Ice protection systems and retrofits: Performance and experiences

Winterwind
INTERNATIONAL WIND ENERGY CONFERENCE

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February 5, 2020, Åre, Sweden

Background and objectives

- Evaluation of the performance of IPS and Retrofits
  - No standard evaluation method industry
  - Various results available using non-equivalent methods
- Help industry in comparing IPS and Retrofit technologies
- Identify improvements required to help technology providers
- Task 19 working towards standardization of IPS performance evaluation -> New guidelines coming in 2020!

The approach

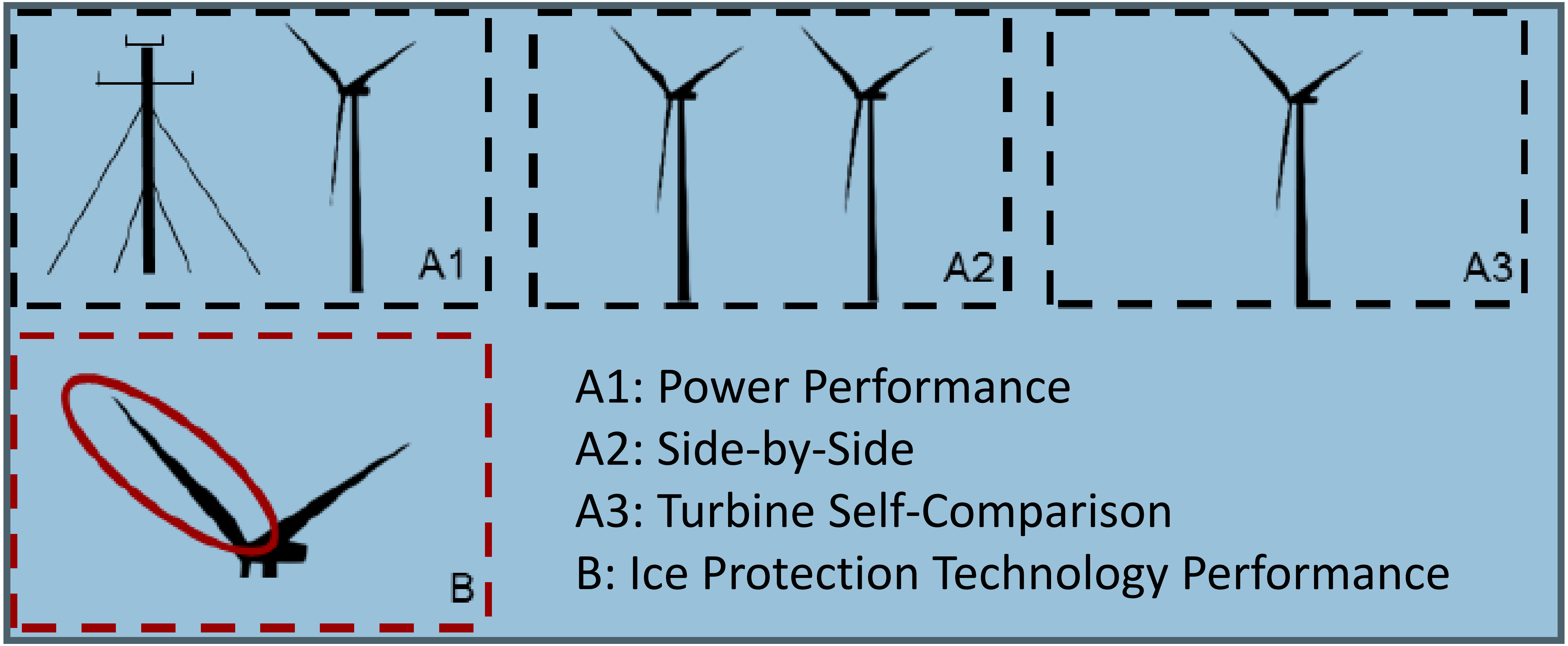
1. Literature review of publically available IPS/Retrofit performance studies
   - 11 distinct studies
   - From 2011 to 2019

2. Open industry survey
   - 19 respondents
   - From 9 countries

Reporting performance studies

Manufacturer	Reference turbine	Performance metric
Technology	Stop turbine reference for Performance Analysis	Result
Operational strategy (Anti-icing / De-icing	IEA Ice class	Analysis period
New IPS/ Retrofit	Number of sites for performance studies	Evaluated by third-party
Method of performance evaluation	Number of turbines for performance studies	Energy consumption

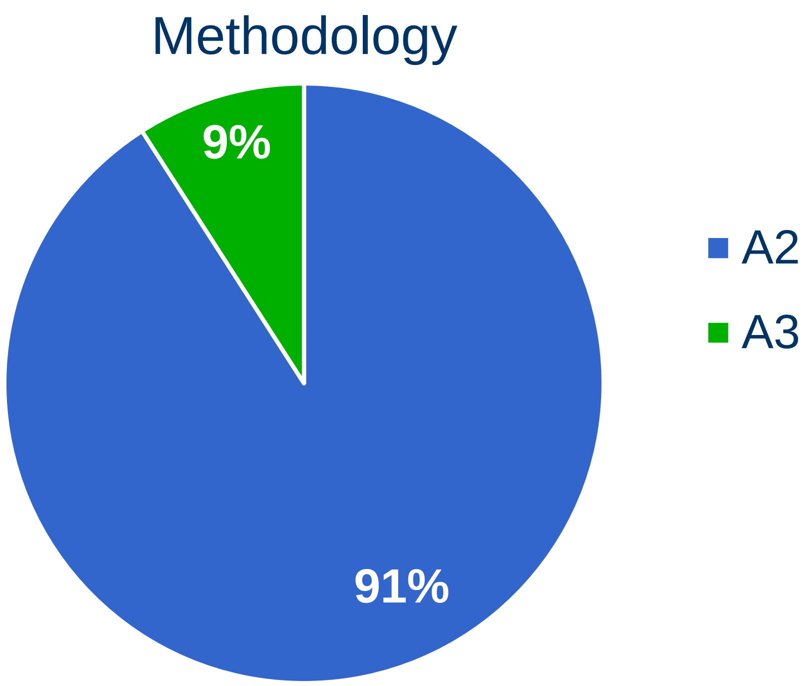
Method of performance evaluation



This performance study review excludes B

Method of performance evaluation

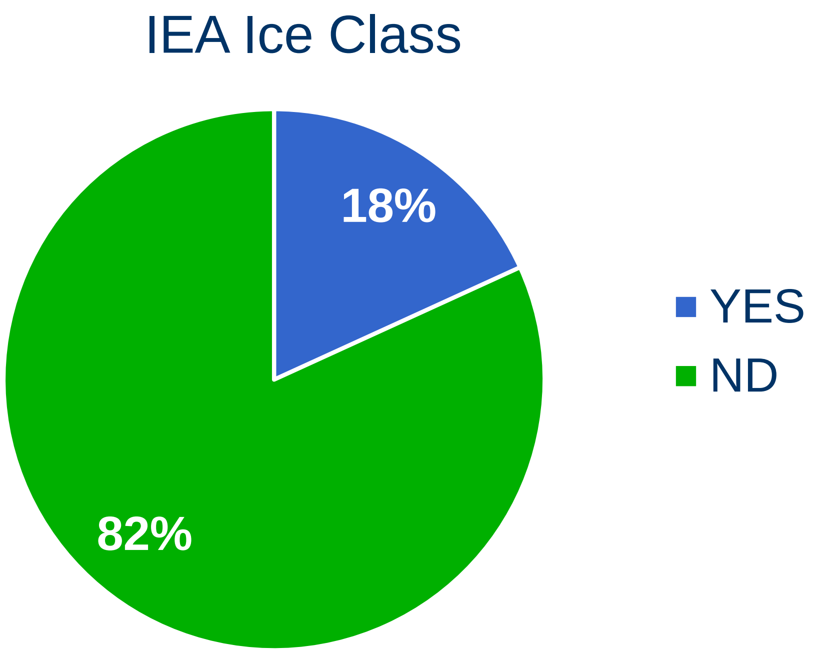
Results



91 % of studies use side-by-side approach (A2), with an operating wind turbine without IPS as a reference.

Site comparison

IEA Class	Met. icing	Inst. icing	Production losses
	% of year	% of year	% of annual production
5	> 10	> 20	> 20
4	5-10	10-30	10-25
3	3-5	6-15	3-12
2	0.5-3	1-9	0.5-5
1	0-0.5	< 1.5	0-0.5



Only two studies provided information useful for site comparison!

Scope of study

- Number of sites: Generally 1, up to 4
- Number of turbines: From 2 to 20
- Duration of study: Few months to 2 winters

Performance metrics

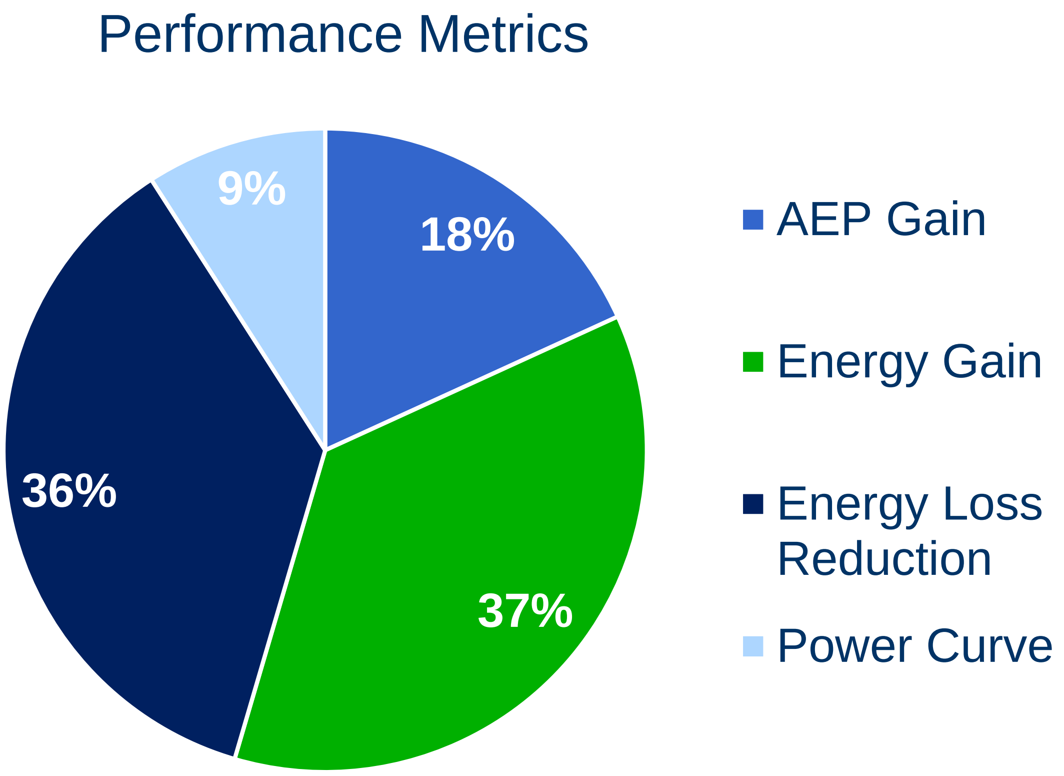
Power Curve

Energy Loss Reduction

AEP Gain

Energy Gain

Performance metrics



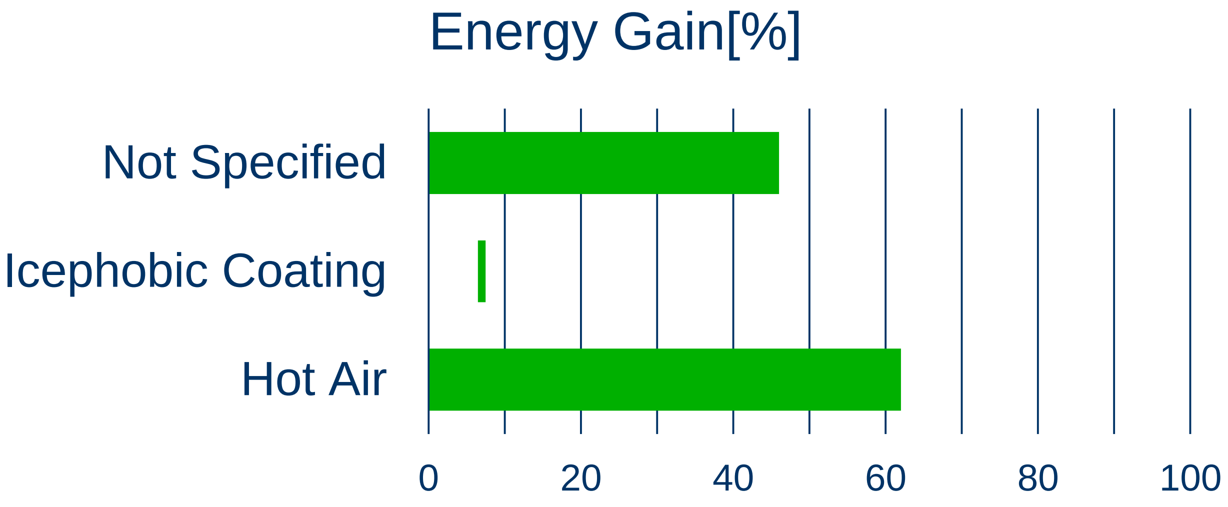
Most popular approaches are Energy Gain and Energy Loss Reduction: Are they the same?

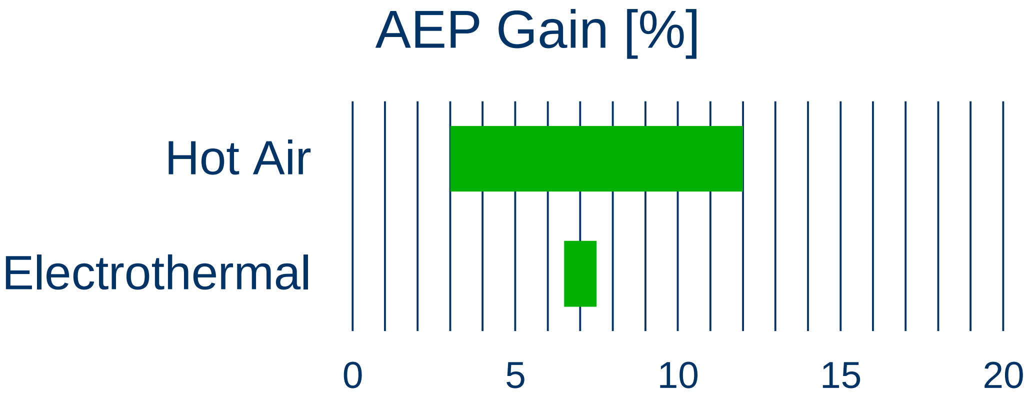
Longer analysis periods required to compute AEP Gain

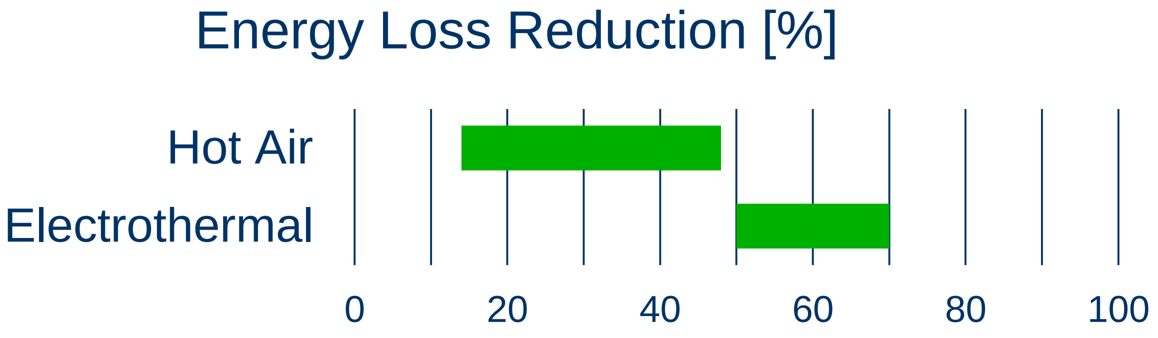
Comparing performance

- Technology
- Performance evaluation method
- Reference turbine used
- Performance metric
- Comparable sites

Performance range





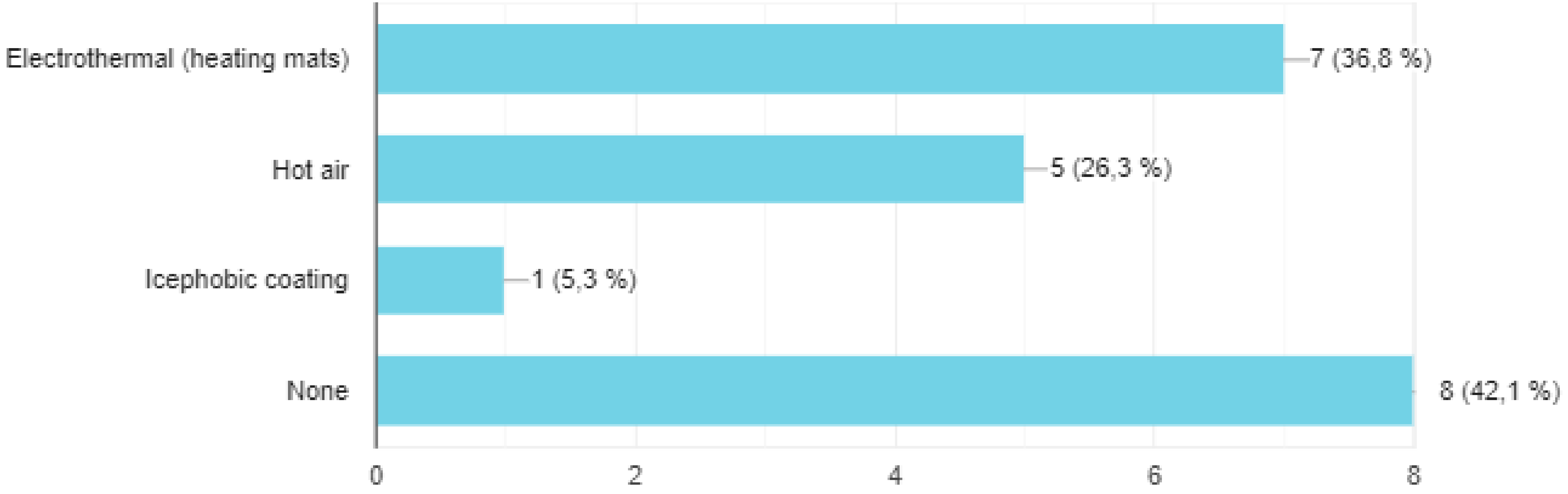


Industry survey

19 answers from 9 different countries

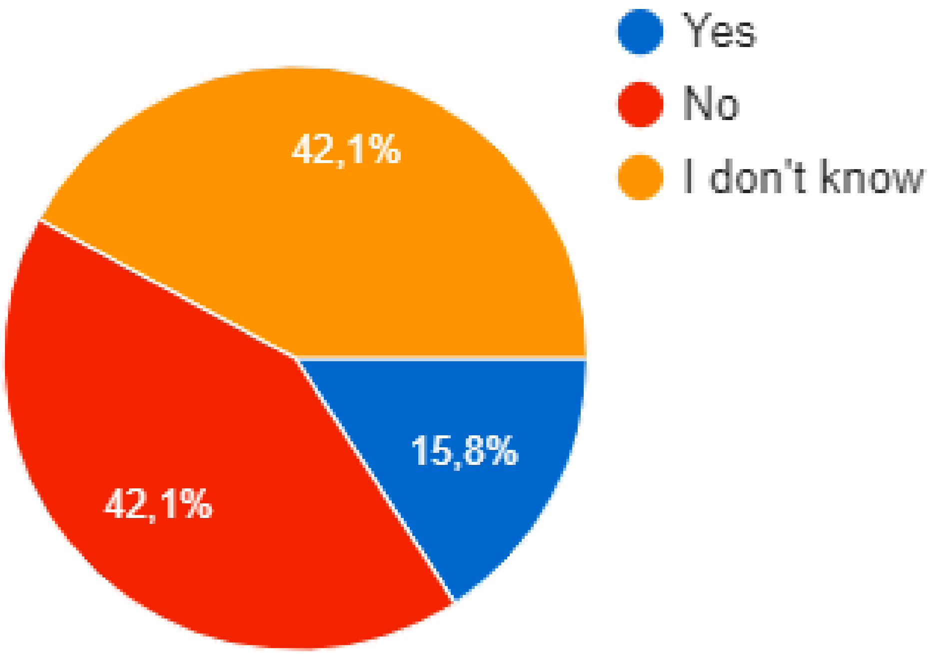
Small sample, results to be analyzed accordingly

In your organization, which Ice protection technology (IPT) are used?

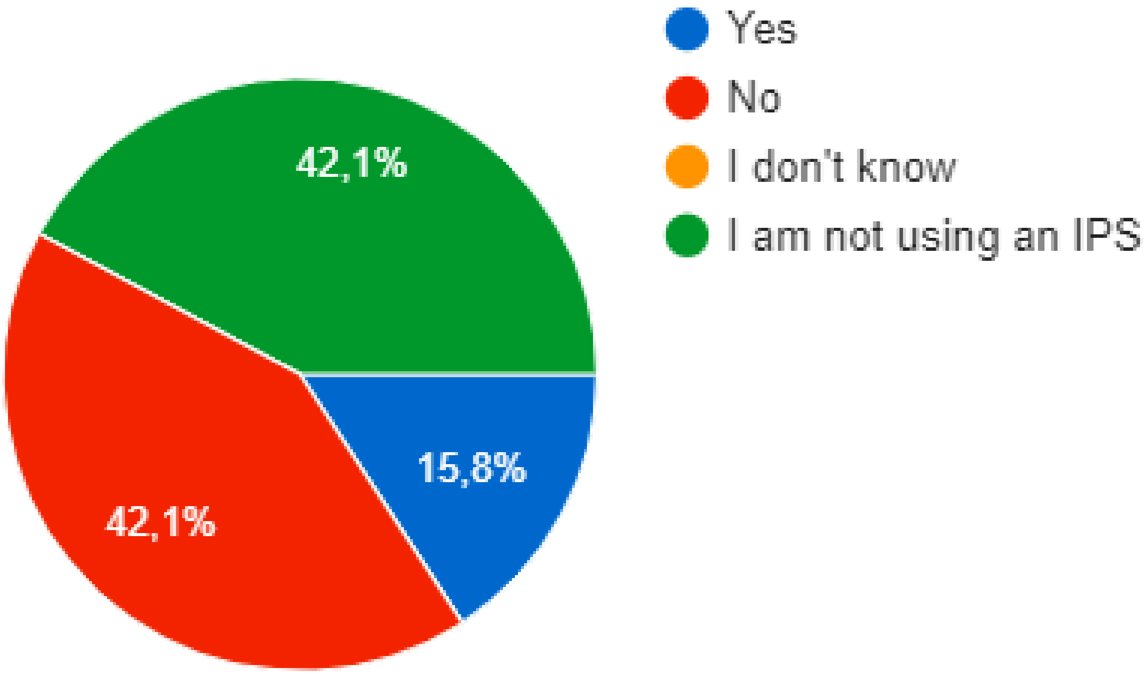


Industry survey

Are you considering the purchase of IPS equipped turbines or retrofits in the near future (< 3 years) ?



Are you satisfied with the performance of the IPS you are using?



Industry survey

Why are you not satisfied regarding IPS performance?

“Robustness is missing”

“Causing long standstill losses in low winds”

“Does not de-ice full blade which still gives losses.”

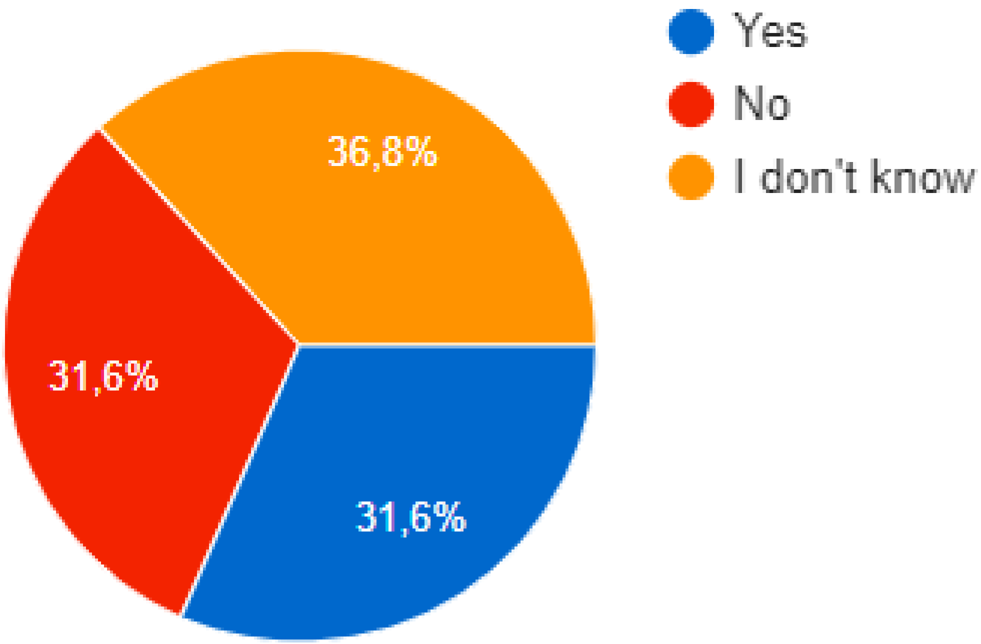
“Don't reduce losses as projected. Only part of the blades are covered. Vortex vanes are not ice protected and creates lots of losses.”

“The performance is lower than expected, especially at low temperature or high wind speed.”

“Heating power is insufficient”

Industry survey

In your experience, do you consider that IPS are reliable?



Which sub-system is affecting the reliability of the IPS you are using?

- Ice detection and control algorithm
- Ice detection triggering heating element
- Control algorithm and power distribution
- Detection, control algorithm, heating elements, power transfer to the elements, mechanical organs of the system
- The default control algorithm is suboptimal
- Heating element

Industry survey

What do you think OEMs and IPS manufacturers should be focusing on to improve the performance of IPS?

“Improve reliability and performance envelope”

“Robustness and durability”

“Smarter or more adaptive, and efficient, de-icing cycles”

“Focus on making the de-icing more efficient time and power wise and to de-ice a larger section of the blade. Find a way to validate if the blade is de-iced enough or not.”

“Focus of de-icing to where it makes most effect. I.e. outer half of blades and including Vortex Generators”

Industry survey

What do you think OEMs and IPS manufacturers should be focusing on to improve the performance of IPS? (continued)

“Detection/anticipation of icing events”

“Smarter (predictive) control algorithms, more heating power, heating during operation.”

“Freely available data of the turbines as well as performance data are necessary to increase the performance of the systems.”

“Reliability, power consumption”

“Cost”

“Reliability of the system during operation and making the system accessible for maintenance.”

Conclusions

- Industry has not come to a standardize evaluation method, this causes dissatisfaction: performance is not meeting expectations -> T19 warranty guidelines to be updated
- Performance of IPS is inconsistent, both in performance studies and end-users opinion
- Robustness and reliability of IPS must be improved
- Other improvements for IPS: Earlier ice detection, adaptive control, increased power and lower costs


Thank you!

Appendix 1 : Summary of published studies

Reference	Manufacturer	Technology	Operational Strategy (Anti-icing / De-icing)	IPS (Delivered during construction) or Retrofit (On existing turbine)	Method of Performance Evaluation [1]	Reference Turbine	Stopped reference turbine for performance analysis	IEA Ice Class	Number of sites for performance studies	Number of turbines for performance studies	Performance Metric	Result [%]	Analysis period	Third party for EVALUATION? Yes/No	Power/Energy Consumption
[2] S. Trudel et C. Godreau, [3] P. Antikainen , M. W.Gagnon [4] *	Wicetec	Electro-thermal	Anti-icing	Retrofit	A2	Yes	No		1	5	Energy Loss Reduction	50	2017-2018	Yes	
[5] K. Sachse	Nordex	Electro-thermal	Anti-icing	IPS	A2	Yes	No		1	2	Power Curve			No	
[6] N. Lehming	Nordex	Electro-thermal	Anti-icing	IPS	A2	Yes	No			2	AEP Gain	8	2011	No	<0.3% of AEP
[6] N. Lehming	Nordex	Electro-thermal	Anti-icing	IPS	A2	Yes	No			20	Energy Loss Reduction	70	2013-10 to 2014-03	Yes	
[7] S. Barup	Enercon	Hot air	De-icing	IPS	A2	Yes	No		4	8	AEP Gain	3 to 12		No	46 to 225 kW
[8] R. Cattin	Enercon	Hot air	De-icing	IPS	A2	Yes	No		3	6	Energy Loss Reduction	14 to 27	01-04 2013	Yes	46 to 225 kW
[9] T. Karlsson				IPS	A3	NA3		2 to 4	4	4	Energy Gain	0 to 45	2016-2018	Yes	
[10] M. Yamazaki et al.	NTT-AT	Icephobic coating	Passive	Retrofit	A2	Yes	No		1	3	Energy Gain	7	11-12 2018	Yes	
[11] D. Roeper	Borealis Wind	Hot air	Both	Retrofit	A2	Yes	No		1	2	Energy Gain	62	11-12 2018	No	
[12] S. Kolar			Both		A2	Yes	No		3		Energy Gain	-1 to 12	2014-2015	Yes	
[13] A. Stokl, A. Krenn	Vestas	Hot air	De-icing	IPS	A2	Yes	No	3	2	8	Energy Loss Reduction	47.5	2017-2018	Yes	

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