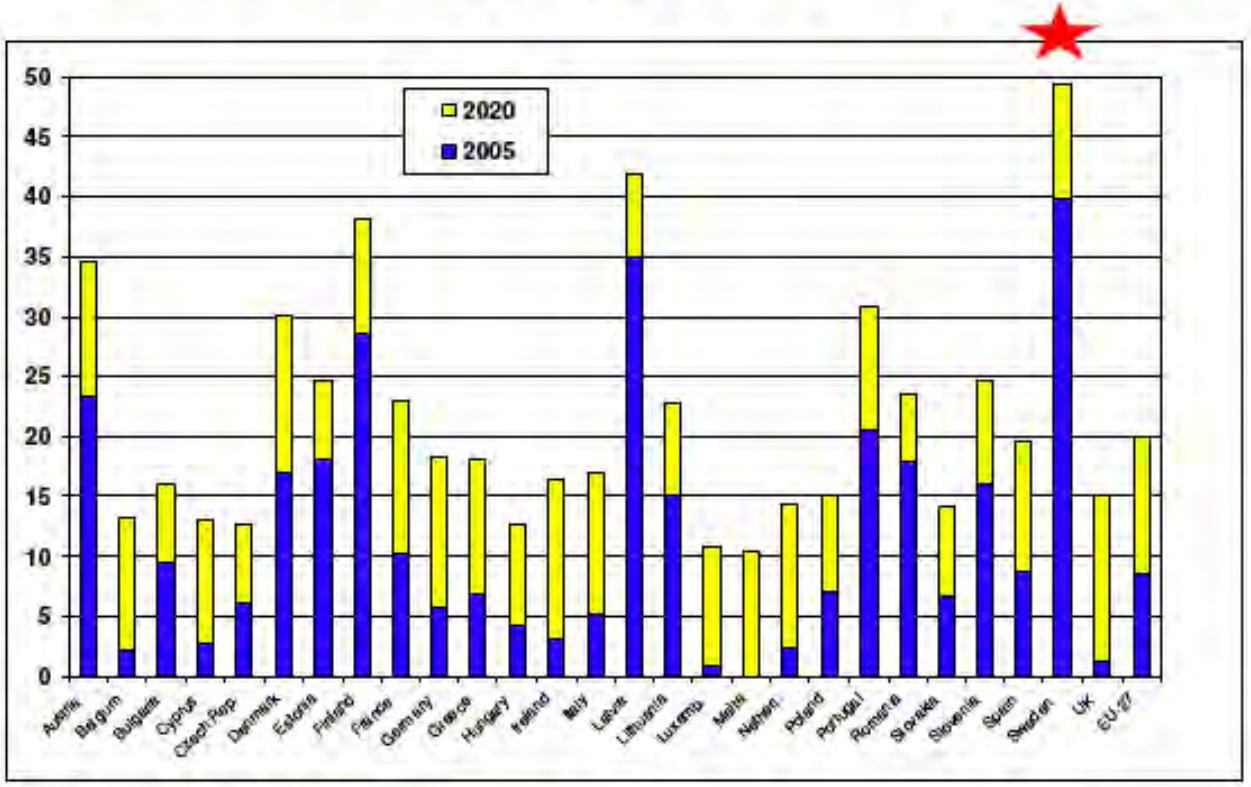
# IEA Task 19 national overview - Swedish activities

in measurements and mapping of icing
and de-icing of wind turbines

*Göran Ronsten, WindREN*

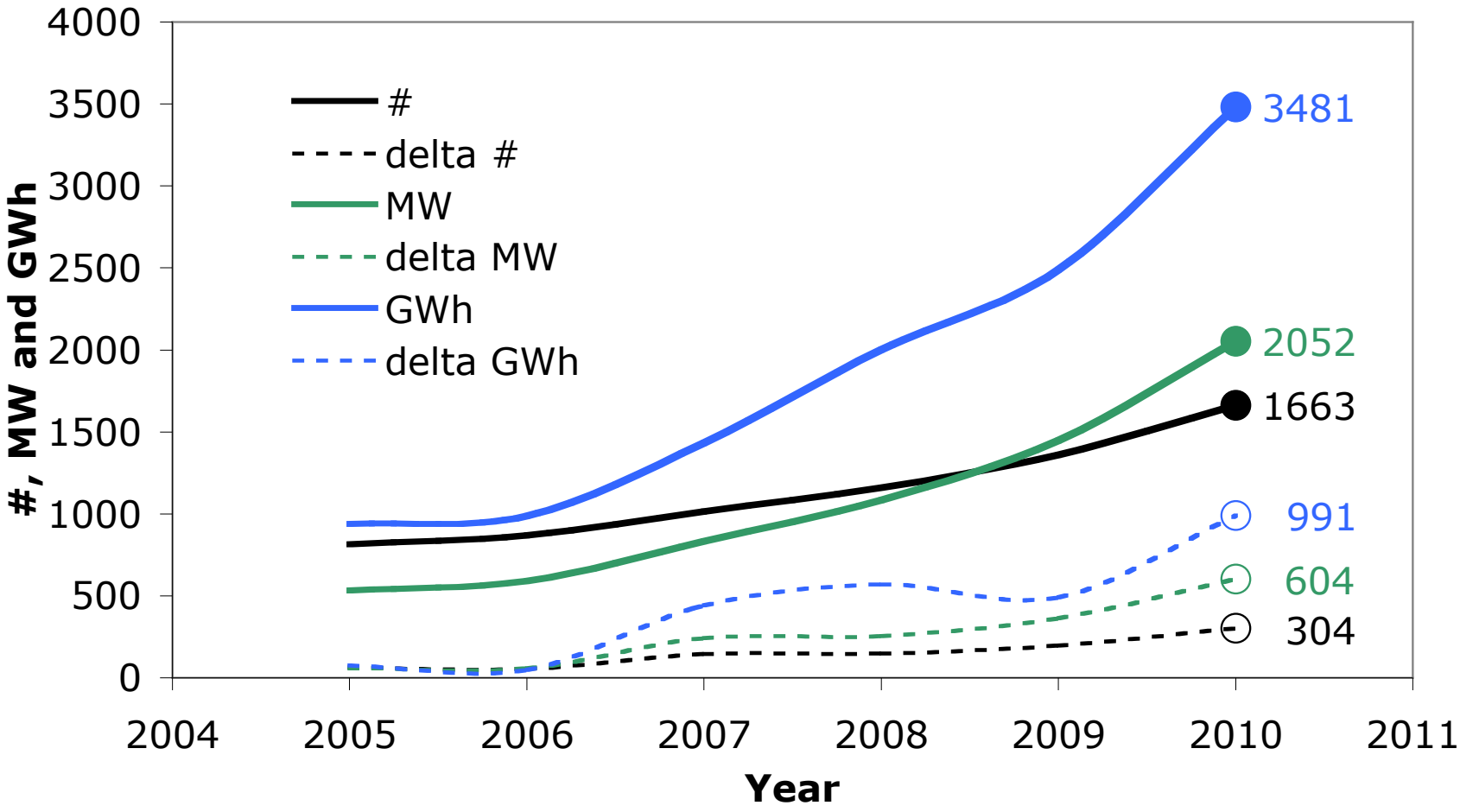
# Why bother? Binding targets to be achieved by 2020

## Shares of RE, 2005 and 2020



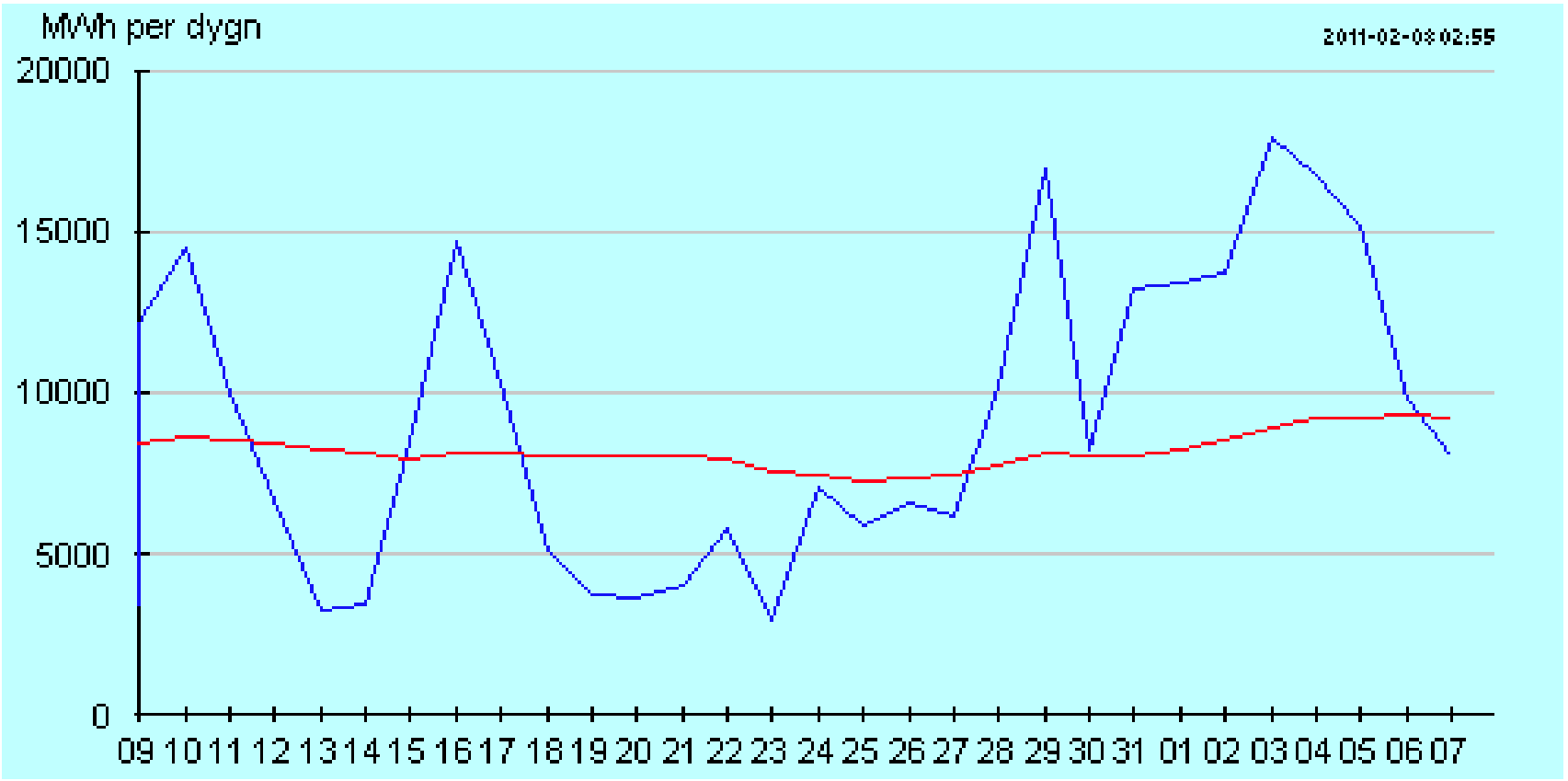

Ministry of Enterprise, Energy and Communications

Government Offices of Sweden

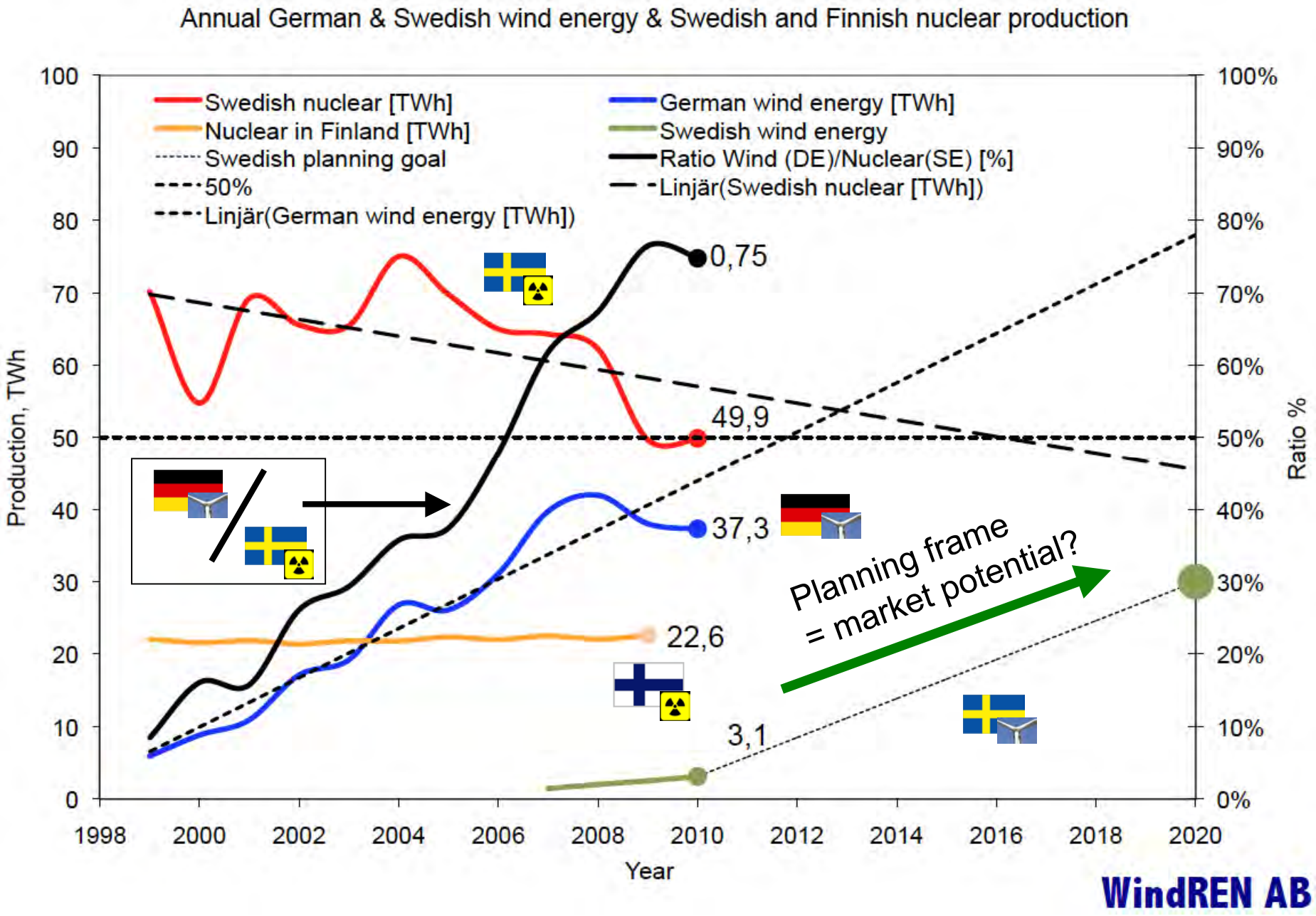

Sweden: # of WT, MW and GWh
#, MW and GWh
4000
3500
3000
2500
2000
1500
1000
500
0
2004
2005
2006
2007
2008
2009
2010
2011
Year
#
delta #
MW
delta MW
GWh
delta GWh
3481
2052
1663
991
604
304

# Daily WE production and a 30 day daily running average

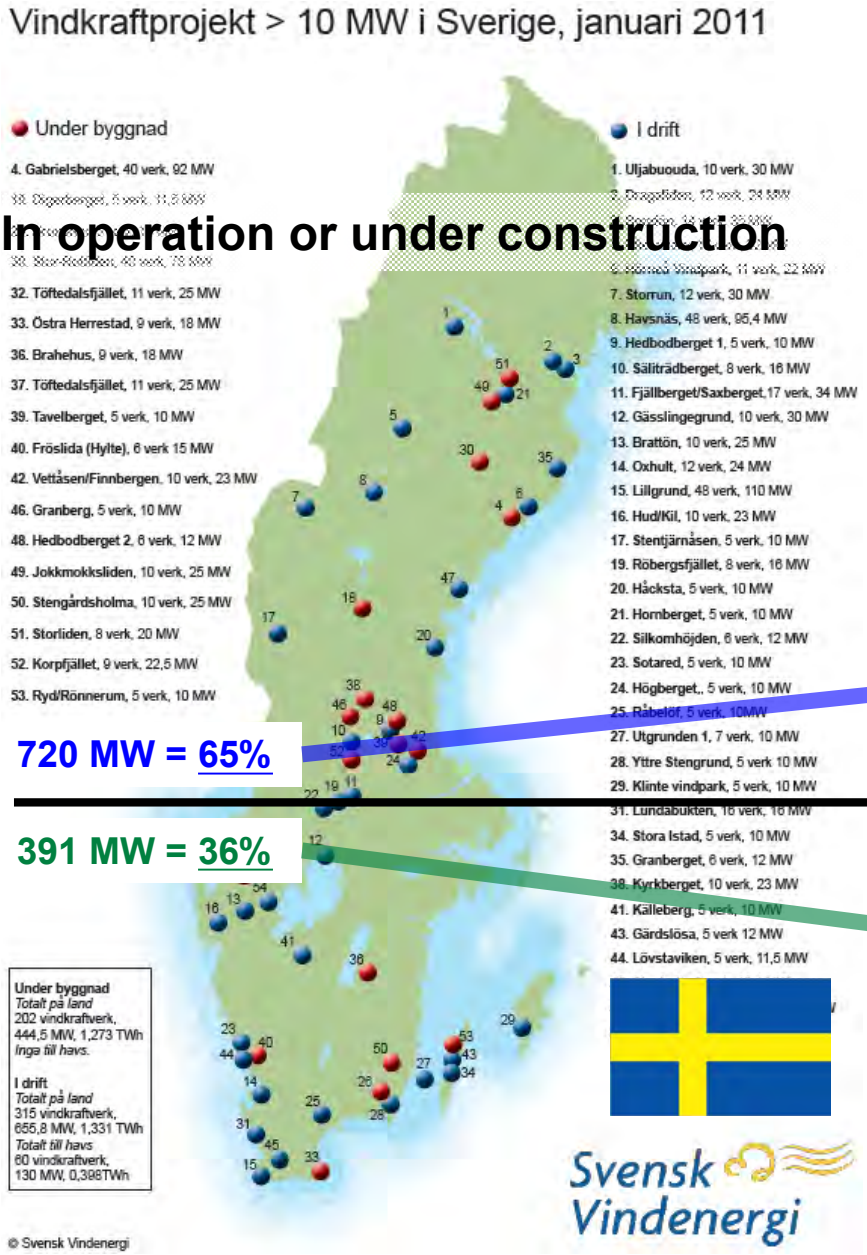
http://www.vindstat.nu/



# Planning frame for wind energy in Sweden until 2020



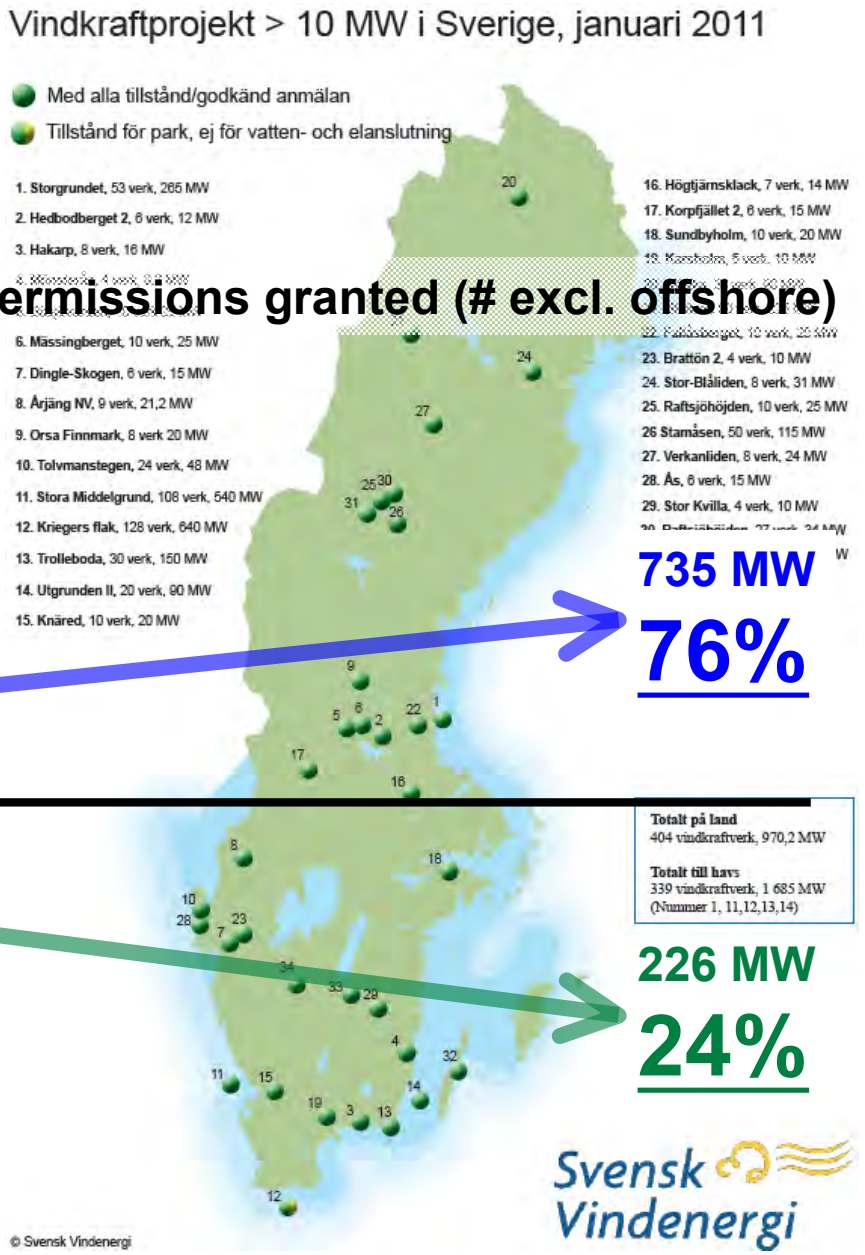

WindREN AB




**In operation or under construction**

**720 MW = 65%**

**391 MW = 36%**




**Permissions granted (# excl. offshore)**

**735 MW**

**76%**

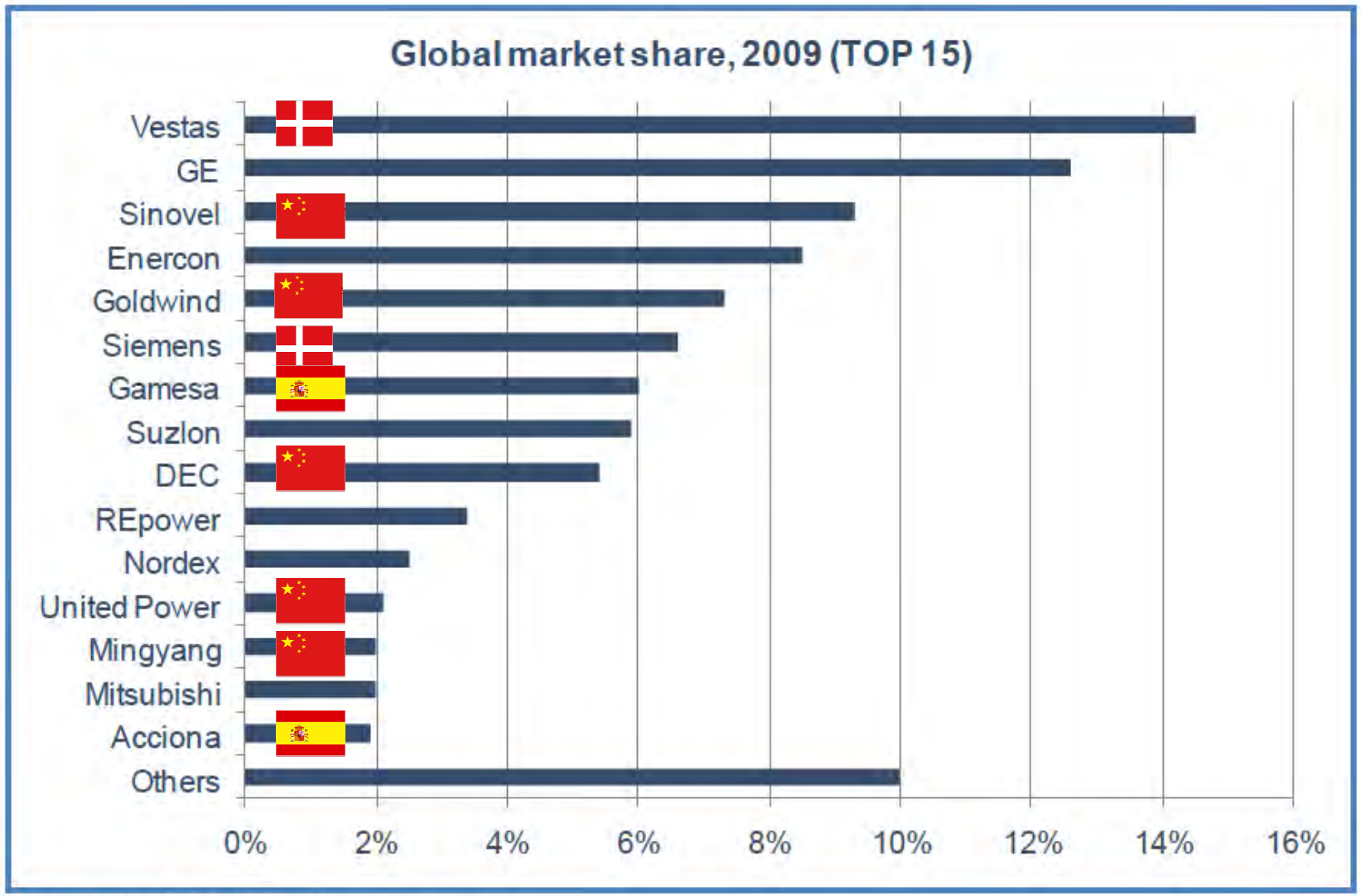
**226 MW**

**24%**

# The Russian WE market; 15 GW by 2020, = Sweden = Canada

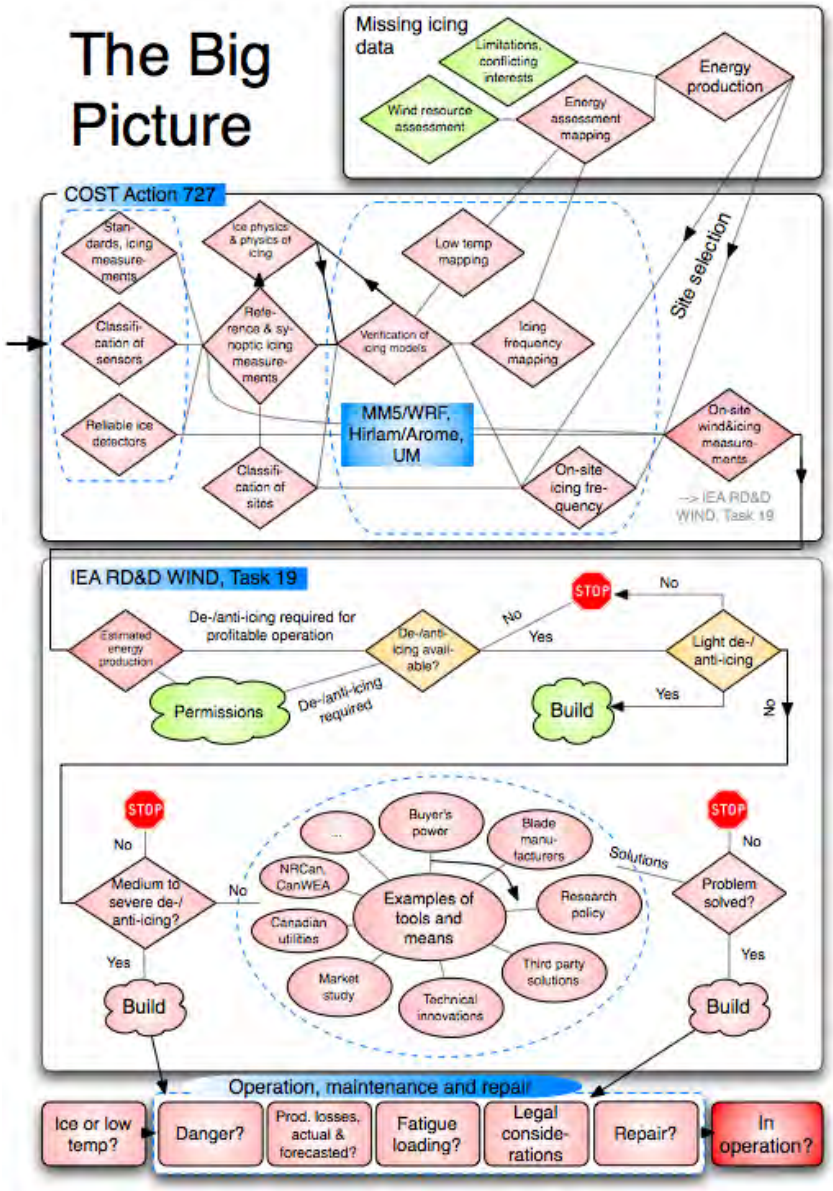
**Denmark, China & Spain are not involved in IEA Task 19**

**Swedish reference group has asked for the Baltic countries to be invited**




Source: MAKE Consulting

A plan to keep WT in icing climates in operation




Planning

De-icing

O&M

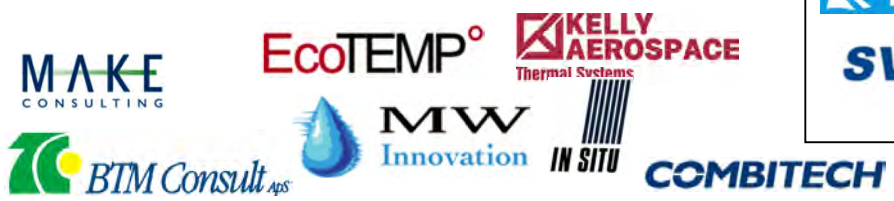
**Q:** Is wind energy in cold climates bigger than offshore?

**Q:** How can wind energy in cold climate best act as a technological bridge to offshore?

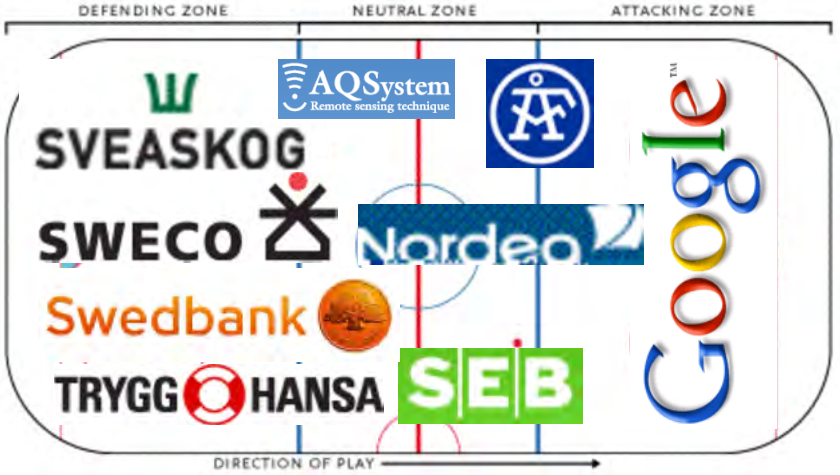
# Technology development for WE in cold climates requires a market study **- not available : - (**

# Which forces drive the different markets - offshore and cold climates?











# A market study requires mapping of icing - **underway, to be ready by 2013**

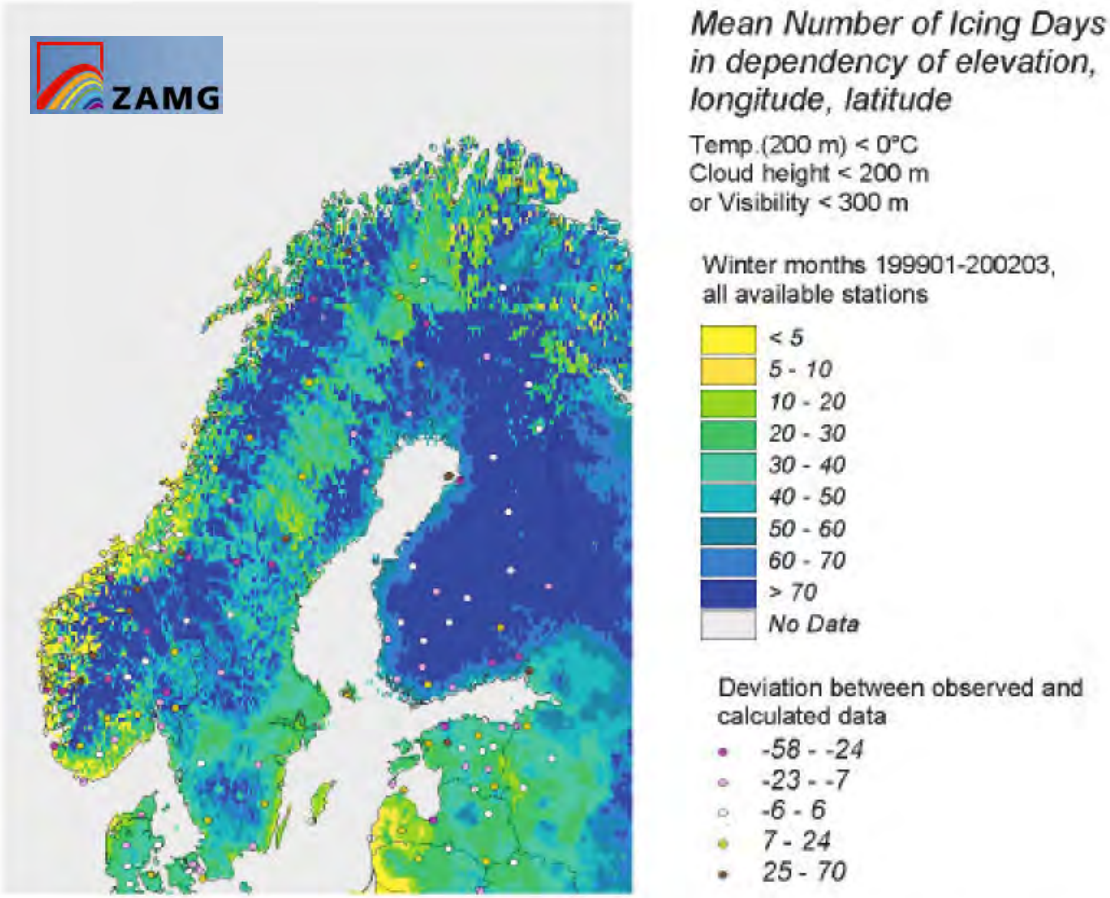
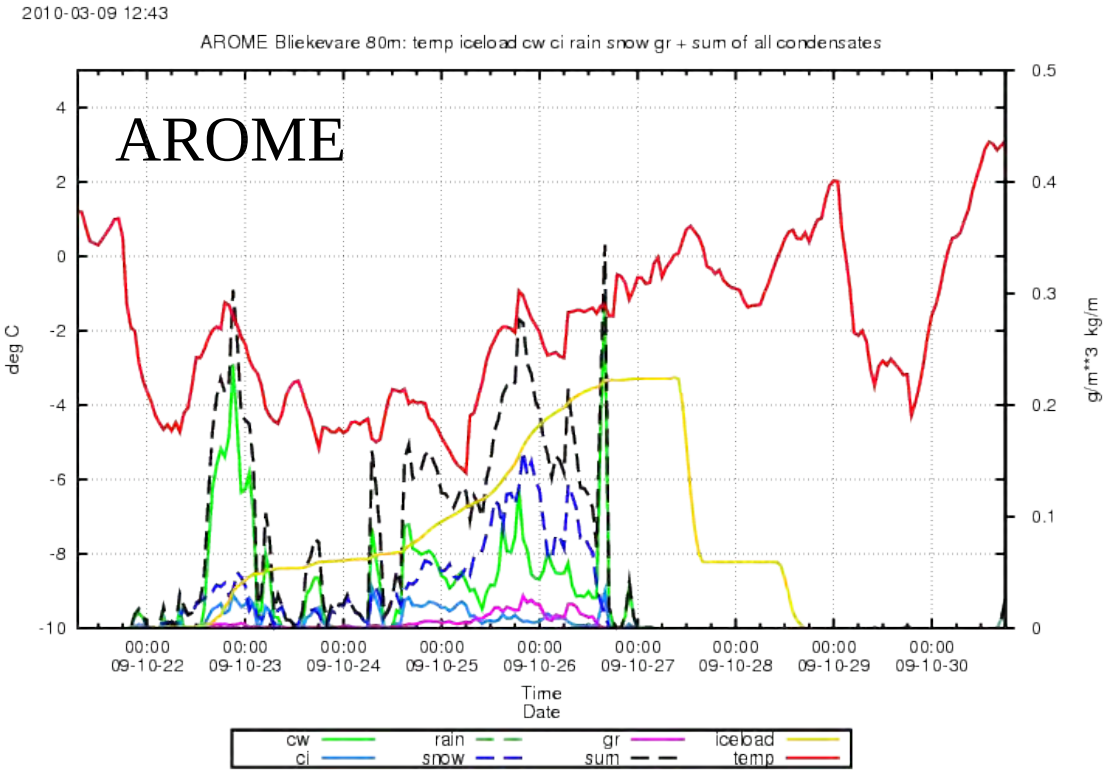


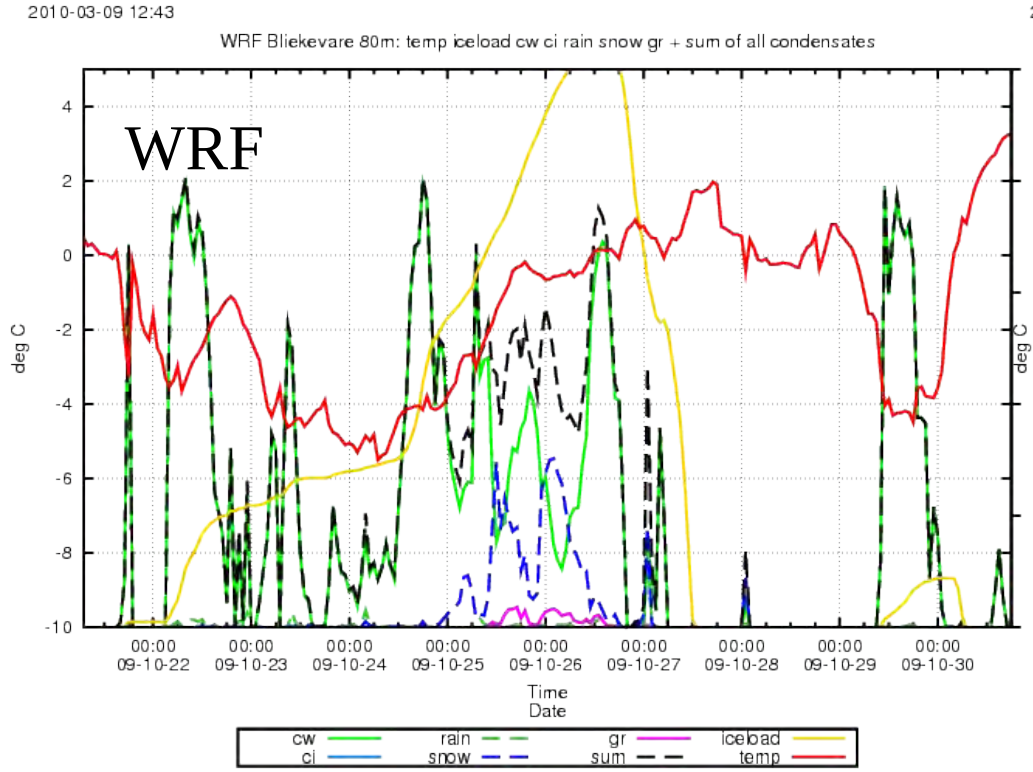

**Figure 5:** Icing days in dependency from geographical coordinates and sea level height for Scandinavia

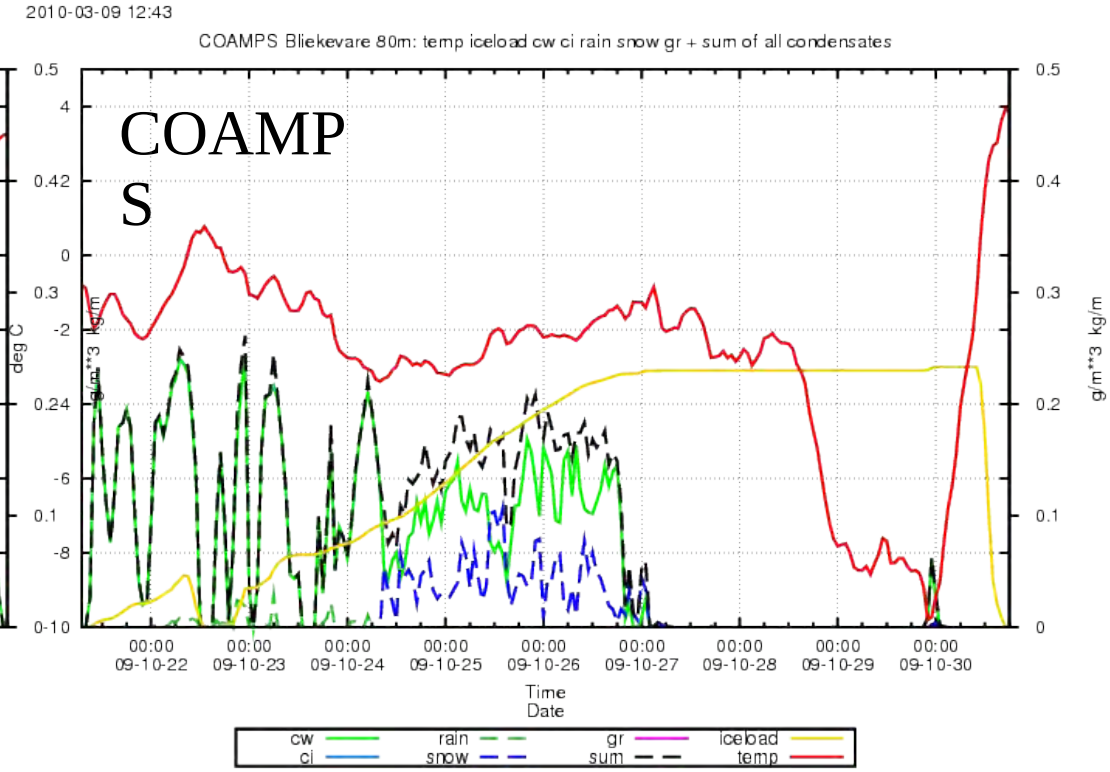
CW RAIN CI SNOW GRAUPEL TOTAL

Olika fördelning och olika mängder ger väldigt olika förutsättningar att modellera nedisning.

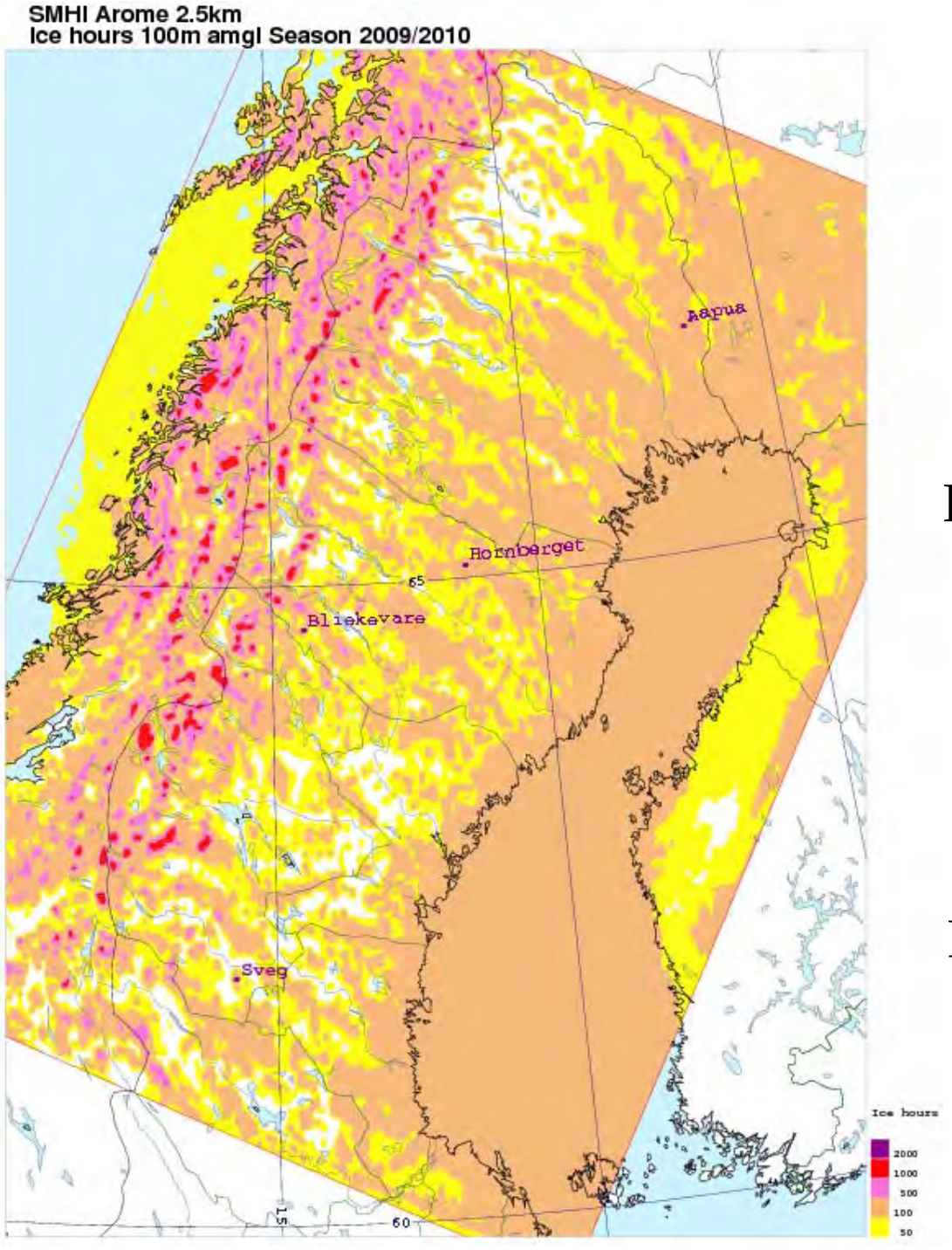
Hur ser det egentligen ut?



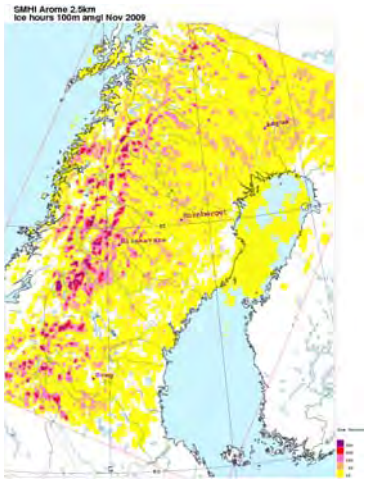



# Summering av den gångna vintern

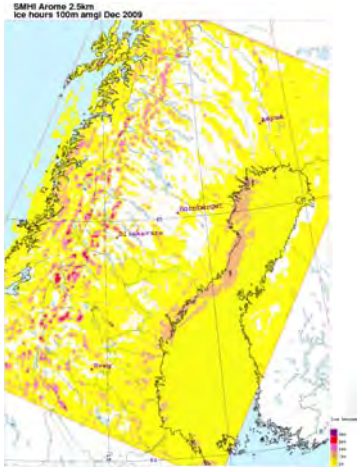



Okt

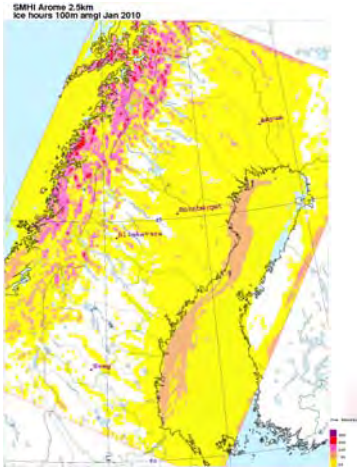
Nov



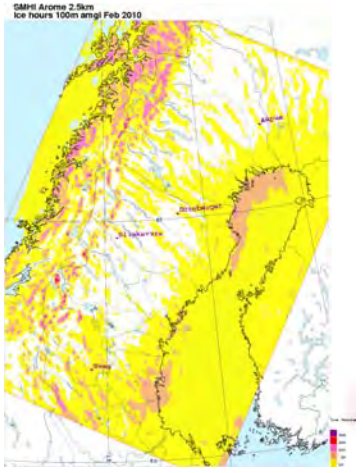
Dec



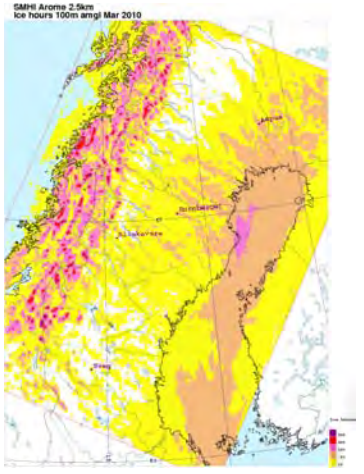
Jan



Feb



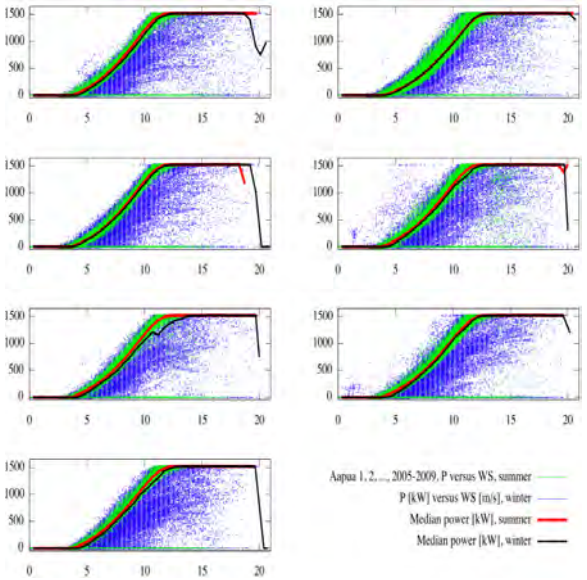
Mar



# Measured and estimated energy production losses **- ongoing**

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

Vindforsk




Example of modeling of production losses For Dec 2010

KJELLER VINDTEKNIK

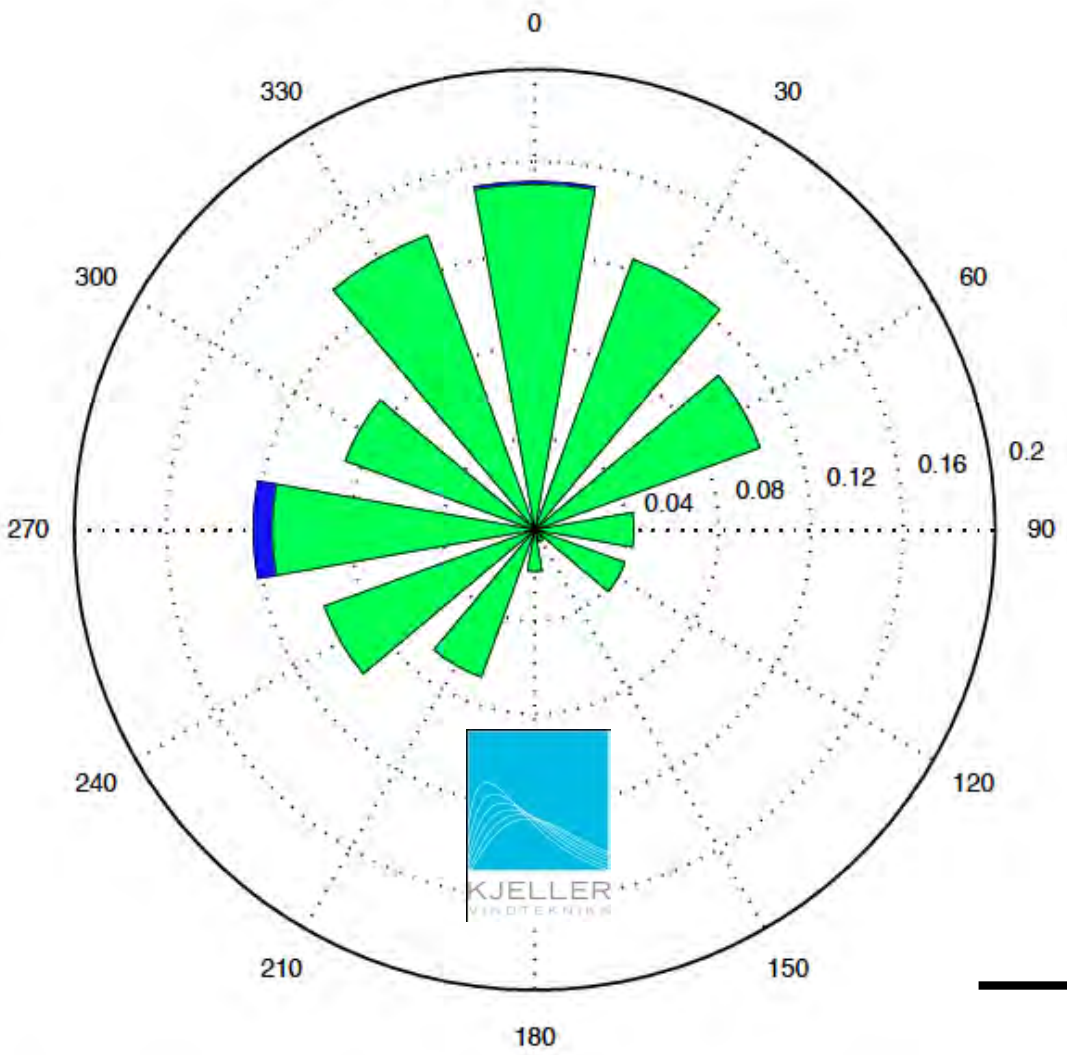
| Site | $U_{mean}$ [m/s] | $T_{mean}$ [°C] | $T_{min}$ [°C] | $T_{max}$ [°C] | Icing [hours] | $P_{full}$ [MWh] | $P_{loss}$ [MWh] |
|---|---|---|---|---|---|---|---|
| Tåsjö | 7.1 | -10.1 | -20.1 | -2.8 | 36 | | |
| Kiruna | 7.1 | -9.1 | -22.0 | 1.3 | 8 | | |
| Sveg | 6.3 | -9.8 | -19.0 | -1.4 | 5 | | |
| Nässjö | 6.6 | -7.1 | -13.4 | 1.6 | 7 | 439 | 8 |

Table 1: Overview of the monthly model data (WRF)

# Data not easily available!

Energimyndigheten

VINDKOMPANIET




**Example: Icing versus wind direction at Nässjö, Dec-11**

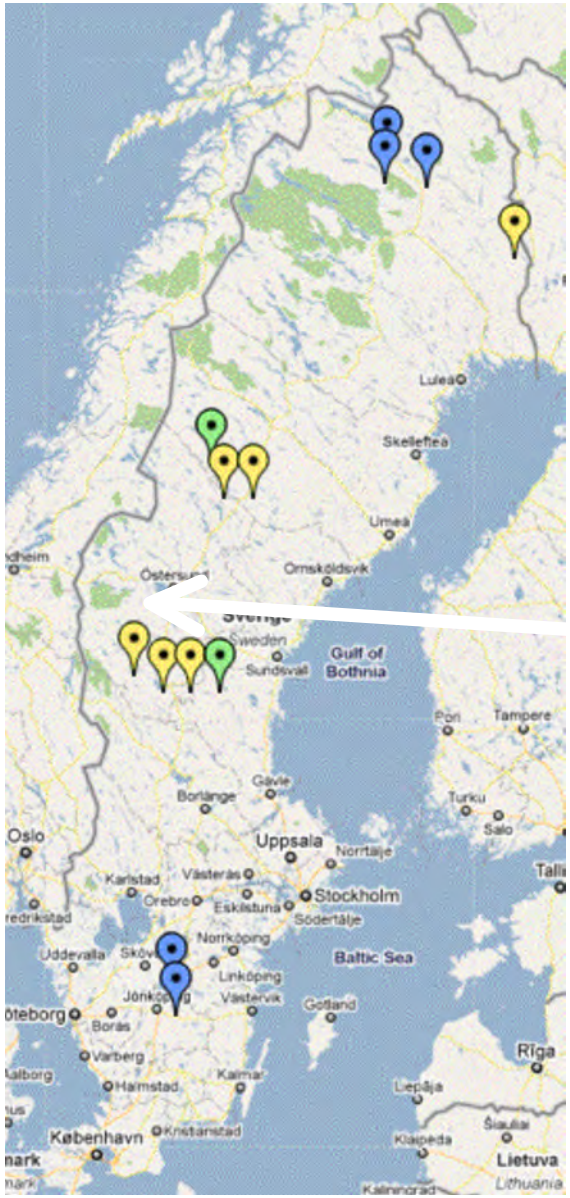
Figure 81: Ice rose for Nässjö. The green part of the rose represents the time without icing, while the blue part represents the time with icing.

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 33 | 40 | 26 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 53 |
| 2001 | 61 | 29 | 27 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 80 |
| 2002 | 26 | 39 | 23 | 3 | 0 | 0 | 0 | 0 | 2 | 20 | 62 | 86 |
| 2003 | 32 | 57 | 5 | 24 | 0 | 0 | 0 | 0 | 0 | 24 | 66 | 60 |
| 2004 | 68 | 28 | 10 | 4 | 0 | 0 | 0 | 0 | 0 | 3 | 75 | 21 |
| 2005 | 22 | 64 | 27 | 0 | 0 | [illegible] | [illegible] | 0 | 0 | 0 | 13 | 41 |
| 2006 | 59 | 42 | 32 | 4 | 0 | [illegible] | [illegible] | 0 | 0 | 0 | 7 | 4 |
| 2007 | 21 | 33 | 22 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | 40 |
| 2008 | 24 | 18 | 34 | 7 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 46 |
| 2009 | 32 | 12 | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 39 |
| | | | | | | | | | | 0 | 0 | 6 |
| 2010 | 83 | 71 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 79 | 25 |
| | 66 | 41 | 35 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 7 |

Table 55: Monthly number of hours with icing intensity $\frac{dM}{dt} > 10\frac{g}{hr}$ for Nässjö (black = 5x5km data set, red = 1x1km data set).

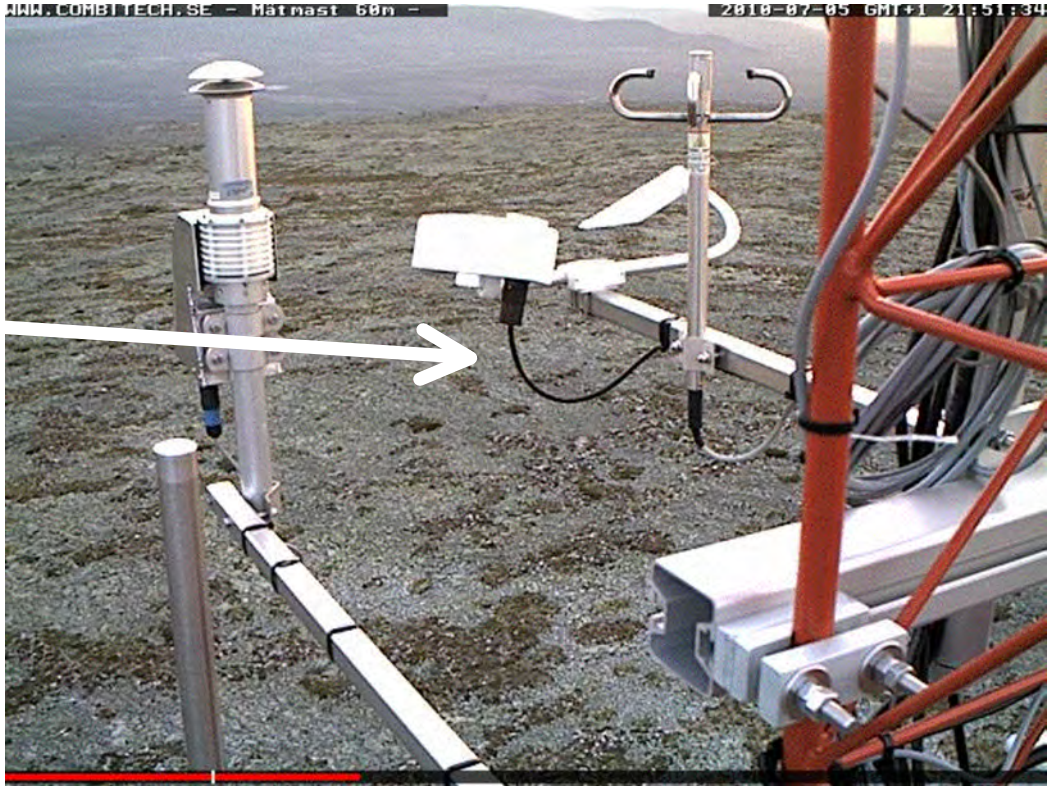
# Example: Number of hours of icing intensity >10g/h, Nässjö

# Mapping of icing requires verification; icing measurements - **underway**




## Icing measurements at 11 sites in 13 stations

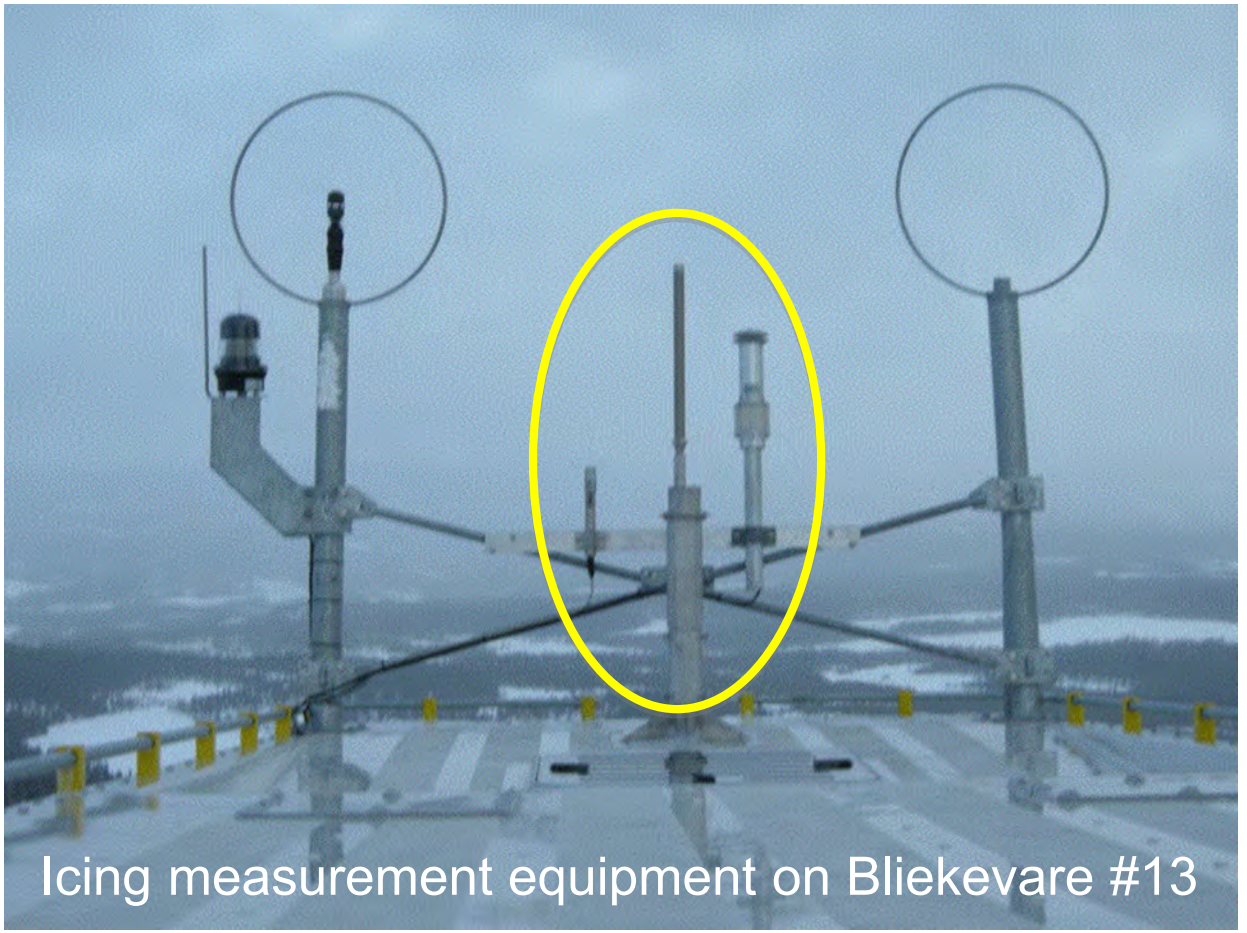
4 telecom. masts and 5 adjacent actual and potential wind farm sites.




Energimyndigheten

VINDKOMPANIET

# Icing, ice and meteorological sensors



Icing measurement equipment on Bliekevare #13

# Equipment used on WT

Ice detector, ice load, met sensor

Long boom for WS

**WindREN AB**

## & in the masts (13 stations)

Visibility

Camera

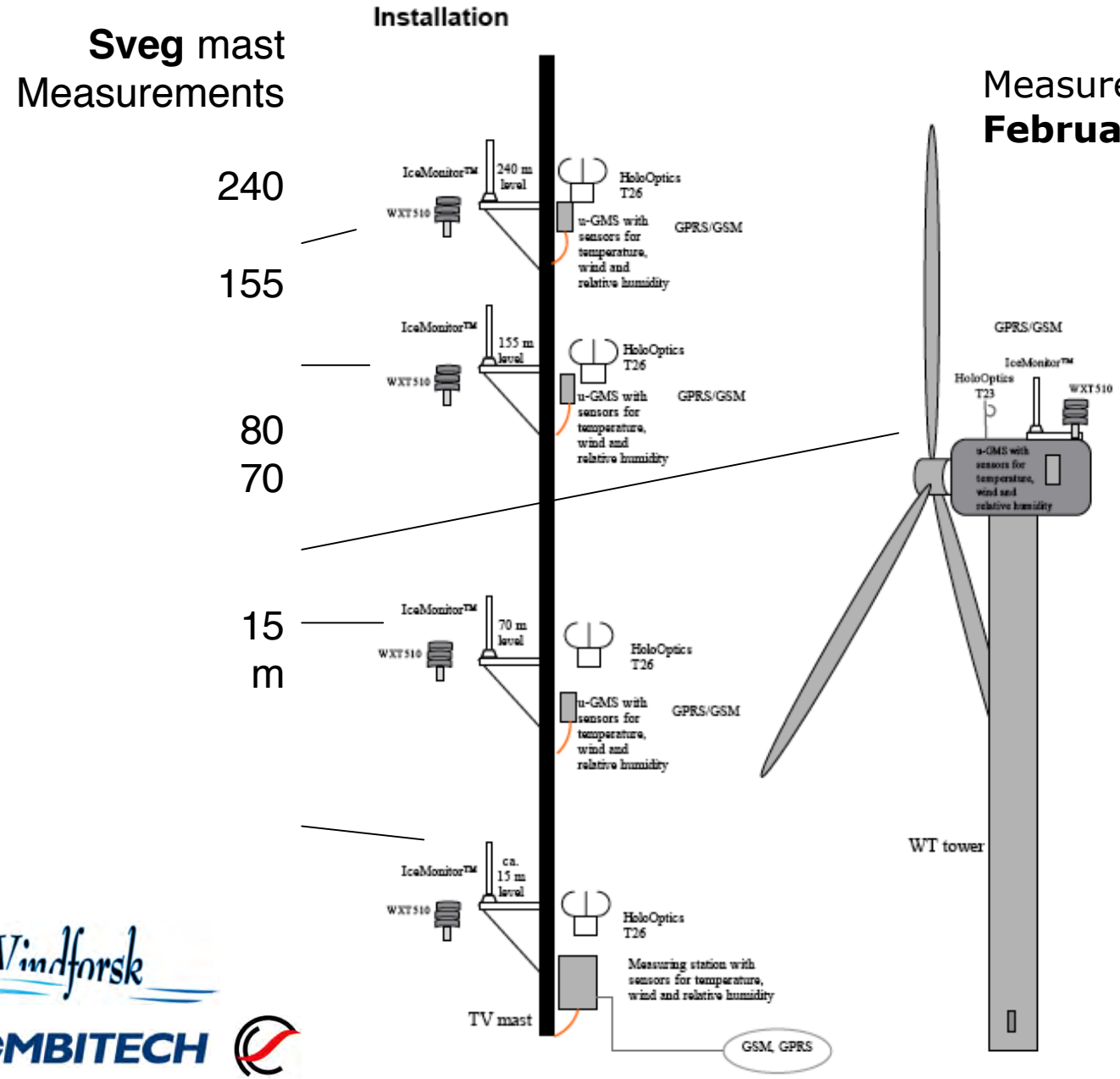
COMBITECH

VINDKOMPANIET

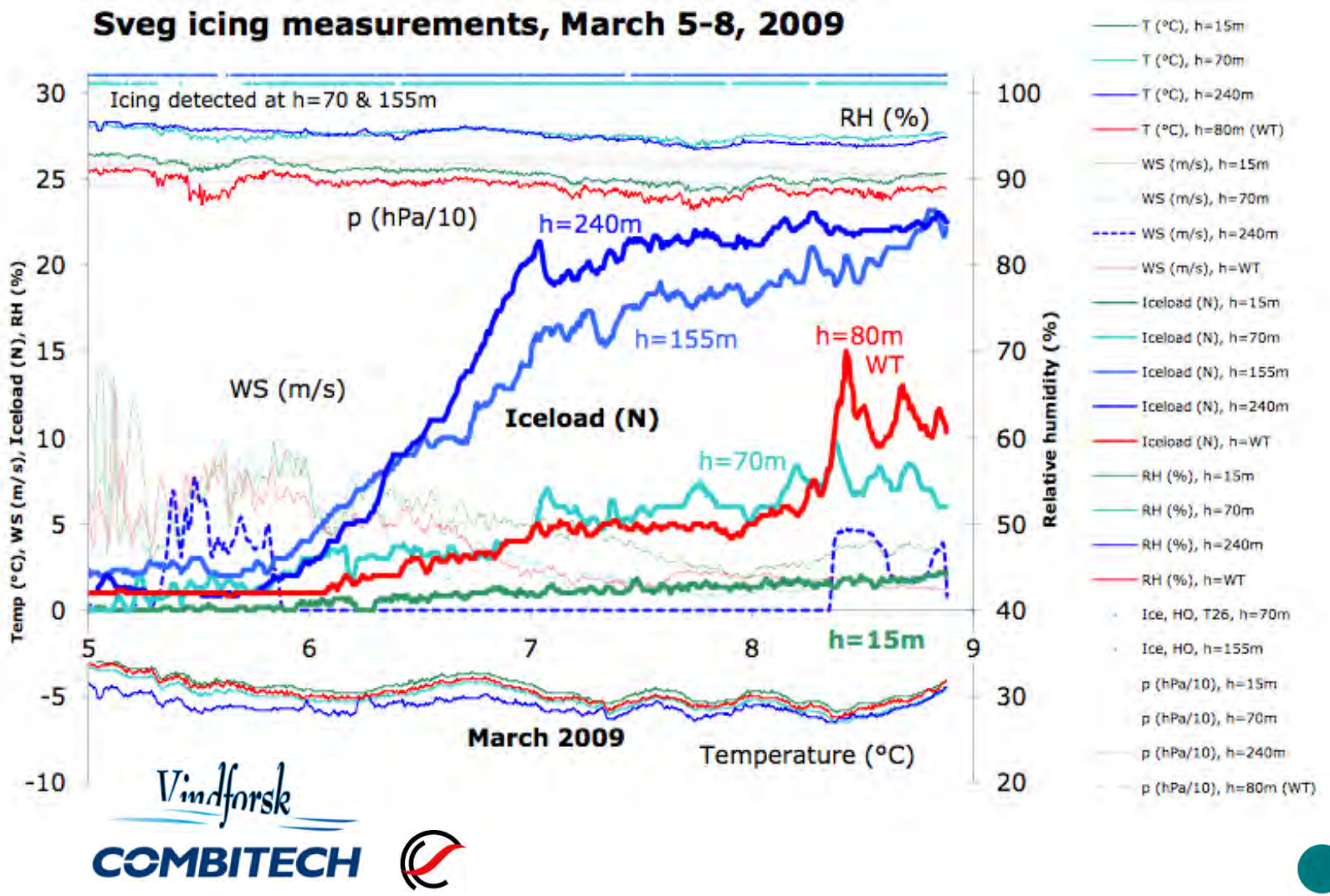
**WindREN AB**

# **Sveg** mast Measurements

Measurements started
**February 2008**

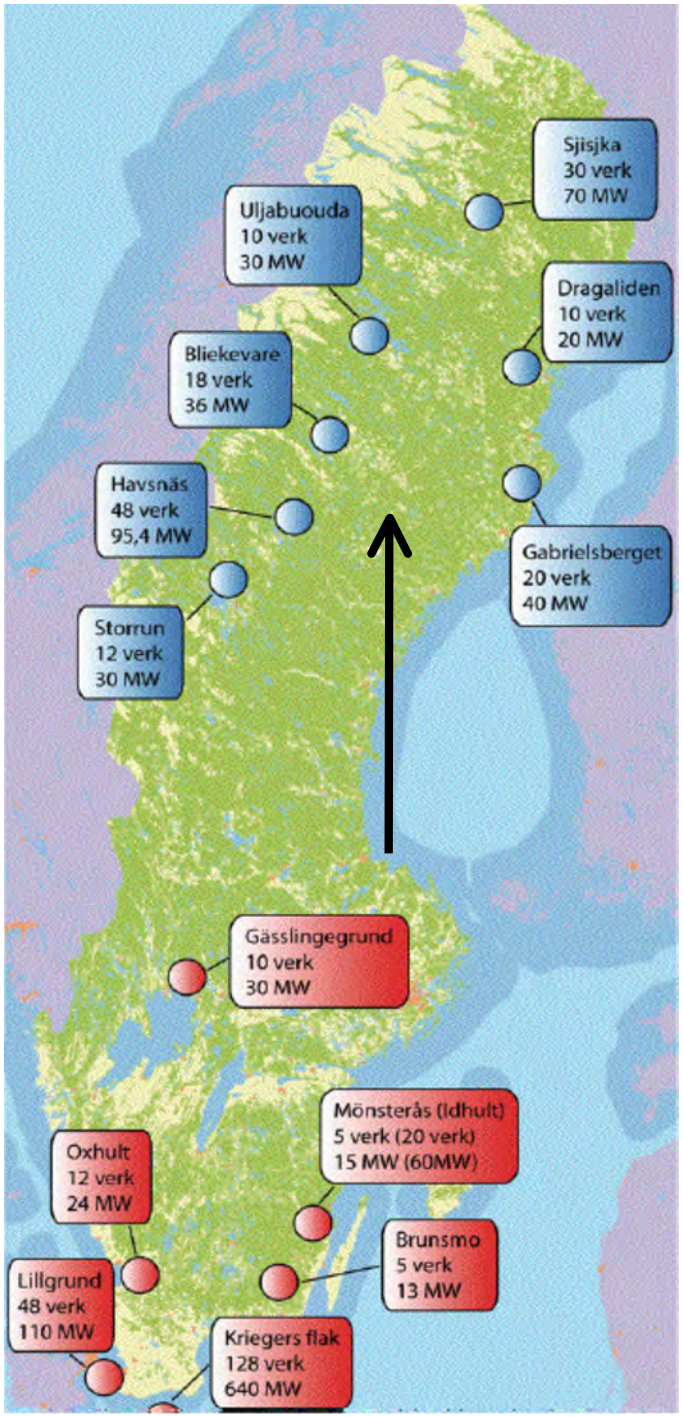


# Unique measurements of icing versus height



Wind pilot projects: 70 Meuro/10years

**From offshore to cold climate and forests**



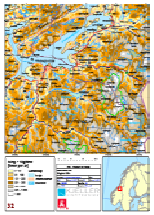
# Sweden, funding has been granted for the following cold climate projects [kSEK]

| | |
|---|---|
| Mapping of Icing, Uppsala University, 2009-2012 | 8 000 |
| Skellefteå Kraft - Anti-icing, 2007-2011 | 35 000 |
| o2 Vindkompaniet - icing meas., anti-icing, 2008-2012 | 72 500 |
| Svevind - 2 cold climate sites, investment subsidy, 2009- | 115 000 |
| Dong Energy - orography, coating and control, 2009- | 26 000 |
| Nordisk Vindkraft - Havsnäs, icing, foundation, 2009- | 20 000 |
| IEA Task 19 - Wind Energy in Cold Climates, 2009-2012 | 800 |
| VindREN - Wind/Reindeer, 2009-2011 | 3 310 |
| Swedish University of Agricultural Sciences, Reindeer | 2 332 |
| Wind in forests, Uppsala University, 2009-2012 | 10 000 |
| **Total: 29.3 MEuro, 27.7 MEuro excl. forest and reindeer** | **293 000** |

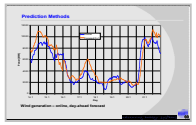
* not including work in kind, 1 Euro = 10 SEK

# IEA Task 19 targets 1-3

WindREN AB



**1. To collect information on ice mapping** and produce and verify ice maps for selected areas in order to ease and support the early phases of project development.
**Yes:** Uppsala Universities and SMHI's combined project and the Swedish Energy Agency's wind pilot projects.



**2. To collect information and experiences related to icing forecasts** with numerical weather models. This topic is expected to become more and more important as it also affects wind forecasts in cold climate regions.
**Yes:** Same as 1.

**3. Find new solutions** and thus improve the available methods for resource assessment and turbine operation at cold climate sites. **Power supply, sensor options and detection of ice** are focus areas.
**Yes:** IGUS, Insensys, CMS towards RMS-system, **SKF**

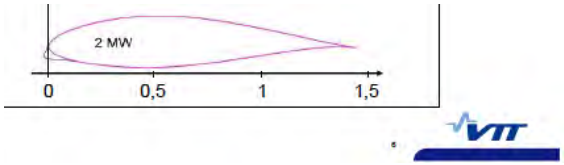
# IEA Task 19 targets 4-6

**4. Follow and collect** up to date information from the current state of **anti- and de-icing and coating solutions** that are already available on the market or currently being developed.
**Yes:** many different products under test.

CGC

**5. Review the current standards and recommendations** from the cold climate point of view and identify the possible needs for updates.
**Yes:** GL has been contacted. Work is on-going.

**6. Find and recommend improved methods to estimate the effects of ice on production** and thus reduce the amount of incorrect estimates and the risks that are involved in cold climate wind energy projects currently. Verify the method on the basis of data from national projects according to the possibilities.
**No:** We're currently lacking competence to follow up on the experience gained by Staffan Meijer.



# IEA Task 19 targets 7-10

WindREN AB

Forces & Dynamics

**7. Clarify the significance of extra loading** that ice and cold climate induce on wind turbine components and disseminate that result.
**Yes:** At least one of the wind pilot projects (o2 Vindkompaniet) contains work in this field.

**8. Initiate a market survey for cold climate wind technology**, including wind farms, remote grid systems and stand-alone systems.
**No:** The work has been ongoing without success since 2002. How to make MAKE and BTM interested in this market segment?

Ice throw

**9. Improve the understanding of the risks** and the mitigation strategies for the problem of **ice throw** from wind turbines at cold climate sites.
**Yes:** A group, coordinated of government agency representatives are working on a common statement

Reports, dissemi-nation

**10. Update state-of-the-art report and update the expert group study** on applying wind energy in cold climates to guidelines.
**Yes:** These tasks are planned to be carried out.

**Jun 2010**

UPPSALA UNIVERSITET

# Modelling of Atmospheric Icing

*An Introduction essay*

Petra Thorsson

Vindforsk

# Measuring routines of ice accretion for Wind Turbine applications

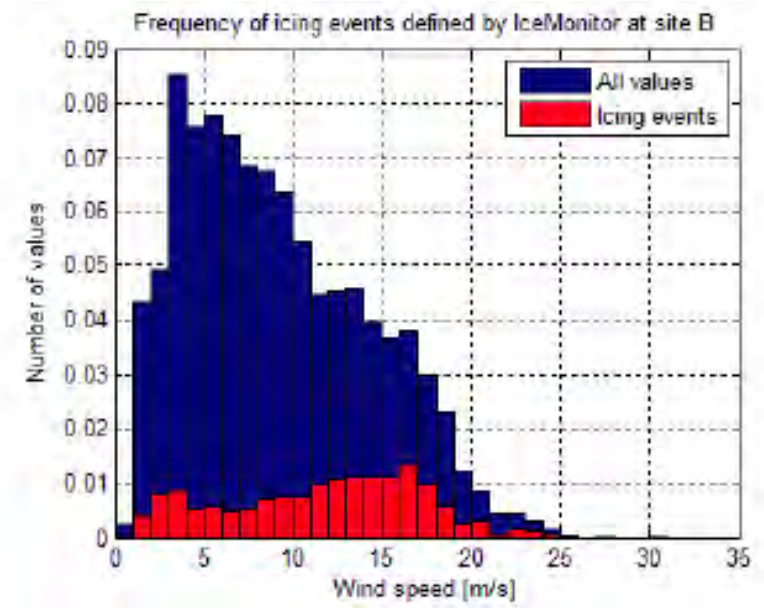
## The correlation of production losses and detection of ice

Viktor Carlsson

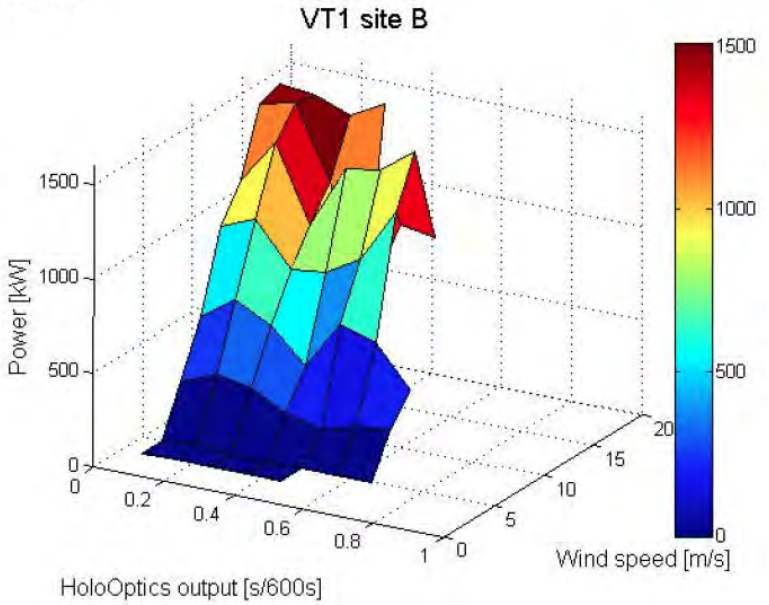
**Viktor Carlsson**
Ht 2009
Examensarbete, 30 hp
Civilingenjörsprogrammet inom Teknisk Fysik, 180 hp

SKELLEFTEÅ kraft

**Sep 2010**




**H.2 Site B**



**Master thesis:** Evaluation of statistical analysis methods for the detection of partial icing of anemometers

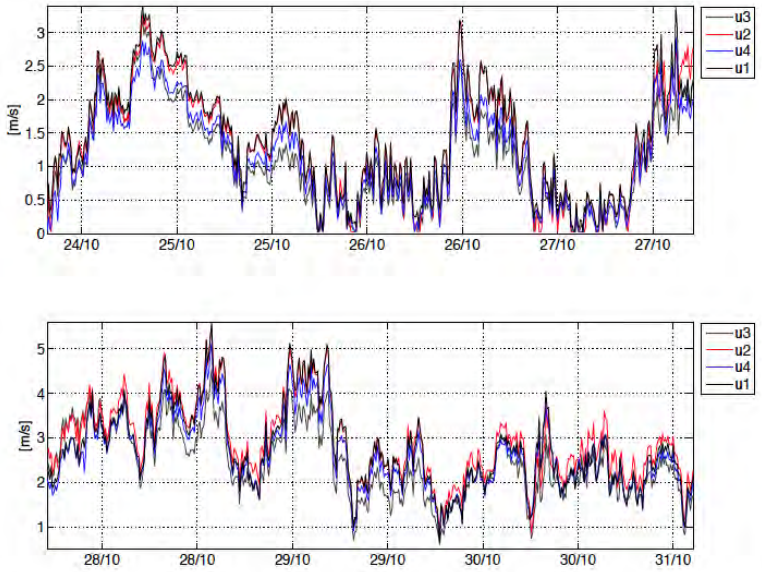
Clear ice in turbulent conditions - risk of overestimating the wind speed
Soft ice - risk of underestimating the wind resource

Examensarbete vid Institutionen för geovetenskaper
ISSN 1650-6553 Nr 209

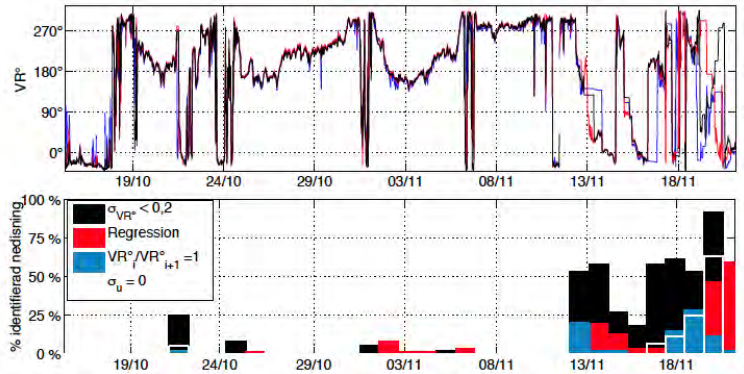
Utvärdering av statistiska analysmetoder för detektion av partiell nedisning av anemometrar

Irene Helmersson

## Jan 2011




Figur 11. Tidsserie av medelvindhastighet indelat i två tidsperioder. U1, svart, är den omodifierade anemometern och jämförs här med de tre modifierade, u2, u3 och u4.




Figur 16. Vindhastighet, temperatur och vindriktningsförhållanden under mätperioden. Nedre bilden visar procentandel detekterad is på 10 timmarsperiod och i olika steg i algoritmer

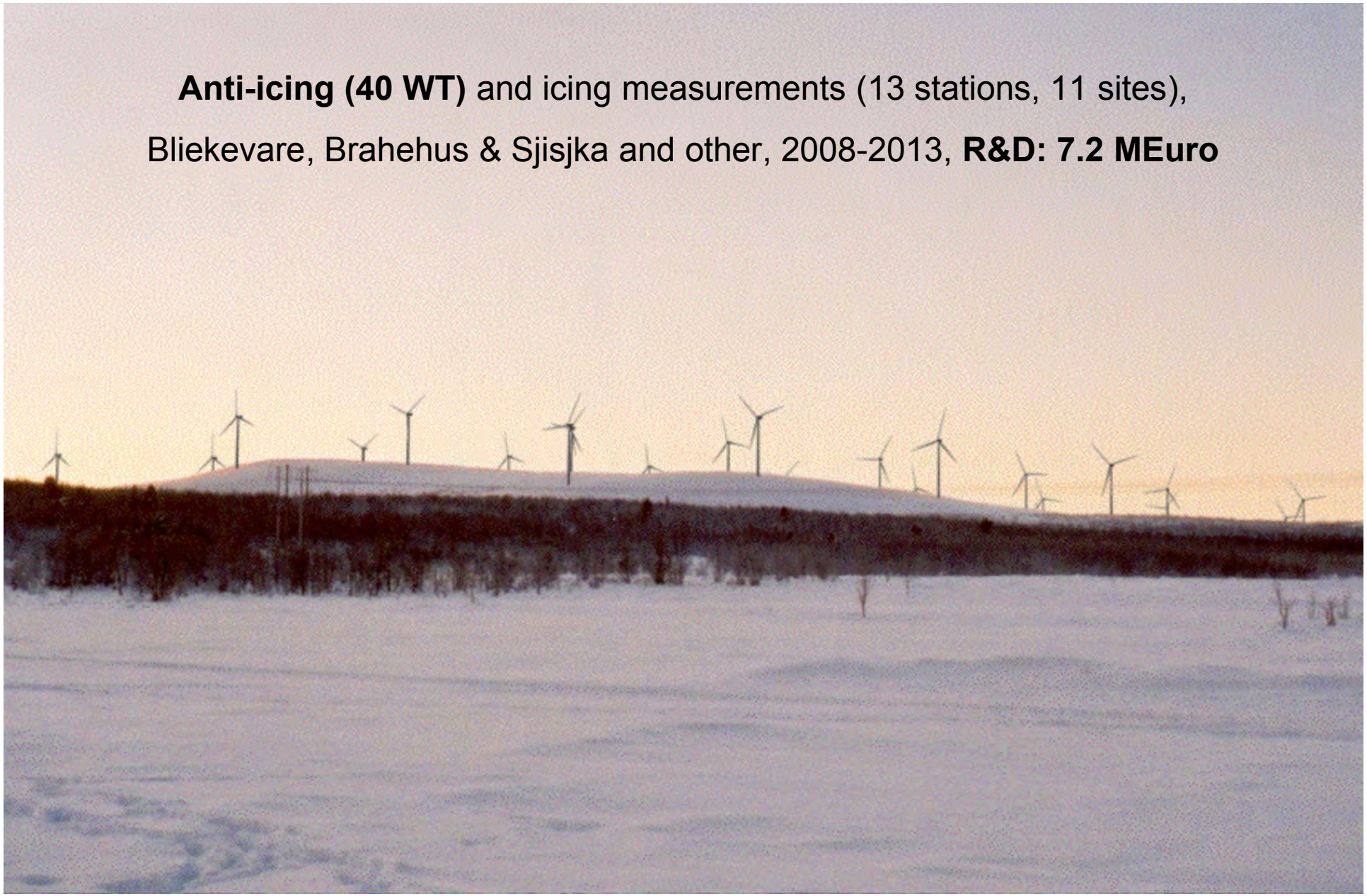
Triventus

# De-/anti-icing systems

1. Black blades - Not sufficient in low solar radiation conditions
2. WindWind/Skellefteå Kraft - A developed JE-system, same as previously used on some 20 Bonus turbines (225 kW-1 MW)? Carbon fibre layer beneath the gelcoat.
3. Enercon/Svevind - Hot air based de-icing system. Official list price: 20 kEuro for 3 fans (20 kW). Will test de-icing during operation at Dragaliden and Silkomhöjden.
4. Nordex/LM/Dong Energy - Hydrophobic coatings and control system development to avoid ice build up.
5. EcoTEMP/o2VK/Vestas/Siemens - Foil based anti-icing system
6. Kelly/o2VK/Vestas - Foil based anti-icing system
7. Goodrich - Foil based anti-icing system, yet to be deployed?

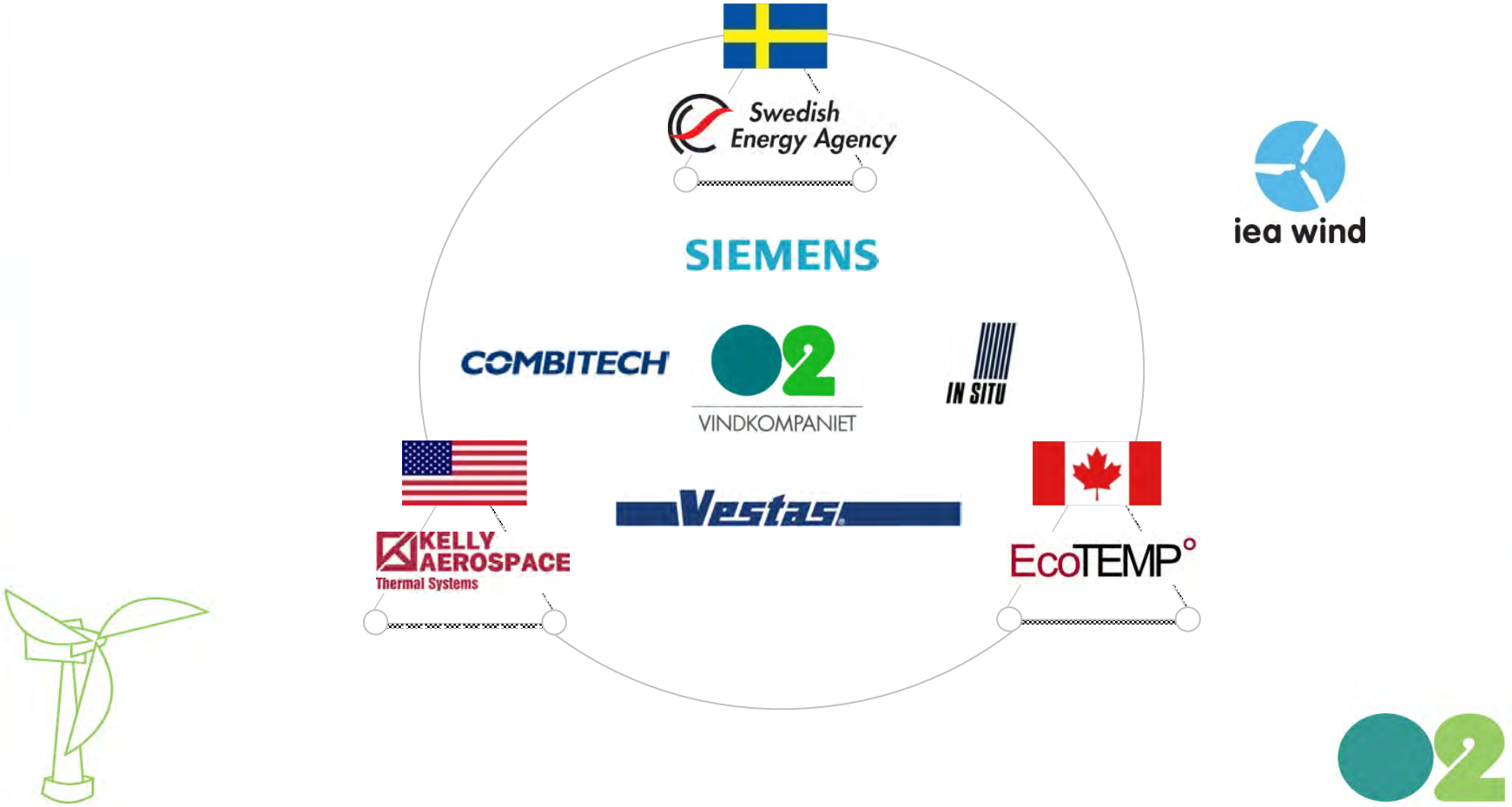
**Anti-icing (40 WT)** and icing measurements (13 stations, 11 sites),

Bliekevare, Brahehus & Sjisjka and other, 2008-2013, **R&D: 7.2 MEuro**



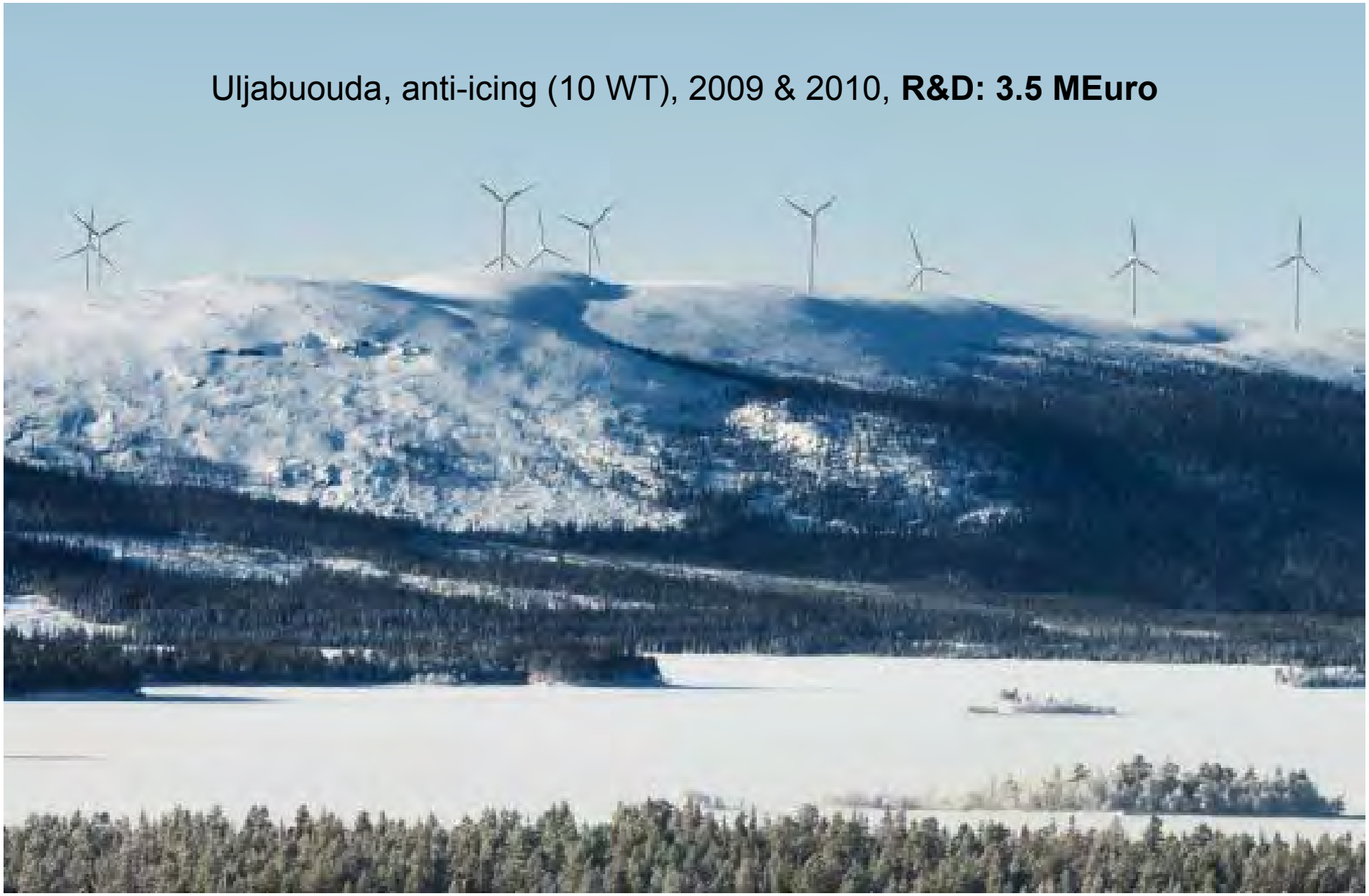
VINDKOMPANIET SIEMENS Vestas KELLY AEROSPACE Thermal Systems EcoTEMP COMBITECH IN SITU ...

# International support for o2 Vindkompaniet's wind pilot project



# Exchanging blades - de-icing systems installed on Bliekevare

Uljabuouda, anti-icing (10 WT), 2009 & 2010, **R&D: 3.5 MEuro**



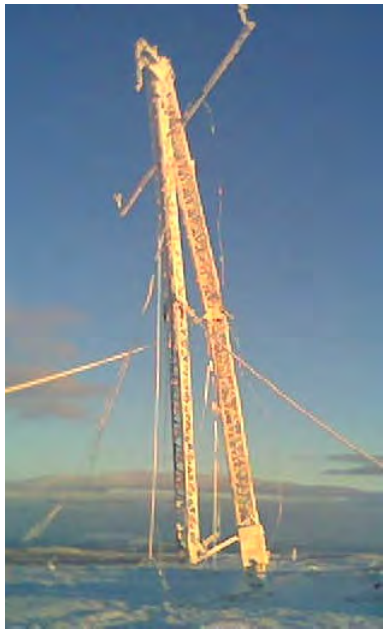
# Anti-icing experiences from Uljabuouda

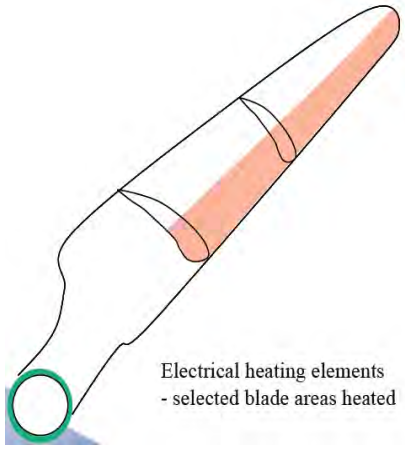
Description:

• Situated in the Lapland Sweden at a low mountain about 780 meters above sea level.

• Consists of 4, installed 2009 (6 to be installed 2010), 3 MW wind turbines with anti-icing system installed.

• Severe icing conditions at the site, several met mast failures due to high ice loads.

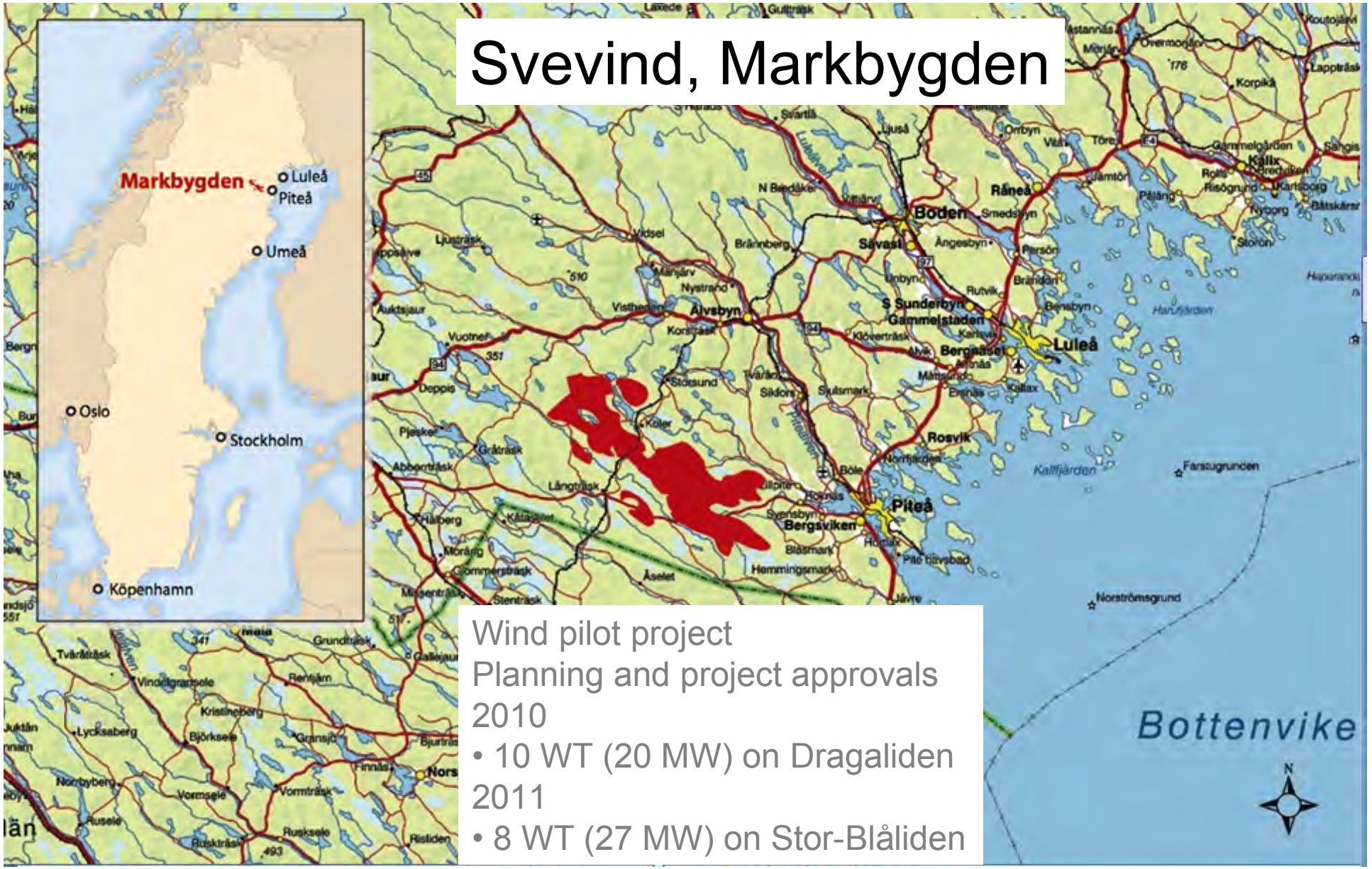





The anti-icing equipment consists of coal-fibre heating elements at the leading edge of the blade.


Svevind, Markbygden,
Aim: 1101 Enercon turbines, 8-12 TWh
**Investment subsidy and R&D: 11.5 MEuro**

# Svevind, Markbygden




Wind pilot project
Planning and project approvals
2010
- 10 WT (20 MW) on Dragaliden

2011
- 8 WT (27 MW) on Stor-Blåliden

SVEVIND powered by nature

ENERCON ENERGY FOR THE WORLD

# Storrun-Icing of WT 2009-, **R&D: 2.6 MEuro**

- Background
  - Significant icing conditions expected at Storrun
  - Causes reduction of production, increased loads and raises safety issues
  - DONG Energy is involved in R&D project in Norway
- Project description
  - Establish base line – Determine extent of icing problems
  - Calculate and validate estimates of production loss
  - Optimisation of start-stop algorithms
  - Testing of anti-icing coating
  - Model loads on structures
- Results
  - Improved adjustment for icing losses in production estimates
  - Reduced production loss due to start-stop hysteresis
  - Practical use of results from basic research
- Partners:
  - LM Glasfiber
  - Nordex
  - Possible coordination to other projects e.g. Uljabuouda and Narvik

DONG energy

NORDEX We've got the power.

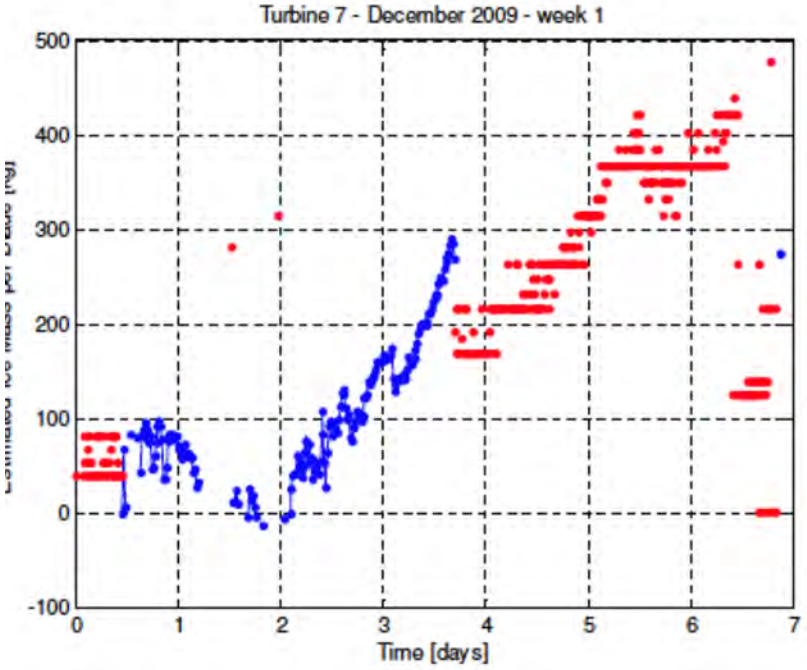
LM

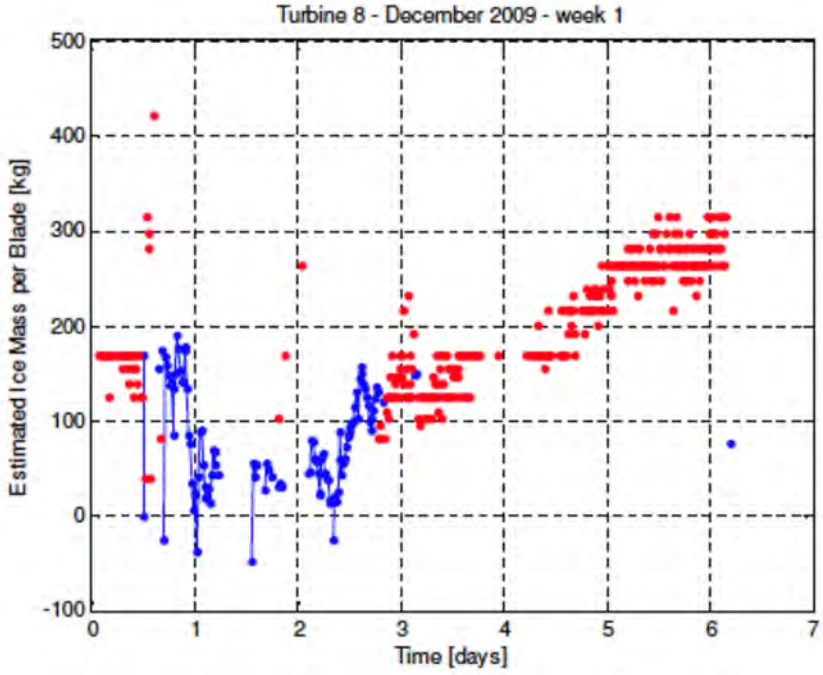
## Preliminary results

# Stor-Run

Ice loads on blades measured by means of frequency analysis

- Significant periods of icing since end October
- Min. 5-10% total production loss – this year!




DONG energy


Havsnäs, 45 * 2 + 3 * 1.8 = 95.4 MW, **R&D: 2 MEuro**

Havsnäs is Sweden’s largest onshore windfarm – no official experience of icing yet

# Driftuppföljning vindkraft

Hem

Översikt

**Tabeller**
Storlek
Nummer
Produktion 1
Produktion 2

Historia dag-1
Historia dag-2
Historia dag-3

Månad

Alla månader

## Alla verk, sorterade i nummerordning

## Avläst 2010-10-10

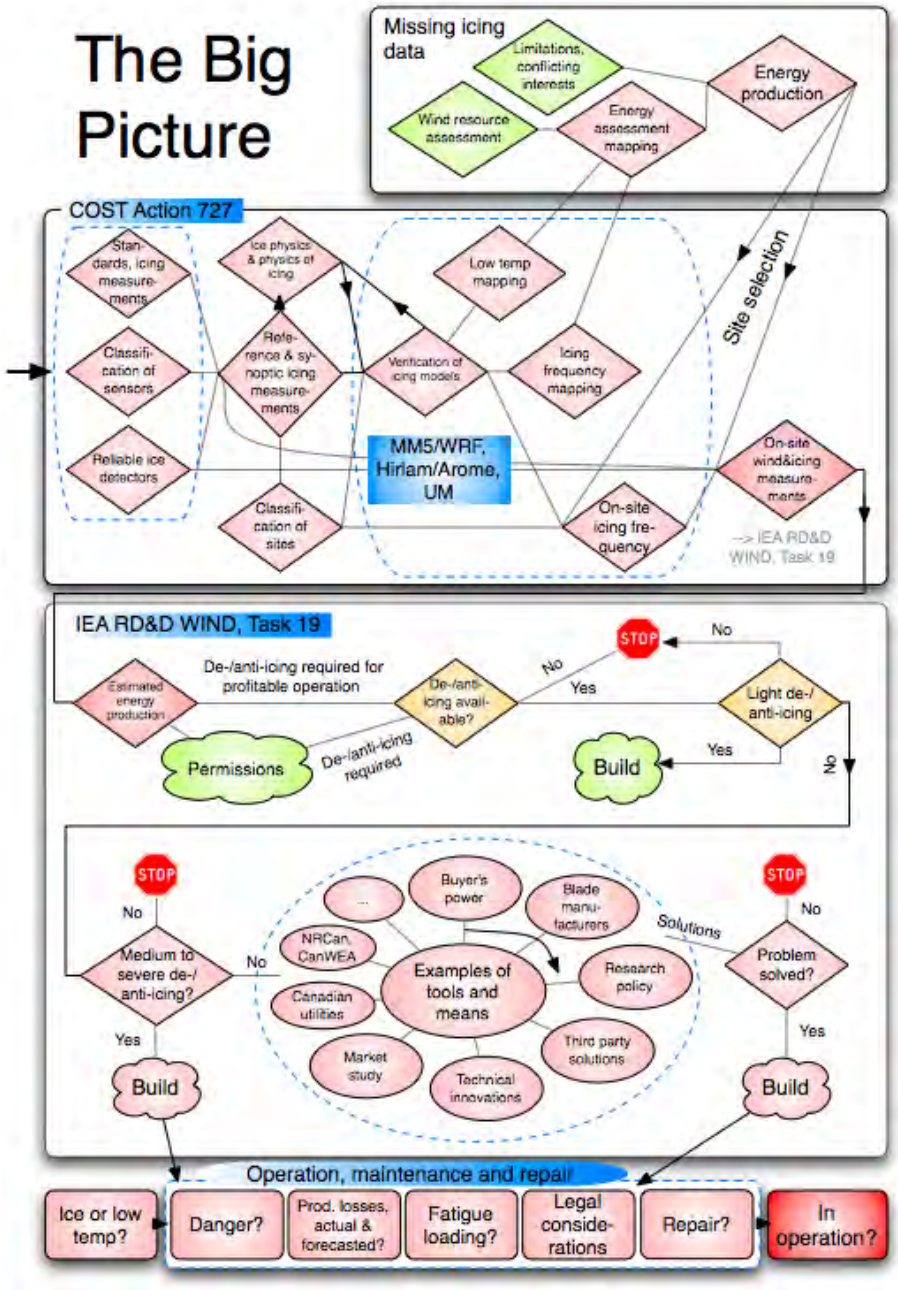
Förklaringar

| Storlek | Typ | Namn | Nr | Status | Effekt | Vind | Temp | Prod | Prod |
|---|---|---|---|---|---|---|---|---|---|
| 2000 | Enercon | Skarstad | 1260 | - | 0 | 1,1 | | 19 | 1414 |
| 2000 | Enercon | Stockebäck | 1261 | - | 0 | 1,9 | | 15 | 1071 |
| 2000 | Vestas | Havsnäs D1 | 1262 | - | 2000 | 13,5 | 7 | 23 | 19410 |
| 2000 | Vestas | Havsnäs D2 | 1263 | - | 2000 | 12,8 | 7 | 23 | 18801 |
| 2000 | Vestas | Havsnäs D3 | 1264 | - | 2000 | 13,1 | 7 | 23 | 17451 |
| 2000 | Vestas | Havsnäs D4 | 1265 | - | 2000 | 13,7 | 7 | 23 | 16293 |
| 2000 | Vestas | Havsnäs D5 | 1266 | - | 2000 | 13,4 | 7 | 24 | 17298 |
| 2000 | Vestas | Havsnäs D6 | 1267 | - | 2000 | 13,2 | 7 | 23 | 19460 |
| 2000 | Vestas | Havsnäs D7 | 1268 | - | 2000 | 15,6 | 5 | 24 | 21619 |
| 2000 | Vestas | Havsnäs D8 | 1269 | - | 2000 | 15,2 | 7 | 24 | 19858 |

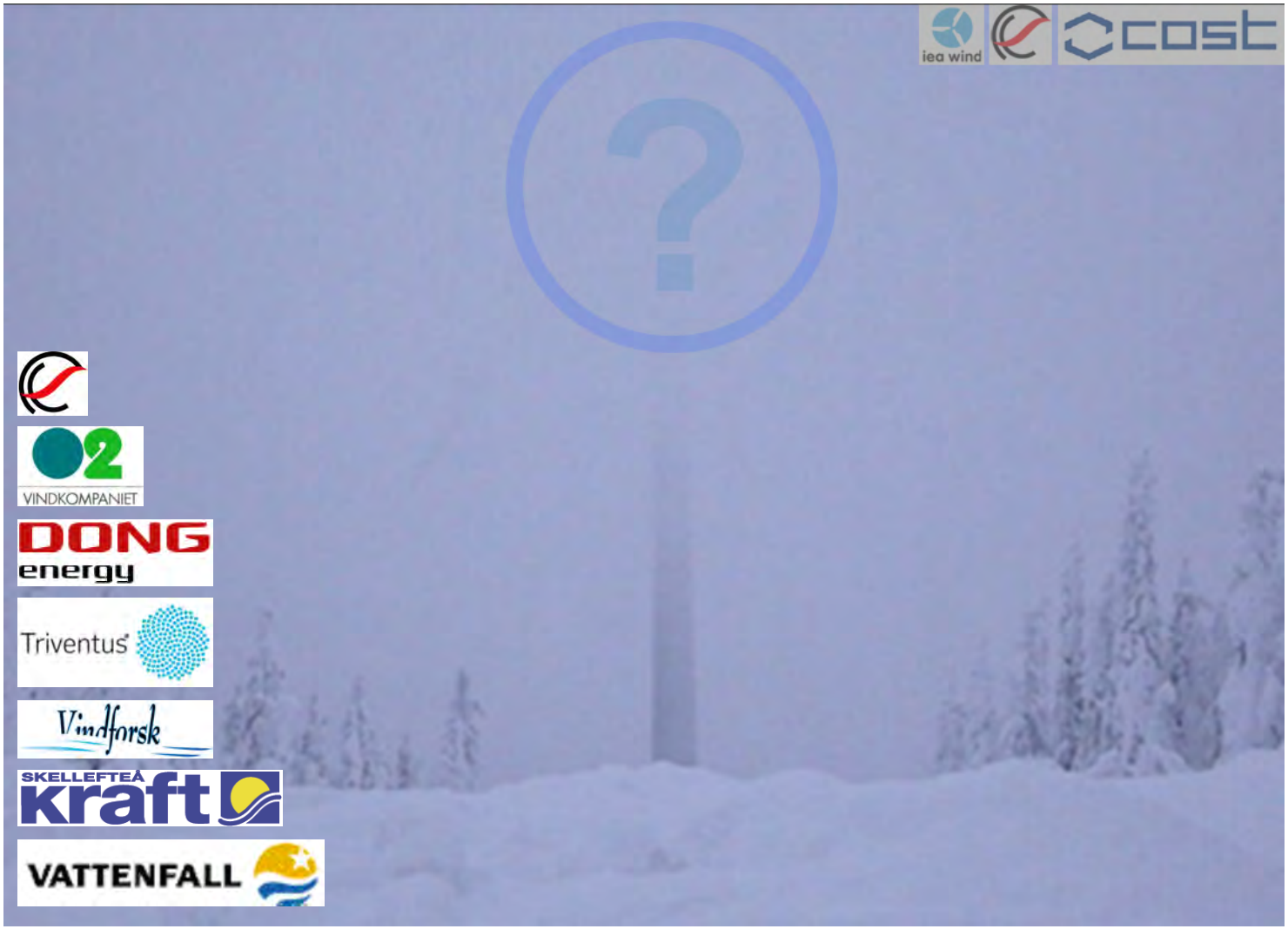
Production losses due to icing will soon be known

## Conclusions with respect to icing

- **We've really got started!**
- Items in red need attention
- Relevant icing measurements at relevant heights for model verification of wind turbine specific icing do not yet exist
- Site specific modelling verification studies needed - to be followed by regional icing studies at 1 km resolution
- Detailed national mapping of icing is not yet a meaningful task
- Commercial de-/anti-icing systems not yet available for medium and severe icing conditions
- **O&M issues to be looked into**



# Thanks to the sponsors of IEA RD&D Wind, Task 19!



# Samme hus ramt af fire biler


Benn Torkild Pedersen foran et af hullerne i muren på familiens staldbygning, der er blevet ramt af biler fire gange på 14 timer.

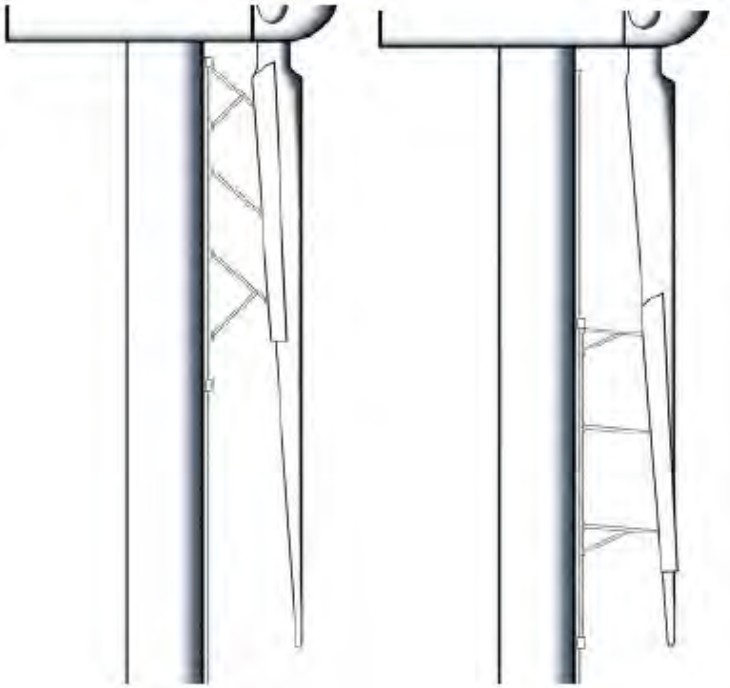
http://www.berlingske.dk/vejret/samme-hus-ramt-af-fire-biler

# New de-icing system for rotorblades on Wind Power turbines

Inventor: Fredrik Öhrvall
Version: 2
Date: 2010-09-21

New ideas for de-icing:

Fredrik Öhrvall



# Pulse Wave Technology

## Electric Impulse De-Icing and Cleaning System


## PWT Impulse Ltd.™

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