R&D and Market Review of Wind Turbines in Cold and Icing Climates

A Report from the IEA Wind Task 19, Wind Energy in Cold Climates

Esa Peltola VTT Finland

Timo Laakso, Pöyry Energy Oy, Finland • Tomas Wallenius, VTT, Finland • Michael Durstewitz, ISET, Germany • Ian Baring-Gould, National Renewable Energy Laboratory, USA • Lars Tallhaug, Kjeller Vindteknikk Norway • Robert Horbaty, ENCO Switzerland • Göran Ronsten, WindREN Ab Sweden, Antoine Lacroix, Natural Resources Canada

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  - ➔ project development
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IEA R&D Wind Task 19
Wind Energy in Cold Climates

Structure: One of the 7 research tasks under the International Energy Agency Co-operative Wind Energy Agreement - www.ieawind.org

Focus: Sites with icing events or low temperatures outside standard operational limits of wind turbines

Aim: To reduce the risk that originates from using wind technology in cold climates and thereby reduce the cost of wind produced electricity

Means: Development of tools, methods, and guidelines; standardization work; information dissemination

Duration: Started in 2001 and currently set to run thought 2008

Participating countries: Finland (OA), Norway, USA, Switzerland, Canada, Germany, Sweden

Web Site: *http://arcticwind.vtt.fi*

Documents: currently being updated

- State-of-the-Art Report (2003)
- Recommendation Guide: Wind Energy Projects in Cold Climates (2005)

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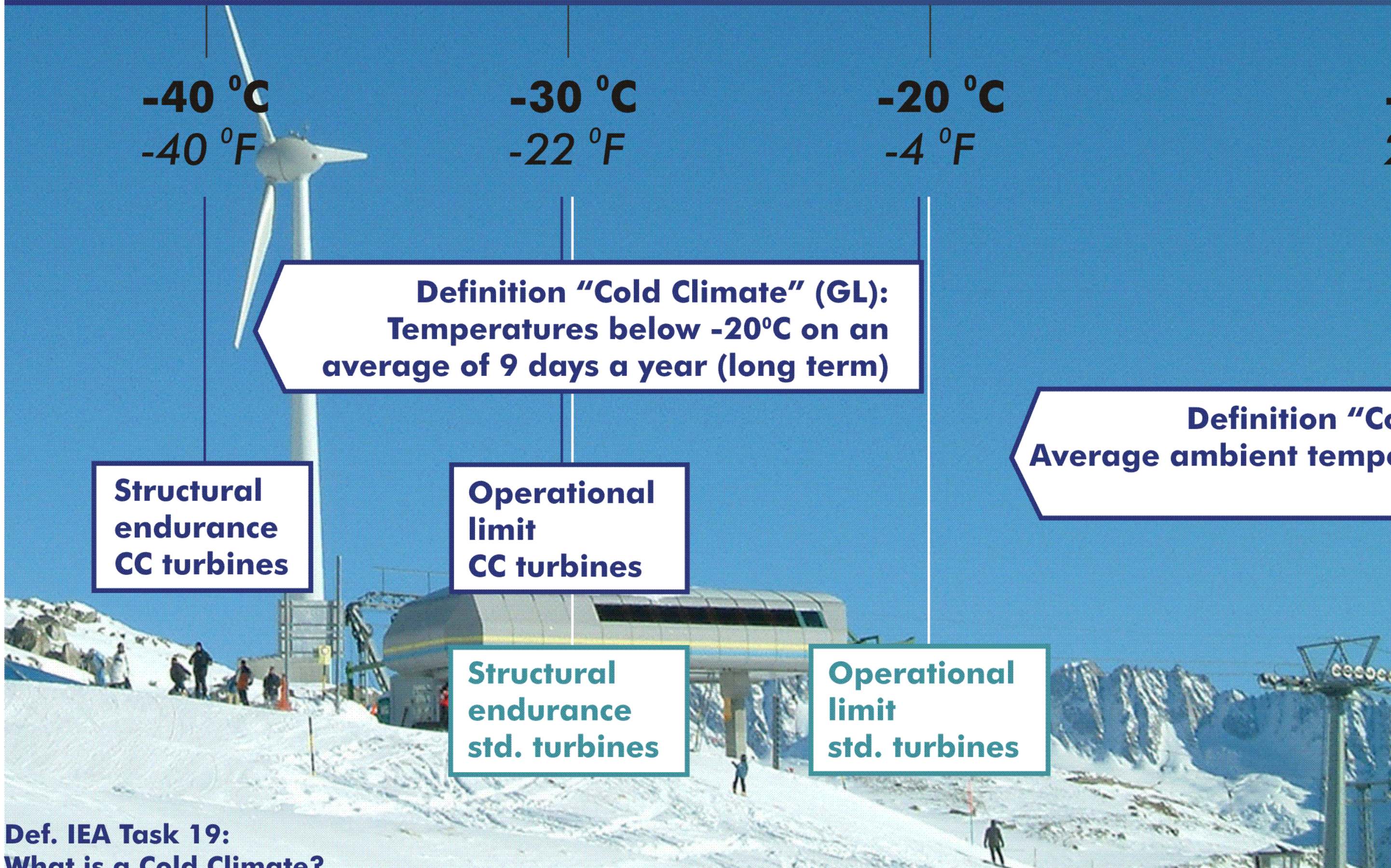
Cold Climate Conditions



-40 °C	-30 °C	-20 °C	-5 °C	0 °C	+15 °C
-40 °F	-22 °F	-4 °F	23 °F	32 °F	+59 °F

(GL): Design temperature for standard turbines (+15 °C)

Definition "Cold Climate" (GL): Temperatures below -20°C on an average of 9 days a year (long term)

Definition "Cold Climate" (GL): Average ambient temperature below 0°C (long term)

Structural endurance CC turbines (-40 °C)

Operational limit CC turbines (-30 °C)

Structural endurance std. turbines (-30 °C)

Operational limit std. turbines (-20 °C)

Icing conditions:
snow, rime,
super cooled rain

Def. IEA Task 19:
What is a Cold Climate?
Wind turbines that either operate at outside the operational limits (lower than -20°C) or that experience icing that causes production losses or impacts the type of turbine required.

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WIND ENERGY IN COLD CLIMATES

Requirements for Project Development

Site Pre-Selection

- Grid connection costs
- Service access (time of year dependent)
- Assessment of the effects of Icing on production and turbine loads

Wind Resource Assessments

- Good expertise in wind measurements needed (anemometer choice, data collection security, met mast choice, and required data consistency)
- Power for heated sensors
- Careful data analysis to understand the actual wind resource
- Correct methods in production forecasts to account for losses due to icing

Environmental Assessment

- Permitting (all the standard stuff)
- Public safety
- Construction timing

Technical Specifications

- Obtaining equipment (anemometers, towers, and turbines) that are truly rated for operation in arctic climates

Digging out the power supply

Photos credit: Lars Tallhaug

Photos credit: Pöyry Energy

Effects of ice on met towers

Photos credit: Pöyry Energy

Met tower installation

Photos credit: Lars Tallhaug

Photos credit: Doug Vought

Reliable Site Data for Project Development

Data gathering for cold climate projects:

- National data for conditions associated with icing, cold temperature, and humidity
- No fully heated first class anemometers available
- No reliable ice detection - multiple levels (temperature, Humidity, iceing type, extent and duration)
- Use of multiple instrumentation for back-up and data quality assessment generally required
- Use of appropriate measurement practices and models for site evaluation

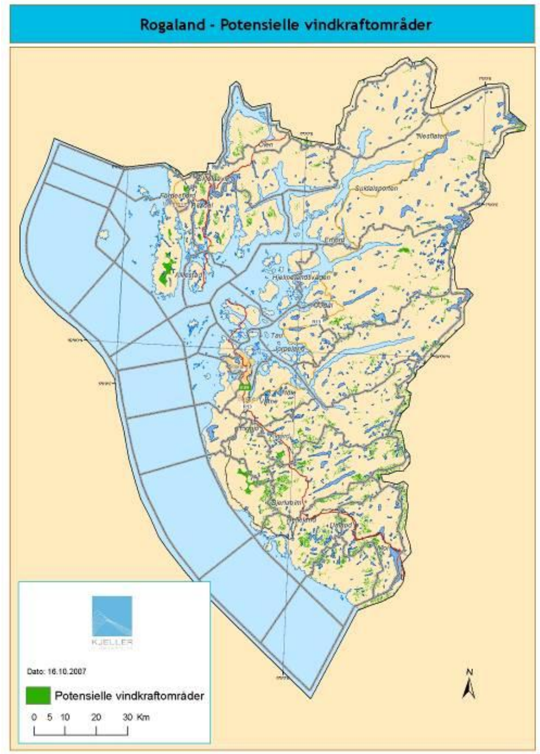
Site assessment models

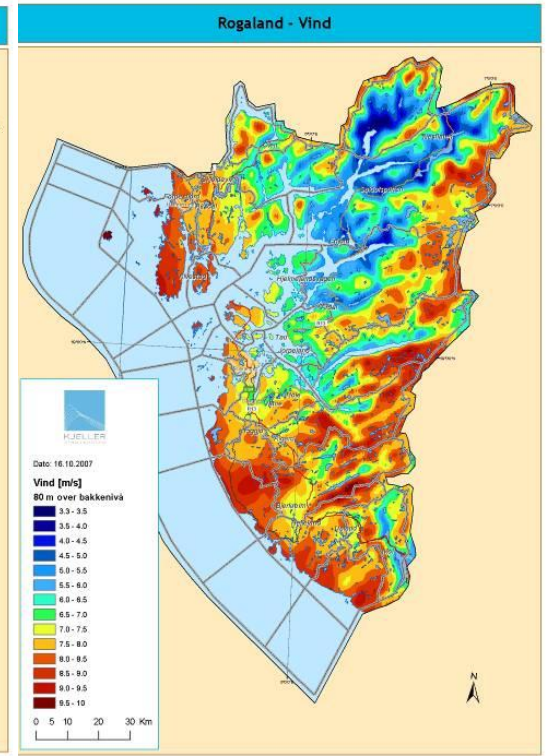
- Models under development to assess icing and improve site selection
- Generally starts with global model data but require some specific input data which is often limited
- Testing in Scandinavian and alpine

Photos credit: Pöyry Energy

Redundant wind assessment devices may improve data capture

Weather Research and Forecasting Model





Topography and development maps generated for southwest Norway
Mean WS > 7.5 m/s,
Topographic inclination < 10°,
Icing < 10% of the time
distance to houses > 1 km.

– Kjeller Vindteknikk – Norway

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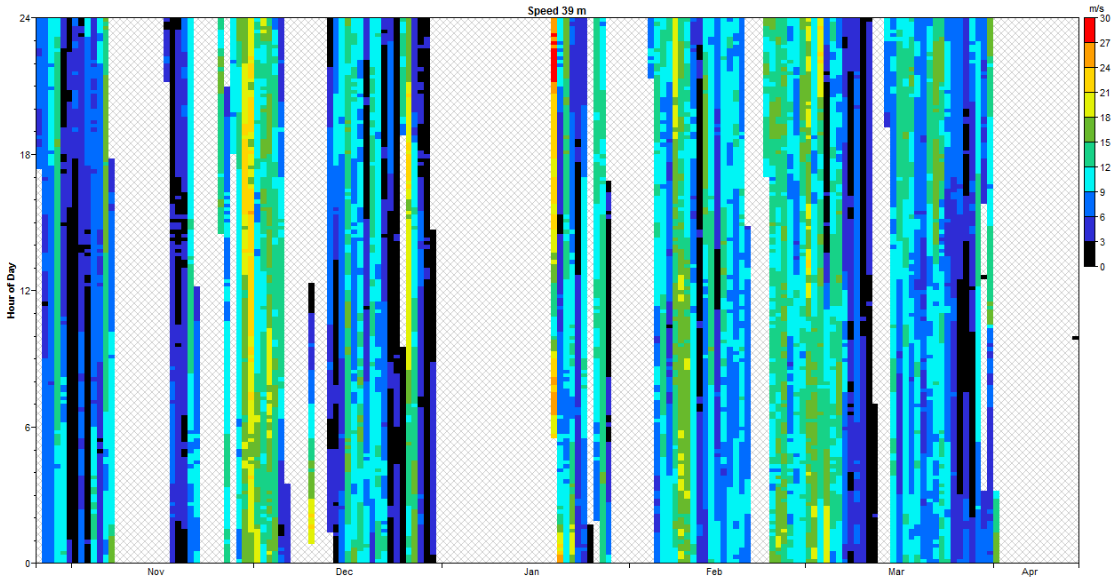
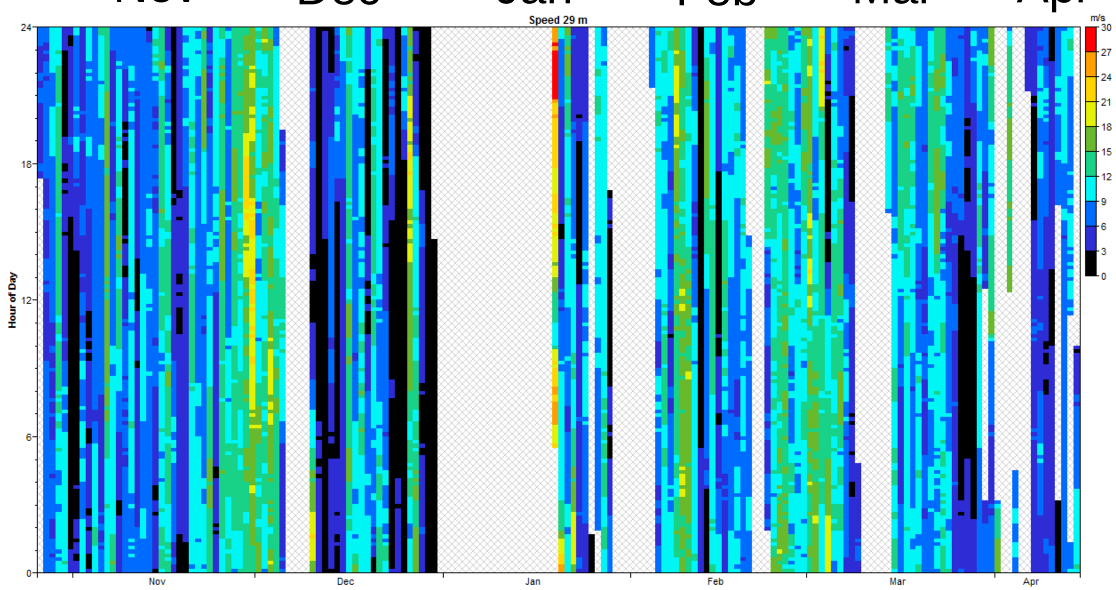
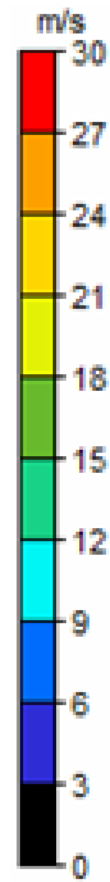
Ice-free Anemometers Will Not Save The Day



Nov Dec Jan Feb Mar Apr



NRG #40S anemometer data from St. Mary's Alaska (Lat. 62° N)



Photos credit: Timo Laakso

Photos credit: Timo Laakso

Same site with an NRG IceFree III anemometer

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Source: Doug Vought, V3 Energy LLC

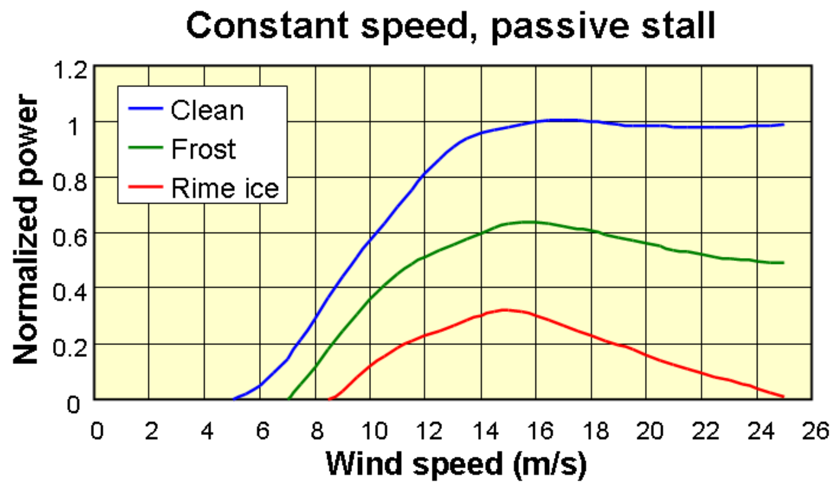
Production Losses Due to Icing

Ice accumulation on blades

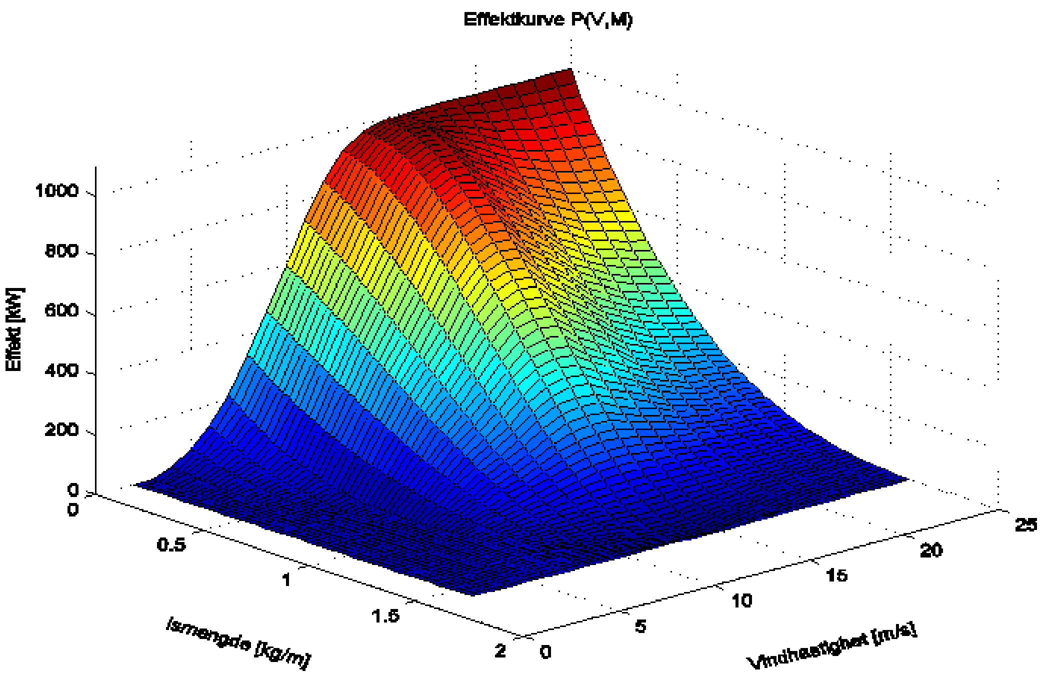
- impacts power production
- not always shut off the turbine

Reduction of losses in light icing conditions possible

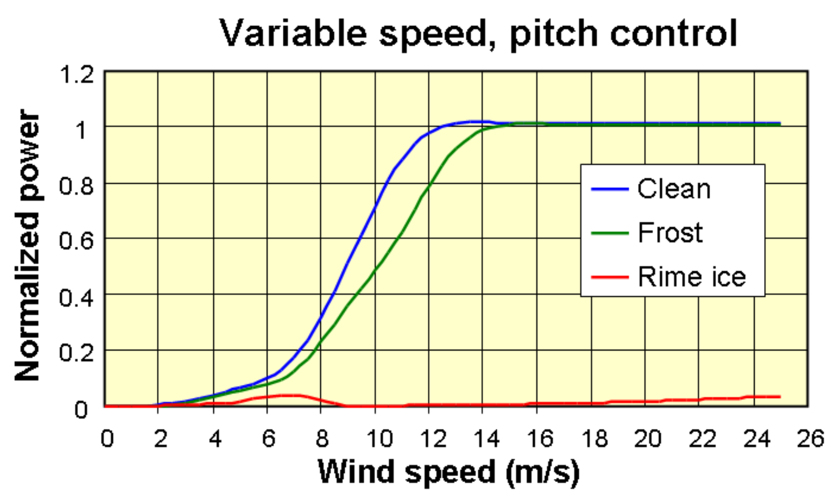
Limits the time the turbine will be impacted



Adams simulation of turbine power curves under different icing conditions – VTT, Technical Research Centre of Finland



Power curve of turbines can be modified to reflect icing – Kjeller Vindteknikk, Norway

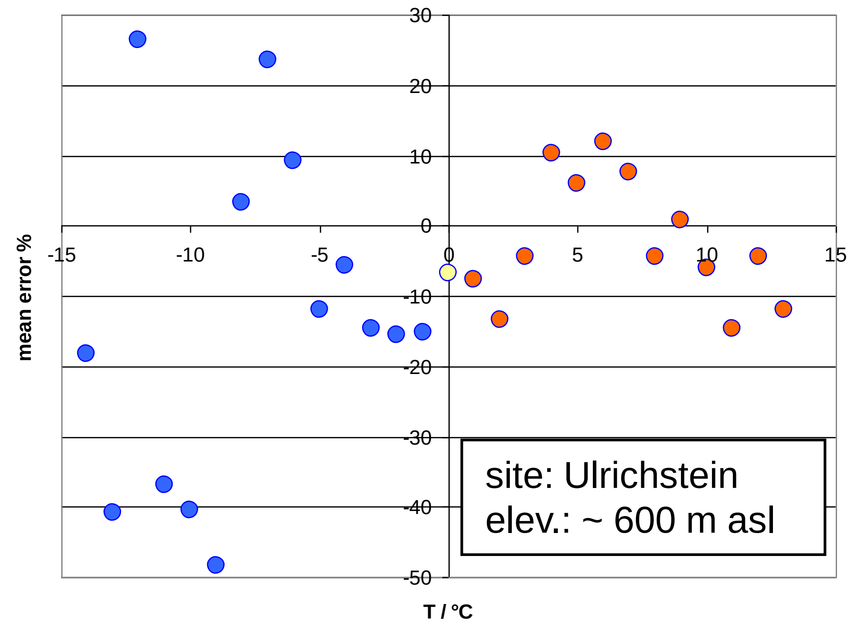


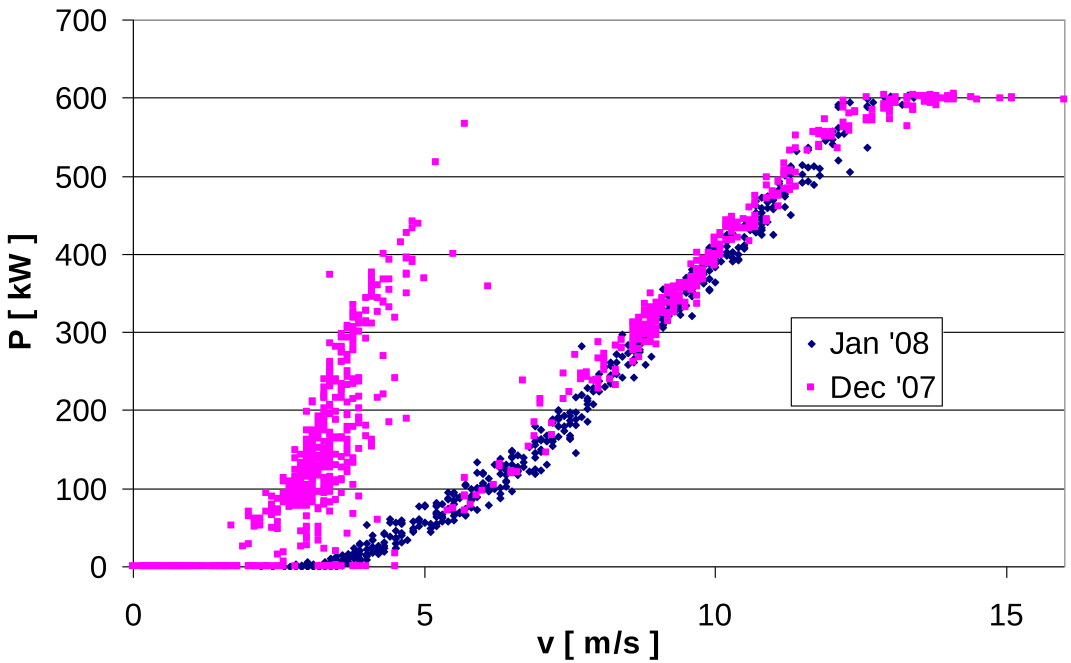
Impacts of Production Forecasting and System Operation

Comparison of a wind turbine power under icing conditions:

the control anemometer is showing signs of icing

results are control and forecasting errors





Larger increase in forecasting error is seen in German wind farms when operated at cold temperatures.

Source ISET, Germany - www.iset.uni-kassel.de.

Atmospheric Icing Research

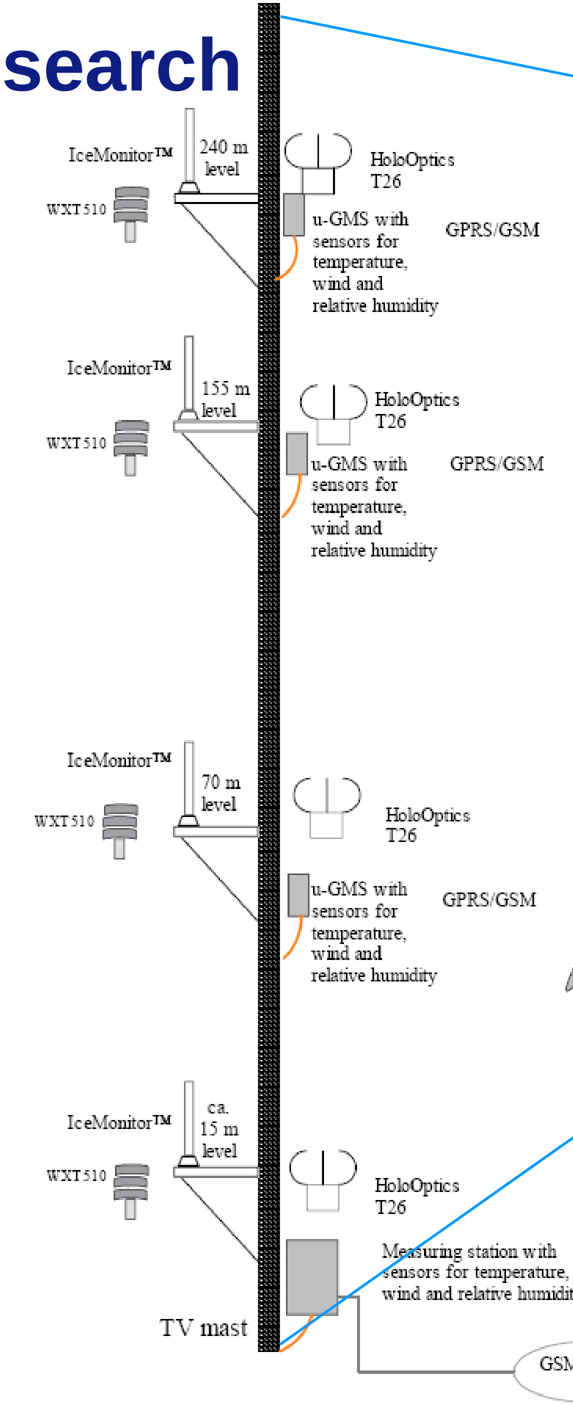
- Sveg, Middle Sweden
- 62° N, 14° E, altitude ~ 700m
- WT – V90-2MW
- CC version, SKF CMS-system (can detect 1P)
- No de-icing system
- Start of synoptic icing measurements?

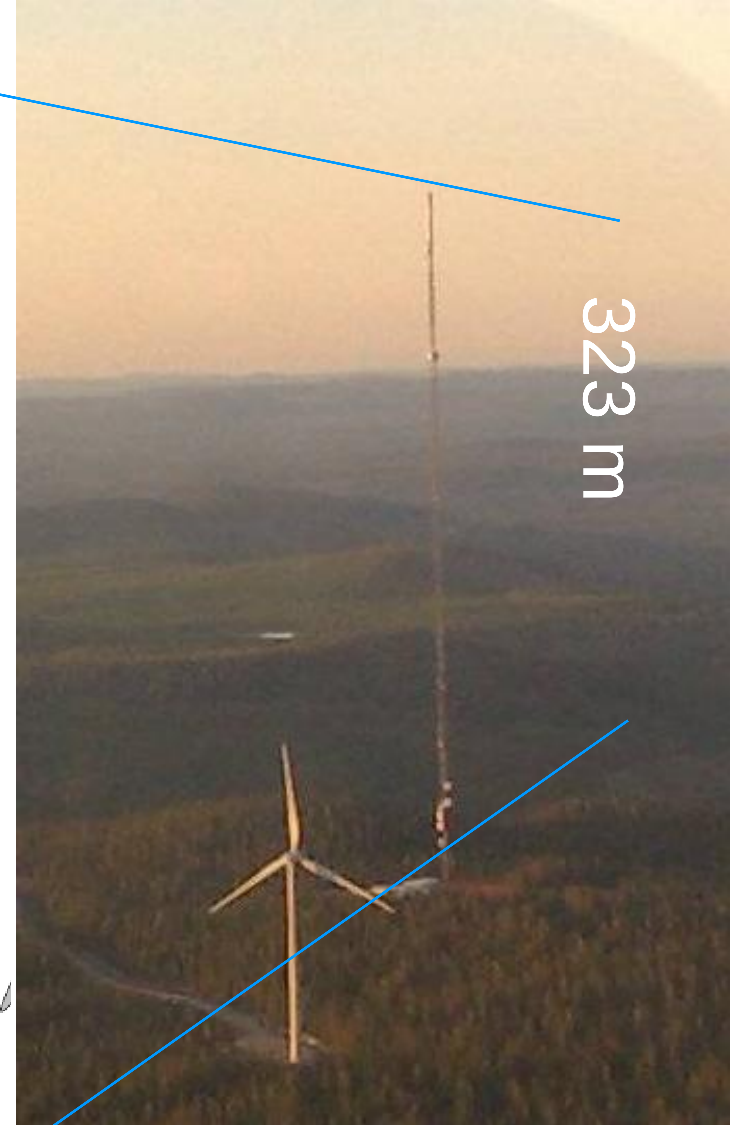
Targets

- Initiate synoptic icing measurements
- Verify forecast models with respect to icing

Preliminary results:

- The task to model icing situations in SVEG have just started.
- Results will be presented at Winterwind 2008, http://winterwind.se/





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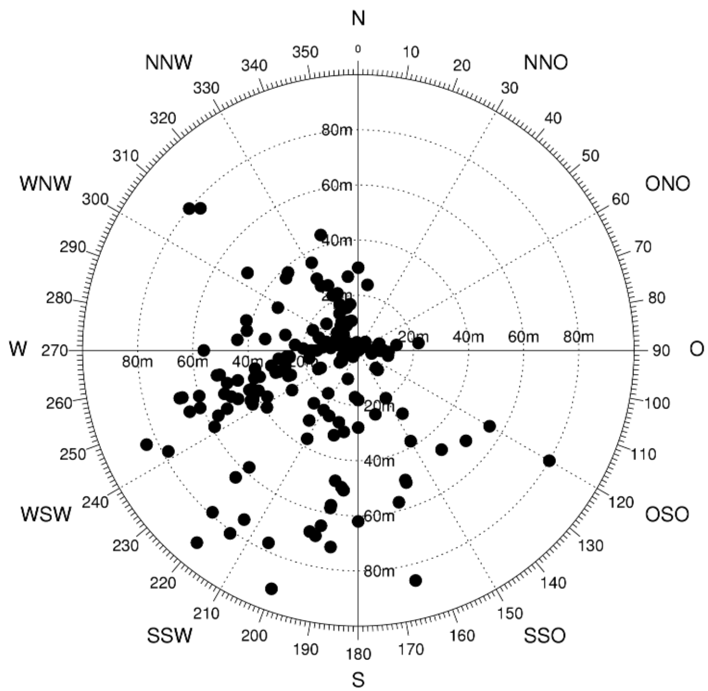
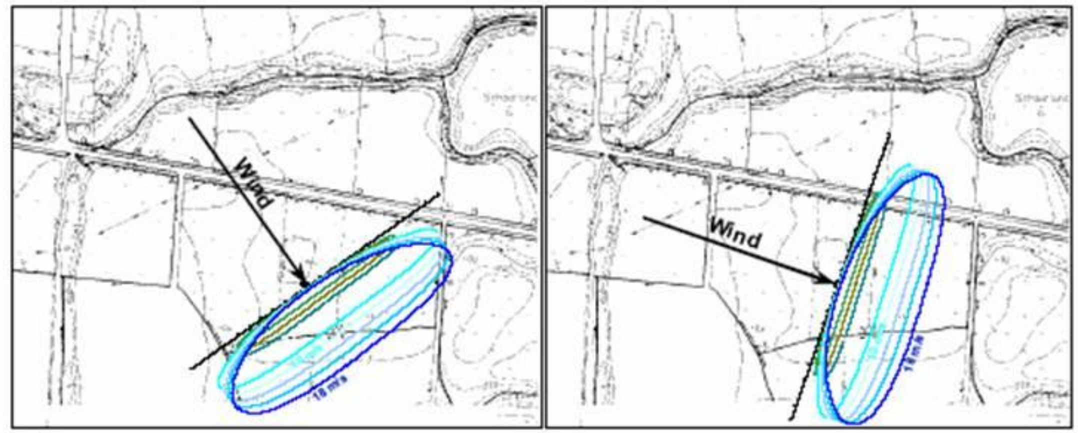
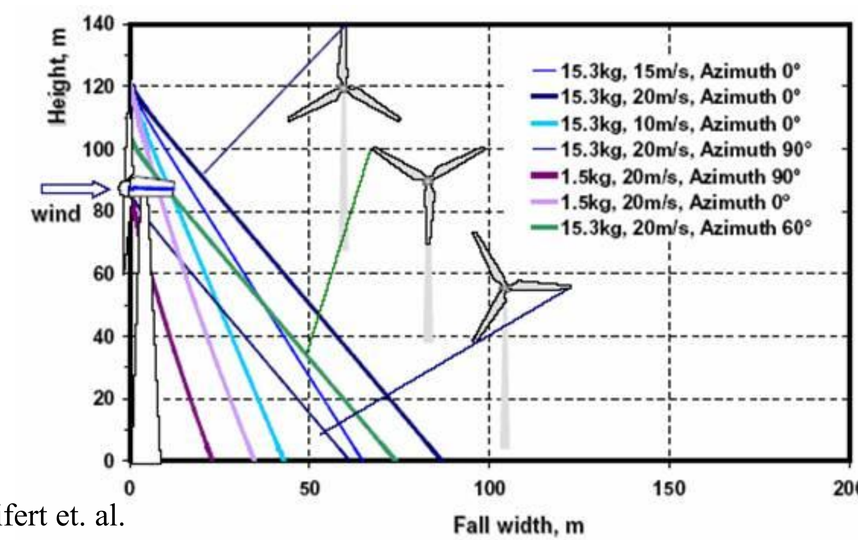
Public Safety – Falling and/or Thrown Ice



Ice fall study from the Gütsch Alpine Wind Test Site in Switzerland with an Enercon E-40 wind turbine. Prevailing wind from the NNO



Falling and thrown ice can impact public safety, but impact assessment is dependent on many factors including wind speed, rotor diameter, and height



Source: "Risk Analysis of Ice Throw from Wind Turbines" by Henry Seifert et. al. from DEWI, Deutsches Windenergie-Institut GmbH, Cuxhaven, Germany

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Mitigation Strategies

Several mitigation strategies are available to reduce the impact of icing events on the turbine fleet:

Ice prevention (anti-icing): Modifications to turbines that prevent ice buildup on blades or other surfaces (example: heating the inside of the blades)

Ice removal (de-icing): Removal of ice from blades after the icing event is over (example: leading-edge heating elements)

Each option has its own set of:

- Capital and maintenance costs
- Power consumption requirements

But both increases energy capture – so it becomes an economics question:

Is the additional cost and energy consumption of the icing retrofit worth the increased energy capture obtained from the turbine?

Several simple models can be used to answer this question for a specific site **if** you have the data

Ice Mitigation Technologies/Strategies

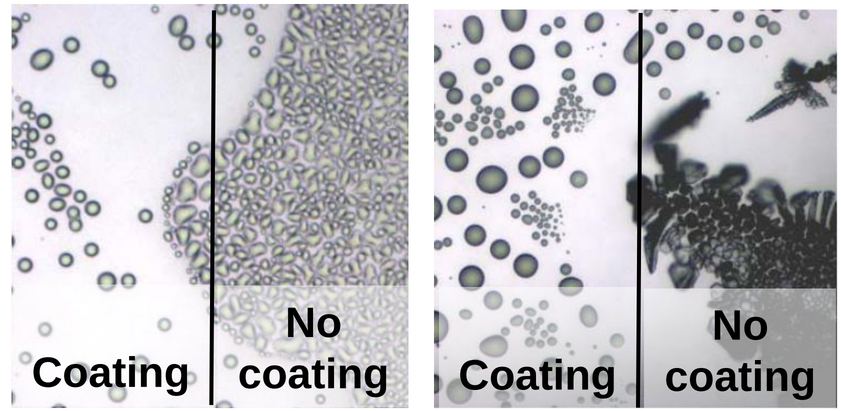
Currently used approaches

- Blade core heating
- Leading-edge heat tape
- Blade color
- Reduced stick coatings

New concepts under development

- Nanotechnologies
- Piezoelectric coatings
- New engineered coatings

Room Temp Below Freezing



Anti-freeze coating developed at the Zurich University of Applied Studies

(a) Plain (b) Icephobic (c) Hydrophobic

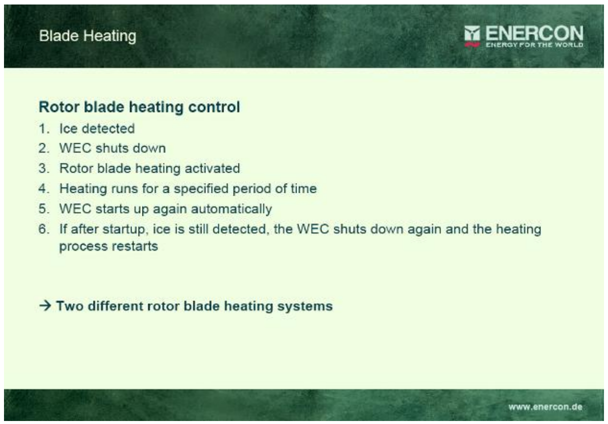
Wind tunnel testing of anti-ice coatings conducted at the University of Manitoba

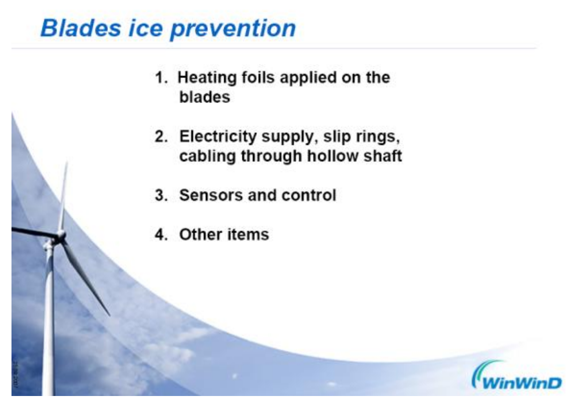
Photos credit: Ian Baring-Gould

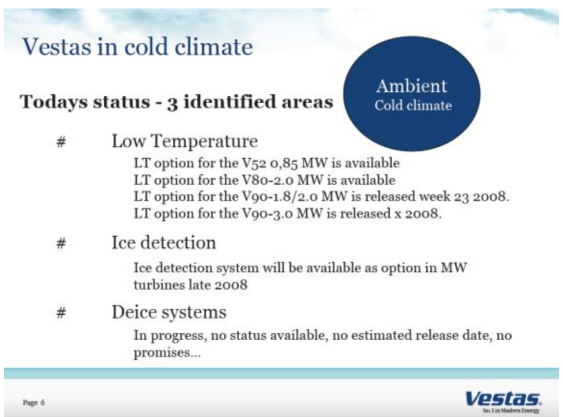
Blades color choice in Kotzebue, Alaska

Industry Solutions for Cold Climates

Many turbine manufactures have “Cold Climate” turbines that feature different lubricants, metals, and fittings to lower the turbines’ operational temperatures. Choices for anti and de-icing are much more limited.







Source: http://www.vintervind2008.se/ -> Dokumentation

Market Present, but Largely Undocumented

Several market assessments conducted in Europe – none in the U.S.

EU NewIcetools-project 2005

- Combination data of wind market and climate conditions
- ~10% of the market by 2020 estimated ”cold climate”

Present assessment indicates larger market

- Expanded production expected in Sweden, Finland, and Norway
- Expanding U.S. and Canadian markets require installation into areas where icing is documented

Industry indications

- Ice problems exist in operational turbines
- Standard turbines commonly used in sites fitting definition as cold climate

Country	CC Installed	Total 2010	CC 2010	Total 2020	CC 2020	CC without Installed
	MW	MW	MW	MW	MW	MW
Austria	47	900	100	1,850	400	353
Belgium	8	250	20	670	50	42
Czech Rep	5	430	340	1,500	1,050	1,045
Denmark	900	4,500	1,350	4,500	1,350	450
Estonia	26	80	80	500	500	474
Finland	82	300	300	1,500	1,500	1,418
France	26	3,000	180	10,000	600	574
Germany	342	28,000	840	30,000	900	558
Hungary	0	300	90	500	150	150
Italy	50	3,600	120	10,000	500	450
Latvia	1	80	8	500	100	99
Lithuania	0	80	8	500	100	100
Poland	0	800	0	4,000	100	100
Slovakia	3	400	200	800	400	397
Slovenia	0	100	80	300	240	240
Spain	0	15,000	150	20,000	200	200
Sweden	71	2,000	400	4,000	800	729
U. K.	0	3,000	60	6,000	120	120
EU-25	1,561	62,820	4,326	97,120	9,060	7,499

Estimated cold climate (CC) turbine capacity in Europe
Source: NewIcetools-project, Georg Kury

North America Icing Regions
Source: www.nws.noaa.gov

Conclusions

- Implementing projects in cold climates generally requires application outside of all standard wind guidelines.
- Care must be taken when assessing projects, especially in areas where ice will be a factor.
- Standard equipment and assessment techniques are generally not applicable in places with heavy icing – nor is most specialized equipment.
- Different approaches for safe turbine operation and maintenance/public safety need to be considered.
- Icing events will impact turbine production, and it is an economic question if the investment in anti- or de-icing technology is appropriate for a specific site.
- Several new techniques are under development to reduce the impact of icing – and while turbines with cold temperature ratings are more common, ice prevention is not heavily developed in the industry.
- A great deal more work must be done to assess the impact of wind turbines in icing climates and develop appropriate assessment and mitigation strategies.
- Some help is available: IEA Task 19 - *http://arcticwind.vtt.fi*

Thank You!

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IEA Task 19 participants

Finland
operating agent

VTT
PÖYRY

KJELLER VINDTEKNIKK
Norway

USA
NREL

ISET
Germany

Canada
Natural Resources Canada

WindREN AB
Wind - Renewable Energy Now
Sweden

Switzerland
ENCO

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