

Nordex Icing Solutions & Performance Evaluation

Nils Lehming, WinterWind,
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40
1985
2025
YEARS
**NORDEX
GROUP**



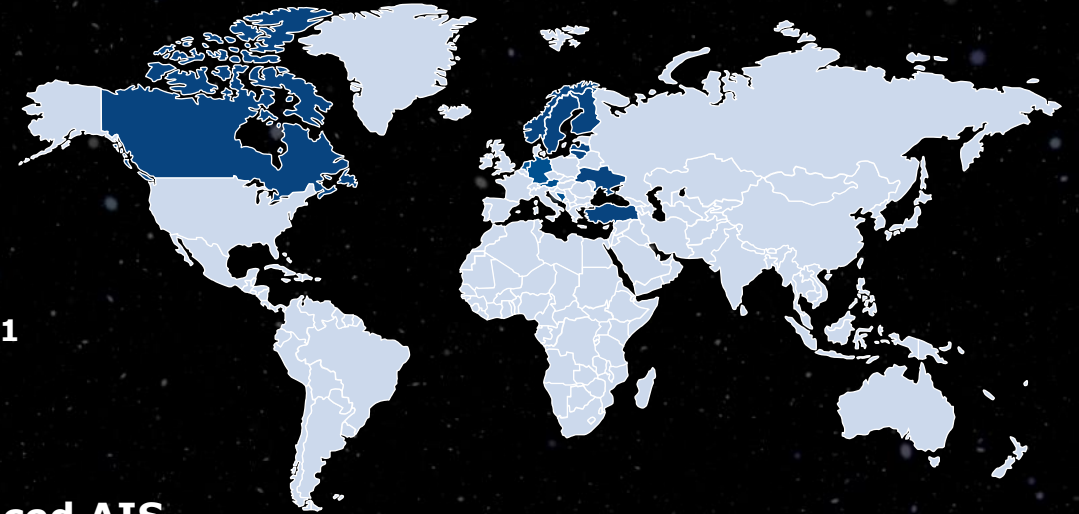
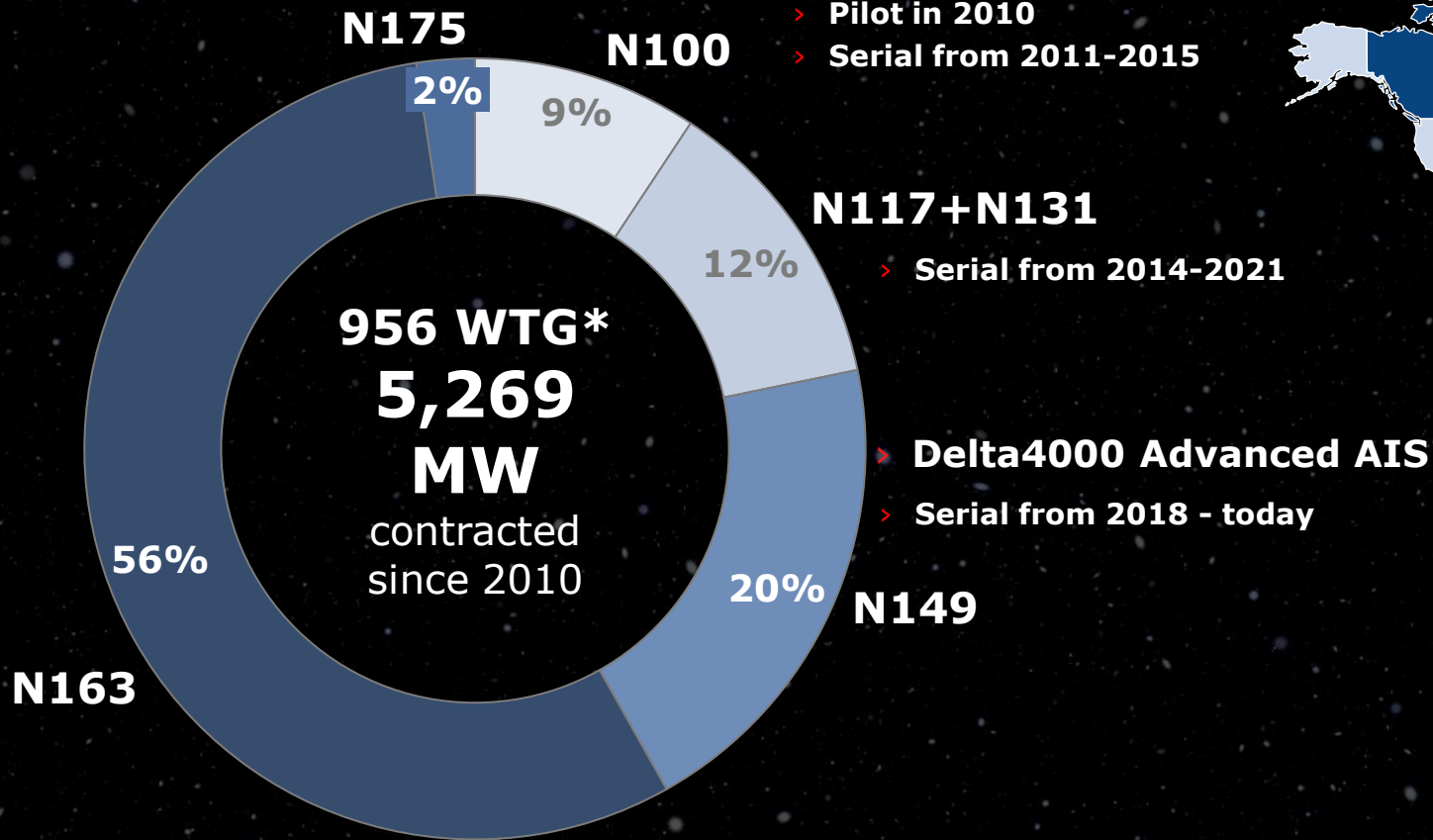
> AGENDA

> **1 AIS Performance Evaluation**

2 AIM Performance Evaluation

3 Wrap Up

➤ **TRACK RECORD - 16 years experience in operating anti-icing systems with different rotor sizes in severe icing conditions**



CANADA	1666 MW
SWEDEN	1614 MW
FINLAND	1043 MW
NORWAY	400 MW
TÜRKIYE	237 MW
LATVIA	112 MW
UKRAINE	61 MW
BOSNIA	48 MW
AUSTRIA	48 MW
LITHUANIA	44 MW
GERMANY	39 MW
NETHERLANDS	6.8 MW

Status Winterwind 2026

CONTINUOUS IMPROVEMENT: based on more than 16 years of operational experience

* Order intake status 12/25

➤ Proven AIS Solution for Enhanced Value Capture – Available for Delta4000 Series

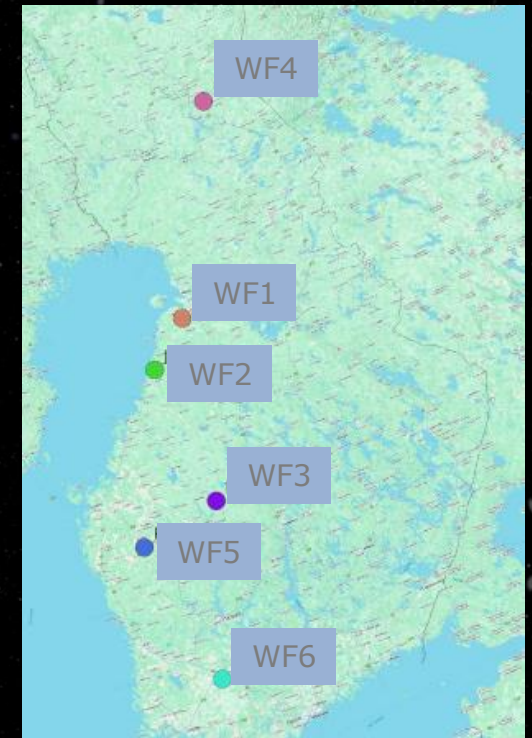
Key Features:

- 16 years of operational experience
- AIS heats rotor blades while turbine is in operation
- Redundant, segmented electrical resistance heating mats
- Increased certainty of production in periods of icing provides benefits in power planning/dispatching
- 2-3 times higher value capture of power price at icing conditions
- AIS performance warranty
- Available for N163/5.X, N163/6.X and N175/6.X



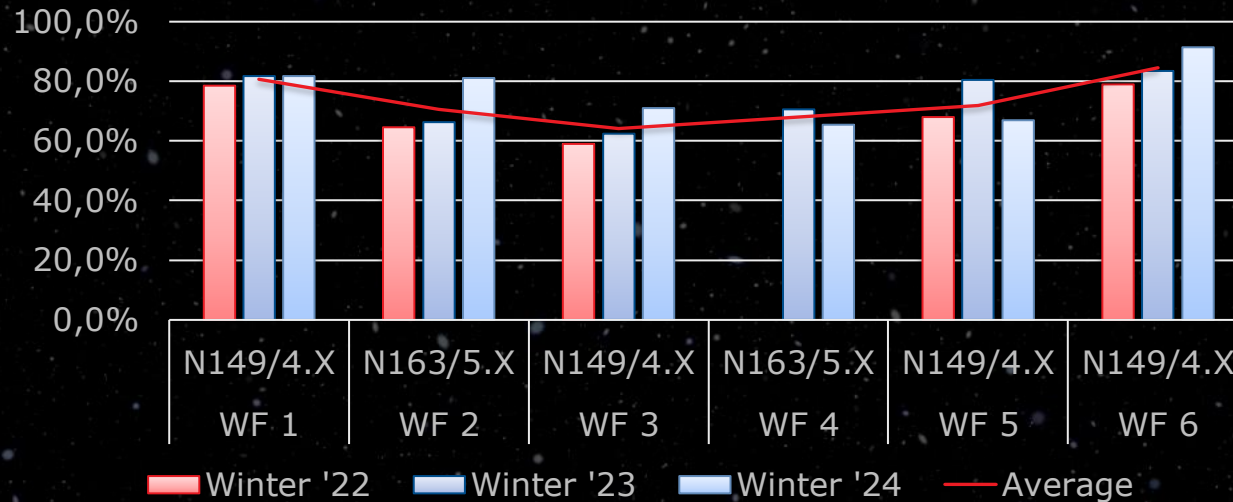
➤ AIS Performance Evaluation in Cooperation with DNV, covering 6 Windfarms with 46 turbines representing data of >100 turbine years

- Nordex has contracted DNV in 2025 to review the performance of Delta4000 turbines equipped with the Advanced Anti-icing System
- Project scope:
 - 6 sites / 46 WTG
 - Rotor sizes 149m and 163m
 - different regions across Finland, 3 winter seasons
- The DNV analysis compares observed icing losses, derived from SCADA data, and the expected icing losses that would have occurred in the absence of the Anti-Icing System (AIS).
- DNV has modelled the ice loss expected without AIS using the state-of-the-art WICE 2.5 ("WICE")

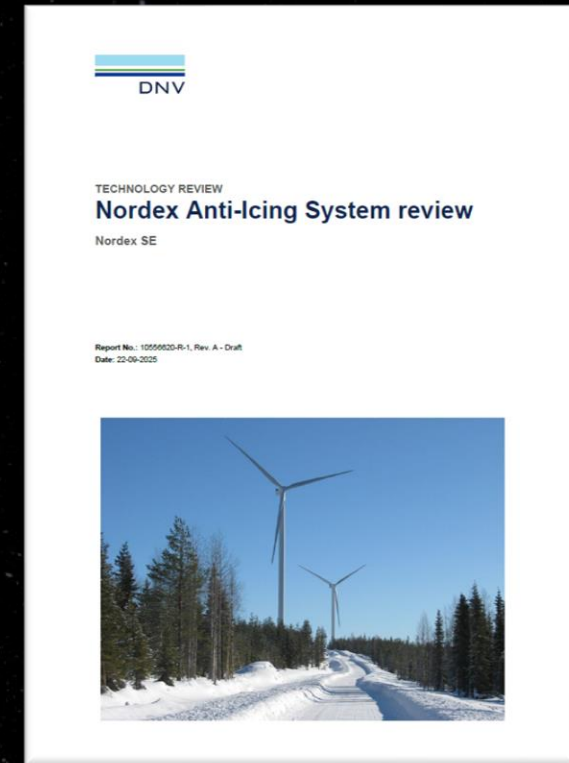


➤ AIS Performance Evaluation in Cooperation with DNV confirms high ice loss recovery of Delta4000 Advanced Anti-icing System

Avoided ice losses in %* (October to March)



*avoided ice related production losses from Oct-March in %



➤ Confirmed ice loss recovery depending on site and winter condition ranging from ~59%-91%

➤ Value Capture of AIS: The Energy market has changed over the years

Icing only happens if:

1. It's wintertime » In the Nordics power prices are higher in the winter than in the summer
2. Wind speed is low » Due to high wind penetration in the grid, prices are higher when wind is low
3. If icing takes place, large parts of the installed fleet (w/o AIS) stop operating.
 - » Even less wind in the system, therefore even higher prices

Icing conditions = high price conditions

Conclusion » During icing events, power prices are usually at least 2-3x higher than average annual power prices



*Ice loss recovery as demonstrated on previous slide

➤ **Increased certainty of production in periods of icing can also lead to cost benefits in power planning/dispatching**

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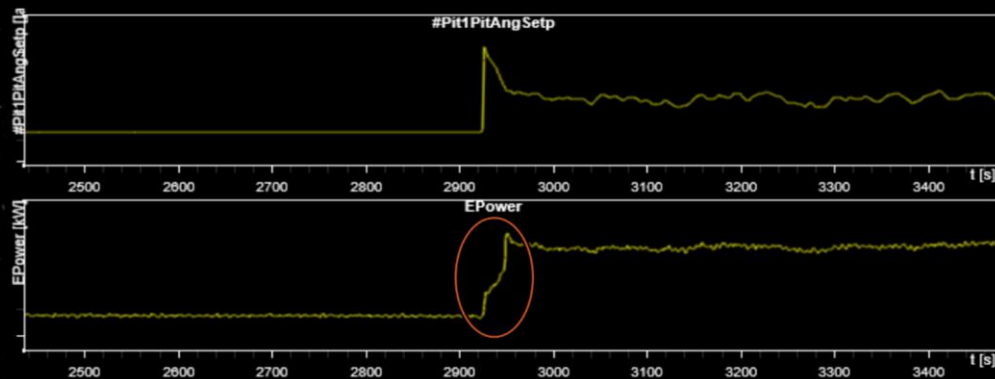
3 Wrap Up

Advanced Ice Mode (AIM) ensures continuous operation of Delta4000 wind turbines for light to moderate icing conditions

AIM IS AN OPTIONAL SOFTWARE FEATURE USING TWO DIFFERENT CONTROL STAGES TO KEEP THE TURBINE OPERATING ALSO UNDER MODERATE ICING CONDITIONS WHEN BLADE STALLING IS DETECTED

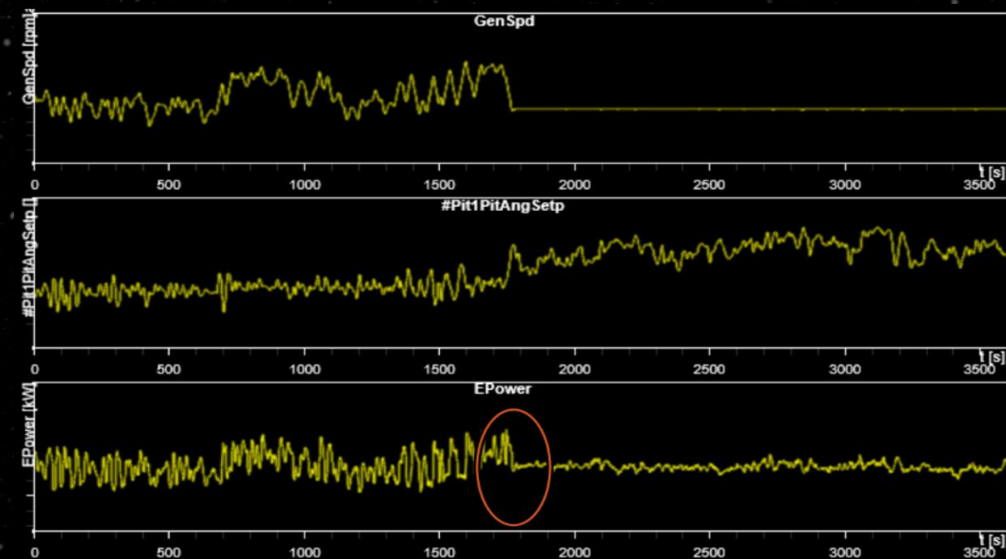
STAGE 1: ADJUSTING THE PITCH OPERATION

- Adjusts the turbine pitch operation to increase power production or reduce shutdowns at moderate icing conditions
- Turbine control will regularly check if icing conditions prevail. When conditions gets worse, WT will automatically switch to stage 2



STAGE 2: ICE OPERATION POWER MODE

- Stage two will apply a specific ice operation power mode with a designated pitch control curve to avoid/reduce shutdowns during prevailing icing conditions



- When conditions have eased, WT will automatically switch back to normal production mode from both stages

➤ AIM Performance Evaluation in cooperation with Kjeller Vindteknik confirms AEP improvement

Validation campaign spanned three winter periods with continuous improvement of the AIM software

- Winter season 22/23: Functional testing, covering N133 & N149 wind turbines
- Winter season 23/24: Further software improvements, AIM validation method was developed, introducing N163/5.X
- Winter season 24/25: Benefit validation was conducted, now including also the N163/6.X

Campaign set-up 24/25

- In sum 11 wind farms participated with a total of 231 turbines under test

Participating turbine types:

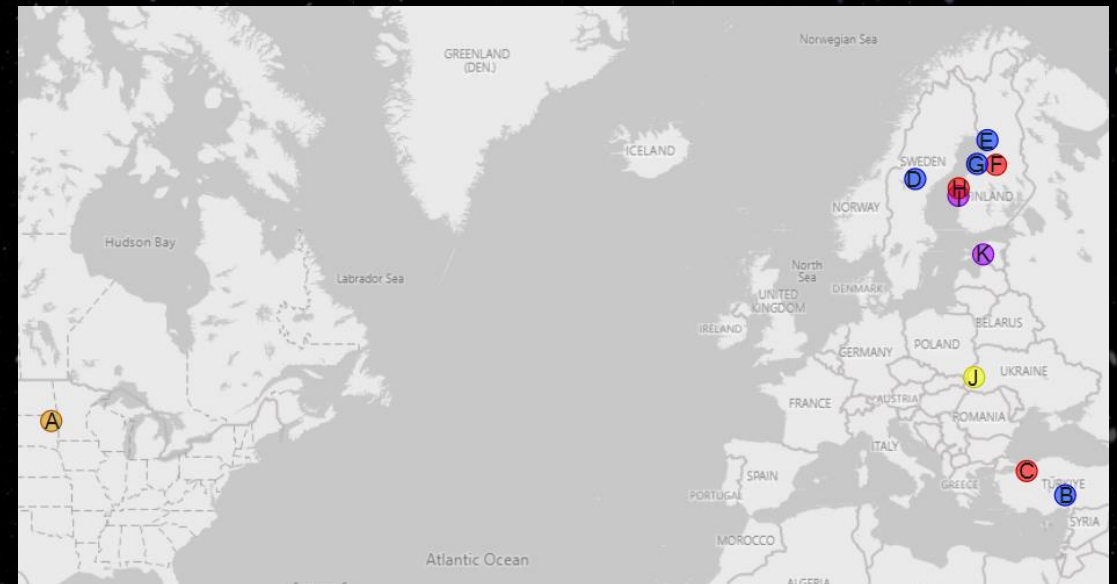
- N149/4.X, N149/5.X, N163/5.X and N163/6.X

Covered regions were:

- Sweden, Finland, Turkey, USA, Ukraine and Estonia

Test turbines were separated in triplets:

1. No AIM (reference)
2. AIM 1 (only stage 1)
3. AIM 2 (stage 1+2) → **final product**



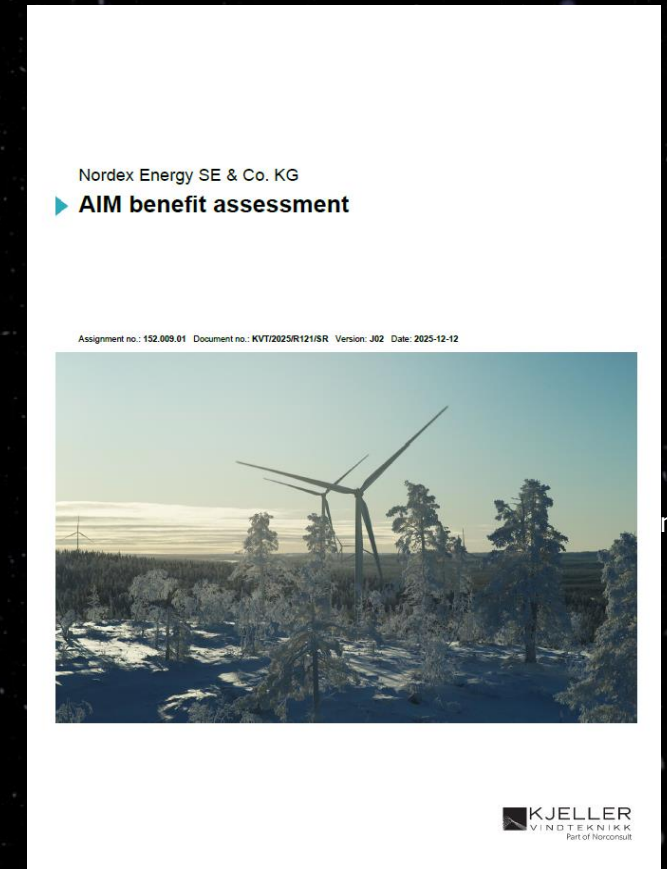
Advanced Ice Mode Validation

Weighted¹ Average benefit of 0.70% AEP gain compared to real AEP²

Park	Region	Height [m]	Turbine type	AIM measurement period	AEP benefit real AEP
A	North of Midwest USA	600	N149 4X (60Hz)	Winter 24-25	x%
B	South Türkiye Mountains (Kayseri)	1,978	N163 5X	Winter 24-25	x%
D	Central Sweden	502	N163 5X	Winter 24-25	x%
E	Finland (Gulf of Bothnia)	55	N163 5X	Winter 24-25	x%
F	Central Finland	140	N149 4X	Winter 24-25	x%
G	West Central Finland (Gulf of Bothnia)	30	N163 5X	Winter 24-25	x%
H	West Central Finland (Gulf of Bothnia) (more south)	30	N149 4X	Winter 24-25	x%
I	West Central Finland (Gulf of Bothnia) (more south)	70	N163 6X	Winter 24-25	x%
J	West Ukraine	760	N149 5X	Winter 24-25	x%
K	Central Estonia	36	N163 6X	Winter 24-25	x%
Weighted average AEP benefit					0.70%

¹ Weighted by number of turbines per project

- > The variation among wind farms demonstrates that site-specific influences and weather conditions have a greater impact than installation height or geographical proximity
- > Results are highly conservative as the measurement period did not cover the full annual icing season. A higher amount of icing events would show an even higher benefit for the turbines with AIM.



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WRAP UP

NORDEX ICING SOLUTIONS SUPPORTS YOUR BUSINESS CASE

Advanced Anti-Icing System (AIS):

- Robust system with proven performance based on 16 years of lessons learned
- Performance for Delta4000 confirmed by DNV
- For medium to heavy icing sites
- Market leading performance warranty

Advanced Ice Mode (AIM):

- New released optional operation mode with validated performance based on field measurements, confirmed by Kjeller Vindteknik
- For light to medium icing conditions





➤ Thank you for
your attention



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