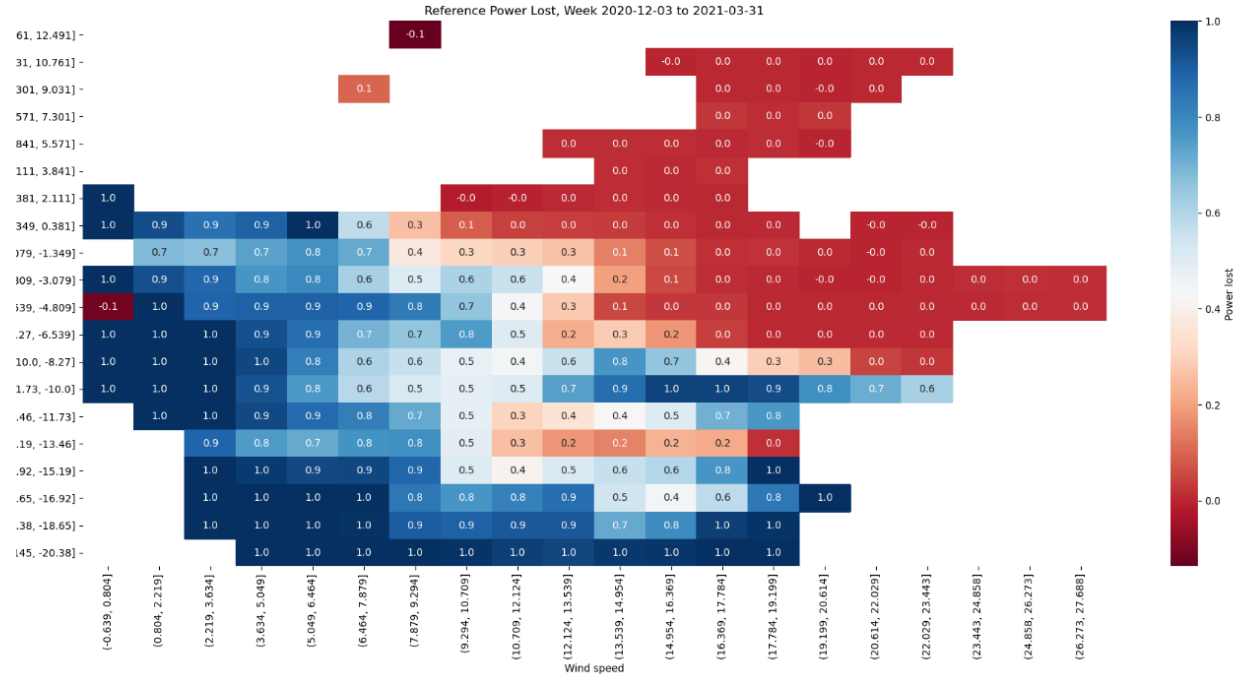




Validation of Operational Envelope using Turbine Data

- Validating performance of turbine vs the operational envelope in icing conditions using production loss in bins of temperature and wind speed





Key take aways

To Developers/Owners/Operators

- Understand icing conditions at the site in bins of wind speed and temperature
- Compare site icing conditions to performance envelope of the IPS to find the right solution
- Know that performance envelope is only one piece of the puzzle to determine % recovery

To IPS Providers

- Choose your measurement strategy carefully and understand how to transfer temperatures to performance envelope
- Anti-icing vs de-icing
- Validate performance envelope with field data

To Do:

- Classify icing conditions with Liquid Water Content
  - **Task54**