Performance envelopes of blade heating systems

IEA Wind TCP Task 54

Cold Climate Wind Power

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Winterwind 2023

29.03.2023

Participants of the workshop on Monday

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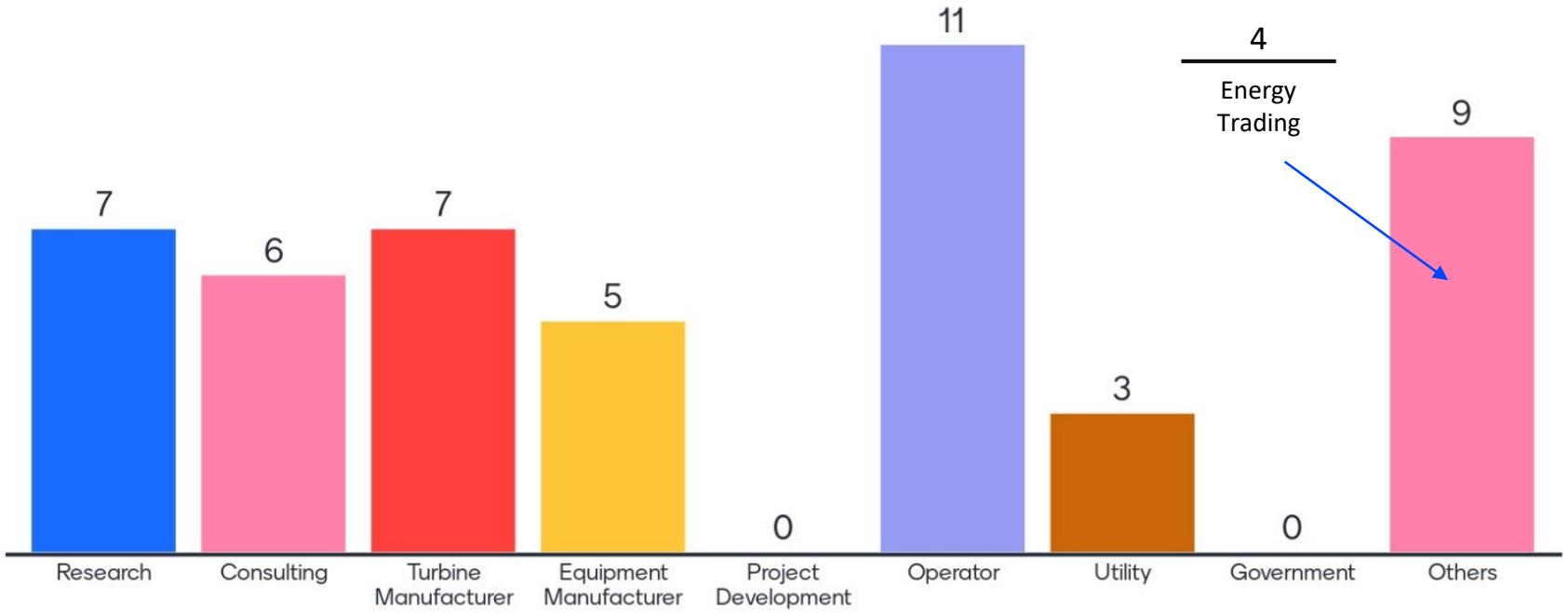
Mentimeter poll



So far adopted concepts in the industry

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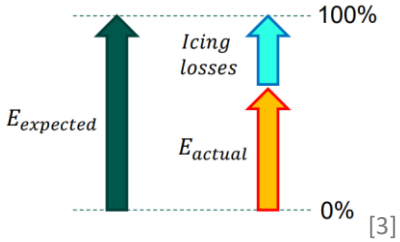
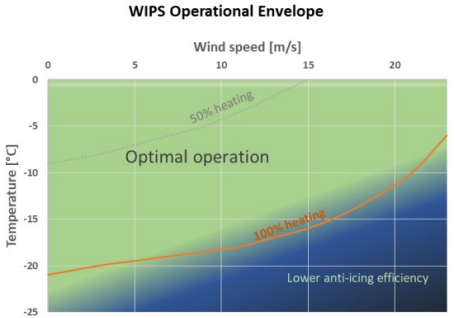
One general distinction can be made with respect to existing concepts:

- Economically driven definitions such as “production retention” and “Ice Production Ratio” related to the produced energy
  - ➢Already available with the IEA Wind TCP Task 19 *“Performance Warranty Guidelines for Wind Turbines in Icing Climates”* [5]



[3]

- Meteorologically/technically driven definitions such as functions of temperature, wind speed etc. related to a systems performance/efficiency



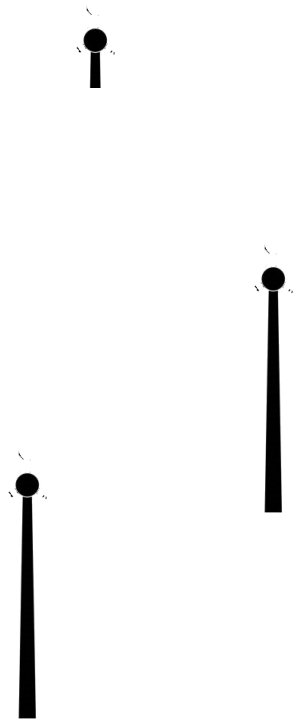
[4]

The subtask and workshop are focused on the latter concepts.

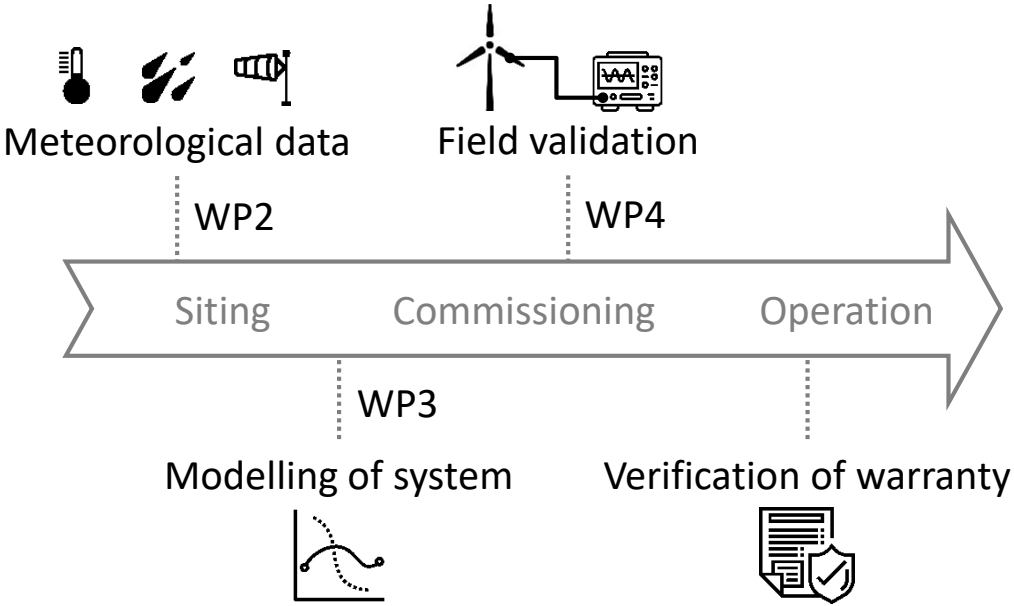
Why assessing a system in the first place?

d TCP

- Manufacturer
  Marketing of systems with standardized evaluation to be compared to competitors
- Project development
  Comparing and choosing systems in site assessment phase
- Operator
  Decision-making for implementation of a heating systems a specific sites, optimized system control during icing events
- Energy trading
  Enable basic projection of the risk of production downtimes of wind farms with heating systems



Subtask organization



- WP1 – Terminology and definitions
- WP2 – Exemplary data of icing events
- WP3 – Modelling of IPS performance
- WP4 – Recommendations on field validation of IPS performance
- WP5 – Collaboration with wind tunnel subtask
- WP6 – Dissemination

WP2 – Which meteorological parameters influence icing events?

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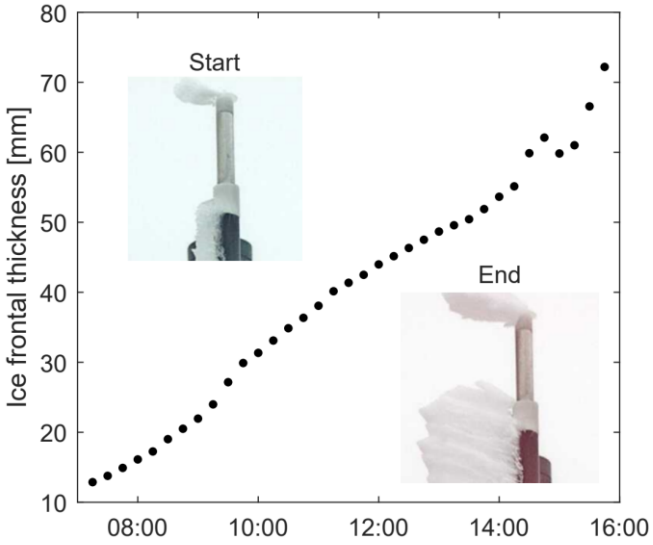
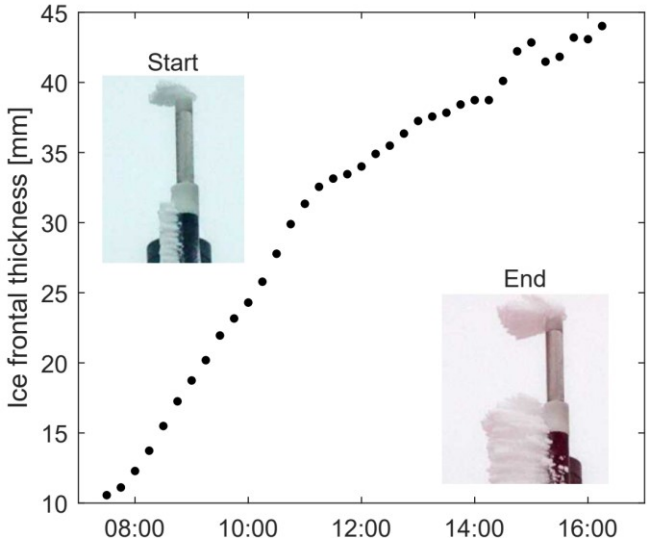


	Avg	Min	Max
Wind speed	8.9	7.2	11.6
Temperature [°C]	-3.2	-4.6	-2.0
LWC	0.12	SD: 0.02	



	Avg	Min	Max
Wind speed	10.6	8.6	13.4
Temperature [°C]	-6.4	-8.7	-5.3
LWC	0.06	SD: 0.04	

[6]

WP2 – Icing loss – different sites / different turbine types

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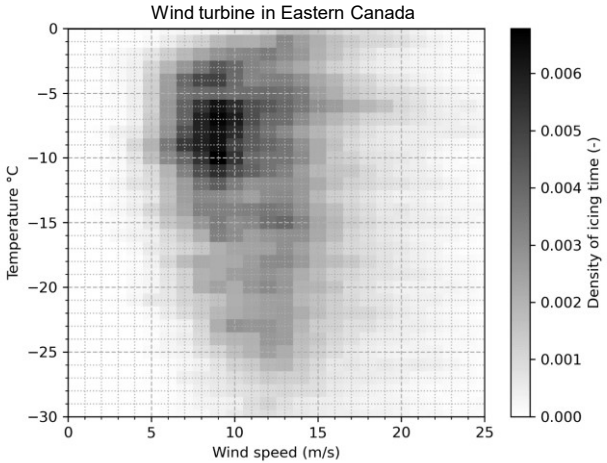

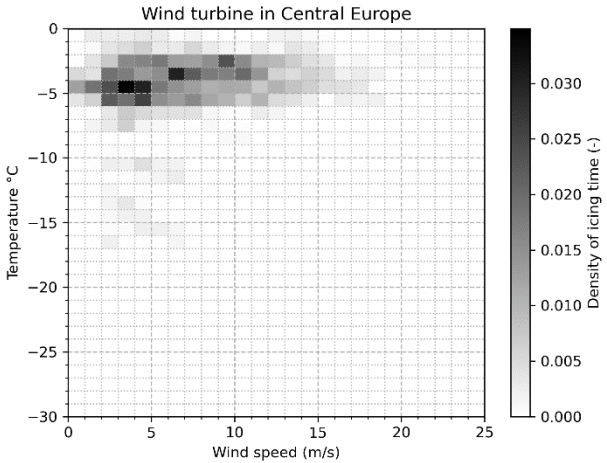

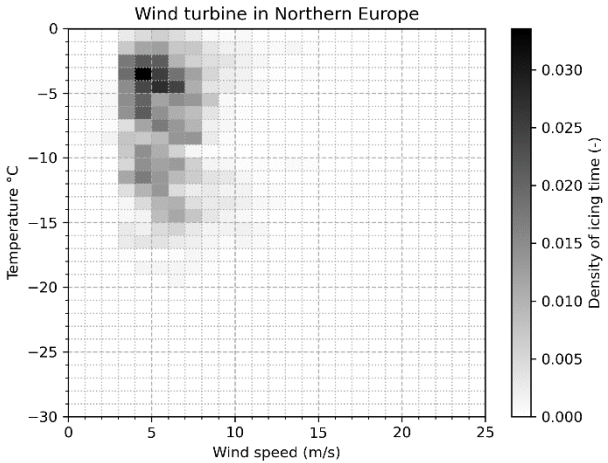

- Different patterns of icing conditions for different locations / different turbine types

WP2 – Stoppage due to icing – different sites / different turbine types

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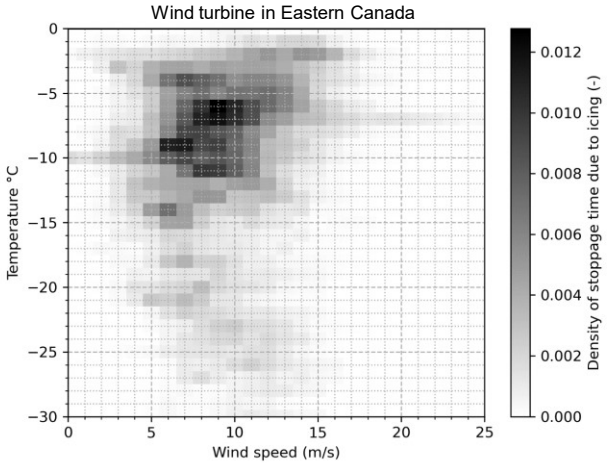

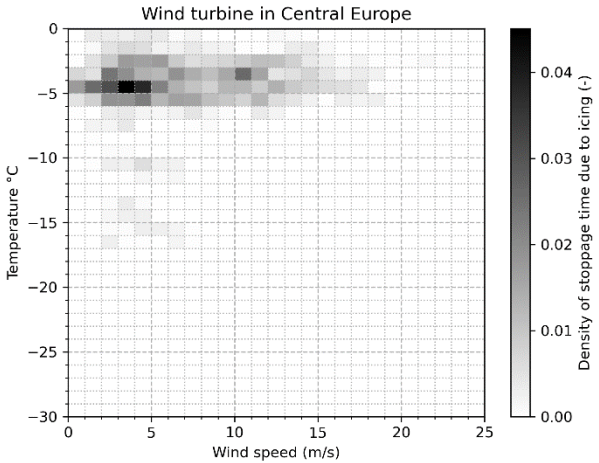

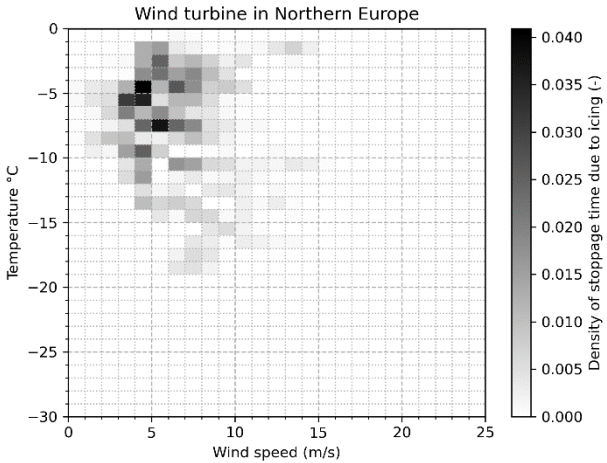

- Different patterns of icing conditions for different locations / different turbine types

WP2 – Exemplary icing events

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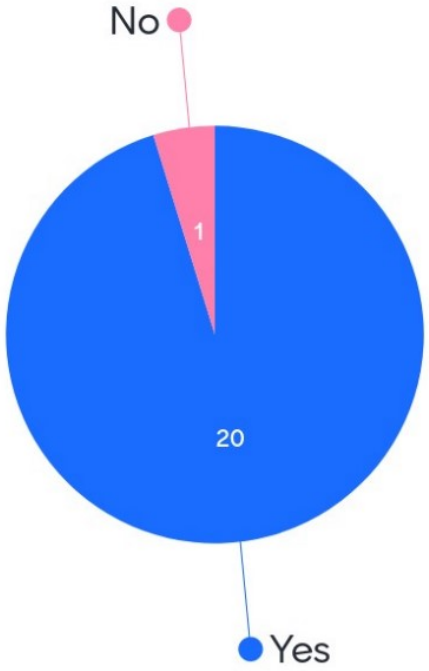
Mentimeter poll – Are you willing to share respective anonymized icing data?



Thank you!
We will definitely get back to you on that!

WP2 – Key take-aways from the group discussions

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- Process for sharing data and anonymization must be as simple as possible to facilitate wide-spread participation
- Recommendations on the proper measurement of icing events would be very much appreciated
- Every type of dataset can be helpful, it does not need to be exhaustive
  Examples of parameters/datatypes:

  Wind speed, wind direction, temperature, relative humidity, air pressure, cloud base height, solar radiation, LWC, tags (e.g. fog, icing type etc.), heating mode (on or off), heating power consumption, turbine power, albedo, ice detection signal, camera images, …

WP3 – Blade surface temperature – f(T_ambient, WSPD, LWC)

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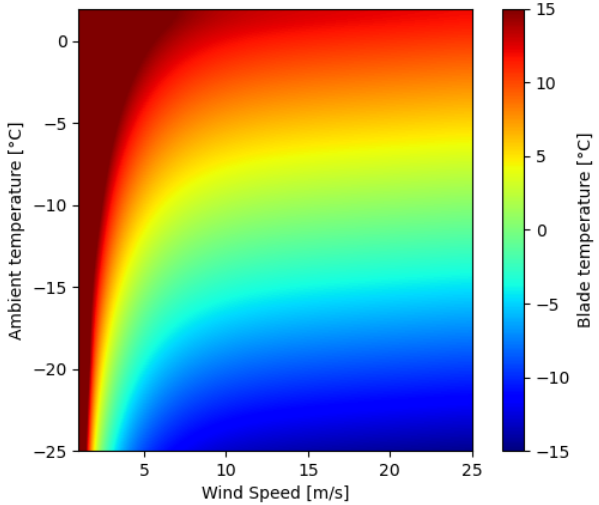
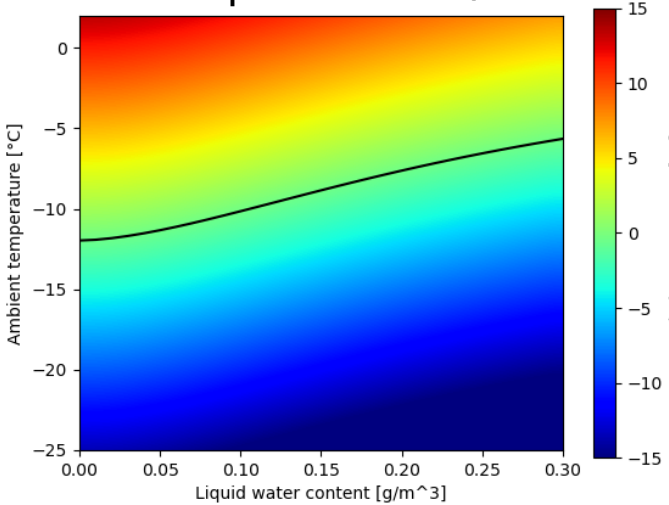
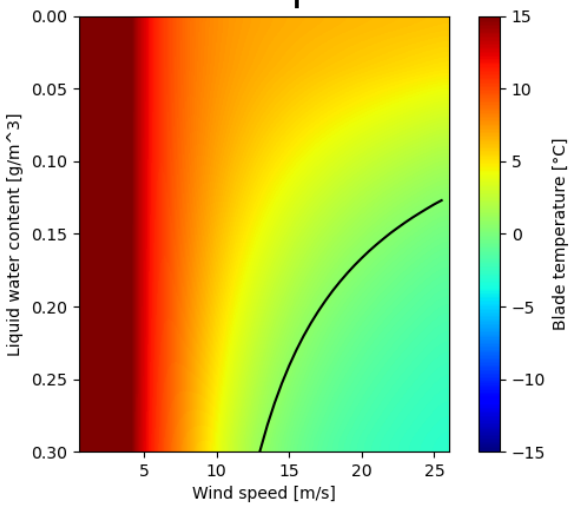
LWC = 0 g/m^3



Wind speed = 5 m/s



Amb. Temp. = -5 °C



Assumptions: Uniform heated surface temperature, blade dimensions, 25 kW per blade, 50m blade, heated section from stagnation point to 1/8th of the chord length on each side, 20% heat loss through other surfaces, empirical rpm curve, no ice on the blade, empirical effect of LWC, air properties calculated at -5°C, estimated collision efficiency.

WP3 – Potential Blade Envelope

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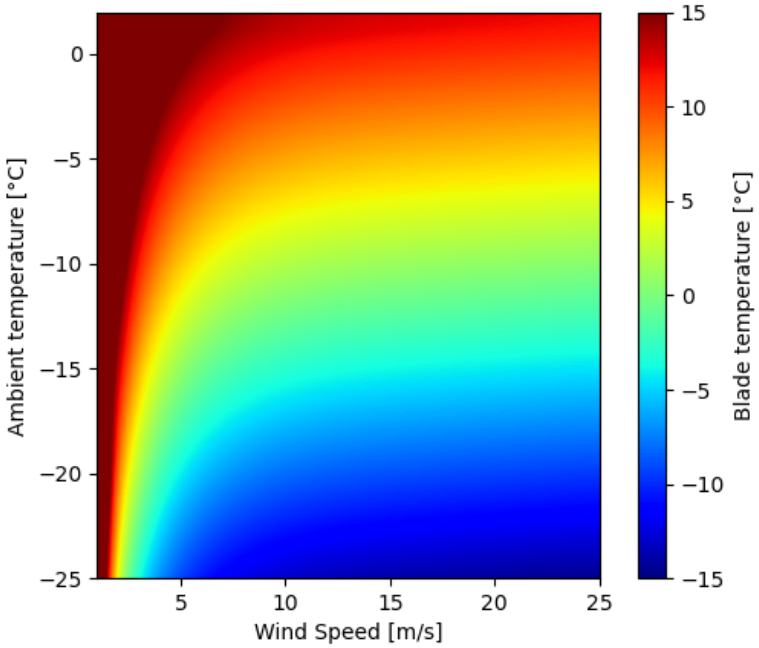
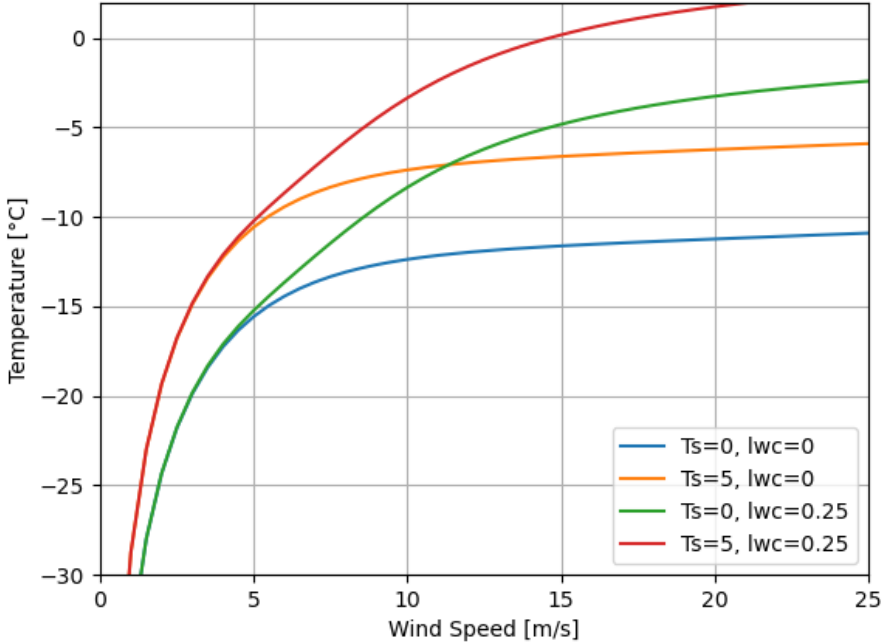
LWC = 0 g/m^3





WP3 – Modelling

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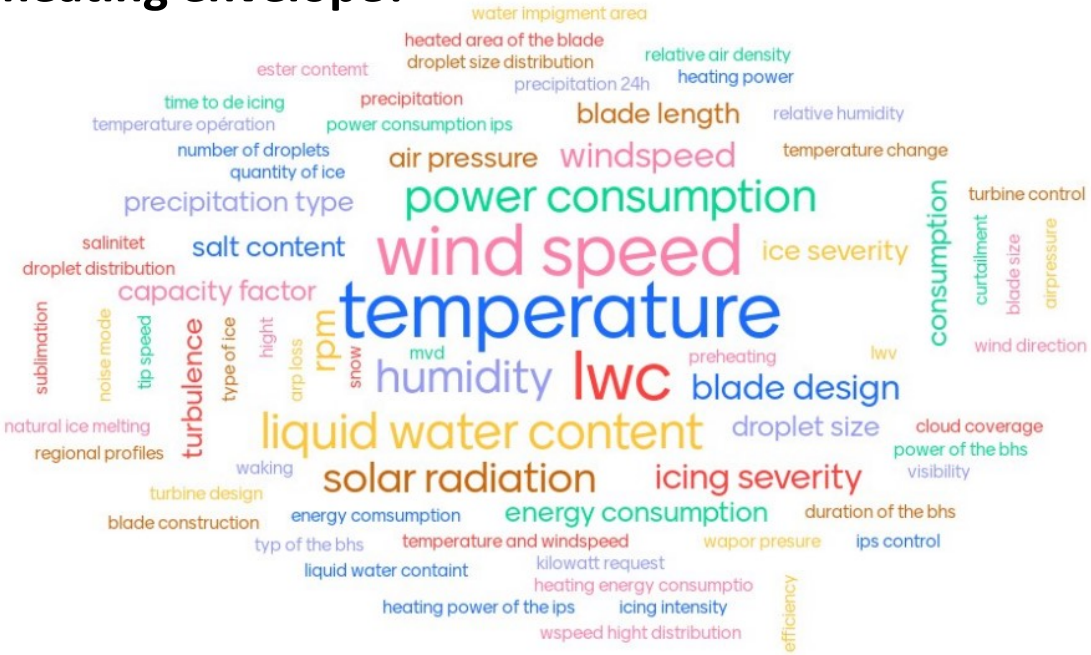
Mentimeter poll - Which parameters need to be taken into account to define a blade heating envelope?



WP3 – Key take-aways/questions from the group discussions

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- Not only consider negative effects such as from LWC which “shrinks” the performance envelope but also positive effects that add to the heat transfer/evaporation (dry air, solar radiation, salt content etc.)
- How could (icing) forecasts be factored into the modelling and further down the road in the operation of BHS?
- More details should be provided from the OEMs on how their turbines perform in icing conditions

WP4 – Bridging the gap

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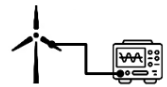
How could we provide more details on a blade heating system performance without doing a long-term wind turbine performance analysis?

By definition, the blade heating system function is to bring the blade surface temperature above 0°C, not to produce energy.



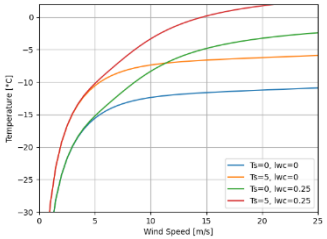
Field validation

WP4

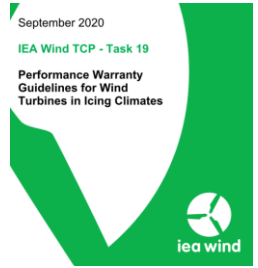
Siting Commissioning Operation

WP3

Modelling of system



Verification of warranty



WP4 – Proposed Method – Introduction

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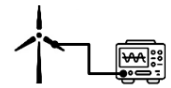
Use thermal imaging (or other blade surface temperature sensor) along with transfer functions developed and validated by Task 54, to extrapolate external blade temperature to IPS performance.



Field validation

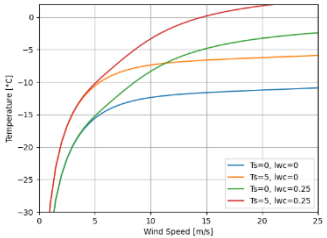
WP4

Siting Commissioning Operation

WP3

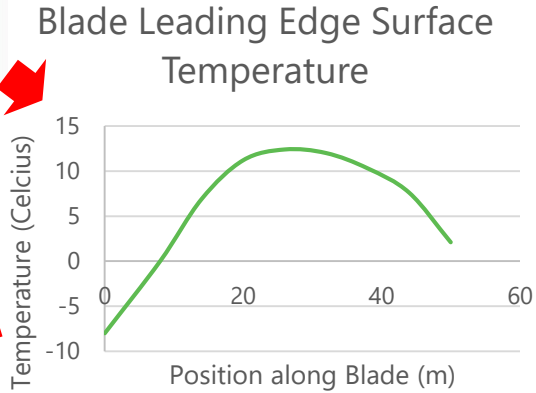
Modelling of system

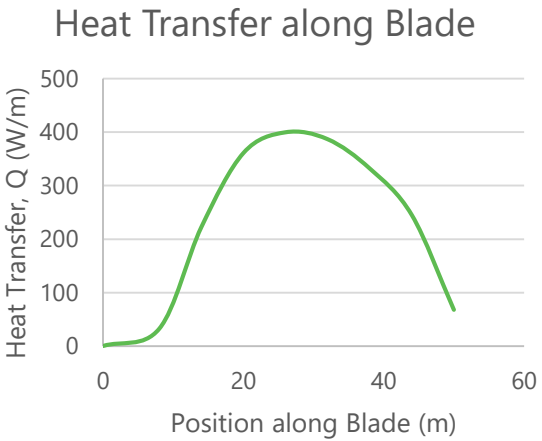
Verification of warranty



WP4 – Proposed Method Step 1

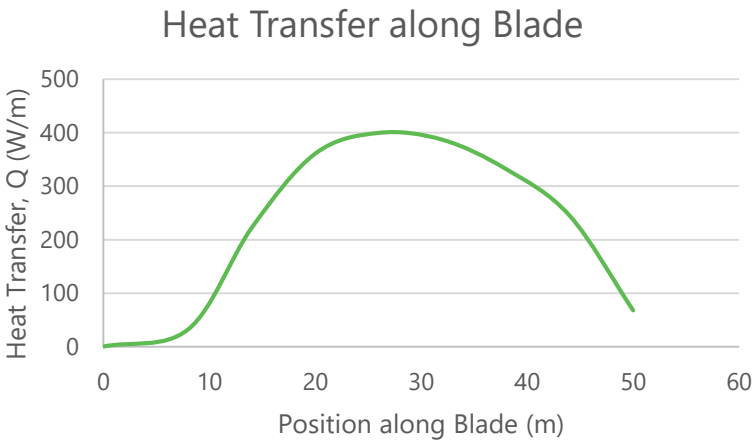
1. Take thermal images with the turbine stopped, below 0°C, and dry conditions (LWC = 0) in at least 3 different conditions (T, WdSpd)
2. Use the thermal image to graph the distribution of temperature along the leading edge of the blade
3. **Task 54 would provide a tool to calculate the <u>heat transfer (Q)</u> along the blade using the temperature**

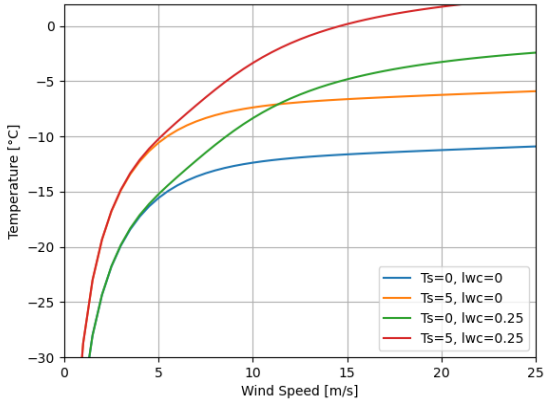




WP4 – Proposed Method – Step 2

1. Using the heat transfer distribution, the temperature distribution in other conditions can be determined (wind speed, temperature, LWC)
2. **Task 54 to prepare a tool to translate the heat transfer to the operational envelope <u>during operation and in icing</u>**





WP4 – Proposed Method – Missing Pieces

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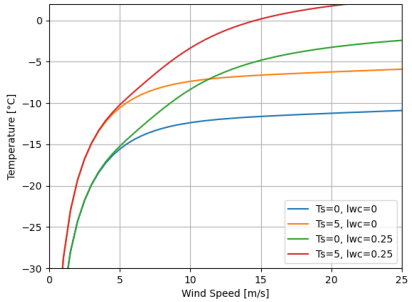
- Transfer the operational envelope to turbine performance
- Consider area of the blade that is heated
- Consider the icing distribution of the site relative to the performance envelope
- **Account for the validated availability of the IPS**



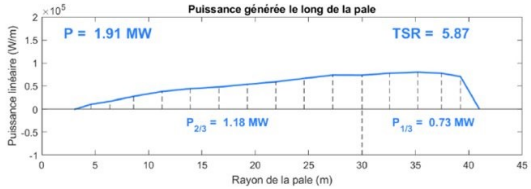


Figure 4 : Distribution de la puissance d'une turbine Senvion MM82 pour une vitesse de vent de 12 m/s.

Annual icing hours	Wind [m/s]											
Temperature	4	6	8	10	12	14	16	18	20	22	24	inf
-20	0.49	1.13	2.03	0.97	0.33	0.31	0.18	0.00				
-18	0.36	0.85	0.94	0.93	0.36	0.16	0.07	0.05	0.02			
-16	0.67	1.62	1.85	1.21	0.68	0.32	0.07	0.06				
-14	1.10	3.13	3.38	2.20	1.16	0.55	0.14	0.02		0.01	0.02	
-12	2.04	4.84	6.07	4.37	2.68	0.74	0.25	0.10	0.03			
-10	2.92	5.86	6.42	5.37	2.77	1.13	0.46	0.09	0.03	0.05		
-8	3.71	6.75	7.79	6.22	4.31	1.75	0.50	0.23	0.04	0.02	0.00	
-6	5.06	9.40	10.74	8.55	4.90	2.23	0.91	0.34	0.06	0.01		
-4	5.93	12.91	13.71	9.85	6.74	4.83	1.24	0.43	0.16	0.04	0.03	0.00
-2	10.27	13.42	16.54	11.01	7.29	3.71	1.75	0.83	0.23	0.06	0.00	0.02
0	12.86	21.67	25.03	17.06	11.85	7.38	2.62	0.91	0.31	0.05	0.07	0.02

95% availability

Mitigation of 53% of icing losses

WP4 – Field validation

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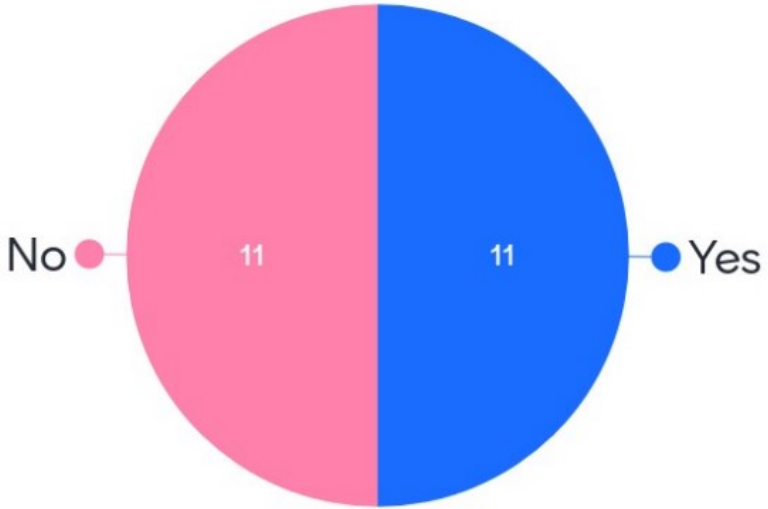
Mentimeter – Do you agree with the proposed method for field validation?



WP4 – Key take-aways/questions from the group discussions

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- Wide-spread unease about the uncertainties of the proposed method
  - But also the comment “Better than nothing – we have to start somewhere?!”
  - Thorough validation and evaluation of the uncertainties of a future method will be key to its acceptance
  - Transparency about used simplifications and resulting limitations
- Who should do these tests, the OEM (to compare different systems in selection phase) or the owner during commissioning to verify performance?

Outlook

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- WP2 – Exemplary icing events
  - Continuation of data gathering on icing events
  - Creation of publicly available data sets, if possible for different regions
- WP3 – Modelling
  - Preparation of recommendations on modelling procedure
  - Creation of generic code examples for individual system aspects
- WP4 – Field validation
  - Validate proposed method using operational data from system manufacturers and project owners that are willing to share data
  - Provide guidelines on procedure/tools required to implement validation method

We should call a spade a spade

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Mentimeter poll - What name would you prefer as standard term?

Performance envelopes of blade heating systems

IEA Wind TCP Task 54

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Thank you for your attention!

Winterwind 2023

29.03.2023