Winterwind
INTERNATIONAL WIND ENERGY CONFERENCE

Book of Abstracts

in session order

Winterwind 2027

Åre, Sweden
February 8 – 10, 2027

Program version 261030 · Abstracts 2026-10-30 (v1)

Winterwind 2027

Conference program · Monday February 8 – Wednesday February 10

Program version 261030 (file 1). Numbers in parentheses after speakers are abstract IDs; numbers after session titles are session IDs.

Monday, February 8 — Welcome to Winterwind 2027!

09:00 — **Registration** 09:00 – 10:00

09:30

Site visit

09:45 Bus departure from hotel

11:15 Welcome to the site!

15:45 Back at the hotel

Electrification seminar (1)

10:00 – 12:00 · Moderators: Lisa Ek and Björn Aronsson

Presentations

Panel discussion

12:00 — **Registration** 12:00 – 13:00 · Lunch on your own

13:00

TBA (2)

13:00 – 14:45 · Chairs: TBA

Storage seminar (3)

13:00 – 14:45 · Moderator: Lisa Ek

Benefits with BESS: a study of optimisation strategies to maximise profitability at wind farms in cold climates
Fredrik Sjödén, Kjeller Vindteknikk, part of Norconsult, SE (19)

Grid-forming battery energy storage: taking responsibility for grid stability as wind and data centers grow in the north
Eric Widéen, Huawei, SE (49)

Panel discussion

IEA Task 54 workshop (4)

13:00 – 14:45 · Moderator: Patrice Roberge

Blade heating performance warranties: What are we actually guaranteeing?
Patrice Roberge, Icetek, CA (15)

14:45 — **Break** 14:45 – 15:00

15:00

Hydrogen seminar (5)

15:00 – 17:00 · Moderator: Björn Aronsson

Presentations

Panel discussion

Grid seminar (6)

15:00 – 17:00 · Moderator: Lisa Ek

Wind power in Sweden: it's about optimising production and value
Lars Skoglund, Ntricity Technologies AB, SE (46)

When the blades ice up, the load steps down: flexible data centers sharing balancing responsibility with wind farms
Lukas Pfeiffer, Gridmetry, DE (42)

From icing signal to bid: forecasting as insurance for cold climate wind
Karl Thunell, rebase.energy, SE (16)

Renewable flexibility for the future, defense, and finances
Kruno Kuljis, Modity Energy Trading, SE (2)

Panel discussion

IEA Task 54 workshop (7)

13:00 – 17:00

18:00

Opening session (8)

18:00 – 19:00 · Moderators: Lisa Ek, Gabriel Niemi-Holén and Per Olofsson

Investigating icing conditions in Norway: Evaluating the Harmonie-Arome model using helicopter campaign data
Eirik Mikal Samuelsen, Norwegian Meteorological Institute, NO (6)

When the blades ice up, the load steps down: flexible data centers sharing balancing responsibility with wind farms
Lukas Pfeiffer, Gridmetry, DE (42)

19:15 — **Student reception** 19:15 – 21:00

Tuesday, February 9

Day 2

08:00 — **Exhibition and registration** 08:00 – 09:00

09:00

Technology, OEM Solutions and Maintenance (9)

09:00 – 10:00 · Chairs: TBA

Validating anti-icing performance on a 6 MW-class turbine with wireless on-blade sensors
Thomas Schlegl, eologix-ping, AT (32)

Global ice detection (GID): Vestas software-based multi-sensor ice detection solution for wind turbines
Johnny Nielsen, Vestas, DK (30)

Ice protection systems: Why installation is only half the job
Paulius Sarapnickis, FabricAir, LT (51)

Forecasting (10)

09:00 – 10:00 · Chairs: TBA

Improving winter wind power forecasting at Hydro-Québec through advanced icing loss modelling
Slavica Antic, Hydro-Québec, CA (11)

Icing-aware power forecasting with on-blade ice sensors: results from two winters
Eike Lueken, eologix-ping, AT (34)

Improving short-term wind turbine power forecasts during icing using on-site operational data
Jonathan Nixon, University of Kent, UK (45)

10:00 — **Break** 10:00 – 11:00

10:15

Poster session 1 (11)

10:15 – 10:45 · Chair: TBA

Physics-informed Bayesian assimilation and forecasting of rotor icing: First results on the IEA Wind Task 54 database
Max Champneys, University of Sheffield, UK (10)

Anti-icing on blades longer than 80 m: second-winter results from heated and unheated turbines
Thomas Schlegl, eologix-ping, AT (33)

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11:00 – 12:30 · Moderators: Lisa Ek and Björn Aronsson

Hydro-Québec's ambitions as a new player in the world of wind energy developers
Monelle Comeau, Hydro-Québec, CA (25)

Cold Climate Claims – How loss experience has shaped the Nordic wind insurance market
Anders Orebrandt, Max Matthiessen, SE (48)

From reactive to predictive asset management – Who takes responsibility when AI enters the control room?
Emma Fjällvide, W3 Energy, SE (12)

12:30 — **Lunch** 12:30 – 14:00

13:25

Poster session 2 (13)

13:25 – 13:55 · Chair: Jens Sperens

How far can SCADA telemetry alone take wind-turbine condition monitoring? A leakage-safe assessment without dedicated CMS sensors
Hith Rahil Nidhan, Delhi Technological University, IN (8)

Leakage-safe multi-resolution forecasting of wind energy production: a comparison of ensemble and deep sequence models
Sanyam Kathed, Manipal University Jaipur, IN (7)

IEA Wind TCP Task 54: IceLossMethod 3.0 and Ice classes review
Charles Godreau, Nergica, CA (28)

Tuesday, February 9

14:00

Wind Farm Performance (14)

14:00 – 15:00 · Chairs: TBA

Where did the energy go? Understanding and quantifying underperformance in modern wind farms in the Nordics
Ben Buxton, Ramboll, UK (5)

Overcoming the performance gap in the Nordic countries
Narges Tabatabaei, DNV Sweden, SE (50)

From modelling to measured results: first EnVentus field validation of Cold Climate Operation (CCO)
Nils Jehring, Vestas, DE (29)

Climate Change, Site Assessment and Long-Term Wind Resource (15)

14:00 – 15:00 · Chairs: TBA

Cold-climate site classification from an ensemble of new reanalysis datasets
Morten Lybech Thøgersen, EMD International, DK (37)

Scaling icing loss classes with global warming levels using DestinE high-resolution scenarios
Gil Lizcano, Climate Scale, ES (3)

Could climate change increase renewable energy production in the Nordics?
Emilie Iversen, Kjeller Vindteknikk, part of Norconsult, NO (36)

15:00

Break 15:00 – 15:45

15:45

IPS Performance warranties (17)

15:45 – 17:00 · Chairs: TBA

From prediction to performance: a common framework for assessing ice protection systems
Dylan Baxter, FabricAir Canada (BorealisWind), CA (40)

Experiences with ice mitigation warranties
Simo Rissanen, Kjeller Vindteknikk, part of Norconsult, FI (13)

The icing trial: Same data, different verdicts
Patrice Roberge, Icetek, CA (26)

Leveraging IPS performance envelope with icing loss uncertainty assessment: lessons for better warranty and project financing terms
David Grenier-Lévesque, Hydro-Québec, CA (9)

Ice detection (18)

15:45 – 17:00 · Chairs: TBA

Direct ice mass detection on wind turbine blades without electrical conducting sensors and wires in the blades of the wind turbine
Jesper Find Nielsen, Polytech, DK (4)

Raising the performance of blade-based ice detection on Nordex turbines – adaptive referencing and field validation
Sonja Hesse, Wölfel Wind Systems GmbH + Co. KG, DE (20)

Difference between ambient and blade temperature impacting the ice detection
Daniel Brenner, Weidmüller Monitoring Systems, DE (21)

Ice throw risk assessment in wind turbines: The role of operational strategies and anti-/de-icing systems
Hamid Sarlak, DTU, DK (23)

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Exhibition break 17:00 – 18:00

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17:15 – 17:45 · Chair: TBA

Comparative thermal modelling of electrical resistance heating and hot-air de-icing systems for wind turbine blades in cold climates
Ali Sarhadi, Technical University of Denmark (DTU), DK (47)

From icing conditions to turbine impact: the two-channel Icing Impact State
Jonathan Nixon, University of Kent, UK (44)

The cost of icing and the gain of forecasts
Sigbjørn Grini, Kjeller Vindteknikk, part of Norconsult, NO (31)

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Leisure time 18:00 – 19:00

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Wednesday, February 10

Day 3

08:00 **Exhibition and registration** 08:00 – 08:30

08:30 **Ice Protection Systems (IPS), OEM Solutions (20)**

08:30 – 09:30 · Moderators: Lisa Ek and Björn Aronsson

From design to field operation: Validation of the NORDEX N175 anti-icing system
Ines Runge, Nordex Energy SE & Co. KG, DE (38)

Advancing anti-icing technology for cold-climate wind turbines: End-to-end validation from concept to field operation
Miguel Angel González-Posada, Siemens Gamesa, ES (39)

Advancing wind turbine performance in cold climates: The Vestas improvement journey
Stephen Jude Buggy, Vestas, UK (43)

09:30 **Break** 09:30 – 10:15

09:40 **Poster session 4 (21)**

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On the transition from glaze to rime ice formation on wind turbines
Sönke Maus, NTNU Trondheim, NO (41)

Structural repair of wind turbine blades using vacuum infusion
Greger Nilsson, Blade Solutions, SE (17)

10:15 **Ice Throw, Safety and Risk Assessment (22)**

10:15 – 11:15 · Chairs: TBA

Managing the ice throw risk – A subtask of IEA Wind Task 54
Claas Rittinghaus, Energiewerkstatt, AT (14)

Improving wind turbine ice-fall risk assessments through site-specific filtering of meteorological data
Kevin Gutbrod, Pavana, DE (1)

Measuring liquid water content where the ice forms: requirements and concept for a wireless sensor on the rotor blade
Michael Moser, eologix-ping, AT (35)

Icing Physics: Wind-Tunnel and Field Experiments, Ice Accretion and Mitigation (23)

10:15 – 11:15 · Chairs: TBA

Effect of surface roughness and adhesion on ice accretion: Preliminary experimental results for airfoil and cylindrical geometries
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Gone with the wind: field observations of the rotor icing ablation mechanism
Charles Godreau, Nergica, CA (27)

Benchmarking ceilometer derived cloud liquid water content against high-end Cloudnet observations
Sara Koller, Meteotest, CH (18)

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12:30 – 14:00 · Moderators: Lisa Ek and Per Olofsson

Could seasonal forecasts provide information about icing losses?
Pia Isolähteenmäki, Kjeller Vindteknikk, part of Norconsult, FI (22)

Renewable flexibility for the future, defense, and finances
Kruno Kuljis, Modity Energy Trading, SE (2)

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Björn Aronsson

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Kruno Kuljis, Modity Energy Trading, SE

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI)
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid, C) Energy storage, hydrogen, sustainable fuels (ammonia, e-fuels, etc), D) Data centers, grid services (BRP and BSP), trading

Benefits with BESS: a study of optimisation strategies to maximise profitability at wind farms in cold climates

Fredrik Sjödén, Kjeller Vindteknikk, part of Norconsult, SE

Emil Sandros (Kjeller Vindteknikk, part of Norconsult, SE), Fredrik Sjödén (Kjeller Vindteknikk, part of Norconsult, SE), Jennie Molinder (Kjeller Vindteknikk, part of Norconsult, SE), Christoffer Hallgren (Kjeller Vindteknikk, part of Norconsult, SE)

For cold-climate wind farms, icing adds a costly layer of production uncertainty and power losses due to icing can vary rapidly, and in the worst case turbines can be completely frozen for days, or even weeks. However, most icing events are more intermittent and production losses due to icing being difficult to predict, causing deviations between planned and actual production which in turn can lead to additional costs in the electricity market. In recent years, extremely volatile electricity prices during icing events, with imbalance prices at times reaching 5000 EUR/MWh, have made these deviations considerably more costly. A battery energy storage system (BESS) could potentially help mitigate economic losses connected to events with underperformance compared to planned production, but also be used to potentially sell electricity at a high price if the battery is fully charged when prices are high during icing.
How to optimize a BESS to maximise wind farm revenue has been widely studied, but rarely in combination with icing conditions. However, as BESS installations in cold climates are increasing and prices are typically high during icing events, there could be a lot to gain with a smart strategy on how to use the battery in the best way.
In this work, we have investigated how a BESS at a cold-climate wind farm can use icing-adjusted production forecasts to schedule its charging and discharging to maximise economic profitability. An optimisation model of a hypothetical BESS connected to a wind farm in SE2 has been built, combining production data from an existing wind farm with power market data from NordPool including day-ahead, intraday, ancillary services and imbalance fees. Forecasts of power production losses due to icing have been calculated using Norconsult/Kjeller Vindteknikk's IceLoss model, building on meteorological data and translating the accumulated icing mass on the turbine blades into expected power production losses. In the optimisation model, different battery sizes and operational strategies have been compared, taking the investment cost for BESS into account.
The study aims to give a better understanding of when, and under which conditions, a BESS can be economically beneficial for wind power producers in cold climates and gives insights into different operational strategies and their effect on economic profitability

Web site: https://www.vindteknikk.com/

Short biography: Fredrik Sjödén and Emil Sandros are in their final semester of the Master's Programme in Energy Systems Engineering at Uppsala University. They are currently writing their Master's thesis in collaboration with Norconsult in Uppsala.

Fredrik likes to spend his free time either mountain biking, skiing or wrestling. As a day to day hobby Emil enjoys climbing but during longer trips his biggest hobby is surfing.

Presentation format: Oral
Themes: 1. Sustainable development (UN: 17 Goals to Transform Our World), 5. Control strategies including forecasting and de-/anti-icing, 7. Innovations presented by suppliers of components and services (incl. data!)
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid, C) Energy storage, hydrogen, sustainable fuels (ammonia, e-fuels, etc), D) Data centers, grid services (BRP and BSP), trading

Grid-forming battery energy storage: taking responsibility for grid stability as wind and data centers grow in the north

Eric Widéen, Huawei, SE

Eric Widéen (Huawei, SE), Haoran Teng (Huawei, SE), Liu Zhen (Huawei, SE)

The Nordic power system is changing quickly. Converter-connected wind and solar now supply a large part of generation, and large new loads such as data centers and electrified industry are applying for connection. In grid-following mode, converters do not provide the inertia, system strength and damping that synchronous generators provide. In weak parts of the grid, where the short-circuit ratio is low, this can limit how much new generation and load can be connected. Who should take responsibility for stability: the TSO, the wind farm owner, the large consumer or the storage operator?

The Nordic TSOs have started to answer. Fingrid already requires grid-forming capability from new large battery storage systems. It has also announced a similar requirement for new large wind and solar plants in the weakest grid areas, and co-located storage can meet it. The draft European network code NC RfG 2.0 also introduces grid-forming requirements.

This presentation argues that grid-forming battery energy storage (BESS) is a practical way for the wind sector to share this responsibility. A grid-forming converter acts as a voltage source behind an impedance, within its current and energy limits. It responds to disturbances inherently and supports voltage in weak grids. Because a BESS has energy available, it can sustain this response over time.

The presentation covers:

1. The stability problem: inertia, system strength and oscillation risk in weak parts of the Nordic grid, and why these differ from thermal capacity limits.
2. Grid-following and grid-forming: control principles, dynamic response and current limits, explained for non-specialists.
3. Cold-climate operation: keeping a BESS available for grid-forming support during long periods of low temperature. This includes thermal management, state-of-charge strategy and auxiliary power supply during grid disturbances.
4. Combined use: how one storage system can provide grid-forming support together with frequency reserves (FFR, FCR-N, FCR-D, aFRR, mFRR) and energy trading, and how much capacity must stay reserved for stability.
5. Requirements and verification: the status of grid-forming requirements in Finland, Sweden, Norway and Denmark. It also covers how simulation models, type testing, certification and site tests should divide responsibility between supplier, owner and system operator.

The aim is to give developers, owners and system operators a clear view of what grid-forming storage can do today, what grid codes still need to define, and how responsibility for stability can be shared.

Web site: https://e.huawei.com/en/industries/grid

Short biography: Eric Widéen is Solutions Manager and Business Developer at Huawei Technologies Sweden AB, in the Nordic Digital Power team. He is responsible for utility battery energy storage and solar PV solutions in Sweden, Norway, Finland and Denmark. He works with developers, utilities and EPCs from early sizing and grid-connection studies through to technical specification and contracting of utility-scale storage.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 3. Validation, field experience including human aspects, 4. Practical operational methods and experiences (incl. financing, construction, O&M, HSE), 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Blade heating performance warranties: What are we actually guaranteeing?

Patrice Roberge, Icetek, CA

Patrice Roberge (Icetek, CA), Philippe Guay (Icetek, CA), Charles Godreau (Nergica, CA), André-Bégin-Drolet (Université Laval, CA)

A wind farm has a difficult winter. Is the production shortfall a weather risk, a heating-system performance issue, or both? And what should the warranty do about it?
An interactive workshop on the practical application of wind turbine blade heating performance warranties will be lead by a Canadian consortium composed of Icetek, Nergica and Université Laval. Using operating examples and simplified cases, participants will compare pass/fail performance thresholds with approaches that quantify compensable energy. We will discuss whether the objective is to demonstrate that the technology works, compensate for underperformance, or achieve both.
A central question will be how meteorological and technological risks should be shared between wind farm owners, turbine manufacturers and heating-system suppliers. How much of the exposure to frequent or severe icing should remain with the owner? What performance should the supplier stand behind, and under which conditions? Participants will examine situations where weather severity, system limitations and technical underperformance are difficult to separate.
The same examples will be used to test different definitions of icing events and calculation periods. By changing when an assessment starts and ends, whether active icing is included, and whether events are evaluated separately or together, we will show how the same operating data can produce different performance results and compensation amounts. Participants will then consider whether those outcomes reflect the risk sharing they intended.
Audience votes, small-group discussions and a short warranty-drafting exercise will structure the session. Drawing on the recent work, the workshop will invite participants to challenge proposed approaches and develop provisions they would accept from either side of the agreement. We will finish by identifying areas of agreement, unresolved questions and the measurements needed to put these warranties into practice.

Web site: www.icetek.ca

Short biography: Patrice completed his Ph.D. in mechanical engineering at Université Laval under the direction of André Bégin-Drolet. He has been working on the operation of wind turbines in cold climates for over 10 years where he had the chance to contribute to the development of an ice detection device. He has authored and co-authored over 15 scientific publications. He now works at Icetek as the Lead Data Scientist where he helps operators understand precisely why their assets are struggling in icing conditions and provides solutions to improve their performance. He is a very inquisitive person that loves to learn and understand the why and the how of the everyday phenomena. He is passionate about football, skiing, snowshoeing and trekking.

Presentation format: Oral
Themes: 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid, C) Energy storage, hydrogen, sustainable fuels (ammonia, e-fuels, etc), D) Data centers, grid services (BRP and BSP), trading, G) Snow, snow removal, avalanches, controlling snow drift, etc.

Wind power in Sweden: it's about optimising production and value

Lars Skoglund, Ntricity Technologies AB, SE

Lars Skoglund (Founder & CEO, SE), Carl Heyman (CTO, SE)

In Sweden, the challenge of wind power is not just capturing the wind. It's making the most of it – even in challenging Nordic winter conditions.

For years, the business model has been straightforward: build a wind farm, maximise production, and sell the electricity on the spot market or through a PPA.

But ice on turbine blades, freezing temperatures and difficult winter conditions can affect production, accessibility and maintenance. Lost production means lost revenue.

At the same time, volatile electricity prices, negative prices and imbalance costs make it increasingly important to understand not just how much we produce, but when and how we sell it.

So how do we maximise the value of wind power throughout the year?

That means combining:

Smarter operations and maintenance to minimise winter losses and maximise availability.

Forecasting and intelligent control to anticipate weather conditions and optimise production.

Market and trading optimisation to manage price fluctuations, imbalance costs and changing market opportunities.

Successful wind power in Sweden is about more than harnessing the wind. It's about operating efficiently, trading intelligently and making every MWh count.

So, how do we make wind power more reliable, productive and profitable in a Nordic climate?

Web site: https://ntricity.com

Short biography: Ntricity Technologies AB develops a software platform for the optimization, trading, and management of flexible energy resources based on real-time data and market signals. The company specializes in maximizing the value of large-scale flexible resources that can contribute to balance and stability in the power grid. Examples of such resources arebattery energy storage systems (BESS), wind farms, and solar power plants with the possibility of flexible production and/or consumption.
Through its proprietary platform, Ntricity continuously connects and optimizes these resources in accordance with current market conditions. The platform enables automatic and data-driven trading and management in electricity markets, including day-ahead, intraday, and ancillary services markets. For Ntricity to deliver its services, the relevant resources must be correctly connected, approved, and qualified for trading. This includes, among other things, access to relevant electricity markets as well as meeting the requirements for participation in markets for support services.

Ntricity was founded in 2019 by Lars Skoglund and has since developed from a startup into a growing scale-up company.

Since May 2025 Ntricity is part of the family-owned group Claesson & Anderzén AB, which operates in several industries and has equity amounting to approximately SEK 6 billion.

Presentation format: Oral
Themes: 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid, C) Energy storage, hydrogen, sustainable fuels (ammonia, e-fuels, etc), D) Data centers, grid services (BRP and BSP), trading, G) Snow, snow removal, avalanches, controlling snow drift, etc.

Ntricity is a growing company with a multidisciplinary team of experts in key areas such as optimization and trading, software development, automation technology, and project management. With a strong foundation, a growing customer base, and continuous investment in expertise, the company is well positioned for sustained growth and long-term value creation.

The company's operations include balance responsibility (BRP and BSP) through its subsidiary, Ntricity Market Services AB.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 3. Validation, field experience including human aspects, 5. Control strategies including forecasting and de-/anti-icing, 7. Innovations presented by suppliers of components and services (incl. data!)
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid, D) Data centers, grid services (BRP and BSP), trading

When the blades ice up, the load steps down: flexible data centers sharing balancing responsibility with wind farms

Lukas Pfeiffer, Gridmetry, DE

Lukas Pfeiffer DE, Niklas Zuther DE

Winter is when wind power in northern Sweden is most valuable and least predictable. Blade icing causes sudden, poorly forecast production losses in exactly the season when demand and prices peak. Under the Nordic single-price imbalance settlement, the resulting deviations are paid for by the wind farm's balance responsible party (BRP), while the flexibility meant to absorb them faces cold-climate limits of its own. With congestion toward the south and falling capture prices already eroding the business case for new wind in SE1 and SE2, the question of who carries balancing responsibility is central to securing the future of wind in cold climates.
We address this question with field data from over 60 MW of flexible data centers in SE1 and SE2, prequalified for FCR-N, FCR-D, aFRR and mFRR.
Four properties make data centers relevant for balancing wind in winter: they respond within seconds in both directions by throttling or pausing computation; their thousands of individually controllable units allow near-continuous modulation and keep the fleet available when single units fail; unlike batteries, they are not energy-limited and can hold a reduced load through a multi-hour icing event; and they consume whenever power is cheaper than the value of their computation, which makes them natural buyers in surplus and negative-price hours. Our earlier co-optimization model for SE2 (2023 to 2025) indicated that data centers able to vary their load by 30 to 50 % within 10 s largely removed the wind farm's exposure to negative prices. We now extend this work to winter operation and test it against measured data:
1 Control: we evaluate a layered strategy that allocates the load's flexibility across time scales: frequency reserves within seconds, wind-following within each 15-minute settlement period to offset icing-induced deficits, and day-ahead and intraday load shifting to absorb curtailment and negative-price hours.
2 Cold-climate comparison: we compare how low temperatures constrain batteries (derating and auxiliary heating), hydropower (ice-related limits on hydropeaking) and compute containers, which gain from free cooling but must stay above minimum temperatures when curtailed. We then assess whether their relative value in winter differs from the full-year picture.
3 Validation: measured response data from prequalification tests and operation are used to check the model's assumptions on ramp rates, availability and service-level limits.
Beyond technology, we discuss responsibility: how imbalance exposure, metering and revenues can be shared among wind farm owner, flexible consumer, BRP and balancing service provider (BSP); what TSOs and grid owners need, such as measurement requirements, prequalification routes for new resource types and flexible connection agreements, to treat large new loads as balancing resources rather than as a burden on the grid; and how co-location keeps renewable energy use and value local (UN SDGs 7 and 9). We also share practical lessons from prequalifying and remotely operating compute loads through Arctic winters.
In cold climates, balancing responsibility for wind cannot rest on wind farms alone. Co-located flexible demand can share it, measurably and at scale.

Web site: www.gridmetry.com

Short biography: With more than nine years of experience in the data center and digital asset industry, Lukas Pfeiffer works at the intersection of energy systems, technology, and infrastructure innovation. He is the Founder of Gridmetry, a company pioneering the integration of data centers into the electricity grid as flexible, grid-supporting assets. By transforming data centers from passive consumers into active participants in the energy market, Gridmetry enables the monetization of renewable overcapacity,

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Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid, D) Data centers, grid services (BRP and BSP), trading

provides real-time curtailment capabilities, and delivers ultra-fast frequency response where the grid needs it most.

Presentation format: Oral
Themes: 5. Control strategies including forecasting and de-/anti-icing, 6. Independent comparisons of methods and products, 7. Innovations presented by suppliers of components and services (incl. data!)
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid, D) Data centers, grid services (BRP and BSP), trading

From icing signal to bid: forecasting as insurance for cold climate wind

Karl Thunell, rebase.energy, SE

Karl Thunell (rebase.energy, SE)

No one can tell in October how cold and harsh the coming winter will be. Nor can anyone fully predict how price volatility and production volatility will develop over the season. For wind power producers and their balance responsible parties (BRPs), that uncertainty has a direct price: ice on turbine blades can account for up to 25% of a wind farm's total imbalance volume, and every missed icing event ends up as an imbalance cost.
We hear from the market that trading strategies have had default to curtailing wind parks during uncertain periods to cap the imbalance downside. That protects the individual trader, but leaves renewable production unused and weakens the case for wind in cold climates. We believe the more responsible path is to keep turbines operating and producing as much as possible, while the traders behind them stay profitable. A resilient, sophisticated and functioning power system needs both.

This presentation is about what happens between the weather model and the market: how an icing forecast becomes a trading decision and, in the end, a bid.
rebase.energy provides an icing risk signal for wind parks: the probability and expected size of icing production losses over the day-ahead and intraday horizon. The signal is based on two models running in parallel, one ice-aware and one ice-blind, fed with weather data from multiple meteorological institutes and predictors such as vertical temperature profiles. The difference between them is a real-time estimate of the loss due to icing. Delivered via API or our modern user interface, the signal amplifies our customers' own data and trading teams, so they can mitigate the risk of high imbalances instead of switching production off.
We see the icing signal as insurance, where preparation is key. During a mild winter, few events occur and the signal mostly confirms business as usual. In a harsh winter with many icing events, it is what separates a controlled position from a season of large imbalance costs or unnecessary curtailment.

We will walk through the full chain in a live demo:

- Signal: how the icing risk signal is produced, verified against observed events and communicated with its uncertainty
- Strategy: how BRPs use the signal in practice, for example adjusting day-ahead volumes, hedging in intraday or applying risk-based discounts during high-probability periods, as an alternative to blanket curtailment
- Bid: how this ends up in the nomination and what it does to imbalance volume, cost and produced energy

We will also discuss where responsibility sits in each step: the forecast provider for a trustworthy and transparent signal, the asset owner for access to SCADA, ice detection and availability data, and the BRP for how much risk to take on. The system has been in operational use with multiple traders across the Nordics and Baltics, and we will share results and field experience from the 2025/2026 season.
The aim is practical: to show how cold climate wind can keep producing and be balanced responsibly, even when the winter and the market cannot be predicted.

Web site: https://www.rebase.energy/

Short biography: Kalle has worked in the energy industry for almost 10 years, first in the EV industry and for the last five years as Chief Commercial Officer at rebase.energy. He enjoys tech development, talking to

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people at events and discussing the industry's challenges with peers. In his free time he does hybrid training, running and lifting weights.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 4. Practical operational methods and experiences (incl. financing, construction, O&M, HSE), 5. Control strategies including forecasting and de-/anti-icing, 7. Innovations presented by suppliers of components and services (incl. data!)
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid, C) Energy storage, hydrogen, sustainable fuels (ammonia, e-fuels, etc), D) Data centers, grid services (BRP and BSP), trading, H) Other

Renewable flexibility for the future, defense, and finances

Kruno Kuljis, Modity Energy Trading, SE

Modity LTP 2026: Susanne Kolmert, Henrik Almström, Ulrik Ljungars, Johan Wigren, Eddie Bowen
Analys MARI/PICASSO: Noah Åkesson, Martin Sällberg, Stefan Ragnarsson, Elias Liljenberg, Per Svenonius, SE

Abstract – English
The Nordic power system is entering a new phase, where electrification, weather-dependent generation and growing capacity needs are turning flexibility into a strategic system resource. Hybrid parks, storage and demand flexibility will therefore play an increasingly important role in the responsibility to create operational security, market value and resilience qualities that are important especially in a cold climate, but also supporting a climate-positive development.
Drawing on TSO information about upcoming market changes, including MARI and PICASSO, and Modity's long-term outlook for 2026–2050, we analyse how the role of balancing markets is evolving in both the near and longer term. As electricity demand grows, investments in new generation remain uncertain and grid capacity continues to constrain the energy system, European market integration can help increase liquidity, reduce scarcity situations and limit extreme price outcomes. However, volatility will not disappear. These integrations also raise the bar for market participants, requiring flexibility to be optimised across multiple markets, time resolutions and geographies.
In a more volatile and exposed energy system, market insight, robust value chains, business ecosystem partnerships and the integration of total defence capabilities become essential to both resilience and business value. Modity shows how market participants can create value in the shift from individual optimisation towards a responsible, integrated flexibility system, and why multi-market-optimisation with increasing AI will become a key capability in tomorrow's integrated energy market.

Web site: https://www.modity.se/sv

Short biography: Presentation av Kruno Kuljis
Kruno Kuljis har ett förflutet i Flygvapnet men har nu jobbat lika länge i Energibranschen som tidigare i Försvarsmakten nämligen 19 år vardera. Lämnade Flygvapnet 2006 och har sedan dess arbetat som energihandlare, analytiker och chef för energihandel på svenska, tyska och schweiziska bolag.
Numera är Kruno, Analyschef på Modity Energy Trading i Lund, där han också bor. Även på fritiden blir det mycket flexibla och väderberoende energiska aktiviteter där han optimerar sina resurser, med bl a tennis, cykling, segling och inte minst skidåkning. Detta för oss in på dagens ämne nämligen vindkraft, flexibilitet, väder och optimering av sina resurser. Kruno ska berätta om ”Förnybar flexibilitet för framtid, försvar och finanser”

Presentation of Kruno Kuljis
Kruno Kuljis has a background in the Swedish Air Force, but has now worked just as long in the energy sector as he previously did in the Armed Forces: 19 years in each. He left the Air Force in 2006 and has since worked as an energy trader, analyst and Head of Energy Trading at Swedish, German and Swiss companies.
Today, Kruno is Head of Analysis at Modity Energy Trading in Lund, where he also lives. Even in his spare time, many of his activities are flexible, weather-dependent and full of energy, as he optimises his own

Presentation format: Oral
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Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid, C) Energy storage, hydrogen, sustainable fuels (ammonia, e-fuels, etc), D) Data centers, grid services (BRP and BSP), trading, H) Other

resources throughout tennis, cycling, sailing and, not least, skiing. This brings us to today's topic: wind power, flexibility, weather and resource optimisation. Kruno will talk about "Fossil-Free Flexibility for the Future, Fortifying Defence and Finances"

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI)
Technologies: F) Drone, helicopters and fixed wing aeroplanes

Investigating icing conditions in Norway: Evaluating the Harmonie-Arome model using helicopter campaign data

Eirik Mikal Samuelsen, Norwegian Meteorological Institute, NO

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3 Norwegian Air Ambulance Foundation, NO

Between February and April from 2023 to 2026, helicopter flight campaigns took place across northern and central Norway to investigate icing conditions. Helicopters, including the Airbus H145 and H175, were equipped with cloud microphysics probes (e.g., Cloud Droplet Probe and Cloud Imaging Probe) and temperature sensors. Measurements of liquid water content, droplet sizes, and temperature were analyzed to characterize typical icing conditions in these regions. The campaigns captured diverse weather scenarios, including orographic, marine stratocumulus, frontal, and convective conditions, ensuring a comprehensive dataset. Observations were compared with output from the Harmonie-Arome model, which uses a grid spacing of 2.5 km and 65 vertical layers. The Harmonie-Arome model is widely used for high-resolution forecasting, making it an important tool for evaluating icing risks in complex terrain.

The Norwegian Air Ambulance relies on output from the Harmonie-Arome model to forecast icing severity and temperature for its operations. However, the limited availability of observational data has made it challenging to validate predictions of liquid water content and, by extension, icing severity in sub-freezing conditions. Since pilots rely on direct model output for planning operations, understanding the quality of icing and temperature forecasts is crucial. Icing conditions pose significant risks to aviation, especially in regions like Norway, where challenging weather and mountainous terrain increase operational complexity.

The results show that the model provides reasonable estimates of overall icing conditions and temperature but struggles to predict the precise location and magnitude of liquid water content. Forecast accuracy is higher for orographic conditions compared to convective scenarios. While the use of higher-resolution models, such as those with grid spacings down to 300 m, could improve liquid water content forecasts, the high computational cost limits their application in operational forecasting. Further research is needed to systematically evaluate high-resolution models at hectometric scales, as current evaluations are often limited to individual case studies.

Web site: https://www.met.no/en

Short biography: Eirik Mikal Samuelsen, PhD, works as an operational weather forecaster and as a Scientific researcher at MET Norway, Tromsø, and he also holds a 20% position as an Associated Professor at UiT - The Arctic University of Norway. He has 20 years' experience as an operational weather forecaster for aviation, and has been working as a scientific researcher following his PhD in sea-spray icing modelling since 2017. Additionally, Eirik also has expertise in numerical weather prediction, atmospheric turbulence, and atmospheric icing. Since 2022 Eirik has been working with the Norwegian Air Ambulance Foundation on a research project on atmospheric icing on helicopters, and is currently supervising a PhD Candidate on this topic. From 2023-2026 he has been participating in several flight campaigns together with Airbus helicopters and the NAAF, contributing to forecasting weather conditions

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI)
Technologies: F) Drone, helicopters and fixed wing aeroplanes

prone to icing, and helping collecting data of the water amount and droplet sizes during such conditions in Norway.

Presentation format: Oral
Themes: 1. Sustainable development (UN: 17 Goals to Transform Our World), 3. Validation, field experience including human aspects, 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Validating anti-icing performance on a 6 MW-class turbine with wireless on-blade sensors

Thomas Schlegl, eologix-ping, AT

Thomas Schlegl (eologix-ping, AT), Michael Moser (eologix-ping, AT)

Anti-icing systems are bought to keep turbines producing through icing events. Whether they do is usually judged indirectly, from production losses in SCADA data and from icing forecasts. Neither shows what actually happens on the blade surface. If the turbine loses production, it often remains unclear whether the heating did not keep the blade free, started too late, or met conditions it was never designed for. OEM, operator and sensor supplier each carry part of the responsibility for ice protection, but they judge its performance without a shared set of measured data.
In a joint study with the turbine manufacturer, eologix-ping validates the performance of a commercial anti-icing system with direct measurements on the blade. Wireless eologix-ping blade sensors are retrofitted on a 6 MW-class turbine in a wind farm in Finland. The sensors are less than 2 mm thick, run on their own photovoltaic cells and energy buffer, and need no cabling inside the blade. Each sensor reports surface temperature (±0.25 °C) and ice accumulation in 5 levels, from a free surface to more than about 15 mm of ice. Sensors sit at at least four radial positions per blade, inside and outside the heated zones.
For each icing event of winter 2026/27, we evaluate when ice first forms at each position, when the heating responds, how surface temperature develops under heating, whether the heated zones stay free of ice during operation, and how long it takes until the surface is free again. We also plan to include the wind farm operator's perspective on how such data can support operating decisions and warranty discussions.
At Winterwind we will present the results of the first icing events: where along the blade the anti-icing system keeps the surface free, where and under which conditions ice remains, and how well loss estimates match what the sensors measured on the blade. Taking responsibility for ice protection performance requires measuring it where it matters, on the blade surface.

Web site: www.eologix-ping.com

Short biography: Thomas Schlegl is co-founder and CEO of eologix-ping. After his PhD in sensor technology in Graz and at Stanford, he co-founded eologix sensor technology in 2014 to detect ice on rotor blades with wireless on-blade sensors, now in use on hundreds of turbines across Europe. In 2023, he led the merger with Australia's Ping Services, which added acoustic monitoring of blade damage to ice and lightning detection. Outside of work, he is usually out on long walks with his beagle Quincy.

Presentation format: Oral
Themes: 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Global ice detection (GID): Vestas software-based multi-sensor ice detection solution for wind turbines

Johnny Nielsen, Vestas, DK

Sara Siniscalchi Minna (Vestas, IT), Marcelo Medeiros Guimaraes (Vestas, BR)

Global Ice Detection (GID): Vestas Software-Based Multi-Sensor Ice Detection Solution for Wind Turbines
Ice accretion on wind turbine blades can significantly reduce energy production, increase structural loads, and create operational and safety risks in cold climate installations. Traditional ice detection solutions often rely on dedicated hardware sensors, increasing system complexity, installation effort, and lifecycle cost. To address these challenges, Vestas has developed Global Ice Detection (GID), a software-based ice detection system that leverages existing turbine measurements and control signals to detect blade icing without requiring additional hardware.
GID combines multiple independent detection methods through a multi-sensor fusion approach, enabling robust performance across a broad range of operating conditions. The system continuously evaluates aerodynamic and structural indicators, including deviations from expected power performance, differences between estimated and measured wind speed, blade load behavior, pitch system response, rotor dynamics, nacelle wind measurements, and environmental conditions. By correlating information from these sources, GID can identify both aerodynamic efficiency losses caused by ice accretion and mass-related imbalances resulting from increased blade weight.
The solution operates during production, idling, and standstill conditions and is fully integrated within the turbine control architecture. When icing is detected, GID can automatically initiate Cold Climate Operational modes, activate the Vestas Anti-Icing System, issue turbine alarms to operators, and, where required by site-specific operational strategies, safely stop the turbine to mitigate safety risks associated with icing events. In addition, the system can adapt turbine control strategies to reduce energy losses and support reliable operation under icing conditions.
This paper presents the GID concept, detection methodology, and operational experience from deployment across the Vestas fleet. Field results demonstrate the capability to detect rotor efficiency losses exceeding 10% within approximately 20 minutes and identify blade ice masses corresponding to approximately 3% of blade weight within minutes. The study highlights how software-based multi-sensor ice detection provides a scalable and cost-effective alternative to hardware-based solutions, enabling rapid fleet-wide deployment through software activation while supporting improved turbine availability, production performance, and cold-climate operation.

Web site: https://www.vestas.com/en/energy-solutions/plant-energy-solutions

Short biography: I hold an M.Sc. in Electrical Engineering with specialization in Control Engineering and have worked at Vestas for nearly 20 years. Throughout my career, I have focused on sensors, signal processing, and information fusion for wind turbine control systems, including wind sensing, blade load sensing, tower and nacelle motion sensing, blade pitch sensing, and rotor speed and azimuth angle sensing.
In recent years, I have been involved in the development of advanced ice detection solutions that combine information from multiple sensing systems to improve detection performance and operational decision-making. My experience also includes fault detection, fault-tolerant control, model-based and data-driven design and condition monitoring systems (CMS).
Over the years, I have led technology roadmaps, innovation initiatives, and development projects within sensing and control software, helping bring new technologies from concept to implementation.
I am named inventor or co-inventor on multiple patented innovations related to wind turbine sensing, control, condition monitoring, and ice detection.
Outside of work, I enjoy road cycling and reading, both of which provide opportunities to challenge myself, explore new ideas, and recharge.

Presentation format: Oral
Themes: 3. Validation, field experience including human aspects, 4. Practical operational methods and experiences (incl. financing, construction, O&M, HSE), 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Ice protection systems: Why installation is only half the job

Paulius Sarapnickis, FabricAir, LT

Paulius Šarapnickis, LT

Ice Protection Systems: Why Installation Is Only Half the Job

As wind energy continues to expand into cold-climate regions, ice protection systems are becoming increasingly important for maintaining turbine availability and minimizing energy production losses. However, successful installation alone does not guarantee reliable performance throughout the system's operational lifetime.

This presentation explores the practical challenges of retrofitting ice protection systems and highlights the importance of preventive maintenance, serviceability, and operational readiness in ensuring long-term performance.

Drawing on field experience from ice protection system installations and maintenance activities across Europe and North America, the presentation will address three critical aspects of system reliability.

First, **installation and commissioning quality**, including technical challenges associated with different turbine platforms and the importance of considering future maintenance requirements during system design and installation.

Second, **preventive maintenance and winter readiness**, demonstrating why regular inspections, functional testing, and early fault detection are essential to minimizing unexpected failures during icing conditions.

Third, **serviceability during winter operations**, examining how component accessibility, system design, remote diagnostics, and spare parts availability influence repair times and operational downtime under challenging weather conditions.

The presentation will also briefly discuss how anti-icing and de-icing operating strategies influence system performance and maintenance requirements.

The key message is that responsibility for ice protection system performance extends far beyond installation. Reliable winter operation requires a lifecycle approach that integrates installation quality, preventive maintenance, effective monitoring, and practical repairability.

Ultimately, the true value of an ice protection system is determined not only by its ability to prevent or remove ice, but also by its readiness and reliability when icing conditions occur.

Web site: www.fabricair.com

Short biography: Paulius Šarapnickis is the Director of Global Installation & Maintenance at FabricAir / BorealisWind, where he leads international installation, commissioning, and maintenance operations for wind turbine ice protection systems.

With over 10 years of experience in the industry, Paulius has extensive practical knowledge of retrofitting ice protection systems across different wind turbine platforms, managing complex international projects, and ensuring reliable system performance in challenging cold-climate environments.

Presentation format: Oral
Themes: 3. Validation, field experience including human aspects, 4. Practical operational methods and experiences (incl. financing, construction, O&M, HSE), 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

His responsibilities cover the entire operational lifecycle, from installation planning and commissioning to preventive maintenance, troubleshooting, and long-term service strategies. Working with projects across Europe and North America, he has gained valuable insights into the technical and operational challenges of keeping ice protection systems reliable throughout the winter season.

Paulius is particularly interested in improving system serviceability, simplifying maintenance procedures, and developing practical solutions that reduce downtime and improve operational efficiency.

Outside of work, he enjoys spending time outdoors, particularly hunting and exploring nature.

Presentation format: Oral
Themes: 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Improving winter wind power forecasting at Hydro-Québec through advanced icing loss modelling

Slavica Antic, Hydro-Québec, CA

Slavica Antic (Hydro-Québec, CA), Ana Poenariu (Hydro-Québec, CA), Guillem Candille (Hydro-Québec, CA)

Improving Winter Wind Power Forecasting at Hydro-Québec Through Advanced Icing Loss Modeling

Atmospheric icing is a major source of uncertainty for wind power production in northern climates. Ice accretion on wind turbine blades degrades aerodynamic performance, changes turbine operating characteristics, and can lead to significant reductions in energy production. As wind energy continues to expand within Hydro-Québec's renewable portfolio, accurately forecasting icing-related power losses has become increasingly important for reliable system operations and energy management.
This study evaluates two advanced approaches for forecasting icing-induced wind power losses. The first is based on a 1.5-billion-parameter Weather Foundation Model (WFT) developed by Silurian AI and fine-tuned using Hydro-Québec meteorological and operational observations [1]. The second is a physics-based framework that combines forecasts from Environment and Climate Change Canada's High Resolution Deterministic Prediction System (HRDPS) with the Makkonen ice accretion [2-4]. Both approaches were integrated into a common evaluation framework and assessed for their ability to predict, up to 72 hours in advance, icing events and associated production losses across 39 wind farms in Québec. Results demonstrate that integrating icing-loss predictions can significantly improve winter wind power forecasts, particularly for wind farms experiencing moderate to severe icing conditions. The study further shows that forecast quality depends not only on the accurate detection of icing events but also on minimizing false-positive icing forecasts, which can lead to unnecessary reductions in predicted power generation. The comparative evaluation highlights the strengths and limitations of both machine learning and physics-based approaches, providing valuable insights into their operational applicability. These findings highlight the importance of reliable icing loss forecasting for reducing forecast uncertainty in cold-climate regions.
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[3] L. Makkonen, « Models for the growth of rime, glaze, icicles and wet snow on structures », Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, vol. 358, p. 2913-2939, 2000
[4] J. Yang, W. Yu, J. Choisnard, A. Forcione, S. Antic, Coupled Atmospheric–Ice Load Model for Evaluation of Wind Plant Power Loss, », Journal of Applied Meteorology and Climatplogy, vol. 54, No. 6, p1142-1161, 2015

Web site: https://www.hydroquebec.com

Short biography: Slavica Antic
Lead, Wind Energy forecasting Advisor
I have contributed to over 4 000 megawatts of wind energy projects, focusing on meteorological data analysis from wind turbines and measurement towers. I hold a B.Sc. in Physics and an M.Sc. in Atmospheric Sciences, with research in mesoscale and microscale wind modelling and small-scale meteorological phenomena. My expertise includes wind production forecasting and modelling wind farm losses due to extreme weather. At Hydro-Québec, I work with multidisciplinary teams to enhance wind production forecasts, considering local conditions and meteorological variabilis.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 5. Control strategies including forecasting and de-/anti-icing, 7. Innovations presented by suppliers of components and services (incl. data!)
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid, D) Data centers, grid services (BRP and BSP), trading

Icing-aware power forecasting with on-blade ice sensors: results from two winters

Eike Lueken, eologix-ping, AT

Eike Lueken (eologix-ping, AT), Thomas Schlegl (eologix-ping, AT), Michael Moser (eologix-ping, AT), Fabio Nicolò (Renewcast, IT), Malo Sellier (Renewcast, IT)

Wind farms that sell power day-ahead pay imbalance costs when ice on the blades cuts output below the sold volume. Standard power forecasts use numerical weather prediction (NWP) and have no information on how blade ice changes production.
eologix-ping and Renewcast combined on-blade ice measurements with an AI-based power forecast. Wireless blade sensors measure ice accumulation in 5 levels and surface temperature directly on the blade. The sensor data has two uses. First, it calibrates an icing probability derived from high-resolution NWP models, which gives an hourly forecast up to 2 days ahead at wind farm level. Second, it shows how much power the farm loses under ice: excluding curtailed and zero-power hours, the median ratio of actual to expected power was 0.77 in sensor-confirmed icing hours and 0.91 without icing. Together, both give a correction factor that lowers the baseline forecast by 10 to 25 % in high-risk hours.
The method was cross-validated over the winters 2024/25 and 2025/26 at an operating wind farm, with 12 % icing hours. The icing probability reached an accuracy of 0.85, a recall of 0.94 and a ROC AUC of 0.93. The forecast error (nMAE) in icing hours dropped from 9.53 % to 9.19 %. Over all hours it stayed practically unchanged (7.90 % baseline, 7.92 % corrected).
The small change in error had a large effect on cost. Over both winters, the corrected forecast saved 957 k€ in day-ahead and 386 k€ in continuous intraday trading compared with the baseline. Every producer carries balance responsibility toward the grid, and in cold climates that responsibility includes forecasting ice. The paper describes the data flow from sensor to forecast, which needs no SCADA integration, and discusses the limits of the method.

Web site: eologix-ping.com

Short biography: Eike Lueken spent more than a decade at Vestas, managing the commercial side of major component exchanges, blade repairs, and spare parts supply. Since joining EOLOGIX-PING in 2022, he has been driving the industry toward proactive asset management through continuous blade monitoring. Outside of work, he is passionate about specialty coffee and perfecting his espresso setup.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI)
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Improving short-term wind turbine power forecasts during icing using on-site operational data

Jonathan Nixon, University of Kent, UK

Abhishek Kallarappayi (Coventry University, UK), Jonathan D. Nixon (University of Kent, UK), Charles Godreau (Nergica, CA)

Ice accretion introduces uncertainty into wind turbine power forecasts, with implications for intraday electricity trading and operational planning. Existing operational icing models estimate production losses using forecast weather conditions and modelled ice accumulation, but these estimates may not fully reflect how individual turbines respond to icing. This study investigates whether recent turbine operating data and icing-sensor measurements including LWC can improve six-hour-ahead power forecasts beyond an existing operational icing model, and examines the influence of machine-learning model complexity on forecasting performance.

The analysis uses data from a Canadian wind farm between December 2023 and April 2024, including 607 operational icing forecasts issued every six hours, one-minute SCADA measurements and observations from a nacelle-mounted icing detector. The relationship between forecast ice accumulation, sensor-measured icing and estimated icing-related energy loss is examined across individual icing events. Regression approaches, including monotonic recalibration, gradient-boosted trees and neural networks, are evaluated using the operational forecast alone and in combination with the preceding six hours of turbine and icing-sensor measurements. Performance is compared against the existing operational forecast and persistence using temporally held-out icing events.

Approximately 80% of the season's estimated icing-related energy loss occurred when both the operational forecast and icing detector indicated ice. However, the magnitude of indicated icing did not consistently correspond to the magnitude of production losses. During periods when the operational model predicted complete production loss, the turbine was still producing power. Machine-learning models improved six-hour-ahead power forecasts compared with the operational forecast in 14 of 17 held-out icing events. Incorporating recent turbine and icing-sensor measurements provided further improvements, particularly during the persistence phase of the icing lifecycle, when production losses continued after atmospheric conditions favourable to ice accretion had subsided.

These findings highlight the importance of distinguishing icing conditions from their consequences for turbine power production. They suggest that combining operational icing forecasts with recent on-site measurements can improve the representation of turbine-specific icing impacts and the accuracy of short-term power forecasts. This approach could support more reliable generation estimates for intraday electricity trading operational planning in cold-climate wind farms.

Web site: https://www.kent.ac.uk/engineering-and-digital-design/people/5704/nixon-jonathan

Short biography: Dr Jonathan Nixon is an Associate Professor at the University of Kent, specialising in renewable energy, systems modelling and artificial intelligence. His research develops AI-driven methods to improve the performance, reliability and resilience of clean energy technologies, with a particular focus on wind energy in cold climates.

His cold-climate wind research encompasses icing prediction, ice-protection performance and adaptive turbine operation, combining machine learning, optimisation and engineering models. He represents the UK within IEA Wind Task 54 on Cold Climate Wind and has undertaken multidisciplinary research on wind turbines operating in cold environments, supported by the Royal Society, the British Council and the European Union.

Beyond wind energy, Jonathan applies modelling, AI and optimisation across a range of renewable-energy and energy-access challenges. His international work has included solar microgrids, smart street lighting

and digital monitoring systems for refugee and displaced communities in Rwanda and Nepal. He recently led the Solar Energy Transitions project on solar-battery e-cooking systems in sub-Saharan Africa and worked with UNICEF on smart, climate-resilient water-pumping solutions.

Presentation format: Electronic poster
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Physics-informed Bayesian assimilation and forecasting of rotor icing: First results on the IEA Wind Task 54 database

Max Champneys, University of Sheffield, UK

Max Champneys (University of Sheffield, UK)

Ice accretion on wind turbine blades is a persistent obstacle to wind-power generation in cold climates, causing production losses, ice-throw risk and additional structural loading.

Operators need accurate, uncertainty-aware icing forecasts that go beyond binary classification and instead target the physical ice load on the rotor. Such forecasts would enable production-loss forecasting and inform operational decisions and icing-mitigation strategies.

Data-driven methods based on meteorological and SCADA data are largely binary icing detectors, and existing probabilistic icing forecasts have been found to be overconfident [1].

In this early work, a physics-informed data assimilation framework for rotor icing is proposed, in which rotor ice load is treated as a hidden dynamical state. Makkonen-type accretion [3] and simple sublimation and melt laws define the icing dynamics given meteorological conditions. Model parameters are learned offline with Bayesian inference. Online, a particle filter updates the ice state as data arrive, using the ratio of produced to expected power and, where available, a blade-mounted ice sensor. The uncertain state is then propagated forward to give probabilistic forecasts, such as the probability of exceeding a given ice load in the next hours.

The approach is demonstrated on two multi-day heavy icing events from the public IEA Wind Task 54 icing event database [2], recorded in different winters on the same turbine at the Nergica site (Canada), where a blade-mounted fos4X sensor estimates rotor ice load.

Parameters are learned on one event and the model is replayed hour by hour on the other, with measured meteorology standing in for a weather forecast. The physics largely transfers between the two events despite very different conditions (around −2 °C and −12 °C). When the blade sensor is assimilated up to the forecast time, forecasts show good agreement with the sensor's ice-load estimates over the first few hours and fair agreement out to around half a day, outperforming persistence of the last reading beyond a few hours. However, forecast uncertainty learned from a single event does not transfer to the other, underlining the need for more data.

Overall, the approach represents a promising direction for probabilistic icing forecasting, but a full evaluation on a dataset with many more events, turbines and sites is essential, and we are very keen to work with operators and data holders towards this goal.

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Web site: https://sheffield.ac.uk/mac/people/research-staff/max-champneys

Short biography: I am a Research Fellow in AI for sustainability and resilience as part of the Centre for Machine Intelligence at the University of Sheffield, a post I have held since November 2024. I was awarded my PhD in nonlinear structural dynamics at the University of Sheffield in March 2023 and I have also held a number of postdoctoral positions looking at the treatment of uncertainty in structural dynamics.

Presentation format: Electronic poster
Themes: 1. Sustainable development (UN: 17 Goals to Transform Our World), 3. Validation, field experience including human aspects, 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Anti-icing on blades longer than 80 m: second-winter results from heated and unheated turbines

Thomas Schlegl, eologix-ping, AT

Thomas Schlegl (eologix-ping, AT), Michael Moser (eologix-ping, AT)

On blades longer than 80 m, the outer section runs at high relative velocity and collects ice fast. This is also where a conductive heating system reaches its power limit first. Severe icing events show whether the system keeps the blade free of ice during operation (anti-icing) or whether the turbine has to stop and de-ice.

The study looks at a commercial conductive blade heating system that uses model-based temperature control without sensors on the blade. Wireless eologix-ping blade sensors add direct surface data: temperature (±0.25 °C) and ice accumulation in 5 levels at each sensor position. The sensors are less than 2 mm thick, energy-autonomous and retrofitted without cabling. Building on our contribution to Winterwind 2026, this study uses data from a wind farm about 200 km from the conference location, where heated turbines are compared with unheated turbines carrying the same sensors. On the heated blades, sensors cover the outer section up to about 10 m from the tip. The thermal profile there is complex: flow separation creates zones with little convective cooling, and these zones set the maximum surface temperature the heater may reach.

This contribution presents the results of the full winter 2025/26 as well as data from the winter 2026/27. For each icing event we compare heated and unheated turbines based on the on-blade measurements: ice accumulation along the blade and time until the surface is free again. Where the data owner agrees, we complement this with operational data of the turbines and the heating system. We then look at the severe events in detail, to show where along the blade anti-icing fails first and how the surface temperature develops in the zones with little convective cooling.

The results feed into heating control with on-blade feedback and into performance envelopes that operators and OEMs can check against measured data. With blades getting longer, OEM, operator and supplier share the responsibility to show where ice protection reaches its limits. Measured data on the blade gives them a common basis to agree on it.

Web site: www.eologix-ping.com

Short biography: Thomas Schlegl is co-founder and CEO of eologix-ping. After his PhD in sensor technology in Graz and at Stanford, he co-founded eologix sensor technology in 2014 to detect ice on rotor blades with wireless on-blade sensors, now in use on hundreds of turbines across Europe. In 2023, he led the merger with Australia's Ping Services, which added acoustic monitoring of blade damage to ice and lightning detection. Outside of work, he is usually out on long walks with his beagle Quincy.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 3. Validation, field experience including human aspects
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Hydro-Québec's ambitions as a new player in the world of wind energy developers

Monelle Comeau, Hydro-Québec, CA

Sébastien Trudel (Hydro-Québec, CA)

Hydro-Québec's Action Plan 2035 [1] establishes five main priorities that shape how Hydro-Québec engages in the field of wind energy. This presentation will highlight the two priorities driving our new endeavors, our collaborative approach, and some initial results in atmospheric icing that we wish to share with the industry.

Of the five priorities set out in Action Plan 2035, the presentation will focus on the following two:

· Increase our power generation capacity (with 10GW of new wind power generation)
· Partner with indigenous communities

The presentation will provide an overview of how we are engaging with Indigenous communities in our current projects, beginning with meteorological mast planning.

We will then explain how the same collaborative spirit guides our technical efforts in wind farm development in cold and icing climates. As an electricity transmission utility, Hydro-Québec has developed expertise in the icing of overhead power lines. Since 2003, when wind energy power purchase agreements were introduced, accurate forecasting of icing events has also become crucial for efficient grid management and energy distribution [2]. Today, as Hydro-Québec becomes a wind energy developer, new needs are guiding our work in the field as we seek to:

- Estimate icing losses and uncertainty, and minimize both

- Obtain IPS availability and performance warrantees

- Obtain reliable on-site icing measurement

- Drive 3rd parties to include on-site icing in their assessments

To tackle these challenges, we draw on both our expertise and the industry's experience through the following:

- VTT was commissioned to produce an icing atlas.
- We have engaged Nergica, a Canadian research and innovation centre, to estimate losses and uncertainties, building on work from an Icetek researchers on performance envelopes [3].
- As part of our framework agreement process, we have asked OEMs to propose research collaborations.
- Hydro-Québec has joined IEA Task 54.

The final part of the presentation will focus on the technical aspects of our ongoing work.

- We have taken steps to select and install sensors to measure icing and icing-related quantities and will share on the challenges encountered so far.
- We have built a library of simple icing-loss estimate methodologies and their related uncertainties by evaluating relationships between estimated operational icing losses at 39 existing wind farms in Québec and other variables: instrumental icing, rotor icing, VTT icing atlas, and elevation asl. We will present the approach, results and uncertainty methodology, for wind farms with and without IPS. The presentation will also show how the data compares to the well-known IEA ice classification table.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 3. Validation, field experience including human aspects
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

The author will also highlight the link between this work and more elaborate approach presented in another session at this conference.

In summary, the audience will gain insight into how Hydro-Québec is shaping its approach to wind farm development—working in partnership with communities and addressing cold-climate and icing challenges—along with an introduction to selected technical developments.

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Web site: https://www.hydroquebec.com

Short biography: Monelle Comeau has worked in wind energy and atmospheric icing since begining starting her master's degree in 2005. Her experience includes developing and validating a meteorological icing atlas for southern Québec, planning field measurement campaigns, and conducting pre-construction wind resource and site suitability assessments at WSP and ENERCON. She subsequently monitored operating wind farms at Power Factors, to improve availability, performance, and preventive maintenance strategies. Throughout her career, she has also contributed to several icing-related research and development projects and collaborated with academic partners on several topics. Since joining Hydro-Québec in 2026, she has supported wind farm development, with a particular focus on assessing and mitigating atmospheric icing challenges.

Presentation format: Oral
Themes: 8. Other
Technologies: H) Other

Cold Climate Claims – How loss experience has shaped the Nordic wind insurance market

Anders Orebrandt, Max Matthiessen, SE

Anders Orebrandt, SE

Wind power in the Nordic region operates under some of the most demanding climatic conditions in Europe. Low temperatures, icing, snow, lightning and severe weather affect not only turbine performance, but also the nature, severity and consequences of insurance claims. Over time, these losses have shaped how insurers assess, price and manage wind energy risks across the Nordic market.

This presentation will share an insurance market perspective on cold-climate wind risks, structured around three questions:

What are we seeing?
Drawing on claims experience from Nordic wind farms, we will explore the types of losses and loss scenarios where cold-climate conditions play an important role. Cold climate is not always the direct cause of a loss. In many cases, it acts as a loss amplifier: difficult site access, challenging repair conditions, crane availability and extended lead times can turn a relatively conventional turbine failure into a significantly larger property and business interruption loss.

What has the insurance market learned?
Claims do not only result in insurance payments – they influence how the next wind farm is underwritten. Nordic loss experience has affected insurers' approach to risk selection, pricing, deductibles, coverage, risk engineering and loss prevention. The presentation will discuss how insurers increasingly consider factors such as turbine technology, OEM track record, site conditions, maintenance strategy, monitoring, spare parts, repair preparedness and business interruption exposure when assessing cold-climate wind risks.

What does this mean for wind farm owners?
Loss experience also provides an opportunity to improve risk. Owners and operators can influence how their assets are viewed by the insurance market through better risk information, proactive maintenance and monitoring, loss prevention measures and robust contingency and repair planning. Understanding what insurers have learned from previous claims can help owners reduce both the likelihood and financial impact of future losses.

In line with Winterwind 2027's theme of Responsibility, the presentation will highlight the shared responsibility of owners, operators, OEMs, service providers, insurers and brokers to turn claims experience into practical risk improvements. By sharing lessons from losses rather than simply paying for their consequences, the industry can strengthen the resilience and insurability of wind power in cold climates.

Web site: www.maxm.com

Short biography: Anders Orebrandt is Head of Renewable Energy Sweden at Max Matthiessen Specialty, specialising in insurance and risk management for the renewable energy sector.

He has more than 20 years of experience in the insurance industry, with a strong focus on wind power and renewable energy. Before joining Max Matthiessen, Anders spent 20 years at Marsh, where he held several senior positions, including Head of Renewable Energy Nordics and Head of Power & Renewable Energy Nordics.

Throughout his career, Anders has advised wind farm owners, developers and investors on insurance, risk management and claims across the Nordic region. His experience covers the full lifecycle of renewable energy projects, from construction and project finance to operations, claims and risk engineering. He has

particular experience of the Nordic wind insurance market and how loss experience, technology and operating conditions influence insurers' approach to risk.

Outside work, Anders enjoys life in the Swedish countryside, where much of his spare time is spent with his family, horses and various projects around the farm.

Presentation format: Oral
Themes: 3. Validation, field experience including human aspects, 4. Practical operational methods and experiences (incl. financing, construction, O&M, HSE), 8. Other
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid, H) Other

From reactive to predictive asset management – Who takes responsibility when AI enters the control room?

Emma Fjällvide, W3 Energy, SE

Emma Fjällvide, COO and Stina Lundqvist, Asset manager (W3 Energy, SE).

Wind farm operations are becoming increasingly data-driven. SCADA, condition monitoring, weather and icing forecasts, production forecasts, market data and maintenance information can increasingly be combined with AI to identify risks, predict events and support decisions before production, safety or asset health are affected.

This creates significant opportunities – particularly in cold climates – but also raises a fundamental question: when AI moves from monitoring to recommending operational actions, who is responsible for the decision?

Traditionally, wind farm operations have largely been reactive: an alarm occurs, the control room responds, the situation is assessed and relevant stakeholders are engaged. The next generation of operations will increasingly become predictive, moving through:

Monitor → Understand → Predict → Decide → Act → Learn

Consider a cold winter day at a Nordic wind farm. Icing risk is increasing, condition monitoring indicates an emerging component deviation, electricity prices are expected to rise, maintenance is planned and personnel are present on site. Each factor may be manageable individually. The challenge – and opportunity – lies in combining them into one operational decision.

AI can help identify patterns, assess scenarios and recommend actions. But should an algorithm decide to postpone maintenance, adjust production, initiate de-icing or change an operational strategy? And where should responsibility sit between the control room operator, Asset Manager, OEM, BRP and asset owner?

Based on practical experience from Asset Management and 24/7 wind farm operations, this presentation explores the transition from reactive to predictive operations and the changing relationship between human judgement, AI and operational responsibility.

The presentation will discuss where AI can strengthen decision-making, where automation introduces new risks, and which decisions should remain under human control. In cold climates, this is particularly relevant as weather, icing, accessibility, personnel safety, asset health, production and commercial conditions often need to be evaluated simultaneously.

The role of the Asset Manager is therefore also changing: from coordinating individual activities towards managing the interaction between assets, algorithms, people, risk and value - Shaping solutions.

The wind farm of the future may become increasingly autonomous. Responsibility cannot.

Web site: https://www.w3e.se/

Short biography: Emma Fjällvide is COO at W3 Energy, an independent Asset Manager specializing in renewable energy and wind power in cold climates. With a background spanning commercial, financial and technical Asset Management, leadership and business development, she brings an owner-focused perspective on how the industry is evolving.

Presentation format: Oral
Themes: 3. Validation, field experience including human aspects, 4. Practical operational methods and experiences (incl. financing, construction, O&M, HSE), 8. Other
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid, H) Other

Her focus is on turning operational data, technology and human expertise into better decisions – and on how AI and automation will reshape the role and responsibility of the future Asset Manager.

Presentation format: Electronic poster
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

How far can SCADA telemetry alone take wind-turbine condition monitoring? A leakage-safe assessment without dedicated CMS sensors

Hith Rahil Nidhan, Delhi Technological University, IN

Hith Rahil Nidhan (DTU, IN), Sanyam Kathed (MUJ, IN), Jens Sperens (Dragaliden Vind AB, SE), Rajkumar Saini (LTU, SE), Petter Kyösti (LTU, SE), Björn Backe (LTU, SE), Sumit Rakesh (LTU, SE)

Operators are being increasingly requested to carry out condition monitoring activities using the existing SCADA without resorting to dedicated condition-monitoring systems that utilize vibration, bearing, and lubrication sensors [1][2]. The main issue at hand is how much can indeed be achieved and at which point genuine capability stops and over-expectation starts. The current study is carried out at a 13-turbine, gearless, cold-climate wind farm in Sweden, which has neither vibration, bearing, and oil sensors nor any maintenance-related proof. Therefore, the key task is to find out how accurately the condition of the turbine can be determined based solely on SCADA data.
We first need to understand what can be done with the data at hand and what cannot. The turbines are not equipped with dedicated condition monitoring equipment, and the failure labels are temporary alarm messages rather than verifiable failures. Thus, it is essential to implement two leakage-resistant layers. The first layer represents the behavioral condition monitoring system based on the historical behavior of the turbine [3][4]. The second is the supervised layer that predicts alarm messages two hours ahead based on causal characteristics [5].
One of the main themes is ensuring against overly optimistic outcomes. For instance, innocent feature selection, such as a downtime-proxy feature or a set baseline year, may lead to inflated performance, which is why we identify and eliminate such leaks through a structured audit, thereby reporting only the leakage-free metrics. On the basis of that, the screening generator model obtains an event recall of about 0.77 for about 3.5 alerts per turbine-month. The methods of evaluation that we use are rolling origin evaluation, leave-one-turbine-out evaluation, bootstrap confidence intervals, and probability calibration, through which we obtain reliable risk scores in the range of 0-100 instead of the merely ranked scores. As far as our findings indicate, we establish that deep learning, algorithm fusion, unsupervised anomaly detection, and history length elongation may not help us improve performance since the ceiling is set by label resolution without physical sensing devices, not model selection.
The outcome is a human-led behavioral watchlist as well as a short-term alarm system, both practical and usable with clear limitations. We also state how an upgrade that combines the use of vibration analysis and the obtained maintenance data would allow attaining precise prediction of the occurrence of failure events. The direct and open nature of the provided baseline is very advantageous for a community where SCADA-assisted condition monitoring technologies are widely used but seldom assessed. This work is new and is presented for the first time. This research is financially supported by the European Regional Development Fund and the MARTINA-project (no. 20367152).
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Web site: https://dtu.ac.in/

Presentation format: Electronic poster
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Short biography: Hith Rahil Nidhan is an engineer specializing in Machine Learning and is a student of the course of Computer Science at Delhi Technological University. The main area of his work includes the practical application of machine learning and data analytics in engineering systems.
Hith has been working on practical machine-learning solutions for the operations of wind turbines utilizing SCADA telemetry data coming from the 13 turbines at Dragaliden AB in Piteå, Sweden under MARTINA project (no. 20367152). He has designed the complete machine-learning pipeline that takes high-frequency operational data and produces valuable information for the process planning and monitoring of wind turbines. His forecasting was able to achieve the value R2 of approximately 0.976 on the data never seen before, while his operational monitoring enabled detection of any possible faults about eight hours earlier than without this approach.
Hith provides a SCADA-based condition-monitoring methodology to Winterwind for use in wind farms that lack dedicated vibration, bearing, or oil sensors. Hith connects the historical data of turbines with instant alarm forecasts to detect unusual conditions and generate risk scores. Instead of depending solely on sophisticated models, the methodology is designed into a practical monitoring workflow whereby operational staff can have a turbine watchlist and be alerted of potential problems. This work also defines the operational boundaries of SCADA-only monitoring and lays down a framework for classifying maintenance and other physical data once it becomes available.
Hith possesses understanding on anomaly detection, distributed computing, computer vision, data analysis from different research and engineering projects done in India, Sweden and Canada. He also has peer-reviewed publications and his core concentration is on creating machine learning systems that can convert huge operational data into useful decision-making tools.

Presentation format: Electronic poster
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Leakage-safe multi-resolution forecasting of wind energy production: a comparison of ensemble and deep sequence models

Sanyam Kathed, Manipal University Jaipur, IN

Sanyam Kathed (MUJ, IN), Hith Rahil Nidhan (DTU, IN), Jens Sperens (Dragaliden Vind AB, SE), Rajkumar Saini (LTU, SE), Petter Kyösti (LTU, SE), Björn Backe (LTU, SE), Sumit Rakesh (LTU, SE)

Short-term forecasts of wind energy generation are useful for grid stabilization, participation in the market, and for planning of curtailments. Most studies only compare models at one particular spatial resolution [1] whereas some studies set explicit rules to avoid target leakage in the creation of features. In this research, we have built one reproducible pipeline applied on a real-time cold climate wind-farm located in Sweden, where predictions are made at two spatial resolutions i.e. turbine-wise and substation-wise. The turbine-wise data consists of twelve turbines measured at a 15-minute frequency for the period of August 2018 to December 2024. The substation-wise data consists of data from the 13th asset operating at a 10-minute frequency from 2010 till 2024. We develop lag features of past production and wind speed at different horizons of time, with a maximum of 24 hours. We introduce rolling stats which are the rolling mean, standard deviation, and maximum, as well as first and second differences, calculated for different window lengths. We encode time using sine and cosine functions for hour of the day, day of the week, month, and day of the year, which allows us to make the representation of periodic boundaries continuous. Also introduced wind physics parameters which include wind velocity squared and cubed along with the other factors illustrating the relationship between wind and power production. There are no leakages in our process. Production is defined as the first derivative of the cumulative energy counter. All original channels connected to power or energy counting are excluded from the feature set to make it impossible to trace the target from the input.
The analysis compares twelve forecasting techniques using the same protocol i.e., the data has been split according to time domain and no randomization was performed. The set of techniques included statistical models, the linear model, the tree ensemble models such as Random Forest, Extremely Randomized Trees, Histogram Gradient Boosting, XGBoost, LightGBM, and CatBoost, deep learning models such as LSTM, GRU, CNN-LSTM, and Transformers and a ridge-stacked meta-ensemble. The results of our comparison indicate that LightGBM achieved the best result among all the methods that we examined, with mean absolute error on farm dataset of about 120 kW and R-Squared value of about 0.97. The tree ensemble models performed well showing limited error on test dataset, but all deep learning models showed significant decrease in performance when moving from validation to testing stage, showing deterioration of a factor of 10. The most important factors employed in the training of the model are the previous values of the production and the wind resource data. In this instance, the stacking ensemble and extremely randomized trees perform equivalently with each achieving an R2 value of about 0.976. The stacking effect considered in the previous cases does not remain straightforward across both farm and substation cases suggesting that stacking's efficacy depends significantly on the structure of the pool of individual producers utilized and not only on the stacking itself who cannot be utilized to various extent for wind forecasting tasks [2]. The abstract presents a convincing and repeatable guiding framework for properly conducting such leakage-free wind real time production grade forecasting operations as well as helping with model selection in terms of network resolution. This research is financially supported by the European Regional Development Fund and the MARTINA-project (no. 20367152).
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2. T. A. Rajaperumal and C. Christopher Columbus, "Enhanced wind power forecasting using machine learning, deep learning models and ensemble integration," Scientific Reports, vol. 15, p. 20572, 2025.

Web site: https://sanyamkathed.vercel.app/

Short biography: Sanyam Kathed is an AI researcher and Machine Learning Engineer who is presently pursuing a B.Tech in Computer Science (Data Science) at Manipal University Jaipur. He emphasizes the

development of applications of reliable machine-learning systems in the practical world. His areas of expertise include time-series forecasting, evaluation of models, and proper deployment of AI systems.

At Dragaliden Vind AB in Sweden, Sanyam has contributed to machine-learning solutions for wind-energy production forecasts related to the MARTINA-project (no. 20367152). Sanyam’s contribution was to develop an end-to-end leakage-safe forecasting pipeline that makes use of high-frequency operational data from a wind farm located in a cold region. The pipeline utilizes historical production and wind-resource data to provide short-term forecasting for both the turbines and substation that can be applied to different tasks including grid balancing and energy planning.

Sanyam has created numerous and measured several different forecasting methods like statistical models, tree-based ensembles, recurrent neural networks, CNN-LSTM models, Transformers, and stacked ensembles. Sanyam's research has emphasized the evaluation of forecasting systems within realistic operating conditions through strict timelines and strategies to prevent target leakages. The research portrayed a successful forecasting outcome with an R2 of about 0.967 and an R2 of approximately 0.976 for new turbine data.

Apart from wind energy, Sanyam has expertise in the field of edge AI, model compression, TinyML, and machine learning implementation. He has been involved in various publications and global research projects, with his main focus being the development of dependable, efficient, and applicable AI systems.

Presentation format: Electronic poster
Themes: 3. Validation, field experience including human aspects
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

IEA Wind TCP Task 54: IceLossMethod 3.0 and Ice classes review

Charles Godreau, Nergica, CA

Patrice Roberge (Icetek, CA), Michaël Morin (Nergica, CA), Étienne Coulombe-Lamarche (Nergica, CA)

As part of the current workplan at IEA Wind TCP Task 54 - Cold Climate Wind Power, Subtask 3 is focussing on the performance of wind turbines in icing.

The first item of work of the group has been to release the IEAIceLossMethod 3.0 open source software to evaluate the icing production loss from SCADA data (https://github.com/IEAColdClimateWind/IceLossMethod). This new version was first introduced during a workshop at Winterwind 2026.

The second item of work of Subtask 3 is to review the IEA Ice classes to better represent the performance of wind turbines in icing climate, especially with the wider adoption of ice protection systems in moderate and severe icing climate sites. The cold climate wind community was also sollicitated at Winterwind 2026 to kickoff the Ice Classes review.

This presentation will provide and update of Task 54 Subtask 3 work. It will also showcase how data from 2 wind farms, one in Canada and one in Sweden can be processed by the IEAIceLossMethod 3.0 to generate validation data for the IEA Ice Classes review exercice. The preliminary revision of the IEA Ice Classes will be presented to collect industry feedback and invite the cold climate wind community to contribute to its revision.

Web site: https://iea-wind.org/task54/

Short biography: Cold climate regions represent a growing share of the global wind market, with an estimated 208 GW of installed capacity by 2024. The IEA Wind TCP Task 54 focuses on the unique atmospheric and operational challenges present in those cold climate regions.

Cold climate sites are defined as those that experience either icing events or temperatures lower than the operational limits of standard wind turbines. Low temperature sites require special solutions to keep turbines operating. In icing conditions, a combination of low temperatures and liquid water in the atmosphere results in ice accretion on surfaces, such as wind turbine blades, towers and nacelle. Blade icing results in loss of lift and increase in drag, resulting in reduced energy production. Icing can increase mechanical loads on the turbine, vibrations in structures and noise. In addition, ice on the blades, nacelles and towers can present a health and safety risk, due to ice falling off or being thrown from the blades. Finally, due to the growing installed capacity, icing events are starting to have systemwide effects in deregulated markets, which fosters the need to improve the performance of forecasts and understanding of the impact of icing events beyond the wind farm.

The task promotes collaboration between the participating countries, research institutions and industry leaders. Task 54 aims to advance industry practices by gathering large-scale experimental data and developing tools that can facilitate the deployment of wind energy in cold climate and improve turbine resilience in cold conditions. By supporting the development of tools like the ice loss tool and industry guidelines like the performance warranty guidelines, Task 54 is ensuring that wind farms in cold climates can operate more effectively and with greater reliability.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 3. Validation, field experience including human aspects
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Where did the energy go? Understanding and quantifying underperformance in modern wind farms in the Nordics

Ben Buxton, Ramboll, UK

Andrew Hay, Fraser Roach and Joel Manning (Ramboll, UK) - Ben Buxton (Ramboll, SE)

We present the latest findings from data-lead investigations of the physical drivers behind the underperformance of wind farms in the Nordics, which has been widely observed in recent years. Production deficits, relative to pre-construction energy yield estimates, have exceeded 10% at some onshore projects. The reasons behind the observed under-performance are used to propose practically applicable predictive methods.

Several recent studies, including work presented by Ramboll at Wind Europe Tech 2026 in Rotterdam, have linked these losses to atmospheric conditions, often named low-level jets, boundary layer stratification or suppressed boundary layer heights, and their interaction with large modern wind turbines. These conditions feature lower wind speeds than generally derived by commonly established analysis methods which apply hub height wind speeds and a log or power law model of the boundary layer. Notably, these losses were not widely observed in earlier generations of wind farms, supporting the suggestion that increasing turbine hub height and rotor diameter increases the impact.

Earlier studies have demonstrated that advanced atmospheric and wind farm modelling approaches are able to simulate some conditions under which this underperformance occurs, which is an important part of the challenge. However, to produce more robust pre-construction energy yield assessments in regions impacted by these effects, we must be able to confidently identify the frequency of these conditions and ultimately quantify their impact on both turbine and wind farm performance to a high level of certainty.

This study advances this area, by applying mast and Lidar measurements combined with operational turbine SCADA production data from multiple wind farms across the Nordics to further investigate the mechanisms responsible for the observed underperformance. The analysis examines the occurrence and magnitude of these events and their impact on individual turbine performance, and wind farm wake modelling approaches.

The findings provide increased clarity around the categorisation and quantification of how these specific atmospheric conditions lead to measurable production losses. Practical predictive methods for quantifying the energy impact due to these effects from readily available site and reanalysis data sets are proposed and assessed, helping improve the accuracy of future energy yield predictions and reducing uncertainty for wind farm developers, investors, and operators.

Similar observations of under-performance have also been made for offshore projects across the North Sea. Although the percentage magnitude of these losses has been observed to be lower, compared to those observed onshore, the financial impact could be greater and with more offshore projects expected to be developed in locations highly likely to also be impacted by reduced boundary layer height, this could be a significant issue. The work presented here represents an important step towards a predictive approach for this potential issue – further increasing its importance.

Web site: https://www.ramboll.com/energy/wind-and-solar

Short biography: Ben has worked in the wind industry since 2010 across markets globally in both consulting and project developer roles. He is skilled in the detailed design and optimisation of projects across the development arc, particularly sites in complex terrain or climates. At Ramboll, Ben is a Chief Consultant within the Site, Yield and Transaction Advisory group. In this role, he is a technical approver of projects and provides support to the analysis team, in due diligence, as well as leading the competence area for onshore site assessment.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 3. Validation, field experience including human aspects
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Prior to this he has worked as a wind energy consultant and project manager at global consultancies and a European developer where he was Team Leader for the Wind & Turbine Performance group.

Presentation format: Oral
Themes: 3. Validation, field experience including human aspects
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Overcoming the performance gap in the Nordic countries

Narges Tabatabaei, DNV Sweden, SE

Narges Tabatabaei (DNV,SE) , Jakub Gubanski (DNV, SE), Henning Straume (DNV, NO), Wolfgang Winkler (DNV, DE)

In recent years, owners, lenders, developers and technical advisors have observed a growing gap between the operational performance of newly commissioned onshore wind farms in the Nordic region and pre-construction energy resource predictions. In several cases, the resulting impact on annual energy production and project economics has been significant, attracting increasing attention from industry stakeholders. While part of the observed underperformance can be explained by factors such as wind climate variability, turbine reliability, icing, curtailment and operational constraints, substantial discrepancies may remain unexplained after these effects have been accounted for. Reconciliation analyses conducted for operational Nordic wind farms show differences of several percentage points in annual energy production, in certain cases exceeding 10%.

This study draws on experience from more than 4 GW of installed wind capacity across Sweden, Finland and Norway and includes several dozen operational onshore wind farms. For each project, energy assessments based on operational data are compared with the corresponding pre-construction assessments prepared using different methodologies and by different consultants. The broad portfolio, covering different site conditions, turbine technologies and assessment approaches, provides a basis for identifying recurring patterns and investigating whether these can be linked to assumptions and modelling approaches commonly applied in energy yield assessments.

The assessment framework systematically decomposes the principal components of the energy assessment. Known contributors to underperformance, including resource variability, turbine availability, icing losses, curtailment and operational constraints, are quantified where possible. Remaining discrepancies are evaluated across projects to identify common trends, potential drivers and areas requiring further investigation. Particular attention is given to factors relevant under Nordic conditions, including atmospheric stability, wind shear representation, extensive forest cover and associated land-use effects, turbine interaction losses, turbine performance under stable atmospheric conditions, and the estimation of icing losses. The cross-project approach allows project-specific effects to be distinguished from systematic trends relevant to Nordic energy assessments.

The analyses performed to date demonstrate a recurring performance gap between pre-construction expectations and operational performance. Although the magnitude and underlying causes differ between projects, residual discrepancies remain in a number of cases after recognised loss mechanisms and operational factors have been considered. Relationships are also observed between performance gaps and site characteristics, indicating that Nordic atmospheric conditions, extensive forest cover, icing and their interaction with turbine and wind farm performance may contribute to the observed deviations. The results suggest that some of these effects may not be fully represented by current resource assessment and loss estimation practices.

The observed performance gap is therefore unlikely to result from a single mechanism, but rather from the combined influence of several factors whose relative contribution varies between projects. Building on the operational evidence, the ongoing work focuses on quantifying these mechanisms and evaluating where improvements to modelling approaches and adjustment factors can be justified. This includes improving the assessment and quantification of icing losses, alongside refinements in wind resource, forestry, atmospheric stability and turbine interaction modelling. The ultimate objective is to translate the findings into refined methodologies and practical industry guidance, supporting more accurate, consistent and reliable energy yield assessments and better-informed technical and investment decisions for future Nordic wind projects.

Presentation format: Oral
Themes: 3. Validation, field experience including human aspects
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Web site: https://www.linkedin.com/in/nargestabatabaei/

Short biography: Narges Tabatabaei is a Senior Wind Energy Analyst at DNV Sweden with more than 10 years of experience in computational fluid dynamics (CFD), fluid mechanics, and wind energy applications. She holds a PhD from Luleå University of Technology, where her research focused on the effects of icing on wind turbine performance. Following her doctorate, she worked as a Postdoctoral Researcher in Fluid Mechanics at KTH Royal Institute of Technology, contributing to experimental and numerical studies of complex flow phenomena and developing automated CFD modelling approaches. Within the 5 years with DNV, she has specializes in energy yield assessments for onshore and offshore wind farms, advanced wind farm flow modelling, including wake and blockage effects, and the integration of remote sensing data. Recently, she also conducted operational energy assessments and reviewed energy assessments of third party consultants. Her work combines research-driven aerodynamic analysis with practical applications for wind energy development across Europe.

Presentation format: Oral
Themes: 3. Validation, field experience including human aspects, 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

From modelling to measured results: first EnVentus field validation of Cold Climate Operation (CCO)

Nils Jehring, Vestas, DE

Philipp Mueller (Vestas, DE)

Icing remains one of the most significant operational challenges for wind turbines in northern climates, impacting aerodynamic performance, availability, and annual energy production. As wind energy deployment continues to expand into increasingly challenging environments, validated operational experience is essential to demonstrate the effectiveness of ice mitigation solutions and support informed investment decisions.
Vestas' Cold Climate Operation (CCO) is a software-based control solution designed to mitigate production losses caused by blade icing through adaptive turbine control. While previous work has focused on modelling, prediction methods and the theoretical performance potential of CCO, this presentation focuses on measured operational results from the first field validation of CCO on the EnVentus platform.
Using operational data from Finnish wind farms during the 2025/26 winter season, turbine performance was evaluated under icing conditions through a comparative turbine-to-turbine methodology. Turbines operating with CCO enabled were benchmarked against comparable turbines operating without the functionality activated, enabling direct assessment of performance improvements under real operating conditions.
The presentation will describe the validation methodology, site operational conditions, and the key performance indicators used to quantify the impact of CCO. Particular focus will be placed on measured production recovery during icing events and the practical considerations associated with validating software-based ice mitigation technologies in commercial wind farms.
Beyond the technical results, the presentation will highlight how operational validation can be used to translate performance improvements into customer value. In addition, an overview of the commercial framework through which CCO is offered will be presented, illustrating how validated field performance can support asset owners and operators in maximizing value from existing wind turbine fleets in cold climate regions.

Web site: https://www.vestas.com/en

Short biography: Nils Jehring is a Technical Sales Engineer at Vestas, supporting customers with Value Engineering solutions in the renewable energy industry. He holds a Master of Science in Mechanical Engineering from the University of Applied Sciences Berlin and has more than a decade of experience in wind energy, structural engineering, and technical sales. Before joining Vestas in 2020, he worked in engineering roles focused on structural analysis, product development, and project management within the wind energy and aerospace sectors. When Nils is away from work, he enjoys spending time with his family, sailing, and fishing.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 3. Validation, field experience including human aspects, 6. Independent comparisons of methods and products
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Cold-climate site classification from an ensemble of new reanalysis datasets

Morten Lybech Thøgersen, EMD International, DK

Marie Cecilie Pedersen (EMD, DK)

Reanalysis datasets are the starting point for most cold-climate site assessments - as boundary conditions for the mesoscale icing models, as long-term reference for correcting short measurement campaigns and often as the basis for the icing maps used for screening new sites. For the last decade the practical choice for wind-energy analysts has been ERA5 (31 km) from ECMWF [1] - with MERRA-2 from NASA still in wide use. We have earlier investigated ERA5, ERA-Interim, MERRA-2 and CFSR as forcing data for icing modelling with EMD-WRF OD ICING [2, 3] - and found ERA5 to be a clear improvement, but also that the improvement is hard to quantify against instrumental icing.

The reanalysis landscape is now changing rapidly - with new global and regional datasets at higher resolution and assimilating far more data. DWD has released ICON-DREAM - a global reanalysis at 13 km with a two-way nested 6.5 km European domain, covering 2010 to present [4]. ECMWF started production of ERA6 in March 2026 - at 14 km resolution and with the first streams (2007 onwards) due by the end of 2027 [5]. ERA6 assimilates about 50% more observations than ERA5, and ECMWF lists an improved representation of super-cooled liquid water, a 5-layer snow model and 3D rain and snow water content among the changes. Regional reanalyses cover the European cold-climate regions at kilometre scale: CERRA (5.5 km) [6], NORA3 (3 km) [7] and CARRA2 (2.5 km) - the latter released in December 2025 and covering the full Arctic north of 60N [8]. The cold-climate regions are often data-sparse - and may benefit the most from the satellite-era observations assimilated into these new models.

In this study, we investigate if this range of reanalysis datasets - used as an ensemble rather than one at a time - gives a better modelling framework for cold-climate site classification. We ask three questions: (a) which cloud-water and icing-relevant parameters are available in each dataset - and how consistent they are across datasets, (b) if the spread between the ensemble members gives a useful map of the uncertainty on icing frequency, IEA ice class and low-temperature exposure, and (c) if the kilometre-scale reanalyses may reduce the need for a dedicated mesoscale downscaling step. The modelled icing is compared with Scandinavian meteorological masts with icing records over several seasons. The work builds on our earlier validations of CERRA and NORA3 wind speeds against 194 and 74 tall masts [6, 7]. ERA6 will enter the comparison as the streams are published .

Who is responsible for the climate data behind a cold-climate project? The analyst picks the datasets - but developers, financiers and consultants all live with the consequences downstream. A reanalysis ensemble is a practical way to make the uncertainty from that choice visible - before the measurement campaign, the layout and the financing are locked in.

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[2] M. L. Thøgersen, L. Svenningsen, T. G. Sørensen and D. Lindholm: Site-assessment and icing impact using ERA5 assimilation data. In Winterwind 2018.
[3] M. C. Pedersen, T. Ahsbahs, W. Langreder and M. L. Thøgersen: On the modelling chain for production loss assessment for wind turbines in cold climates. Cold Regions Science and Technology, vol. 216, 103989, 2023.
[4] EMD: ICON-DREAM reanalysis (DWD). https://help.emd.dk/mediawiki/index.php/ICON-DREAM
[5] H. Hersbach et al.: ERA6 production. ECMWF Newsletter 188, 2026.
[6] M. L. Thøgersen, L. Svenningsen and T. G. Sørensen: CERRA - accuracy and validation of wind speeds. EMD, 2022. https://help.emd.dk/mediawiki/index.php/CERRA
[7] M. L. Thøgersen, L. Svenningsen and T. G. Sørensen: NORA3 - accuracy and validation of wind speeds. EMD, 2022. https://help.emd.dk/mediawiki/index.php/NORA3
[8] C3S: Copernicus Arctic Regional Reanalysis (CARRA). https://climate.copernicus.eu/copernicus-arctic-regional-reanalysis-service

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 3. Validation, field experience including human aspects, 6. Independent comparisons of methods and products
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Web site: https://www.emd-international.com/

Short biography: Morten Lybech Thøgersen is team lead of the HPC and API team at EMD International A/S in Denmark - the windPRO Vanguards - a role he took on in August 2026 after several years as head of the software development department. The team runs EMD's high-performance computing cluster and the EMD-API, and delivers the mesoscale, reanalysis and satellite datasets that feed windPRO and energyPRO. Morten's research interests are rooted in applied methods: data analysis, probabilistic methods and loads, global and regional reanalysis data, GIS and land-surface data, machine learning, big data and high-performance computing - with a particular interest in how these are put to use in cold-climate modelling of renewable energy. He is a long-standing advocate of Agile methods in software development and of building software that integrates data and models to deliver real end-user value - and an avid GTD (Getting Things Done) practitioner. Morten joined EMD in 2001. Before that he was a researcher at Risø National Laboratory, now DTU Wind Energy. Outside work he enjoys time with family and friends, running, and water sports in both the liquid and frozen state - sailing, scuba diving, kite surfing and snowboarding. His liking for cold-climate activities mirrors his professional interest in cold-climate modelling.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI)
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Scaling icing loss classes with global warming levels using DestinE high-resolution scenarios

Gil Lizcano, Climate Scale, ES

Juan Manuel Queirel (Climate Scale, ES)

Icing is one of the main sources of production loss and uncertainty for wind farms in cold climates. Yet energy yield assessments (EYA) are calibrated on the historical climate, implicitly assuming stationarity over a 20–30 year project lifetime. Recent high-resolution studies challenge this assumption. In Fennoscandia, annual icing hours are projected to fall by 10–50% by mid-century, while annual maximum ice loads persist or increase in the north and at higher elevations [1,2]. In eastern Canada, freezing rain shifts northward and concentrates in mid-winter [3], and over central and southeastern Europe freezing rain is projected to decrease [4]. No comparable projections exist for Iberian or Carpathian wind sites. Taking responsibility for long-term risk means bringing this signal into how icing losses are estimated, financed and mitigated.
We combine a historical hindcast (ERA5 dynamically downscaled with WRF) with high-resolution DestinE Climate Digital Twin scenario data (SSP3-7.0). For comparability with previous studies, icing potential is diagnosed from the same physical drivers: temperature (time below 0 °C and within the −20 to 0 °C window), moisture (relative humidity and, where available, cloud liquid water content) and wind speed, evaluated at hub-relevant heights (100–200 m). From these we derive icing potential days, annual icing hours and icing episode durations, classified as short, medium and long. We also derive annual maxima and 99th percentiles of icing intensity. For Québec, freezing rain hours are included given their dominant role there. Model data are calibrated against the hindcast using standard machine learning methods. The historical period is evaluated against downscaled data and open-access observational and reanalysis datasets.
The analysis covers Scandinavia, Québec, and high-altitude sites in Spain and Romania, representing contrasting icing climates with active wind development.
Rather than a full multi-scenario analysis, the study exploits the high resolution of DestinE to assess sensitivity across three independent runs representing plausible futures. The aim is to show how winters and cold-weather events may look over the next one to two decades, as warming brings fewer cold nights and shifts the temperature–moisture combinations that drive icing.
The main outcome is a scaling factor linking icing occurrence to global warming levels, used to recalibrate icing loss classes with a focus on the 20–30 year horizon. To bring climate change into EYA, the factor is split into 5-year steps, distributing risk across the project lifetime.
Results show a window of opportunity: long-duration icing decreases. Short, more intense spells show region-dependent shifts from the baseline, consistent with the persistence of annual maxima reported for northern Fennoscandia [1]. Short-duration icing therefore remains an operational concern for forecasting and de-/anti-icing strategies. The work gives developers, consultants, financiers and operators a transparent way to include climate change in icing loss assessments.
[1] Rockas et al. (2026), Nat. Hazards Earth Syst. Sci. 26, 1813–1834.
[2] Iversen et al. (2023), Cold Reg. Sci. Technol. 210, 103836.
[3] Marinier et al. (2023), Clim. Dyn. 60, 1369–1384.
[4] Kämäräinen et al. (2018), J. Geophys. Res. Atmos. 123, 13291–13304

Web site: https://climatescale.com

Short biography: Gil Lizcano is a climate scientist with a background in Physics and Climate Variability. His career has combined climate modelling research with applied work for the wind energy sector, with the aim of turning scientific knowledge into practical solutions for organisations facing climate challenges.

At the University of Oxford, he provided climate modelling support for research projects and international collaborations, and trained students and researchers in climate data analysis.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI)
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

In 2008 he joined Vortex, where he has driven implementation and innovation in high-resolution wind data for wind farm development. In 2019 he founded Climate Scale, which translates climate projections into actionable information for assessing climate risks and impacts.

His expertise includes turning complex climate projections into practical insights for decision-making, building tools to assess exposure to physical climate risks, and designing training and capacity-building programmes that strengthen climate resilience. His current work bridges these fields by bringing climate change signals, such as future icing conditions, into the long-term energy yield and risk assessments that shape wind projects in cold climates.

Beyond climate science, Gil runs an independent bookshop specialising in architecture, design, art and ideas.

Presentation format: Oral
Themes: 1. Sustainable development (UN: 17 Goals to Transform Our World), 2. Recent research (theories, methods, verifications, visualization, applied AI), 8. Other
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid, H) Other

Could climate change increase renewable energy production in the Nordics?

Emilie Iversen, Kjeller Vindteknikk, part of Norconsult, NO

Jennie Moldiner (Kjeller Vindteknikk, part of Norconsult, SE), Mona Kurppa (Kjeller Vindteknikk, part of Norconsult, FI), Pia Isolähteenmäki (Kjeller Vindteknikk, part of Norconsult, FI)

Climate change is typically associated with negative consequences for society, infrastructure and ecosystems. However, some of the projected changes may have beneficial effects for renewable energy production in the Nordic region.

For wind energy, our research indicates a future reduction in atmospheric icing at many Nordic wind farm locations. Using climate model projections together with Norconsult's IceLoss model, we assessed future production losses caused by icing for a range of locations across the Nordic countries. The results show a decrease in icing-related production losses for most sites, potentially increasing future winter production.

Projected changes in annual mean wind speeds remain uncertain and relatively small. However, a stronger seasonal signal emerges when the individual seasons are analysed separately, with tendencies towards lower wind speeds in summer and higher wind speeds in winter. Since winter is typically associated with both higher wind energy production and higher electricity prices, such seasonal shifts could have positive implications for both energy yield and revenues.

For hydropower, our study of Norwegian small-scale hydropower plants suggests increasing winter discharge in many snow-dominated catchments. Warmer winters result in a larger fraction of precipitation falling as rain rather than snow, together with more frequent mid-winter snowmelt events. This may increase hydropower generation during the season with the highest electricity demand and typically the highest market prices. At the same time, reduced snow accumulation is projected to decrease the magnitude of the spring flood. Since many hydropower plants cannot fully utilize peak flood flows, a reduction in spring flooding may reduce spill losses and improve the utilisation of available water resources.

For many snow-dominated catchments, climate change may therefore lead to a more favourable seasonal distribution of water resources, with increased winter production and reduced spill losses potentially outweighing the effects of declining summer discharge from increased evaporation.

Taken together, the results suggest that climate change may not only present challenges for Nordic renewable energy systems but also create opportunities. Understanding these effects is essential for future energy planning and climate adaptation.

Web site: www.vindteknikk.com

Short biography: Emilie has worked on the topic of atmospheric icing and meteorological modelling for 10 years, through consultancy work at Kjeller Vindteknikk and several large research projects. She completed her Doctoral degree in this field in 2022, which also contained research on climate change impacts on icing. The complex topic of climate change is of specific interest to her, and particularly how it will affect our winter climate in the years to come. This is also of high relevance for her spare time passions, snowboarding and split boarding.

Presentation format: Oral
Themes: 3. Validation, field experience including human aspects
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

From prediction to performance: a common framework for assessing ice protection systems

Dylan Baxter, FabricAir Canada (BorealisWind), CA

Dylan Baxter (BorealisWind, CA)

Owners considering ice protection systems (IPS) for wind turbines need credible estimates of recoverable production. After installation, they need an equally credible assessment of what the system delivered. When prediction and reporting use different assumptions or baselines, their results can be difficult to reconcile. This presentation examines how a common performance-assessment framework can connect these decisions through explicit baselines, comparison periods and limitations.
The approach uses turbine-specific learned power curves, historical relationships between turbines, and concurrent SCADA measurements to estimate production with and without IPS. For equipped turbines, actual production is compared with estimated production without IPS. Reversing the comparison allows observed performance from equipped turbines to inform potential gains on suitable unheated turbines at the same site. The method retains negative as well as positive interval gains and makes reference selection, installation dates and data exclusions traceable.
The framework builds on the reference-power-curve and comparative assessment principles described in IEA Wind TCP Task 19's icing-loss methodology and Performance Warranty Guidelines for Wind Turbines in Icing Climates. The presentation will distinguish shared principles from adaptations in historical normalization, data treatment and prediction, and explain the reasons for these differences.
A multi-winter case study from an anonymized Canadian wind farm will illustrate the approach. It examines how a turbine that initially experienced greater production losses than its neighbouring reference subsequently improved its relative performance following IPS installation, despite evidence of increased icing exposure. Nearby instrumental-icing measurements and the reference turbine's icing-related status codes provide complementary context for interpreting the production comparison.
The presentation connects responsible performance reporting with practical requirements for owners, suppliers and analysts: agreeing the baseline, preserving access to relevant data, documenting exclusions, distinguishing estimated recovery from directly measured production, and using consistent energy-accounting boundaries. Delegates will learn how a shared assessment basis can support retrofit decisions and subsequent reporting, while recognizing the limitations of reference-based predictions and single-case comparisons.

Web site: https://www.fabricair.com/ice-protection-system/

Short biography: Dylan Baxter, P.Eng., is an engineering leader with over 10 years of experience in the wind industry, specializing in the design, optimization, and operation of Ice Protection Systems (IPS). As a founding member of the BorealisWind product, his experience spans R&D in electrical, mechanical, controls, and SCADA systems, as well as analytics, safety (HSE), operations, and organizational leadership. He has led multidisciplinary and international teams to deliver end-to-end solutions for cold-climate wind turbines. Outside of work, he enjoys backcountry skiing in the winter, backcountry camping in the summer, and spending the rest of his time traveling or renovating his home.

Presentation format: Oral
Themes: 4. Practical operational methods and experiences (incl. financing, construction, O&M, HSE), 6. Independent comparisons of methods and products
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Experiences with ice mitigation warranties

Simo Rissanen, Kjeller Vindteknikk, part of Norconsult, FI

Jennie Molinder (Norconsult, SE)

The first generation of wind farms operating under ice mitigation performance warranties has now accumulated sufficient operational history for ice mitigation system warranty evaluation. These projects provide an opportunity to assess how ice mitigation warranties perform in practice and what challenges arise when theoretical warranty concepts are applied to real operating data. Depending on the turbine manufacturer, these warranties may cover active Ice Prevention Systems (IPS) based on blade heating or winter operation concepts based on operational strategies without blade heating.

Kjeller Vindteknikk/Norconsult has performed warranty assessments for several wind farms representing multiple different turbine manufacturers and different ice mitigation technologies. This presentation provides an overview of warranty approaches currently used by different turbine manufacturers and discusses practical experiences gained from executing warranty tests in operating wind farms. Based on real warranty evaluation projects, the presentation highlights lessons learned from the verification process and demonstrates how methodological choices can influence warranty outcomes.

Web site: https://www.vindteknikk.com/

Short biography: Simo Rissanen is a Senior Adviser at Kjeller Vindteknikk / Norconsult with more than 15 years of experience in cold-climate wind energy. His work focuses on various wind energy analysis including icing assessment, ice mitigation technologies, energy yield assessment and SCADA-based wind farm performance assessment. He has participated in numerous wind energy research and consulting projects. He has more than a decade of experience in wind energy research at VTT technical research centre of Finland.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 3. Validation, field experience including human aspects, 4. Practical operational methods and experiences (incl. financing, construction, O&M, HSE), 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

The icing trial: Same data, different verdicts

Patrice Roberge, Icetek, CA

Patrice Roberge (Icetek, CA), Philippe Guay (Icetek, CA), André-Bégin-Drolet (Université Laval, CA)

A blade heating system can pass or fail a performance warranty depending on which hours are included in the calculation. This raises a practical question for owners and suppliers: how much does the result depend on the system's performance, and how much on the assessment rules?
We examined five seven-day case studies from four wind farms, comparing measured production with expected ice-free production. Each case was assessed with and without active meteorological icing in the calculation period. We calculated both production retention and compensable energy, defined as the shortfall below the warranted production target.
In one case, excluding active meteorological icing increased production retention from 81% to 93%, changing a failure against a 90% target into a pass. Compensable energy fell from 36 MWh to zero. In another case, the system remained below the target, but compensable energy decreased from 366 MWh to 200 MWh.
The presentation uses these results to examine how icing-event definitions and calculation periods affect which losses fall within a warranty. We discuss what this means for sharing meteorological and technological risk between owners and suppliers, and the distinction between determining whether a system has failed its performance requirement and calculating the amount of energy eligible for compensation.

Web site: https://icetek.ca/

Short biography: Patrice completed his Ph.D. in mechanical engineering at Université Laval under the direction of André Bégin-Drolet. He has been working on the operation of wind turbines in cold climates for more than 10 years where he had the chance to contribute to the development of an ice detection device. He has authored and co-authored over 15 scientific publications. He now works at Icetek as the Lead Data Scientist where he helps operators understand precisely why their assets are struggling in icing conditions and provides solutions to improve their performance. He is a very inquisitive person that loves to learn and understand the why and the how of the everyday phenomena. He is passionate about football, skiing, snowshoeing and trekking.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI)
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Leveraging IPS performance envelope with icing loss uncertainty assessment: lessons for better warranty and project financing terms

David Grenier-Lévesque, Hydro-Québec, CA

David Grenier-Lévesque (HQ, CAN), Monelle Comeau (HQ, CAN)

The uncertainty related to performance under icing conditions is a key LCoE factor, both for yield and cost of financing. As a developer, Hydro-Québec has the will to tackle this challenge with its industry partners through four main tracks.

The first track consists of modifying an open-source Task 54 Blade heating Envelope model [1] to include additional type of precipitation beyond cloud-icing, namely wet snow and glaze. The model uses simplified thermodynamics to describe the different environmental conditions in which an IPS can efficiently remove ice from the blade (or not). Some meteorological parameter calculations were also refined, and all wind turbine input parameters (seven wind turbine models, from five OEMs) were validated with OEM's experts (blade geometry, IPS power and thermal parameters, RPM per wind speed curve, etc.).

The second track consists of merging the results from the first track (thermal model of specific wind turbines) with Nergica's tool GPEO, a numerical tool for predicting wind farm icing losses based on meteorological data time series. The goal of the collaboration with the Canadian research end innovation center was to refine the performance analysis of any wind turbine model on different developing wind sites in Quebec. This results in more accurate ice loss predictions than usual commercially available tools.

A third track was conducted to evaluate the cumulative uncertainties from the two first assessments on the net icing loss evaluation. This considers the uncertainties inherent to the OEM's wind turbine specifications, and from the meteorological model's assumptions used to simulate environmental conditions. Monte Carlo simulations helped to aggregate all parameters' uncertainties into a final ice loss uncertainty result with 95% confidence level range. The goal being to reduce the standard IEC 61400 figure used in relation with ice loss uncertainty.

The fourth track consists of working with OEMs to put in place IPS availability and performance warranty models in line with IEA Task 54 guidelines [2]. Foundation for the availability and performance warranties are the results of the three first tracks.

It is believed that having developers, OEMs, and independent third parties will lead us towards strong and clear warranty levels embedded in TSA and SMA agreements. Increasing the confidence level towards IPS performance and reducing ice loss uncertainty helps increasing the confidence on project yield, reducing financial costs, hence reducing LCoE.

The presentation shows lessons learned of the above: did it work, was it complicated, what was the uncertainty of this method compared to others, and did it help in decision-making processes?

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2. Godreau C, Wickman H, Karlsson T, Söderberg S, et al. Task 19 Performance Warranty Guidelines for Wind Turbines in Icing Climates. IEA; 2020.

Web site: https://www.hydroquebec.com/power-generation-grid/energy-sources/wind-power/

Short biography: I am a mechanical engineer that started with stress and design-to-cost management with Airbus, before joining small-wind industry at Eocycle, a 20 yo startup based in Québec and Flanders. I

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI)
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

learned how to lead the design and development of 30-100kW stall-regulated wind turbines (I could play with aerodynamic, mechanical, electrical, controls, certification, cold climate development), and how to install, maintain, and repair them.

Two years ago, I joined Hydro-Québec, a nationalized utility historically dedicated to hydroelectricity production (+ transport and distribution), as the organization launched its plan 2035 which includes deployment of wind power for 10GW+. My role is to lead turbine technology requirements, technical relationships with OEMs and wind-related R&D activities.

Presentation format: Oral
Themes: 7. Innovations presented by suppliers of components and services (incl. data!)
Technologies: H) Other

Direct ice mass detection on wind turbine blades without electrical conducting sensors and wires in the blades of the wind turbine

Jesper Find Nielsen, Polytech, DK

Jesper Find Nielsen (Polytech A/S, DK)

Ice accretion on blades can be a significant problem in cold climates. Numerous ways to detect ice has be developed over the years, we present a way, where the actual ice mass is measured, this gives the possibility to have the wind turbine running until a severe amount of ice is accreted on the wind turbine blades, and to restart the wind turbine as soon as the ice is gone again.
The presented ice mass detection on wind turbine blades, using fiber optic accelerometers, uses some measurable parameters for calibration and operation.

The best spot to place the accelerometer in a blade is where most eigenfrequency eigenmodes has highest vibration amplitude and away from nodes of these eigenfrequencies. This is normally around one third of the blade length from root but divagates from blade-to-blade type.

Using fiber optic sensors only in the blades, no extra effort needs to be made to make sure lightning is not an issue, fiber optic sensors can be used in lightning intense areas.

When detecting ice mass on Wind Turbine Blades, several eigenfrequencies are needed to make sure no false positives and false negatives are measured.
With our current system we can detect down to roughly 10kg of ice on the outer half of a 70m long onshore blade, this is approximately 3mm thick ice 10cm wide on the outer half part of the blade. Ice thicknesses below 2cm is considered safe for people and buildings below if the ice falls of the Wind Turbine Blades, because thinner ice will evaporate before it fits the ground.

Web site: https://www.polytech.com/solutions/ice-monitoring/

Short biography: M.Sc. Physics, Master of Wind Energy Jesper Find Nielsen.
Currently at Polytech for the last 3 years.
12 years combined experience doing Wind Turbine Blade Certification tests, from Sparkær Centret (Risø), Siemens Wind Power/SGRE, and BLAEST.
10 years combined experience with optical sensors in Wind Turbine Blades on running Wind Turbines and data handling of these, from Siemens Wind Power/SGRE, BLAEST, Vestas, and Polytech. As part of this introduced and integrated optical FBG sensors as sensor technology for component and turbine tests at Siemens Wind Power/SGRE 2012 to 2019.

Presentation format: Oral
Themes: 3. Validation, field experience including human aspects, 4. Practical operational methods and experiences (incl. financing, construction, O&M, HSE), 5. Control strategies including forecasting and de-/anti-icing, 7. Innovations presented by suppliers of components and services (incl. data!)
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Raising the performance of blade-based ice detection on Nordex turbines – adaptive referencing and field validation

Sonja Hesse, Wölfel Wind Systems GmbH + Co. KG, DE

Dr. Carsten Ebert (Wölfel Wind Systems, DE), Christoph Klein (Wölfel Wind Systems, DE)

For ice detection, reliable shutdown is only half the task. In cold climates, operators also need a reliable basis for bringing a turbine back into operation once the icing event has ended. Vibration-based blade ice detection has been used on Nordex wind turbines for many years. Based on this field experience, the evaluation algorithms have now been further developed.

A new generation of algorithms has been developed to make the ice evaluation more adaptive to changing turbine behaviour. Instead of relying on a limited number of predefined operating ranges, the new approach automatically builds and continuously extends its reference of normal blade dynamics. New operating conditions can be learned during operation. Improved signal processing and the treatment of interfering frequencies further increase the availability and stability of the ice indicator.

The full field evaluation covers seven pilot WTGs of the Nordex N117, N131 and N149 platforms over two winter periods. The turbines are analysed with regard to indicator availability, false alarms, indicator stability and icing-related alarm times. For selected turbines, the same recorded measurement data are processed with both the previous and the new evaluation method. This provides a direct comparison without differences in turbine operation, weather or icing conditions between the two evaluations.

As one example, the evaluation of a reference turbine showed 25% less accumulated ice-alarm time with the new algorithm, corresponding to 34.6 hours. During these avoided alarm periods, the turbine produced an additional 64.83 MWh. The same comparison also showed even higher indicator availability and more stable indicator behaviour.

The presentation will discuss the field results across the pilot WTGs and relate them to the technical changes in the evaluation method. The aim is to show where an established blade-based ice detection system can still gain performance through improved evaluation software, while keeping the measurement principle unchanged.

A short outlook will show how the same analysis of blade dynamics can also be used for monitoring tasks beyond ice detection.

Web site: https://www.woelfel.de/branchen/windenergie/shm-idd-blade.html

Short biography: Sonja Hesse is Product Manager Monitoring Systems at Wölfel, where she is responsible for the product management of monitoring solutions for wind turbine rotor blades, with a particular focus on blade-based ice detection. She joined Wölfel and the wind industry in 2024, bringing more than 15 years of previous experience in product management for medical systems and medical devices. In her current role, she has closely supported the field validation of the new ice detection algorithms presented at WinterWind.

Sonja holds a degree in Industrial Engineering from TU Kaiserslautern. Outside work, she has practiced karate for many years and holds a black belt. She strongly believes that many of today's challenges could be addressed more effectively if people treated each other and the natural environment with greater respect.

Presentation format: Oral
Themes: 3. Validation, field experience including human aspects
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Difference between ambient and blade temperature impacting the ice detection

Daniel Brenner, Weidmüller Monitoring Systems, DE

Daniel Brenner et al (Weidmüller Monitoring Systems, DE)

Ice growth at blades of wind turbines occurs at a temperature around 0°C, but it may stay at the blade at much higher or lower ambient temperatures.

The presentation will show, based on our measurements of blade temperature and the ambient temperature values from the turbine, that the two can differ significantly.

The speech will present several icing examples with temperature trends and specifically show cases of ice accretion at ambient temperatures above +5°C, since the blade's huge thermal inertia with the isolating ice crust keeps the blades temperature low.

Furthermore, the effect of solar radiation at 0°C can melt the ice before the ambient temperature rises.

On the other hand, ice growth does not occur at very low temperatures, e.g. below -5°C since there is nearly no humidity in the air. Nevertheless, already existing ice accretion on the blade may stay at the blade even if it is cooling down to e.g. -15°C.

These examples show that blade temperatures give important additional information for improving ice detection on turbine blades.

The presentation additionally gives the audience a deeper insight into how fast ice growth as well as ice melt can occur, including an estimation of the ice mass for different icing events.

Web site: https://www.weidmueller.com/int/

Short biography: As Head of Monitoring at Weidmüller Monitoring System GmbH in Dresden, Germany, Dr. Brenner and his team continuously monitor over 7000 turbine rotors of various manufacturers in different regions and climates.

Dr. Brenner studied electrical engineering in Dresden and worked for BMW in Munich during his diploma thesis. He graduated with a PhD in mechanical engineering from the University of Magdeburg where he studied the lifetime of wind turbine gearboxes. During the last 17 years he has been responsible for the development of condition monitoring methods for wind turbine rotor blades. In the beginning of his career in the wind industry he also climbed into the blades of several turbines.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 3. Validation, field experience including human aspects, 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Ice throw risk assessment in wind turbines: The role of operational strategies and anti-/de-icing systems

Hamid Sarlak, DTU, DK

Hamid Sarlak (DTU, DK)

Ice throw from wind turbines is an established safety concern in cold climates, yet current risk assessment approaches often treat ice shedding primarily as a function of natural icing and turbine operation. The increasing deployment of anti- and de-icing technologies, together with operational strategies such as shutdown, curtailment, reduced rotational speed, and controlled restart, introduces additional mechanisms that may alter ice accumulation, detachment, and throw characteristics. However, the extent to which these measures modify ice throw risk is not yet systematically established, and their effects are rarely integrated consistently into existing risk assessment frameworks.

This presentation provides a state-of-the-art review of ice throw risk assessment, focusing specifically on the interaction between turbine operational strategies, ice protection systems, and ice shedding. Existing approaches for modelling ice accumulation, detachment, fragment characteristics, trajectories, and spatial impact probability are reviewed and compared. Particular attention is given to evidence concerning active de-icing during rotor operation and the potential risk reduction associated with effective anti-icing.

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Web site: https://www.linkedin.com/in/hamid-sarlak/

Short biography: Hamid Sarlak is an associate professor of aerodynamics and CFD and an educational lead at the Technical University of Denmark.

Presentation format: Electronic poster
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI)
Technologies: G) Snow, snow removal, avalanches, controlling snow drift, etc.

Comparative thermal modelling of electrical resistance heating and hot-air de-icing systems for wind turbine blades in cold climates

Ali Sarhadi, Technical University of Denmark (DTU), DK

Hamid Sarlak, Technical University of Denmark (DTU), DK

Ice accretion on wind turbine blades in cold climates can reduce aerodynamic performance, compromise operational reliability and result in significant energy production losses. Active blade heating offers a means of mitigating these effects, but the relative thermal performance and energy requirements of different heating technologies remain important considerations for cold-climate wind turbine operation.

This study investigates two blade heating approaches: electrical resistance (Joule heating) surface heating using resistive heating elements and internal hot-air circulation. A comparative numerical finite element (FE) framework is developed using a representative blade cross-section based on the DTU 10 MW Reference Wind Turbine. The model incorporates a realistic composite blade structure to investigate how material thermal properties, laminate thickness and internal structural features influence heat transfer from the heating system to the external blade surface.

For Joule heating, resistive heat generation is represented as a heat source input within or adjacent to the blade laminate. For hot-air circulation, conjugate heat transfer between the internal airflow and the composite blade structure is modelled to resolve convective heat transfer and conduction through the blade wall. Both configurations are assessed under comparable ambient temperatures, external airflow conditions and heating-power constraints. The analysis focuses on transient temperature distributions, surface temperature uniformity, and required heating time to achieve the melting temperature, accounting for internal and external convective heat transfer and thermal losses to the surroundings.

The study aims to identify the principal thermal limitations of each heating approach and establish the operating conditions under which Joule heating or hot-air circulation may offer advantages. By applying a common modelling framework to both technologies, the work will provide a basis for evaluating their relative thermal performance and a guideline for the design of energy-efficient blade heating systems for wind turbines operating in cold climates. The framework can subsequently be extended to include ice melting, water-film transport and refreezing to assess de-icing effectiveness under realistic icing conditions.

Web site: https://orbit.dtu.dk/en/persons/ali-sarhadi/

Short biography: I am a Senior Researcher at the Technical University of Denmark (DTU), Department of Civil and Mechanical Engineering, with a PhD in Mechanical Engineering.
My research expertise lies in coupled multi-physics modeling of manufacturing processes and ro-botic polymer composite 3D printing, solid mechanics, design optimization and machine-learning-assisted thermographic analysis of composite structures in wind turbine blades. I combine FE coupled multiphysics modelling, material constitutive models, computational mechanics, and machine-learning methods to understand and predict interactions be-tween physical phenomena in a manufacturing process/engineering system, and accordingly optimize the process/system performance.
I enjoy football, nature and wildlife. Beyond my research activities, I have a strong interest in emerging technologies and scientific innovation, as well as following developments in advanced manufacturing and sustainable engineering solutions.

Presentation format: Electronic poster
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI)
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

From icing conditions to turbine impact: the two-channel Icing Impact State

Jonathan Nixon, University of Kent, UK

Abhishek Kallarappayi (Coventry University, UK), Jonathan D. Nixon (University of Kent, UK)
Charles Godreau (Nergica, CA)

Icing conditions and their effects on wind turbine operation do not always coincide. Ice may accumulate with little effect on production, while operational losses may persist after atmospheric icing conditions have subsided. This study introduces the Icing Impact State (IIS), a two-channel framework that distinguishes atmospheric ice-accretion potential from turbine operating response, providing a clearer interpretation of icing events and turbine recovery.

The framework was developed using one-minute SCADA, meteorological and icing-sensor data from a Canadian wind farm between December 2023 and April 2024. The analysis covered 77 icing events from the primary turbine, with additional evaluation on a second turbine at the same site. The atmospheric channel estimates accretion potential using a Makkonen-based formulation, while the response channel combines icing-sensor severity with rotor-speed shortfall relative to clean operation. Neither channel uses measured power as an input, although rotor speed and power are physically linked.

During March–April, the atmospheric channel was strongly associated with sensor-measured ice growth over the following 30 minutes (Spearman's $\rho = 0.803$), while the response channel distinguished reduced from normal production (ROC-AUC = 0.919). Analysis of 49 transitions from sensor-defined accretion to persistence showed that the same icing phase could involve substantial production loss, standstill or little operational impact. In 28 events, the IIS response channel indicated sustained recovery towards normal turbine operation, accompanied by low relative power loss, a median of 2.1 hours before sensor-defined ablation began. This shows how IIS can identify operational recovery despite continued sensor indications of ice, helping operators distinguish the presence of ice from its impact on turbine operation.

The IIS therefore provides a more informative representation of icing events by separating conditions favourable to ice growth from their observed operational consequences. This distinction could support the assessment of ice-protection performance and turbine recovery, although further validation across sites and winters is needed before operational benefits can be established.

Web site: https://www.kent.ac.uk/engineering-and-digital-design/people/5704/nixon-jonathan

Short biography: Dr Jonathan Nixon is an Associate Professor at the University of Kent, specialising in renewable energy, systems modelling and artificial intelligence. His research develops AI-driven methods to improve the performance, reliability and resilience of clean energy technologies, with a particular focus on wind energy in cold climates.

His cold-climate wind research encompasses icing prediction, ice-protection performance and adaptive turbine operation, combining machine learning, optimisation and engineering models. He represents the UK within IEA Wind Task 54 on Cold Climate Wind and has undertaken multidisciplinary research on wind turbines operating in cold environments, supported by the Royal Society, the British Council and the European Union.

Beyond wind energy, Jonathan applies modelling, AI and optimisation across a range of renewable-energy and energy-access challenges. His international work has included solar microgrids, smart street lighting and digital monitoring systems for refugee and displaced communities in Rwanda and Nepal. He recently led the Solar Energy Transitions project on solar-battery e-cooking systems in sub-Saharan Africa and worked with UNICEF on smart, climate-resilient water-pumping solutions.

Presentation format: Electronic poster
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 4. Practical operational methods and experiences (incl. financing, construction, O&M, HSE), 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

The cost of icing and the gain of forecasts

Sigbjørn Grini, Kjeller Vindteknikk, part of Norconsult, NO

Sigmund Guttu (Kjeller Vindteknikk, part of Norconsult, NO), Christoffer Hallgren (Kjeller Vindteknikk, part of Norconsult, SE), Mona Kurppa (Kjeller Vindteknikk, part of Norconsult, FI)

Atmospheric icing on turbines remains a significant challenge for wind farms operating in cold climates. The most pronounced impacts are production losses, increased operational costs, turbine degradation and safety risks. Nevertheless, continuous improvements in weather forecasting, ice detection systems and camera imaging for instance, together with more empirical data and machine learning provide new tools to manage these challenges and reduce the cost of icing. The following work highlights two areas where forecasting may significantly reduce the cost of icing: personnel safety and participation in the electricity markets.

The research project Safe Operation of Wind Farms in Winter Climates has been finalized in 2026, where a decision-support dashboard has been developed to help service personnel assess the current icing situation in the wind farm and anticipate upcoming icing events over the next seven days. Here, the safety of the personnel is key, but managing that risk may contribute to maintenance being performed more timely and also reduce the downtime cost.

A second area concerns the impact of icing on power production forecasts and energy market participation. The IceLossForecast model combines physical understanding of icing processes with machine learning techniques and ensemble forecasting to improve predictions of icing-related production losses. More accurate forecasts can provide balance responsible parties and asset owners with improved information for day-ahead and intraday bidding, thereby reducing uncertainty associated with power production forecasts.
Analysis of operational wind farm data indicates that improved forecasting of icing losses can reduce the costs associated with forecast errors by approximately 10%. For a representative Finnish wind farm experiencing annual icing losses of around 4% of the total energy production, this corresponds to average reductions in imbalance costs of approximately €15,000 per year over the period 2016-2025. During years characterized by particularly high imbalance price volatility, such as 2023 and 2024, the estimated value increased to as much as €80,000 per year. These findings suggest that the economic value of improved icing forecasts is strongly influenced by prevailing market conditions and may increase substantially during periods of extreme price volatility.

Both these examples demonstrate how modern icing forecasting solutions can reduce the cost of icing making the risk more manageable and creating value through reduced downtime and improved production forecasting.

Web site: www.vindteknikk.com

Short biography: Sigbjørn Grini holds a PhD in Solar Energy and is head of R&D for wind and solar in Norconsult. He has for the past 7 years been working at Kjeller Vindteknikk focusing on research, especially within icing, operational services and solar energy. In his spare time you will likely find him playing tennis or programming using AI.

Presentation format: Oral
Themes: 3. Validation, field experience including human aspects
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

From design to field operation: Validation of the NORDEX N175 anti-icing system

Ines Runge, Nordex Energy SE & Co. KG, DE

Ines Runge et al (Nordex, DE)

Atmospheric icing can significantly reduce the energy yield and operational availability of wind turbines in cold climates. Effective anti-icing systems are therefore essential to prevent ice accretion on aerodynamically critical regions of the rotor blades. Beyond demonstrating the overall functionality of such a system, its validation requires a detailed assessment of the blade surface temperature distribution under representative operating conditions.
This contribution presents the anti-icing system of the N175 rotor blade and the measurement methods used for its thermal validation. The system description covers the underlying design concept, the heated blade areas, and the integration and operation of the anti-icing system within the wind turbine.
A key element of the validation is the measurement of blade surface temperatures using infrared thermography. Thermographic measurements are conducted both at turbine standstill and during rotor operation. Measurements at standstill provide detailed information on the spatial temperature distribution and enable the identification of local temperature variations within the heated blade sections. Measurements of the rotating rotor complement this assessment by capturing the thermal behavior under representative operating conditions, including the effects of forced convection and the continuously changing blade position.
In addition, temperature sensors installed directly on the blade surface provide continuous local measurements. These data are used to assess the transient thermal response of the heating system and to support the interpretation and verification of the thermographic measurements.
The presentation addresses the measurement configurations, the specific challenges associated with infrared thermography of stationary and rotating rotor blades, and the complementary use of thermography and surface-mounted temperature sensors. By combining spatially resolved thermal imaging with continuous local temperature measurements, the proposed approach provides a comprehensive assessment of the thermal performance of the N175 anti-icing system and supports its validation for operation under cold-climate conditions.

Web site: www.nordex-online.com

Short biography: Dr. Ines Runge is a Senior Engineer in the Blade Engineering department at Nordex Energy and holds a PhD in mechanical engineering. She began her professional career at an automotive supplier before joining Nordex. Since 2011, she has been working on the Nordex anti-icing system, with a focus on system design and prototype evaluation. Outside of work, she enjoys long walks with her dog and baking cakes for her family.

Presentation format: Oral
Themes: 3. Validation, field experience including human aspects
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Advancing anti-icing technology for cold-climate wind turbines: End-to-end validation from concept to field operation

Miguel Angel González-Posada, Siemens Gamesa, ES

Hannes Friedrich (SGRE, DE), Esteban Belmonte (SGRE, ES), Javier Garcés (SGRE, ES), Felix Rittel (SGRE, DK)

In recent years, Siemens Energy Wind Power has developed an advanced Anti-Icing System (AIS) to improve wind turbine performance and reliability in icing conditions. The program applies an end-to-end, cradle-to-cradle validation approach spanning design studies, modelling, component and subsystem testing, full-system verification, and field validation.
Extensive subsystem testing—including validation of the Lightning Protection System (LPS)—has confirmed performance, durability, control strategies, and operational robustness. A full-scale turbine prototype, operating since 2023, complements this work by providing a growing track record and valuable multi-season data from real icing conditions.
Together, subsystem and prototype validation link laboratory results to field performance, reduce technical risk, and establish the maturity needed to integrate the technology into future products.
Keywords: Anti-Icing System, Cold-Climate Wind Energy, Technology Validation, Prototype Testing, Technology Maturation, Ice Mitigation, Risk Mitigation.

Web site:
https://www.bing.com/ck/a?!&&p=38daf39618098118509d115f9b60c8061e8ae595854408e16fa89d8a0e3632edJmltdHM9MTc5MTE1ODQwMA&ptn=3&ver=2&hsh=4&fclid=0e7e2ea4-7104-6e9e-3042-383d709a6f36&psq=siemens+gamesa+url&u=a1aHR0cHM6Ly93d3cuc2llbWVuc2dhbWVzYS5jb20vZ2xvYmFsL2VuL2hvbWUuaHRtbA

Short biography: Senior Key Expert in Product Management at Siemens Energy, with extensive experience in the wind energy sector. He specializes in product strategy, technology portfolio management, and innovation governance, helping bridge the gap between technology development, market needs, and business value creation.

Throughout his career, Miguel has worked at the intersection of engineering, product management, and strategic planning, leading initiatives related to renewable energy technologies, turbine product development, and long-term technology roadmaps. His expertise spans product lifecycle management, technology prioritization, market intelligence, business case development, and cross-functional stakeholder alignment.

A strong advocate for innovation-driven growth, Miguel has been actively involved in shaping the future of wind energy solutions, with particular focus on cold climate technologies, blade innovations, leading-edge protection, circularity and recyclability, anti-icing systems, and next-generation turbine platforms. He combines deep technical understanding with a strategic business mindset to identify opportunities that improve customer value, competitiveness, and profitability.

Areas of expertise: Product Management, Wind Energy, Technology Strategy, Innovation Management, Product Roadmaps, Portfolio Prioritization, Business Case Development, Renewable Energy Markets, Competitive Benchmarking, Circular Economy, and Cross-Functional Leadership

Presentation format: Oral
Themes: 8. Other
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Advancing wind turbine performance in cold climates: The Vestas improvement journey

Stephen Jude Buggy, Vestas, UK

Stephen Jude Buggy (Vestas, UK)

Wind turbines operating in cold climates face a unique combination of environmental and operational challenges. Icing can affect aerodynamic performance, energy production and turbine operation, making effective detection, mitigation and control an important part of optimising turbine performance in these environments.
Vestas has developed a range of technologies and operational approaches to address these challenges, including ice detection, blade anti-icing systems and associated turbine and plant-level control strategies. These solutions continue to evolve as operational experience, field data, testing and technology development provide new opportunities for improvement.
This presentation provides an overview of the ongoing Vestas cold-climate solutions improvement journey. It will consider how experience from operating turbines in icing environments is used to identify improvement opportunities and how these are subsequently evaluated through analysis, testing and technology development.
The presentation will highlight selected examples from current cold-climate development activities, illustrating how improvements in areas such as system performance, reliability, monitoring, control and validation can contribute towards more effective operation of wind turbines in challenging icing environments.

Web site: https://www.linkedin.com/in/judebuggy

Short biography: Dr. Stephen Jude Buggy is an Engineering Specialist at Vestas, specialising in blade protection and cold climate wind turbine technologies. He has led the development and integration of anti-icing systems and advanced electrical solutions for wind turbines operating in harsh environments. With more than 20 years of experience spanning renewable energy, sensing technologies, condition monitoring, and systems engineering, Stephen brings a practical perspective on the challenges of operating wind energy assets in cold climates. He holds a PhD from Cranfield University and is a Chartered Engineer (CEng MIET). Originally from Ireland and now based on the Isle of Wight, he enjoys trail running and exploring the outdoors when not working on wind energy innovation.

Presentation format: Electronic poster
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI)
Technologies: E) Offshore

On the transition from glaze to rime ice formation on wind turbines

Sönke Maus, NTNU Trondheim, NO

Sønke Maus, NO

An important aspect of icing and ice adhesion on wind turbines is the transition from glaze to rime ice formation. This transition depends on several factors like the temperature and humidity of air, the liquid water transport onto the blades, the blades' rotational velocity, shape and heat transfer. Less known is the dependence on impurities (e.g. the seawater salinity for offshore wind turbines). Here a theoretical analysis is presented how the transition is affected by these factors and environmental conditions, with particular focus on the differences in glaze and rime ice regimes during atmospheric versus sea spray icing, contrasting on- and offshore wind turbines.

Web site: https://www.ntnu.edu/employees/sonke.maus

Short biography: I am genuinely interested in ice, its physics and role in the environment. Educated as physical oceanographer (University of Hamburg, Germany) I have approached sea ice from the ocean and based on topics related to sea ice physics in the climate system. For my Phd (University Bergen, 2007) I studied sea ice microstructure and crystal growth to improve the understanding of sea ice properties on a fundamental level. During the following years as Researcher and associate Pofessor (University Bergen, 2007-2013) I started working with X-ray imaging of ice and snow, in the lab and at synchrotron radiation facilities. This research has always been guided by the challenge to incorporate micro-scale sea ice physics into larger scale models of ice-atmosphere-ocean interaction, climate and engineering applications.

In the coming years I had a short break from research as a consultant (2013-2014, www.sea-ice.no) and have since 2015 been working with research on ice at the Department of Civil and Environmental Engineering (IBM) of the Norwegian University of Science and Technology (NTNU). Here I extended my expertise to applied engineering problems where ice and sea ice microstructure is relevant, e.g. sea-ice-oil interaction, sea spray icing, frost-concrete interaction, as well as sea ice microphysics related to Arctic climate (MOSAiC expedition, https://mosaic-expedition.org/).

My personal interests are hiking, cross-country skiing, music and cooking. I am engaged in disseminating ice and climate research to school kids and the general public, and convinced that human being in the richer states of the world need to change consumption and life style to create a better and sustainable world.

Presentation format: Electronic poster
Themes: 7. Innovations presented by suppliers of components and services (incl. data!)
Technologies: H) Other

Structural repair of wind turbine blades using vacuum infusion

Greger Nilsson, Blade Solutions, SE

Oskar Bergquist (Blade Solutions, SE)

During operation, wind turbine blades are exposed to cyclic loading, erosion, impacts, and environmental conditions that can cause delamination, cracking, and local damage to the composite structure. This paper describes a systematic workflow for structural repairs using vacuum infusion. Blade Solutions performs these repairs on site using industrial rope access, enabling work to be carried out directly on the blade without dismantling it. Working at height also imposes specific requirements regarding safety, access, weather protection, equipment, and process control. Following damage assessment, the repair area is prepared with a controlled layup. Replacement materials are selected and oriented to minimize stress concentrations. The repair patch is then sealed using vacuum bagging film, sealant tape, and prepared for resin distribution and air evacuation. Before infusion, a vacuum test is performed to identify leaks and ensure a stable vacuum level. During infusion, the pressure differential drives the resin through the dry fibre reinforcement. Once full impregnation has been achieved, the laminate is cured under continuous vacuum in accordance with the processing requirements of the selected resin system. Finally, the repair is visual inspection to detect porosity. Loads are transferred from cracks and damage to a repair patch. Compared with traditional hand lay-up, vacuum infusion generally produces higher laminate quality through more consistent fibre impregnation and lower void content. The method can provide uniform fibre impregnation, low void content, and good repeatability, but it requires careful process planning and adaptation to the blade geometry, materials, damage characteristics, and prevailing working conditions. A standardised approach to preparation, vacuum control, infusion, and verification is therefore essential for a safe and durable structural repair.

Web site: bladesolutions.se

Short biography: My interest in composite materials began before I started Blade Solutions. As I have been using composite materials a long time through sailing and skiing, where strong, lightweight, and durable materials make a real difference. This led me to study and research about composites, building expertise in material properties, damage development, and repair methods. Applying that knowledge to wind turbine blades was a next step.
I am motivated by helping wind turbines operate longer and safer. Early inspection and repair can prevent costly downtime, limit larger repairs, and reduce component replacement, creating both economic and environmental value.
I focus on safety and quality repairs in every project. By combining research-based expertise with practical craftsmanship, I aim to be a flexible and reliable partner and contribute to a more resource-efficient wind energy industry. That is for me responsibility.

Presentation format: Oral
Themes: 6. Independent comparisons of methods and products
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Managing the ice throw risk – A subtask of IEA Wind Task 54

Claas Rittinghaus, Energiewerkstatt, AT

Alexander Stökl (Energiewerkstatt, AT)

Wind turbine icing has been a challenge in wind farm development and operation for the past twenty years and it will be for the years to come with ever growing turbine dimensions, closer proximity to infrastructure and populated areas as well as cold climate locations gaining in development interest. The risk of ice throw from wind turbines is one crucial factor influencing siting decisions, turbine selection and operational strategies in cold climate wind power.

IEA Wind Task 54 (former Task 19) introduced the first standardized procedure for ice throw risk assessment in 2018. Before that, the treatment of icing induced health & safety risks varied throughout the regions and countries with icing climates quite significantly. But even with the IEA Wind International Recommendations on Ice Fall and Ice Throw Risk Assessment being widely adopted nowadays, some differences remain, in particular with respect to the conclusions drawn from the assessments' results.

Within the current term of IEA Wind Task 54 a subtask working group was formed targeting a comparative study on the management of ice throw risk in wind energy projects. It shall cover a benchmark of ice throw simulation procedures for risk assessment in the development and permitting phase as well as mitigating measures required by authorities and operational strategies implemented to secure a safe operation. As the general risk assessment procedure has also been adopted in IEC standardization (IEC TS 61400-31) over the past years, the comparative study shall support this advancement as well as a further standardization of methodologies and interpretation of results throughout the cold climate impacted countries and regions.

The presentation outlines the preliminary results compiled by the subtask working group and gives an overview of current and planned activities as well as related research activities in the participating countries.

Web site: https://energiewerkstatt.org/wind/?lang=en

Short biography: Claas Rittinghaus earned his diploma in physics at the University of Bielefeld, Germany. After 10 years of working as a product manager for Phoenix Contact in Blomberg, Germany, he joined the Energiewerkstatt in Friedburg, Austria, in 2021 as a project manager in research and consultancy services. As Austrian participant of IEA Wind TCP Task 54 specifically icing topics are in his focus. He is a mountain enthusiast, in summer as in winter, and enjoys hiking, climbing, bouldering, downhill skiing and ski touring. Another passion of his is music, especially playing the guitar and singing.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI)
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Improving wind turbine ice-fall risk assessments through site-specific filtering of meteorological data

Kevin Gutbrod, Pavana, DE

Janina Leinberger (Pavana GmbH, DE), Martin Richter-Rose (Pavana GmbH, DE), Martin Schneider (anemos Gesellschaft für Umweltmeteorologie mbH, DE), Ignacio Martin Santos (anemos Gesellschaft für Umweltmeteorologie mbH, DE)

Risk assessments for ice fall from wind turbines are an essential part of wind farm planning and permitting in regions exposed to icing conditions. The quality of the underlying wind data has a decisive influence on the outcome of the analysis. Based on wind data, the maximum fall distance of ice fragments of various sizes and shapes, as well as their probable points of impact, are calculated. Ice fall calculations are typically based on annual wind distributions, for example in the form of Weibull distributions over a twelve-month period. However, this data set does not consider the fact that ice formation on wind turbines only occurs under specific meteorological conditions and that, consequently, not all periods – such as the summer months – are equally relevant to ice formation on wind turbines.
This study examines how filtering wind data according to defined environmental factors affects the results of the risk assessment. It considers several sites in Central Europe that represent different wind zones and climatic conditions. Meteorological variables that promote the formation of ice accretion on wind turbines are compared as filtering criteria.
The trajectories of the ice fragments were simulated using a simulation tool developed by Pavana GmbH. The results show that both the calculated maximum fall distances and the sector-specific probabilities of ice fragments striking a target depend significantly on the wind data set selected. Consequently, identical locations may yield markedly different risk assessments when based on different data sets.
The study provides practical recommendations for the site-specific processing of wind data and sets out a systematic approach to selecting suitable filtering criteria. The result is a regionally differentiated procedural model that can contribute to more realistic and, at the same time, robust risk assessments for ice fall.

Web site: https://www.pavana-wind.com/

Short biography: As Teamlead Noiuse, Shadow, Ice at Pavana GmbH, Kevin Gutbrod combines a strong engineering background with extensive expertise in wind energy. He holds a bachelor's degree in Mechanical Engineering with a specialization in Automotive Engineering and a master's degree focused on Wind Energy Technology. As part of his academic career, he completed his master's thesis at the Fraunhofer Institute for Wind Energy Systems (IWES) in Bremerhaven. Drawing on this solid scientific foundation and several years of industry experience, he has become a trusted expert in environmental and permitting assessments for wind energy projects.

In his role as an expert consultant, Kevin Gutbrod supports project developers and operators in addressing environmental and safety challenges throughout the planning, permitting, and operational phases of wind energy projects. His areas of expertise include noise emissions, infrasound, periodic shadow flicker, as well as ice fall and ice throw risk assessments. Through his work, he helps ensure regulatory compliance while contributing to the safe and sustainable development of renewable energy projects.

Beyond his day-to-day project work, Kevin Gutbrod is actively involved in technical knowledge exchange and industry dialogue. He regularly represents Pavana GmbH as a speaker at trade fairs, conferences, and industry events, where he shares practical experience and presents current methodologies and regulatory developments in environmental and risk assessment for wind turbines.

Outside of his professional activities, he enjoys sports and exploring different cultures through travel, reflecting his curiosity, openness, and enthusiasm for connecting with people from diverse backgrounds.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 7. Innovations presented by suppliers of components and services (incl. data!)
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Measuring liquid water content where the ice forms: requirements and concept for a wireless sensor on the rotor blade

Michael Moser, eologix-ping, AT

Michael Moser (eologix-ping, AT), Thomas Schlegl (eologix-ping, AT)

Liquid water content (LWC) and droplet size determine how fast ice builds up on a rotor blade and how much power a blade heating system needs to keep it free. In the field, LWC is measured at best on the nacelle or on a met mast. These positions do not always see the conditions on the blade. On large rotors, the blade tip can pass through the cloud base while the nacelle stays below it.

Instruments that measure LWC quantitatively come from aviation and atmospheric research. They need a power supply, mounting space and a budget that do not fit series use on wind turbines.

OEMs are now asked for performance warranties on ice protection systems. Performance envelopes based on wind speed and temperature leave out LWC, although it is one of the main drivers of heating demand. Without a field measurement of LWC, neither OEM nor operator can show whether an icing event was inside or outside the envelope. Who carries the risk of an event outside the envelope is then a matter of opinion, not of data.

eologix-ping develops an optical LWC measurement for its wireless blade sensor platform (patent pending). The sensor evaluates light scattered by droplets in the air volume next to the blade surface. Instead of an exact concentration, it resolves LWC in a few discrete intensity classes, normalized with the local inflow speed that the sensor derives from its own inertial measurement unit. Like the existing on-blade ice sensors, it is wireless, energy-autonomous and designed for any radial position up to the blade tip. Several synchronized sensors along one blade are intended to show how LWC changes with radius and to relate it to the ice accretion and surface temperature measured on the same blade section.

The contribution presents the measurement principle and first laboratory results against the calibration curve of an icing wind tunnel, including the resolution and the limits of the class-based approach. If available by February, we add first measurements from the field. We also discuss what a measured LWC on the blade can mean for heating control and for warranties that OEM and operator can both verify.

Web site: www.eologix-ping.com

Short biography: Michael Moser is co-founder and managing director of eologix-ping. After his PhD in electrical measurement engineering at Graz University of Technology, he co-developed the sensing technology behind the company's wireless blade sensors in 2014. Since then, he has worked on ice detection and blade heating for wind turbines in cold climates, from icing wind tunnel tests to field campaigns. Outside of work, he plays the piano - now "improvising" together with his one-year-old son and also teaches his daughter to play.

Presentation format: Oral
Themes: 3. Validation, field experience including human aspects
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Effect of surface roughness and adhesion on ice accretion: Preliminary experimental results for airfoil and cylindrical geometries

Hamid Sarlak, DTU, DK & VTT, FI

Hamid Sarlak (DTU, DK), Timo Karlsson (VTT, FI)

Surface characteristics can influence the initiation and development of ice accretion on wind-turbine components. This study presents preliminary experimental results from two complementary investigations, performed at the climatic wind tunnel at VTT, Finland, examining the influence of surface properties on ice formation.

The first experimental campaign investigated the performance of icephobic surfaces applied to a non-rotating cylindrical geometry. Two configurations were tested under controlled icing conditions, where ice accretion and surface behaviour was compared for a iceophobic surface compared against a reference smooth surface (polished Alumunim). Under the conditions investigated, the tested icephobic surfaces did not demonstrate a significant reduction in ice accretion, highlighting the potential limitations of icephobicity as a standalone strategy for preventing ice build-up.

The second campaign examined the effect of surface roughness on ice accretion over an NACA airfoil. Two surface conditions were considered: a smooth reference surface and a surface modified using 40-grit sandpaper. The resulting ice accretion are characterized and identify differences in ice build-up associated with surface roughness.

Web site: https://www.linkedin.com/in/hamid-sarlak/

Short biography: Hamid Sarlak is a researcher and associate professor of aerodynamics and CFD at DTU, DK. And a member of the IEA Task 54, responsible for the Danish activities.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI)
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Gone with the wind: field observations of the rotor icing ablation mechanism

Charles Godreau, Nergica, CA

Ege Dundar (Nergica, CA)

In Eastern Canada, one or two extreme icing events per winter can account for over 80% of the annual icing loss at a wind farm. These extreme events are characterized by much longer duration of rotor icing persistence, leading to long standstill. With a more favorable electricity market based on long term PPAs, these icing events have less impact on the electricity price in Canada than in the Nordics . However, based on several discussions in recent editions of Winterwind, a similar pattern can be seen in the Nordics: isolated, long and extreme icing events happen and their duration extends beyond typical short-term forecast horizons.

In recent years, Nergica has been gathering icing events data at its research site in Gaspé, Québec, Canada. In the last year, these events have been parsed into the three main phases of an icing event: Accretion or meteorological icing as well as persistence and ablation for instrumental and rotor icing. Quantitative metrics corresponding to each phase have been developed and careful attention has been given to the transition between each phase.

The transition from rotor icing persistence to ablation is of particular interest in the context of extreme events for turbines without active ice protection systems: Why does the ice stay longer? Why can’t the ice shed from the rotor? What happens when it starts shedding?

The presentation will cover the experimental data gathered, compare quantitative metrics of icing event phases and discuss the key drivers of icing event phases transitions with a focus on rotor icing persistence and ablation.

Web site: www.linkedin.com/in/charles-godreau

Short biography: Charles Godreau specializes in wind turbine performance assessments in cold climates as well as icing detection and protection systems. He possesses strong skills in data analysis for operational turbines as well as for developing, planning and implementing research projects. He notably represents Canada in the International Energy Agency’s Task 54 working group on wind energy in cold climates and is an active member of Winterwind's program committee. In his free time, he enjoys improv and splitboarding.

Presentation format: Oral
Themes: 2. Recent research (theories, methods, verifications, visualization, applied AI), 5. Control strategies including forecasting and de-/anti-icing
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid, F) Drone, helicopters and fixed wing aeroplanes

Benchmarking ceilometer derived cloud liquid water content against high-end Cloudnet observations

Sara Koller, Meteotest, CH

Mathias Aschwanden (Meteotest, CH), Fabian Umbricht (Meteotest, CH), Sara Koller (Meteotest, CH)

Accurate calculation of liquid water content (LWC) profiles remains a significant challenge in observational meteorology. Precise LWC profiling for diagnosing and forecasting icing conditions is essential for industrial applications, particularly in wind energy, where blade icing impacts performance, and in aviation, icing on airfoils and rotor blades poses significant safety hazards.
A pragmatic method to derive vertical LWC profiles is calculating the adiabatic LWC. The adiabatic LWC represents the theoretical maximum liquid water available in a cloud, assuming an air parcel that undergoes moist adiabatic ascent starting from cloud base without entraining environmental air or losing water to precipitation. Adiabatic LWC can be calculated using the parameters temperature and pressure combined with cloud base height. The thermodynamic profiles are provided by numerical weather prediction models, while cloud base height is continuously measured using ground-based ceilometers.
To evaluate the uncertainty of this simplified adiabatic ceilometer approach, a field campaign was conducted at a Swiss Federal Institute of Technology (ETH Zürich) research site in Switzerland, equipped with full Cloudnet instrumentation (Cloudnet supersite). Meteotest supplied and operated a ceilometer (Vaisala CL61) during the campaign.
Cloudnet is an operational data-processing framework, network, and data portal developed and maintained by the Finnish Meteorological Institute for continuous ground-based remote sensing of cloud and aerosol profiles. Cloudnet combines multi-sensor measurements including cloud radar, optical lidar, microwave radiometer, and thermodynamic profile data to accurately characterize cloud microphysics up to 15 km with high temporal and vertical resolution.
While the LWC derived by the Cloudnet algorithm with measurements of a supersite can be assumed as best possible guess by remote sensing, such supersites are too expensive to operate on an industrial scale. The option to reliably estimate LWC with relatively in-expensive ceilometer in near-real time could open new possibilities in icing monitoring, especially given the fact that cloud microphysics representation in numerical weather prediction models is also underlying significant uncertainties.
The objective of this study is to quantify the uncertainty of the ceilometer based adiabatic LWC calculation and explore further possibilities to estimate icing relevant parameters with ground-based LiDAR instruments. To do so, adiabatic LWC, backscatter and depolarisation profiles as well as numerical weather prediction-based icing algorithms are compared against Cloudnet's multi-instrument retrievals. This comparison helps to evaluate the possibilities of LiDAR measurements such as ceilometers for real time monitoring of icing conditions, which would represent a reliable, cost-effective solution for operational wind energy and aviation applications.
https://cloudnet.fmi.fi/

Web site: www.meteotest.ch

Short biography: Sara Koller holds a Master's degree in Environmental Geosciences from the University of Basel. Since 2009, she has worked in the wind department at Meteotest in Switzerland. In 2020, she was appointed head of the Wind & Ice team. Meteotest represents Switzerland in IEA Tasks 54 and 52, where Sara is an active member of the LiDAR in Complex Terrain working group and leads the LiDAR in Cold Climate working group for Task 52. With 17 years of experience, wind in all its aspects has been her primary focus. In her second life, Sara is a performance artist.

Presentation format: Oral
Themes: 4. Practical operational methods and experiences (incl. financing, construction, O&M, HSE)
Technologies: A) Wind, photo voltage, hybrid systems and hydro power incl. grid

Could seasonal forecasts provide information about icing losses?

Pia Isolähteenmäki, Kjeller Vindteknikk, part of Norconsult, FI

Mona Kurppa (Kjeller Vindteknikk, part of Norconsult, FI)

Interest in seasonal forecasts has increased in the energy market. The electricity demand is increasing due to electrification and the share of renewable energy of total production is constantly growing. This creates an emerging need for information about future power production and market conditions to support risk management. Seasonal forecasts have traditionally been useful for hydropower, where the important weather drivers such as precipitation and snowmelt change relatively slowly. Wind power is different, as there is no inherent storage associated with the resource. Wind conditions can change rapidly, and in cold climates wintertime production depends not only on wind conditions but also on icing conditions.

This raises a simple question: can seasonal forecasts also provide information about icing-related power production losses? Observations of icing-related production losses are available only for a limited number of winter seasons, which restricts the amount of historical data available for analysis. In addition, icing is the result of a complex interaction between several weather variables, including temperature, moisture and wind conditions. These factors may be combined in different ways under different large-scale weather patterns. Once ice has accumulated, the production impact can persist much longer than the weather conditions that initially caused the icing.

To explore this question, we reviewed recent research on seasonal forecasting and wind power, as well as the documentation of operational seasonal forecast providers. We also examined the seasonal forecasts available months before an icing episode in Nordics in recent years and compared them with observed weather and icing losses. The case highlights that understanding the relevance of seasonal forecasts for icing prediction requires both meteorological expertise and a good understanding of the icing process.

Web site: https://www.vindteknikk.com/

Short biography: Pia Isolähteenmäki works as an advisor at Kjeller Vindteknikk. She holds a double master's degree in Meteorology and Energy Technology and has seven years of experience as an operational meteorologist. Her work has also included research on future climate icing conditions in the Nordics. Pia is particularly interested in energy systems and markets, and how improved forecasting can support more efficient and sustainable energy use. Outside of work, she is an enthusiastic orienteer who enjoys challenging terrains and night races.