

# **Experiences and challenges with wind farms in cold climates**

*Göran Ronsten, WindREN*

Aarhus, 2014-12-03

**Icewind final conference**

## Why we need to solve the icing issue



It's not always easy  
to be a Swede.

Photo taken in  
Hamburg 2004-05-  
11

This war was  
declared against  
Vattenfall



# Ashamed of ad – Vattenfall promotes lignate WindREN



WAS WICHTIG IST

Peter Franke,  
Spreewaldkoch aus Werben:

**Unsere Gäste!**  
sind mir wichtig

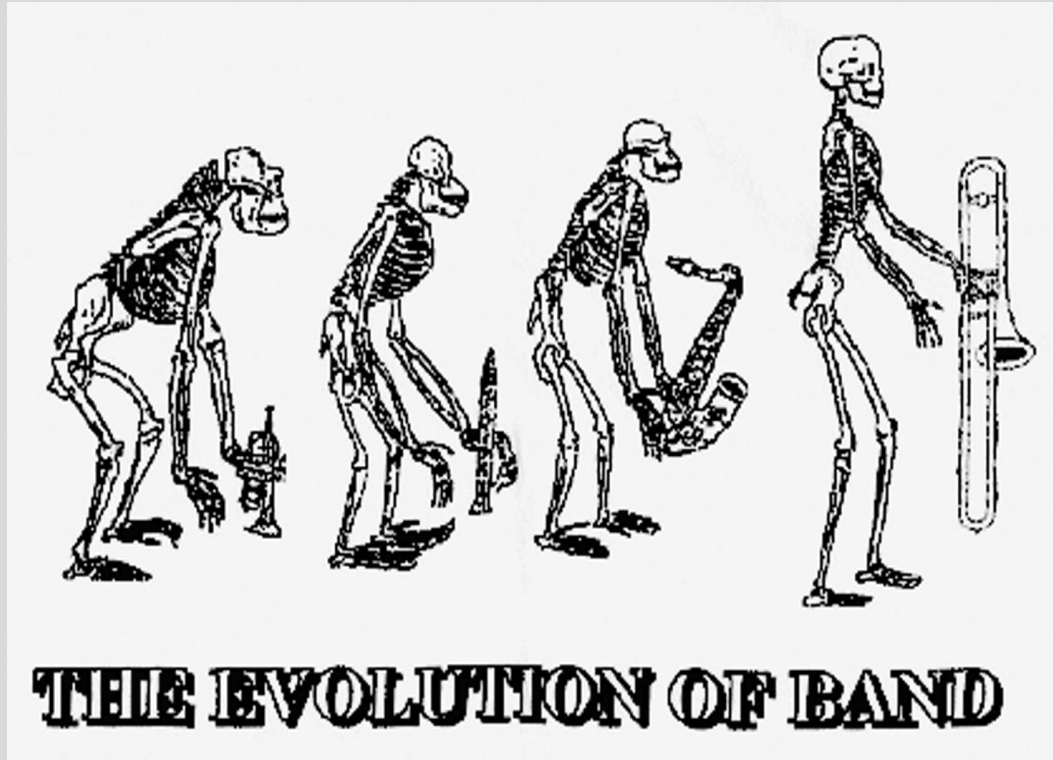
Es gibt gute Gründe, Touristen  
die Lausitz schmackhaft zu machen.  
Was uns dabei hilft? Die Braunkohle.

Das Foto: © M. B. / M. B.

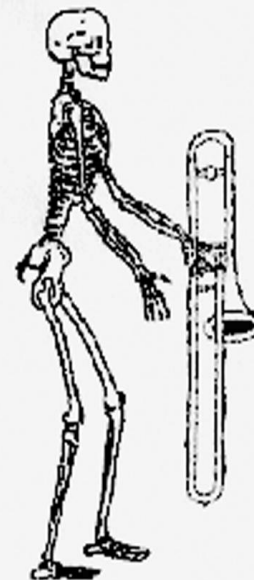
VATTENFALL

8000031

*Evolution of wind energy*

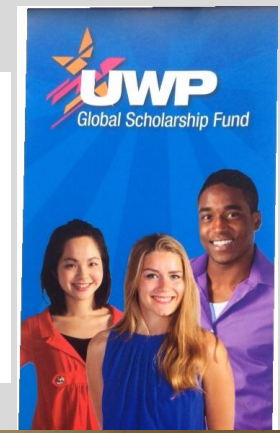


*wind energy*

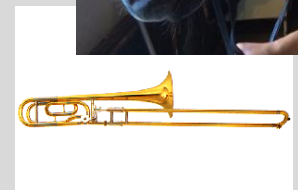


**BAND**

# Göran Ronsten

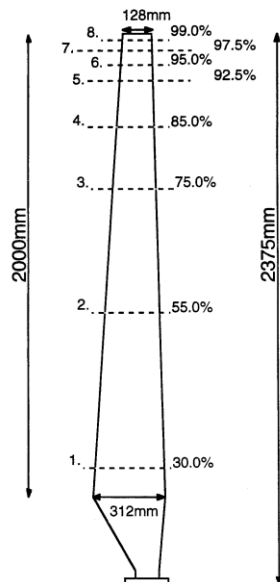


Aapua Vind AB



## Geometry and Installation in Wind Tunnels of a STORK 5.0 WPX Wind Turbine Blade Equipped with Pressure Taps

*Göran Ronsten*

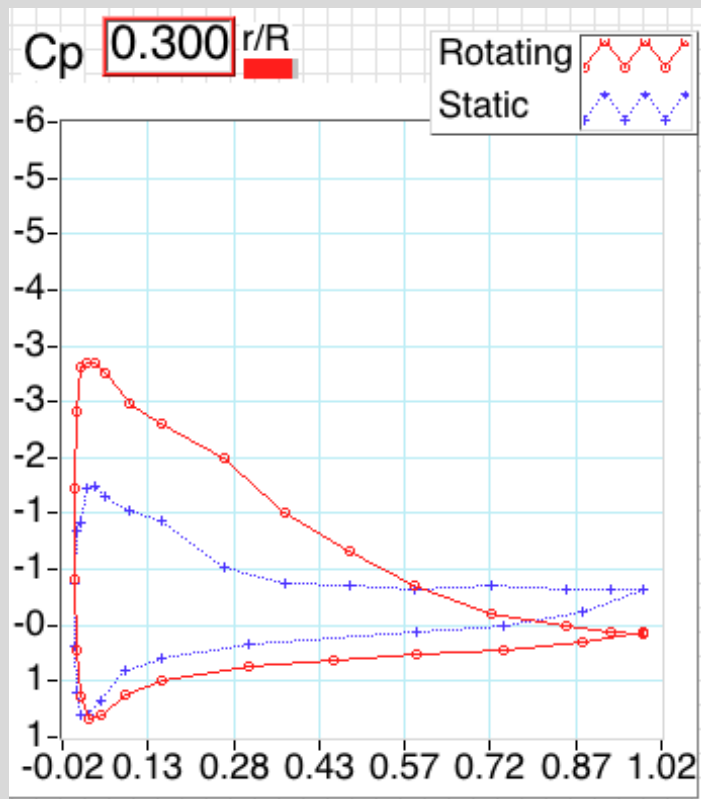


**FFA** FLYGTEKNISKA  
FÖRSÖKSANSTALTEN  
THE AERONAUTICAL RESEARCH INSTITUTE OF SWEDEN

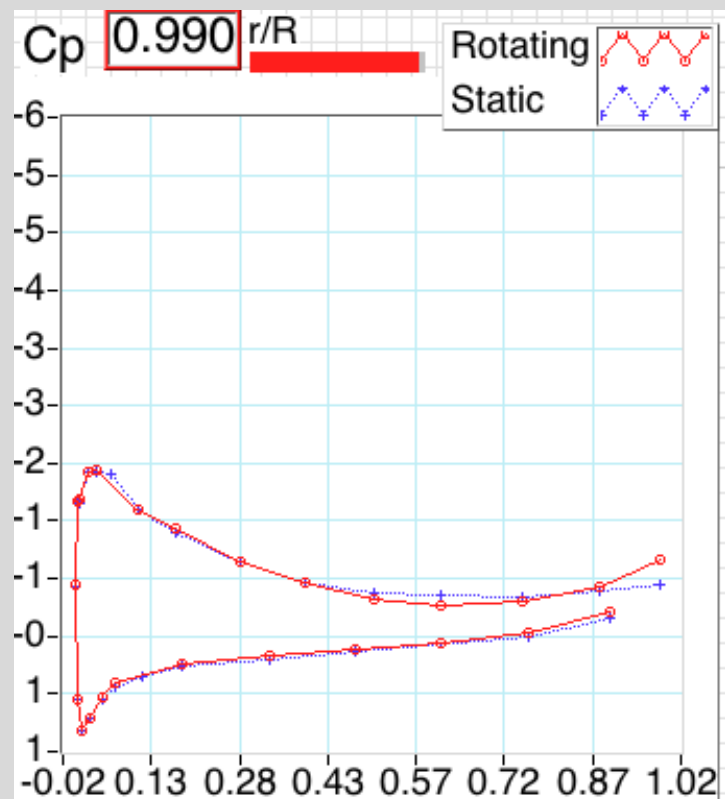




## The Himmelskampeffect on the rotating blade

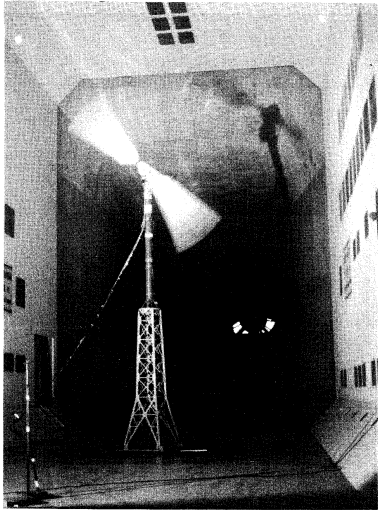


## The influence of rotation on $C_p$ near the tip



## Aerodynamic Section Characteristics of a Rotating and Non-rotating 2.375 m Wind Turbine Blade

Anders Björck, Göran Ronsten and Björn Montgomerie



**FFA** FLYGTEKNISKA  
FÖRSÖKSANSTALTEN  
THE AERONAUTICAL RESEARCH INSTITUTE OF SWEDEN

Comparison of non-rotating and rotating cases  
 $r/R=30\%$   
Lift coefficient as function of angle of attack

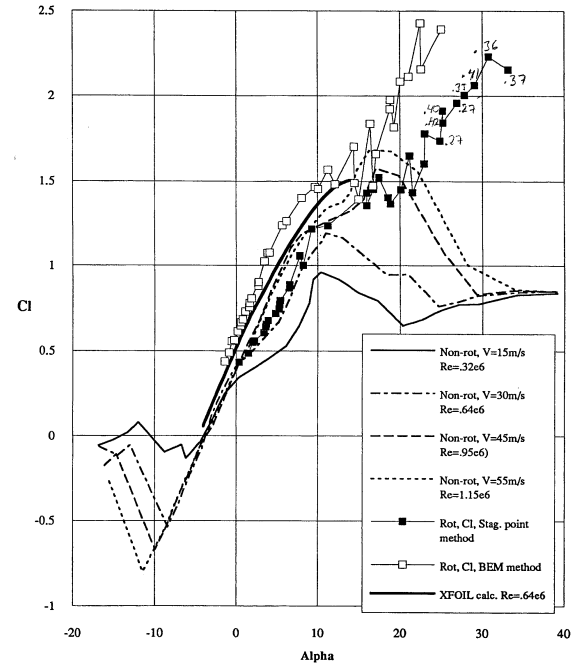


Figure 8d.



**FLYGTEKNISKA  
FÖRSÖKSANSTALTEN**

The Aeronautical Research  
Institute of Sweden

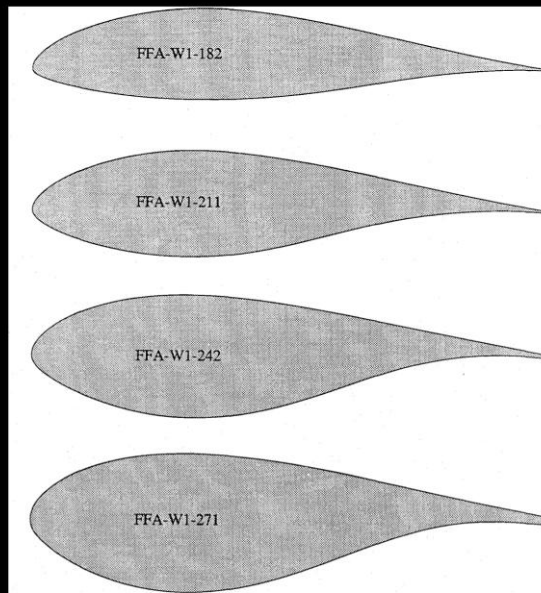
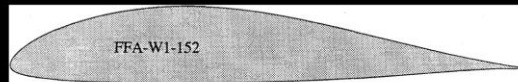
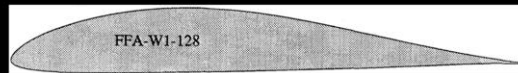
FFA TN 1990-15

COORDINATES AND CALCULATIONS FOR THE  
FFA-W1-xxx, FFA-W2-xxx AND FFA-W3-xxx SERIES  
OF AIRFOILS FOR HORIZONTAL AXIS WIND  
TURBINES

by

Anders Björck

Stockholm 1990





# OX2's wind pilot project

Large-scale, cost-effective wind energy development

in icing climates,

*Göran Ronsten*

*2008 - 2015*

*8 MEuro*





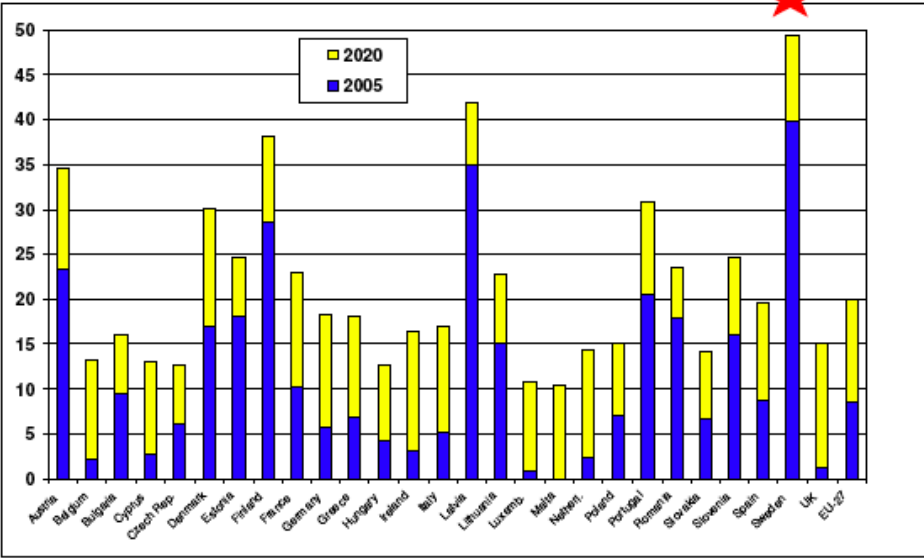
Wind pilot projects: 70 M€ over 10 years

**From offshore to cold climate and forests**



# Why renewable energy?

## Shares of RE, 2005 and 2020



Ministry of Enterprise, Energy and Communications



# Why Sweden and Holland failed in wind energy development

ENERGIFORSKNING



Kärnkraftens vara eller inte vara har lagt en hämsko på utvecklingen av förnybar energiteknik i Sverige. Det tillsammans med en felaktig tro på att alla problem är tekniska, har lett till att Sverige inte har omvandlat forskningsresultat till nya produkter och tjänster. De svenska satsningarna på förnybar energi har också varit för ensidigt inriktade mot forskning och för lite har satsats på att åstadkomma växande marknader.

Det menar Anna Bergek, som nyligen doktorerade på hur marknader skapas för förnybar energiteknik.

**"Kärnkrafttraumat" har satt stopp för utvecklingen**

## Anna Bergek, Chalmers (2002):

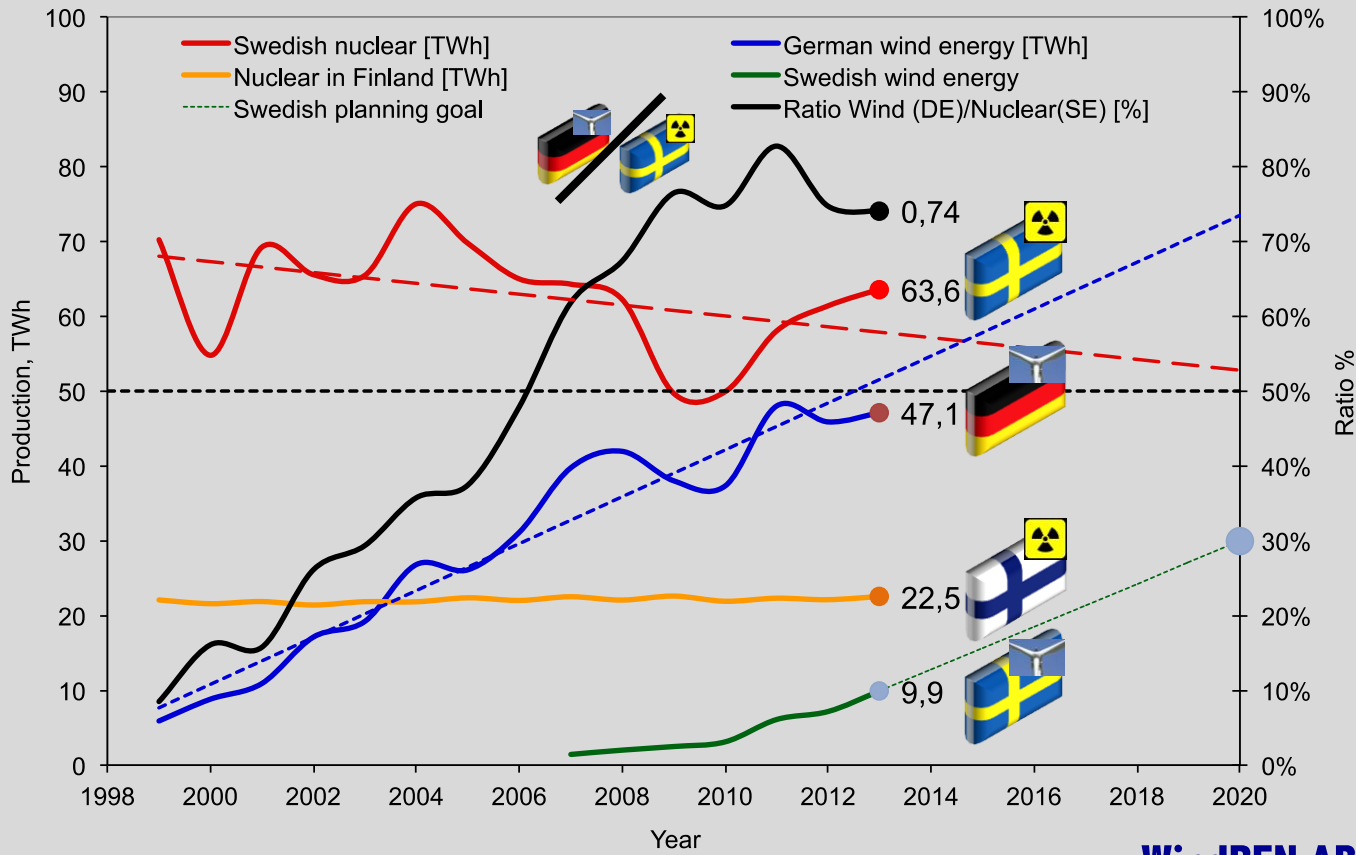
1. No home market
2. Too few manufacturers
3. A nuclear trauma

# EU targets will not be reached without a clear roadmap





Annual German & Swedish wind energy - Swedish and Finnish nuclear energy production



Can wind make a significant contribution?

**China 2012:**  
60 GW of wind = All electricity from the country's 17 nuclear power plants

**China 2013:**  
75 GW of wind = 150 TWh = Sweden's electricity consumption



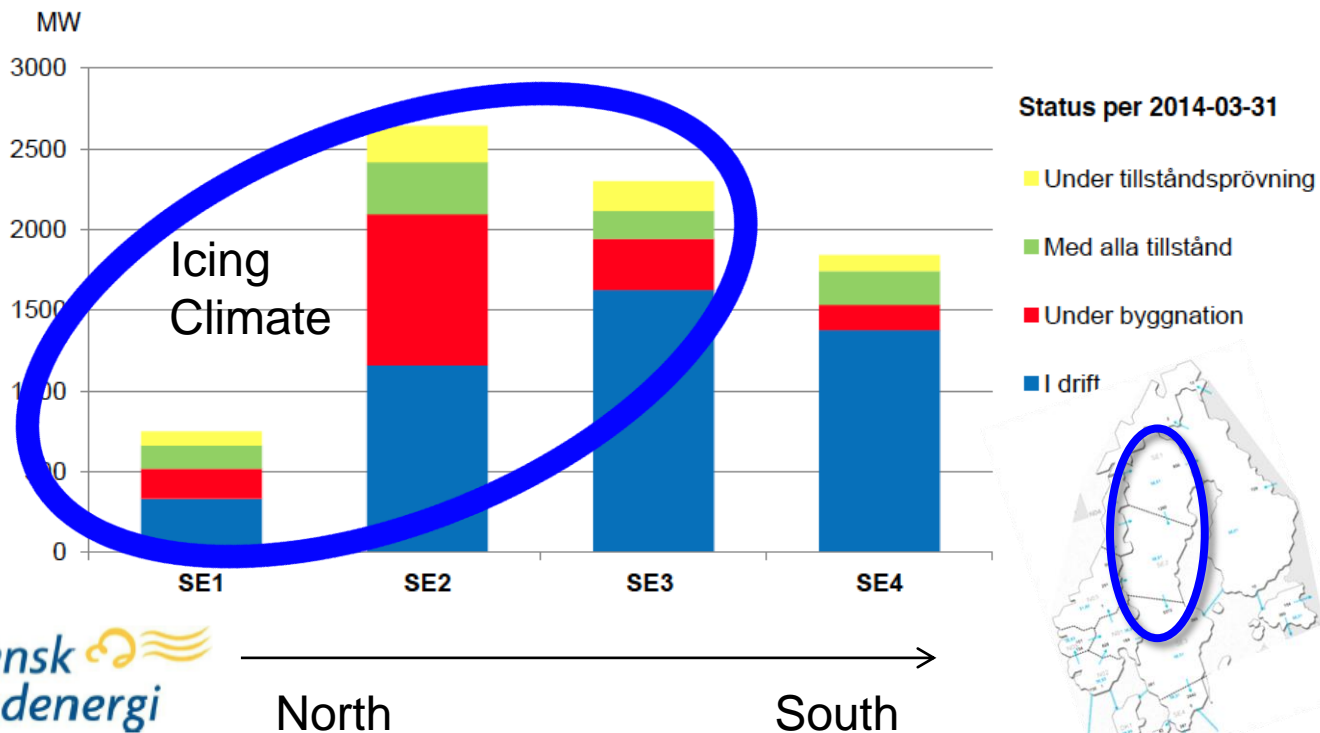
# Installed power per electric region Dec 2017, Base scenario

## Sweden

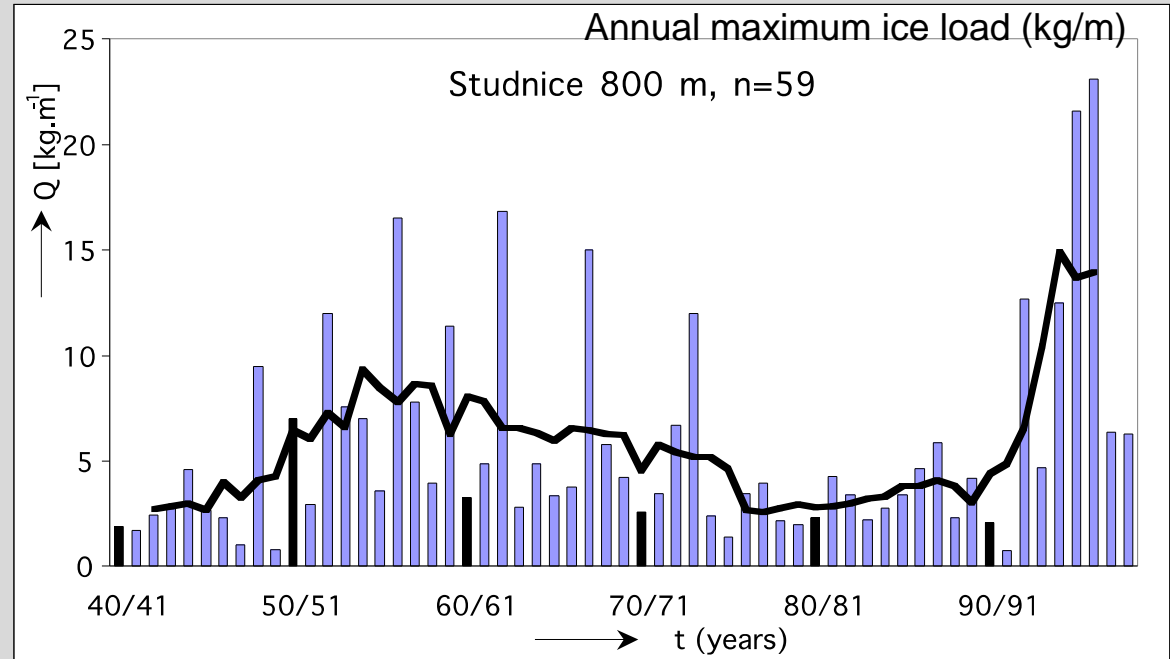
Installed power  
per region  
Q1, 2014

2017 scenario

Blue Installed  
Red Constr.  
Green Permits  
Yellow Applied



# Examples of measurements and existing icing data



Czech Republic (Studnice), 1940-1999

**First Swedish  
experiences of iced up  
wind turbines (2004)**

**Report available from  
Elforsk (Swedish only)**

**Most references from  
Boreas (Finland)**

**Svenska erfarenheter av vindkraft  
i kallt klimat – nedisning, iskast  
och avisning**

Elforsk rapport 04:13

## Deicing in Åre (SE)







## Access challenge



## What is going on?





# We don't want to stay onboard!



Icing on a  
lighthouse  
in the Bay  
of Bothnia



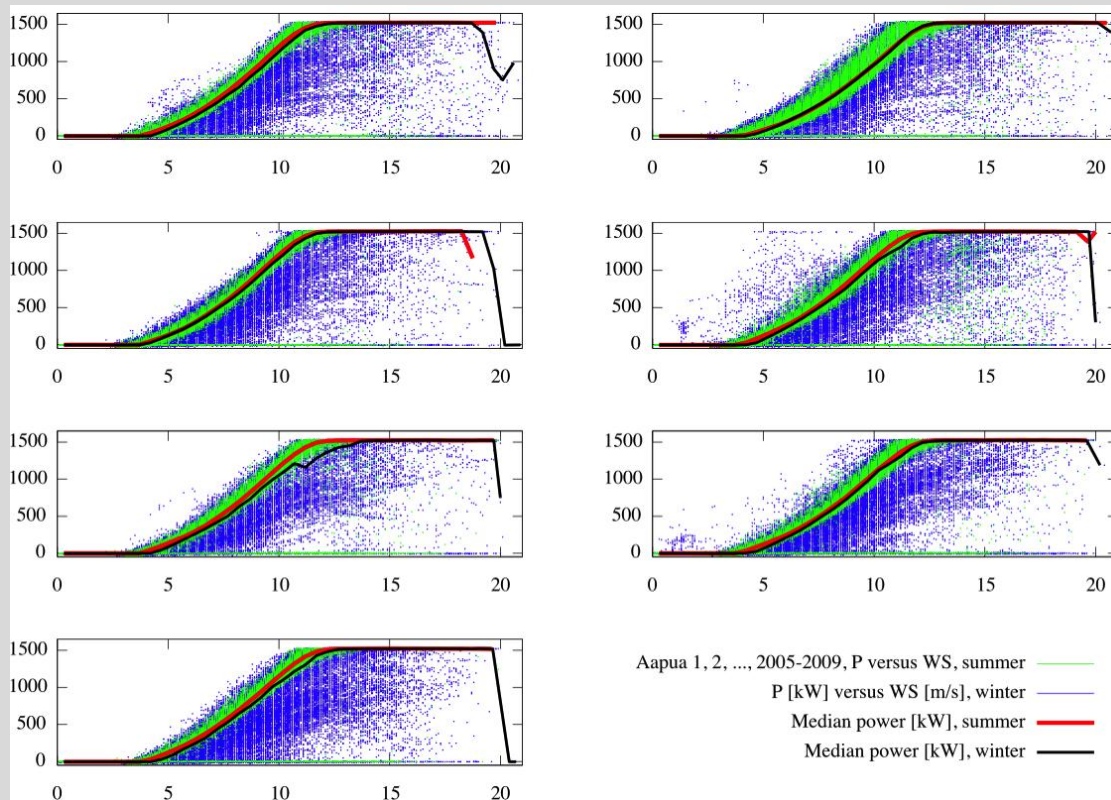


**The main challenge in Sweden  
is icing, not low temperatures**

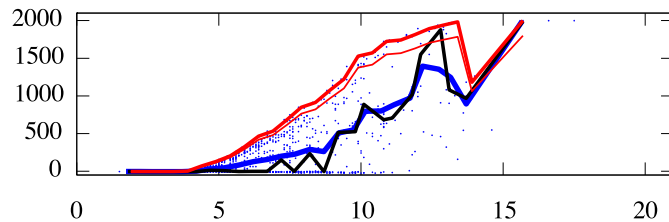
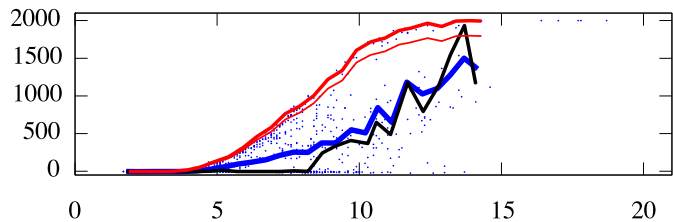
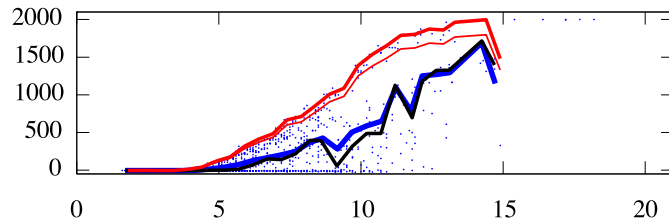
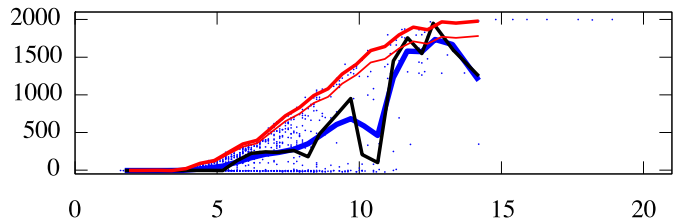
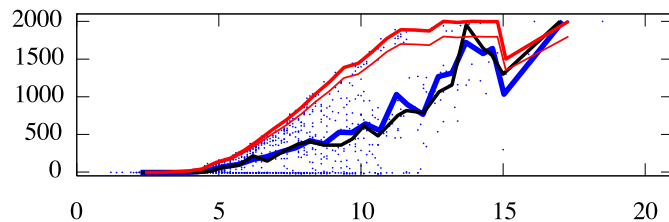
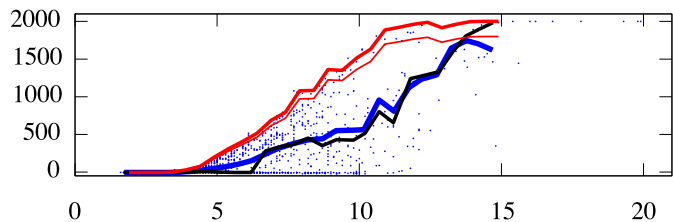




## >25% wintertime energy production losses, V82-1.5 (Aapua)

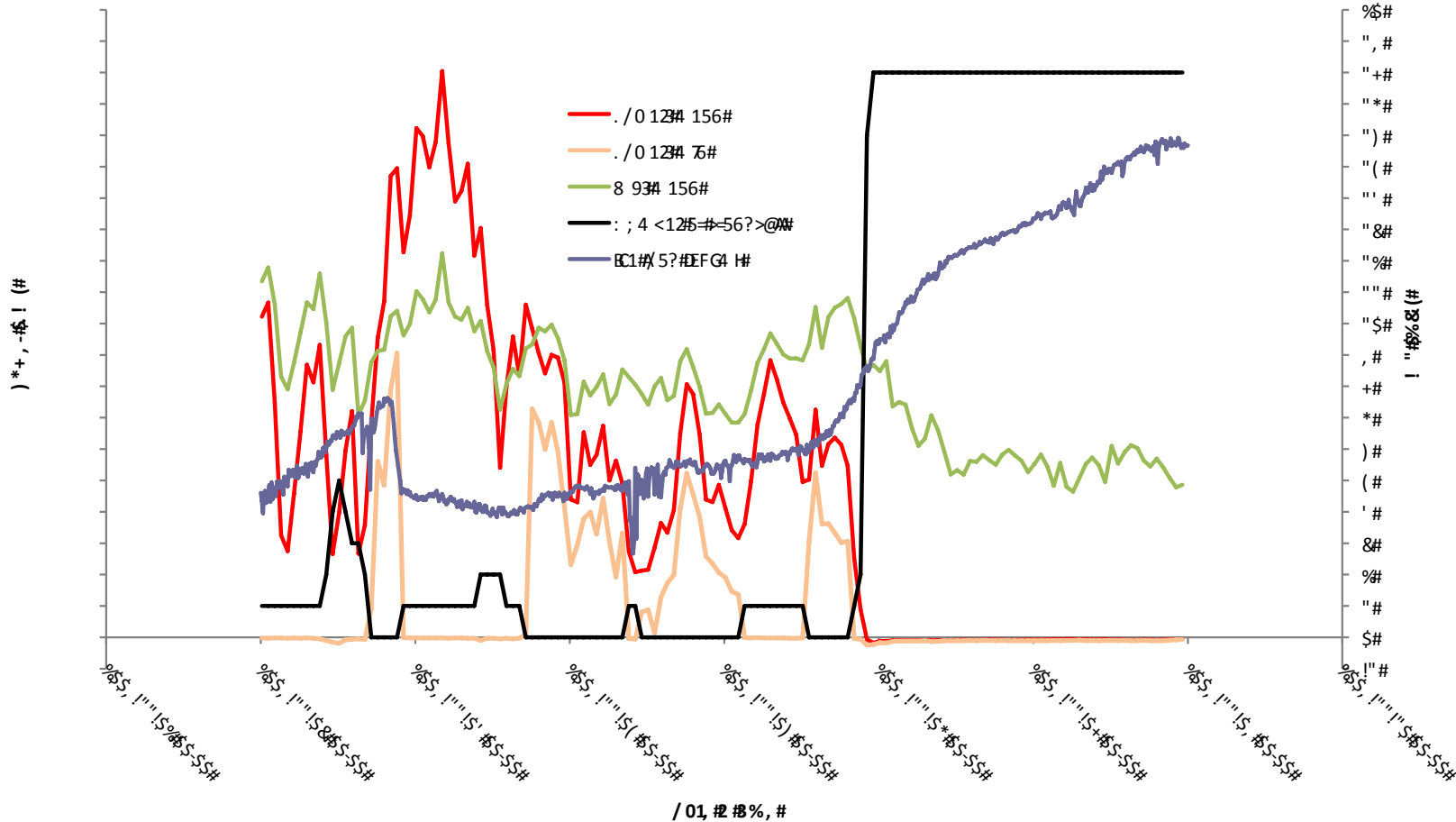


## Ice influences production - 1 hour data

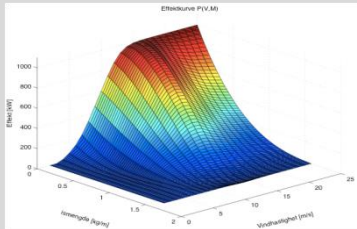
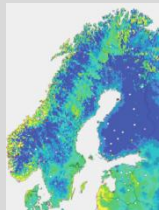
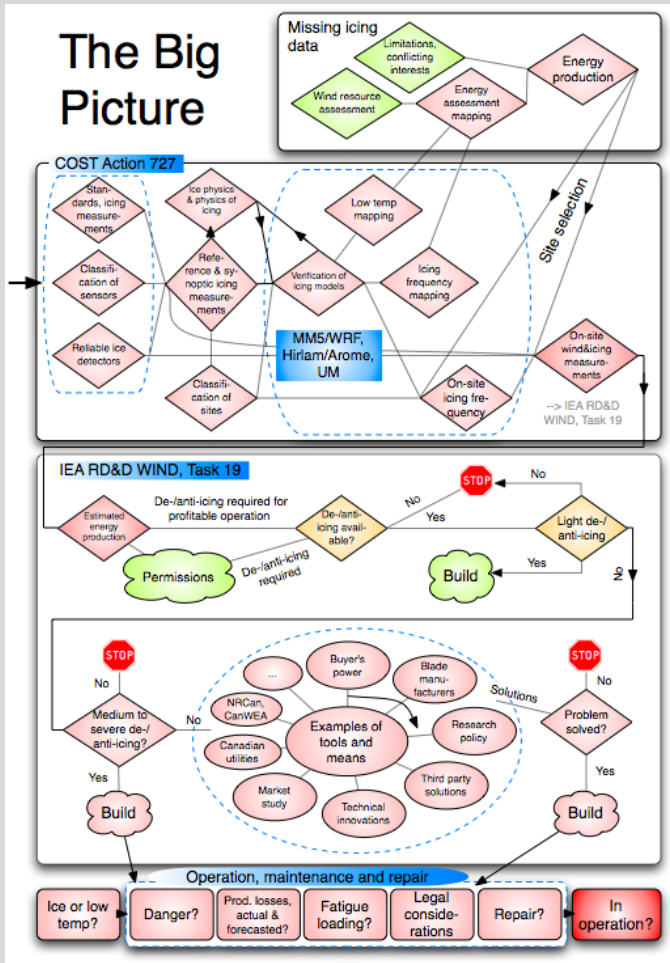


Bliks 1-6      max [kW] ———  
 mean [kW] ———      90% of max ———  
 median [kW] ———

# ; << : => ; << : ? #



# The Big Picture



Red fields need attention



Tools needed to predict, detect and remove icing

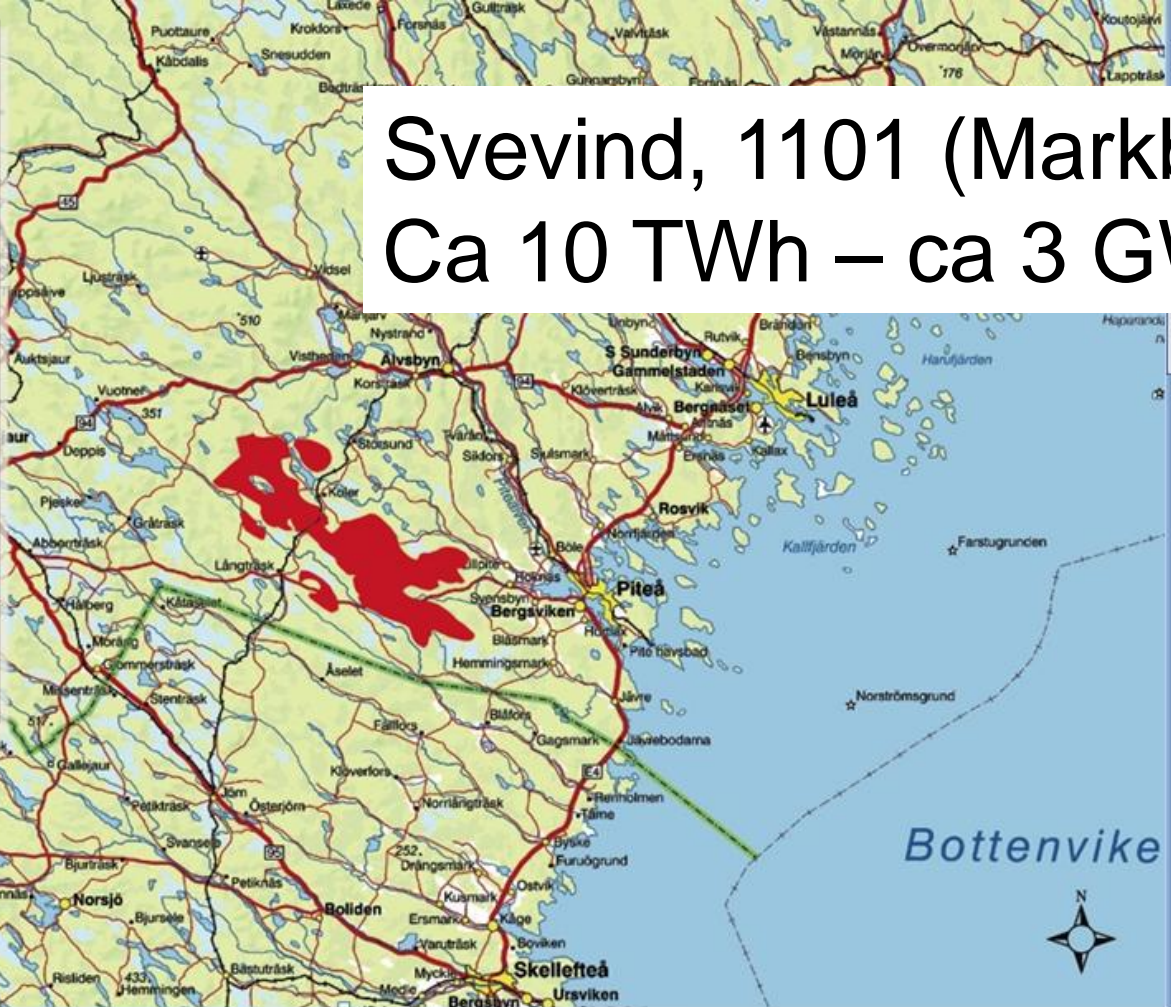




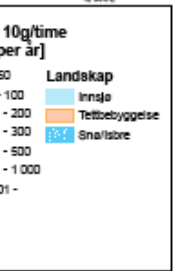
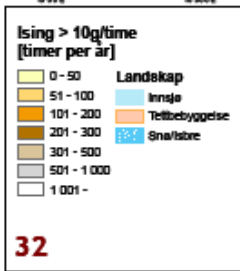
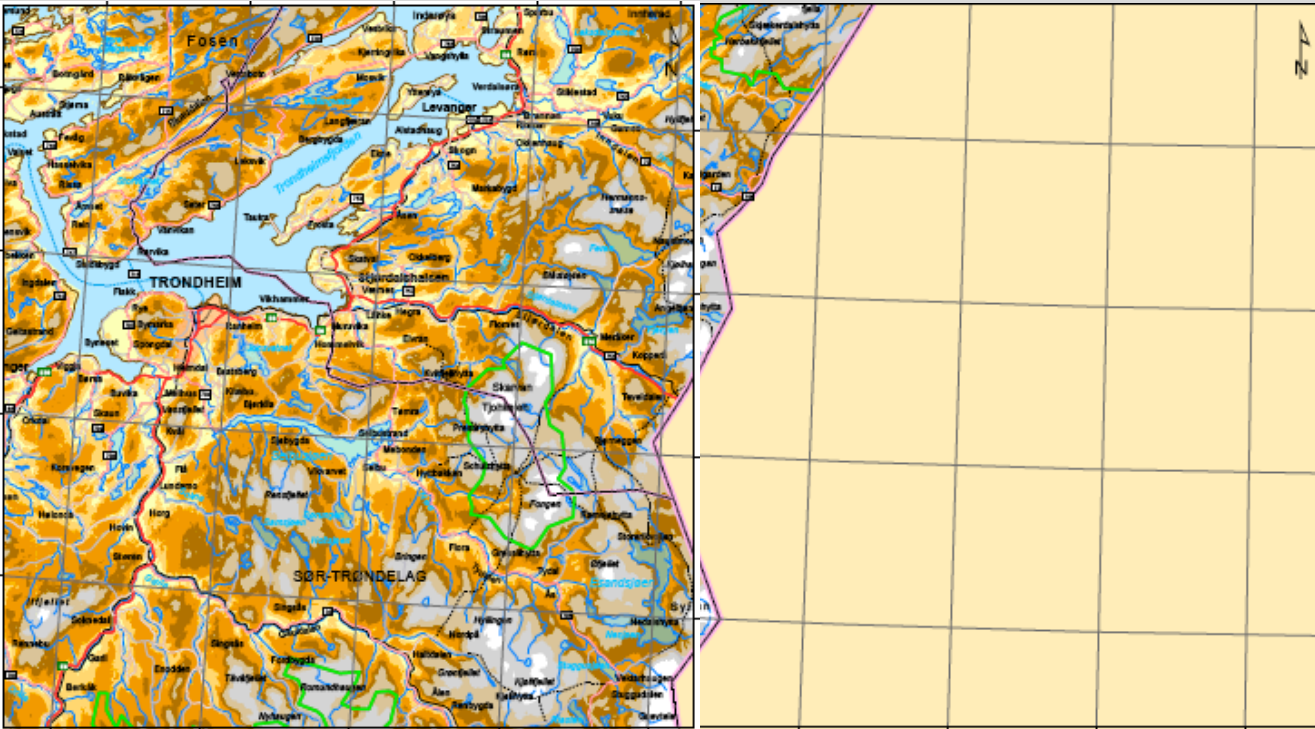


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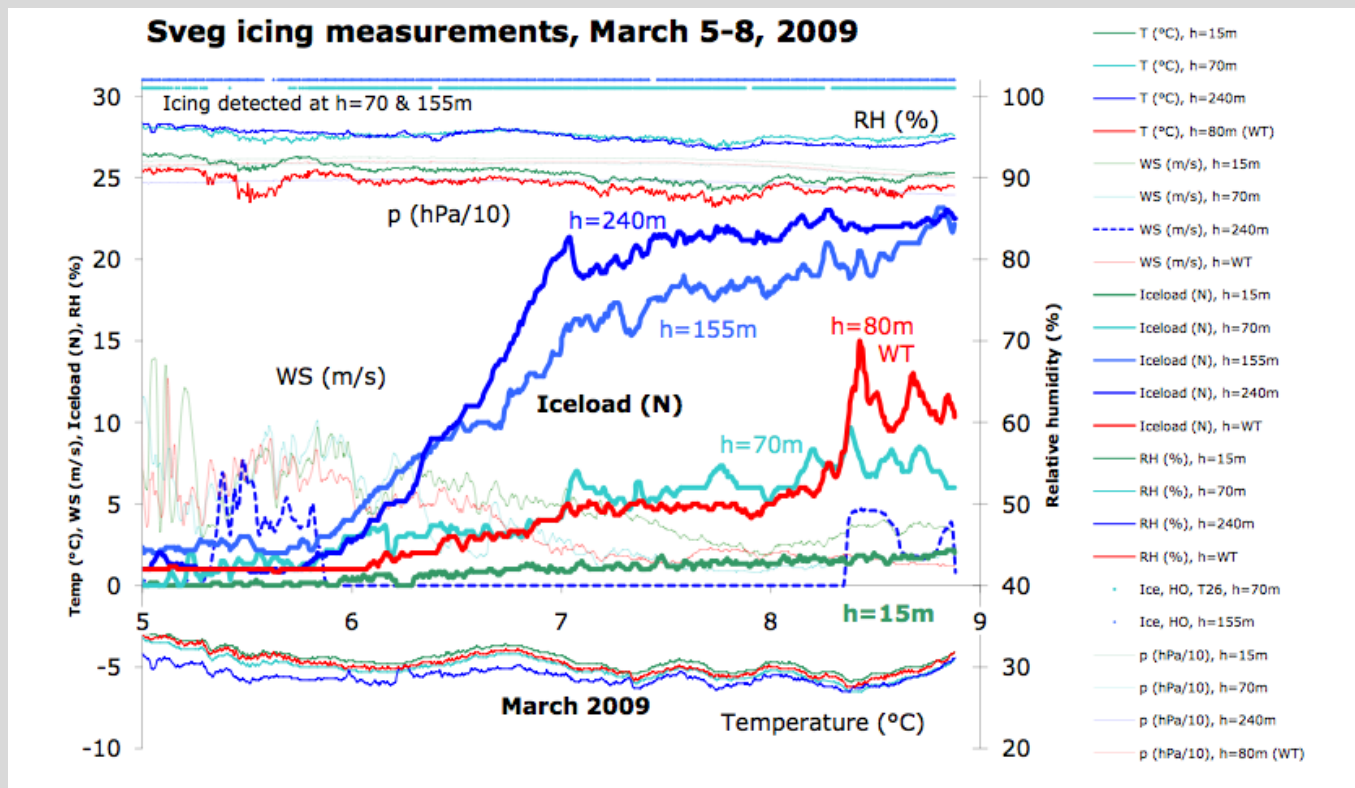
# Svevind, 1101 (Markbygden) Ca 10 TWh – ca 3 GW



# Kjeller Vindteknikk presented an icing map for Norway



# Unique measurements of icing versus height



But we don't want to see this....

# The Newspaper

## Wind turbine kills young skier in north Sweden

Umeå 9 February 2011  
A 5 year old girl out skiing with her parents was killed yesterday in western Lapland as she was hit by a huge ice block falling off a nearby wind turbine.

*[Placeholder text for newspaper article content]*

12 | Winterwind 2011 | 2011-02-09



Det fruktansvärda ljudet från vindturbinerna får orsakar stort lidande. Bir de boende i Örtjärn. Katrin Karlsson, här med sin man Janne Furumås och barnen Emilia och Eslin, tråder nu fram och ger nu en tillgångsproblem ett ansikte. FOTO: FREDRIK LARSSON

### Dömd för våld mot poliser

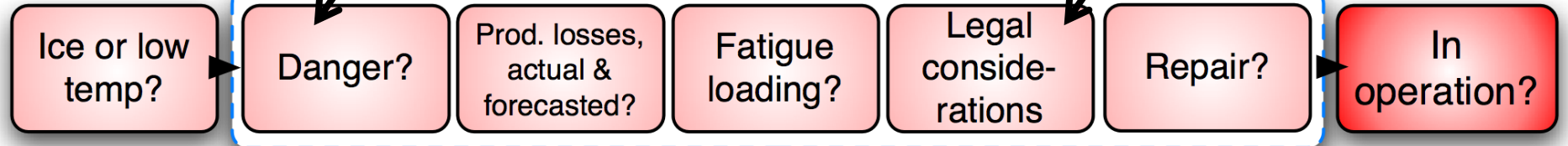
GRÄNGESBERG  
Vilkenlig dom och 75 timmars samhällstjänst.  
Det blev straffet när en 22-årig man från Grängesberg dömdes av Faltingsrätt misstänkt för våld mot tjänsteman, försök till död och vådssamt motstånd. Det var i november förra året som mannen kom i deli med polisen utanför McDonalds i Ludvika. En polis knuffades omkull och slog sig bänd annat i ryggen, höften och i en arm.  
Tjän i år ska den dömda i ett annat sammanhang. I Ludvika ha blivit våldsam mot en polis och misstänkt sparkar mot domme dock utan att träffa.  
En knivar till mannen stod medtalad för skadegörelse på en lastbil.  
I det fallet blev beslutet att åtalet ogjordes.

**Misstänkt för prövot rattfylleri!**

# "Man blir vansinnig"

- Örtjärnsbor svårt störda av vindkraftverken

## Operation, maintenance and repair



Leading  
edge?



Leading  
edge?



Foto: Timo  
Laakso, VTT



Yes



No



Foto: Timo  
Laakso, VTT



**Let's set  
things  
straight**

## THE MACHINERY DIRECTIVE SAYS...

DIRECTIVE 2006/42/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL  
of 17 May 2006  
on machinery, and amending Directive 95/16/EC (recast)

**“Machinery must be designed and constructed so that it...can be operated, adjusted and maintained without putting persons at risk”**

*Risks due to falling or ejected objects*

Precautions must be taken to prevent risks from falling or ejected objects.

**Prosecutor:**

**Wind turbines do fullfill the EU machine directive although they throw ice.**

# Safety distances due to the risk of ice throw (ref: WECO)

Figur 51. Rekommenderat riskavstånd för iskast när vindkraftverket är igång.  
Källa: WECO och DEWI.

$$d = (D + H) \cdot 1.5$$

Rotating

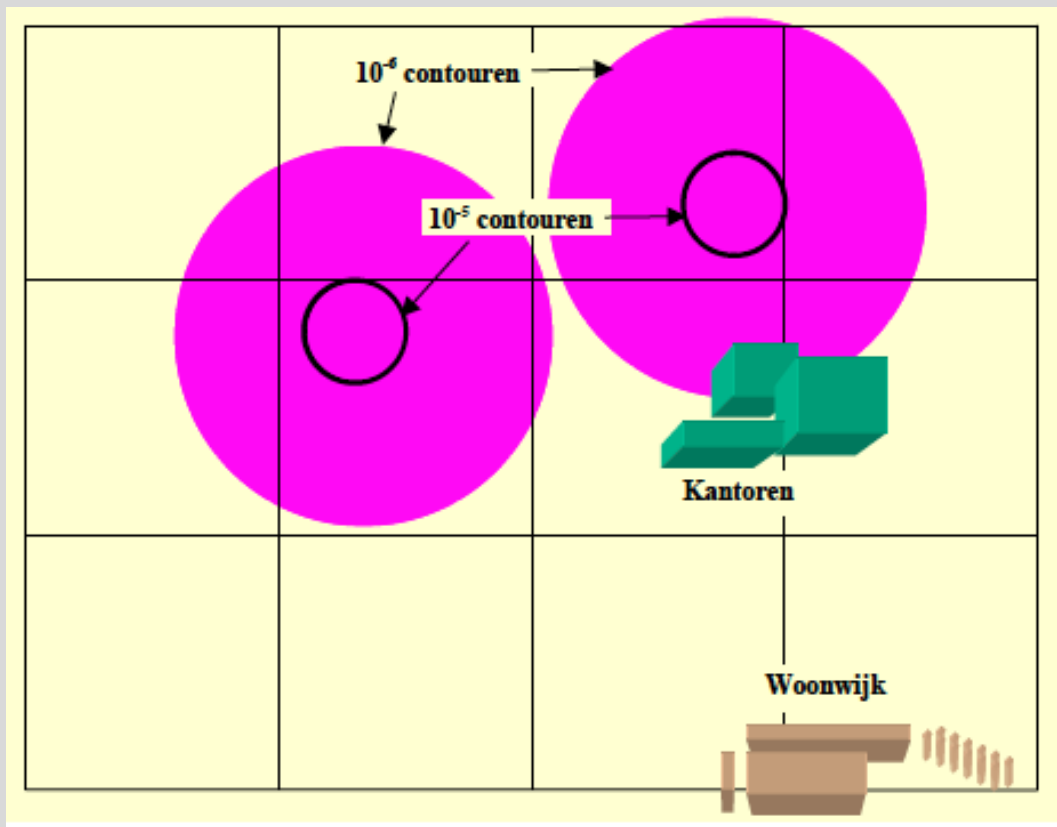
58 (80)

Figur 52. Rekommenderat riskavstånd för iskast när vindkraftverket står stilla.  
Källa: WECO och DEWI.

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

Standstill

## A risk assessment can be presented in a similar manner as noise





## REDOVISANDE DOKUMENT

FOI: E62137, Skellefteå Kraft: 2006-03-17, SSP

Dokumenttyp Sidsnummer

FOI MEMO 1 (30)

Förstudie av nedisning på lågfjället Uljabuouda i Arjeplogs kommun

Datum Memo nummer  
2006-04-15 FOI Memo 1703

Handläggare  
Göran Ronsten

### Förstudie av nedisning på lågfjället Uljabuouda i Arjeplogs kommun



Varningsskylt vid vindpark nära Kassel, Tyskland, november 2003 . Foto: Göran Ronsten

Sändlista: Skellefteå Kraft AB, Stefan Skarp  
FOI, IC Anette Näs  
FOI, AC Monica Dahlén

## Pilot study of icing on the Uljabuouda hilltop in Arjeplog, Sweden

*Göran Ronsten, FOI*

Deicing required  
10 X 3 MW WinWind

# Are signs, sirens and lights enough to prevent accidents?



Ice can fall from the tower  
and the nacelle

Ice can damage stairs



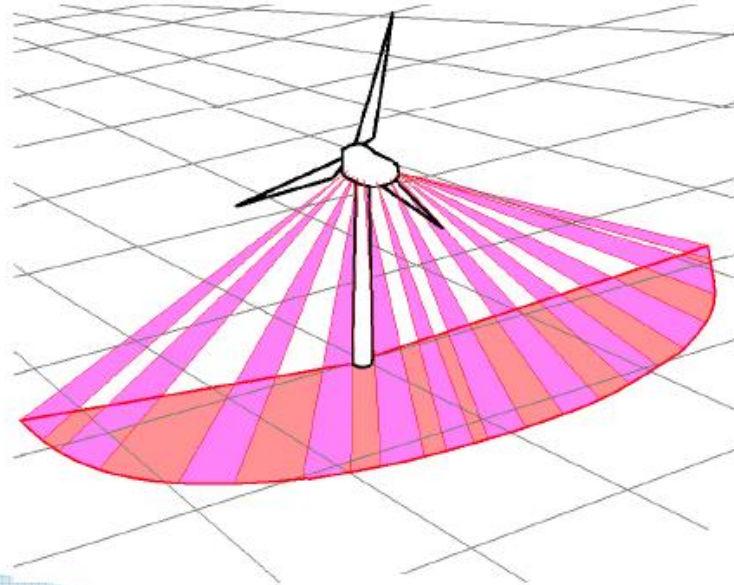
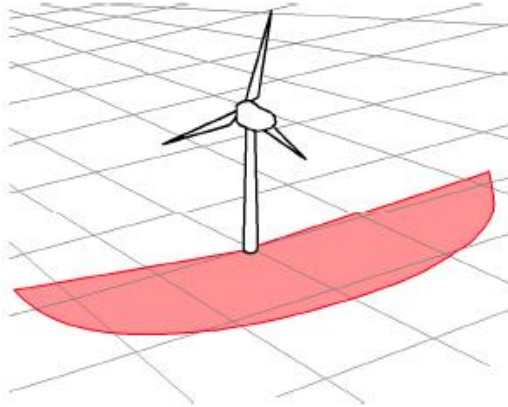


## A car roof hit by a piece of ice





# 5 Visual Ice-Throw Warnings





## International influence on OX2's wind pilot project



**IEA Task 19 – Wind Energy  
in Cold Climates  
Umeå, Feb 7-8, 2011  
Participants from:**

*Austria  
Canada  
China (observer)  
Denmark (observer)  
Finland  
Germany  
Norway  
Sweden  
Switzerland  
USA*

**Potential new members**

*Denmark  
China  
Italy  
Japan*



**International interest in CC: IEA RD&D Wind, Task 19 meeting in Beijing, Oct 2013  
Followed by a meeting in Gaspé (CA) in June 2014 and in Aarhus (DK) in Dic 2014**

**Participants from:**

Austria  
China  
Finland  
Germany  
Sweden



**Not in photo**

Canada  
Denmark  
Norway  
Switzerland  
USA






## IEA Task 19 home page - <http://arcticwind.vtt.fi/>



EXPERT GROUP STUDY  
ON  
RECOMMENDATIONS FOR  
**WIND ENERGY PROJECTS IN COLD CLIMATES**  
EDITION 2011



*Submitted to the Executive Committee  
of the International Energy Agency Programme  
for  
Research and Development  
on Wind Energy Conversion Systems*


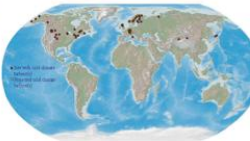

• Recommendations report – 2012!

• State-of-the-art report - 2012

• Continuation 2013 - 2015

**WIND ENERGY IN COLD CLIMATES**

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<p><b>About the project:</b></p> <ul style="list-style-type: none"> <li>■ Objectives of the project</li> <li>■ Participants</li> <li>■ Project's external aspects</li> <li>■ Restricted access</li> </ul>  <p>Wind Turbine at Aspa-fjell Sweden. Photo by Kent Larsson, Alvee.</p> <p><b>Links:</b></p> <ul style="list-style-type: none"> <li>■ Measuring and forecasting atmospheric icing: COST T27</li> <li>■ Conference: <a href="#">Winterwind 2011 - Wind Energy in Low Temperature and Icing Conditions</a>, Lönne, Sweden, Feb 9-10</li> <li>■ International Workshop on Atmospheric Icing on Structures: <a href="#">Icing and consequences of WIAS 2009</a></li> <li>■ Cold climate wind farms: <a href="#">Svalbard, Svalbard, Arctic Circle, Switzerland</a></li> <li>■ Discussion Forum</li> </ul>	<p style="text-align: center;"><b>IEA Wind RD&amp;D Task 19</b></p> <p>This is the home page of an International Energy Agency collaboration called Wind Energy in Cold Climates, under R.D&amp;D Wind <a href="http://arcticwind.org">http://arcticwind.org</a>. The purpose of this project is to gather and provide information about wind turbine icing and low temperature operation.</p> <p><a href="#">Recommendations for wind energy projects in icing and cold climate can be found here (pdf)</a>. The Recommendations report will give guidelines and information to wind energy developers to minimize the extra risks involved in wind energy projects in icing and cold conditions.</p> <p><a href="#">State-of-the-art of wind energy in cold climates (pdf)</a>, summarises existing experiences in wind energy in cold and icing conditions.</p> <p style="text-align: center;"><b>Wind turbines operating in cold or icing climate worldwide</b></p>  <p>What is a Cold Climate?</p> <p>Sites at which significant icing events or periods with temperatures lower than the operational limits of standard wind turbines may occur.</p> <p style="text-align: right;">Mail: <a href="mailto:Tommas.Walsterus@ec.europa.eu">Tommas.Walsterus@ec.europa.eu</a></p>	<p><b>Information (TO BE UPDATED...):</b></p> <ul style="list-style-type: none"> <li>■ Publications</li> <li>■ Specifications</li> <li>■ Experience</li> <li>■ Technical solutions in use</li> <li>■ Measurements &amp; Instruments</li> <li>■ Knowledge on climate conditions and resources</li> </ul>  <p>Control anemometer and wind vane at Olusfjär-fjell Finland</p> <ul style="list-style-type: none"> <li>■ Send us information about icing and low temperature events</li> <li>■ Add a low temperature or icing VTT site in our list and map</li> </ul>
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# Technology development for WE in cold climates

## Market study required – **Available in BTM's WMU 2012 (Mar 2013)**



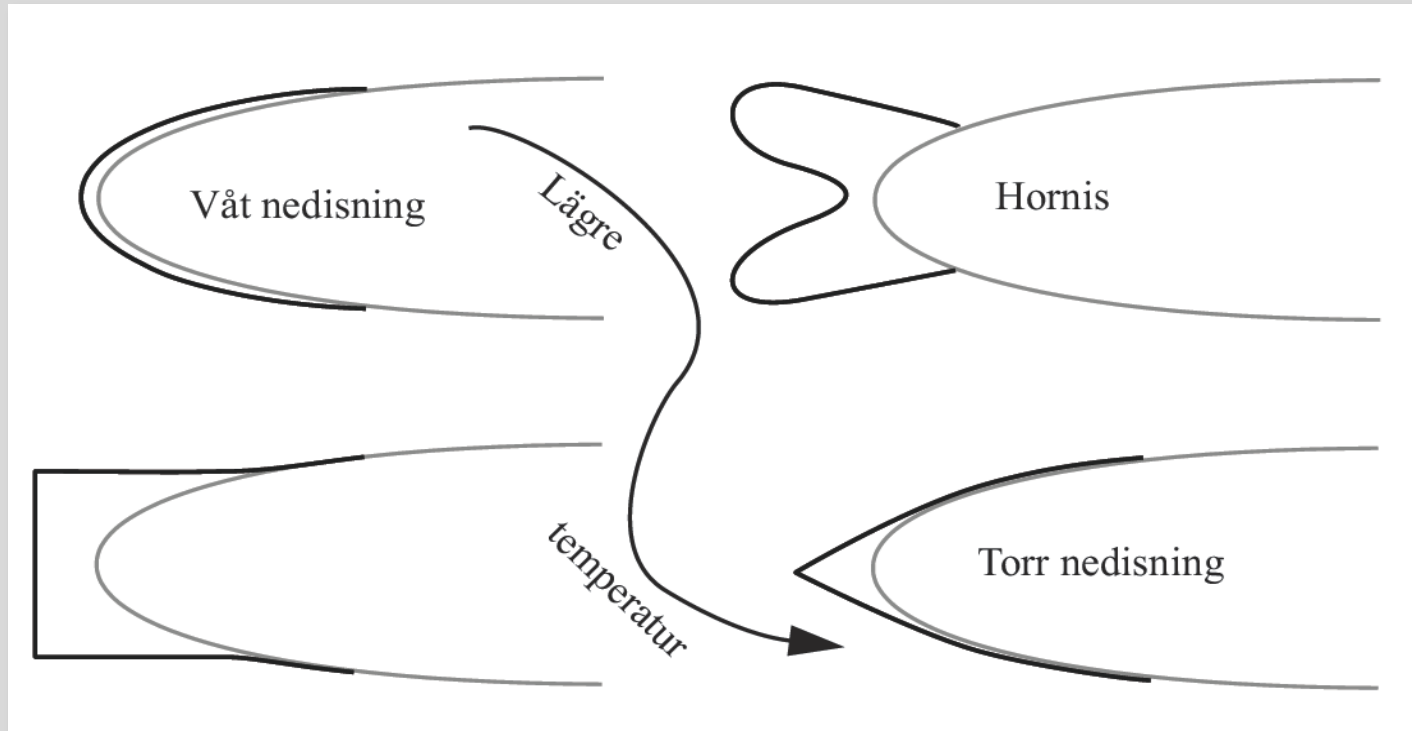


Modern LED obstacle lights need heating to be seen






## Icing versus temperature





OX2

 Swedish  
Energy Agency





# OX2's wind pilot project

Large-scale, cost-effective wind  
energy development  
in icing climates,

*Göran Ronsten*

*2008 - 2015*

*8 MEuro*

**Anti-icing (40 WT) and icing measurements (13 stations, 11 sites),**  
Bliekevare, Brahehus, Sjisjka, Glötesvålen and other, 2008-2015, **R&D: 8 MEuro**



...





## International participation in OX2's wind pilot project







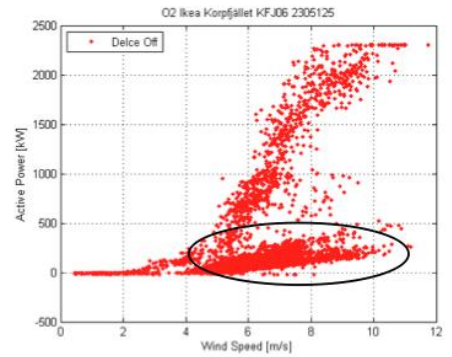


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# International participation in OX2's wind pilot project

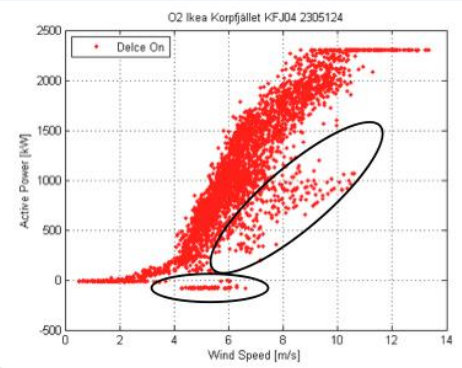


Power curve from reference turbine



© Siemens AG. All rights reserved. E W CTO INNO

Power curve from turbine with de-icing

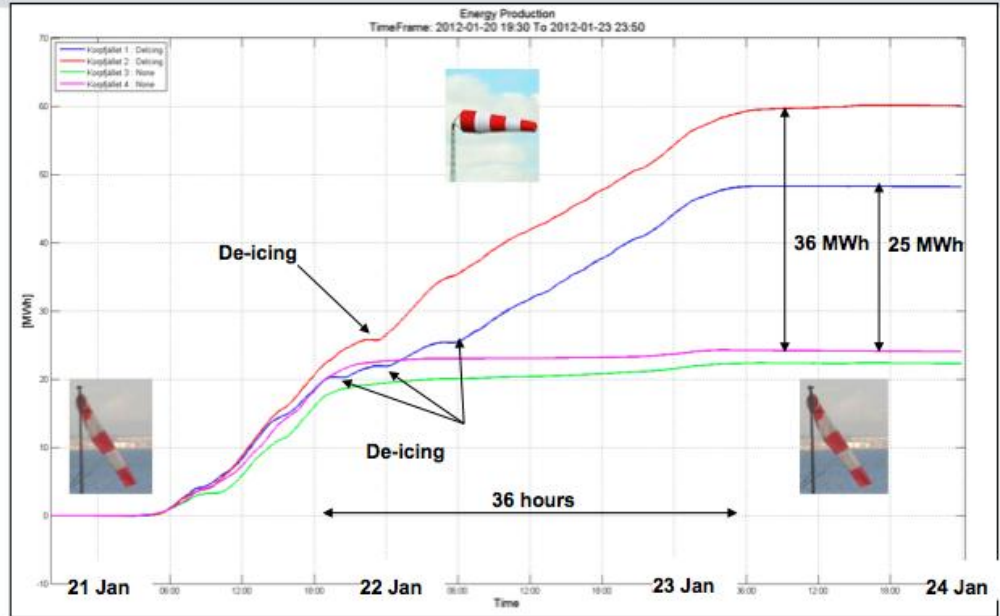


© Siemens AG. All rights reserved. E W CTO INNO

Turbines keep operating in spite of icing conditions



Power production in icy conditions



© Siemens AG. All rights reserved. E W CTO INNO

## International participation in OX2's wind pilot project

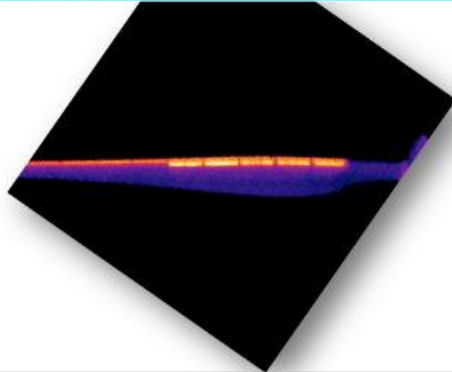


## Testing Active: Outside hot panels

### Top 5 reasons for not pursuing leading edge heating

- AEP
  - Losses during summer time to large compared to the gain during icing conditions
- O&M cost proved to be too high
- High system costs
  - Component costs and lightning protection
- Lifetime
  - It remains unproven that a reasonable lifetime can be achieved
- Damage from lightning

In terms of **performance** it has to be said that the technology didn't receive a full and fair *trial* in *severe ice conditions*



Vestas De-icing solution



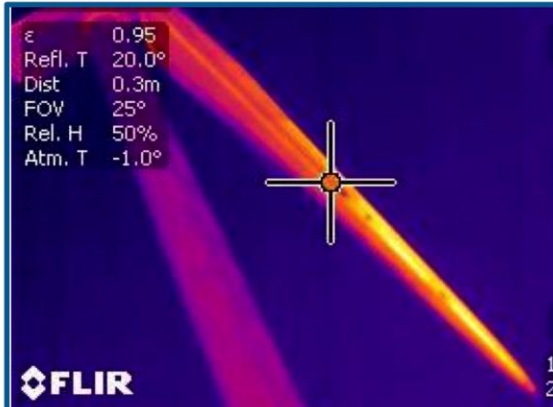
Wind. It means the world to us.™

As presented by Vestas at Winterwind 2012

Applying external panels isn't a proven technology

# Vestas De-icing system

Designed for production optimization and operation



- **Active** blade de-icing solution
- **Hot Air technology** within each blade root
- **Simultaneous** de-icing of blades
- **Automatic system** based on power curve and ambient conditions



- No impact on overall turbine performance – **20 year lifetime** maintained
- **No impact** on lightning protection
- **Easy access** for service from the hub and blade root end
- Full **turbine software** implementation
- Follow type certificate with a **statement of compliance**

Wind It means the world to us™

As presented by Vestas at Winterwind 2014

# Challenge 2014/2015 – 30 Vestas V90 equipped with hot air based de-icing IKEA

WindREN

Vestas

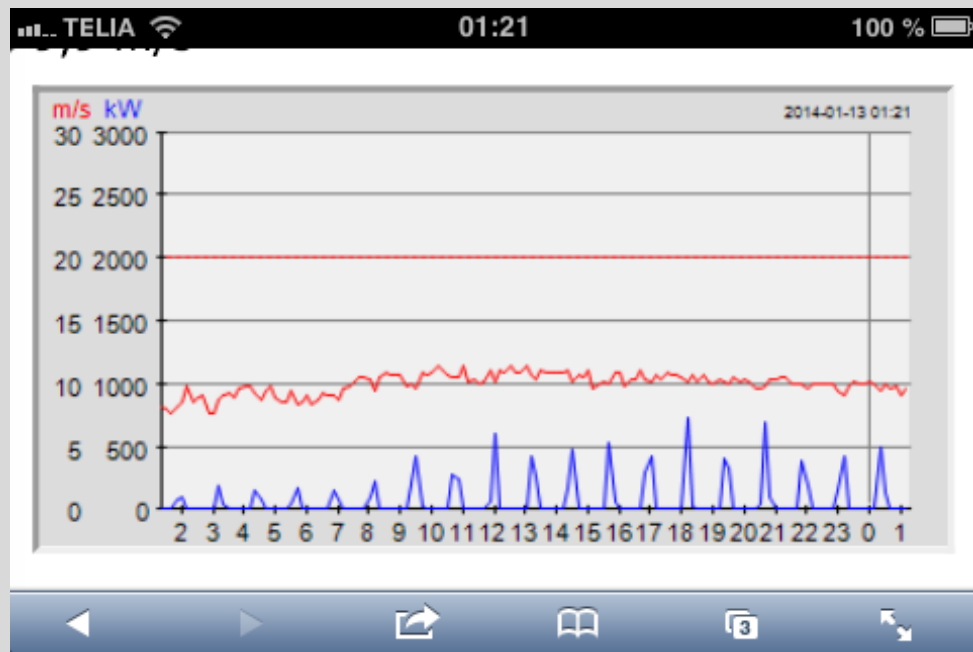
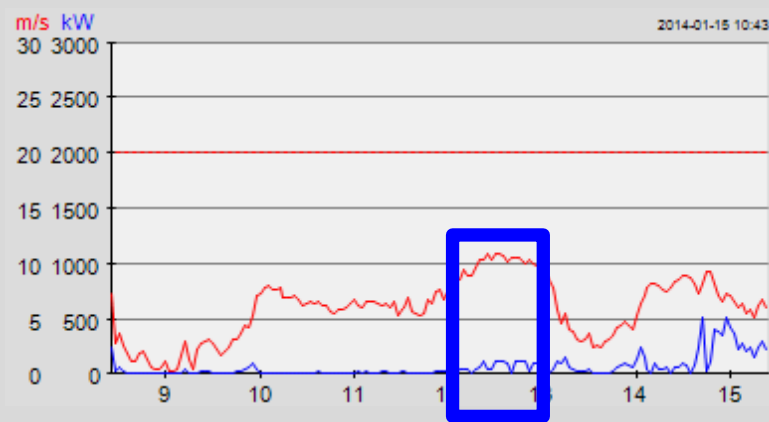
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Challenge 2014/2015 – 30 Vestas V90 equipped with hot air based de-icing

Q: Will the power transferred by means of hot air suffice on Glötesvålen?

Example of an Enercon E82 trying to de-ice during the 2013/2014 season.

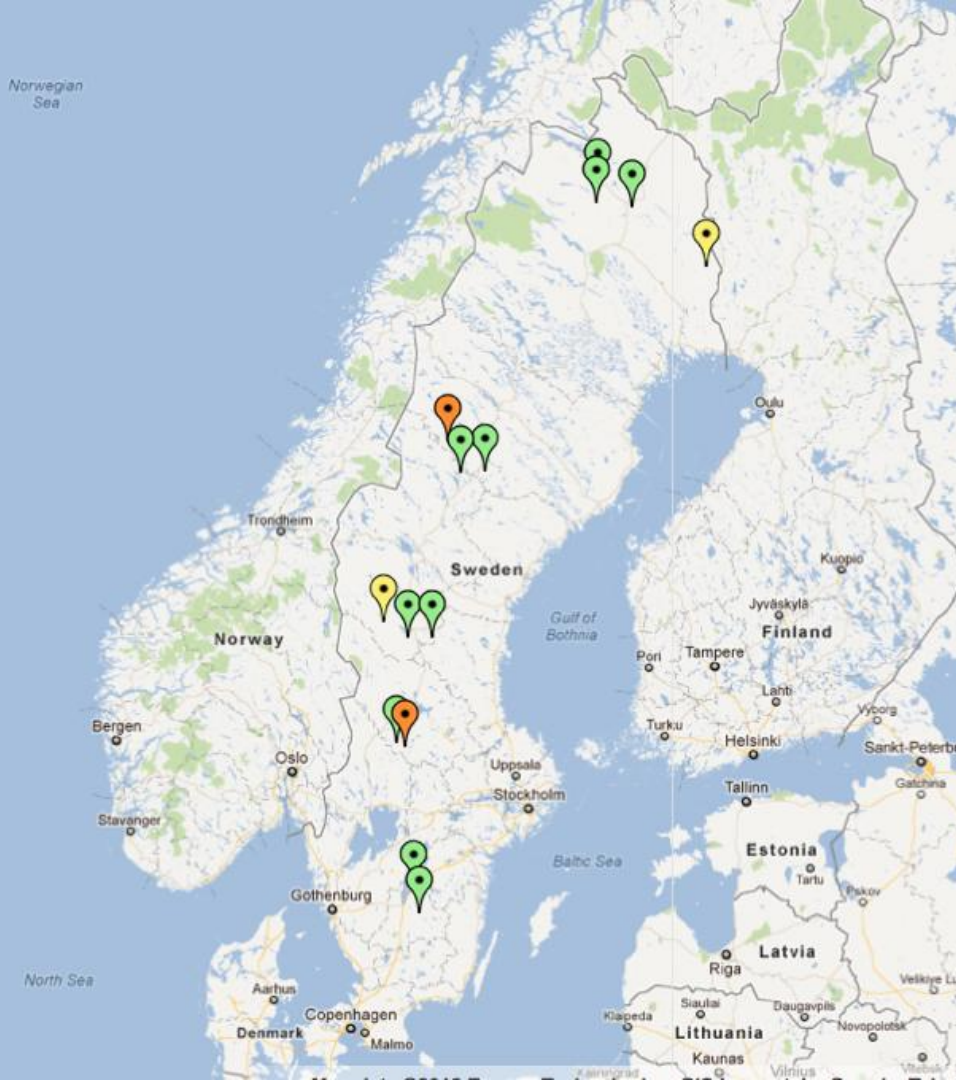






Mapping and forecasting of icing requires verification

Icing measurements are ongoing



# International participation in OX2's wind pilot project



# Equipment used on WT

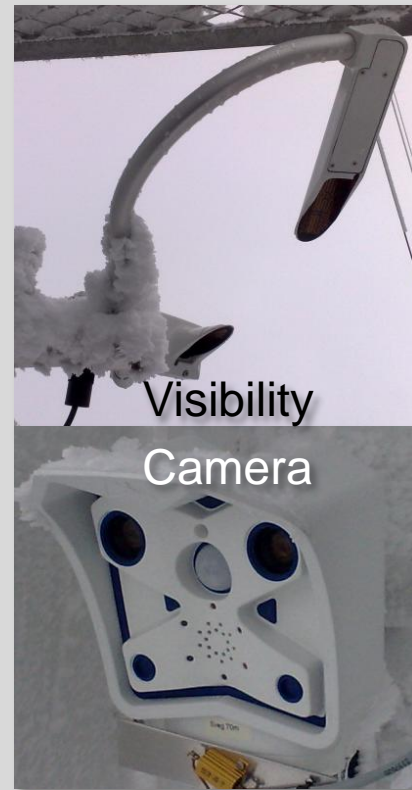


Ice detector, ice load, met sensor

Long boom for WS



# & in the masts (13 stations)



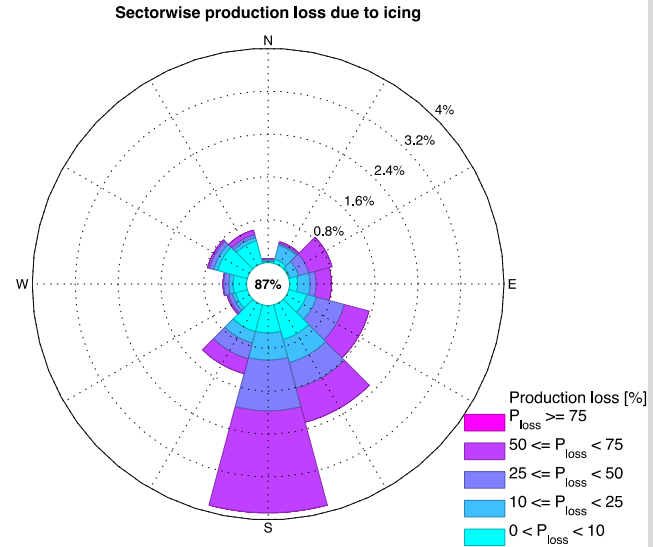
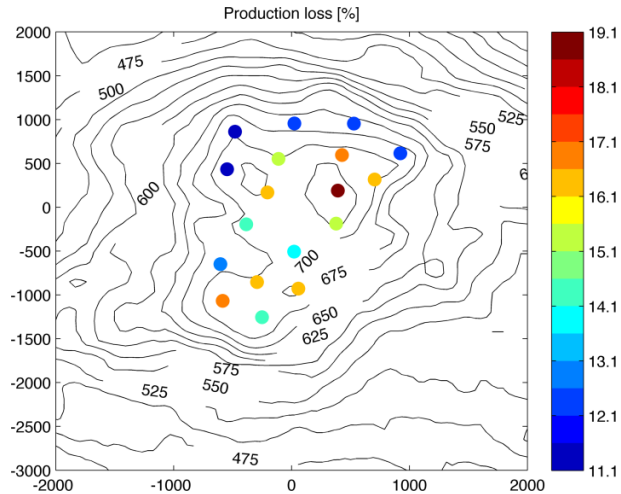
Visibility

Camera

# International participation in OX2's wind pilot project



# 2013 - 2014

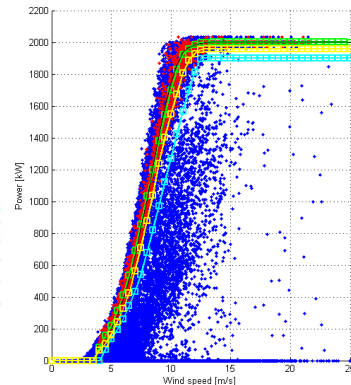


## Definition of icing periods from the turbine data

- Icing is defined as the points located below the P10 - power curve (yellow) if the temperature at hub height is below +3 degrees.
- We further require that icing is identified for 3 consecutive time steps.
- The production loss due to icing is defined as the difference between the real production and the production according to the power curve for the periods when icing is identified.
- Alarms directly after icing is calculated separately



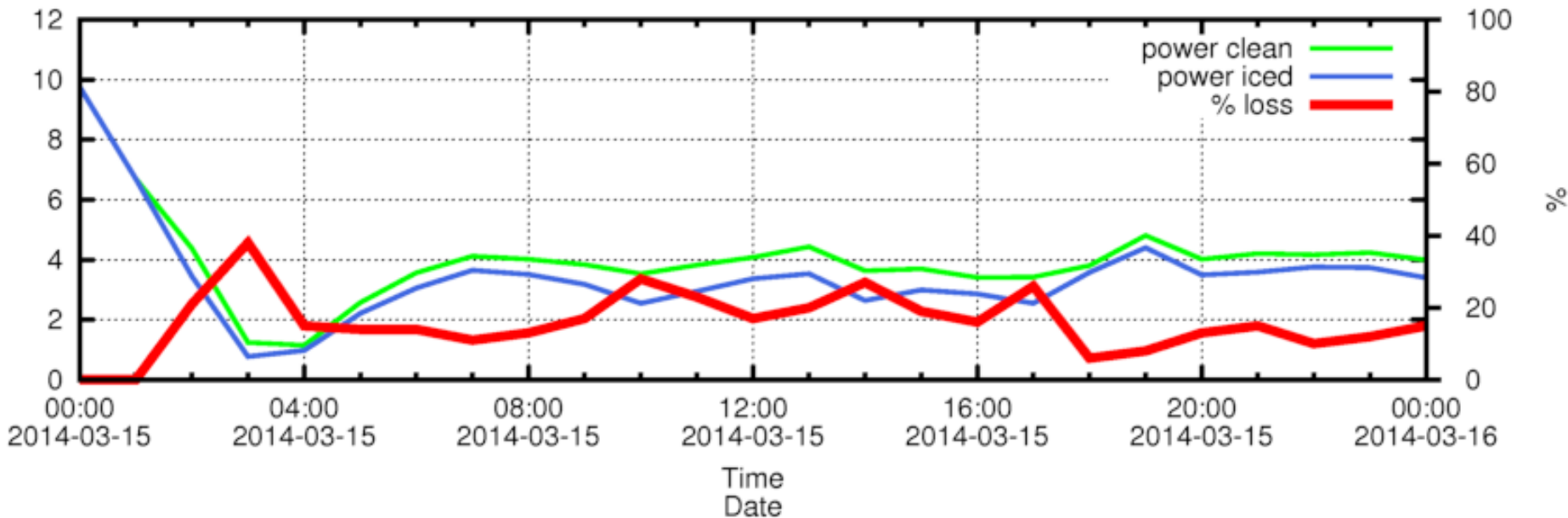
We're applying a proposed IEA standard for assessing ice induced production losses



**Example:** Forecasted energy production with and without ice



Aapua 7 Vestas VE82: forecast of power clean, power iced and power loss



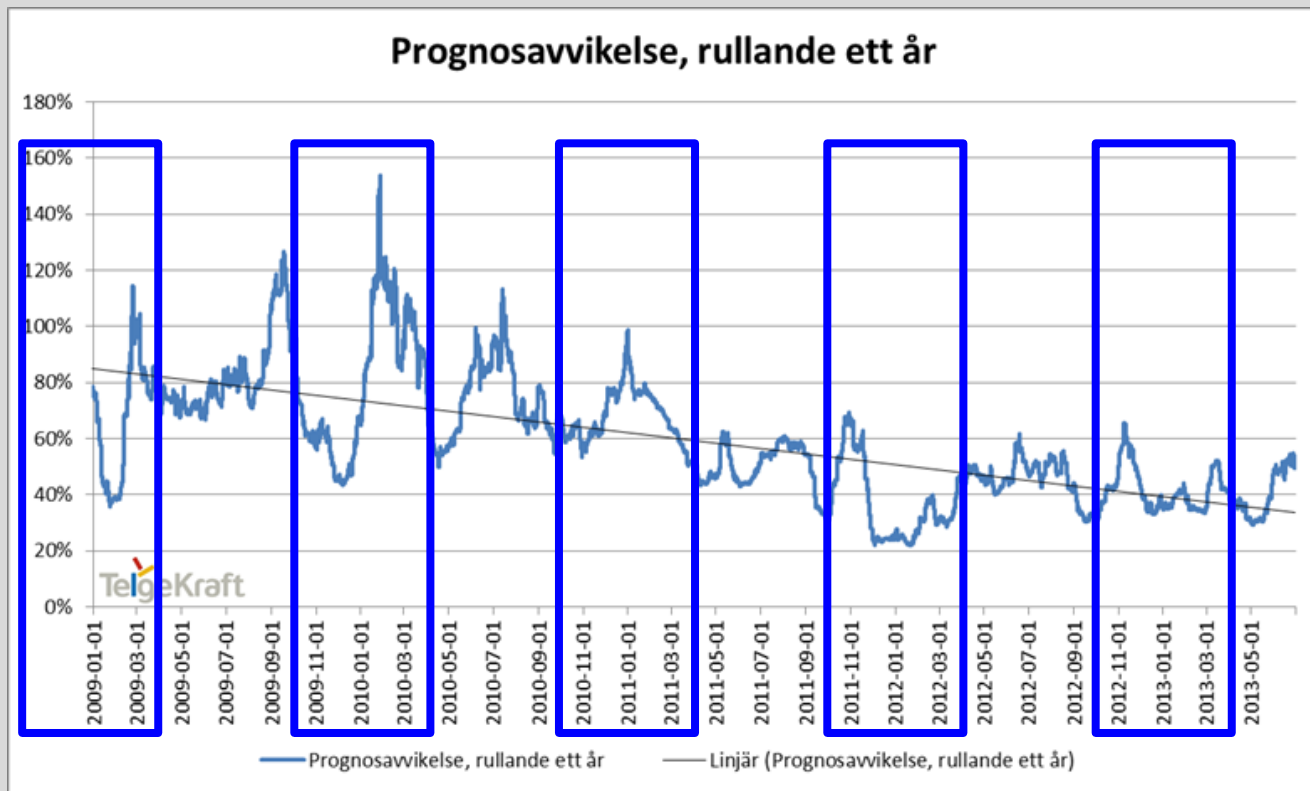
## Pricing in power systems: Sweden



- **Hydro + Nuclear + wind (90%)**
- **Large part of the rest is CHP (industrial and distr. heat) →**
- Price is set by the **water value** = the expected marginal cost in the future to which the water could be stored. →
- **Price is not set in Sweden!**



## An example of decrease in annual moving average forecast error



The forecast error is defined per h as:

$$\text{abs}(prod-for)/prod$$

Increase in uncertainty during winter periods?

Winter - prices are generally higher!!!

## International activities to assess the balancing cost

*“We are studying these issues as a part of the **Icewind** project for the four Nordic countries in Nordpool spot power market: Denmark, Norway, Sweden and Finland. First we are looking at the variability of the wind and the load, country by country and for all; then at the forecasting done in the four countries and the accuracy and uncertainty of the forecasting. Lastly we will try to assess the impact of icing on forecast errors. At this point of time we are not sure we will be able to isolate this issue on a power market level. In any case the answer is approximately one year away.”*

...

*So far we have only looked at the cost of balancing for Finland and found a level of 1-1.4 EURO/MWh.*

Niels-Erik Clausen, Senior Advisor, Head of Study Board, **DTU Wind Energy**

*“In our new project **IcedBlades** we have the target to identify short term uncertainties. So it connects directly to the first steps from the results of 2008. There will be a EWEA workshop on forecasting in December. I am not sure if they are aware of the problems that we recognize for cc sites. Details here: <http://www.ewea.org/events/workshops/wind-power-forecasting/>*

Michael Durstewitz, **Fraunhofer IWES**

**26 European countries participate in COST 1002, Weather Intelligence for Renewable Energies (but not Sweden)**

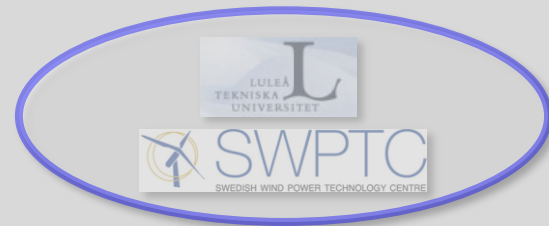
*“have a look at our website, in particular our Current State report (to be officially published in a couple of months) as well as the benchmark exercise we are presently involved in. By the way, we will submit tomorrow a new COST Action... May be the SMHI will find it interesting this time....”*

Dr. Alain Heimo, Meteotest

# International participation in OX2's wind pilot project



Reference group Meteorology:  
Silke Dierer, Meteotest  
Frank McDonough, Dendrite  
Carla Ribeiro, DNV GL



**Prefabricated  
gravity foundation  
using high  
strength steel  
cellular  
reinforcement**

**Aim: Shorten the  
construction  
period**

**Structural  
dynamics and  
fatigue loads of  
iced up WT using  
current CMS-  
systems**

**Aim: Input for  
update of IEC  
61400-1**

**Independent  
evaluation of  
performance of de-  
icing systems**

**Aim: Verification of  
performance of de-  
icing systems**

# Schematic, estimated de-icing capability



## Preliminary Winterwind 2015 program

### Sunday Feb 1

Afternoon and evening      Arrival to Luleå, Hotel Nordkalotten

### Monday Feb 2

Starting Location: Hotel Nordkalotten, Luleå

09:00	Study visit to SSAB or SKF
	Morning arrivals
11:00	Lunch at Hotel Nordkalotten
12:30	Study visit to SSAB, SKF or Markbygden
17:00	Arrival to Pite Havsbad
18:00-20:00	Registration

### Tuesday Feb 3

#### Outside session rooms

#### Session room 1

#### Session room 2

#### Session room 3

08:00-11:00	Registration			
09:00-10:30		SKF, SSAB and markbygden	Green branding	Logistics
10:30-11:00	Break			
11:00-12:30		Inauguration and keynote presentations		
12:30-14:00	Lunch - 13:00 poster presentations			
14:00-15:30		R&D programs	Energy production	Finance, risk
15:30-16:00	Break - poster presentations			
16:00-17:30		De-/anti-icing	Noise	Resource
17:30-19:00	Mingle			
19:30-	Dinner			

### Wednesday Feb 4

#### Outside session rooms

#### Session room 1

#### Session room 2

#### Session room 3

08:30-10:00		Icewind	HSE	Market potential & offshore
10:00-10:30	Break - poster presentations			
10:30-12:00		IEA Task 19 Cold Climates	Inspection and repair	Forecasting
12:00-13:00	Lunch			
13:00-14:30		Plenary session		



## Preliminary Winterwind 2015 program

Tuesday Feb 3

Outside session rooms

Session room 1

Session room 2

Session room 3

08:00-11:00

Registration

**09:00-10:30**

**Site visit presentations**

**Green branding**

**Logistics**

SKF

Innovatum

10:30-11:00

Break

SSAB

Markbygden

**11:00-12:30**

**Inauguration and keynote presentations**

12:30-14:00

Lunch - 13:00 poster presentations: Combitech, VTT, LTU

**14:00-15:30**

**R&D programs**

**Energy production**

**Finance, risk**

Re-Turn, SP, PEGIL, MW, Vattenfall

DNV GL

Neas Energy

H Gedda Consulting, Alpine Helicopter

DNV GL

OX2

Vindforsk

Meteotest

Marsh

Chalmers

15:30-16:00

Break - poster presentations: LTU, Labkotec, SP

**16:00-17:30**

**De-/anti-icing**

**Noise**

**Resource**

Bosch Rexroth

E.ON

LUT (FI), Alstom

TechnoCentre Éolien, SENVION

APL Systems

Kjeller Vindteknikk

eologix

Richard Hann Cons.

WeatherTech Scandinavia

WestWind

17:30-19:00

Mingle

19:30–

Dinner

**Wednesday Feb 4**

**Outside session rooms**

**Session room 1**

**Session room 2**

**Session room 3**

**08:30-10:00**

**Icewind**

DTU Wind Energy  
WeatherTech Scandinavia  
Kjeller Vindteknikk  
Kjeller Vindteknikk, VTT

**HSE**

Lloyd's Register Consulting  
TÜV NORD  
DTU

**Market potential & offshore**

SMHI  
VTT

10:00-10:30

Break - poster presentations: Lund University, TÜV SÜD, LTU

**10:30-12:00**

**IEA Task 19 Cold Climates**

DTU  
Meteotest  
TechnoCentre Éolien  
VTT

**Inspection and repair**

Sirris-OWI-Lab  
Blade Solutions  
Bladefence

**Forecasting**

DNV GL  
Uppsala Univ. SMHI  
VTT  
Mid Sweden University

12:00-13:00

Lunch

**13:00-14:30**

**Plenary session**

Siemens  
Nordex  
Enercon  
Gamesa



**Thank  
you!**

