

Ice and Snow – and the Winds do Blow

NWCC Technical Considerations in Sitting
Wind Developments
December 1-2, 2005

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The Problem – its not a Winter Wonderland

- Ice is an issue
- Site assessment and monitoring
- Higher maintenance
- Increased downtime
- Higher loading on components
- Increase safety risks for staff and the public



And its more common than most people think

Projects located throughout the North from the Pacific to the Atlantic are in areas where ice, snow, and cold temperatures can impact the assessment and operation of wind plants.



Icing areas of the US

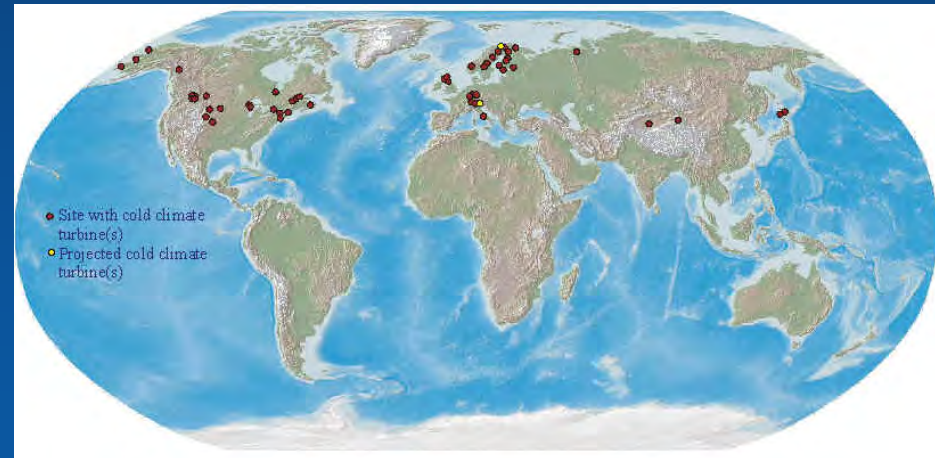
In all cases these impacts should be assessed at the start of the project, accounted for in project development and supported through long term assessment and consideration.

Presentation Overview

- Current experience
- Site assessment
- Turbine operation
- Safety considerations & recommendations
- The latest on ice throw – an inexact science
- References and further information

Current Experience

- A good number of sites have been studied in Europe
- Several European research programs (Icetools)
- Little data has been collected in the US on impacts of cold and ice
- IEA Annex XIX – Wind turbines in cold climates
- The International BOREAS Conference series on wind in northern Climates
- CanWEA Conference on wind turbine operation in northern climates
- Wind / Diesel Workshop



Assessment of Site Characteristics

Understanding if the area that you are looking at is likely to see icing events and how often

Key considerations

- Days of low temps
- Cloud cover
- Days of precipitation

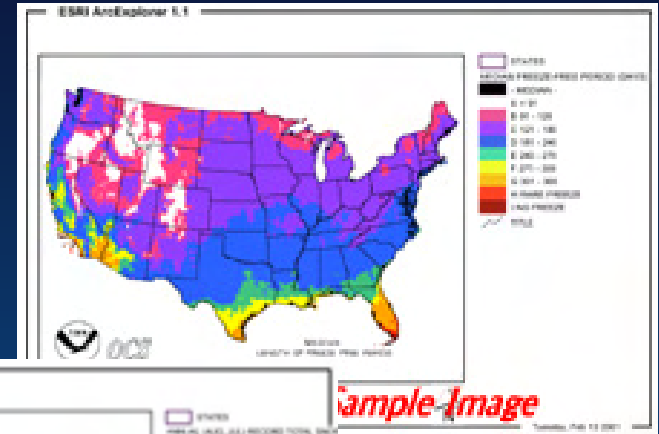
Additional factors

- Height of the towers
- Altitude

Web references

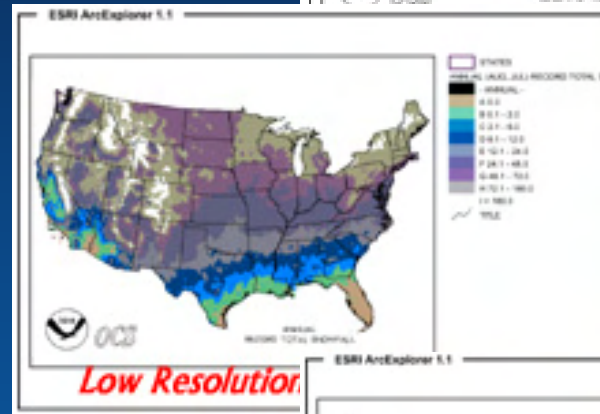
- www.nws.noaa.gov
- www.ncdc.noaa.gov

days of snow



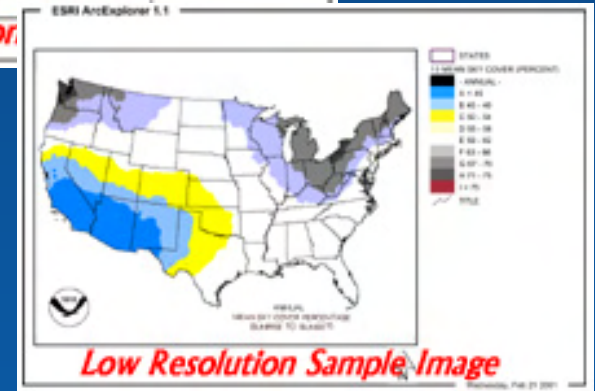
Sample Image

days with temps below freezing



Low Resolution

days with heavy fog

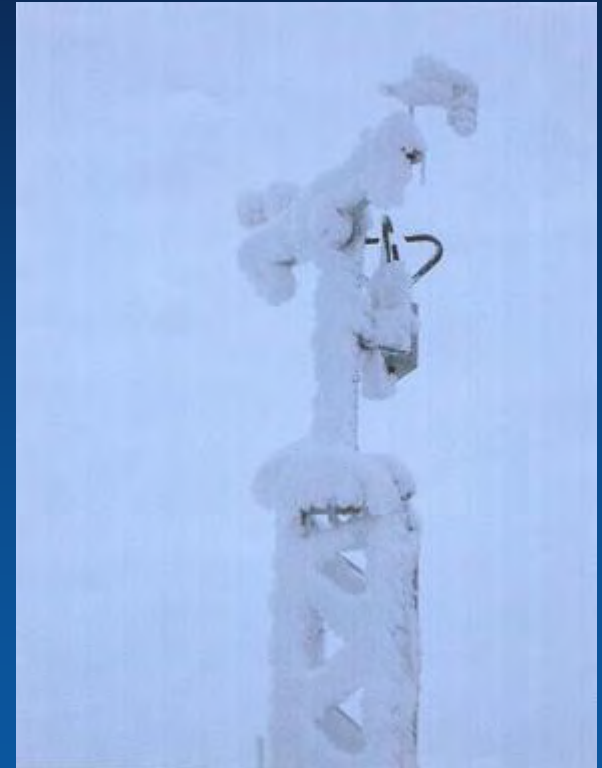


Low Resolution Sample Image

Site Assessment

Sites with severe weather require rethinking the current paradigm of measurements

- Accurate wind measurements
- Icing events
- Severity of icing
- Icing duration



Wind Measurements

- Need to use heated anemometers to accurately assess wind speed and direction
- Requires additional cost, stronger towers, higher energy requirements and more analysis for data accuracy.



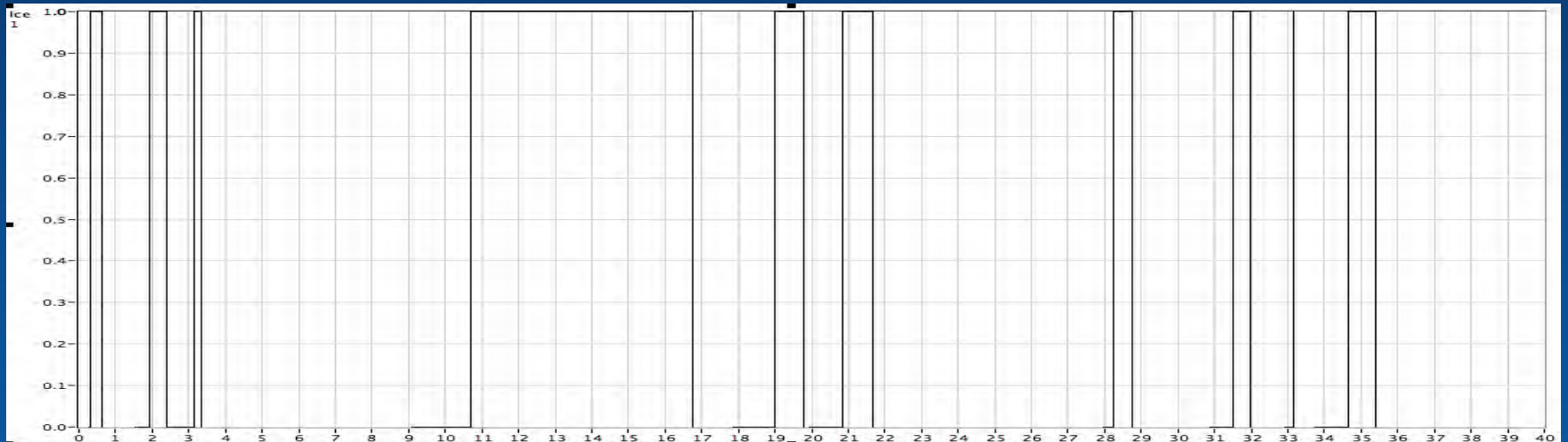
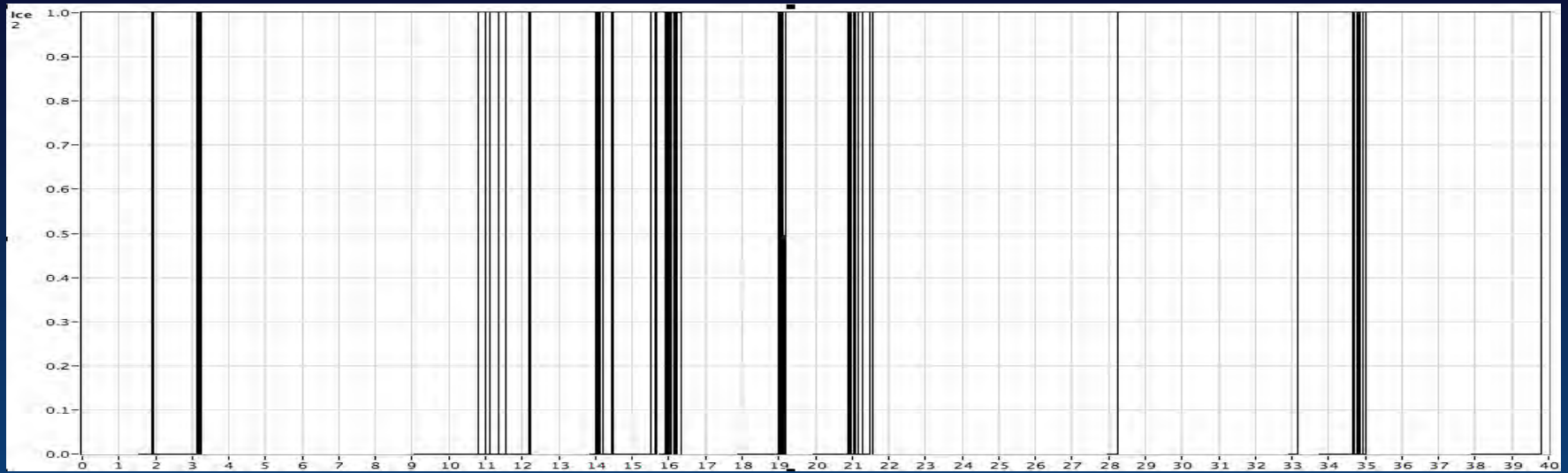
Icing events

It is not enough to know if icing occurs, you need to know when, how much and how long it will last.

Because icing events will impact:

- Turbine structural loads
- Forced downtime
- Energy capture
- Increased and more difficult maintenance
- Higher project risk
- Site accessibility
- Cost of ice mitigation strategies





Output comparison of heated & unheated Ice detection sensors

Mitigation Strategies

Ice prevention: Modifications to turbines that prevent ice buildup on blades or other surfaces. (Example – heating the inside of the blades)

Ice removal: Removal of ice from blades after the icing event is over. (Example – leading edge heating elements)

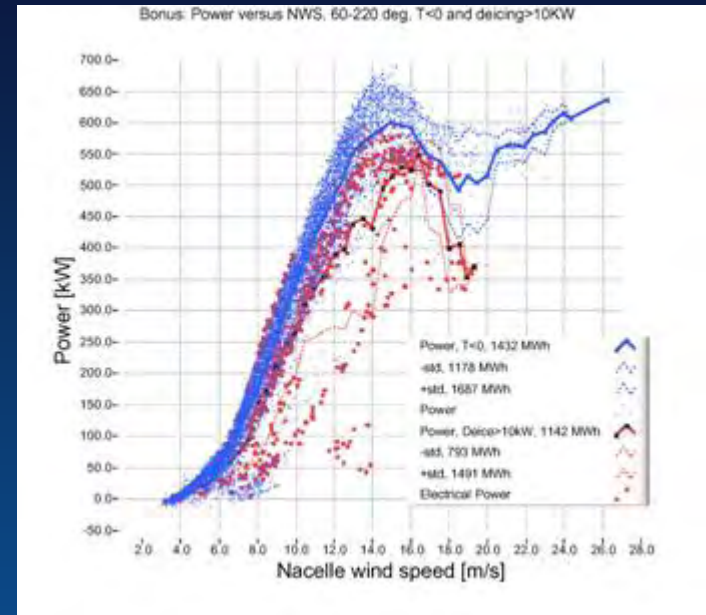
Each option has its own set of:

- Capital and maintenance costs
- Power consumption requirements

But increases energy capture

Turbine Operation

Depending on the severity of icing, high reliability may require modification of sensors, control algorithms and improved remote assessment due to lack of site accessibility



The
Äppelbo
turbine



Ice buildup on Blades

An understanding of the performance and cost impacts of icing environments can be critical to project assessment and determination of the benefit of anti-icing technologies.



Safety Considerations and Recommendations

In Europe, safety considerations are paramount in the siting of wind turbines in icing climates, specifically locations in Germany and Austria; such as:

- Requirements of manual startup following an icing shutdown
- Special monitoring requirements
- Special use permits
- Controlled site access
- Ice through and risk analysis
- Rejection of siting permits

However, there are no recorded injuries due to ice.



Danger of Falling Ice

Risk assessment considers area use and ice fall probability, given local conditions;

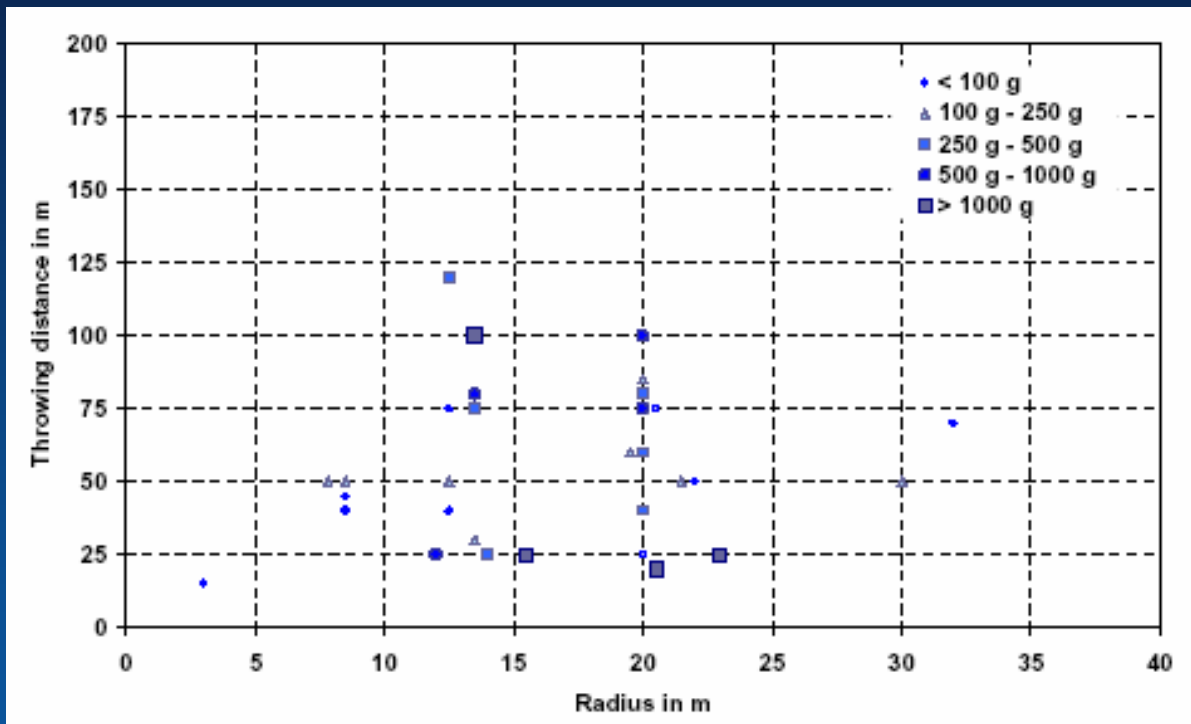
- During Operation (ice throw)
- At Standstill (Falling ice)

Primary conclusions: service personnel and local infrastructure (buildings) are most at risk

Very little scientific study exists but as the issues grow in Europe more will be conducted.

Most scientific reference is “Risk Analysis of Ice Throw from Wind Turbines by Henry Seifert et. al. from DEWI, Deutsches Windenergie-Institut GmbH, Cuxhaven, Germany

The Ice Does Come Down



Ice is thrown and where it lands depends largely on

- Height
- Ice size
- Wind speed
- Turbine characteristics

Ice Throw During Operation

Advanced analysis looks at
wind speed and direction
in relation to obstacles

Simple formula:

d: Max throw distance

D: rotor diameter (m)

H: Hub height (m)

$$d = (D + H) * 1.5$$



Ice Fall at Standstill

Simple formula:

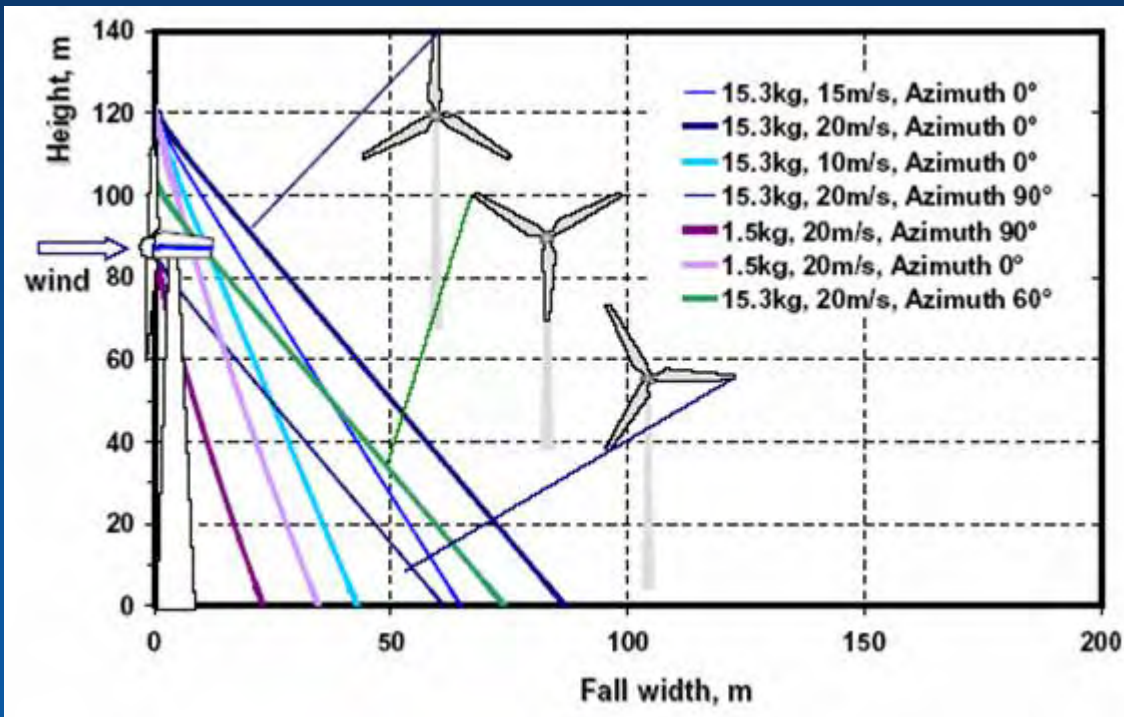
d: Max falling distance

V: hub wind speed (m/s)

D: rotor diameter (m)

H: Hub height (m)

$$d = v \frac{(D/2) + H}{15}$$



Advanced Analysis uses ice size, wind speed, and rotor position to assess safety areas. This is no different than ice falling off any tower or structure

Risk Analysis

- The previous calculations allow an assessment of ice throw and ice fall, but then this needs to be put in context with the likelihood of icing events, site access, weather conditions and turbine operation.
- In the study by Henry Seifert it was calculated that if 15,000 people walked by the study turbine each year there would be one accident every 300 years.
- This has to be assessed in perspective with other community risk factors and local regulations

Risk Mitigation Strategies

- Site Access limitations
 - Moving trails
 - Redirecting traffic
- Increased Signage
- Starting signals
- Public awareness



Conclusions

- Icing can be an issue in turbine siting
- Initial assessment of the likely hood of icing should be conducted early
- During site assessment the impact of icing should be assessed, documented and included in project cost and power production
- If icing is going to be an issue, there are likely other siting considerations (temperature, snowfall, site access, foundations) that should be considered
- Care should be taken to consider the impact of ice damage and proper precautions assessed
- Mitigation strategies are available
- Understanding of icing and ice issues is increasing

References and Further Information

- IEA Wind Research Annex XIX, wind energy in cold climates: <http://arcticwind.vtt.fi/>
 - Wind Energy in Cold Climates, An IEA recommendations Document
 - State-of-the-art of wind energy in cold climates
 - Other publications
- BOREAS conferences - Finnish Meteorological Institute: <http://www.fmi.fi/en/>
- “Risk Analysis of Ice Throw from Wind Turbines” by Henry Seifert et. al. from DEWI, Deutsches Windenergie-Institut GmbH, Cuxhaven, Germany