

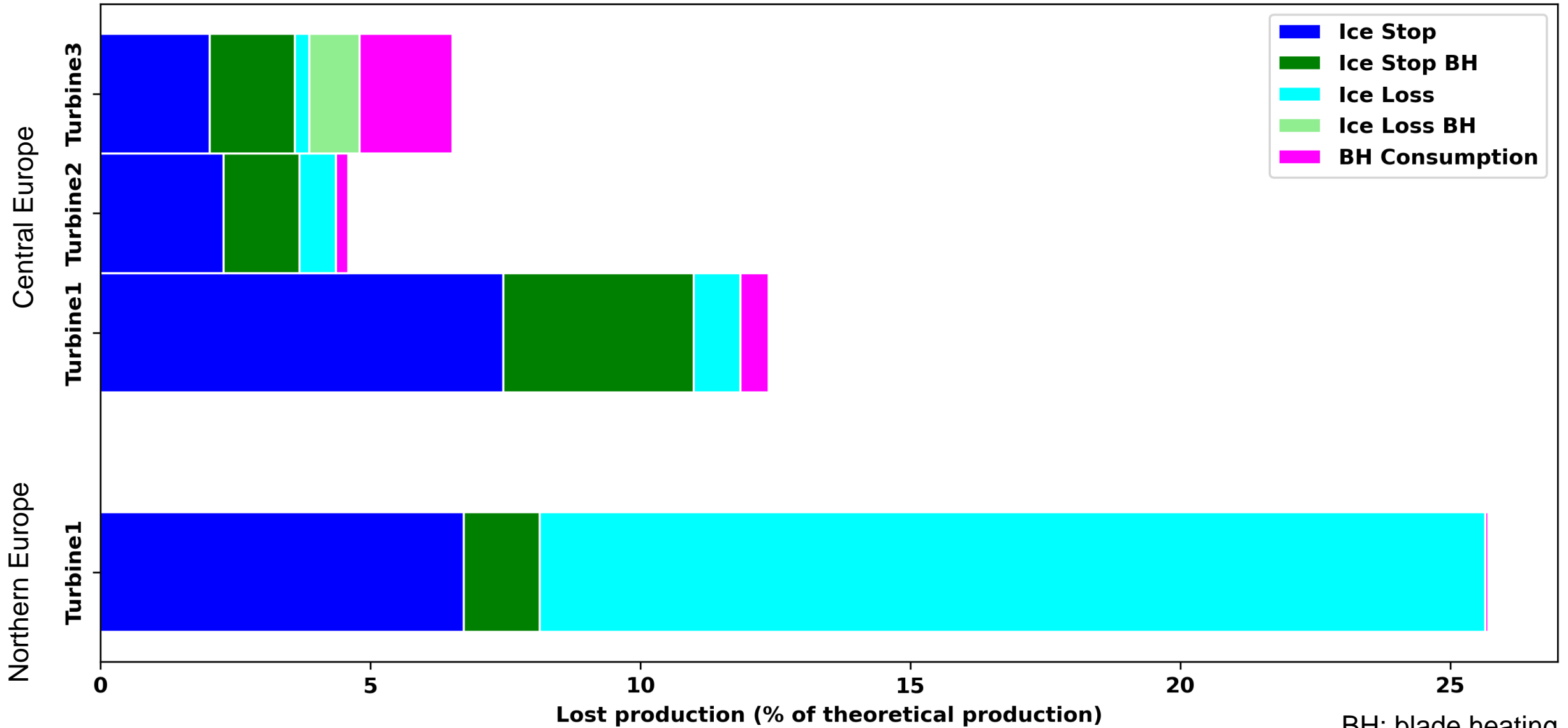
# Can we make better use of ice protection systems?

Franziska Gerber, Paul Froidevaux  
29.3.2023

# Current performance of ice protection systems (IPS)

# Current performance of ~~ice protection systems (IPS)~~ blade heating systems (BHSs)

# Production losses due to icing



BH: blade heating

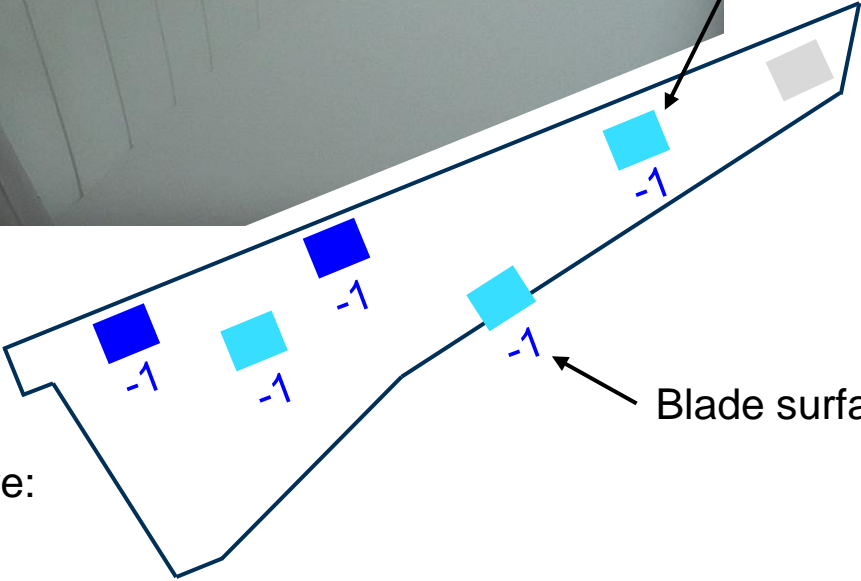
# Blade surface temperatures - eologix

Date: 1.12.2020 07:00



### Eologix icing

- Ice > 10 mm
- Ice 1-10 mm
- Ice < 1mm
- Dry
- missing



Ambient temperature:  
**-1 °C**

Blade surface temperatures

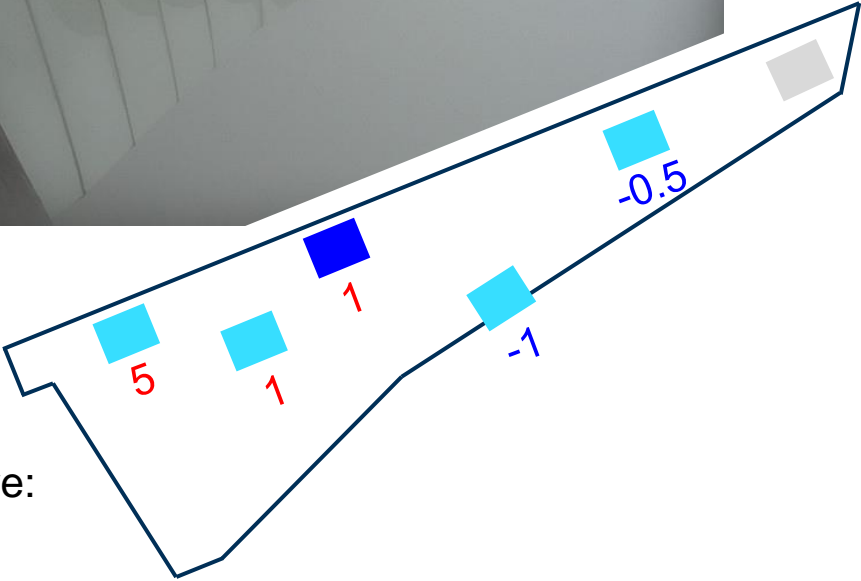
# Blade surface temperatures - eologix

Date: 1.12.2020 07:30



### Eologix icing

- Ice > 10 mm
- Ice 1-10 mm
- Ice < 1mm
- Dry
- missing



Ambient temperature:  
**-1 °C**

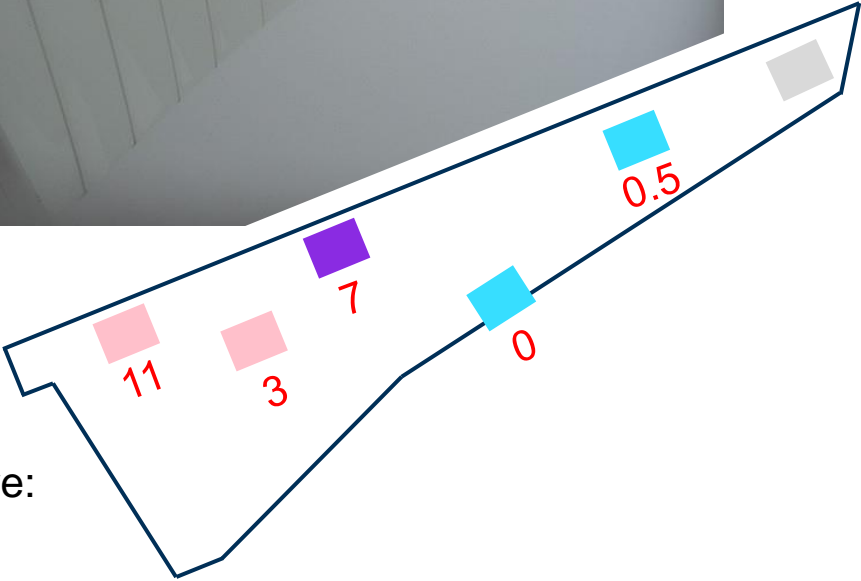
# Blade surface temperatures - eologix

Date: 1.12.2020 08:00



### Eologix icing

- Ice > 10 mm
- Ice 1-10 mm
- Ice < 1mm
- Dry
- missing



Ambient temperature:  
**-1 °C**

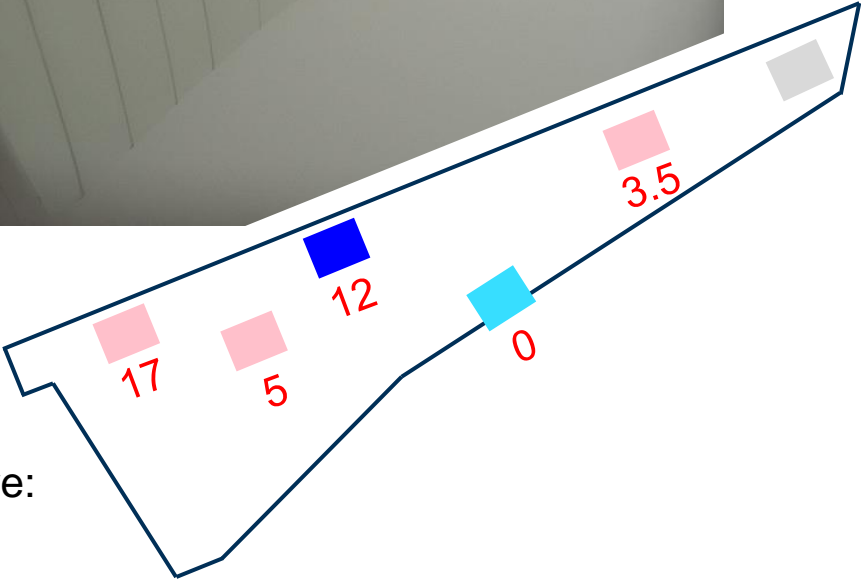
# Blade surface temperatures - eologix

Date: 1.12.2020 08:30



### Eologix icing

- Ice > 10 mm
- Ice 1-10 mm
- Ice < 1mm
- Dry
- missing

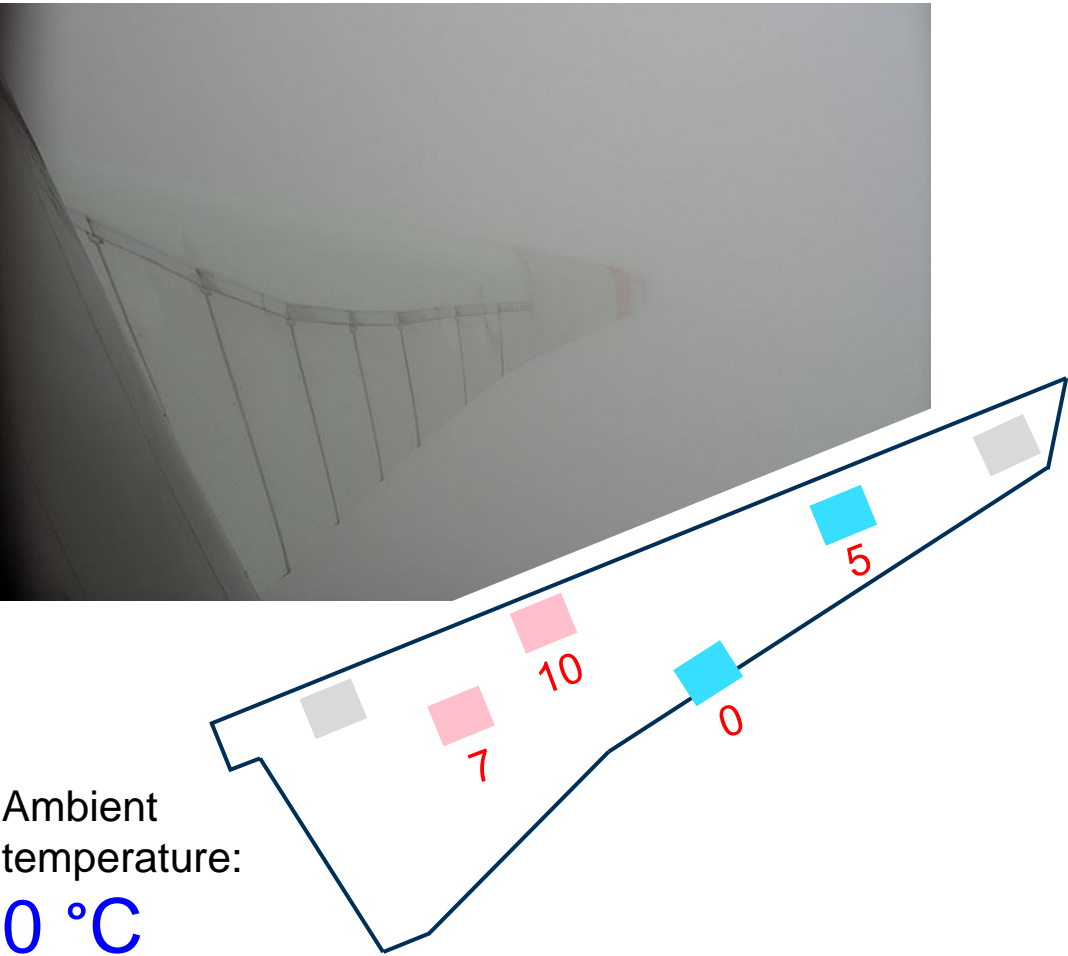


Ambient temperature:  
**0 °C**



# Blade surface temperatures - eologix

Date: 1.12.2020 09:00

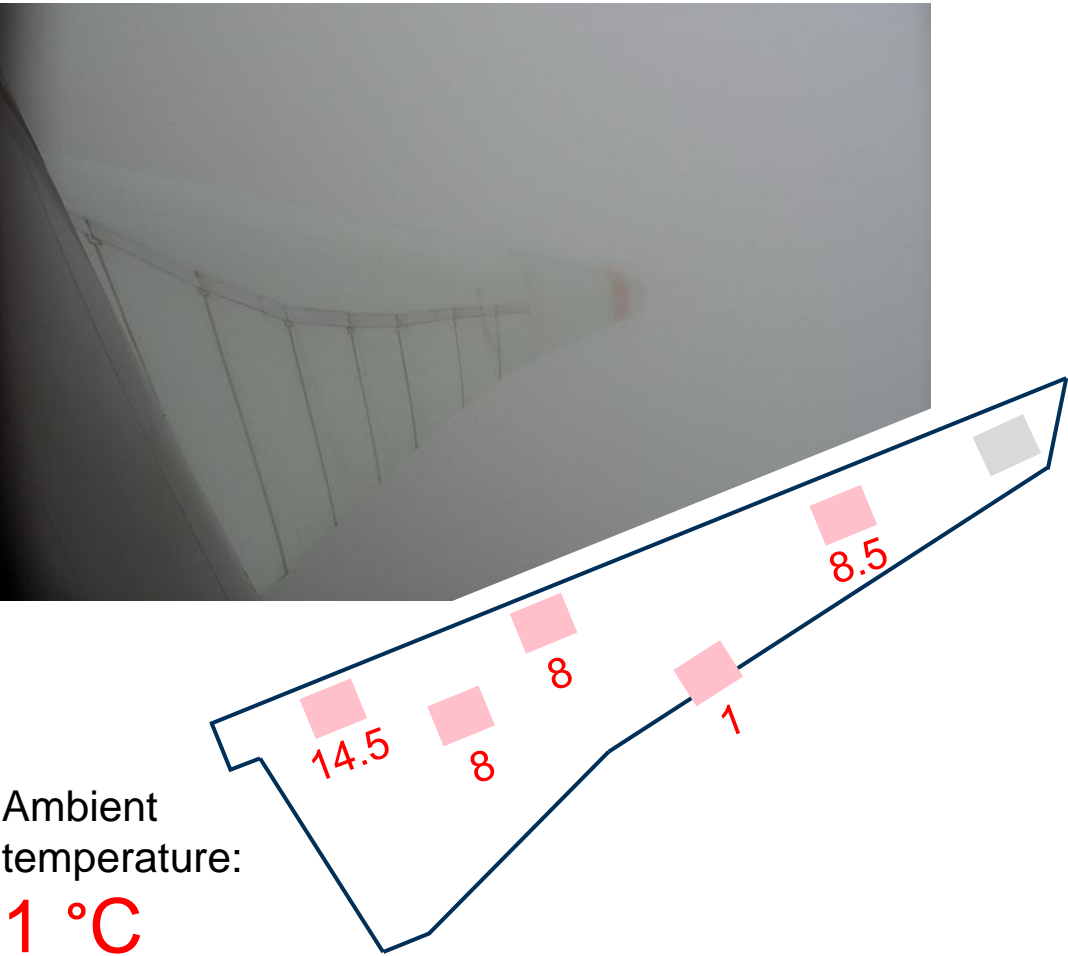


### Eologix icing

- Ice > 10 mm
- Ice 1-10 mm
- Ice < 1mm
- Dry
- missing

# Blade surface temperatures - eologix

Date: 1.12.2020 10:30



### Eologix icing

- Ice > 10 mm
- Ice 1-10 mm
- Ice < 1mm
- Dry
- missing

- Successful deicing
- Ambient temperature positive
- Blade surface completely dry

Before heating: 1.12.2020 07:00



Restart at: 1.12.2020 11:10



# Blade surface temperatures - eologix

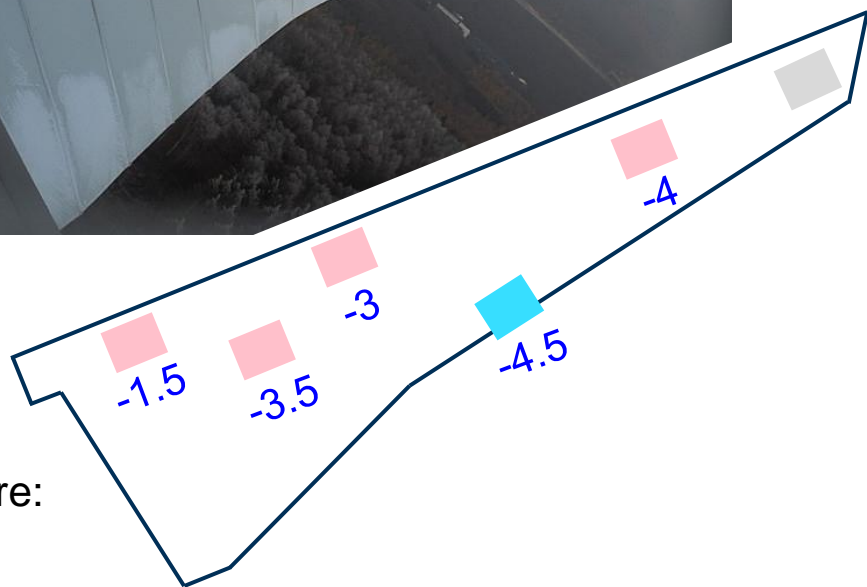
Date: 29.11.2020 15:00



## Eologix icing

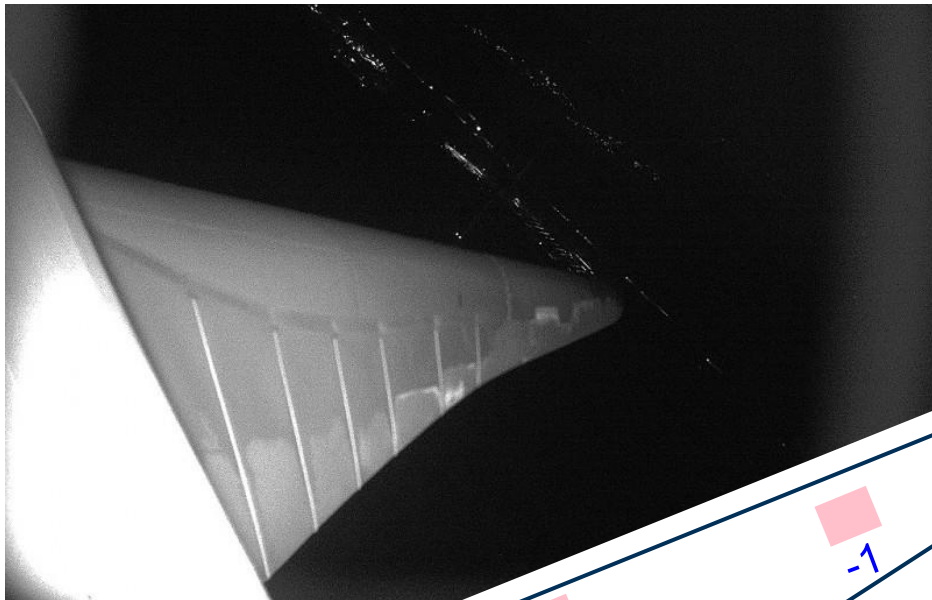
- Ice > 10 mm
- Ice 1-10 mm
- Ice < 1mm
- Dry
- missing

Ambient temperature:  
**-2 °C**



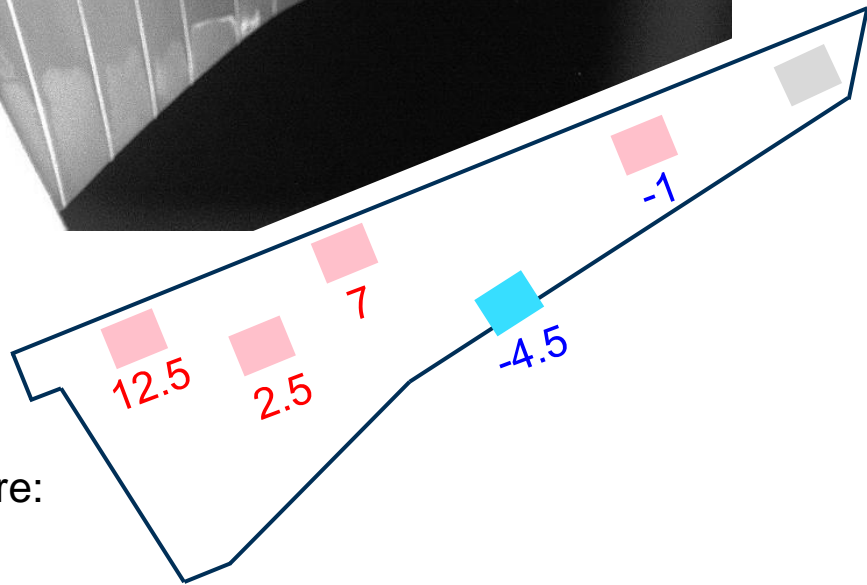
# Blade surface temperatures - eologix

Date: 29.11.2020 19:00



## Eologix icing

- Ice > 10 mm
- Ice 1-10 mm
- Ice < 1mm
- Dry
- missing



Ambient temperature:  
**-2 °C**

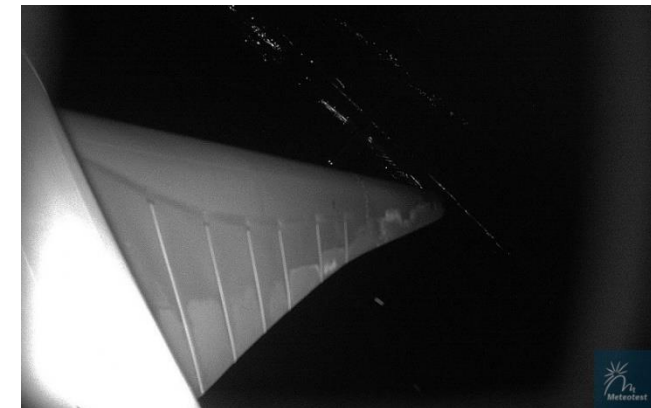
- Not successful deicing
- Ambient temperature negative
- Blade icing stays almost unchanged

→ Heat does not reach all areas of blade

Before heating: 29.11.2020 15:00

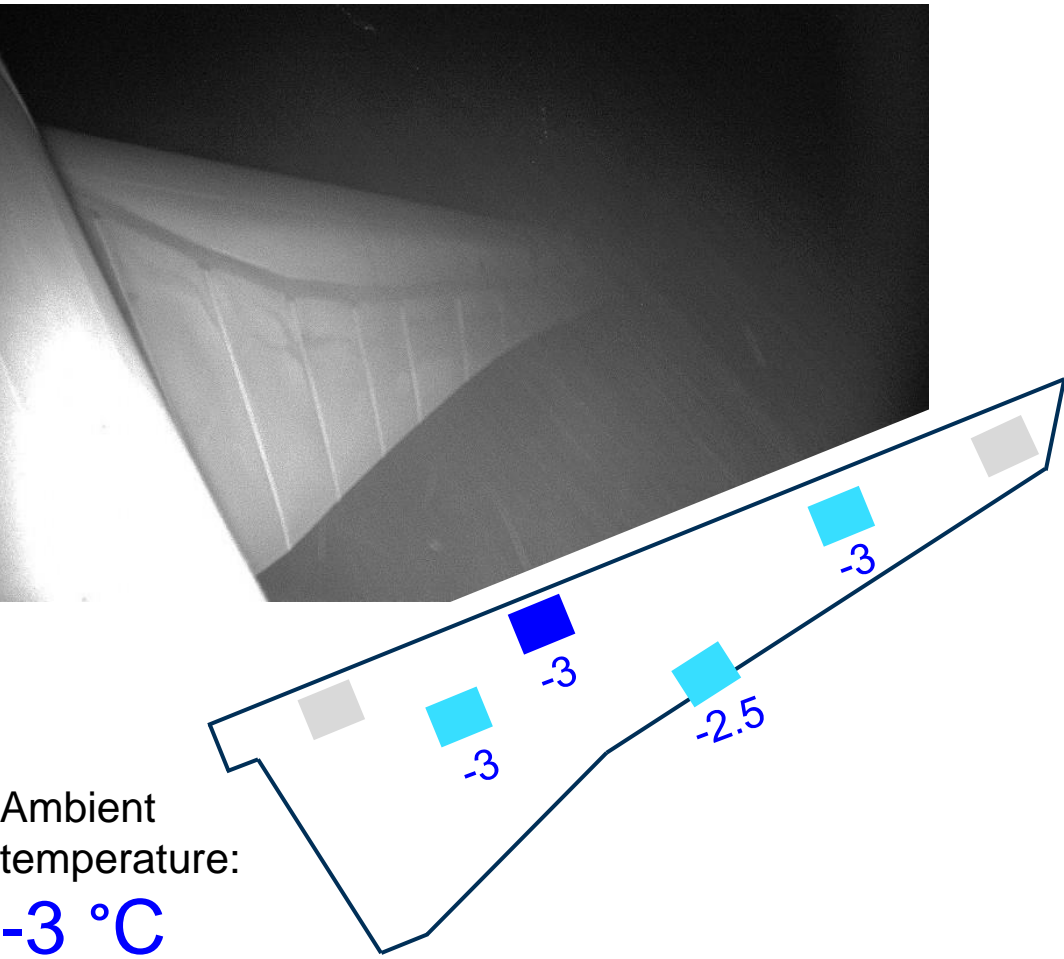


Restart at: 29.11.2020 19:40



# Blade surface temperatures - eologix

Date: 26.1.2021 06:00



### Eologix icing

- Ice > 10 mm
- Ice 1-10 mm
- Ice < 1mm
- Dry
- missing



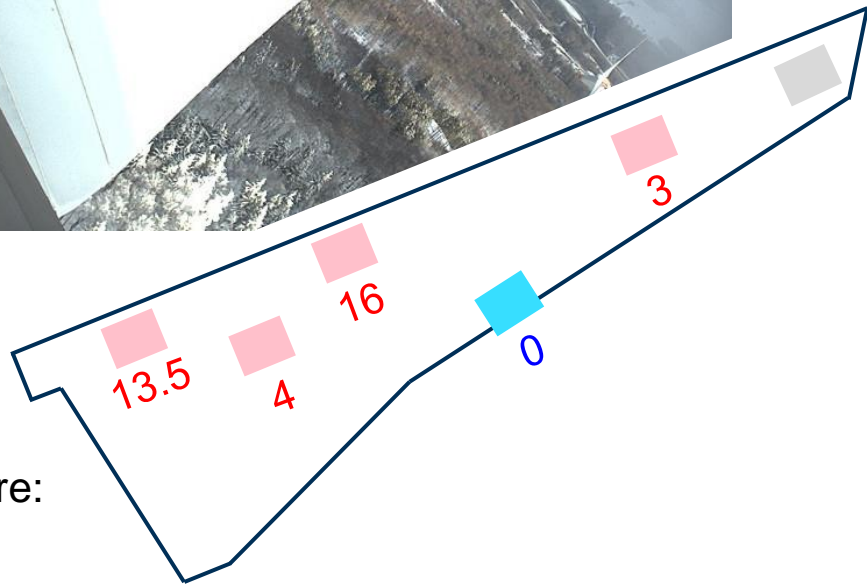
# Blade surface temperatures - eologix

Date: 26.1.2021 09:30



## Eologix icing

- Ice > 10 mm
- Ice 1-10 mm
- Ice < 1mm
- Dry
- missing



Ambient temperature:  
**-2 °C**

- Successful deicing
- Ambient temperature negative
- Full blade reaches 0 °C

Before heating: 26.1.2021 06:00



Restart at: 26.1.2021 10:10



Loose several percent of winter production

Heating cycles not always successful

## Current performance of BHSs

Parameter settings of BHSs are fixed

No information about weather forecast taken into account

# Can we make better use of blade heating systems?



Parameter settings of BHSs are fixed



Analyze past data

Adapt constant BH settings

Can we make better use of blade heating systems?

HOW ?

**Adaptation of constant BHS settings**

- Ice detection and BH triggering
- BH cycle duration
- Heating power
- Use turbine / location specific blade heating envelope

Maybe different for:

Anti-Icing systems with dynamic heating settings

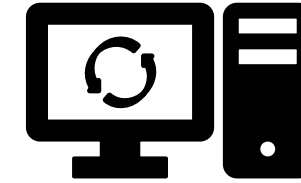
Adaptation of BHS settings

→ But: Not always possible due to operational restrictions



No information about weather forecast taken into account

Weather forecast



Knowledge about past performance

Analyze past data

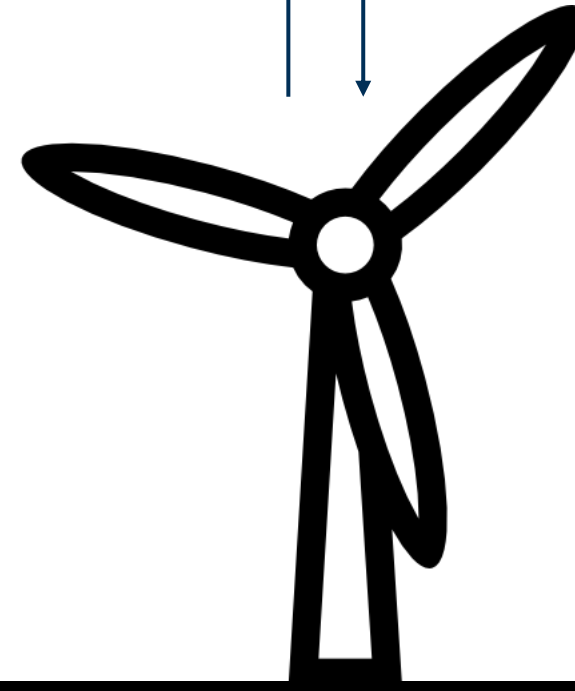
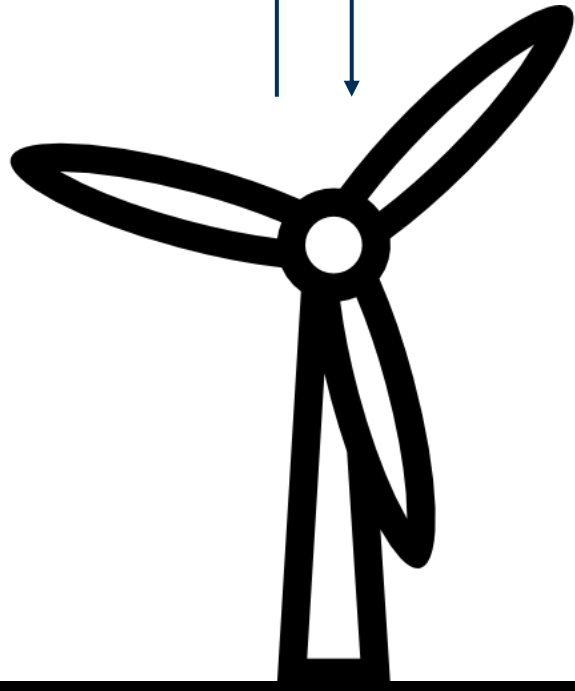
Adapt constant BH settings

Can we make better use of blade heating systems?

HOW?

Real-time data

Send heating signal



Adaptation of BHS settings

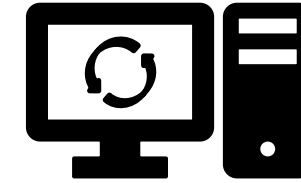
Smart Algorithm

BH: blade heating

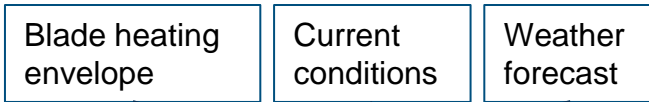


No information about weather forecast taken into account

Weather forecast



Knowledge about past performance



**Smart Algorithm**

1. Simulate scenarios with heating at different times
2. Find scenario with highest production
3. Select best scenario

Best scenario now?

yes

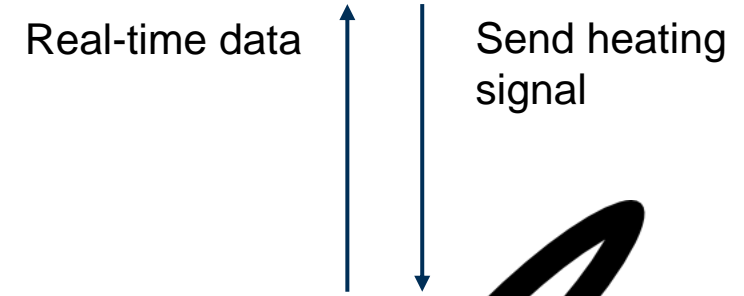
no

Heat now

Don't heat now

# Can we make better use of blade heating systems?

## HOW?



Smart Algorithm

# A smart algorithm – framework

## **SOWINDIC – Smart Operation of Wind Turbines under Icing Conditions**

Financed: FFG (Austrian Research Promotion Agency)

Project partners:  
Verbund  
University of Vienna  
Austrian Institut of Technology

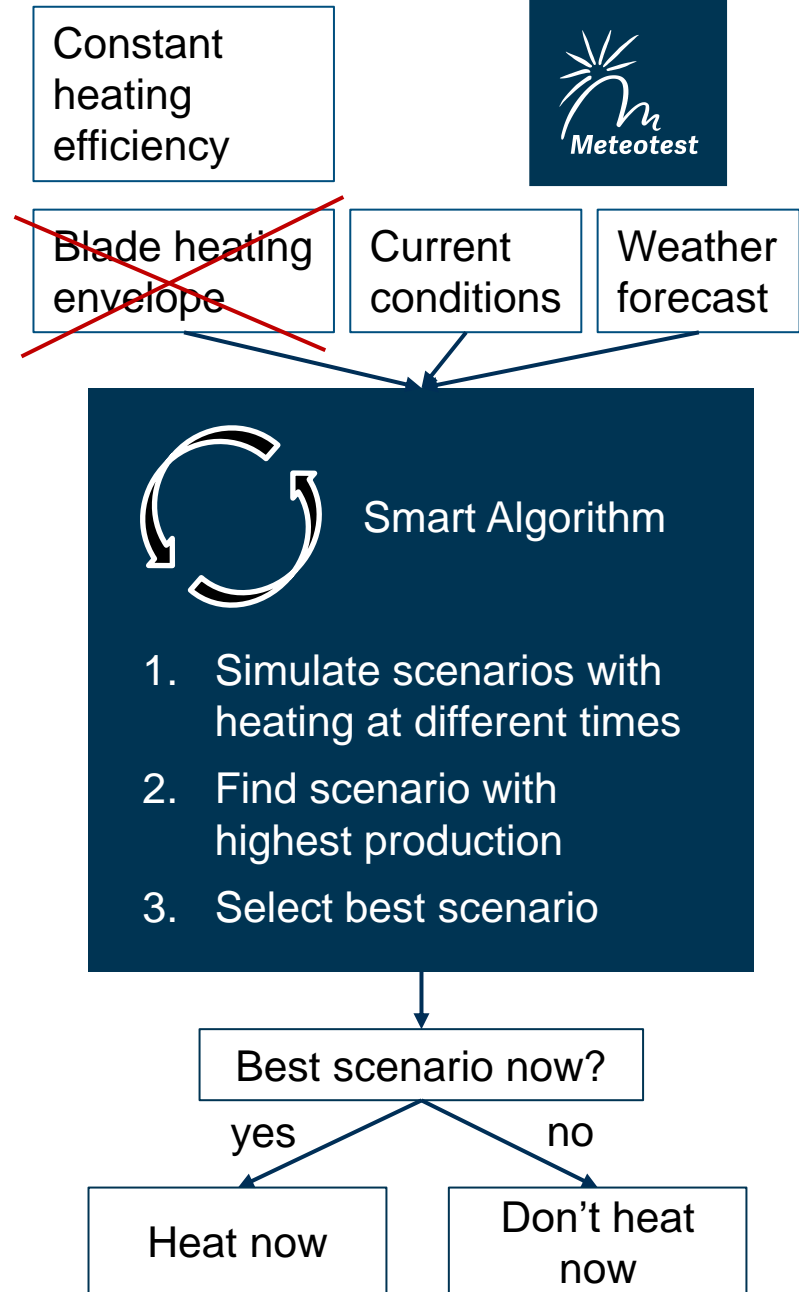
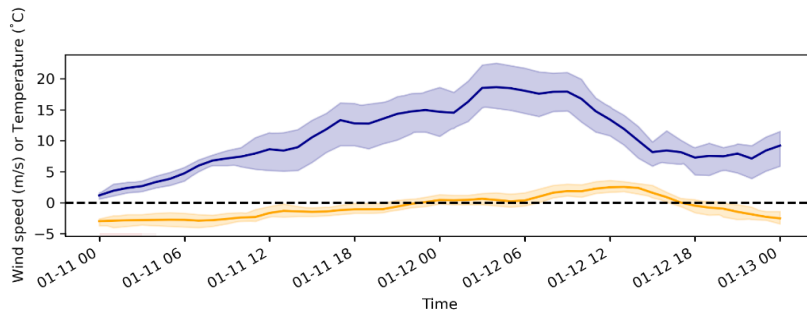
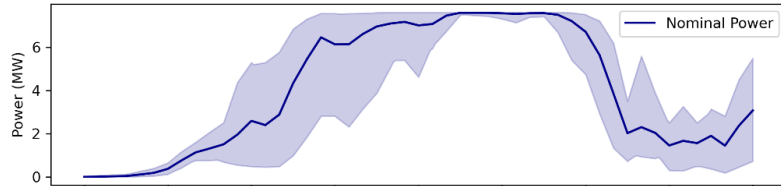
## **SOPWICO – Smart Operation of Wind Power Plant in Cold Climate**

Financed: VGBE partners  
Data sharing and financing partners:  
BKW, CGNEE, Vattenfall, Verbund

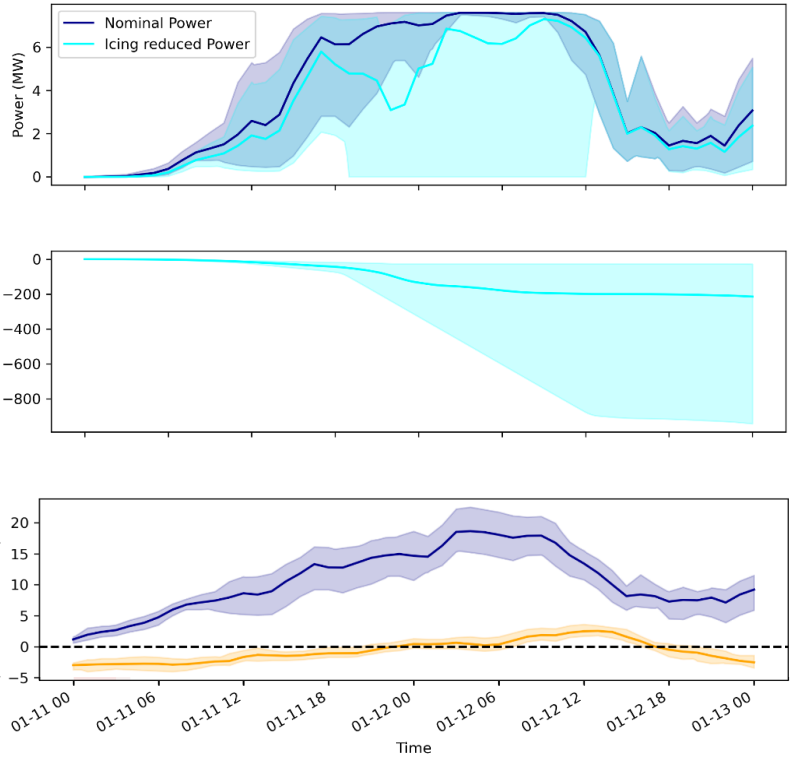
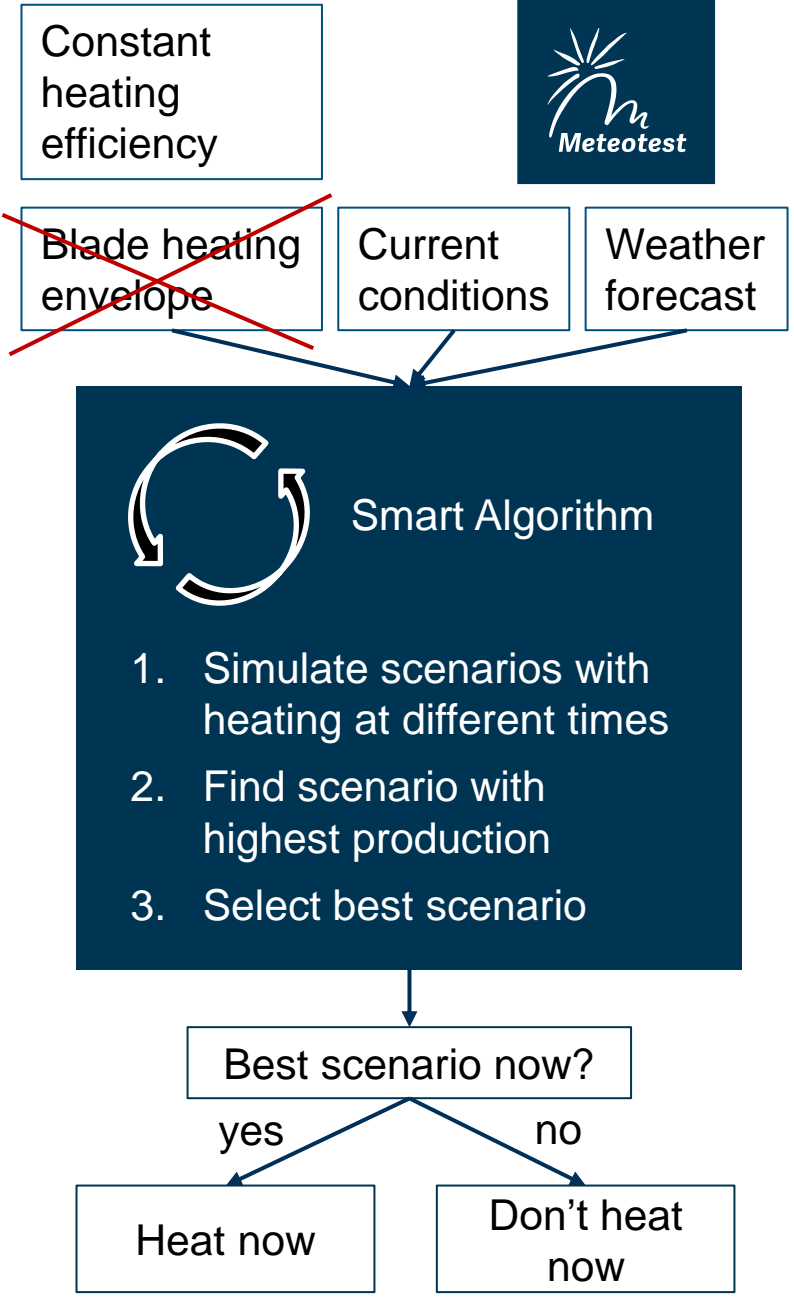
Financing partners:  
EVN, fortum, SWM, steag

Weblink: <https://www.vgbe.energy/en/news/sopwico-wpp-cold-climate/>

# A smart algorithm – framework



# A smart algorithm – framework



# A smart algorithm – framework



Constant heating efficiency

~~Blade heating envelope~~

Current conditions

Weather forecast



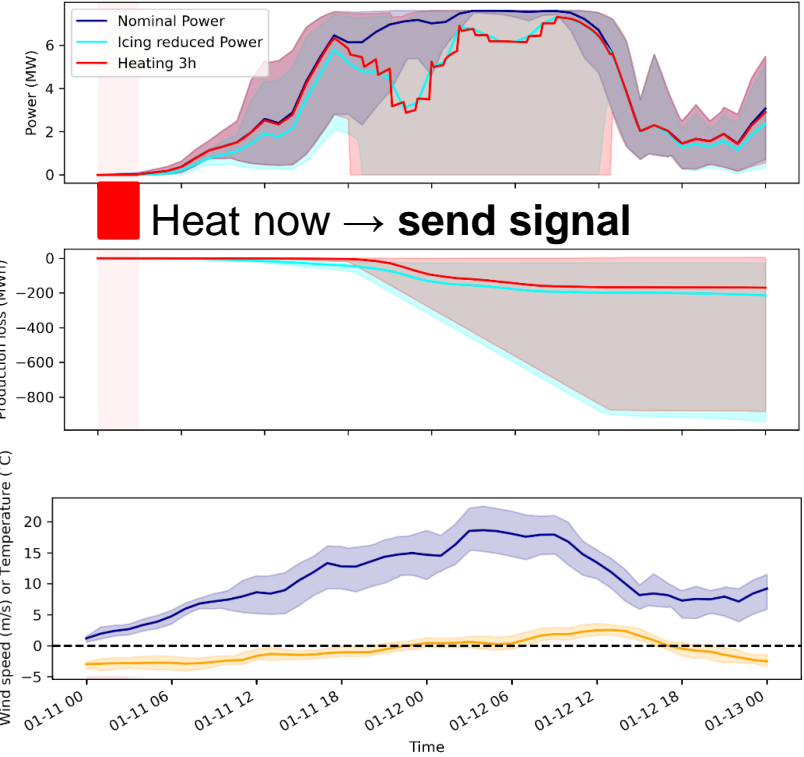
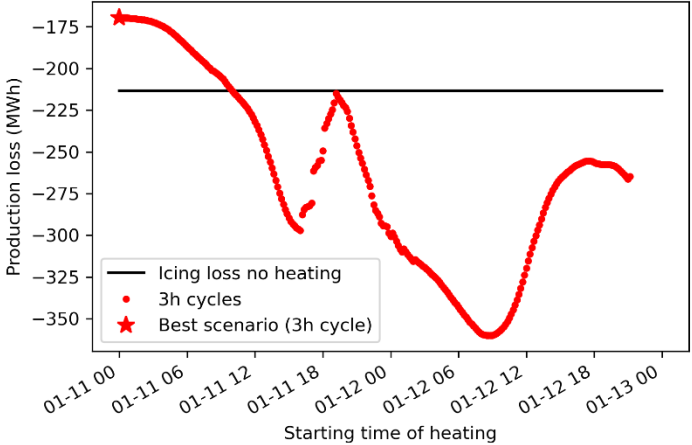
Best scenario now?

yes

no

Heat now

Don't heat now



# A smart algorithm – framework

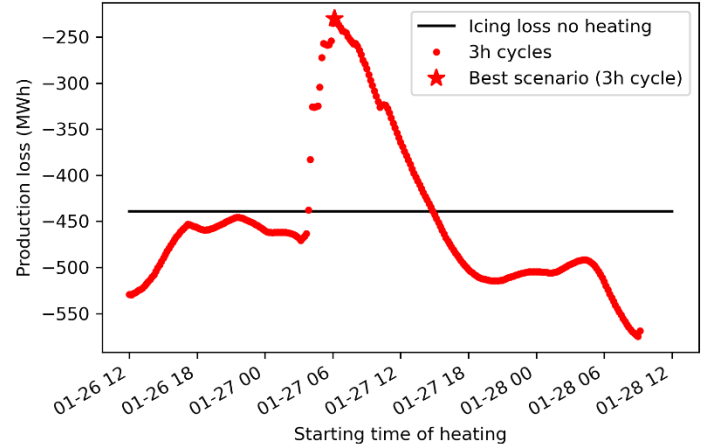
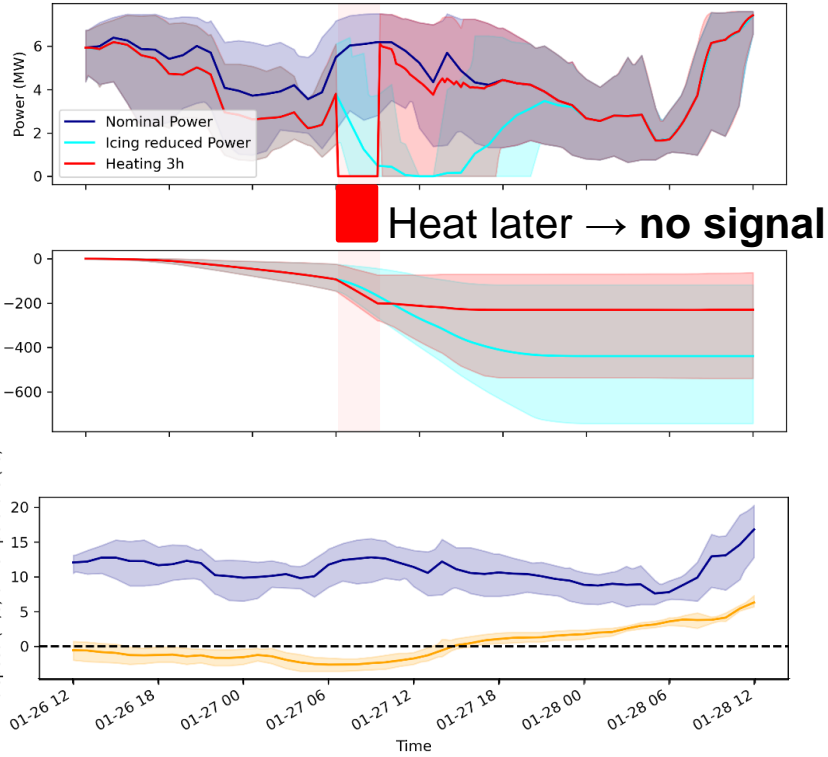


Constant heating efficiency

~~Blade heating envelope~~

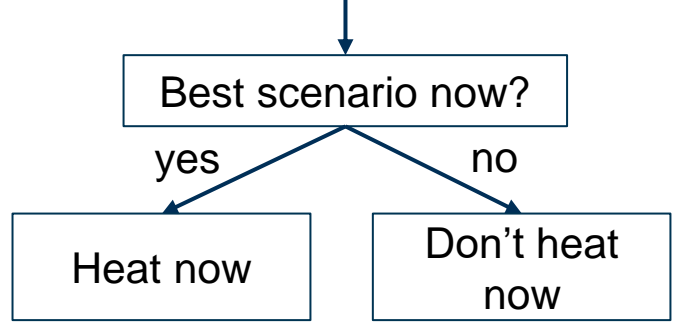
Current conditions

Weather forecast



**Smart Algorithm**

1. Simulate scenarios with heating at different times
2. Find scenario with highest production
3. Select best scenario

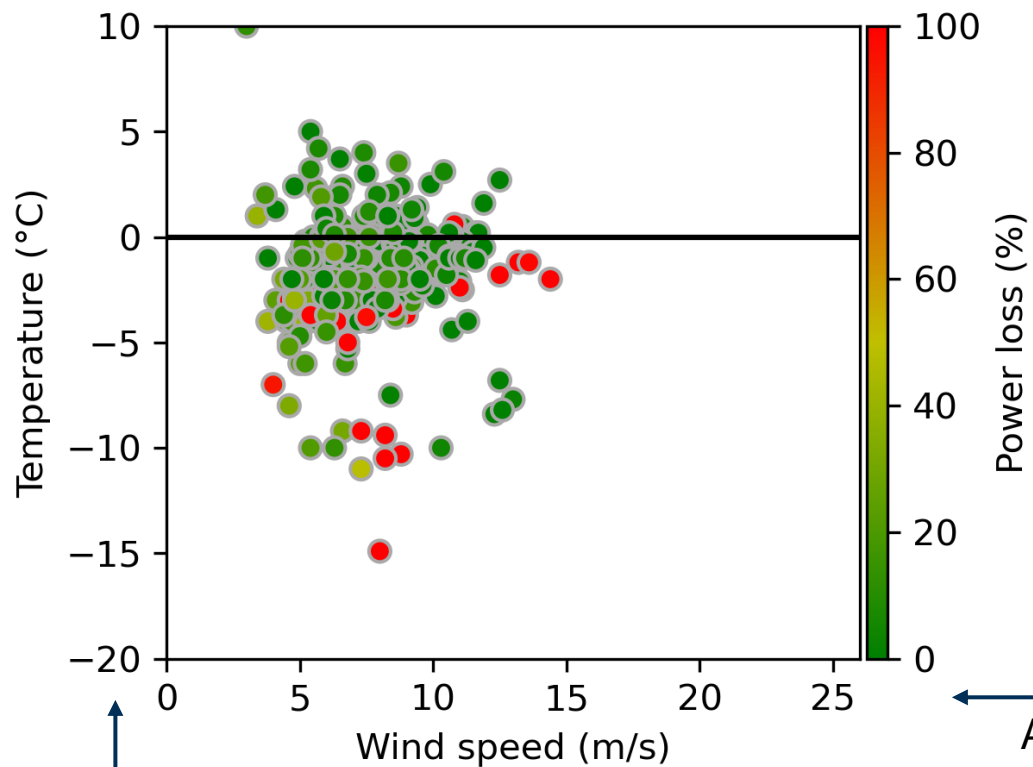




# Blade heating envelope

# Blade heating envelope – data analysis

Power loss during BH events  
(one turbine / two winter seasons)



Average temperature during heating cycle

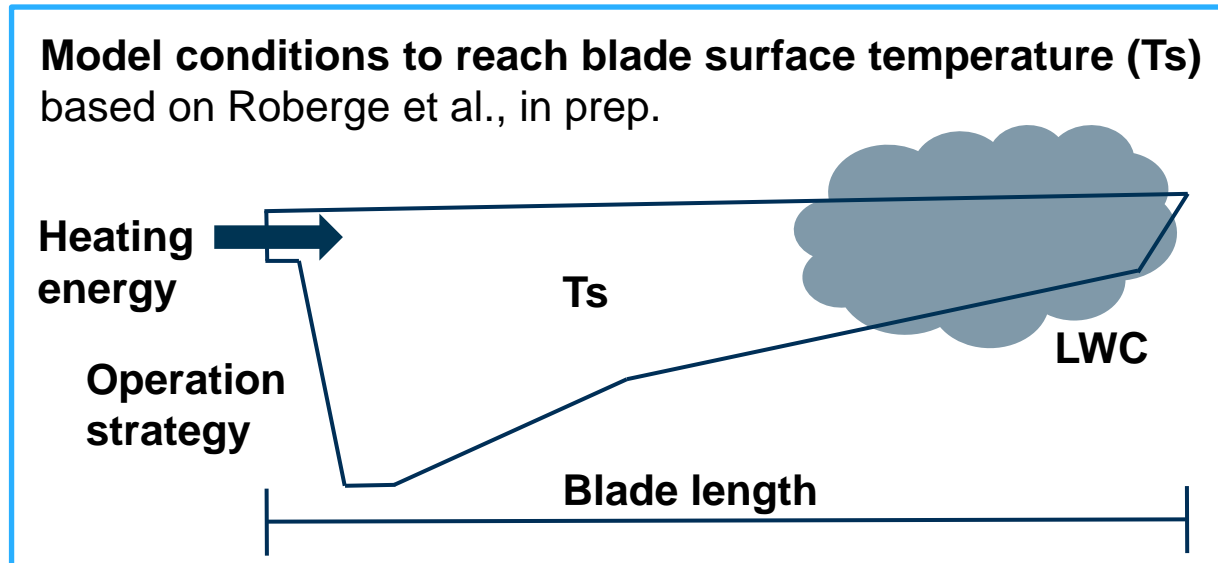
Average wind speed during heating cycle

## Definition of power loss (to be refinded):

- Lost power (with respect to theoretical power) in the first hour after the heating cycle

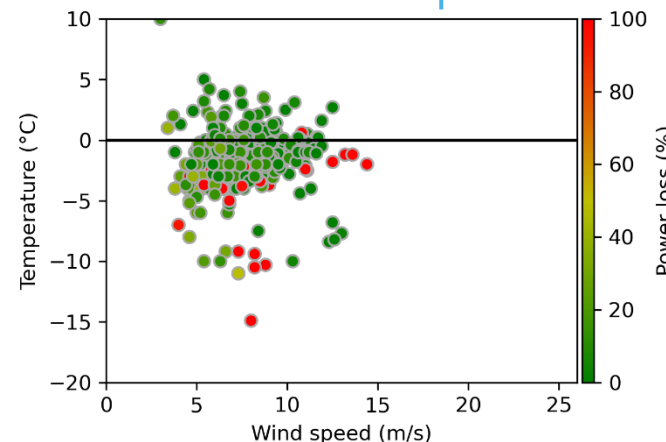
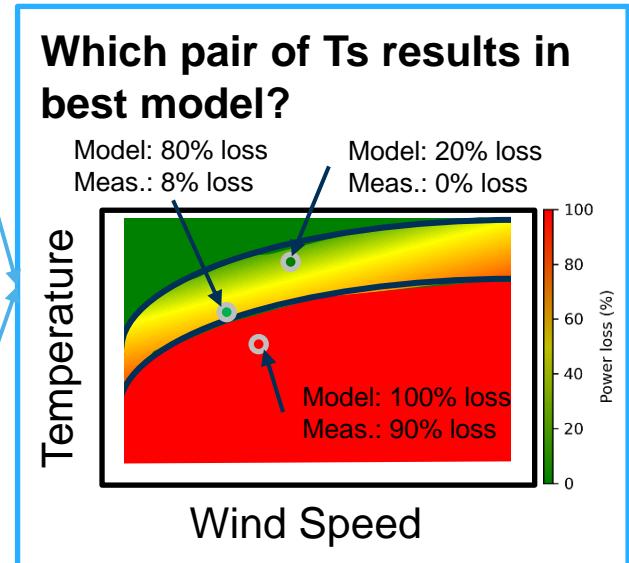
# Blade heating envelope – modelling attempt

(Based on blade surface temperature modelling by Roberge et al., in prep.)



Set of curves to reach different  $T_s$

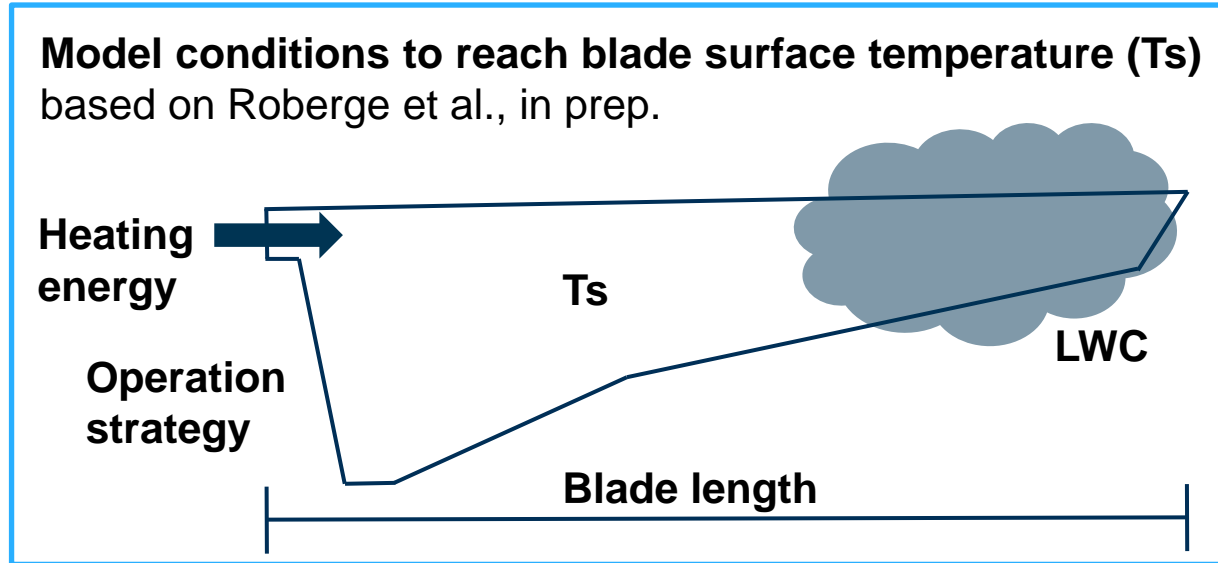
Past heating cycles



LWC: liquid water content

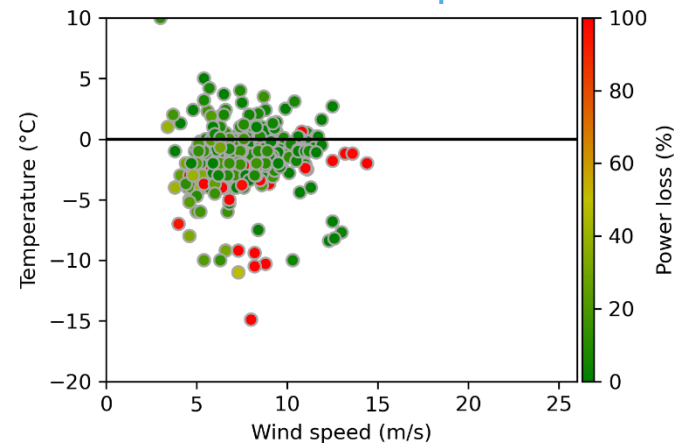
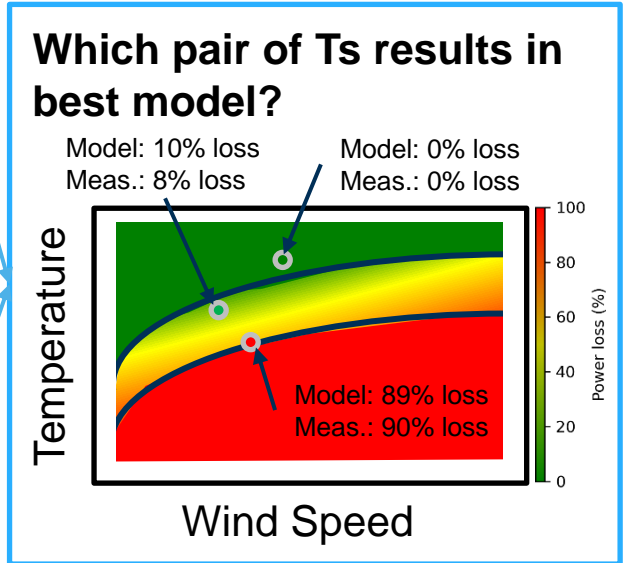
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Set of curves to reach different  $T_s$

Past heating cycles

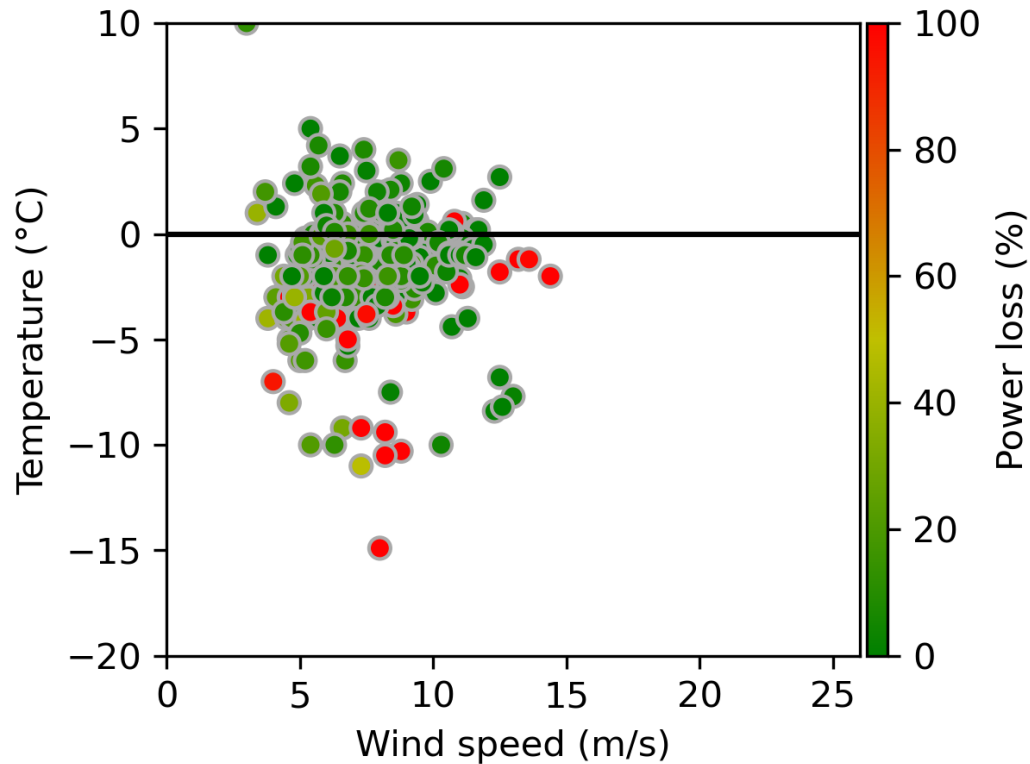


LWC: liquid water content

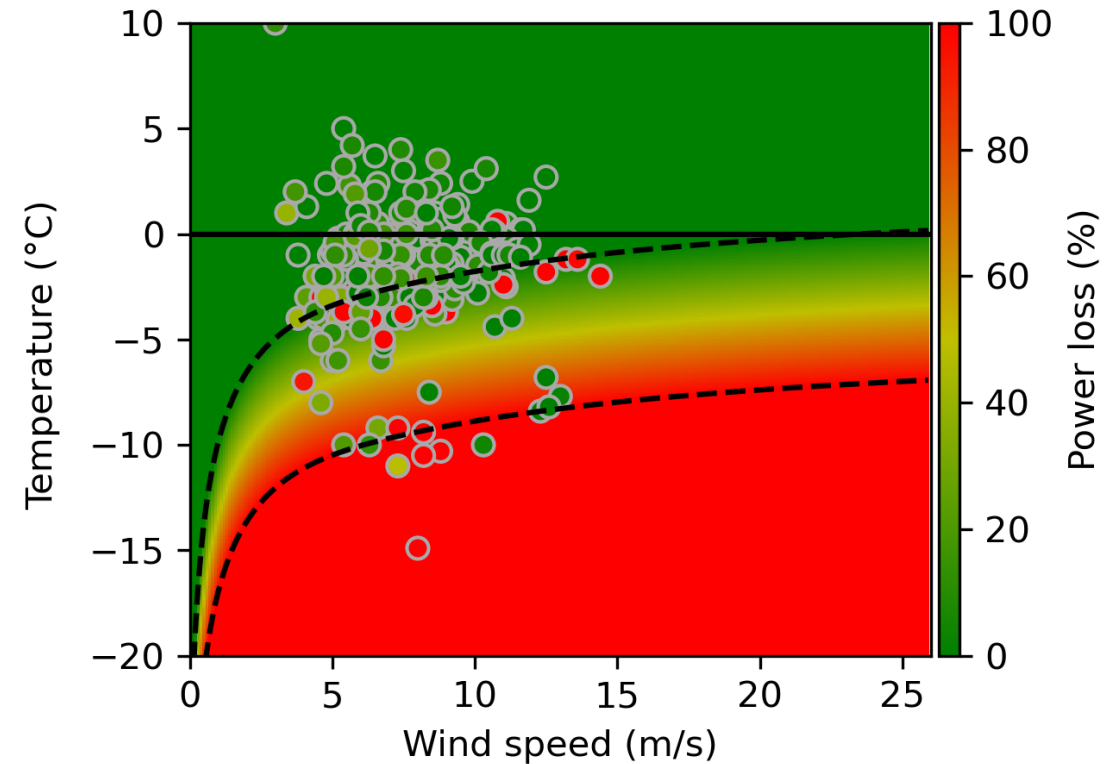
# Blade heating envelope – modelling attempt



Power loss during BH events  
(one turbine / two winter seasons)



Modelled blade heating envelope  
based on power loss during BH events

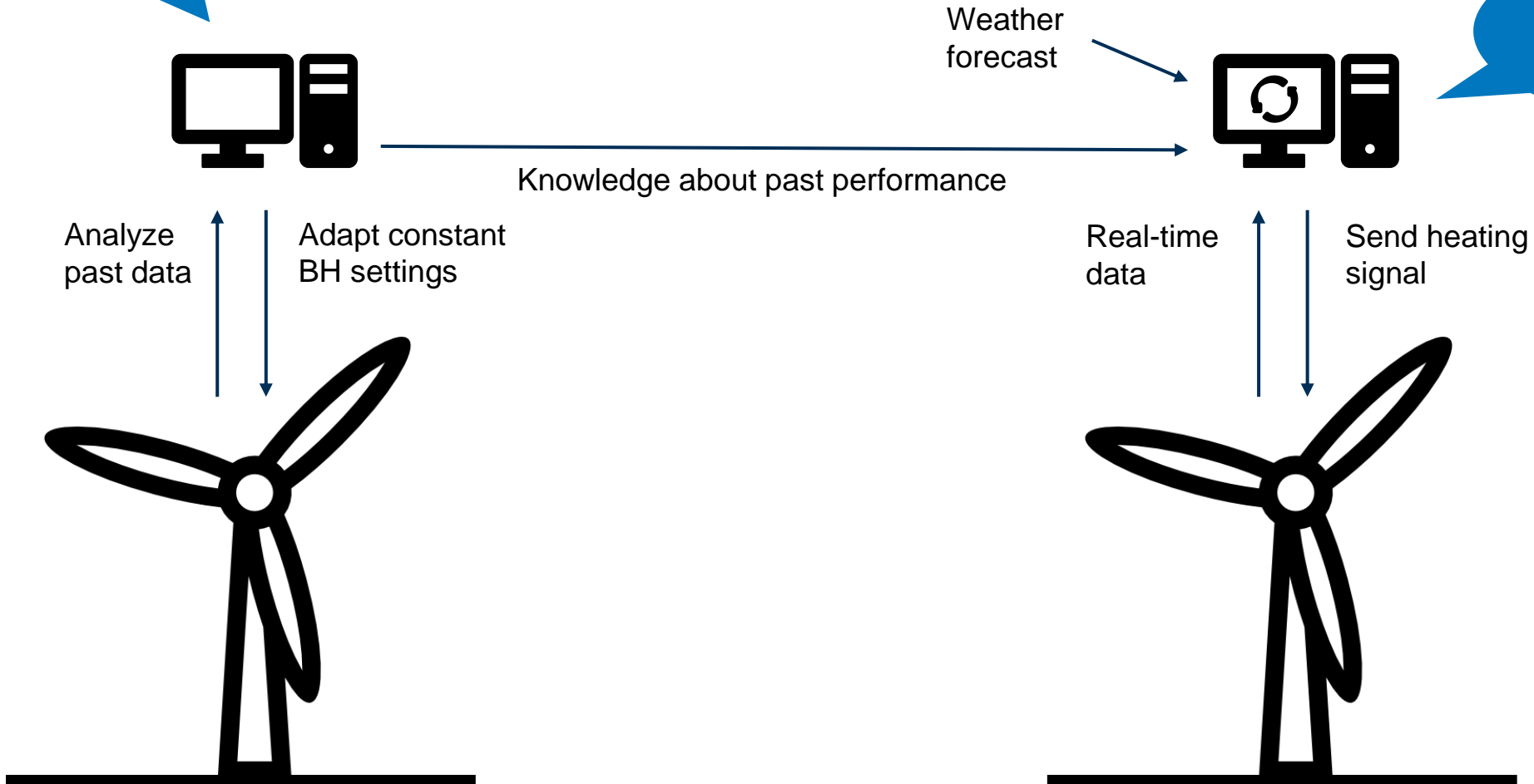


# Can we make better use of blade heating systems?

HOW? 

Take into account past performance

Use information of weather forecasts



Adaptation of BHS settings

Smart Algorithm

BH: Blade heating

# Can we make better use of blade heating systems?

HOW?

- Adaptation of constant BHS settings
- Smart algorithm to find best heating time taking into account weather forecast and knowledge about past performance

## Thanks to:

### **SOWINDIC – Smart Operation of Wind Turbines under Icing Conditions**

Financed: FFG (Austrian Research Promotion Agency)

Project partners:

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University of Vienna

Austrian Institut of Technology

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## Questions?



[www.meteotest.ch](http://www.meteotest.ch)