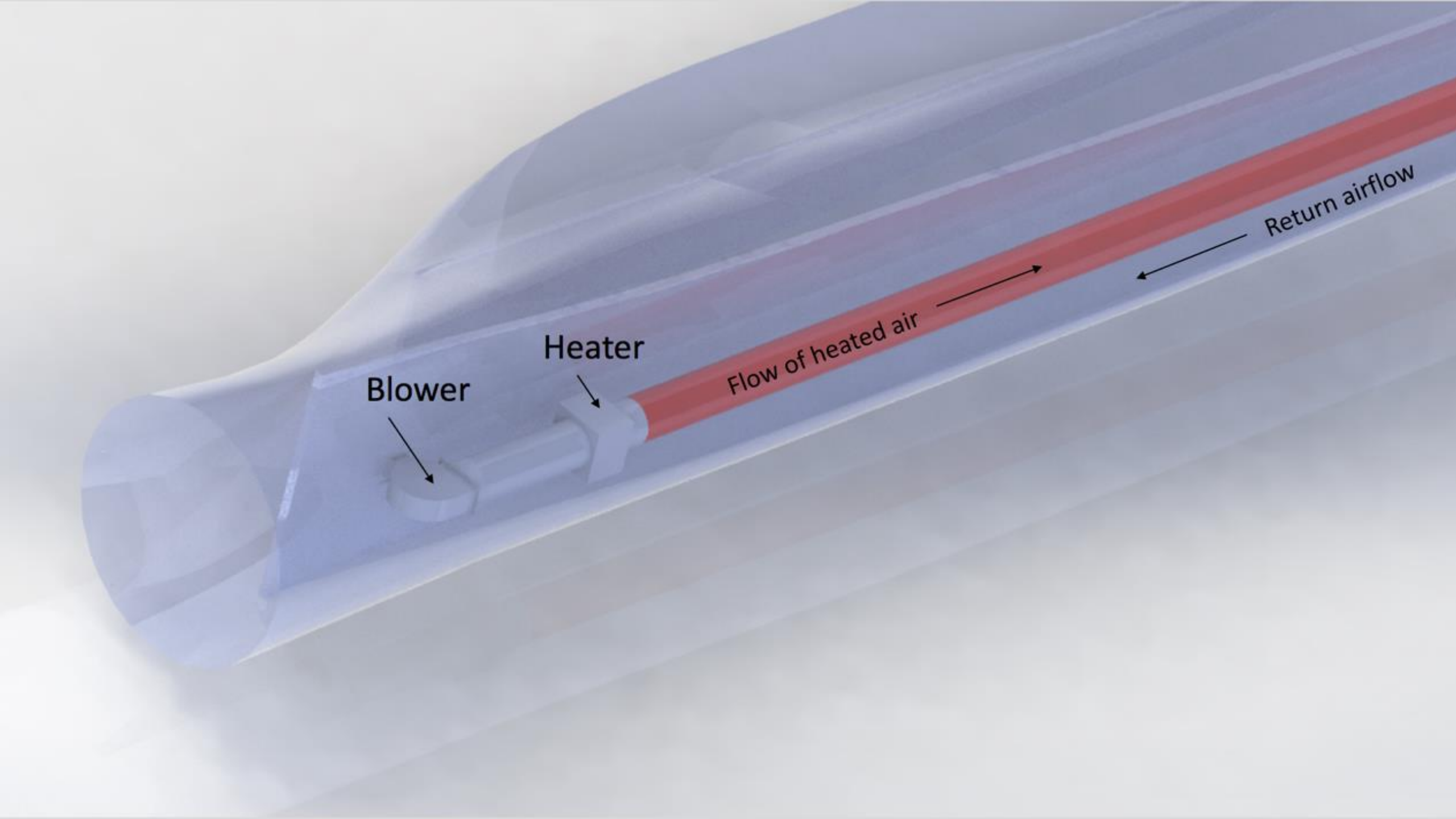
FabricAir | BorealisWind Ice Protection System

Cost Benefit Analysis of Ice Protection Systems – Validated with Field Data

Daniela Roeper, March 2024

Who are we?

- Provide retrofit Ice Protection Systems (IPS)
- 5 wind farms retrofitted in Canada
- 5 winters of operational validation
- 500 MWh energy gain per turbine
- 10% AEP increase on average


Blower
Heater
Flow of heated air
Return airflow

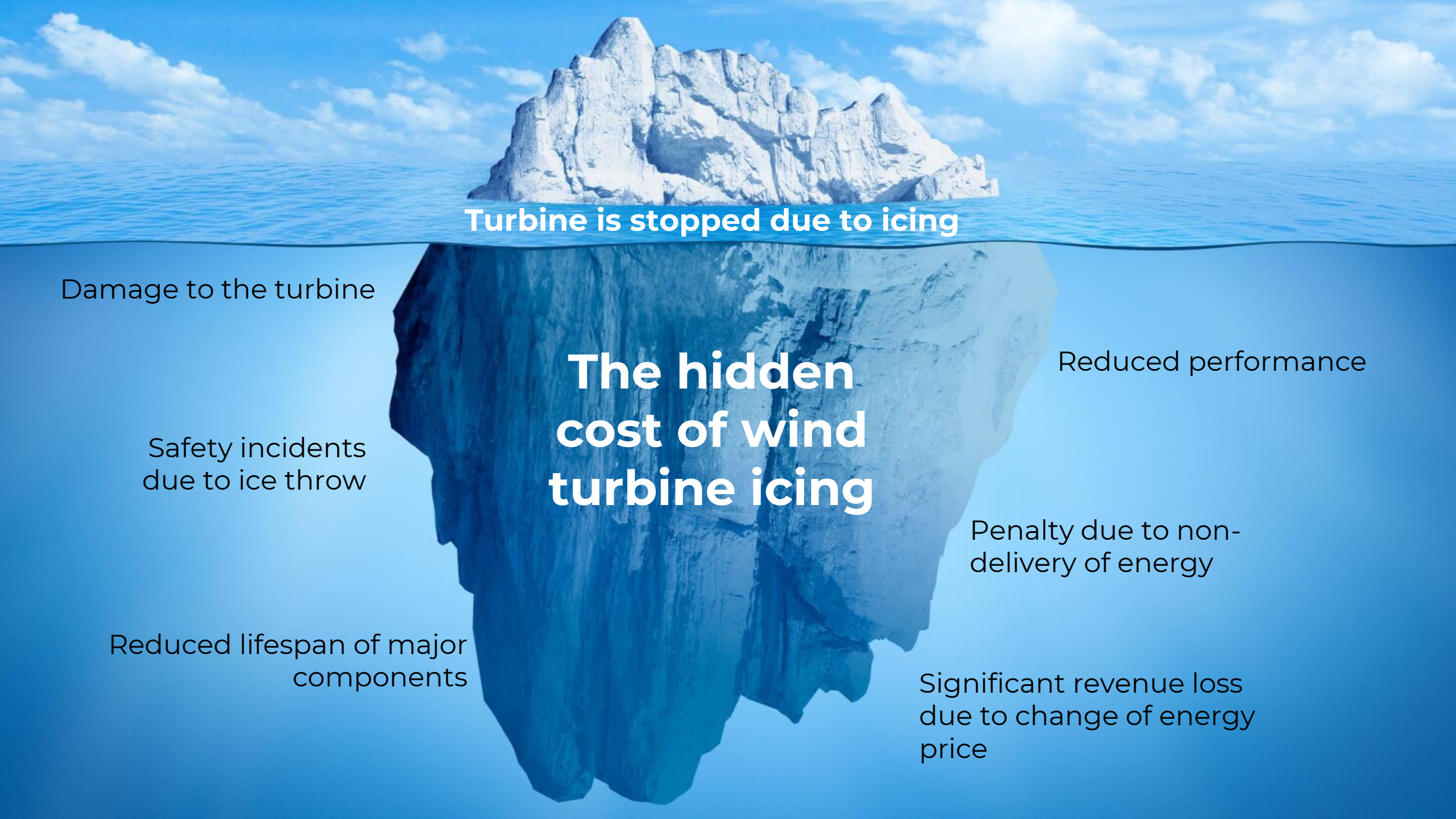
Infrared Picture of Blade with Ice Protection System

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

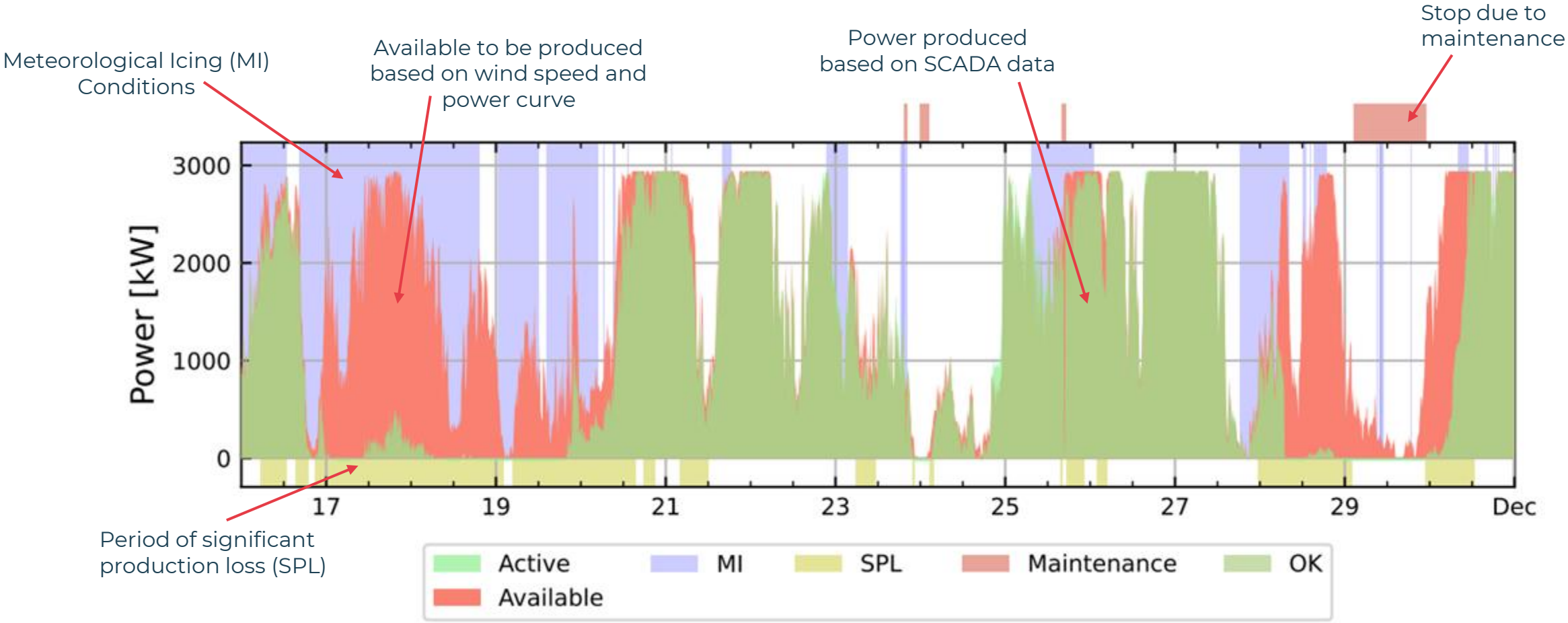
Case Study: Wind Farm in Canada

- Case study is based on real data that is anonymized
- Class 3 icing site in Canada
- Located on hilly terrain
- Most severely impacted turbines have IPS
- We will review:
  - Costs of icing
  - Costs of the IPS
  - ROI calculation
- Bonus: Global icing data and where an IPS will have a positive ROI


Photo/Robert F. Bukaty

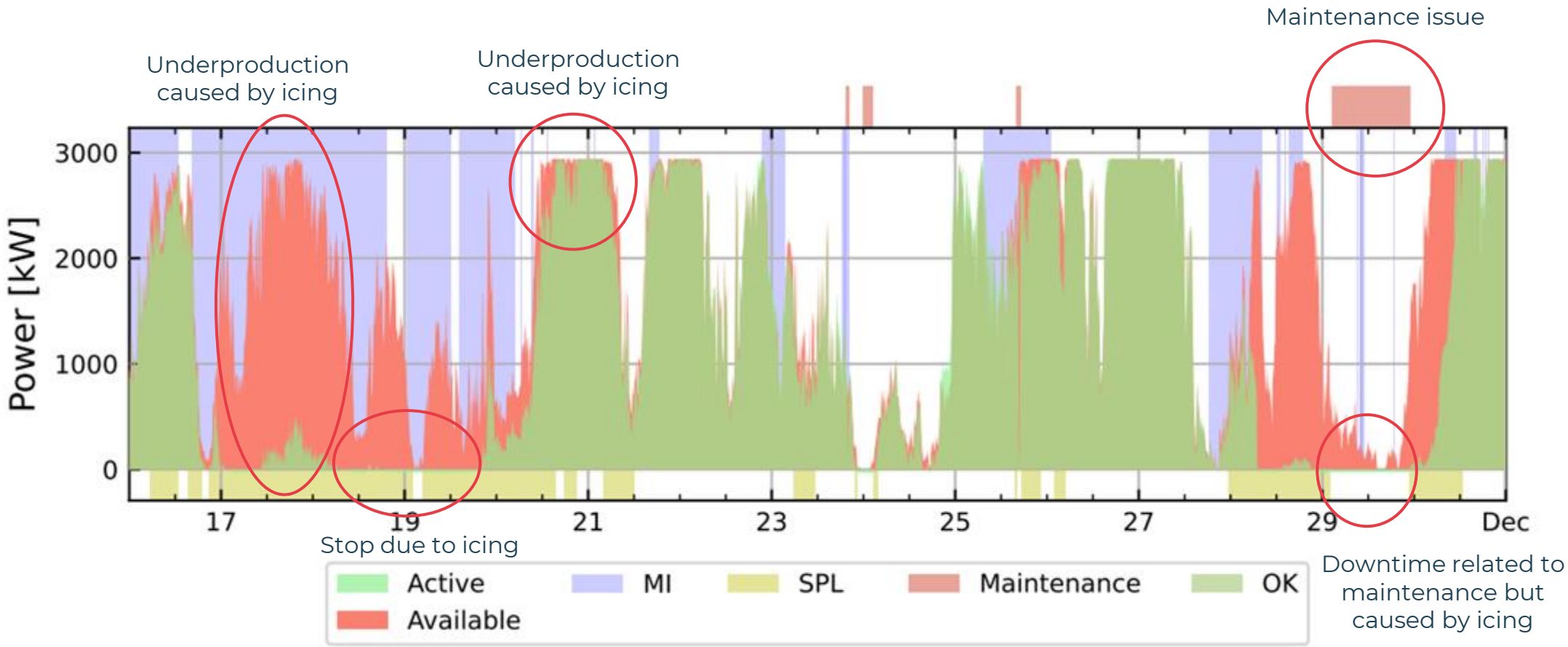

Turbine is stopped due to icing
Damage to the turbine
The hidden cost of wind turbine icing
Reduced performance
Safety incidents due to ice throw
Penalty due to non-delivery of energy
Reduced lifespan of major components
Significant revenue loss due to change of energy price

Cost of Ice – Production Loss



Analysis and Graph by Icetek (Icetek.ca)

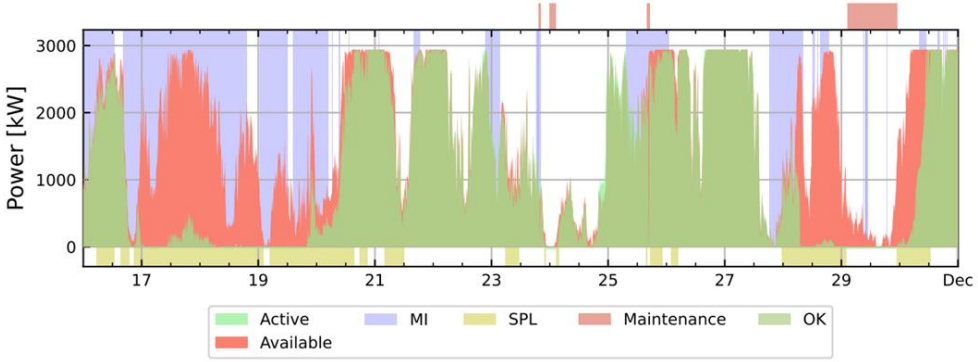
Cost of Ice – Production Loss



Analysis and Graph by Icetek (Icetek.ca)

Cost of Ice – Production Loss

- Reviewed the data for the whole winter in a time series analysis
- Cost:
  - 1180 MWh / turbine / winter
  - PPA at 58 €/MWh
  - **68.440 €** of revenue loss / winter due to lost production



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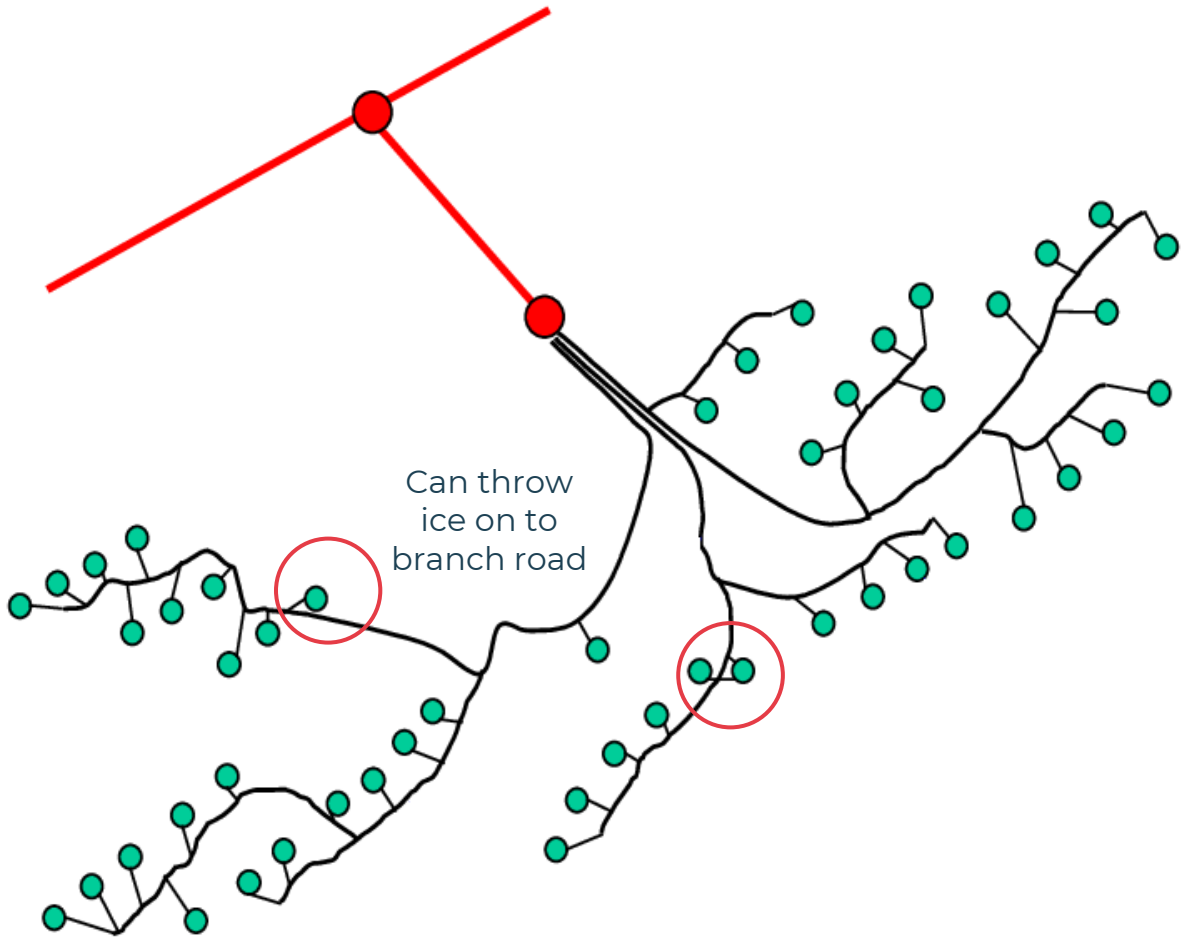
Cost of Ice – Ice Safety Losses

- Ice safety related losses:
  - Inability to access turbine for troubleshooting
  - Inability to access a branch of turbines for troubleshooting
  - Safety of people and workers at risk
- Cost:
  - 3 days of turbine stopped due to no access
  - **4635 € / winter**

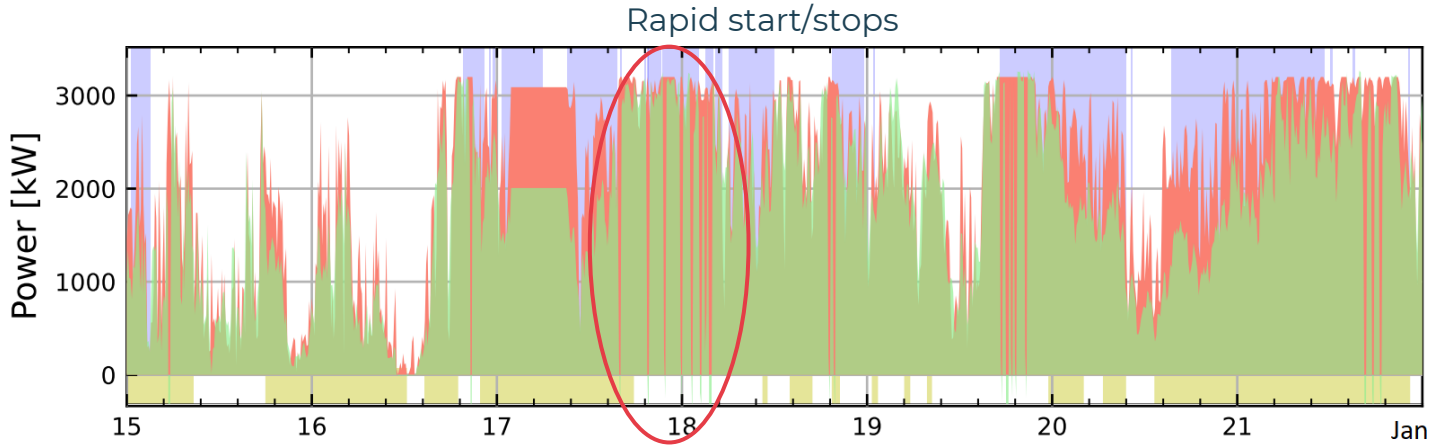


Cost of Ice – Direct Damage

- Ice throw can cause damage to the turbine itself
  - Blades, nacelle, transformer, stairs
- Can damage nearby buildings
- Can damage vehicles or equipment
- Cost:
  - Damage to turbine stairs: 7000 €
  - Damage to truck windshield: 600 €
  - Assume damage occurs once every 3 winters per turbine: **2533 € / winter**

Cost of Ice – Lifespan of major components

- Additional load and mass imbalance can impact major components
- Additional load often causes the turbine to stop in vibration or oscillation error codes
- Icing can also cause rapid start/stops of the turbine which puts significant strain on the turbine



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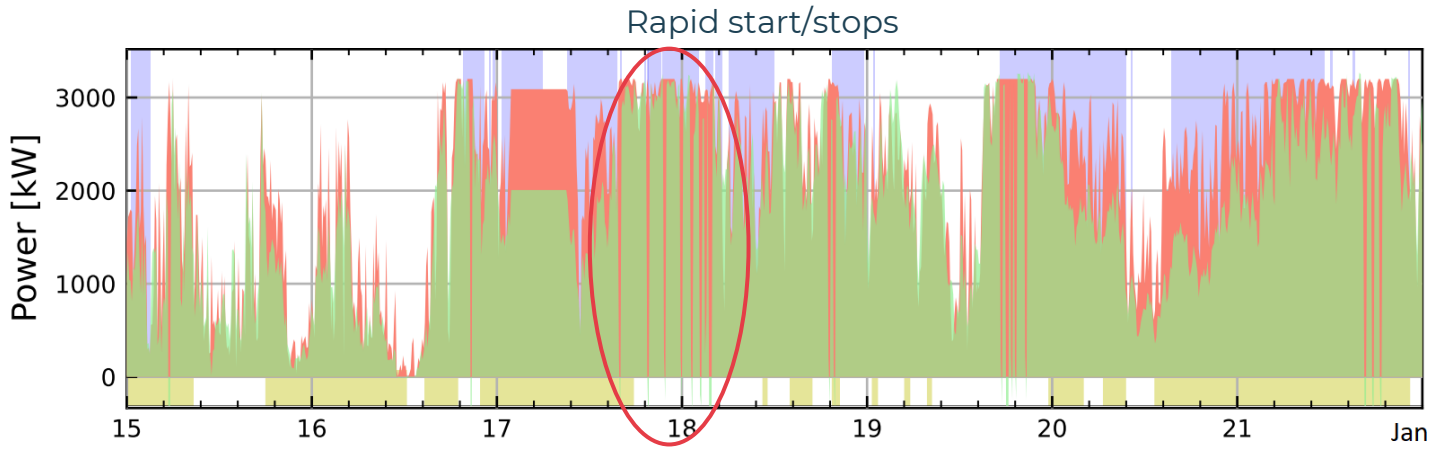
Cost of Ice – Lifespan of major components

- Cost:
  - Hard to quantify
  - Estimate as: 1 case per 20 turbines per 10 years, with each instance incurring 500k €
  - Annual cost of **2500 €**



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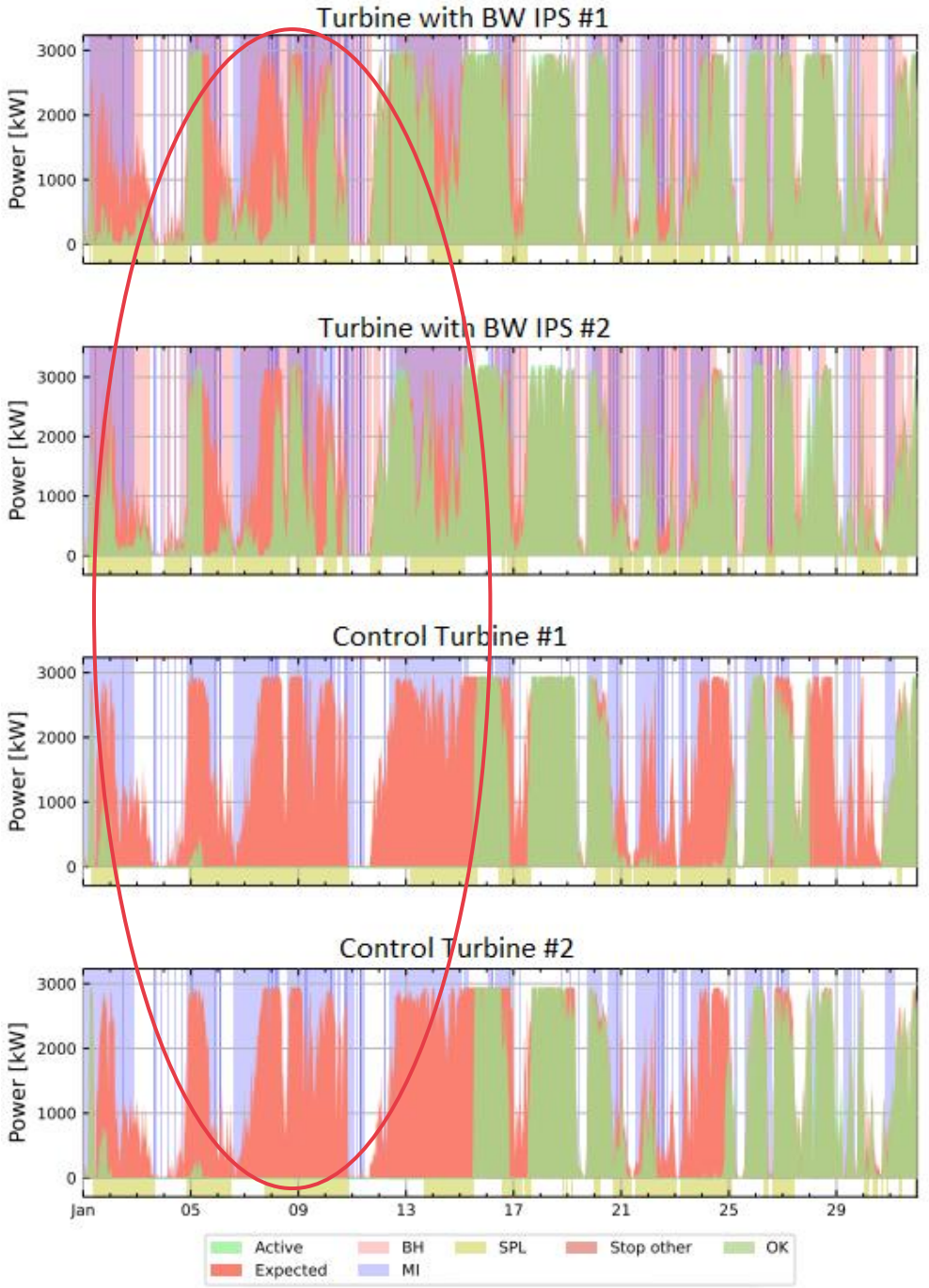
Benefit of IPS – Recovered Production

- Performance of turbines with IPS were compared to neighboring control turbines
- Data is analyzed on a time series basis
- Benefit:
  - 767 MWh / turbine of production loss recovered
  - PPA at 58 €/MWh
  - **44.486 €** of revenue recovered / turbine / winter
  - **65% rate of recovery**



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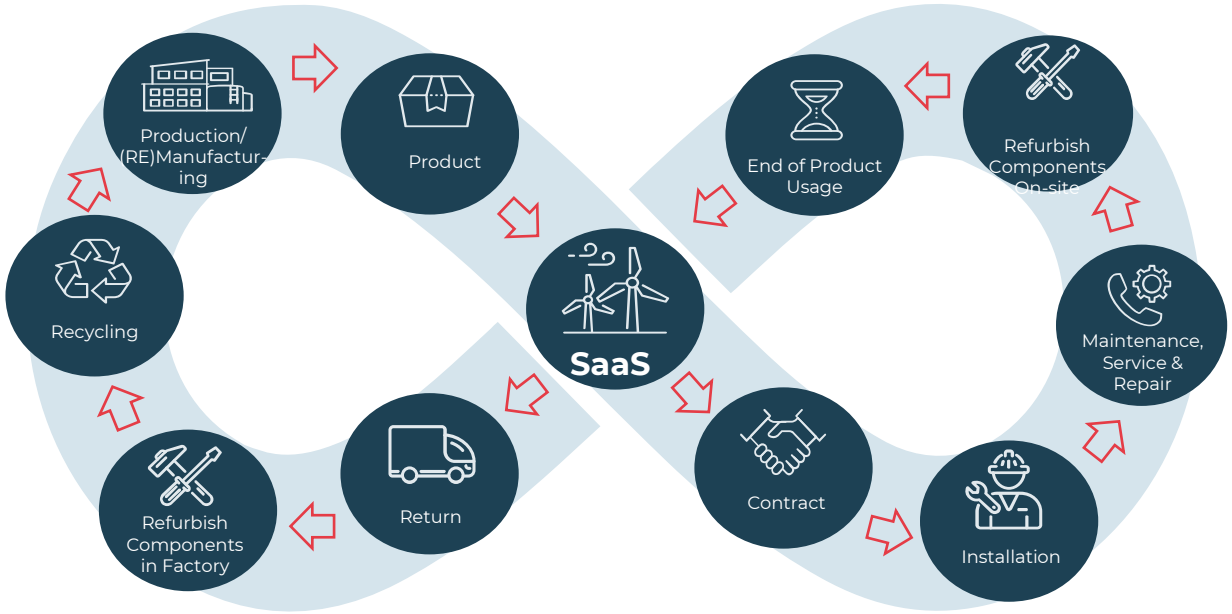
Recoverable Icing Losses

	Costs of Ice	Recoverable with IPS
Production Loss	68.440 €	44.486 €
Safety Losses	4.635 €	3.013 €
Direct Damage	2.533 €	1.647 €
Long term Damage	2.500 €	1.625 €
Total	**78.109 €**	**50.771 €**

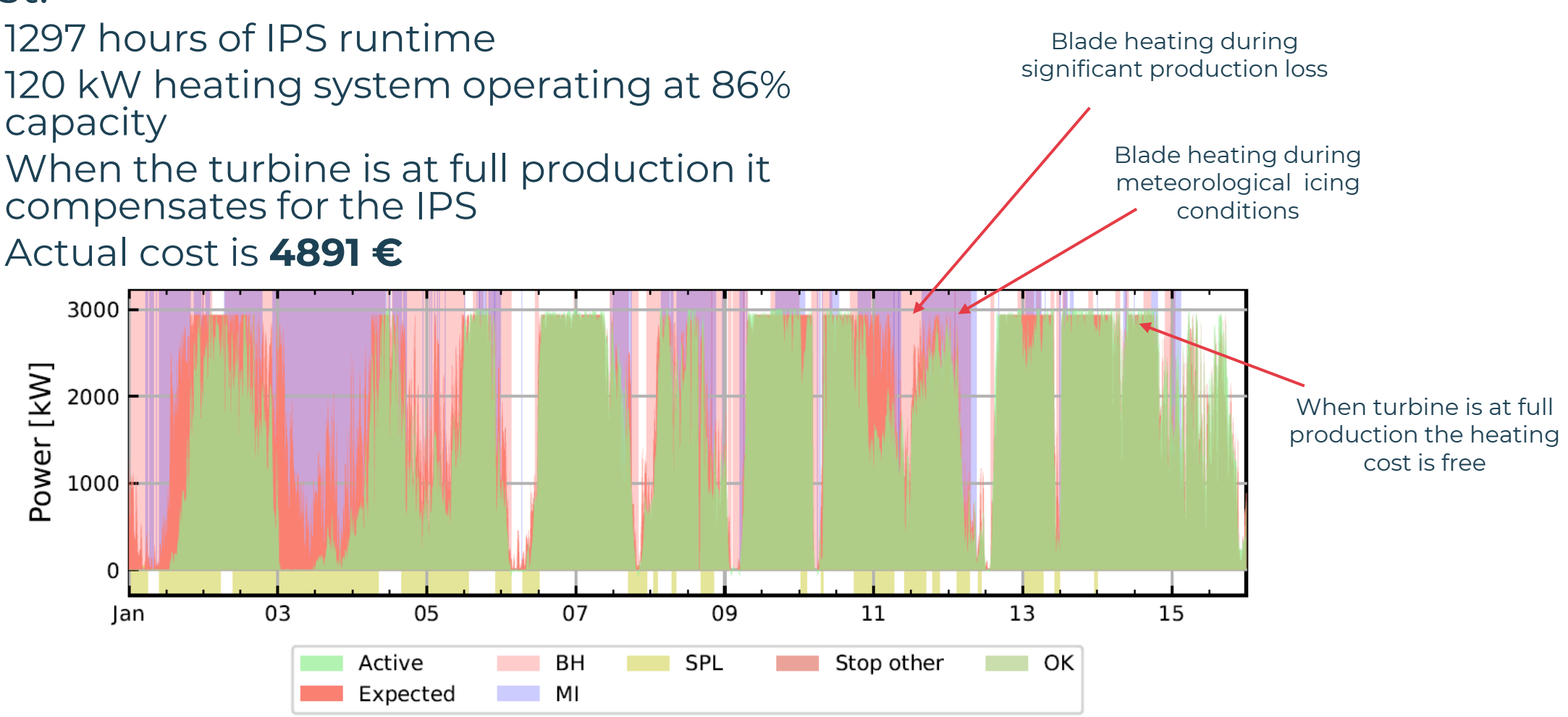
Cost of IPS – IPS & Maintenance

- BorealisWind IPS is based on a system as a service model
  - Installation, maintenance and service are included
  - Availability of the system falls under the comprehensive warranty
- Pricing is based on size of the blade heating system and requirements for maintenance
- For this case study the cost of the IPS is **24.000 € / year**
- Each year there will be 2 days on maintenance stoppage which is therefore worth **780 €**



Cost of IPS – Power Consumption

- Cost:
  - 1297 hours of IPS runtime
  - 120 kW heating system operating at 86% capacity
  - When the turbine is at full production it compensates for the IPS
  - Actual cost is **4891 €**



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IPS Cost Benefit Summary

	Recoverable with IPS	Cost of IPS
Recovered Revenue	50.771 €	
Cost of IPS		24.000 €
Power Consumption		4.891 €
Maintenance Downtime		780 €
Net Profit	**21.100 €**	
Effective AEP Increase	**4%**	

Conditions for Return on Investment (ROI)

Legend
- Excellent ROI
- Positive ROI
- Negative ROI

Estimated Production Loss at 58 €/MWh		Ice Class				
		1	2	3	4	5
Size of Turbine (MW)	2	1.880 €	11.280 €	26.320 €	45.120 €	75.200 €
	3	2.820 €	16.920 €	39.480 €	67.680 €	112.800 €
	4	3.760 €	22.560 €	52.640 €	90.240 €	150.400 €
	6	5.640 €	33.840 €	78.960 €	135.360 €	225.590 €

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For more information:

dro@fabricair.com

Booth 9 at Winterwind