Wind Power in cold climate

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UNITED BY OUR DIFFERENCE

Scope of work – aspects of icing

- Conditions for icing to occur
- Effects of icing
- Methods for de-icing and prevention of icing
- Economic aspects of icing and de/anti-icing

- Also methods of measurements and forecasts, instruments

- Existing reports and research, but also point out knowledge gaps

The content of the report

- Results and development in the Nordic countries
- Compared to Canada

- Each aspect described, reflections included

- Analysis – what should be done

- Several references…

- Appendix with several on-going and completed research and development projects

Agenda for this presentation

- Summary - the results from each country

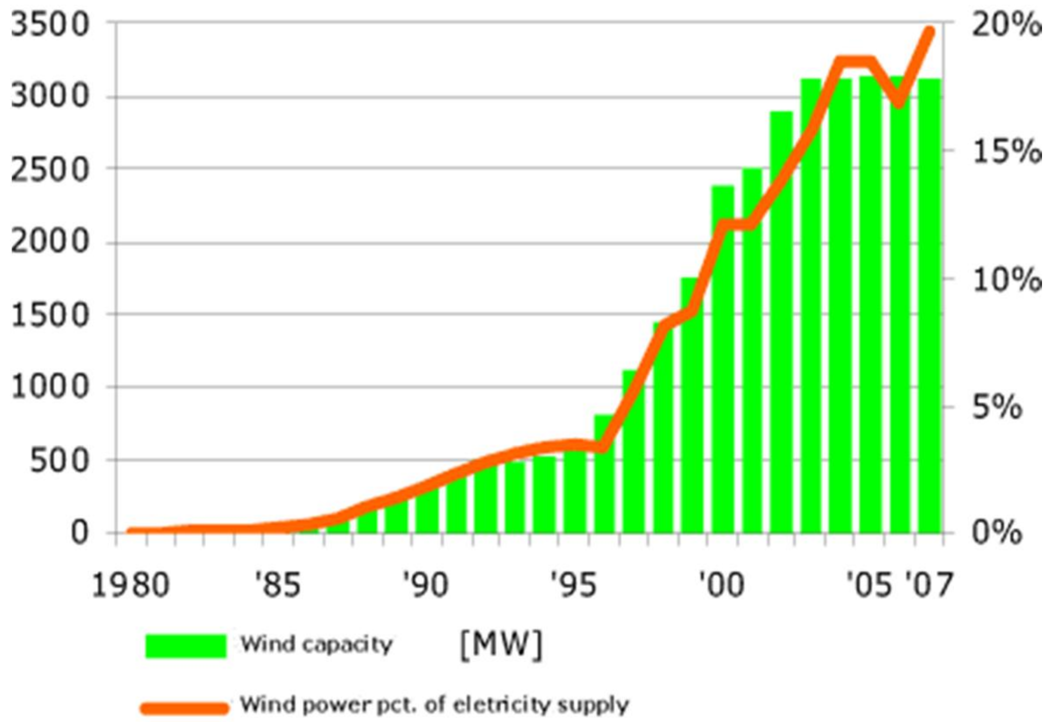
- Each aspect described and some reflections

Discussion

- Can we make any conclusions from the report?
- How severe are the economic risks when planning wind power plants?
- Any knowledge gaps from your angles?
- What will happen in the future?
- What incitements are there for further research? Who should pay?
- Are existing forums and possibilities for sharing information enough?
- More interdisciplinary research and cooperation can solve the problems?

Denmark

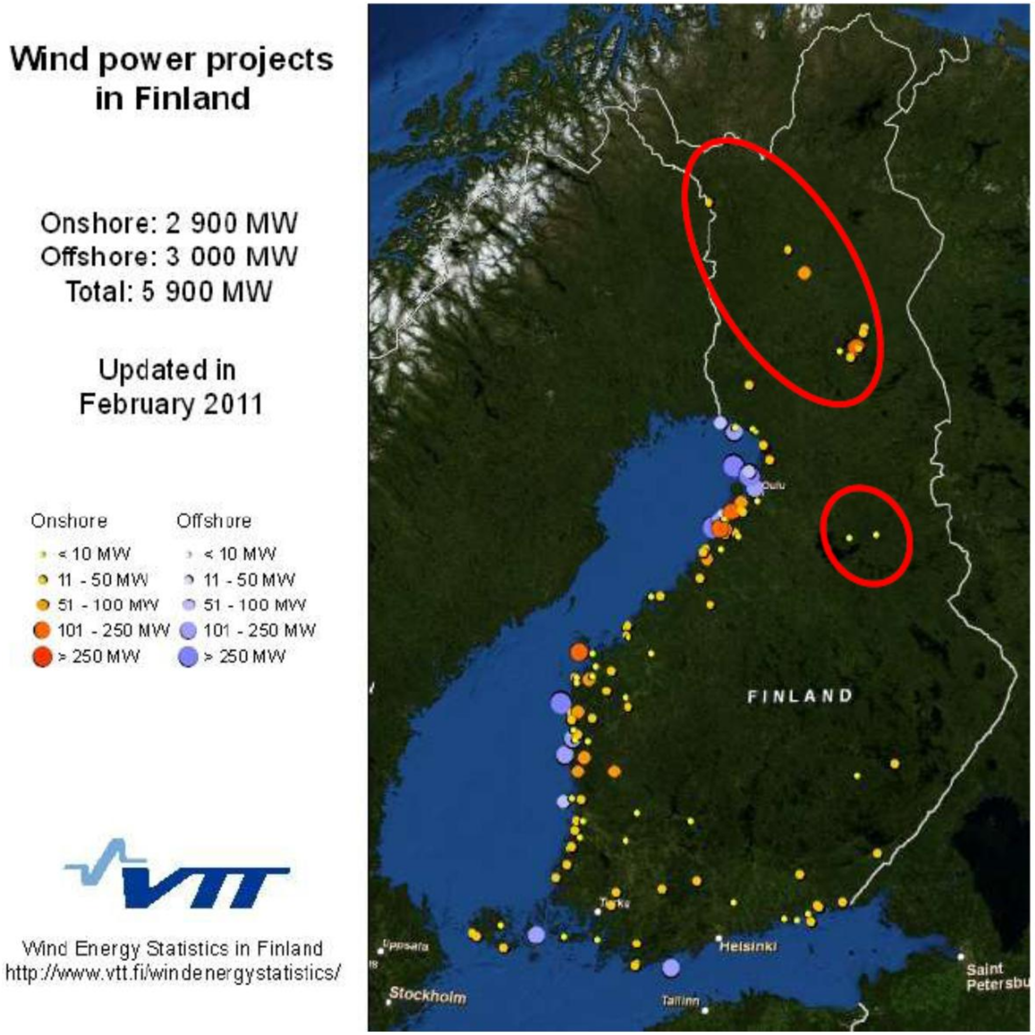
- Wind power in Denmark
- Climate
- Research and development



Wind power development in Denmark
Reference : Danish Energy Agency, 2011-07-07

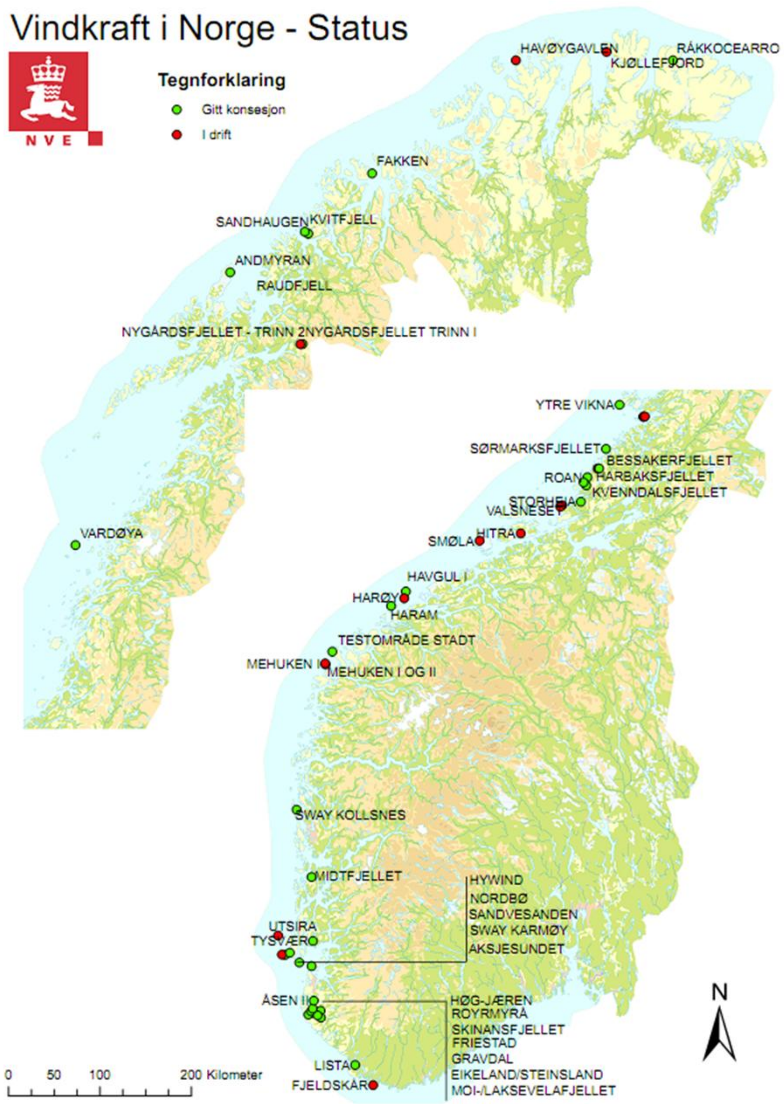
Finland

- Wind power in Finland
- Climate
- Research and development



Planned wind power projects with strong risk for icing of blades.
Reference : VTT, 2011-06-20

Norway



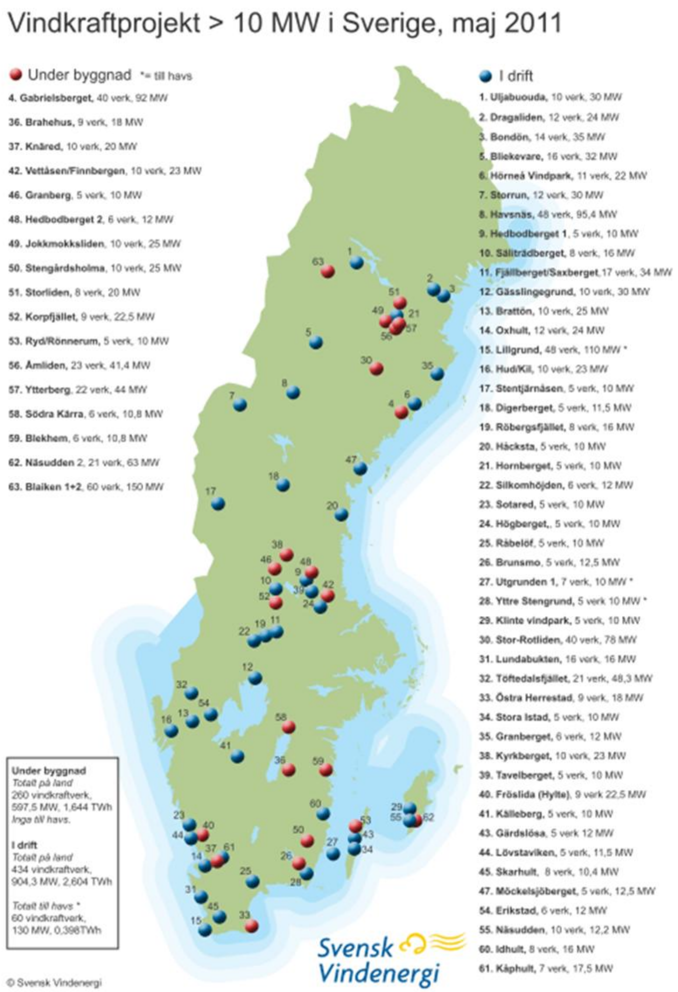
- Wind power in Norway
- Climate
- Research and development

Wind power plants in operation and under construction in Norway, 2011

Reference : vindkraft.no, 2011-11-28

Sweden

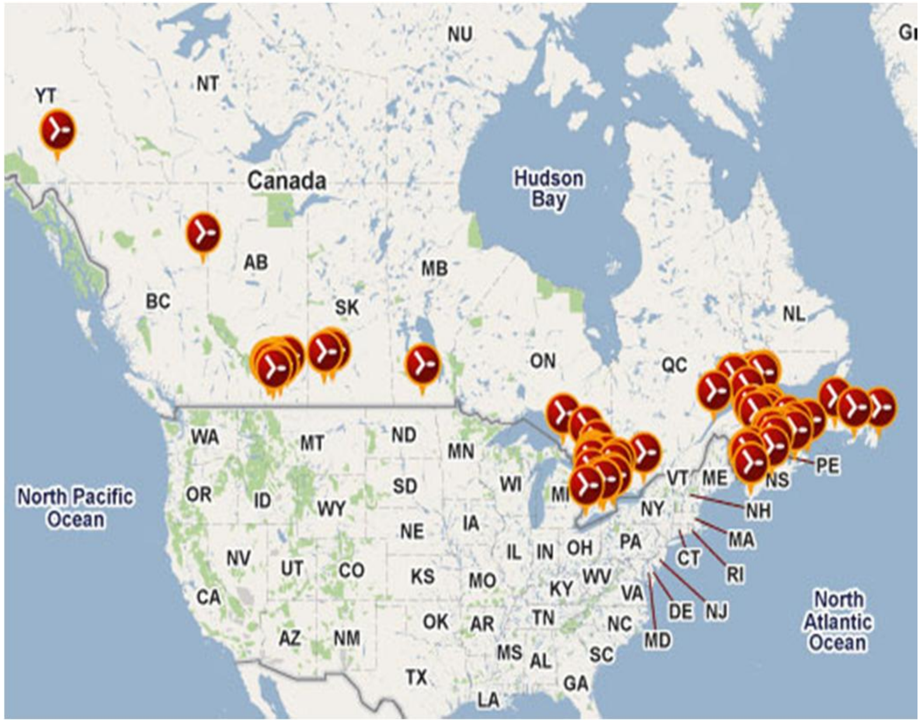
- Wind power in Sweden
- Climate
- Research and development



Wind power plants in operation and under construction in Sweden, May 2011
Reference : Svensk Vindenergi, 2011-09-05

Canada

- Wind power in Canada
- Climate
- Research and development



Wind power installations in Canada 2011

Reference : Canadian Wind Energy Association, 2011-07-06

Reflections - Differences and similarities between Scandinavia and Canada

- **Similarities**
  - Conditions for icing
  - Type of icing
  - Effects
  - Solutions
  - R&D projects
- **Differences**
  - Regional and local weather
  - Conditions for icing
  - Type of icing
  - Effects
  - Solutions

- Problems are similar at macro level, but different at local level
- Different types of icing may cause different effects. The similarities and differences are connected to the local climate.

Conditions for icing

- Weather conditions and different types of icing
  - Icing is a complex process dependent on different weather conditions, which results in different types of icing (precipitation icing, in-cloud icing, hoar frost).
  - Icing on wind turbines appears most commonly at sites/conditions with high humidity and temperatures just below 0 ^{o} C.
- Geographical impact
  - Icing depends on height, i.e. the taller turbines the higher is the icing rate.
- Ice build up on wind turbines
  - Different formations on the blades depending on the weather conditions.
- ISO standard
  - For icing on structures

Conditions for icing
- Summary and reflection

- Much is known about conditions and appearance

- Icing on wind turbines in Scandinavia most commonly depends on the liquid content of air in combination with low temperatures

- The icing accelerates with the height above ground

Effects of icing…

- Production losses
  - Icing changes aerodynamics of the blade resulting in production losses

- Turbine loads
  - Additional vibrations caused by mass and aerodynamic imbalance
  - Production losses when turbine is stopped
  - May increase the structural loads of a turbine significantly

- Shortening of component´s lifetime
  - Vibrations cause higher loads

- Difficulties in production forecasts
  - Icing of anemometers, difficulties both in resource estimation and in turbine control

…Effects of icing

- Unfulfilled power curves
  - Iced up blades makes rotor speed slower

- Safety risks – ice throw
  - Ice thrown off the blade may pose a safety risk even in areas where icing is infrequent.
  - Mitigation methods are available.
  - Risk assessment

- Increase of blade generated noise
  - Changes in blade structure cause higher noise

Effects of icing
- Summary and reflections

- Icing cause several problems, with **production losses as a result**

- Available and reliable ice detectors and wind measurement instruments for measurements in icing conditions is significant
  - To enable forecasts and investment decisions on prevention systems

- Development of de- and/or anti-icing systems is most likely needed. Preferably to be installed pre-construction.

- Ice loads are not simulated in the development of turbines today - this may pose a problem if icing:
  - Cause shorter life time of components
  - Cause higher insurance costs
  - Cause lower warranty levels

Measurements and prediction of ice accretion…

- Measurement of icing parameters

  - Expected key parameters are ***droplet size distribution*** and *l****iquid water content of air****, combined with ***temperature*** and ***wind speed*** - currently not possible to measure

  - Strategies used today are:

    - Measurement of visibility and estimation of vertical velocity to approximate droplet size distribution and liquid water content of air

    - Air temperature combined with humidity

…Measurements and prediction of ice accretion

- Icing detection methods and instruments
  - Several ice detection instruments have been developed, none is fully reliable.
  - Instruments are iced up and therefore show unreliable results
  - Heated anemometers have been developed and are in use. They still need further development.
  - The occasion when icing starts can be detected quite well with available instruments. Icing of sensors gives overestimations of the icing period.
  - Measurements of icing at the highest elevation of the blade are difficult.

…Measurements and prediction of ice accretion

- Ice mapping and other forecasts
  - Is today in regular use within civil and military aviation services
  - Models have been developed for wind power
  - Models need higher resolutions to capture terrain effects as well as to be verified by measurements

Measurements and prediction of ice accretion - Summary and reflections

- Icing of instruments is a big problem
- Suitable ice detectors are needed for direct measurements of icing
- No verified and fully reliable ice detectors are available on the market, development on-going.
- We know how and why icing occurs – remaining questions are where and for how long?
- Ice maps presented for entire nations are not fully reliable
- Ice maps/models for small, local sites are more reliable
- Models need to be developed at several points such as parameter used, terrain resolution, altitude resolution and verifications. The models are under constant development.
- Classification of sites, reliable measurement instruments and icing prevention systems could simplify the wind power planning.

Methods for de-icing and icing prevention

- Most common techniques are ;***heating of the blades (***by pumping hot air through the blades), ***electric heating*** and ***coatings***

- De-icing is the most popular and frequently used method – lower energy demand

- Little interest from turbine manufacturers in developing solutions
  - Probably due to a high development cost compared to a low demand from the market.

- No technique yet available for medium and sever icing conditions

- No technique sufficiently tested and developed for commercial use

- Results from on-going projects are expected in the coming years

Methods for de-icing and icing prevention
- Summary and reflections

- Methods are developed on small scale by wind farm developers – there is no “number one solution” developed

- From energy saving point-of-view it is desirable to apply strategies adapted for the icing conditions at the specific site

- Classification of sites would be a helpful guide in the decision on what method is needed for the specific site

Economic aspects

- Very little information available on actual costs

- Possible economic aspects are (based on results from the study):
  - Increased loads
    - De- and/or anti-icing may be economically viable when looking at turbine loads and wear during the turbine life time.
    - No available research or studies
  - Insurance
    - Insurance costs are higher for wind farms in cold climates.
  - Production losses and costs
    - De- and anti-icing systems are not economically profitable to install today when looking at production losses
    - May be an increasing problem as more turbines are being built in locations where icing occurs.
    - Different strategies for de- or anti-icing due to the severity and the length of time in which icing occurs at a specific site may increase the cost-efficiency.

…Economic aspects

- Maintenance
  - Maintenance in cold climate is harder
  - Maintenance can not be performed at chilly and icing occasions
- Financial losses
  - Results from an assumed risk in cold climates – lost energy production, low temperatures, more demanding maintenance.
  - Higher economic uncertainty compared to “normal” sites
- Safety regulations
- Mapping of ice
  - Time consuming
  - Costly
  - Better forecasts on cost may be possible to achieve by further development and verifications of forecast models.
- Expensive measurements
- Cost evaluations
  - No specific guidelines for assessing the economic impacts and risks associated with projects in extreme and arctic climates.

Economic aspects
- Summary and reflections…

- Estimations of additional costs when developing a wind farm in cold climate is difficult today - little information available.
- We don´t know if de- or anti-icing systems are economically feasible due to increased loads and a decrease in component life time
- We know that de- or anti-icing systems are not economically feasible due to production losses ***today***, we don´t know what the future will show
- In order to draw any conclusions more projects needs to be analysed

…Economic aspects
- Summary and reflections

- Developed forecast models can be a tool in cost estimations
- Icing and wind climate measurements are the keys to cost estimations for the specific site.
- It might be cost-efficient to adapt the strategy for de- or anti-icing to the severity and the length of time in which icing occurs at the specific site.

Other effects of cold climate

- Operation and maintenance:
  - Brittle fracture of materials
  - Insufficient lubrication of bearings and gearbox
  - Malfunctioning hydraulics
  - Malfunctioning electronics
  - Service and monitoring under difficult conditions
- Most manufacturers offer different turbine component solutions.
- When building turbines in cold climate, freezing grounds may cause instable foundations when the ice in the ground melts.
- Offshore foundations need to be adapted to ice loads from the sea.

Discussion…

- The report shows some differences between the Nordic countries. But the local differences are bigger. We seem to be part of the same problems and also of the same solutions in a whole
- How severe is the problem of icing today? Can we trust the methods to measure? Do we know enough about conditions for icing to take action?
- What will the near future probably look like? More wind power in cold climates and higher wind power plants?
- Are there enough reasons to avoid building wind power plants in cold climate? Many developers build wind power plants without any sort of ice prevention. Is it a matter of Insurance companies possibility to demand higher fees?

…Discussion…

- We really have to find out the actual costs of icing. Before that we can not compare this figures with the costs and eventual benefits of actions and different methods of de-icing and icing prevention
- What sort of research and projects do we need? Who has the interest of the research? Is it necessary with any sort of public funding due to the public effects?
- Is it a matter of sharing the information we got? Are existing forums enough? Interdisciplinary research?

Thank you for listening and participating in the discussion!