| Start time | Mo April 19 | Mo April 19 |
|---|---|---|
| 12:00 | Exhibition break 60 min | |
| 12:15 | | |
| 13:00 | **Opening session (1)**<br>Moderators: Jeanette Lindeblad & Stefan Gsänger | |
| 13:05 | Wind Power Around the World , Stefan Gsänger, World Wind Energy Association WWEA (45) | |
| 13:15 | Record 2020 masks mounting onshore wind challenges, Isabelle Edwards, Bloomberg, GB (12) | |
| 13:35 | Climate resilience vs. low cost renewables, Rosemary Barnes, Pardalote, AU (43) | |
| 13:55 | Announcements | |
| 14:00 | Exhibition break 30 min | Break 15 min |
| 14:15 | | **Workshop - Standards & warranties (3) 14:15-15:30** |
| 14:30 | **Improvements (2)**<br>Chairs: Tove Hamberg & Stefan Bill | Chairs: Jenny Longworth & Anders Björck<br>IEA Wind Task 19: Standardization of pre-construction icing loss assessment in upcoming IEC 61400-15 standard , Ville Lehtomäki, Kjeller Vindteknikk, FI (23) |
| 14:35 | Wear resistane multi-composite coating for wind power blades, JUN CHEN, Lulea University of Technology, SE (34) | Performance warranty guidelines for wind turbines in icing climates, Helena Wickman, Vattenfall, SE (29) |
| 14:50 | Yaw optimisation, Thomas van Delft, DNV, UK (17) | 5 minute break |
| 15:05 | Q&A | Workshop - Standards & warranties 14:50-15:30 |
| 15:15 | Exhibition break 30 min | Conclusions |
| 15:30 | | Break 15 min |
| 15:45 | **Modelling ice (4)**<br>Chairs: Luca Durstewitz & Enrico Sindici | **Ice Protection Systems (5)**<br>Chairs: Johanna Bohn & Bastian Ritter |
| 15:50 | On-site estimation of effective liquid water content, Patrice Roberge, Université Laval, CA (35) | The evaluation of state-of-the-art anti-icing surface solutions using a large scale icing test set-up, Joey Bosmans, Sirris, BE (24) |
| 16:05 | Operational icing forecast with a probabilistic approach, Jesper Thiesen, ConWx, DK (20) | Assessment of ENERCON blade heating performance in various conditions, Gilles Boesch, ENERCON Canada, CA (27) |
| 16:20 | Q&A | Q&A |
| 16:30 | Exhibition break 30 min | |
| 17:00 | **Modelling ice on WT (6)**<br>Chairs: Jennie Molinder & Alexander Stoekl | **Icing and its consequences (7)**<br>Chairs: Carla Ribeiro & Paul Froidevaux |
| 17:05 | Icing impact on trailing edge noise in wind turbines, Timo Karlsson, VTT Technical Research Centre of Finland, FI (28) | Development and calibration of state-of-the-art icing loss estimates using a new meteorological dataset, Øyvind Byrkjedal, Kjeller Vindteknikk, Norconsult, NO (33) |
| 17:20 | A complete model chain for icing of wind turbines, Johan Revstedt, Lunds Universitet, SE (8) | Towards improving wind energy in cold climate: how to quantify the use of alternative operational strategies, André Bégin-Drolet, Université Laval, CA (32) |
| 17:35 | Q&A | Q&A |
| 17:45 | Exhibition break/Mingle 45 min | |
| 18:30 | End of day | |

| Start time | Tu Apr 20 | Tu Apr 20 |
|---|---|---|
| 12:00 | Exhibition break 60 min | Break 15 min |
| 12:15 | | **Workshop - Risk of ice fall (9) 12:15-14:15** |
| 13:00 | **Session (8) - Load control**<br>Chairs: Rosemary Barnes & Richard Sahlberg | Chairs: Åsa Elmqvist & Michael Durstewitz<br>TRiceR, a cloud-based web application for supporting risk-based decisions associated with ice falling from wind turbine blades, Xavier VANWIJCK, Tractebel, BE (3)<br>Timeseries-based approach for volume risk assessment, Enrico Sindici, Natural Power, GB (4)<br>Challenges and opportunities in the communication of risk from Ice Throw, Karl Ove Ingebrigtsen, Norconsult, NO (15) |
| 13:05 | 6D inertial sensing on the blade surface - know the moves of your blade's surface, Michael Moser, eologix sensor technology, AT (10) | Break 10 min |
| 13:15 | Improving turbine annual energy production (AEP) and reducing O&M costs with real-time blade airflow quality monitoring and quantification under all environmental conditions and levels of blade contamination, John Maris, Marinvent, CA (13) | Workshop - Risk of ice fall (9) |
| 13:35 | Blade intelligence - Combined ice measurement and load monitoring, Nils Lesmann, Pheonix Contact, DE (2) | |
| 13:55 | Q&A | |
| 14:00 | Exhibition break | Conclusions |
| 14:15 | | Break 15 min |
| 14:30 | **Detecting ice - sensors (10)**<br>Chairs: Marianne Rodgers & André Bégin-Drolet | **Repairs (11)**<br>Chairs: Anna Lundsgård and Sven-Erik Thor |
| 14:35 | From turbines to farms: Using distributed ice detection to increase safety and accessibility, Theresa Loss, eologix sensor technology, AT (9) | Structural blade repair in artic climate, Resistive Vacuum Infusion, Greger Nilsson, Blade Solutions, SE (19) |
| 14:50 | Tackling ice throw risks by using sophisticated algorithms of blade-based ice detection, Bastian Ritter, Wölfel Wind Systems, DE (16) | Cost effective de-icing blade repairs, Morten Handberg, Wind Power LAB, DK (25) |
| 15:05 | Q&A | Q&A |
| 15:15 | Exhibition break 30 min | |
| 15:30 | | |
| 15:45 | **Mapping ice (12)**<br>Chairs: Eva Sjögren & Nils Lesmann | **Ice protection systems (13)**<br>Chairs: Mélissa Hugeux & Charles Godreau |
| 15:50 | Atmospheric icing on offshore wind farms in Northern Europe – a risk map, Carla Ribeiro, Wood Thilsted, UK (1) | Linnovation concepts for operation and service in cold climates, Sven-Erik Thor, Lindskog Innovation, SE (39) |
| 16:05 | Validation of a wind turbine icing model for site assessment, Noemi Tölg, Fraunhofer IEE (Research Institute), DE (31) | IPS retrofit for complex blades, Daniela Roeper, Borealis Wind, CA (40) |
| 16:20 | Q&A | Q&A |
| 16:30 | Exhibition break 30 min | |
| 17:00 | **Keynote session (14)**<br>Moderators: Elektra Kleusberg & Stefan Gsänger | |
| 17:05 | Comparison of four blade-based ice detection systems installed on the same turbine, Paul Froidevaux, Meteotest, CH (18) | |
| 17:20 | IEA Wind Task 19: Cold climate wind market study, Timo Karlsson, VTT Technical Research Centre of Finland, FI (21) | |
| 17:35 | Q&A | |
| 17:45 | Exhibition break/Mingle 45 min | |
| 18:30 | End of day | |

| Start time | We Apr 21 | We Apr 21 | We Apr 21 |
|---|---|---|---|
| 12:00 | Exhibition break 60 min | | Break 15 min |
| 12:15 | | | **Workshop - HSE (16) 12:15-14:15** |
| 13:00 | **Interesting odd topics (15)**<br>Chairs: Tanja Tränkle & Michael Moser | | Chairs: Maria Röske & Michael Henriksson<br>Safe turbine operation in icy conditions, Eva Sjögren, ENERCON GmbH, SE (26)<br>Return on experience: Working on a wind farm in icing conditions, Charles Godreau, Nergica, CA (14)<br>Simple rules-of-thumb for ice fall/throw safety distances, Alexander Stökl, Energiewerkstatt, AT (5) |
| 13:05 | Protection and lifetime improvement for bearings and gears by using silicon-based additive technology, Stefan Bill, Croda, DE (38) | | Break 10 min |
| 13:15 | Synergies between icing on wind turbines and UAVs, Richard Hann, Norwegian University of Science and Technology (NTNU), NO (11) | **The social and ecological environment (20)**<br>**Chairs: Sigrid Carstairs & Sebastian Meyer** | Workshop - HSE (16) |
| 13:35 | Re-use of wind turbine blade for construction and infrastructure applications, Alann André, RISE Research Institutes of Sweden, SE (37) | A road map for the wind energy industry: taking a proactive approach to the biodiversity challenge, Tove Hägglund and Åsa Abel, Ecogain, SE (41) | |
| 13:55 | Q&A | Digital business and collaboration platform for local anchoring and collaboration, Charlotte Larson and Oskar Ahlman, Vindkraftcentrum and Umeå University, SE (42)<br>Q&A | |
| 14:00 | Exhibition break | | Conclusions |
| 14:15 | | | Break 15 min |
| 14:30 | **Icing losses (17)**<br>Chairs: Theresa Loss & Øyvind Byrkjedal | | **Experiences of icing (18)**<br>Chairs: Isabelle Edwards & Matthew Wadham-Gagnon |
| 14:35 | Modelled icing losses with WICE: A blind test in France, Stefan Söderberg, DNV, SE (30) | | Lesson in winterisation from the UK, David Armour, Natural Power, GB (7) |
| 14:50 | Uncertainties of modelled production losses due to Icing, Marie Pedersen, EMD International, DK (6) | | Skellefteå Kraft:s experiences of operating wind turbines in cold climate and the need of a physical testing, Krister Efverström, Skellefteå Kraft, SE (36) |
| 15:05 | Q&A | | Q&A |
| 15:15 | Exhibition break 30 min | | |
| 15:30 | | | |
| 15:45 | **Final session (19)**<br>Moderators: Jeanette Lindeblad & Stefan Gsänger | | |
| 15:50 | Combining ensemble icing forecasts with real-time measurements for power line and wind turbine applications, Bjørn Egil Nygaard, Kjeller Vindteknikk, part of Norconsult, NO (22) | | |
| 16:05 | Comparison of wind's fatalities to that of other Industries, Paul Gipe, Wind-works, US (44) | | |
| 16:20 | | | |
| 16:30 | Exhibition break 30 min | | |
| 17:00 | End of Conference | | |

R&D areas/s: 05. Forecasting of wind and ice, cloud physics, aerodynamics, noise, 08. Offshore and near offshore – access, foundations incl. artificial islands

## Atmospheric icing on offshore wind farms in Northern Europe – a risk map

*Carla Ribeiro, Wood Thilsted, UK*

Jon Collins (WT, UK), Bruna de Queiroz (WT, UK)

The research into atmospheric ice build-up on offshore wind turbines is limited and, there is a generalised absence of references regarding methodologies on estimating these for offshore environments. According to [1], existing icing maps are based on: atmospheric models usually calibrated for onshore conditions; empirical data collected by anemometers or turbines located solely onshore; or a combination of both. This is valid both for assessing the duration of icing events, as well as the load associated with these. Therefore, there remains high uncertainty in the prediction of atmospheric icing conditions for offshore sites.

This is, however, an area of significant relevance, not just for the estimation of production losses, but also as input to the design basis of offshore foundations. A correct assessment of ice loads will aid in the adequate design of site specific foundations, reducing risks on one side and, on the other, removing any unnecessary conservatism, which will, in turn, lower costs and decrease LCoE.

Based on the research findings of several industry stakeholders [2,3,4,5,6,7, 8, 9, 10], it can be inferred that:

- Most of the onshore turbine icing events in North Europe are caused by in-cloud icing, which occurs when turbine blades surpass the height of the cloud base height, or during fog events;
- The type of ice which forms during these events is predominantly rime ice;
- Due to the relationships between altitude, temperature lapse rate, and cloud base height, there is an exponential correlation between altitude and icing (both events duration and load). Meaning icing is rare at altitudes close to sea level, even at high latitudes;
- The steepness of this exponential curve seems to become more acute as we move from coastal areas of Northwest Europe towards East. This may be associated with a gradual decrease of the golf stream moderating influence, or a progressive drop on the average cloud base height.

Based on the above, as well as the analysis of SCADA data from offshore wind farms located in cold climates, WT has developed an offshore icing map for Northern Europe. This map shows a scale of likelihood of icing occurrence, as well as a qualitative indication of ice load. The goal is to create a tool which allows for the identification of sites where further assessment of icing may be necessary, as well as areas where LCoE may be impacted.

References:

[1] – IEA Wind Task 19, "Available technologies for wind energy in Cold Climates – report" (2nd Edition), 2018

[2] – S. Lindahl, T. Beckford, C. Ribeiro, DNV GL, "Quantification of energy losses caused by blade icing and the development of an Icing Loss Climatology Using SCADA data from Scandinavian wind farms," in Winterwind, Piteå, Sweden, 2015

[3] – T. Beckford, C. Ribeiro, S. Lindahl, DNV GL, "Estimating Energy Losses caused by blade icing from pre-construction wind, " in Winterwind, Piteå, Sweden, 2015

[4] – T. Beckford, DNV GL, "DNV GL's empirical icing map of Sweden and methodology for estimating annual icing losses," in Winterwind, Åre, Sweden, 2016

[5] – C. Ribeiro, T. Beckford, DNV GL, "Icing losses, what can we learn from production and meteorological data," in WindEurope 2016, Amsterdam, 2016

[6] – T. Beckford, DNV GL, "Estimating icing losses at proposed wind farms: An update of DNV GL's empirical methods for estimating icing losses at proposed wind farms, " Winterwind, Skellefteå, Sweden, 2017

[7] – T. Beckford, DNV GL, "Understanding Icing in the Nordics and North America, " Winterwind, Åre, 2018

[8] – S. Rissanen and V. Lehtomäki, VTT, "Global Wind and icing optimization atlas: case Finland," in Winterwind, Åre, Sweden, 2016

[9] – V. Lehtomäki, T. Karlsson and S. Rissanen, VTT, "Wind Power Icing Atlas – tool for financial risk assessment," in Winterwind, Sundsvall, Sweden, 2014

[10] – S. Rissanen and V. Lehtomäki, VTT, "Wind Power Icing Atlas (WIceAtlas) & icing map of the world," in Winterwind, Piteå, Sweden, 2015

R&D areas/s: 05. Forecasting of wind and ice, cloud physics, aerodynamics, noise, 08. Offshore and near offshore – access, foundations incl. artificial islands

**Web site:** https://www.linkedin.com/in/carla-ribeiro-3a34b4/

**Short biography:** Carla is a wind resource assessment expert with more than 16 years of experience in various regions across the world. She is currently the Head of Department for Energy and Climate Analytics at Wood Thilsted (WT), managing a team of engineers that analyse wind, metocean and SCADA data to deliver services for both onshore and offshore wind projects.
Carla's background is in Environmental Engineering, Climate Physics and Renewable Energy. She has also been a member of the IEA task 19 for the development of wind projects in cold climate, having been particularly involved in the development of guidelines for ice protection system warranties.

R&D areas/s: 04. De-/anti-icing including new technologies, ice detection & control incl. standards, 09. Big Data, AI, digitalization and machine learning applied to cold climate challenges

## Blade intelligence - Combined ice measurement and load monitoring

*Nils Lesmann, Pheonix Contact, DE*

-

The Phoenix Contact Blade Intelligence System combines ice detection with load, lightning as well as structural health monitoring in one controller technology.
But what is the benefit of combining such systems? Is there any customer benefit due to data analytics? What are the benefits of using an open control Platform for this kind of systems?
Phoenix Contact equipped a turbine in eastern Canada with the newest generation of the ice detection system and now retrofitted the load monitoring to the turbine.
The aim of this presentation should be to point out the WTG behavior on roar frost, light and severe icing on the blades how do those outer effects on the blade effect the power production as well as the loads on the wind power blades.

**Web site:** http://www.phoenixcontact.com

**Short biography:** Being with Phoenix Contact for twelve years Nils Lesmann is doing working now with eight years most of his business career in the wind sector. Starting as application engineer, he is now in charge for the blade monitoring platform called “Blade Intelligence”
If he doesn’t feel the wind at work he likes to feel the wind while driving his motorbike.

R&D areas/s: 01. Environmental Impact Assessments (EIA), risk mitigation, financial analysis, bankability, financing, market potential, 02. Pre-construction - agreements, assessments, permissions, building, operation and dismantling, 05. Forecasting of wind and ice, cloud physics, aerodynamics, noise, 09. Big Data, AI, digitalization and machine learning applied to cold climate challenges

**TRiceR, a cloud-based web application for supporting risk-based decisions associated with ice falling from wind turbine blades**

*Xavier VANWIJCK, Tractebel, BE*

Mr Pascal GEERINCK (Tractebel), Mr Johan COBBAERT (Tractebel), Mr Tom GHENNE (Tractebel)

General summary
In the context of energy transition, the development of wind energy projects situated in an industrial environment or close to cities is a preferred option in regions with high population densities, since it represents some major advantages related to landscape and noise pollution, NIMBY (Not In My Backyard) and the availability of an electrical connection to the grid. On the other hand, it also represents a drawback in terms of safety during winter conditions due to the presence of people in the vicinity of the wind turbine where ice accretion on the wind turbine blades represents a major risk as ice fall may cause incidents, even lethal accidents. The current common methodology to identify the potentially risky areas below and around wind turbines uses the Seifert formula which is based on a deterministic approach. The safety factors associated to this method lead to excessively large zones around the turbines without granularity or circumstantial sub-zones. The approach presented in this paper is a probabilistic risk-based methodology associated with an acceptance framework. Developed by Tractebel, this methodology allows a much more detailed mapping of the risk zones and also enables to model the impact of mitigating measures. This represents a real risk-based decision tool for windfarm developers and operators. This tool has been translated into a cloud-based application called TRiceR (TRactebel Ice Fall Risk Assessment Digital Application), available recently.
Method
The risk-based decision icefall-model developed by Tractebel calculates the risk as a product of a probability, an exposure and a consequence. The probability is computed through three modules: ice accretion, ice fragment shedding and Monte-Carlo ice fragment trajectory model all taking into account local meteorological and wind turbine data. The exposure is computed by an human exposure model combined with occupational and environmental data. The consequence is computed through risk estimation and risk assessment models associated with an acceptance framework. The combination of above described model components leads to a quantitative risk measure as being a combination between probability and effect.
Results
In order to be able to evaluate the calculated risk level, a risk acceptance framework has been defined for both individual and societal risk which is based on international societal and industry standards integrating also the ALARP-concept (As Low As Reasonably Practicable).
The risk exposure of individuals and groups of people in the surroundings of the wind turbine is quantitatively calculated and presented using graphical maps. The effect on the risk of all kind of technical and organizational mitigating measures such as preventive stops, blade heating, yaw position, warning signs …. can be assessed by a separate module. Together with the cost estimate of the analyzed mitigating measures the methodology can be used as a risk-based decision tool.
Conclusions
With the developed risk assessment model, a rigorous methodology and acceptance framework is defined that enables the different stakeholders to quantify the risks of ice fall during icing conditions and assess them against clear criteria. The effect of different mitigating measures can be simulated providing developers and operators with a risk-based decision tool. The model can be used in design and operating phases of wind farms with both long-term climate data and short-term forecasts.
Learning Objectives
This study addressed several challenges. To combine two different worlds with different codes, languages and methodologies: safety and risk management on one side and wind and meteorological engineering on the other side. The algorithms had to cope with different international regulations and frameworks. To increase their efficiency and reduce the computing time, the algorithms have been parallelized and coded to allow cloud-computing.

R&D areas/s: 01. Environmental Impact Assessments (EIA), risk mitigation, financial analysis, bankability, financing, market potential, 02. Pre-construction - agreements, assessments, permissions, building, operation and dismantling, 05. Forecasting of wind and ice, cloud physics, aerodynamics, noise, 09. Big Data, AI, digitalization and machine learning applied to cold climate challenges

**Web site:** https://tractebel-engie.com/en/tricer

**Short biography:** Xavier obtained his Master Degree in Electro-Mechanical Engineering at the University of Liege (Belgium) with distinction in 1998; He spent the first year of his career developing finite element models for non-linear applications. The next five years, Xavier worked in Paris for the French Defense in an Aerospace research center (ONERA.fr); his main responsibilities were the tracking of satellites using ground radar and the development of constellation of satellites for Earth observations for both civil and military applications.
Xavier came back to Belgium in 2009 to work as a Senior Expert in Wind Technology for the 3E consultancy company (3e.eu). His duties were twofold: to develop the wind turbine technology team for the company and to perform due diligences for international projects. These assignments allowed him to inspect numerous wind farms and to assist financial institutions in several countries including Romania, Tanzania, France and Belgium.
In 2013, Xavier created the XANT company (XANT.com) to propose mid-power wind turbines (100 and 330 kW) for grid-connected projects and off-grid applications. As technical manager of the company, Xavier developed the product portfolio and managed the development teams including abroad (India). Xavier was responsible for the fleet availability and ensured the correct operation of the wind turbines to respect the contract availabilities with local maintenance teams. As operations manager, Xavier managed the installations of the turbines all around the world including Alaska, Scotland, Vanuatu and Singapore. Xavier started in Tractebel Belgium in 2020; he is managing wind international projects.

R&D areas/s: 01. Environmental Impact Assessments (EIA), risk mitigation, financial analysis, bankability, financing, market potential, 02. Pre-construction - agreements, assessments, permissions, building, operation and dismantling

## Timeseries-based approach for volume risk assessment

*Enrico Sindici, Natural Power, GB*

Taurin Spalding (NP), Devin Saywers (NP), Iain Dinwoodie (NP), Enrico Sindici (NP), Daniel Marmander (NP), Peter Denholm (NP)

Power purchase agreements (PPA) are frequently negotiated in the renewable energy industry to contribute to project financing, and increasingly so for Nordic sites. A key contributor to the energy risks which are considered in a PPA negotiation are power production shortfalls, which may result in the producer incurring penalties during periods of production under budget thresholds. The sampling rate for the production settlement may be in the hourly or sub-hourly time frame, therefore the periods of underproduction are best assessed in the time rather than averaged frequency domain.
We propose a timeseries-based approach to derive a long-term production profile representative of real wind farm operations. Secondary losses are not applied as a flat contribution in the frequency domain, but are instead applied dynamically to reflect the patterns of production expected from the wind project. The model may incorporate elaborate curtailment strategies such as noise, bat, bird, wind sector management and extreme temperature shutdown.
The interplay of losses is accounted for and the distribution of de-rating events is based on real historical wind farm operational data and climatic conditions parameters. For instance, icing losses are assigned within the appropriate temperature and humidity ranges and exclusively during periods of no curtailment. Icing is a significant cause for de-rating in Nordic sites, therefore a realistic modelling of icing events on an hourly basis is key for capturing production shortfalls.
The stochastic nature of wind farm energy production and de-rating events is implemented in our model to accurately estimate the mean frequency of shortfalls expected in a given year and its interannual variability. The outputs of our methodology may inform on production shortfall mitigation strategies, such as aggregation of settlement periods and tracking accounts.

**Web site:** https://www.naturalpower.com

**Short biography:** As graduate from the University of Strathclyde, with a PhD in Theoretical Quantum Physics, Enrico has worked on resource estimation and optimization in quantum mechanical systems. His research interests cover a broad spectrum of topics, including solid-state physics, optics, atomic and mathematical physics. Enrico has academic expertise in the mathematical modelling and numerical simulation of complex physical systems, with focus on statistical methods and matrix analysis. His long-standing interest in renewable energy generation and environmental issues has led him to work for Natural Power, where he is employed as an Energy Analyst, working within the Analytics team to provide state of the art assessments throughout the lifecycle of renewable energy projects. Key areas of focus include both pre-construction and operational energy yield assessments of onshore wind farms, wind resource estimation and wind farm performance engineering. He also holds a Master's and Bachelor degree in Physics at the University of Trieste. His personal interests revolve around live music and travel.

R&D areas/s: 06. Requirements and experiences of cold climate solutions - ice throw, thresholds, operational strategies, best practices incl. O&M, inspection and repair

## Simple rules-of-thumb for ice fall/throw safety distances

*Alexander Stökl, Energiewerkstatt, AT*

Alexander Stökl (Energiewerkstatt e.V., AT), Andreas Krenn (Energiewerkstatt e.V., AT)

Ice pieces falling or being thrown from wind turbines (WT) are an important safety consideration for the development and operation of wind farms in temperate and cold climates. One way to address this threat are ice fall risk assessments where the meteorological conditions (icing, wind), the infrastructure on site, and the expected presence of people in the vicinity of the WT are taken into account.
However, in many cases, useful guidance can be given from much simpler rules-of-thumb for a minimum safety distance that are based on conservative estimates and a generalization of site characteristics.
For Austria, such rules-of-thumb have been systematically derived in the research project R.Ice for a number of regions in eastern Austria. This project, funded by the Austrian Research Promotion Agency (FFG) was aligned to the local meteorological conditions and the Austrian regulations, where the latter include the obligation to shut-down wind turbines once ice has formed on the rotor blades.
In our presentation, we will extend these results beyond the Austrian scope and investigate more general operation conditions.
For doing so, a large number of numerical simulations for various turbine configurations and sizes have been performed, considering both ice-fall (iced-up WT stopped) and ice-throw (iced-up WT in operation). Based on the resulting impact distributions of the ice pieces, individual and collective risks of persons in the vicinity of the wind turbine are assessed for different categories of infrastructure (local roads, farm roads, hiking paths, etc.) and conservative assumptions for the usage scenarios. Risk acceptance criteria are chosen according to the IEA Wind Task 19 ice-fall recommendations. This then leads to estimates regarding the minimum distances for each category of infrastructure.
For each IEA icing class, we thus arrive at simple rules-of-thumb with reference to the turbine size that can be used for a simple estimation of the required safety distance between wind turbines and infrastructure on a site.

**Web site:** https://www.energiewerkstatt.org/

**Short biography:** Alexander Stökl earned his PhD in astrophysics and has worked in this field for many years, mostly on fluid dynamics and numerical methods. His first occupation in wind energy was from 2010 - 2012, followed by some more years in academia.
In 2018 he has joined Energiewerkstatt e.V. where he is primarily responsible for wind energy research projects and ice-fall related risk assessments. Apart from cold-climate related topics, Alexander's research activities include remote sensing techniques where he currently leads an international effort on LIDAR measurements in complex terrain. Along these lines, he is actively participating in IEA Wind Tasks 19 and 32.

R&D areas/s: 02. Pre-construction - agreements, assessments, permissions, building, operation and dismantling, 05. Forecasting of wind and ice, cloud physics, aerodynamics, noise, 09. Big Data, AI, digitalization and machine learning applied to cold climate challenges

## Uncertainties of modelled production losses due to Icing

*Marie Pedersen, EMD International, DK*

Morten Lybech Thøgersen, Lasse Svenningsen & Thorkild Guldager Sørensen
(EMD International A/S, Denmark)

Estimating the loss of production due to icing is still a major challenge in the planning phase of any wind farm in cold climates. However, an unofficial industrial standard for modelling of such losses does exist; it basically consists of a three-step downscaling and modelling chain:
1) modelling atmospheric icing conditions using mesoscale weather data – and microscale downscaling,
2) modelling ice-loads using a version of the empirical standard icing cylinder based model by Makkonen [1], also used in the ISO 12494 standard [2], and
3) translating the modelled ice loads into aggregated wind farm (or turbine specific) production losses.
Acknowledging the uncertainties related to the modelling chain and the variety of the interpretation of each step, it configures as a state-of-the art methodology in the industry.
This study presents a sensitivity and uncertainty analysis with selected model chain variations: Mesoscale modelling by different atmospheric boundary conditions – ERA5 and MERRA2. A cylinder-based icing model driven by different boundary conditions and model configurations and finally, transferring the modelled ice loads into an estimated production loss using the well-known IEA task-19 classification model [3].
Actual "ground-truth" production loss data are obtained from SCADA records from windfarms in Scandinavia. The loss of production due to icing from these sites have been determined by two different methods: by the Task19 - Ice Loss Tool [4] and by the windPRO module "Performance Check". The production losses at the sites are evaluated against modelled losses and from ice-load data from the New European Wind Atlas [4]. The results of this study are presented and discussed – with emphasis on the uncertainties in the modelling chain.
References
[1] L. Makkonen, "Models for the Growth of Rime Glaze Icicles and Wet Snow on Structures," Royal Society, vol. 1776, no. Ice and Snow Accretion on Structures, pp. 2913 - 2939, 2000.
[2] ISO, "DS/ISO 12494:2017 Atmospheric icing on structures," Danish Standard Association, København, 2017.
[3] I. Baring-Gould, R. Cattin, M. Durstewitz, M. Hulkkonen, A. Krenn, T. Laakso, A. Lacroix, E. Peltola, G. Ronsten, L. Tallhaug and W. T., "13 Wind Energy Projects in Cold Climate," IEA Wind, http://ieawind.org, 2011.
[4] https://map.neweuropeanwindatlas.eu
[5] https://github.com/IEAWind-Task19/T19IceLossMethod

**Web site:** https://www.emd.dk/windpro/

**Short biography:** Marie Cecilie Pedersen is a wind energy R&D specialist at EMD International A/S and has been involved with wind power in cold climates since 2014. She has, among others, worked with modelling icing on structures using Computational Fluid Dynamics (CFD) and with production loss assessment for wind power in cold climates for pre-construction. Marie is interested in flow modelling for wind power applications, data analysis and the "green energy transition". Marie holds a PhD. (2018) and a M.Sc. in Energy Technology from Aalborg University.

R&D areas/s: 03. Construction of wind farms in cold climates - preparations, wind turbine, balance of plant

# Lesson in winterisation from the UK

*David Armour, Natural Power, GB*

David Armour (NP)

Introduction
Are the Lessons in site winterisation and emergency response learned in the UK transferable to other countries?
Background
In recent years there have been several serious incidents within the UK wind industry where, following investigation, a combination of winter weather, lack of winter preparation and failures in emergency response planning were all identified as contributory factors.
Given the proposed increase in both onshore and offshore construction required to meet our environmental commitments, we are anticipating further growth in the sector to deliver these projects. There is a chance that if not managed it will result in increased incidents. As such, we have a duty to do all that is possible to protect our workforce and ensure they all go home in the same condition they came to work in.
Onshore wind has several inherent risks that include:

- remote work locations;
- difficult weather conditions;
- communication challenges;
- limited means of access and egress; and
- transient / multiple service providers attending sites

These concerns have led to the industry in the UK collaborating via its onshore wind safety body, SafetyOn, and look at this problem and develop guidelines on emergency response for the industry. These guidelines can be found at www.safetyon.com
What is winterisation?
The term "Winterisation" has many accepted definitions or understandings, but essentially it is considered to focus around the preparation of a site location and associated operations in a manner that takes winter specific risk and their mitigation into account.
Considerations for Winterisation
Although the above risks are present all year round, the winter period adds another layer of complexity that needs to be managed, as examples; extreme weather and reduced daylight. Often an organisation's winterisation plan mainly focusses around the provision of equipment to make access to site and delivery of work easier e.g. snow clearing services, provision of winter PPE and suitable vehicles.
While this and the physical preparation of site is important, effective winterisation should be viewed as a continual process and not become a consideration in the weeks before the forecasted weather is due to arrive. There are a number of all year-round activities we can take to reduce risk over this period. These include:

- recording lessons learned from previous winter periods, carrying out reviews and improving operations based on the findings;
- scheduling of work with the view of avoiding more complex and riskier activities like complex lifting operations; and
- the effective analysis of SCADA data and other forms of condition monitoring to identify potential component failures

Emergency Planning
Even with the most robust planning in place, things can go wrong, and as such, we must have plans in place to ensure any emergency is dealt with quickly and correctly. Often a sites emergency plan has been developed without taking winter specific hazards and risks into account similarly site drills are scheduled during summer periods and may not be truly representative of site winter conditions.
In the presentation we will provide the above context and describe the indicators we use and provide real world examples of what good site preparation and emergency response looks like. Our intention is to raise awareness and create momentum around this topic in this vitally important sector.

**Web site:** https://www.naturalpower.com/uk

R&D areas/s: 03. Construction of wind farms in cold climates - preparations, wind turbine, balance of plant

**Short biography:** David has been involved in health and safety for the past 15 years having formally worked as a mechanical maintenance engineer and serving in the UK Military.
Having both health and safety, and engineering experience in a number of technical industries including offshore and onshore wind, solar, civil construction, port, maritime, and electrical utilities.
Working in multiple industries has allowed for a unique perspective on what solutions can be used to deliver our works safely.
He holds a BSc in Occupational Safety and Health and is a Chartered Member of the Institute of Occupational Safety and Health (IOSH) and currently chairs the SafetyOn Technical Advisory Committee (TAC).
Outside of Health and safety his main personal interest is road cycling when his wife and 5year old permits it.

R&D areas/s: 05. Forecasting of wind and ice, cloud physics, aerodynamics, noise

### A complete model chain for icing of wind turbines

*Johan Revstedt, Lunds Universitet, SE*

Henrik Asmuth (Uppsala Universitet, SE), Robert Szasz (Lunds Universitet, SE), Metodija Shapkalijevski (SMHI, SE), Heiner Körnich (SMHI, SE), Stefan Ivanell (Uppsala Universitet, SE)

The power output from wind turbines in cold climate is in winter time affected by ice accretion on the turbine during the winter season. Accounting for this when estimating the potential power output at a prospective new site is important. This can be done in several ways, for example utilizing mesoscale atmospheric models together with, for example the Makkonen [1] model for the ice build-up.
The model we are developing for predicting production losses is based on a modelling chain from mesoscale simulation of the atmospheric conditions via CFD simulations of the ice accretion to CFD of the full iced turbine, in the latter case using the actuator line model.
In the present state of this project we are connecting the three parts of the modelling chain, i.e. based on meteorological data we simulate the ice accretion process and extract aerodynamical data for the blade sections which are then used in full turbine simulations to obtain for example the power and thrust on the turbine. The turbine we are considering is the NREL 5MW.
The mesoscale numerical weather-prediction HARMONIE-AROME system [2] is used to provide the meteorological forcing for the icing model. Simulations of interest have been conducted by using the 2.5km horizontal grid resolution for a full domain over Sweden with minimum of 48 hours system spin up time. The required output of meteorological fields at the lower model levels (up to 300 meters above the ground surface) is corrected to account for the topographic difference between the smoothed model and the reality.
The data from the mesoscale simulations outlined above, mainly wind speed and liquid water content is then used to find the ice accretion. To do so, we apply 2D-simulations using OpenFOAM 4.1 with an LPT model for the liquid droplets. Turbulence is modelled using a RANS based model and turbulent dispersion of the particles is accounted for. At certain intervals the simulation will be stopped and the surface changed using an in-house software. The simulations are then restarted and the process is repeated until the icing event is ended. Iced aerofoil profiles are then extracted at certain time intervals and again using OpenFOAM, varying the angle of attack, to obtain the lift and drag of each section.
The final step of the model chain investigates the impact of the iced aerofoil profiles on the performance and wakes of the turbine. To this end, we perform large-eddy simulations (LES) of the entire turbine in atmospheric boundary layer flows. For the simulation of the ambient flow we employ a GPU-accelerated lattice Boltzmann LES framework. The turbine itself is represented by an actuator line model (ALM). Hence, altered lift and drag coefficients obtained from the 2-D aerofoil simulations can be directly incorporated.
We will present data from an artificial test case as well as from the whole modelling chain for some icing events typical to Swedish winter climate. Our results indicate that the lift and drag are most sensitive to the amount of surface roughness applied in the aerofoil simulations. This also reflects in the overall effect on turbine thrust and power and the resulting characteristics of the wakes. Furthermore, simulation results from the aerofoil sections also show a sensitivity to the choice of turbulence model, as will be outlined in the presentation.
Acknowledgements: This work is financed by the Swedish Energy Agency, project no. 47053-1. Computational resources are provided by SNIC.
References:
1. Makkonen, L., 2000, "Models for the growth of rime, glaze, icicles and wet snow on structures", Philosophical Transactions of The Royal Society London A 2000 358, pp. 2913-2939.
2. Bengtsson, L., et al., 2017, "The HARMONIE–AROME Model Configuration in the ALADIN–HIRLAM NWP System", Mon. Wea. Rev., 145, 1919–1935, https://doi.org/10.1175/MWR-D-16-0417.1.

**Web site:**

**Short biography:** Professor Revstedt got his master degree in mechanical engineering in 1996 and a PhD in fluid mechanics in 1999 at Lund University, Sweden. He is since 2011 professor in Fluid Mechanics at the department of Energy Sciences, Lund University. His main research interests are multiphase flow, fluid-structure interactions and wind turbine aerodynamics. He has been involved in several research

R&D areas/s: 05. Forecasting of wind and ice, cloud physics, aerodynamics, noise

projects concerning wind turbine aerodynamics, some including ice accretion and aeroacoustics. Among his extracurricular activities one may mention a keen interest for swimming

R&D areas/s: 04. De-/anti-icing including new technologies, ice detection & control incl. standards, 05. Forecasting of wind and ice, cloud physics, aerodynamics, noise, 06. Requirements and experiences of cold climate solutions - ice throw, thresholds, operational strategies, best practices incl. O&M, inspection and repair

**From turbines to farms: Using distributed ice detection to increase safety and accessibility**

*Theresa Loss, eologix sensor technology, AT*

Theresa Loss (eologix, AT), Michael Moser (eologix, AT)

In areas suffering from icing conditions during the cold period, accessibility of turbines for service and maintenance is often limited by safety concerns. In order to efficiently schedule technicians while ensuring occupational safety at the same time, a valid data source is required. Meteorological measurements often do not reflect the icing status of different turbines in a park. Measurement data from a large number of sensors per wind farm - distributed not only over the surface of a single turbine but also over strategic points of the farm - can be used as the basis for a working schedule.
Without valid measurement data, it needs to be decided on the premise itself if access to a park is safe. Hence, lack of knowledge on the actual icing situation in the park and consequent delay of maintenance work can lead to prolonged production losses and additional maintenance costs.
A blade-based ice detection system can deliver exact ice measurements (including the detection of very thin layers of ice) and thereby significantly decrease the risk of damage by ice throw. Ice detection needs to be functional in standstill of the (iced) turbine in order to obtain an overview of the icing status of an entire park e.g. after a major icing event.
Further development from turbine-based ice detection to park-based ice detection includes data fusion of icing data of single turbines with meteorological knowledge. Data-based approaches can e.g. predict icing of all turbines based on historic icing patterns or can even be used to predict icing events for other parks in the same region. Here, it needs to be ensured that detection thresholds are as low as possible.
To sum it up, icing and temperature data analysis over an entire wind farm allows for a detailed view of the icing conditions in a wind farm. Thereby, real-time remote assessment of the accessibility of a farm (i.e. which roads and turbines are safe to use and approach) is possible. In doing so, it reduces standstill by carrying out critical maintenance as soon as possible while at the same time increasing the safety of employees.
In the full paper, we will deliver an analysis of large-scale icing events and the effects caused thereby in selected wind farms. We will analyse characteristic icing patterns and thereby assess accessibility of the farm. Finally, an increase of accessibility times will be estimated based on historic icing patterns.

**Web site:** http://www.eologix.com

**Short biography:** Theresa Loss was born in southern Germany in 1991. She received her B.Sc. and M.Sc. degrees in electrical engineering and audio engineering (with honors) from the Technical University of Graz, Austria, in 2014 and 2017, respectively. She is currently pursuing her doctoral studies at the Institute of Electronic Sensors Systems in Graz. Her main areas of interests include structural health monitoring, sensor systems and signal processing.

R&D areas/s: 06. Requirements and experiences of cold climate solutions - ice throw, thresholds, operational strategies, best practices incl. O&M, inspection and repair, 09. Big Data, AI, digitalization and machine learning applied to cold climate challenges

## 6D inertial sensing on the blade surface - know the moves of your blade's surface

*Michael Moser, eologix sensor technology, AT*

Theresa Loss (eologix, AT), Michael Moser (eologix, AT)

Increased vibrations of the blade as a whole or at certain locations may not only lead to increased noise levels at certain operational conditions but also increase fatigue, leading to reduced life time of the blade. Also, increased vibrations come along with an increased probability of severe blade damages.
In order to identify critical operational conditions and to detect structural damage of the blade as early as possible, e.g. excessive vibrations need to be measured at multiple, strategic locations of the blade. Mounting sensors inside the blades at positions of interest is often limited due to the presence of support structures and limited accessibility by staff. For example, highest vibration levels are expected close to the blade tip but aceessibility is poor. Consequently, it is the method of choice to mount sensors on the outside of the blades and to use a wireless sensor solution .
We propose using 6D-IMUs with gyroscopes and accelerometers. Reference data from turbine SCADA data may or may not be used. The 3D orientation of the blade is determined at multiple positions of the blade, which allows for deriving the pitch angle of the blade and detecting turbine imbalances. Also, increased vibrations can be detected and be related to specific turbine settings. Furthermore, eigenfrequencies of the blades can be derived from data acquired at multiple support points along the blade to increase accuracy of the measurement.
A system with e.g. three sensors per blade - deployed at strategic locations - allows for monitoring harmful vibrations and measuring pitch angle in full production, i.e. at nominal speed, which is hard to achieve by current measurement methods. Load can be estimated by combining the information of multiple sensors per blade by means of advanced methods. This allows for a complete inertial data set to optimise turbine operation modes and to schedule maintenance, e.g. by detecting a change in vibrational characteristics due to early damage). Additionally, knowledge about the behaviour of the blade in operation (from a fleet of turbines in the field rather than from a test stand) can be used to complement blade design and simulations.
In the full paper, we will show measurements of pitch angles at multiple positions along the blade and relate results to vibrational characteristics of the blade. Additionally, SCADA data will be used as a reference and increased vibrations will be related to specific turbine settings. Finally, we will demonstrate the importance of several strategic measurement positions along the blade by comparing vibrational characteristics at several measurement points.

**Web site:** http://www.eologix.com

**Short biography:** Michael Moser studied Electrical Engineering and Sound Engineering at University of Music and Performing Arts Graz and Graz University of Technology. Between 2007 and 2013, he was a research assistant at the latter, where in 2013 he completed his PhD thesis focusing on energy harvesting and icing detection on electrical power transmission lines. Since 2014, he is managing director of eologix sensor technology. When he finds time, he still likes to play the piano.

R&D areas/s: 04. De-/anti-icing including new technologies, ice detection & control incl. standards

**Synergies between icing on wind turbines and UAVs**

*Richard Hann, Norwegian University of Science and Technology (NTNU), NO*

Richard Hann (NTNU)

In recent years there has been a strong development and an increased utilization of unmanned aerial vehicles (UAVs). These automated drones are suitable for a wide range of applications and are used in many different industry areas today. Cold climate conditions are a very special challenge for UAVs that has only recently shifted into the focus of research. The physical mechanisms leading to icing on wind turbines and fixed-wing UAVs are highly related to each other, as they both operate at flow velocities of the same order of magnitude. This does distinguish them from aircraft icing, which is typically experiencing much higher velocities and Mach-numbers. Therefore, the same modeling and simulation tools that are used for UAVs can also be applied for rotor blades. This is in particular relevant when it comes to the validation of these simulation tools.
This presentation will outline the overlap between the fields of icing on wind turbines and UAVs. Particular focus is given to synergies in the areas of numerical simulations. Furthermore the topics of ice detection, ice protection systems, and ice forcasting topice are covered.

**Web site:** http://www.richardhann.com

**Short biography:** Richard Hann graduated as an aerospace engineer at the University of Stuttgart in 2013. He is a specialist for computational fluid dynamics (CFD), computational aeroacoustics (CAA) and icing simulation. Richard obtained his PhD from the Norwegian University of Science and Technology (NTNU) in summer 2020 on the topic of icing on unmanned aerial vehicles. Today, he is continunig his research at NTNU and is also a project manager in the start-up company UBIQ Aerospace.

R&D areas/s: Global wind market forecast, market updates

# Record 2020 masks mounting onshore wind challenges

*Isabelle Edwards, Bloomberg, GB*

Isabelle Edwards, Wind Power Associate at Bloomberg/BNEF

The wind sector has shown resilience in 2020. It is set to deliver its highest-ever installations in a year when Covid-19 has wrought unprecedented economic and logistical chaos on other industries. Wind has emerged from the pandemic in a stronger position than before, with many governments around the world striving to make renewable energy a central part of economic recovery packages.
Investors are bullish about the industry's prospects. First Trust Global Wind Energy ETF – the world's only exchange-traded fund (ETF) targeting the global wind industry – has seen gains of over 44% since the beginning of the year. By contrast, iShares Oil & Gas Exploration & Production UCITS ETF, an ETF tracking performance of global companies involved in oil and gas production, has fallen by almost 30%.
Next year could be even bigger and better for wind. We expect onshore installations could break the records set this year. From 2022, though, growth in the onshore sector looks set to stall. The 40GW increase in our China forecast this quarter hides a worrying slip elsewhere. Ex-China onshore additions fall from just below 50GW in 2021 to around 30GW in 2025 in our forecast.
The U.S. provides one of the clearest examples of this decline. Amidst growing calls that the sector should compete on its own after years of government support, the country's flagship subsidy scheme, the production tax credit, is phasing out before expiring in 2026. While the most competitive projects will still find a route to market, without a new subsidy, this will inevitably lead to shrinking installations.
These ups and downs shows onshore wind's vulnerability to sudden swings in political sentiment. We have seen it before. Spain and the U.K. were two of Europe's most promising onshore wind energy markets in the early 2010s. A political backlash against lavish legacy subsidy schemes, however, saw damaging retroactive subsidy changes in Spain and was partially responsible for harsh cuts in the U.K. Installations plummeted. Both now have two of the most active markets for subsidy-free onshore wind, but once again political sentiment has changed. Governments have already lined up new onshore wind auctions. While a renewable energy sector that does not need support is attractive, new administrations in both countries acknowledged that subsidy-free projects alone would not deliver capacity on the scale required to hit ambitious climate targets.
Governments in other regions do not share such ambition or have such deep pockets. Markets will continue to slash tariffs and either edge towards auctions, like in Japan, Ukraine and Vietnam, or look to phase out subsidies altogether like in the Nordics. To deliver consistent growth, onshore wind developers will need to find creative ways to secure revenue and reduce risk in projects increasingly exposed to volatile power prices. Finding routes to market without subsidies and freeing themselves from the whims of politicians could help deliver more consistent growth.
Another problem that developers face in established markets is growing local opposition. Resistance from communities is one of the key bottlenecks in markets from Germany to South Korea. Efforts to resolve the issue include establishing community benefit funds (compulsory in Ireland's new auction scheme), or allowing locals to invest directly in nearby wind projects. Solving this problem could be key to unlocking a new wave of installations in Europe and beyond.
Undercut on price by solar, and facing more opposition than offshore turbines, onshore wind does not enjoy the rapid growth forecasts of its competition. As the sector matures, it must learn to better champion its value to the grid, cope better without subsidies and live in closer harmony with local communities if it is to maintain consistent growth and stay relevant in the energy transition.

**Web site:** https://about.bnef.com/blog/record-2020-masks-mounting-onshore-wind-challenges/

**Short biography:** Isabelle Edwards covers onshore wind markets across Europe, Middle East and Africa at BloombergNEF, the leading independent provider of analysis, tools, data and research to decision makers leading change in the energy system. Her recent analysis has focused on wind farm acquisitions and pricing, and wind turbine manufacturer competition. Prior to joining BloombergNEF's wind research team, Isabelle spent four years in strategy research and data management positions at Bloomberg. She holds a degree in Economics from the University of Exeter.

R&D areas/s: 04. De-/anti-icing including new technologies, ice detection & control incl. standards, 05. Forecasting of wind and ice, cloud physics, aerodynamics, noise, 06. Requirements and experiences of cold climate solutions - ice throw, thresholds, operational strategies, best practices incl. O&M, inspection and repair, 07. Laboratory and full-scale testing, small wind turbines and everything else, 09. Big Data, AI, digitalization and machine learning applied to cold climate challenges

## Improving turbine annual energy production (AEP) and reducing O&M costs with real-time blade airflow quality monitoring and quantification under all environmental conditions and levels of blade contamination

*John Maris, Marinvent, CA*

William Reeve Hicks (Marinvent Corporation, CAN)

Real-time airflow "quality" measurements taken at the blade surface in the form of the Turbulence Intensity Ratio provide precise, actionable data that can be used for turbine orientation and blade pitch optimizations to significantly increase turbine Annual Energy Production (AEP) and reduce O&M expenditure. The Turbulence Intensity Ratio metric directly correlates to the airfoil's aerodynamic performance and stall margin, thereby providing both a current aerodynamic performance metric and a quantification of the remaining achievable performance margin for each individual blade.

The Enhanced Airfoil Performance Monitor (EAPM), which is derived from commercially available aerospace technology, addresses important wind industry cost pressures, turbine integration considerations and blade aerodynamic concerns. EAPM data can support turbine manufacturers and operators by:

1. Maximizing AEP with real-time insight into how well each blade is aerodynamically performing, as well as the remaining performance margin under any conditions, with any level of contamination (e.g. ice, frost, sea-salt, insects, leading-edge erosion);
2. Improving health tracking and O&M decisions by immediately identifying and quantifying aerodynamic anomalies on individual turbine blades that can be caused by local damage, contamination or defects, and avoid potential black swan events;
3. Quantification of the aerodynamic impact of icing accretion, including optimization of de-ice and/or anti-ice system operation, if installed. EAPM also supports the safe restart of turbines following an icing-related shut-down, thereby minimizing unnecessary downtime;
4. Immediately distinguishing between aerodynamically induced vibrations versus those from other sources.

EAPM is currently undergoing a long-duration (18-month), two phased, government funded test program on 2MW utility scale turbines at the Nergica wind test facility in Quebec, Canada. During this testing, EAPM data is being collected alongside multiple turbine and icing sensors, including SCADA data. This will be analyzed with support of an AI data analytics firm to derive all potential insights. The system will then be used to direct turbine control to actualize and quantify real-time optimizations available achievable by the use of EAPM.

A successful 2019 EAPM validation test program demonstrated the sensor's ability to aerodynamically quantify blade performance, as well as detect and quantify the impact due to leading edge contamination from light leading-edge erosion (simulated with 40-grit sandpaper) up to more significant icing accretion (using plastic simulated ice forms). These aerodynamic impacts, detected and quantified by EAPM, alter the optimal blade performance angles and are not fully characterized or adapted to in real-time by existing optimization control systems.

The foundational aerospace technology, APM (the Airfoil Performance Monitor), was developed to provide pilots and aircraft avionics systems with the margin remaining to stall for their airfoils, even when iced, contaminated or degraded. This has proven of particular benefit for Unmanned Aerial System (UAS) operators that do not have the benefit of being able to visually inspect their airfoil conditions during flight.

Based on years of extensive wind tunnel and flight testing, and more recent 2MW turbine testing, the EAPM test program is expected to demonstrate and quantify AEP production improvements and O&M cost reductions through the integration of EAPM airfoil turbulence intensity data into turbine control operations.

R&D areas/s: 04. De-/anti-icing including new technologies, ice detection & control incl. standards, 05. Forecasting of wind and ice, cloud physics, aerodynamics, noise, 06. Requirements and experiences of cold climate solutions - ice throw, thresholds, operational strategies, best practices incl. O&M, inspection and repair, 07. Laboratory and full-scale testing, small wind turbines and everything else, 09. Big Data, AI, digitalization and machine learning applied to cold climate challenges

Acknowledgements:
1. This work has been supported by the National Research Council of Canada (NRC) through the Industrial Research Assistance Program (IRAP) and the Natural Sciences Engineering and Research Council of Canada (NSERC).
2. All turbine testing has been conducted at the Nergica test facility in Gaspé, Quebec, Canada.

**Web site:** http://www.marinvent.com/

**Short biography:** Dr. John Maris is the President and founder of Marinvent Corporation, a multiple-award-winning Canadian aerospace research firm. He is an Aviation Week and Space Technology Laureate, and was awarded Canada's oldest aeronautical prize, the Trans-Canada (McKee) trophy, for his contributions to Canadian aerospace.
Dr. Maris is a test pilot and aeronautical engineer with master's degrees in Air Science and Management, and a Ph.D. in Aviation Safety and Human Factors. He is a Fellow of the Canadian Aeronautics and Space Institute, a Fellow of the Royal Aeronautical Society, and an Associate Fellow of the Society of Experimental Test Pilots. He has published numerous papers, lectures, and articles on aerodynamics and systems engineering, and has made several televised appearances as an aerodynamics expert. His publications include "The turbulence intensity parameter as a basis for stall prediction" which earned the Canadian Aeronautics and Space Institute's (CASI) Ronaasen award for best conference paper.
Dr. Maris is the Chairman of the Royal Aeronautical Society's Montreal Chapter, where he is heavily engaged with youths just starting their careers, and where he is also spearheading an ambitious Diversity and Inclusion agenda.
Dr. Maris was inducted into the Canadian Aviation Hall of Fame in June, 2018.

R&D areas/s: 06. Requirements and experiences of cold climate solutions - ice throw, thresholds, operational strategies, best practices incl. O&M, inspection and repair

**Return on experience: Working on a wind farm in icing conditions**

*Charles Godreau, Nergica, CA*

To be determined

Nergica is a research center based in Gaspé, Canada, that stimulates innovation in the renewable energy industry through research, technical assistance, technology transfer and technical support for businesses and communities. We own and operate a research wind farm in Cold Climate (CC) since 2010. The two Senvion MM92 turbines as well as two 126 meters met masts are used for various R&D projects. These projects, as well as the operation and maintenance of the wind farm involve, at times, accessing the turbines in icing conditions.
In this presentation, we will cover the various references, procedures and tools we use to plan, assess the conditions and take decisions on how to proceed with work on a wind farm in icing conditions in line with the industry's best practices for health and safety.
To reach this objective, and to make the exercise more engaging, we will present a real case from the ongoing winter, from the first indication of potential icing in the long term forecast to the final risk assessment of the team on the ground before entering the turbine. The presentation will be supported with images, videos and data from several ice detectors.

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

**Short biography:** As Project Manager, Research and Innovation, Charles Godreau specializes in wind turbine performance assessments in cold climates and icing detection/protection systems. Besides possessing strong skills in data analysis for operational turbines as well as developing, planning and implementing research projects, he has also participated in a number of conferences. He notably represents Canada in the International Energy Agency's Task 19 working group on wind energy in cold climates and is an active member of Winterwind's program committee.

R&D areas/s: 01. Environmental Impact Assessments (EIA), risk mitigation, financial analysis, bankability, financing, market potential, 02. Pre-construction - agreements, assessments, permissions, building, operation and dismantling

## Challenges and opportunities in the communication of risk from Ice Throw

*Karl Ove Ingebrigtsen, Norconsult, NO*

Karl Ove Ingebrigtsen (Norconsult AS)

Blade icing is a major issue for wind farms in cold climate areas. The ice that builds up on the turbine blades will, in addition to production losses, also present a potential risk of ice throw or ice fall for people in the wind farm areas, including service personnel, hikers, hunters, reindeer herders as the ice can fall off or be thrown large distances from the turbine blades.
Often used mitigations are production stop and/or control access in the vicinity of the wind turbines. This presentation focuses on the risk assessment to be performed to ensure a safe use of the wind farm area during the winter season.
There is a clear need to improve how to communicate the risk to the different users of the area. Key elements to be taken into consideration in the forecast process will be presented and examples on communication process toward users to ensure acceptance and control of the risk.
Methods developed in the R&D project for forecasting of icing is based on an advanced meteorological modelling approach to forecast icing on the turbine. To evaluate the probability of having thrown ice pieces on the ground that might cause a hazard (risk) to the users of the area do have a large degree of uncertainties and need to be communicated to those exposed to the hazard.
Hence it is a need for communicating the risk to the users to ensure that they both understand and can handle the risk. By handling the risk correctly, the area can be utilized based on real-time risk assessment instead of fixed distances that not related to the real weather conditions.
The main benefits from communicating the risk in an understandable way are:

- Increase availability of the wind farm while still handling the risk
- Reduces risk for injuries and damages from wind turbine ice throw
- A common communication platform for distribution of information to users and nearby people.
- Improved information to the users of the wind farm areas.
- Improved understanding of the risk of ice throw and ice fall in their wind farm.
- Enable the operator of a wind farm to make reliable risk communication.

The risk will be better understood and accepted by the users of the wind farm area after following a structured process in the evaluation of ice risk and in the communication of risk from ice throw. Creation of trust between users of the wind farm and the operators is key for success. The deterministic use of a fixed given distance does not necessarily account for the real weather conditions at the day of entering. The use of online forecast and risk communication will increase the safe use of the area and reduce cost of preventing access to the site.
This presentation will give you a guided tour on how to identify, forecast, control and mitigate the risk from ice throw.

**Web site:** https://www.norconsult.no/

**Short biography:** Karl Ove Ingebrigtsen has more than 30 years of experience within risk and emergency preparedness analysis for a wide range of industries like transportation, oil and gas, onshore industry, renewable, nuclear, and authorities. He is currently advisor at Norconsult and project manager for a major project on Risk from Ice throw from onshore wind turbines. Previously he headed Lloyds Register renewable branch for 3 years before he started at Norconsult

R&D areas/s: 04. De-/anti-icing including new technologies, ice detection & control incl. standards

# Tackling ice throw risks by using sophisticated algorithms of blade-based ice detection

*Bastian Ritter, Wölfel Wind Systems, DE*

Bastian Ritter (Wölfel Wind Systems, D), Timo Klaas (Wölfel Wind Systems, D)

Since the efficiency of wind turbines (WT) is primarily reflected in their possibility to produce energy at any time, the down times of WTs due to damages or ice detection are costly and unwelcome for WT investors.
Especially the danger of ice throw from rotor blades has to be avoided for personal safety reasons at any time. Furthermore, the ice on rotor blades can cause severe damage to the wind turbine itself. Not only to the rotor blades, but also other parts of the structure, e.g. the gear box and the tower are strongly affected by higher loads and rotor imbalances.
For this reason the Wölfel Wind Systems has developed a wide product line-up with vibration-based structural health monitoring (SHM) systems for damage and ice detection in rotor blades, foundation and tower monitoring (onshore and offshore), to give wind turbine operators the opportunity to reduce the number of WT inspections and increase availability and potential yield.
The centerpiece of this paper is the presentation of the latest innovations and developments around SHM systems with the specific focus on Health and Safety applications:
In this context the following will be presented:

- The importance of ice and damage detection on rotor blades
- Advanced insights: Additional blade monitoring features and offshore applications
- Smart data: How to use advanced data analytics to gain new findings

**Web site:** https://www.woelfel.de/en/wind-energy.html

**Short biography:** Bastian Ritter studied mechatronics engineering at Technical University of Darmstadt and obtained his PhD in the field of wind turbine control. He is 36 years old and lives with his family close to Frankfurt am Main. In private, Bastian enjoys to spend time outside in the nature with his children.
As product manager at Wölfel Engineering, he is highly committed to the advancement of the structural health and condition monitoring systems for rotor blades, towers and foundations. In his daily work, he is focused on the customer benefit in order to bring added value to the table.

R&D areas/s: 06. Requirements and experiences of cold climate solutions - ice throw, thresholds, operational strategies, best practices incl. O&M, inspection and repair

## Yaw optimisation

*Thomas van Delft, DNV, UK*

Josiah Chamberlain (DNV, USA)

Yaw misalignment has been a hot topic in recent years. This is largely driven by the fears of wind farm owners that this issue, which is notoriously difficult to detect, may be losing them revenue without them ever knowing. In response to these concerns, DNV has recently developed a new approach to address, not only yaw misalignment but, more widely, non-optimal yawing behaviour.

When operating correctly, wind turbines constantly track the wind such that the turbine is pointing into the wind flow. Ideally, this yawing behaviour ensures that the turbine is extracting the maximum amount of energy from the wind at any given moment. Unfortunately, in certain circumstances, a wind turbine might be misaligned with the wind flow and consequently unable to extract as much energy.

The possible causes of yaw misalignment are often related to an incorrect measurement of the wind direction. This may be due to a miscalibration of the wind vane, or it may be due to a distortion of the wind flow causing the wind direction at the measurement point (normally behind the rotor) to not be the same as the wind direction in front of the rotor. In addition, with the increased size of rotors and hub heights, and the increased rotor veer at higher latitudes and in more stable conditions, the potential for sub-optimal yaw behaviour in the Nordics is higher than in many other markets.

One approach to detecting and correcting for yaw misalignment is to measure the wind direction in front of the rotor. This approach usually requires the installation of additional hardware and so will necessarily be more costly than a purely analytical approach. Another approach is to measure the performance of the turbine as a function of yaw offset angle (the relative wind direction). It can be inferred that the offset angle that corresponds with the greatest performance is the angle at which the turbine is truly facing into the wind.

In this presentation, delegates will learn how DNV has adopted the latter approach to detect non-optimal yawing behaviour using high-resolution SCADA data. They will hear how yaw misalignment can be identified and how the associated energy losses are accurately quantified, as well as the calculation of the yaw adjustment required to maximise energy yield.

A case study will be presented in which Taaleri, a Finnish based owner of a large European wind farm portfolio, asked DNV GL to investigate a range of potential issues including yaw alignment. DNV identified that one turbine had a very different yawing behaviour than the rest in the wind farm. Its yawing response was very slow and corresponded with many yaw-system-related alarms. This malfunction was causing a loss in efficiency of 1.8 %. The root cause was identified and Taaleri has been able to resolve the issue.

**Web site:** https://www.dnvgl.com/power-renewables/

**Short biography:** Thomas is a Senior Engineer in DNV's Renewable Energy Analytics – Nordics and Baltics team. He joined DNV in 2011 after reading MEng Renewable Energy at the University of Exeter. He has experience in assessing operating wind plant worldwide; working for owners, operators and investors on a wide range of services including long-term SCADA-based energy production forecasts, ongoing wind farm monitoring services, and wind turbine performance optimisation. Thomas also manages R&D activities aimed at improving analytical methods and the development of new services. Thomas has attained Chartered Engineer status through the Institution of Mechanical Engineers.

R&D areas/s: 04. De-/anti-icing including new technologies, ice detection & control incl. standards

**Comparison of four blade-based ice detection systems installed on the same turbine**

*Paul Froidevaux, Meteotest, CH*

Paul Froidevaux (Meteotest, CH), René Cattin (Meteotest, CH), Ulrich Langnickel (VGB PowerTech e.V., DE)

We installed four blade-based Ice Detection Systems (IDS) on the same Vestas V90 wind turbine at Stor-Rotliden, Sweden: eologix, fos4X, Weidmüller and Wölfel. eologix relies on point-measurements of impedance at the blade surface while the three other tested IDS (hereafter the "vibration-based" IDS) rely on shifts of the blade vibrations frequencies which are related to changes in the overall blade mass.
After four winters, we collected a unique dataset of 5'700 hours of simultaneous operation of these four systems, covering around 60 icing events for a total of roughly 2'500 hours of blade icing. We also monitored the blade icing with a nacelle-based webcam pointing at the blades during the entire period. This unique dataset allows for a robust and detailed comparison of the four systems. We will show some anonymized results.
Overall, all four systems appear very reliable in detecting icing. Neither clear false alarm nor missed event has been identified. The availability of ice detection was close to 100% for all systems during production hours for a simulated use case where the test turbine would have been controlled by each IDS according to its respective system certification. In such a use case, the turbine is stopped as soon as the IDS reaches icing alarm. During the field test however, no IDS did control the turbine which was operated without restrictions during icing.
The numeric icing indexes of the three vibration-based IDS are very similar. We nevertheless observed differences in the total duration of the simulated turbine stops due to different sensitivities of the icing alarms applied. Compared to the most sensitive of the three vibration-based IDS, the two other IDS would have triggered turbine ice safety stops approximately 30, respectively 90, minutes later on average.
In terms of turbine stops, larger differences were found between eologix and the vibration-based systems. Overall, eologix would have triggered less and shorter turbine stops. These differences are likely related to the fundamentally different approaches used to derive blade icing.
We had very constructive discussions with each IDS manufacturer about the specific results of its system. This experiment also represented a rare opportunity for them to gain more experience on the behavior of their system during conditions that they otherwise never, or very rarely, encounter such as a wind turbine operating with several hundreds of kilograms of ice on its blades.

**Web site:** https://meteotest.ch/en/division/icing

**Short biography:** Paul Froidevaux holds a PhD in Climatology. He has been working at Meteotest for 6 years. He is the Swiss representative in the IEA Task 19 and has been active in wind energy in cold climate since 4 years, mainly by providing operational icing forecasts and performing consultancy for OEM manufacturers on their ice protection systems. Apart from wind energy, Paul has diverse activities at Meteotest, such as e.g. developing an icing forecasting tool for Swiss rescue helicopters, performing extreme wind assessments for cable cars in the Alps or providing operational numerical weather predictions for mountain expeditions in the Himalaya. Paul also likes direct contact with snow and ice as a hockey player and Nordic skier.

R&D areas/s: 06. Requirements and experiences of cold climate solutions - ice throw, thresholds, operational strategies, best practices incl. O&M, inspection and repair

## Structural blade repair in artic climate, Resistive Vacuum Infusion

*Greger Nilsson, Blade Solutions, SE*

Greger Nilsson, Blade Solutions

Blade Solutions has developed a blade repair method to be used year-round in artic climate. The method is called Resistive Vacuum Infusion (RVI). In RVI the repair patch is also the heating layer. The new solutions give possibilities to perform structural blade repair year around in temperatures far below zero degree Celsius.
Blade repairs outside of the summer months has previously been difficult even whit external heat. Temperatures in the repair patch and the blade interface teds to be uneven. Both curing rate and viscosity of the resin are highly affected by the temperature. Another option is to use techniques such as UV-curing systems which can extend the temperature range, but such techniques have other limitations. The UV-light cant penetrates thick a repair patch and gives lower volume fraction glass fibres.
A structural blade repair is best carried out in the same environment as the in the blade factory. This means bring the blade factory environment to wind turbine site. Therefore, the RVI aims to replicate the blade factory environment's conditions at the wind turbine site in the repair patch and the blade interface. The method has first been developed on specimen level and later tested on wind turbine blade. In RVI a conductive layer is applied in the interface between the blade surface and the repair patch. Electric current is applied to the conductive layer. Power is adjusted to desired temperature. Specimens has been repaired down to -20°C, both infusion and curing. Mechanical properties have been evaluated in Crack Opening displacement test were the force for a crack to propagate in the interface between repair patch and blade laminate is logged. Result showed specimens repaired by the RVI-method in -20°C had same Crack Opening displacement properties as specimens repaired in the laboratory. This prof that RVI-method is working. Blade factory conditions can be applied year around in artic winter conditions.
RVI is primally developed for blade fibre wrinkle crack repairs. Dangerous cracks can be repaired all year around at premium quality. Blade Solutions has also successfully repaired dangerous fibre wrinkle cracks in temperatures down to -12°C, using the RVI-method.
Blades can be repaired immediately and run in production instead of waiting for repair.

**Web site:** https://bladesolutions.se/

**Short biography:** Has a background in composite research. Started Blade Solutions 7 years ago. Has since the start of the company focused on repair and development of the de-icing systems in the wind blades. Personally: In winter there is a lot of times on skis and outdoor life. In summer there is sailing and boating.

R&D areas/s: 05. Forecasting of wind and ice, cloud physics, aerodynamics, noise

## Operational icing forecast with a probabilistic approach

*Jesper Thiesen, ConWx, DK*

Iben Holfort Voxen

Operational icing forecasts with Bayesian network
ConWx have long history in forecasting wind power fore Scandinavian wind farms. The icing forecasting challenge have so fare been having a physical approach together with machine learning. The results and knowledge we have from forecasting curtailment by using Bayesian network, a probabilistic why to forecast situation that are more binary, have now been introduced to icing forecasts.
What is Bayesian learning?
We have made prof of Eisman forecast and icing forecast by using advanced machine learning, which combines Bayesian Networks with linear regression.
Due to the utilization of priors in Bayesian probabilistic methods, the Bayesian Networks have an advantage for unbalanced classes (i.e. rare events,). The outcome of Bayesian network is a probabilistic result in percentage. Bayesian ML is a paradigm for constructing statistical models based on Bayes' Theorem.
$p(\theta|x)=p(x|\theta)p(\theta)p(x)$
The goal of Bayesian ML is to estimate the posterior distribution ($p(\theta|x)p(\theta|x)$) given the likelihood ($p(x|\theta)p(x|\theta)$) and the prior distribution, $p(\theta)p(\theta)$. The likelihood is something that can be estimated from the training data.
In fact, that is exactly what we are doing when training a regular machine learning model. By performing Maximum Likelihood Estimation, an iterative process which updates the model's parameters to maximize the probability of seeing the training data xx having already seen the model parameters θθ.
The challenges for the trader at the Nordpool stock market is the distribution of probabilities for a binary event, either we have icing or not. Should they in practical work with different thresholds like 0.5, 0.6 or different thresholds?
The network gives us a probability of icing not the intensity of the icing. The intensity have to be estimated whish we do with advanced machine learning.
What we did:
We have from a client 2 years of icing data and power production data for 4 parks in Sweden.
We defined the combined turbine icing information with alarm codes 'ice detect' to true/false per park.
If 1 or more turbines are iced – we see the park is iced.
We have trained Bayesian Neural Network using variables using input from our different weather models, the parameters used in 1 hour granularity are:

- Density of droplets in 100 meters
- Temperature 100 meters
- Windspeed 100 meters
- Humidity

Besides from the meteorological parameters the network has been trained with the icing data, production data, seasonal, time of the day.
The results of this training give us scaled normal power curve per windspeed bin to icing data and the smoothed new powercurve so icing-poweroutput will be continues whish in the used to estimate the intensity of the icing affecting the production.
The forecast delivered for the client are the ideal power production (not taken icing into account) , scaled production (using icing the icing algorithms to estimate the power loss of the icing event) and the probability for icing.
Results
We have compared the icing accuracy with the base line as show in the table below:
Overall Accuracy vs baseline:

| Accuracy: | Predict all to FALSE | Icing Network |
|---|---|---|
| SE_1 74 % | 84 % | |
| SE_2 79 % | 83 % | |
| SE_3 84 % | 87 % | |
| SE_3 82 % | 87 % | |

The improvement of the icing forecast with respect to power production are very site depending as show in the table below:

R&D areas/s: 05. Forecasting of wind and ice, cloud physics, aerodynamics, noise

Improvement of predicted power vs observations during icing:
Forecast improvement during icing
SE_1 0.5 %
SE_2 9 %
SE_3 6 %
SE_4 17 %
Ideas for further specification:

- Add threshold for how many turbines should be iced before the park is classified as iced.
- Receive more information about heating as periods after heating might be classified as icing due to icing condition. This might affect optimizing + evaluation.

**Web site:** https://conwx.com/

**Short biography:** PhD, Project Manager, Lead Data Scientist at ConWx
Summary Data Scientist with background in Digital Signal Processing and Applied Mathematics. Master of Science in Electrical Engineering. PhD degree in adaptive algorithms with applications in ultrasound imaging.
Specialties: Technical Project Management R&D Project Management Scientific Software Development Machine Learning, Data Mining Data Analysis, Applied Mathematics, Numerical Algorithms Signal Processing: Digital Signal Processing, Adaptive Array Processing, Beamforming Numerical Weather Prediction: Operational NWP, Wind Power and Solar Power Prediction Programming: Python, Matlab, C, C#/.NET, Shell scripts. Teaching
Education Danmarks Tekniske Universitet Doctor of Philosophy (Ph.D.), Digital Signal Processing, Data Analysis, Medical Ultrasound Imaging · (2006 - 2009)
Danmarks Tekniske Universitet Master of Science in Engineering (M.Sc.), Digital Signal Processing, Applied Mathematics, Data Analysis · (2000 - 2006)

R&D areas/s: 01. Environmental Impact Assessments (EIA), risk mitigation, financial analysis, bankability, financing, market potential

# IEA Wind Task 19: Cold climate wind market study

*Timo Karlsson, VTT Technical Research Centre of Finland, FI*

Timo Karlsson ( VTT-FI)

Wind power deployment in cold climate conditions has been growing steadily for several years now, at the same time the technologies related to cold climate are becoming more mature. Cold climate sites are attractive due to high wind speeds, and increased production due to low temperature. In cold climate areas wind farms can be built on remote locations away from populated areas. In Europe, the best sites to build large onshore wind power plants tend to be in cold climate areas.
IEA Wind Task 19 has been following the growth of the wind power market for a some time now. Initially the first global cold climate market study in BTM World Market Update report 2012[1]. Then at Winterwind 2017, a follow-up was presented. The estimates made in 2012 were found to be slightly overestimating the number of sites at severe icing conditions and underestimating the light icing sites. Overall the forecast was quite close.
The horizon of the study done in 2015 ended in 2020. An outlook on the present state o the cold climate market size will be presented and the accuracy of the previous growth estimates is evaluated.
Also a new forecast for a five year horizon will be presented based on publicly available climate data [3], VTT global icing atlas [4], and databases on wind power sites. Growth estimate will be made based on forecasts of the growth of onshore wind power market globally.
The approach used in the study will divide the cold climate market into partially overlapping segments: Low temperature sites and icing sites. Low temperatures create their own set of issues for operations in those areas but not all low temperature sites are in icing conditions. Similarly, majority of wind power sites that suffer from icing conditions are not low temperature sites.
Definitions of these terms, the methods used to estimate the market size and the results on country level will be presented.

References:
[1] Navigant Research,2013.World Market Update 2012, Chicago, Illinois: Navigant Research, ISBN: 978---87---994438---4---0
[2] Karlsson, T: IEA Task 19: Cold climate wind power market study 2015-2020, Winterwind 2017, Skellefteå
[3] Copernicus Climate Change Service (C3S) (2017): ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate . Copernicus Climate Change Service Climate Data Store (CDS), date of access. https://cds.climate.copernicus.eu/cdsapp#!/home
[4] ] VTT. Wind Power Icing Atlas – WIceAtlas, http://www.vtt.fi/sites/wiceatlas

**Web site:**

**Short biography:** Timo received his M.Sc. degree form Aalto University in 2012, from the School of electrical engineering, with speciality in automation and control engineering. He has been employed at VTT since 2011 working as a research scientist in VTT Wind power technologies group. During his time at VTT Timo has been working on numerous R&D projects related especially to wind power technology development. These projects have covered developing signal processing tools for wind turbine performance assessment and automatic ice detection, control system design for blade heating system, embedded system development, and development of GIS tools for icing risk assessment for wind power applications. He is currently the operating agent of IEA Wind Task 19: Wind power in cold climates.

R&D areas/s: 05. Forecasting of wind and ice, cloud physics, aerodynamics, noise

**Combining ensemble icing forecasts with real-time measurements for power line and wind turbine applications**

*Bjørn Egil Nygaard, Kjeller Vindteknikk, part of Norconsult, NO*

Sigbjørn Grini (KVT, NO), Amund Søvde Haslerud (KVT, NO), Kristian Ingvaldsen (KVT, NO)

Forecasting atmospheric icing of structures is inherently challenging due to the large sensitivity to several meteorological variables such as wind speed, wind direction, cloud water content, droplet size distribution temperature etc. When single or deterministic forecasts fail, they may cause poor or wrong decisions because the forecast uncertainty is unknown. Therefore, Kjeller Vindteknikk (part of Norconsult AS) has developed an ensemble forecasting product that forms the basis for probabilistic short-term icing forecasts, currently in operation in two different projects. Firstly, the R&D project Icebox, where real-time icing measurements are used as input to the probabilistic icing forecasts. Secondly, Wind Energy in Icing Climates (WEIC) where wind turbine SCADA data are analyzed in real-time and coupled to the probabilistic icing forecasts.
From a power grid operation perspective, icing is particularly challenging due to the limited information available in real-time. Often, the first indication of a severe icing event is an outage due to flashover from sagging conductors to the ground, or even worse, a sudden outage due to collapsed towers or tower components. Icebox is a research and development project lead by Statnett, the transmission system operator in Norway. In this project we develop a system for real-time monitoring and probabilistic forecasting of ice loads on overhead transmission lines, that will be used by the grid operators to limit outages due to ice and wind loads, by actively utilize de- and anti-icing technologies on the power lines when critical weather situations are detected or predicted by the ensemble forecast.
With regards to wind energy, the probabilistic icing forecast is combined with real-time measurements to identify imminent risks of ice throw in the ongoing WEIC project. The WEIC project is an initiative by Kjeller Vindteknikk along with several wind farm operators in Norway and Sweden to improve the accuracy of ice throw forecasts as well as communication platforms for such forecasts. Ice sensors within the wind farm as well as icing signals derived from SCADA data are used to validate/correct the initial conditions of each forecast iteration and thereby improve the accuracy of icing nowcasts (forecasts for the very near future). Furthermore, real-time SCADA data are used to perform running calibrations of already issued icing forecasts.

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

**Short biography:** Meteorologist educated at the university of Oslo with a PhD on numerical modelling of atmospheric icning on structures. I've been seven years at the norwegian meteorological institute and been working at Kjeller Vindteknikk since 2013. I am a true weather nerd, and as a child, my favourite TV show was the weather forecast.

R&D areas/s: 02. Pre-construction - agreements, assessments, permissions, building, operation and dismantling

# IEA Wind Task 19: Standardization of pre-construction icing loss assessment in upcoming IEC 61400-15 standard

*Ville Lehtomäki, Kjeller Vindteknikk, FI*

IEA Wind Task 19

Every wind farm needs a pre-construction energy yield assessment to evaluate the planned project's financial feasibility and to ensure bankability. Icing losses have been one of the driving forces in Nordics kick-starting the WinterWind conferences in 2009 and much of the conference's program revolved around icing losses still in 2020. In 2021, icing still remains a complex problem for wind turbines.
Standardization has been at the core of IEA Wind Task 19 international expert group's activities from the start. The development of the new IEC 61400-15 standard regarding pre-construction energy yield assessment started in 2013 and was a natural place for Task 19 involvement that started in 2017. The progress has been somewhat slower than expected but considering the new standard's global importance and the fact that the work started from a clean table, this is understandable.
The new IEC standard has been called to be the most important standard for wind energy to-date once published as it addresses directly one of the most important aspects of project bankability: how to standardize the uncertainty estimation process in energy yield assessments. The new standard is very different from previous IEC standards as it will not define how to do things but rather provide minimum requirements and a framework process how to quantify uncertainty drivers for the most important energy yield assessment loss e.g. wakes, turbine performance, environmental losses (icing, bats) etc.
Task 19 is now responsible for the chapter in the standard regarding the quantification of icing loss uncertainty drivers. The current draft text for icing losses uncertainties has two main elements:

1. 4 different criteria when an icing loss uncertainty assessment is needed (an icing loss uncertainty assessment won't be needed in areas such as Brazil or India etc)
2. If one of the above criteria is "yes", then the icing loss uncertainties need to be quantified.

The current draft icing loss uncertainty drivers are:

1. Quality and accuracy of method (e.g. measurements, weather modelling) chosen to estimate site icing conditions
2. Method and length of data used to estimate long-term, expected site icing conditions
3. Knowledge of the turbine technology and site control strategy for iced turbines (e.g. systems to mitigate ice, shut down due to iced blades as quickly as possible or normal operation until safety limits are reached)

The presentation will have some practical examples of fictive sites considering the above uncertainty driver framework.
Cold climate wind energy is quickly transforming from a niche, special climate industry to a global, mainstream industry. In this transformation, standards are of paramount importance.

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

**Short biography:** Mr Lehtomäki works as Managing Director at the science-based consultancy company Kjeller Vindteknikk Oy (Finnish office). In addition to managing the Finnish office's commercial operations, his technical work today focuses on wind energy topics such as energy yield assessments, icing loss evaluations and wind measurement analyses. From 2009-2018, he worked at VTT Technical Research Centre of Finland Ltd in Wind Power team having extensive international wind energy experience, coordinating and developing new projects and creating new technology innovations mainly in the field of wind energy.
Mr Lehtomäki has a Master's degree in mechanical engineering (product development) from Helsinki University of Technology.
In his spare time, he runs around badminton and floorball arenas and prefers downhill over cross-county skiing.
He is on a mission to help unlock the full potential of wind energy in Finland.

R&D areas/s: 07. Laboratory and full-scale testing, small wind turbines and everything else

**The evaluation of state-of-the-art anti-icing surface solutions using a large scale icing test set-up**

*Joey Bosmans, Sirris, BE*

Pieter Jan Jordaens (Sirris OWI lab, BE), Daniele Brandolisio (Sirris OWI lab, BE), Ozlem Ceyhan Yilmaz (Sirris, BE), Arthur Buyck (Hogere zeevaartschool antwerpen, BE)

Icing causes performance loss, material degradation and can create safety issues in many applications and industries. This happens especially in polar regions where severe icing occurs frequently, but also in low and moderate temperate climates, where icing events are less frequent, the optimal response to icing represents a significant economic value.
Recent technological developments (e.g. sensors, detectors, machine learning algorithms, anti-ice coatings and surface treatments) have made new solutions available for detecting, preventing or removing ice. However, many companies are struggling to adequately and cost effectively cover the icing aspect when developing, validating or implementingg new ice-sensitive systems.
For this purpose, a test set-up for icing tests is developed in a large climatic test chamber [1]. The test setup consist of a nozzle array of 25 nozzles placed in 5x5 configuration at a dimensions of 6 m x 3 m x 5 m. It allows for the formation of different types of ice by using different droplet sizes and spray pressures. This test set-up will make it possible to test and validate the reliability and functionality of the coatings applied to real scale equipment or test samples with large dimensions and/or complex shapes.
Thermal camera, ice measuring sensors and specifically developed ice-adhesion testers are used to examine ice shapes, ice thickness, ice colour, ice adhesion.. The uniqueness of this setup is that it allows both the evaluation of new active and passive anti-icing systems, new monitoring equipment and allows durability testing of large scale parts under specific conditions.
In primary testing, the influence of ice formation in the splash zone of marine vessels or offshore structures have been evaluated on coated metal test panels. Results show clear differences between different coating technologies but also emphasises the importance of durability in order to provide long term protection. [2]
In future work, Sirris will validate the large scale test set-up on different state of the art anti-icing or de-icing surfaces. Coatings, coated parts and de-icing units are currently provided by leading companies with track record in the field of ice protection.
The large icing test set-up should offer the infrastructure for accelerated, controlled and cost-effective icing tests for companies active in the fields of energy production, aviation and transport, drones, building and construction, etc…
This work is partially funded by VLAIO through “Fighting icing” project [3] and Newskin project [4] with clear goals to build up knowledge and develop solutions to mitigate icing problems.
References
1_: https://www.sirris.be/largest-climatic-test-chamber-in-europe valid 1/2021
2_ Thesis Hogere Zeevaartschool Antwerpen (HZS), Comparative study of coatings to prevent ice formation on board of marine vessels, Arthur Buyck, 2019-2020
3_VLAIO funded ‘Fighting icing’ project HBC.2019.2495 https://www.sirris.be/fighting-icing
4_Innovation Eco-system to Accelerate the Industrial Uptake of Advanced Surface Nano-Technologies https://www.newskin-oitb.eu/

**Web site:** https://www.sirris.be/fighting-icing

**Short biography:** Joey Bosmans is project engineer at Sirris Smart coating lab, with 10 years of experience in the field of paints, inks and coatings for industrial applications. With a background of chemistry, Joey is offering guidance to companies with specific questions on functionalities, coating formulation, paint application and curing of several types of coatings. Joey is responsible for the coating testing program within the materials group of Sirris.
In the Fighting Icing project, I can combine the knowledge on coatings and testing to show the true potential of anti-ice coatings.

R&D areas/s: 05. Forecasting of wind and ice, cloud physics, aerodynamics, noise, 06. Requirements and experiences of cold climate solutions - ice throw, thresholds, operational strategies, best practices incl. O&M, inspection and repair

## Cost effective de-icing blade repairs

*Morten Handberg, Wind Power LAB, DK*

Morten Handberg

This presentation will present a cost effective deicing repair solution for cold climate turbines.
Ice on blades requires an installed deicing system. An active deicing system utilize the electrical properties of carbon fiber to heat the blade Leading edge and remove icing. The deicing system is sensitive to effects from lightning, fatigue or external impact that reduce the ability to transfer current and provide uniform heat distribution
If the deicing system fails, consequences can be severe and expensive. If an area of the system is damaged and the area ability to transfer current is affected, a hot and cold zone is created. The cold zone will reduce the ability to remove icing from the blades. In severe cases the hotspots can damage and cause burns to the blade.
The solution is a repair on deicing systems to establish electrical contact between the original laminate and the de icing repair. If a repair is successful the temperatures difference over the repair is less than 20 C.

**Web site:** https://windpowerlab.com/

**Short biography:** Mr. Handberg has more than 10 years of experience from the international wind power industry where he has obtained profound knowledge of complex aspects of wind turbine blades, i.e. blade defect causes, consequences, and development risks. Mr. Handberg specialises in blade defect and integrity assessment, blade defect risk assessment, blade repair method assessment and recommendation, and blade defect root cause analysis. Mr. Handberg also has on-site experience and expertise in inspecting wind turbine blades (internally and externally) and checking blade damage after structural tests. Mr. Handberg has worked as Project Lead and Blade Expert on numerous projects covering production of new blade prototypes, qualification of new improved inspection, repair methods, large-scale offshore repair campaigns, definition of quality specification, repair scopes, and review and validation of repair methods and instructions. Mr. Handberg has conducted blade defect and integrity assessment of 1,000+ wind turbines and prepared End Of Warranty claim recommendations.

R&D areas/s: 06. Requirements and experiences of cold climate solutions - ice throw, thresholds, operational strategies, best practices incl. O&M, inspection and repair

## Safe turbine operation in icy conditions

*Eva Sjögren, ENERCON GmbH, SE*

Gilles Boesch, ing., M.Eng, Power Performance Engineer ENERCON Canada Inc and Danela Jacob Entwicklung Rotorblatt WRD GmbH

The development of windfarms in icing conditions involves specific risks related to climatic conditions. Health and safety is of key priority when it comes to the time to operate a windfarm. Workers in the windfarm are faced daily with such kind of risks: icefall, ice throw, slippery road etc. As wind industry is delivering an essential service, wind turbines need to be operated and maintained while ensuring worker's safety. In the first part of the presentation, ENERCON will give an insight on safe turbine access for service personnel under icing conditions. The focus will be on different regulations and thus solutions in different cold climate regions.
In addition to workers who are in the front line of any ice-related risks, protection of population living nearby the windfarm is also to be ensured. ENERCON helps customers to secure a safe turbine operation under icing conditions for all sites. The ENERCON power curve method is a long-established and well tested method to make sure the turbine is stopped when people or the turbine itself are in danger due to ice throw. A variety of additional ice detection measures are offered to prevent the turbine from ice throw. These options allow the turbine to restart when the blades are free of ice. Regulations in different countries will be discussed based on examples. Different options that are offered to windfarm owners in order to optimize the yield and comply with the regulations will be shown.

**Web site:** https://www.enercon.de

**Short biography:** Depending on the final Winterwind Programme, ENERCON will decide who will present this abstract. We will submit presenter biography later on. Thanks for your understanding in advance.

R&D areas/s: 04. De-/anti-icing including new technologies, ice detection & control incl. standards

## Assessment of ENERCON blade heating performance in various conditions

*Gilles Boesch, ENERCON Canada, CA*

Gilles Boesch (ENERCON, CA), Tarik Daqoune (ENERCON, CA), Sten Barup (ex-ENERCON, SE), Julian Schödler (ENERCON, DE)

The development of windfarms in icing conditions involves specific risks related to climatic conditions. Health and safety is of key priority when, after installation, the time has come to enter regular windfarm operation, particularly in populated areas. In such situations, the operation of an Ice Protection System (IPS) is guided by local regulations. In other areas, where safety risk is lower, turbines equipped with IPS are tuned towards highest possible yield.
ENERCON has nearly 3900 turbines installed worldwide equipped with its hot air blade heating system. In areas with minor health and safety risks, turbines are allowed to continue operation with ice accumulated on the blades and with a heating system operating at the same time while remaining in the turbine's design limits. This allows for reduction of downtime and increase of performance in icing conditions. The efficiency of the heating system determines the extent of this improved performance and is used in the planning phase of a windfarm to estimate losses due to icing. In areas where high icing losses are expected, a proper evaluation of the heating system efficiency could actually render a project financially feasible or not.
Based on the existing database of ENERCON WECs, the study, we present herewith, evaluates the efficiency of ENERCON's de-icing system in different ambient and operational conditions and validates three specific KPIs proposed by ENERCON taking into account existing initiatives from the industry in particular IEA Task 19.
ENERCON's cold climate fleet, representing a relevant fleet subset generally exposed to icing conditions, provides a database of statistical significance for this purpose. This database holds more than 1000 turbine years after sampling. The assessment of the metrics with this database shows a clear correlation between efficiency of the heating system with wind speed and temperature. Turbine model and site location is also of critical importance.

**Web site:** https://www.enercon.de

**Short biography:** Gilles has been involved in the wind industry since 2009 where he started as wind data analyst after his graduation from Ecole Polytechnique de Montréal. He worked in a consulting company in various field of renewable energy: wind, solar, hydro mainly. In 2015 he joined ENERCON as a power performance engineer and is currently involved in various icing subject. During his career he was essentially working on Canadian windfarms development and operation, so he has always been confronted to the « Icing challenge ».

R&D areas/s: 05. Forecasting of wind and ice, cloud physics, aerodynamics, noise

# Icing impact on trailing edge noise in wind turbines

*Timo Karlsson, VTT Technical Research Centre of Finland, FI*

Timo Karlsson (VTT-FI), Franck Bertagnolio (DTU-DK), Alexander Meyer Forsting (DTU-DK)

In cold climate wind power sites wind turbine blades can collect ice. Icing happens when the turbine blades come into contact with liquid water in sub-zero temperatures. This can either happen as in-cloud icing, where the turbine blades
collide with super cooled cloud droplets or as a result of freezing rain.
The impact that icing has on power production has been studied in detail and the impacts that icing has on power production are quite well known at this point. Icing degrades the performance of a wind turbine because the ice accretion on the blades changes the shape and surface properties of the airfoil. The same process will also have an impact on the sound produced by the wind turbine blades.
A brief literary review on the publicly available references on the impact of icing in aerodynamic noise will be presented. The focus will be in wind power, if possible. In absence of wind power related references an overview from related fields like aviation can be considered.
In the present context of this work, an attempt is made to evaluate the noise increase that could result from a relatively thin ice sheet on a rotating rotor blade. The assumptions of the model are the following. It is assumed that the ice sheet affects the boundary layer flow developing on the blade surface, and that this can be modeled using a roughness model as part of a 2D CFD airfoil calculation. This yields an increase of the boundary layer turbulence developing along the airfoil. This turbulent flow, when convecting past the trailing edge, is scattered resulting in so-called trailing edge noise emission. The latter is recognized as the dominating aerodynamic noise source from wind turbines in the audible range (for clean blade conditions). The above model (including roughness, CFD calculation and trailing edge noise modelling) is used as input for a more general code that can model acoustic emissions from a full wind turbine rotor.
It is important to stress here that the above assumptions leave out other possible noise generation mechanisms due to icing. Ice clumps may also create complex flow turbulent features that may radiate noise through other mechanisms [1]. To these days, it is not clear what could be the dominating factor of noise increase due to blade icing, if such increase indeed exists. The focus here is to estimate the potential noise increase through the mechanism assumed above only.
A series of calculations for different roughness parameters and other possible geometrical aspects (e.g.extent of icing area) will be conducted to compute the noise emission increase providing a rough estimate of the minimum noise level increase due to icing under the above assumptions.
References:
[1] Richard Hann: Simulating Iced Wind Turbine Noise, winterwind 2015

**Web site:**

**Short biography:** Timo has a background in industrial automation is currently working as a research scientist in the Wind Power Technologies team at VTT. He has more than 100 years of experience in Wind power, most of this has been dealing with numerous cold climate issues form ice detection to resource assessment to blade heating.
Franck Bertagnolio is a Senior Scientist at DTU Wind Energy, in the group of Aerodynamic Design. He hasa background in Computational Fluid Dynamics and hydrodynamics. Then, his scientific work has focused on the aerodynamics and aeroelasticity of wind turbines. More recently, aeroacoustics of wind turbines has become his primary research subject, covering both modelling and experimental aspects.

R&D areas/s: Performance Warranties for Wind Turbines in Icing Climates

**Performance warranty guidelines for wind turbines in icing climates**

*Helena Wickman, Vattenfall, SE*

Charles Godreau (Nergica, Canada), Stefan Söderberg (DNVGL, Sweden), Timo Karlsson(VTT, Finland)

IEA Wind Task 19 considers wind turbine performance testing in icing climates as a key element to mitigate risks when developing wind farms in cold climates and for accelerating wind turbine technology improvements in cold climate conditions.

The first edition of the "Performance warranty guidelines for wind turbines in icing climates" was published by Task 19 in May 2018. The aim of the second edition was to present and further detail the most promising available options on how wind turbines with icing climate adaptations can be warranted and tested with affordable and reasonably accurate test methods.
The second edition is based on information collected during a Task 19 workshop that was held during the last Winterwind conference 2020. In the workshop 36 cold climate experts from 8 countries and 27 organizations participated and shared their experiences as consultants, developers, turbine manufactures and retrofit providers.

**Web site:**

**Short biography:** Helena Wickman has worked in the wind industry for more than 7 years. For the last 4 years she has been wind resource engineer at Vattenfall Wind. Before that she worked as a wind and site consultant. Since 2014 she has been a Swedish representative in the IEA Task 19 working group on wind energy in cold climates, where she has been leading the update of the Performance Warranty guidelines for wind turbines in icing climates report. She holds a master in Engineering Physics from Uppsala University.

R&D areas/s: 02. Pre-construction - agreements, assessments, permissions, building, operation and dismantling, 04. De-/anti-icing including new technologies, ice detection & control incl. standards

**Modelled icing losses with WICE: A blind test in France**

*Stefan Söderberg, DNV, SE*

Giacomo Rossitto (DNV, FR), Min Zhu (RES Ltd, GB), Laurie Gilbert (RES Ltd, FR),, Alan Derrick (RES Ltd, GB)

Technical innovations and improved understanding of challenges in cold climate areas have in recent years allowed for the development of wind farm projects in regions where severe icing conditions can be expected. Nevertheless, accurately predicting the expected ice loss is still a challenge and there is a need to further improve and validate the tools used by the industry.
To estimate production losses, DNV uses a tool called WICE [1,2,3,4]. The WICE model chain includes site-specific mesoscale modelling using the mesoscale model WRF [5], the modelling of ice accretion on a simplified turbine blade, a machine learning model to predict production losses due to icing and methods to long term correct the model results. The model chain has previously been validated in an internal study [4] and a blind test for RES [6]. RES is the world's largest independent renewable energy company with a portfolio of 19 GW.
In previous WICE validation efforts, the wind farms used were all located in Scandinavia, which is the same region that the SCADA data used to train the WICE model is located. The idea behind WICE is however that the ice loss model responds to modelled atmospheric conditions wherever they are, and is not tied to a specific region. Therefore, a new blind test was set up for 5 wind farms operated by RES in southern France. This blind test is the first step to independently validate WICE outside Scandinavia.
For each individual turbine in the 5 wind farms included in the blind test, DNV provided hourly timeseries of wind speed, wind direction, air temperature, expected power, and reduced power due to icing. These were taken by RES and compared with operational data. The observed ice loss was estimated by using the IEA Task 19 method (T19IceLossMethod) [7].
In analysing the results, good agreement was found for 3 wind farms, one wind farm was found to significantly underpredict, and the final one found to significantly overpredict. Investigations highlighted that turbines where the icing loss was underpredicted were either shutting down erroneously or had ice detectors installed to intentionally stop the turbines. At the time of writing, investigations into the overpredicted wind farm have not highlighted any reason for the low observed icing losses, and investigations are continuing.
The validation performed here highlights one of the challenges when comparing data from operational wind farms with modelled data – it is vital to correctly account for operational strategies and/or regulations before drawing firm conclusions. It also shows how modelling can be used to review operational performance – are all turbines performing as expected relative to the modelling expectations, or are there unexplained differences which may highlight sub-optimal turbine performance which can be corrected?
The work presented here forms a basis for further development of the WICE model taking into account different operational strategies and ice detectors, and the presentation shall discuss how this can be implemented in WICE and how ice loss predictions can be extended to include these systems.
[1] Söderberg, S, M Baltscheffsky, and H Bergström: Estimation of production losses due to icing - a combined field experiment and numerical modelling effort. EWEA 2013
[2] Baltscheffsky, M and S Söderberg: Estimation of Production Losses Due to Icing – Development of methods for site assessment and forecasting. Winterwind 2013
[3] Söderberg, S and M Baltscheffsky: A novel model approach to test de-icing strategies and de-icing efficiency. Winterwind 2014
[4] Söderberg, S, J Collins, T Beckford, and C Ribeiro: WICE 2.0 – The new generation of ice loss models. Winterwind 2019
[5] Skamarock et al. (2008): A Description of the Advanced Research WRF Version 3
[6] Söderberg, S, T Beckford, C Ribeiro, A Derrick, and M Zhu: Validation of turbine specific modelled ice losses. Winterwind 2020
[7] https://community.ieawind.org/task19/t19icelossmethod

**Web site:** https://www.dnvgl.com/

R&D areas/s: 02. Pre-construction - agreements, assessments, permissions, building, operation and dismantling, 04. De-/anti-icing including new technologies, ice detection & control incl. standards

**Short biography:** Stefan has worked in the wind industry since 2006. In DNV GL Stefan is and expert in numerical mesoscale modelling and icing climate studies. Prior to DNV GL, Stefan founded and worked in WeatherTech Scandinavia developing services based mesoscale model data such as wind resource mapping and estimates of production losses due to icing.
In the Renewable Energy Analytics Team, Stefan is Technical Lead responsible for the development and application of mesoscale modelling techniques in wind and solar resource assessment, working together with DNV GL's global pool of specific energy assessement challenges affecting the NEMEA (North Europe, Middle Easts and Africa) region, such as production losses due to icing, wind flow modelling and wakes offshore, among others.

R&D areas/s: 01. Environmental Impact Assessments (EIA), risk mitigation, financial analysis, bankability, financing, market potential, 02. Pre-construction - agreements, assessments, permissions, building, operation and dismantling

## Validation of a wind turbine icing model for site assessment

*Noemi Tölg, Fraunhofer IEE (Research Institute), DE*

Noemi Tölg (Fraunhofer IEE, DE), Pascal Wehler (ABO Wind AG, DE), Christian Jonsson (ABO Wind AG, DE)

For a good wind farm planning an accurate site evaluation regarding icing is essential. This allows the prediction of possible losses due to icing and supports the choice of adequate wind turbine types and equipment. The modelling of ice mass using an icing accretion model and numerical weather prediction (NWP) data becomes an important instrument to achieve this goal.
Therefore, a physical model with the purpose to simulate the icing mass of a wind turbine with a high certainty was developed at Fraunhofer IEE. The model is based on the Makkonen model for a standard cylindrical body structure. With respect to the specifications of the ISO 12494 the calculations were adapted for the specific use of turbine blades including additional mass reduction processes such as sublimation and melting.
As input parameter the local NWP model COSMO-DE is used. However, it can be easily adjusted for any other NWP model on a local or global scale. With respect to site assessment the icing model returns the mass of ice in kg per length of turbine blade as well as the prospective icing hours per year. Moreover, the model output gives information about type of icing and the duration of icing events.
The validation of the model has been carried out for a wind farm located in an icing relevant region (IEC classification 3 with 6 to 15 % of instrumental icing) with several wind turbines. The local NWP COSMO-DE model with a horizontal resolution of 2,8 km was used. The dataset contains over 3,5 years including three winter periods. For a single wind turbine an accuracy of modeled icing hours between 98 % and 94 % were performed. For the whole wind farm a model accuracy of 95 % could be achieved. Hence, the preciseness between the detected and the modeled icing occurrence can be determined as reliable.
Thus, the Fraunhofer turbine icing model provides accurate ice mass predictions for regional site assessments specifically for wind turbines. Extending the usage by adapting the NWP model input it is worldwide applicable and does not require costly measurements.
Further investigations will be carried out with a global NWP model. Testing the lower horizontal resolution and comparing it with the results of the local model.

**Web site:** https://www.iee.fraunhofer.de/

**Short biography:** Noemi Tölg completed her bachelor's degree in chemical engineering at Clausthal University of Technology in 2018. She recently finished her master thesis at Fraunhofer IEE in the field of wind energy with focus on wind measurements via multi-LiDAR systems for site assessment. As newcomer to the topic of icing, she quickly became enthusiastic about the influence of icing in wind energy application. As a research assistant she contributed to the validation of the icing model for wind turbines presented here.

R&D areas/s: 04. De-/anti-icing including new technologies, ice detection & control incl. standards, 06. Requirements and experiences of cold climate solutions - ice throw, thresholds, operational strategies, best practices incl. O&M, inspection and repair

**Towards improving wind energy in cold climate: how to quantify the use of alternative operational strategies**

*André Bégin-Drolet, Université Laval, CA*

Patrice Roberge (Université Laval, Can), Jean Ruel (Université Laval, Can), Jean Lemay (Université Laval, Can)

As of 2020, the share of onshore wind energy in cold climate represents ~30% of the actual onshore installed capacity. Detailed maps for Europe and North-America have been generated using data from different database to cross reference the geographical location and icing severity of every site. It is nowadays widely accepted that the annual energy production is adversely affected by winter conditions such as icing. To cope with this problem, Alternative Operational Strategies (AOS) such as: blade heating, icephobic coatings, operation with ice, early stopping, are now being try and implemented by many operators and researchers. However, there is still a need to develop methodologies to assess the performances of such systems whether it be a turbine side-by-side comparison or a self-comparison. A review of the traditional metrics used to quantify the performances of AOS is presented. The pros and cons of traditional metrics such as the difference in energy produced, the difference in energy losses, the difference in energy efficiency and the relative ice loss recovery are discussed. The principal drawbacks of traditional metrics is that they require accurate power curves, they are sensitive to the period of reference over which they are applied, they often assume that both turbines under evaluation (experimental and reference) are experiencing the same conditions and should output the same energy. Two new metrics, the energy gain and the potential recovery are then presented and discussed to overcome with the drawbacks of traditional metrics. When it comes to comparing turbines and quantifying the use of AOS, we believe that these two new metrics are giving a better portrait of the actual situation being assess, hence giving a better outlook at the net value of implementing such AOS.

**Web site:** http://www.gmc.ulaval.ca

**Short biography:** André Bégin-Drolet is a professor of mechanical engineering at Université Laval in Canada and CEO of Instrumentation Icetek a spinoff company launched in November 2020 that commercialize the ice sensor he and his team have developed at Université Laval. His research, in the wind energy sector, focuses toward improving wind power production in cold climate where atmospheric icing is prevalent. His research led him to the design of a patented smart sensor, the Meteorological Conditions Monitoring Station (MCMS), adapted to measure meteorological conditions in cold and icy environment. He is very interested in developing methods to improve the production of wind energy in cold climates and have done so with many industrial partners. Wind is also part of his hobbies as he is an active racing sailor who loves to perform in both inshore and offshore regattas.

R&D areas/s: 02. Pre-construction - agreements, assessments, permissions, building, operation and dismantling, 05. Forecasting of wind and ice, cloud physics, aerodynamics, noise

## Development and calibration of state-of-the-art icing loss estimates using a new meteorological dataset

*Øyvind Byrkjedal, Kjeller Vindteknikk, Norconsult, NO*

Simo Rissanen (KVT, FI)

Through the research project IceLoss 2.0, Kjeller Vindteknikk has developed the IceLoss tool to estimate the production losses due to icing for the development of new wind farms. With the development of new meteorological data for the Nordic countries, the calibration of the IceLoss method is revisited and an update of the validation is performed. This presentation will show the development of the new dataset for the Nordic countries and the calibration and validation of the IceLoss model using this data set.
The WRF model has been developed with a more sophisticated microphysical parameterization specifically tailored toward icing related issues. A hindcast data set with high spatial resolution has been developed based on the ERA5 reanalysis for the Nordic region using the updated model microphysics. Several wind farm owners have contributed with SCADA data to the project and a database with historical icing losses from about 400 WTGs from 24 wind farms (~2000 WTG years) spread over Sweden, Norway and Finland has been created. This database has been used to calibrate and validate the IceLoss model with the updated hindcast data set. Parts of the SCADA icing loss database will be dedicated to optimizing the modelled icing loss on turbine level to get as close match as possible to the historical losses. The simulated variables used in the calibration process are wind speed, accumulated ice load on a rotating blade cylinder and the icing intensity. SCADA data independent from the calibration process, are then used for the validation of the IceLoss model. The presentation will discuss the challenges of the calibration process and show the results of the validation study.
The presentation will also display the benefits of the IceLoss model for estimating a long-term icing loss for a wind farm in operation by applying the optimization methodology to the historical SCADA data of a single wind farm.
IceLoss 2.0 was a research project partly funded by the Swedish Energy Agency and finalized in 2020. The overall goal with the project was to increase the knowledge of production losses due to icing and to develop a next generation IceLoss model, able to provide wind power project developers, investors and banks with better estimates of the production losses due to icing on the turbine blades.

**Web site:**

**Short biography:** Byrkjedal currently has the position as R&D Manager at the Kjeller Vindteknikk, which is a department in Norconsult. He has worked with icing related topics in Kjeller Vindteknikk since 2007. Byrkjedal has a phd in meteorology from the University of Bergen.

R&D areas/s: 04. De-/anti-icing including new technologies, ice detection & control incl. standards

**Wear resistane multi-composite coating for wind power blades**

*JUN CHEN, Lulea University of Technology, SE*

Jun Chen(LTU, SE) Pär Marklund(LTU, SE) Marcus Björling(LTU,SE) Yijun Shi(LTU,SE)

In order to keep the wind turbine running normally in winter, there were many ways to remove ice from the blades. This work is developing a composite coating to achieve the purpose of deicing. First, we will adapt suitable conductive additives (Such as graphene, graphite, CNT or others) to fill the non-organic solvent polyurethane, which can not only obtain high conductive coating, but also avoid the influence of volatile substances in the coating on the environment. Resistance drops by 7 or 8 orders of magnitude through the best content. At the same time, the polyurethane is selected to make it have great tough and excellent aging resistance. In addition, a protection coating which was designed by us will cover the conductive layer to avoid the risk of exposure of the conductive layer. It also has great thermal conductive, wear resistance and aging resistance. Finally, the composite coating with scientific circuit design and monitor part build a completely deicing system. This system can work well with under 110V. Our goal is lower energy cost and higher efficient deicing.

**Web site:**

**Short biography:** JunChen is currently a PhD student at Lulea university of technology. He obtained his master degree from Nanjing Forestry University in Nanjing City in 2019. His research interest includes the Nano-modified polyurethane and multi-function self-healing polymers, and its application in organic coatings and engineer materials.

R&D areas/s: 04. De-/anti-icing including new technologies, ice detection & control incl. standards

**On-site estimation of effective liquid water content**

*Patrice Roberge, Université Laval, CA*

Patrice Roberge, Jean Lemay, Jean Ruel, André Bégin-Drolet. Université Laval mechanical engineering department, Canada.

The performance of wind turbine ice protection systems is highly dependent on meteorological conditions (i.e. wind speed, temperature and liquid water content). Therefore, analyzing IPS performance requires a reliable method to assess meteorological conditions. Previous research has shown that a lot of work still has to be done to yield accurate icing conditions from numerical predictions. Thus, on-site icing sensors are currently the best alternative for assessing accurate indications on icing conditions. Multiple ice sensors for wind turbine applications are available but few of them provides information on LWC while being robust enough to deliver valid measurements during and after severe icing events. Consequently, the development of an ice sensor should focus on balancing precision and robustness. The current standard in the analysis of on-site icing conditions is the analysis of images from a nacelle-mounted camera. The camera is an easy and fairly reliable instrument that allows the identification of ice on the nacelle. The quantification of icing rate with the observation of ice frontal thickness on a reference cylinder can also be made with a camera. However, the camera becomes less reliable when the visibility is low (e.g. at night or during harsh icing events). Moreover, it takes a certain amount of time to generate significant ice accretion on the reference cylinder to yield reasonable icing rate resolution. This results in a compromise between temporal resolution and icing rate resolution. With a camera installed on a nacelle, image recognition software and Makkonen's ice accretion model, it is possible to estimate the effective LWC from the increase of ice thickness on the reference cylinder. The effective LWC is defined as the fraction of the LWC that collides, sticks and accretes to the reference cylinder. In this study, on 8 selected days that presented severe icing events, the effective LWC values were inferred using the camera. The limitations of the camera method limited the analysis to daytime since the visibility of the setup did not allow reliable measurements at night. The camera effective LWC estimates were compared to the meteorological conditions monitoring station (MCMS) estimates on the same 8 days. It was found that the two methods presented good agreement on a temporal basis. The MCMS method for estimating the effective LWC provides a temporal LWC signal with better resolution and is independent of visibility. The proposed methodology can be easily implemented on-site and is a simple solution to compare the accuracy of any ice sensor to the standard camera observations.

**Web site:**

**Short biography:** Patrice is currently doing his Ph.D. in mechanical engineering at Université Laval in André Bégin-Drolet's lab. He has been working on the operation of wind turbines in cold climates for 5 years where he had the chance to contribute in the development of an ice detection device. He has authored and co-authored four scientific publications. He completed his bachelor's degree in engineering physics with a distinction mention. He also completed a master's degree in mechanical engineering. He was awarded the undergraduate student research award form NSERC three times, the FRQNT scholarship for his master's degree, the NSERC Alexander Graham Bell Graduate Scholarship (for both his masters and Ph. D.). 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 skiing, snowshoeing and trekking.

R&D areas/s: 06. Requirements and experiences of cold climate solutions - ice throw, thresholds, operational strategies, best practices incl. O&M, inspection and repair

**Skellefteå Kraft:s experiences of operating wind turbines in cold climate and the need of a physical testing**

*Krister Efverström, Skellefteå Kraft, SE*

Krister Efverström

Cold Climate Test Center
The goal for 2040 is 100% renewable energy where wind power are estimated to account for a large part of the electricity production that is to be expanded. The conversion to renewable energy requires a large proportion of wind power. Many of Sweden's municipalities and energy companies want to contribute to and promote sustainable development and thereby ensure that the establishment of wind power are as efficient as possible in terms of technical accessibility but also from a work environment and environmental perspective.
This presentation will deal with the need and possibility of testing turbines for cold climates in a physical environment. A turbine is not only a machine with certain requirements for performance but also a workplace for a large number of technicians who must remedy and maintain turbines in cold climates. The demands are high, not least on the turbine, but also on the personnel and organization that will maintain them.
Skellfteå kraft has long experience of operating wind power plants in cold climates. Experience shows that it is not enough to test turbines in a controlled laboratory environment. The knowledge and development of new turbines for cold climates must take place in the environment in which they will operate.
Icing that attaches to structures (Blade, Tower, Nacell) and the climate as a whole is a challenging factor technically, but it also affects the technician's availability to the turbines for remedial and preventive maintenance, which ultimately affects the production in a plant.
The energy losses of a cold climate turbine are about 5-10% due to icing of blades. Energy losses due to that service technician do not reaching the turbine are also an important aspect when it comes to cold climate turbines and HSE. In this case, it is not just about icing blades, but also about icing on the structure as a whole. The utilization of wind power in cold climates requires better technology and methods to cope with, not only anti-icing of blades, but also structural icing.
Since 2018, Skellefteå Kraft AB has run a project with about 20 co-financiers and partners with financing from VINNOVA to create a test site in Uljabuouda, Arjeplog municipality.
The concept of a test site is to offer a test environment for verification and establishment of technical development, working methods and risk assessment linked to wind farms in cold climates. The relationship and collaboration between participants provides natural networking and synergies enabling to develop the turbines of the future for cold climates.
A test site could not only contribute to the technical development of turbines for cold climates, but could also test and develop methods and routines that ensure a good working environment for the technicians. The results created in the test facility will contribute to increased availability, efficiency and safety of electricity production using wind power in cold climate.

**Web site:**

**Short biography:** Field Operation Mangager at Nordex, HSO (Helth and Safety Officer) as an consultant for Enercon, Site manager at Skellefteå Kraft, Project manager at Skellftå Kraft AB regarding test site development and a new anti-icing system developed by Linnovation.

R&D areas/s: Re-use of End-of Life wind turbine blades

## Re-use of wind turbine blade for construction and infrastructure applications

*Alann André, RISE Research Institutes of Sweden, SE*

Alann André (RISE, SWE), Georgi Nedev (SWECO, SWE), Cecilia Mattsson (RISE, SWE), Reza Haghani (Chalmers, SWE)

In a near future, many wind turbine blades will reach end-of-life or will be replaced. Within 5 years, an estimate of 36 000 blades in Europe are expected to be dismantled, which corresponds to 240 000 t of composite waste. Today, there is no sustainable and efficient solution to recycle these structures, as they are complex to recycle. New strict EU directives against landfill have been legislated, and therefore new solutions must be developed to tackle this environmental problem.
In order to achieve in the future a more resource-efficient society with reduced carbon dioxide emissions, new technological challenges must be taken. One way to reach a more sustainable world is to start reusing end-of-life structures and waste and give them a 'Second Life" with a new function in the society. As composite structures are lightweight, strong, stiff and durable materials, there is great potential to utilize them for new resource-efficient solutions in the building and infrastructure sector.
The present paper investigates innovative solutions in re-using wind turbine blades as elements in new bicycle and pedestrian bridges designs. Several bridge concept-designs where wind blades are utilized as load bearing structures have been studied. The main design requirements for pedestrian bridges have been considered. Assumptions regarding wind blades quality and their mechanical properties have been taken based on interview with industries working with wind blades repair and recycling. Initial cost comparison with bridge made of traditional materials are presented.
The aim of this paper is to contribute to a sustainable use of GFRP waste and at the same time provides a more cost-effective FRP bridge. In a larger perspective, the authors would like to highlight the economically profitable potential of recovering and reusing / re-manufacturing end-of-life GFRP composites.

**Web site:**

**Short biography:** Alann André have a PhD in structural engineering of composites from Chalmers University of Technology and currently work as senior scientist at RISE Research Institutes of Sweden. Focus areas are:

- Modeling and Simulation – damage initiation and propagation in composite structures
- Structural Engineering, bringing FRP to Infrastructure applications
- Re-use of End-of-Life (EoL) composite parts in new applications, with focus on construction and infrastructures application areas.

R&D areas/s: 10. National strategies, research programs, grid access, system services and new developments

## Protection and lifetime improvement for bearings and gears by using silicon-based additive technology

*Stefan Bill, Croda, DE*

Stefan Bill (REWITEC GmbH, DE), Dr. Petr Chizhik (REWITEC GmbH, DE)

REWITEC is a part of Croda Int Plc and developer and manufacturer of an innovative phyllosilicate-based surface treatment additive technology for gears. The particles with a platelet-shape use lubricants as a carrier and build through their adsorption a protective phyllosilicate-based coating on the surface. The modified surface has a significantly lower surface roughness, which ensures a better load distribution and lower local pressure. Additionally, due to the special layered material structure the particles can be sheared in the tribological contact, which leads to a significant reduction in friction. All in all, when applying the products treated systems can run better with reduced friction, wear, surface roughness and temperature.
For the further improvement and development of the technology, especially for the first fill applications, REWITEC has been working closely with several research institutes, universities and OEMs for many years, which can perform tribological tests with high accuracy and reliability in the lab and in the field. The tribological performance was proven with different test bench configurations like 2-discs, pin-on-disc, FE8, 4-ball, MTM, SRV and other model tests. Beside numerous scientific experiments there are more than 3000 successful treated wind turbines, where REWITEC was applied in the gearbox, and many thousands of applications in automotive gears.
In this presentation show highlights of the scientific studies about REWITEC in gear tribology and examples of technology application in technical systems. Generally, REWITEC achieves in running systems like gears a friction reduction between 20 and 60 % in mixed friction areas, a roughness reduction of up to 54 %, a weld load increase of up to 15 % and a reduction of standstill damage of up to 76 %. Due to the system modification the surface temperature decreases too. All in all, these effects provide a longer lifetime and higher efficiency of the tribological systems.

**Web site:** https://www.rewitec.com/index.php/de/

**Short biography:** From 1985-1988 Stefan Bill studied electrical engineering at the University of Applied Science Giessen, Germany. From 1988-2002 he was sales manager at LTI Motion GmbH in Lahnau. In 1999 he did a business administration training at the St. Gallen Business School. From 2002-2004 Mr. Bill was Head of Motors & Drives at ABB Automation Products in Mannheim. Since 2004 until today Mr. Bill is Managing Partner of REWITEC GmbH in Lahnau, developed the nano silicon based additive technology and applied the relevant international patents. Since July 2019, after the acquisition of REWITEC by CRODA, he has an additional position as a Global Business Director at Croda GmbH.

R&D areas/s: 04. De-/anti-icing including new technologies, ice detection & control incl. standards

**Linnovation concepts for operation and service in cold climates**

*Sven-Erik Thor, Lindskog Innovation, SE*

Kjell Lindskog, Sven-Erik Thor (both Lindskog Innovation, SE), Krister Efverström (Skellefteå Kraft AB, SE)

The main challenges operating windturbines in cold climates are as follows:
- Production losses due to icing
- Damages on blades due to falling ice
- Health and Safety Issues

The Linnovation concept for anti-icing addresses all three topics above. This presentation will give information about the latest development and experiences of the new and innovative anti-icing system. It is a system for retrofitting existing blades as well as to be incorporated in initial production of blades. The project has contributed to the development of the different sub-systems and interaction between them. The system now meets TRL level 7, at least.

Experiences from operation of the system on a wind turbine close to Malå in Sweden during severe icing conditions (fall 2020-winter 2021) will be presented. Comparisons with two other wind turbines in the windfarm will be presented and discussed in detail, mainly with focus on production losses/gains and availability.

In addition to that, information will be presented related to the Linnovation concepts for service and repair of different components in wind power plants operated in cold climate.

Examples are:
- Improved service platform. During the initial project it was realized that the existing platforms for service and repair of wind turbine blads had many drawbacks. The newly developed light weight platform incorporates among others a closed area where work can be performed in controlled and protected environment. The development is financially supported by the Swedish Energy Agency. A first demonstration of the platform on a wind power plant is planned late 2021.
- Repair and strengthening of blades. Severe damages on blades from falling ice is a challenge for operators of wind power plants. The new platform is an essential part of the concept.
- Nacelle and spinner anti-icing, uses the same technology as used on the anti-icing on the blades.
- New type of ice sensors

Support from the Swedish Energy Agency and Skellefteå Kraft is greatly acknowledged.

**Web site:**

**Short biography:** Kjell is an inventor and entrepreneur with long experiences related to fibre reinforced plastics and the inventor of the anti-icing system. The system is based on the bestselling technology used for safe handling of money.

Sven-Erik has been working in wind energy for 30 years in various positions. It started at the Aeronautical Research Institute of Sweden where fibre reinforced plastics was the main topic of interest. The first contact with wind was the structural design of a wind turbine blade to a 70kW machine. Ten years before retirement he was responsible for wind power RD&D at the utility Vattenfall. Today he works as a consultant in wind energy. Sven-Erik holds a MSc in Mechanical Engineering from The Royal Institute of Technology in Stockholm Sweden.

R&D areas/s: 04. De-/anti-icing including new technologies, ice detection & control incl. standards

**IPS retrofit for complex blades**

*Daniela Roeper, Borealis Wind, CA*

Daniela Roeper (Borealis Wind, Canada)

Borealis Wind, jointly with ULC Robotics, have been developing a method to modify blades which normally would not be retrofittable with a hot air IPS, due to internal structures that prevent airflow throughout the inside of the blade ("complex blades"). In 2020 we successfully completed the field testing, pilot testing and retrofit on to a turbine with complex blades. I would like to present the development process and the outcomes of this development.

**Web site:** https://www.borealiswind.com

**Short biography:** Daniela is a mechanical engineer with a passion for the environment. While still completing her undergraduate degree from the University of British Columbia, Daniela founded Borealis Wind, a startup that provides a blade de-icing retrofit for wind turbines, improving their reliability as well as increasing production. The company is now in its 5th year of operation and the system has been validated through implementation in Canada. The innovative system can be installed up-tower without removing the blades of the turbine, saving significant installation and maintenance costs. Daniela leads the company in her role as CEO, taking part in the technical and business development.

R&D areas/s: 01. Environmental Impact Assessments (EIA), risk mitigation, financial analysis, bankability, financing, market potential, 02. Pre-construction - agreements, assessments, permissions, building, operation and dismantling

## A road map for the wind energy industry: taking a proactive approach to the biodiversity challenge

*Tove Hägglund and Åsa Abel, Ecogain, SE*

Åsa Abel, Ecogain, asa.abel@ecogain.se (NOTE: Co-presenter)

The climate threat and the loss of biodiversity are the fateful issues of our time, which we as a society must deal with in order to ensure our welfare. The rapid expansion of wind power is a direct response to the urgent need to convert our energy system to renewable sources. At the same time, we cannot solve one environmental challenge without taking the other into account. The lengthy environmental assessments, where biodiversity is often a key issue, clearly show that the balance between the benefits of renewable energy and biodiversity can be a major challenge for society.
Biodiversity has in a short time become an important strategic issue in business and finance. New global goals will be negotiated within the Convention on Biological Diversity in 2021. This places new demands on actors offering renewable energy. Our reconnaissance is that fossil-free will not be enough to attract customers and investors.
The national strategy for sustainable wind power expansion, which was launched in 2021, shows that there are only a few areas left with good opportunities for different interests to coexist successfully. At the same time, coexistence is crucial.
How can wind power companies navigate the emerging new landscape?
We believe that the wind power industry has a lot to gain from being inspired by the mining and minerals industry, which recently launched the first Swedish industry roadmap for biodiversity. The goal of the roadmap is to strengthen the industry, nationally and internationally, through a proactive approach to the biodiversity challenge.
Through an industry-wide investment, wind power players can investigate and identify possible solutions and ways forward for how wind power can coexist with, and also strengthen, biodiversity. By agreeing on a high industry-wide level of responsibility in biodiversity issues, the public image of the entire industry can be enhanced, which can increase society's support, on both a local and a national level.
We at Ecogain have been managing the work with the mining and mineral industry's roadmap and are happy to share our experiences with Winterwind 2021. We will go into the work process, the mining companies' motives for developing a common roadmap, and what added value the roadmap has already given the industry.

**Web site:** https://www.ecogain.se/

**Short biography:** Tove Hägglund is head of the business area “Natural Capital” at Ecogain. She is an expert in creating strategies for a responsible approach to biodiversity and recently managed the development of “Mining With Nature”, Sweden’s first industry roadmap for biodiversity. She leads assignments on voluntary and statutory ecological after-treatment and compensation, carries out environmental assessments and is also an esteemed lecturer and educator. Tove studied geoscience and natural geography as well as environmental and health protection at Umeå University.
Åsa Abel is head of “Process Management species and habitat” at Ecogain. Based on the UN's global goals for sustainable development, she takes a comprehensive approach to companies' needs and challenges linked to responsible land use.
She has extensive experience of strategic and solution-focused work at management level, within both private companies and politically controlled organizations.
Åsa is an ecologist from Linköping University, which she combined with education in business administration and business management.

R&D areas/s: 01. Environmental Impact Assessments (EIA), risk mitigation, financial analysis, bankability, financing, market potential, 10. National strategies, research programs, grid access, system services and new developments

## Digital business and collaboration platform for local anchoring and collaboration

*Charlotte Larson and Oskar Ahlman, Vindkraftcentrum and Umeå University, SE*

Charlotte Unger Larson (Vindkraftcentrum, SE) and Oskar Ahlman (Umeå Universitet, SE)

Digital business and collaboration platform for local anchoring and collaboration
Vindkraftcentrum has together with Umeå University, 1 April 2019-31 March 2020, implemented the project "Digital business and collaboration platform for local anchoring and collaboration". The project has been funded by the Swedish Energy Agency.
The purpose of the digital business and collaboration platform was to facilitate a positive development in sparsely populated areas and to create business benefits when establishing wind farms. By making it easier for local companies and wind power developers to find each other and exchange services, increased acceptance of wind power and sustainable business development are created.
A problem for the wind power industry has been to easily find local service providers and for local companies to find ways to offer their services. In the new platform, companies enter their information about what they offer and where they operate and are matched with buyers of the services. Depending on what the company puts in for information about themselves, will affect when they get matched.
The platform is not static but is structured so that a dialogue can take place. When you have entered a directed wish or offer, you will receive an SMS in your mobile that you can answer.
The new business platform enables customers and suppliers to start at an early stage negotiations about their needs, offers or requests and then move on to simpler agreements.
The requirement to register is that the companies state the company name and organization number, which acts as a kind of certification.
As the industry is international with investors, developers and labor from several different countries, a translation service has been added so that it is possible to have multi-party conversations.
The conclusion is that there is great interest from municipalities and players in the wind power industry to use the platform to increase the local benefit in connection with wind power establishments. The platform is currently free of charge. A large-scale practical experiment is planned to be carried out in 2021-2022 to further demonstrate the added value for the local community and thereby create the conditions for commercial or public funding.
There are currently over 400 companies registered in the platform.

**Web site:** https://vindkraftcentrum.se/

**Short biography:** Biography - Charlotte Unger Larson
Charlotte Unger Larson is the former CEO of the Swedish Wind Energy Association (2015-2020) a trade association for companies working with wind power. The organisation publishes e.g. quarterly statistics and forecast for the Swedish wind power market, a yearly updated Roadmap 2040 that aims to help decision-makers and authorities achieve national energy and climate targets.
Charlotte has a degree of Licentiate of Medical Science from the Karolinska Institute. She has 30 years of experience working for a sustainable development within areas as pesticides, chemicals, waste, nuclear and pharmaceuticals. During 10 years she work for the Governmental offices both in Stockholm and in Brussels. Her focus has been to facilitate and to create an understanding between business and environment, and the positive effects this could have for both interests.
After commuting to Stockholm for 3 years she now lives permanently in Jämtland, together with her husband, cats and chickens, at their forest farm. When she is not working with wind power she works with clay mainly pottery.
Biography Oskar Ahlman
Innovation Project Leader at Umeå University, studying digital marketplaces and developing platform technologies for cities, industries, entrepreneurs and communities. Recent projects include Innovation in

R&D areas/s: 01. Environmental Impact Assessments (EIA), risk mitigation, financial analysis, bankability, financing, market potential, 10. National strategies, research programs, grid access, system services and new developments

Times of Crisis: How organizations Can Leverage Digital Platforms for Rapid Transformation in the Wake of Covid-19.

Founder and CEO of Peer Digital, developing platform strategies and building digital platform solutions, including a business platform for the wind power industry.

Co-founder of Sharing Lab, a research center for digital sharing technology at the Umeå University Department of Informatics.

Oskar Ahlman
PEER Digital
+4673-800 92 93
oskar.ahlman@peerdigital.se

R&D areas/s: keynote

# Climate resilience vs. low cost renewables

*Rosemary Barnes, Pardalote, AU*

no coauthors

This winter's extreme weather in Texas put the phenomenon of wind turbine icing into the mainstream. Extreme weather events like the Texas Freeze are predicted to become more common in the future due to climate change, and electricity grids along with other critical infrastructure will need to become more climate resilient as a result. All eyes are on blade heating and winterised wind turbines now, making this an unprecedented opportunity for the winter wind community. But it is also a challenge that will need to be carefully managed. Those of us working in the field know that there are technologies that – if installed – could have allowed Texas' wind turbines to operate through the cold snap. But long-term climate resilience is not that simple. If every turbine in every site with a climate like Texas is winterised in the future, the main thing we will achieve will be to make wind energy very expensive, and only marginally more reliable. Future clean energy systems need to be low cost as well as reliable, and wind energy can't be considered in isolation if we are going to achieve this. We will need to take a systemic approach to carefully consider what are the lowest cost technologies and market mechanisms to achieve a resilient electricity grid.

**Web site:**

**Short biography:** Rosemary is the principal at Pardalote, a consulting service for energy transition technologies. She is an engineer specialising in new technology development, with over 15 years' experience in the field including 4 years as the system owner of ice mitigation at LM Wind Power. She has bachelors degrees in systems engineering and philosophy from the Australian National University and a PhD in composite materials structural design from the University of New South Wales. She is also the owner of a YouTube channel: Engineering with Rosie, through which she educates and excites her audience about renewable energy technologies. Rosemary spends as much as possible of her spare time outdoors and is a keen skier, mountain biker and surfer.

R&D areas/s: Industry observer

**Comparison of wind's fatalities to that of other Industries**

*Paul Gipe, Wind-works, US*

wind-works.org

The capture and concentration of energy—in any form--is inherently dangerous. Wind energy exposes those who work with it to hazards similar to those in other industries. Of course, there are the hazards that, taken together, are unique to wind energy: high winds, heights, rotating machinery, and the large spinning mass of the wind turbine rotor. Wind energy's hazards, like its appearance on the landscape, are readily apparent. Wind energy hides no latent killers, no black lung, for example. When wind kills, it does so directly and with gruesome effect. Unpleasant as this topic may be, it emphasizes the need to work safely—because your life and that of your colleagues quite literally depends on it. We'll compare wind's record with that of other sources of generation.

**Web site:** http://wind-works.org

**Short biography:** Paul Gipe is an author, advocate, and analyst of the renewable energy industry. He has written extensively about the subject for the past four decades, receiving numerous awards for his efforts. Gipe also writes about his experience driving electric vehicles. He's driven electric since 2014.
Gipe has lectured before groups from Patagonia to Puglia, from Tasmania to Toronto, and from Halifax to Husum. He has spoken to audiences as large as 10,000 and as small as a private presentation for Vice President Al Gore. Gipe is well known for his frank appraisal of the promise and pitfalls of wind energy, including his stinging critiques of Internet wonders and the hustlers and charlatans who promote them. He led the campaign to adapt electricity feed laws to the North American market—the same policy that has stirred a renewable energy revolution in Germany. His most recent book, Wind Energy for the Rest of Us, introduces Germany's electricity rebels to a North American audience for the first time. The book, Gipe's seventh on wind energy, debunks novel wind turbines, rebukes revisionist historians, and argues that renewable energy is too important to be left to electric utilities.

R&D areas/s: worldwide wind energy developments

**Wind Power Around the World**

*Stefan Gsänger, World Wind Energy Association WWEA*

Stefan Gsänger, WWEA

Latest trends in global wind power deployment will be presented, based on statistics published recently by WWEA. In the year 2020, the world set a new record in new wind power installations, adding 93 gigawatts of new wind turbines within the year 2020. Some countries set new installation records, including China, the USA and Russia, while most European markets saw only modest growth. The strong growth comes as a surprise to some observers as many countries reported delays over the past year due to disrupted international supply chains and lack of labour availability. Developments will be analysed and current trends will be outlined.

**Web site:** https://wwindea.org/

**Short biography:** Stefan Gsänger has managed WWEA since its foundation in 2001. Under his direction, WWEA has become the voice of the wind sector worldwide, with members in more than 100 countries. WWEA attained Special Consultative Status at the UN.
Stefan Gsänger holds various other positions, including co chair of the Global100% Renewable Energy Platform as well as member of the managing committee of the REN Alliance and of the REN21 steering committee. He chairs the IRENA Coalition for Action Community Energy Group, and is adviser to governments and international organisations.
Mr Gsänger has supervised and co-chaired 19 World Wind Energy Conferences, and has been an invited speaker at conferences in 40 countries. He has published numerous articles and studies and is editor of various publications including the WWEA policy paper series.