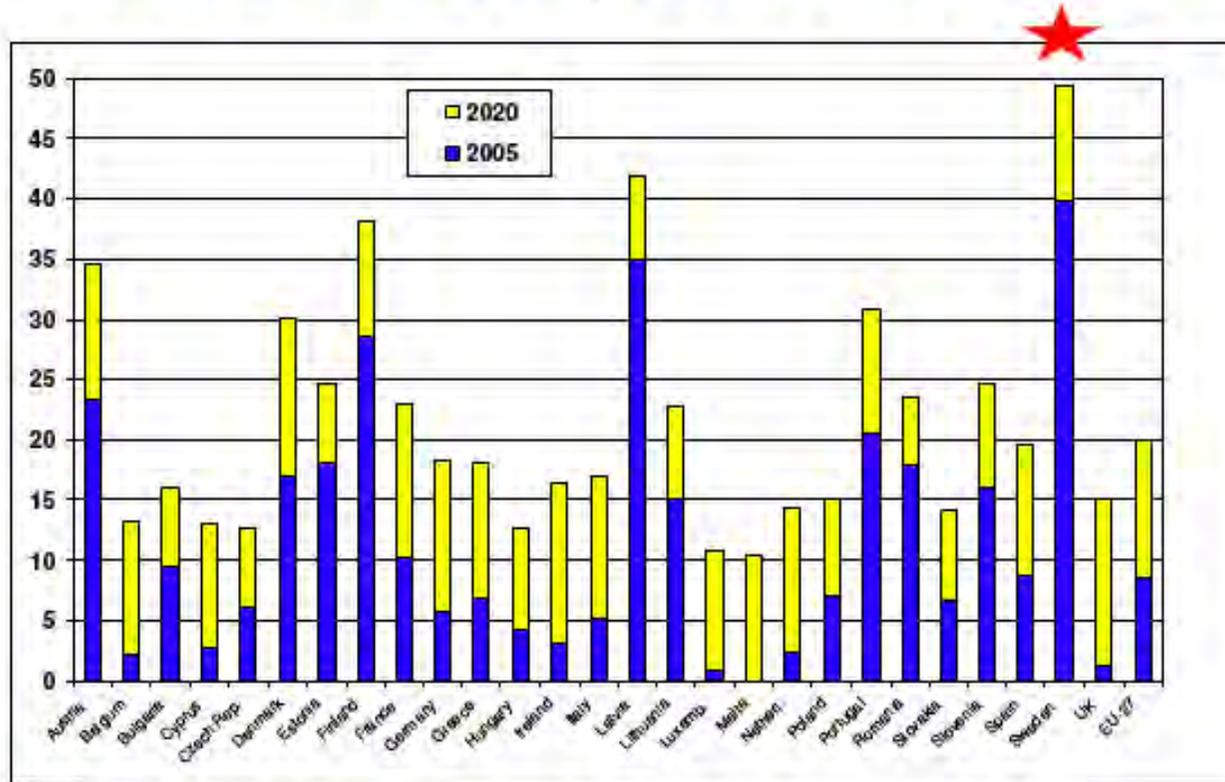


IEA Task 19 national overview - Swedish activities
in measurements and mapping of icing
and de-icing of wind turbines
Göran Ronsten, WindREN

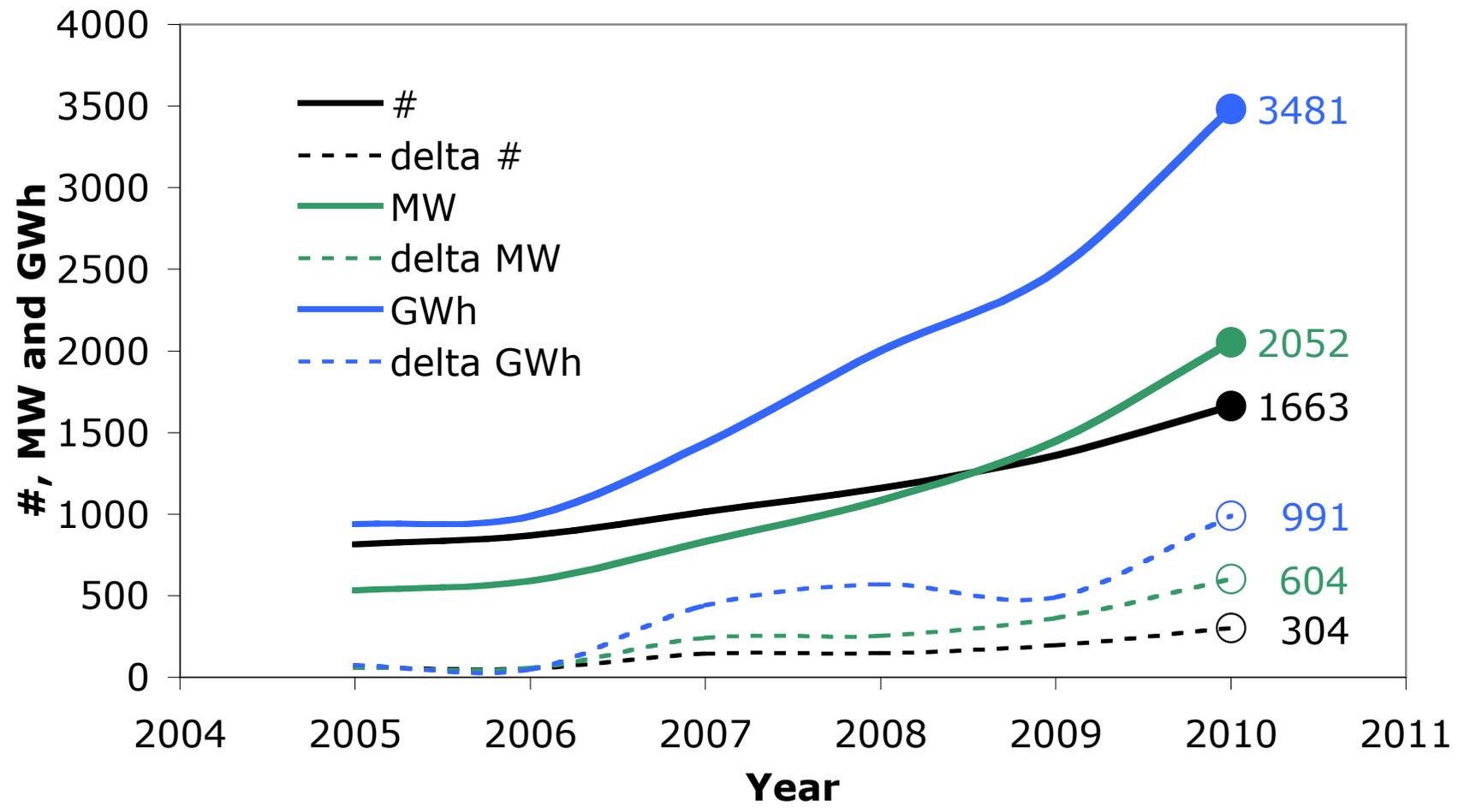
Why bother? Binding targets to be achieved by 2020

Shares of RE, 2005 and 2020



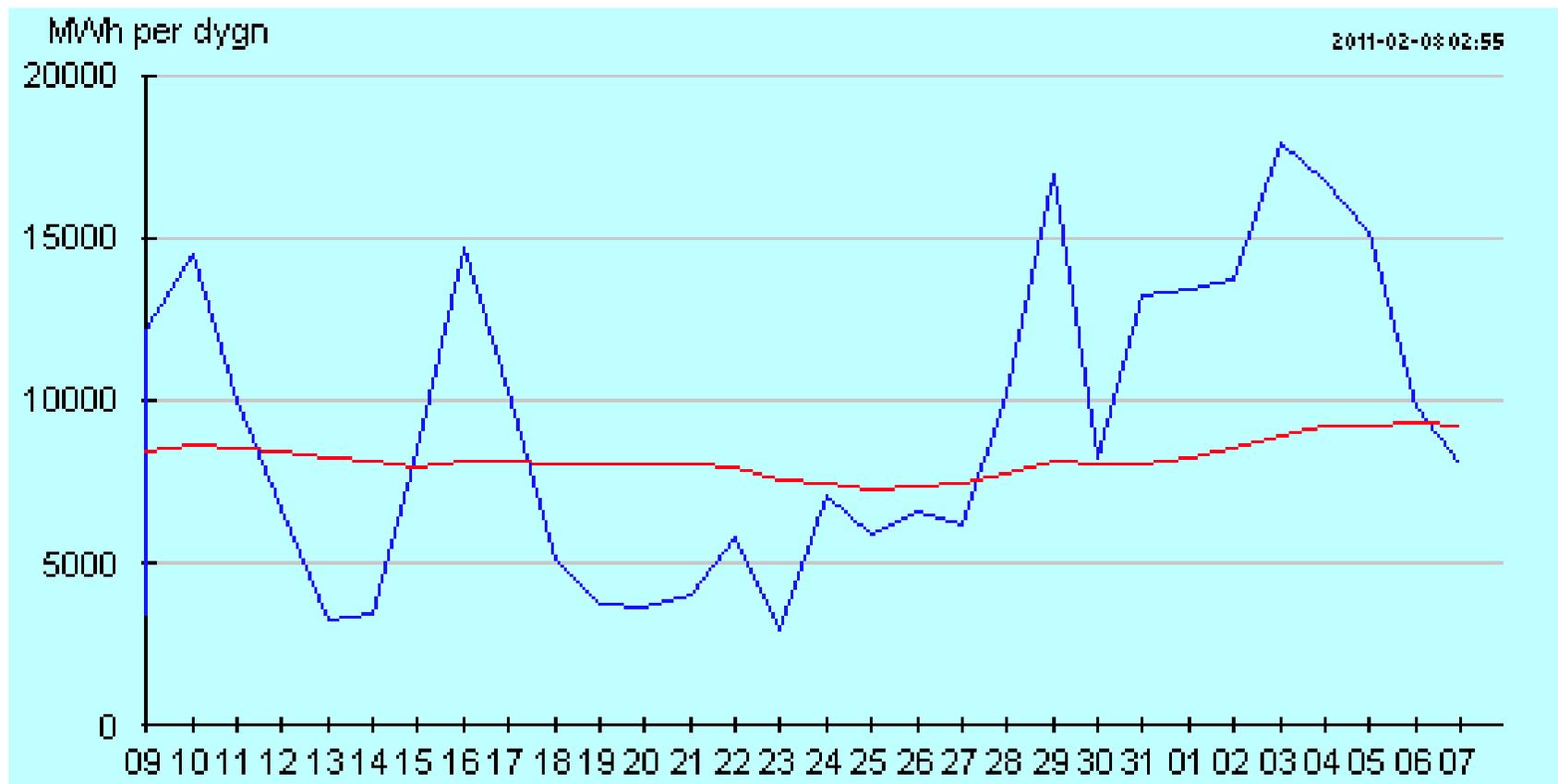


Sweden: # of WT, MW and GWh



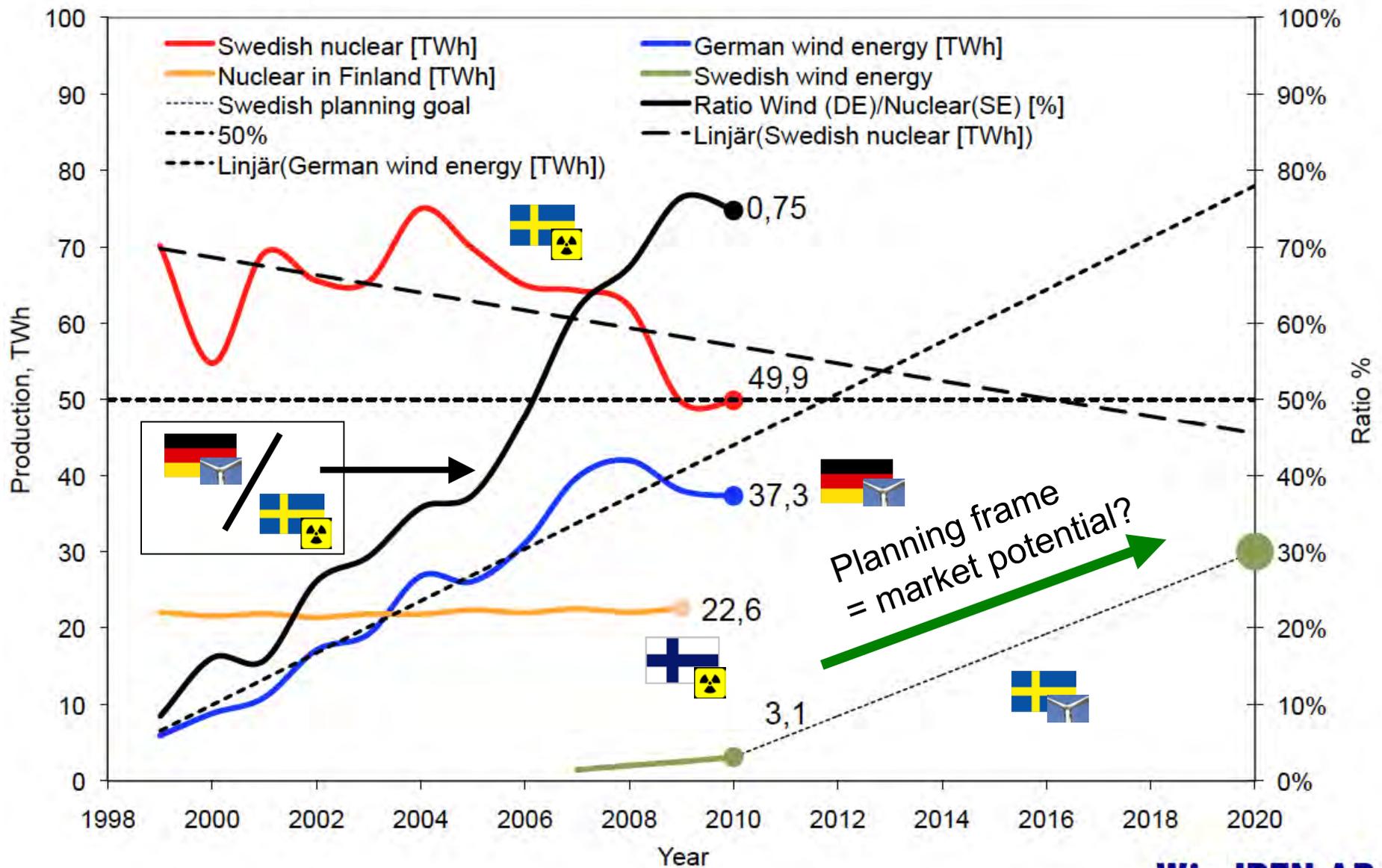
Daily WE production and a 30 day daily running average

<http://www.vindstat.nu/>



Planning frame for wind energy in Sweden until 2020

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



Planning frame
= market potential?

Vindkraftprojekt > 10 MW i Sverige, januari 2011

● Under byggnad

● I drift

- 4. Gabrielsberget, 40 verk, 92 MW
- 32. Ölgårberget, 5 verk, 11,5 MW
- 33. Töftedalsfjället, 11 verk, 25 MW
- 34. Östra Herrestad, 9 verk, 18 MW
- 36. Brahehus, 9 verk, 18 MW
- 37. Töftedalsfjället, 11 verk, 25 MW
- 39. Tavelberget, 5 verk, 10 MW
- 40. Fröslida (Hylte), 6 verk, 15 MW
- 42. Vettåsen/Finnbergen, 10 verk, 23 MW
- 46. Granberg, 5 verk, 10 MW
- 48. Hedbodberget 2, 6 verk, 12 MW
- 49. Jokkmokksliden, 10 verk, 25 MW
- 50. Stengårdsholma, 10 verk, 25 MW
- 51. Storliden, 8 verk, 20 MW
- 52. Korpfjället, 9 verk, 22,5 MW
- 53. Ryd/Ronnerum, 5 verk, 10 MW

- 1. Uljabuouda, 10 verk, 30 MW
- 2. Dragsfiken, 12 verk, 24 MW
- 3. Storsjö, 44 verk, 88 MW
- 5. Hönö Vindpark, 11 verk, 22 MW
- 7. Storm, 12 verk, 30 MW
- 8. Haysnäs, 48 verk, 96,4 MW
- 9. Hedbodberget 1, 5 verk, 10 MW
- 10. Säliträddberget, 8 verk, 16 MW
- 11. Fjällberget/Saxberget, 17 verk, 34 MW
- 12. Gäslingegrund, 10 verk, 30 MW
- 13. Brattön, 10 verk, 25 MW
- 14. Oxhult, 12 verk, 24 MW
- 15. Lillgrund, 48 verk, 110 MW
- 16. Hud/Kil, 10 verk, 23 MW
- 17. Stentjämnåsen, 5 verk, 10 MW
- 19. Röbergsfjället, 8 verk, 16 MW
- 20. Håcksta, 5 verk, 10 MW
- 21. Hornberget, 5 verk, 10 MW
- 22. Silkomhöjden, 6 verk, 12 MW
- 23. Sotared, 5 verk, 10 MW
- 24. Högberget, 5 verk, 10 MW
- 25. Råbøl, 5 verk, 10 MW
- 27. Utgrunden 1, 7 verk, 10 MW
- 28. Yttre Stengrund, 5 verk, 10 MW
- 29. Klinte vindpark, 5 verk, 10 MW
- 31. Lundabukten, 16 verk, 16 MW
- 34. Stora Istad, 5 verk, 10 MW
- 35. Granberget, 6 verk, 12 MW
- 38. Kyrkberget, 10 verk, 23 MW
- 41. Källeberg, 5 verk, 10 MW
- 43. Gärdslösa, 5 verk, 12 MW
- 44. Lövstaviken, 5 verk, 11,5 MW

720 MW = 65%

391 MW = 36%

Under byggnad
Totalt på land
202 vindkraftverk,
444,5 MW, 1,273 TWh
Inga till havs.

I drift
Totalt på land
315 vindkraftverk,
656,8 MW, 1,331 TWh
Totalt till havs
80 vindkraftverk,
130 MW, 0,398TWh



Svensk Vindenergi

Vindkraftprojekt > 10 MW i Sverige, januari 2011

● Med alla tillstånd/godkänd anmälan

● Tillstånd för park, ej för vatten- och elanslutning

- 1. Storgrundet, 53 verk, 265 MW
- 2. Hedbodberget 2, 6 verk, 12 MW
- 3. Hakarp, 8 verk, 16 MW
- 4. Mönsterås, 4 verk, 8 MW
- 6. Mässingberget, 10 verk, 25 MW
- 7. Dingle-Skogen, 6 verk, 15 MW
- 8. Årjärg NV, 9 verk, 21,2 MW
- 9. Orsa Finnmark, 8 verk, 20 MW
- 10. Tolvmanstegen, 24 verk, 48 MW
- 11. Stora Middelgrund, 108 verk, 540 MW
- 12. Kriegers flak, 128 verk, 640 MW
- 13. Trolleboda, 30 verk, 150 MW
- 14. Utgrunden II, 20 verk, 90 MW
- 15. Knäred, 10 verk, 20 MW

- 16. Högjärnsklack, 7 verk, 14 MW
- 17. Korpfjället 2, 8 verk, 16 MW
- 18. Sundbyholm, 10 verk, 20 MW
- 19. Marsboke, 5 verk, 10 MW
- 22. Fällöberget, 10 verk, 25 MW
- 23. Brattön 2, 4 verk, 10 MW
- 24. Stor-Blåiden, 8 verk, 31 MW
- 25. Raftsjöhöjden, 10 verk, 25 MW
- 26. Stamåsen, 50 verk, 115 MW
- 27. Verkanliden, 8 verk, 24 MW
- 28. Ås, 6 verk, 15 MW
- 29. Stor Kvilla, 4 verk, 10 MW
- 30. Råbøl, 5 verk, 10 MW

Permissions granted (# excl. offshore)

735 MW
76%

Totalt på land
404 vindkraftverk, 970,2 MW

Totalt till havs
339 vindkraftverk, 1 685 MW
(Nummer 1, 11,12,13,14)

226 MW
24%

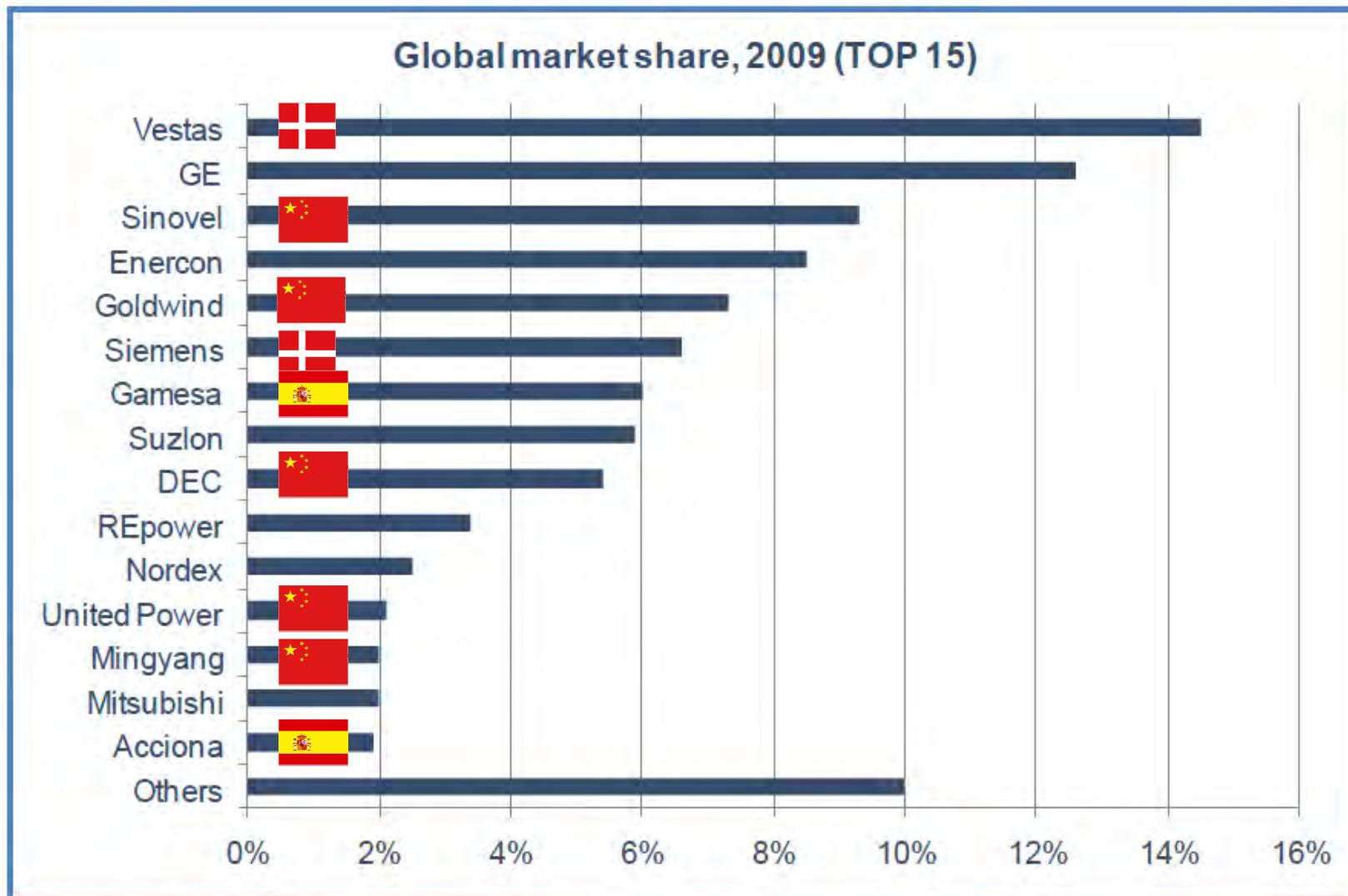
Svensk Vindenergi

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



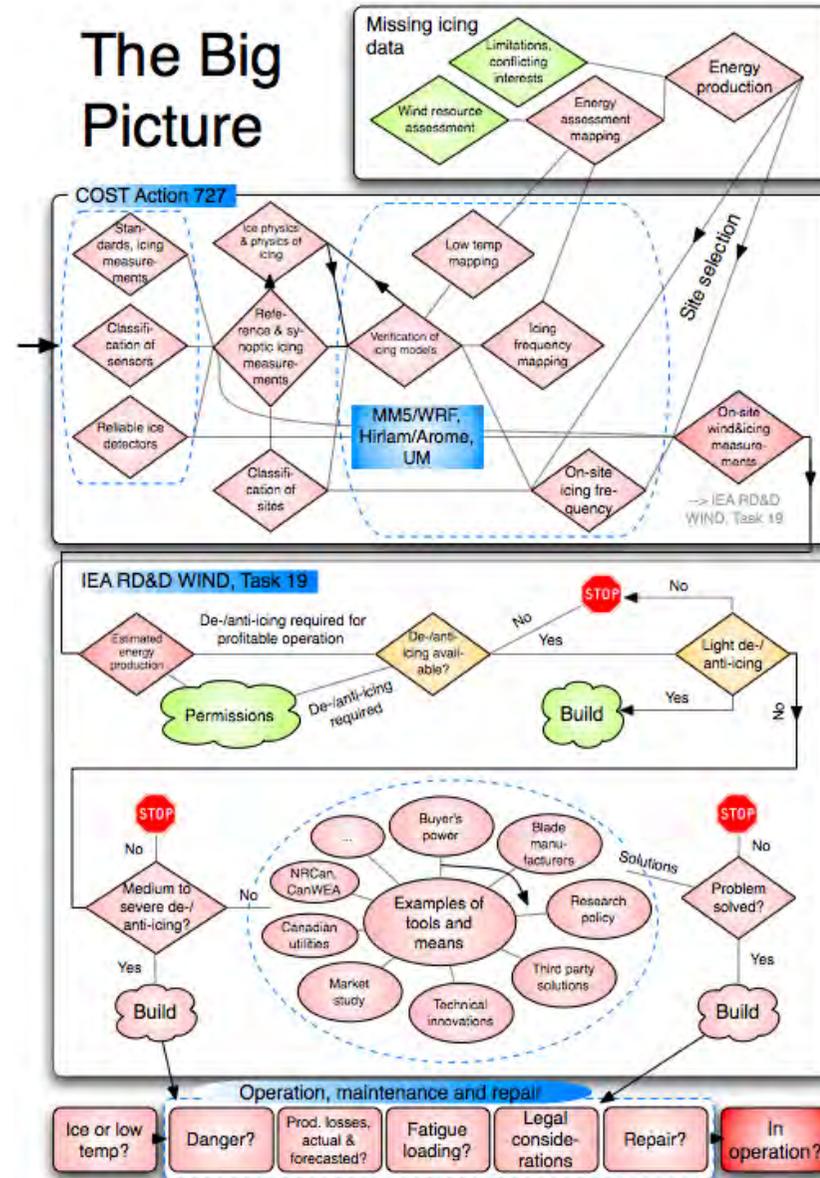
Denmark, China & Spain are not involved in IEA Task 19

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 :- (




The collage consists of four overlapping report covers from MAKE Consulting, all of which are crossed out with a large black 'X'. The reports are:

- Business Study** (October 2002): Cover features a wind turbine in a snowy landscape.
- International Wind Energy Development** (March 2009): Cover features a wind turbine in a snowy landscape.
- International Wind Energy Development** (March 2010): Cover features a wind turbine in a snowy landscape.
- Offshore Report 2010** (November 2010): Cover features a large offshore wind turbine in the ocean.

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

Interest org.

VINDMØLLEINDUSTRIEN
www.windpower.org

Canadian Wind Energy Association
Association Canadienne de l'Énergie Éolienne

EWEA
THE EUROPEAN WIND ENERGY ASSOCIATION

vindkraft
FORENINGEN

Swedish Wind Energy

Wind farm dev.

arise WINDPOWER

Triventus

VINDKOMPANIET

VATTENFALL

Kraft

Stena Adactum

Fred. Olsen Energy ASA

SVEVIND
powered by nature

Statkraft

DONG energy

MAKE CONSULTING

EcoTEMP

KELLY AEROSPACE
Thermal Solutions

BTM Consult

MW Innovation

COMBITECH

Manufacturers

SKF

SIEMENS

Vestas

ABB

GE

ENERCON
ENERGY FOR THE WORLD

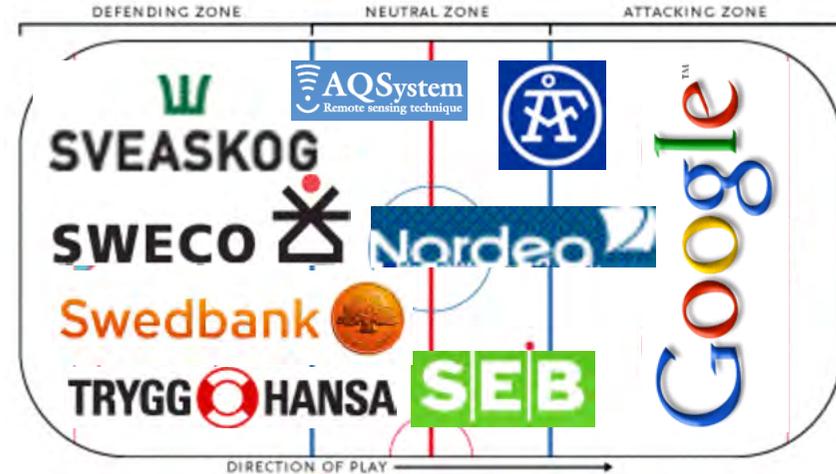
LM

NORDEX
We've got the power

Gamesa

REpower Systems

SUZLON



Research & Education

YKI

ELFORSK
ELFÖRETAGENS FORSKNINGS- OCH UTVECKLINGS - ELFORSK

UPPSALA UNIVERSITET

Höskolan på Gotland
Gotland University

KTH
TEKNIKA OCH KONST

RISO

LULEÅ TEKNISKA UNIVERSITET

Vindforsk

Högskolan i Halmstad

Högskolan i Narvik

Government & Intl

Strömsunds Kommun

VTT COST 727

Energimyndigheten

iea wind

Natural Resources Canada
Ressources naturelles Canada

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

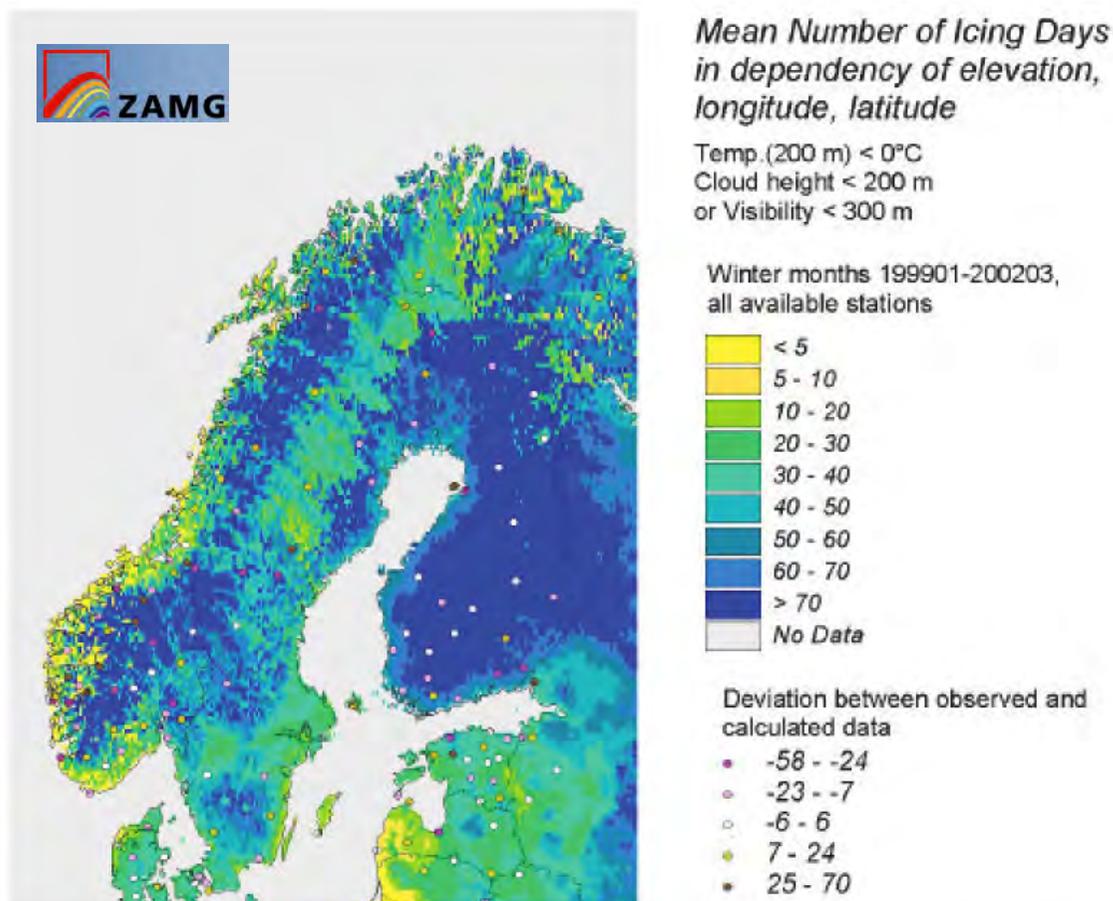


Figure 5: Icing days in dependency from geographical coordinates and sea level height for Scandinavia

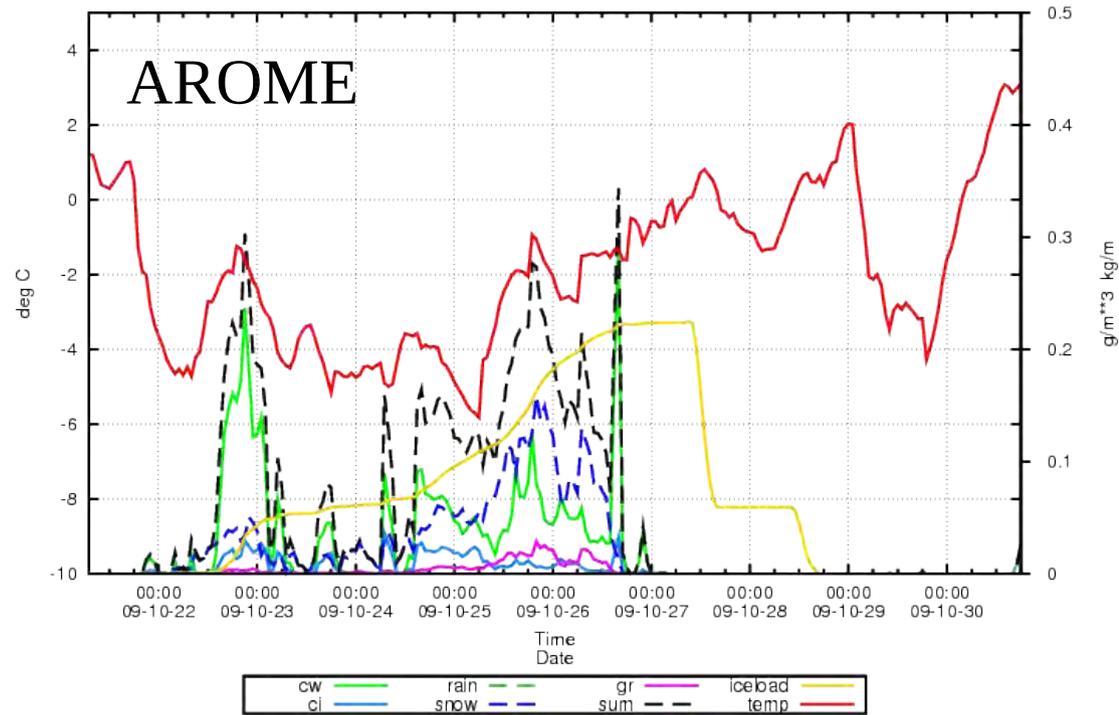
CW RAIN CI SNOW GRAUPEL TOTAL

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

Hur ser det egentligen ut?

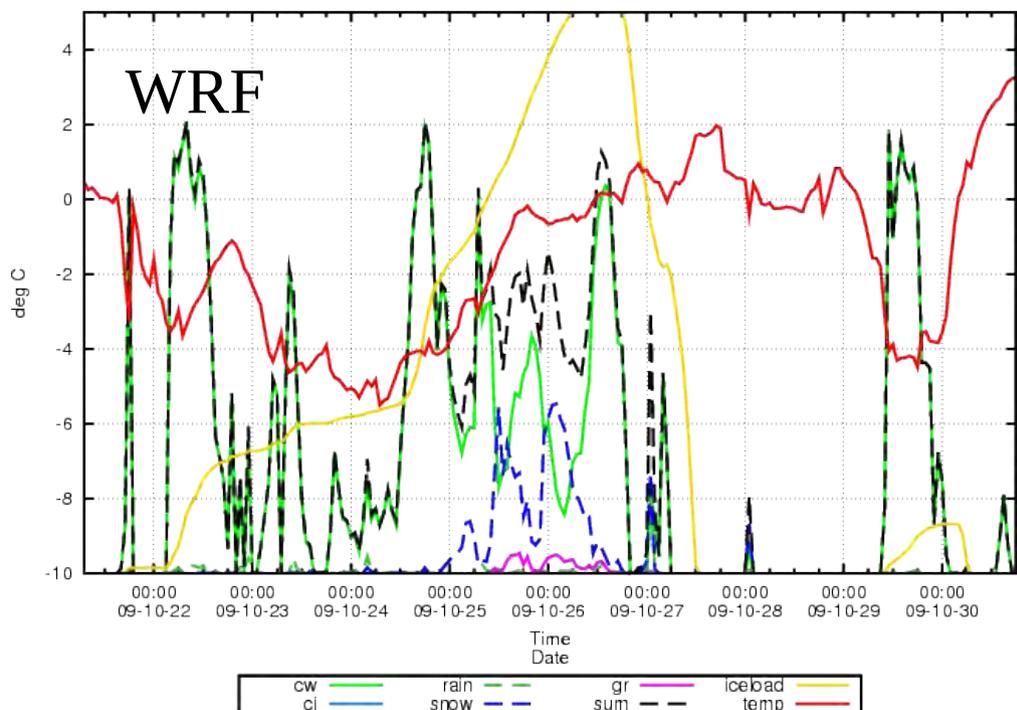
2010-03-09 12:43

AROME Bliekevare 80m: temp iceload cw ci rain snow gr + sum of all condensates



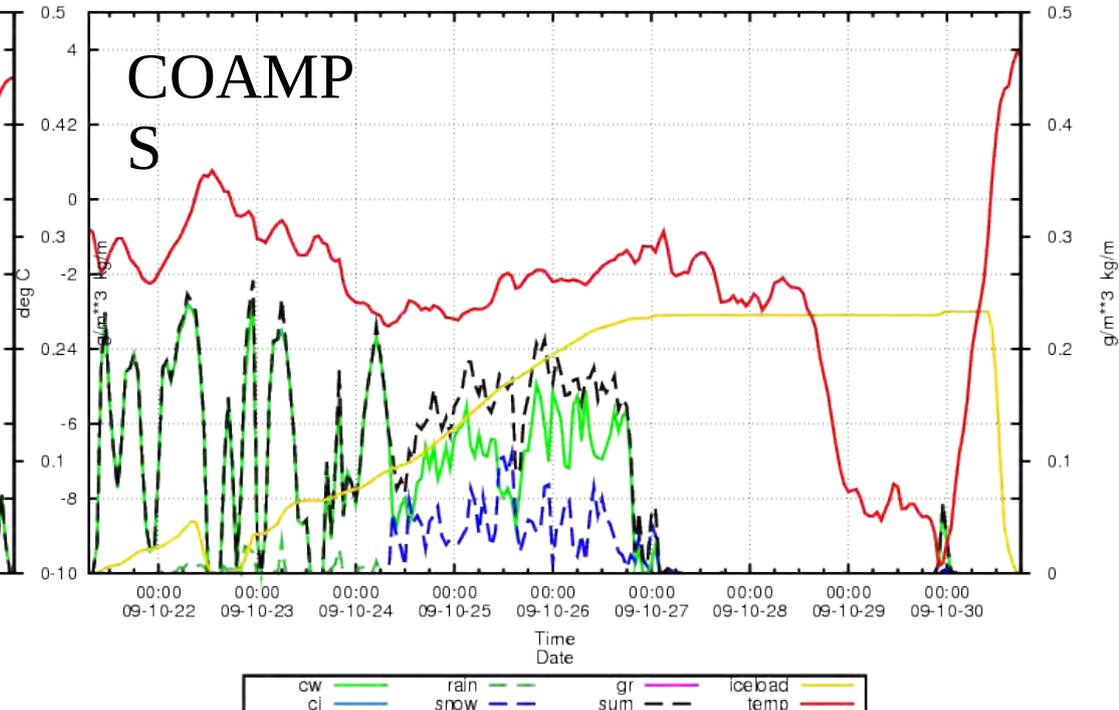
2010-03-09 12:43

WRF Bliekevare 80m: temp iceload cw ci rain snow gr + sum of all condensates



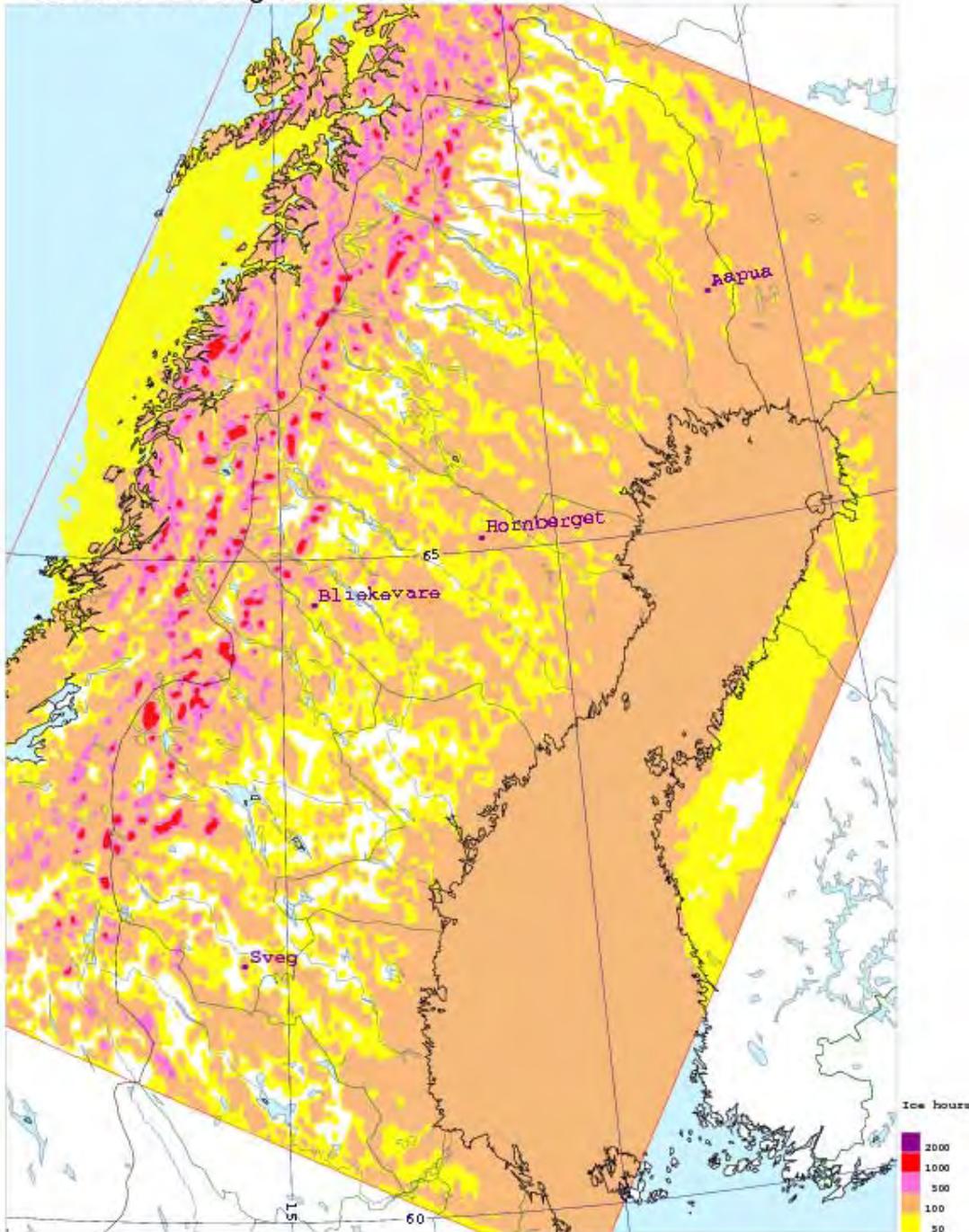
2010-03-09 12:43

COAMPS Bliekevare 80m: temp iceload cw ci rain snow gr + sum of all condensates

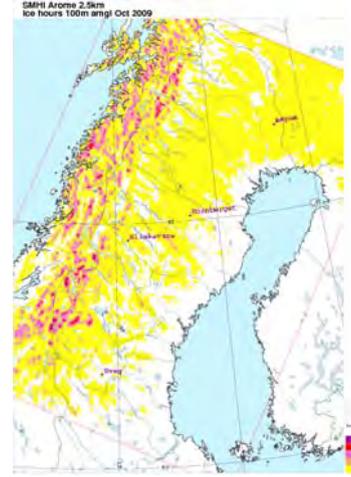


Summering av den gångna vintern

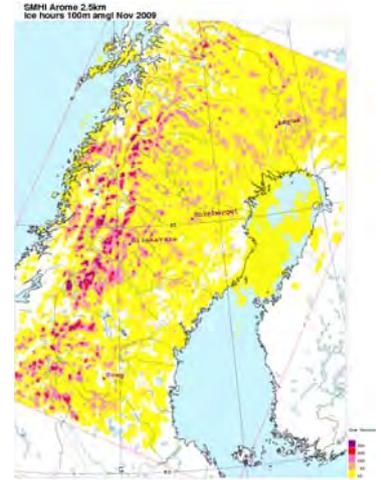
SMHI Arone 2.5km
Ice hours 100m amgl Season 2009/2010



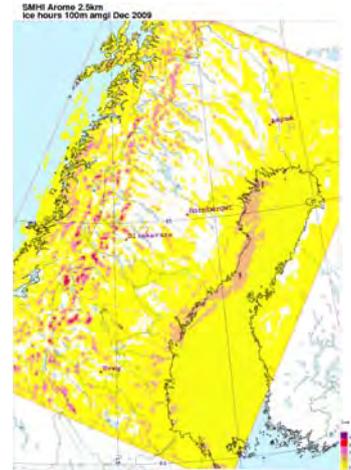
Okt



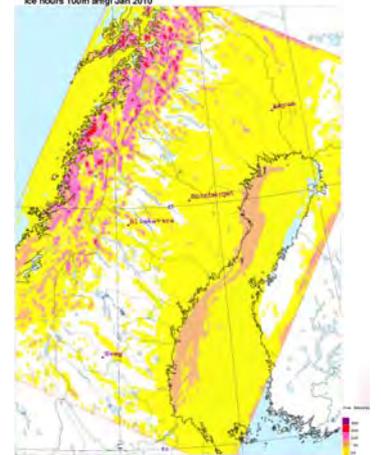
Nov



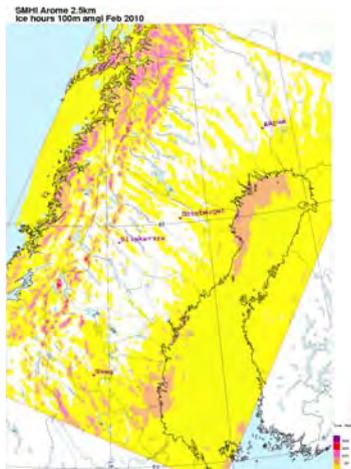
Dec



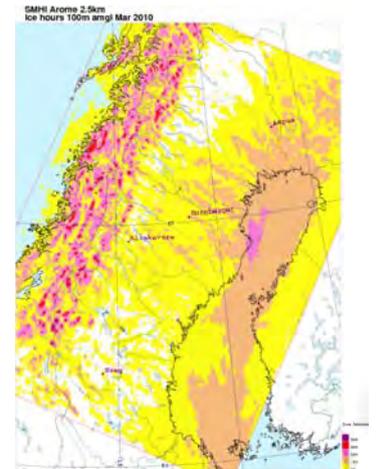
Jan



Feb



Mar

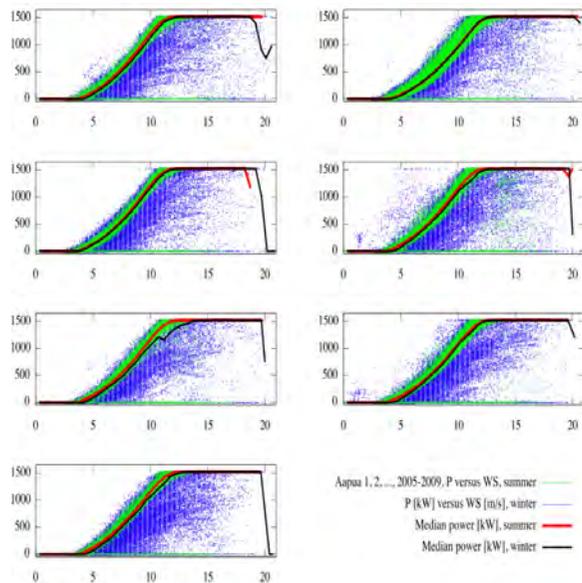


Measured and estimated energy production losses - ongoing

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



Aapua



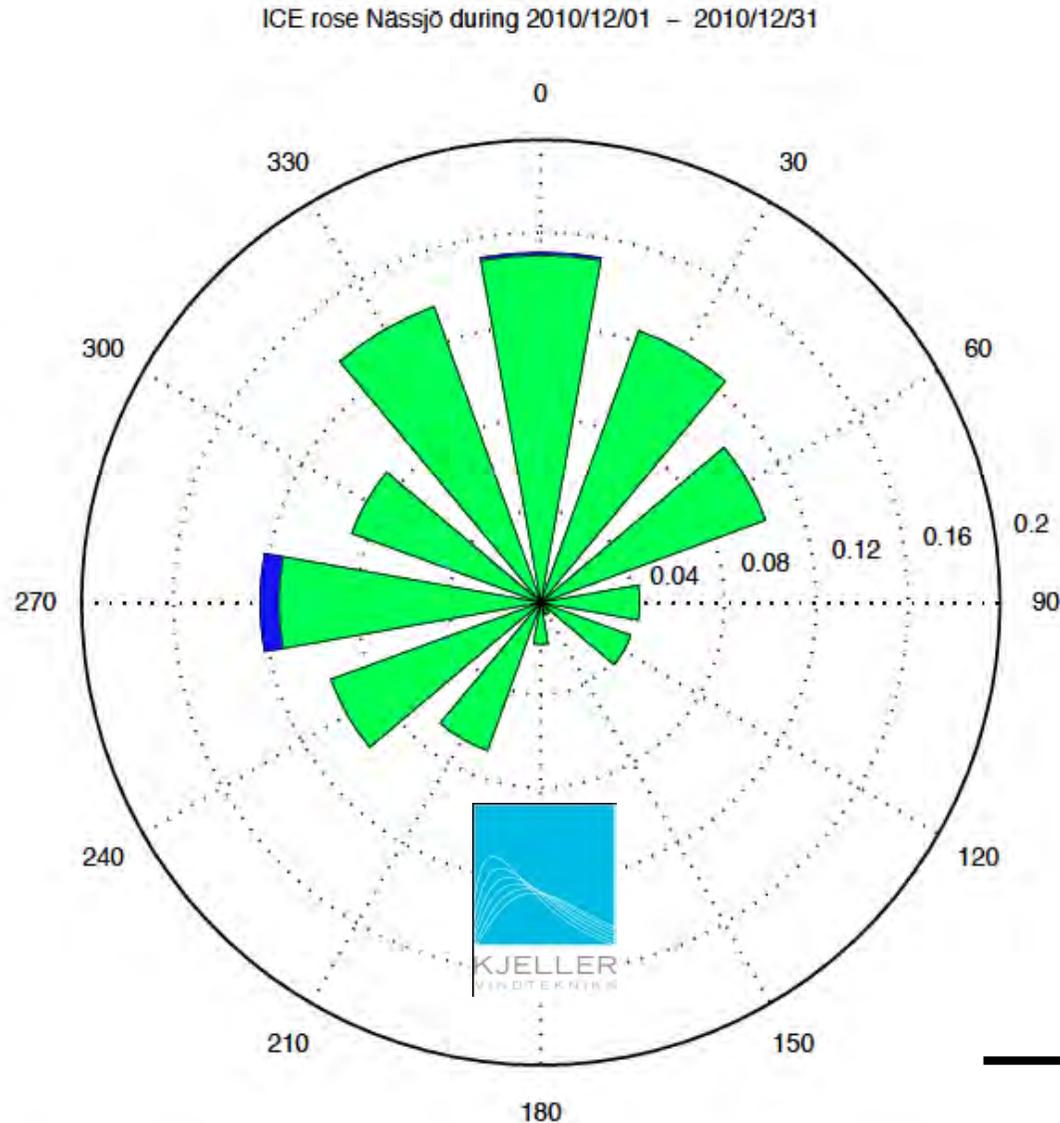
Example of modeling of production losses
For Dec 2010



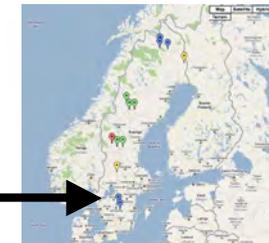
Site	U_{mean} [m/s]	T_{mean} [°C]	T_{min} [°C]	T_{max} [°C]	Icing [hours]	P_{full} [MWh]	P_{loss} [MWh]
Täsjö	7.1	-10.1	-20.1	-2.8	36		
Kiruna	7.1	-9.1	-22.0	1.3	8		
Sveg	6.3	-9.8	-19.0	-1.4	5		
Nässjö	6.6	-7.1	-13.4	1.6	7	439	8

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

Data not easily available!



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



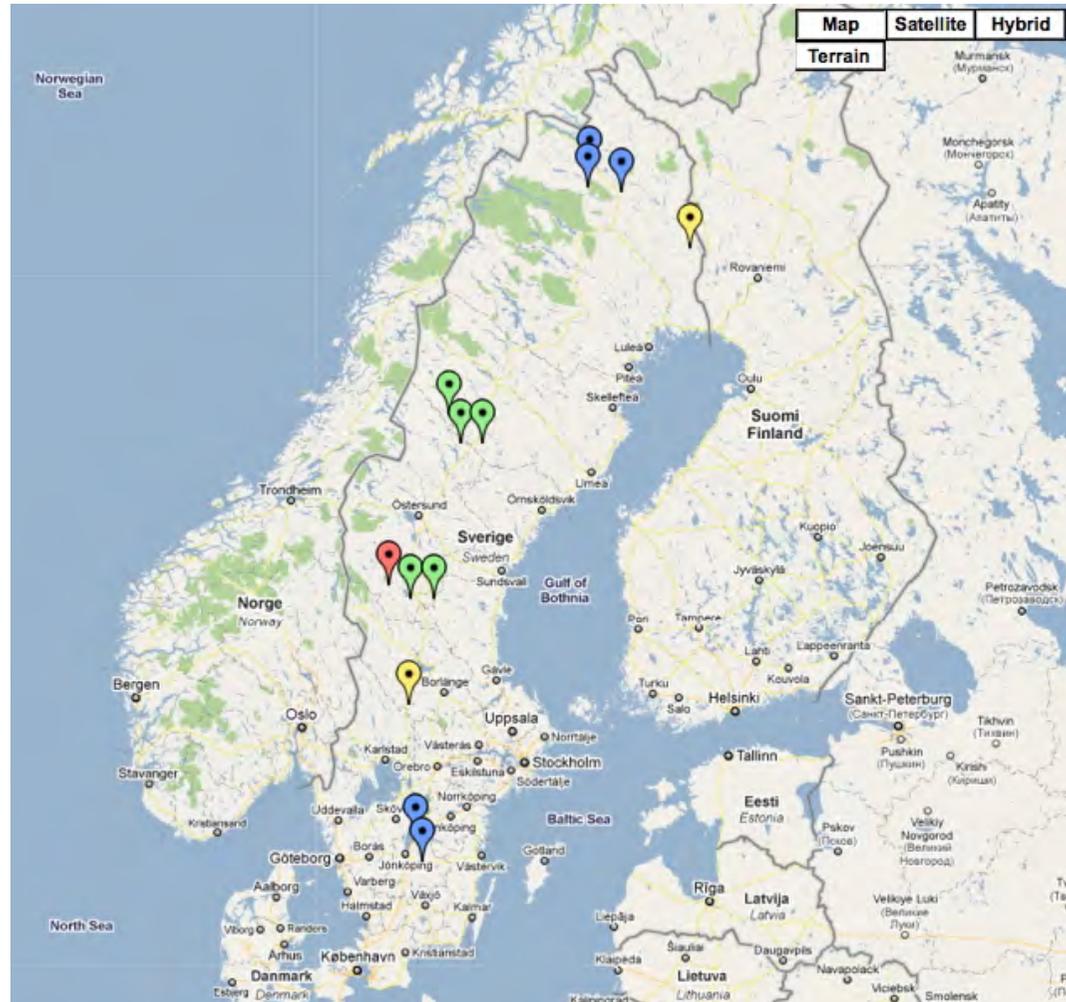
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	33	40	26	10	0	0	0	0	0	0	0	53
2001	61	29	27	13	0	0	0	0	0	0	11	80
2002	26	39	23	3	0	0	0	0	2	20	62	86
2003	32	57	5	24	0	0	0	0	0	24	66	60
2004	68	28	10	4	0	0	0	0	0	3	75	21
2005	22	64	27	0	0	0	0	0	0	0	13	41
2006	59	42	32	4	0	0	0	0	0	0	7	4
2007	21	33	22	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
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

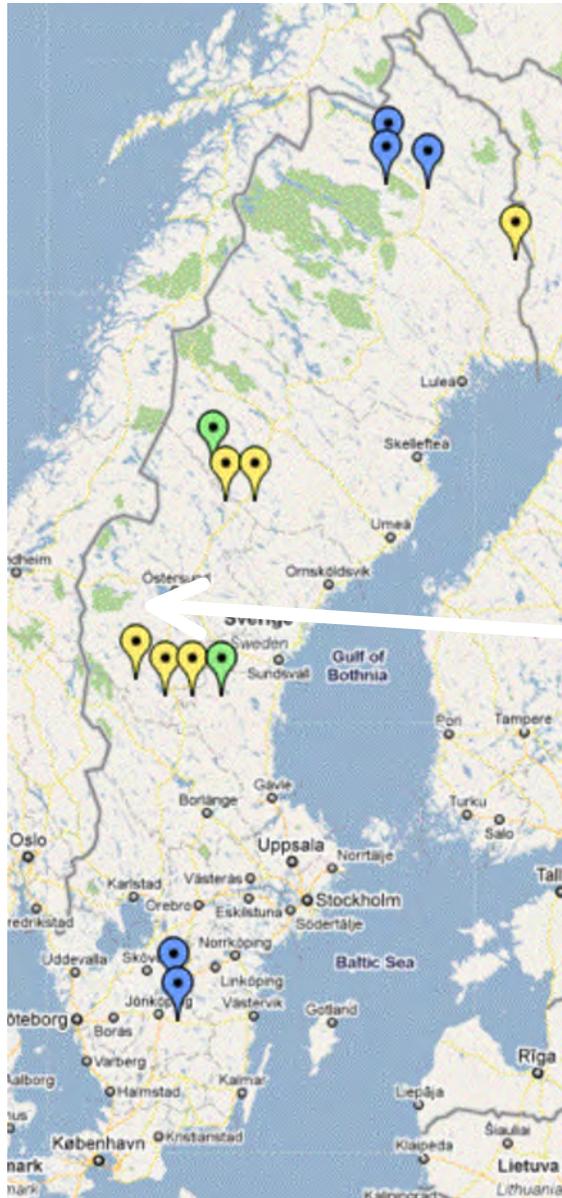
**Example:
Number of
hours of
icing
intensity
>10g/h,
Nässjö**



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).

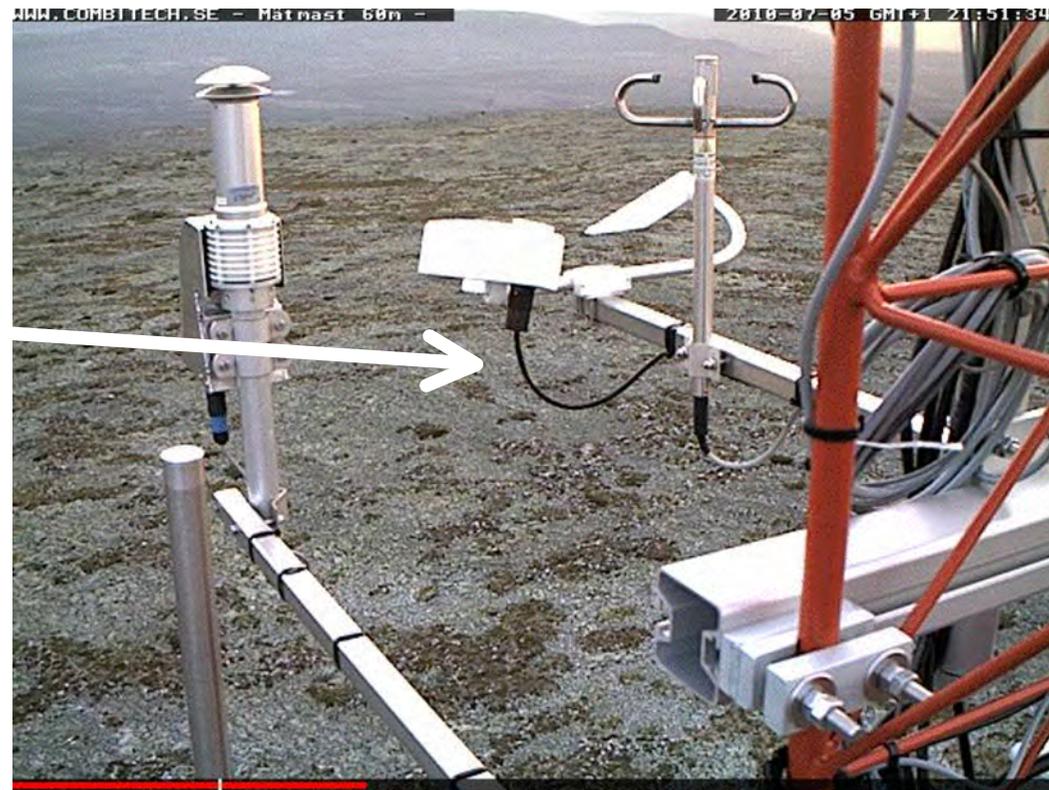
Mapping of icing requires verification; icing measurements - underway



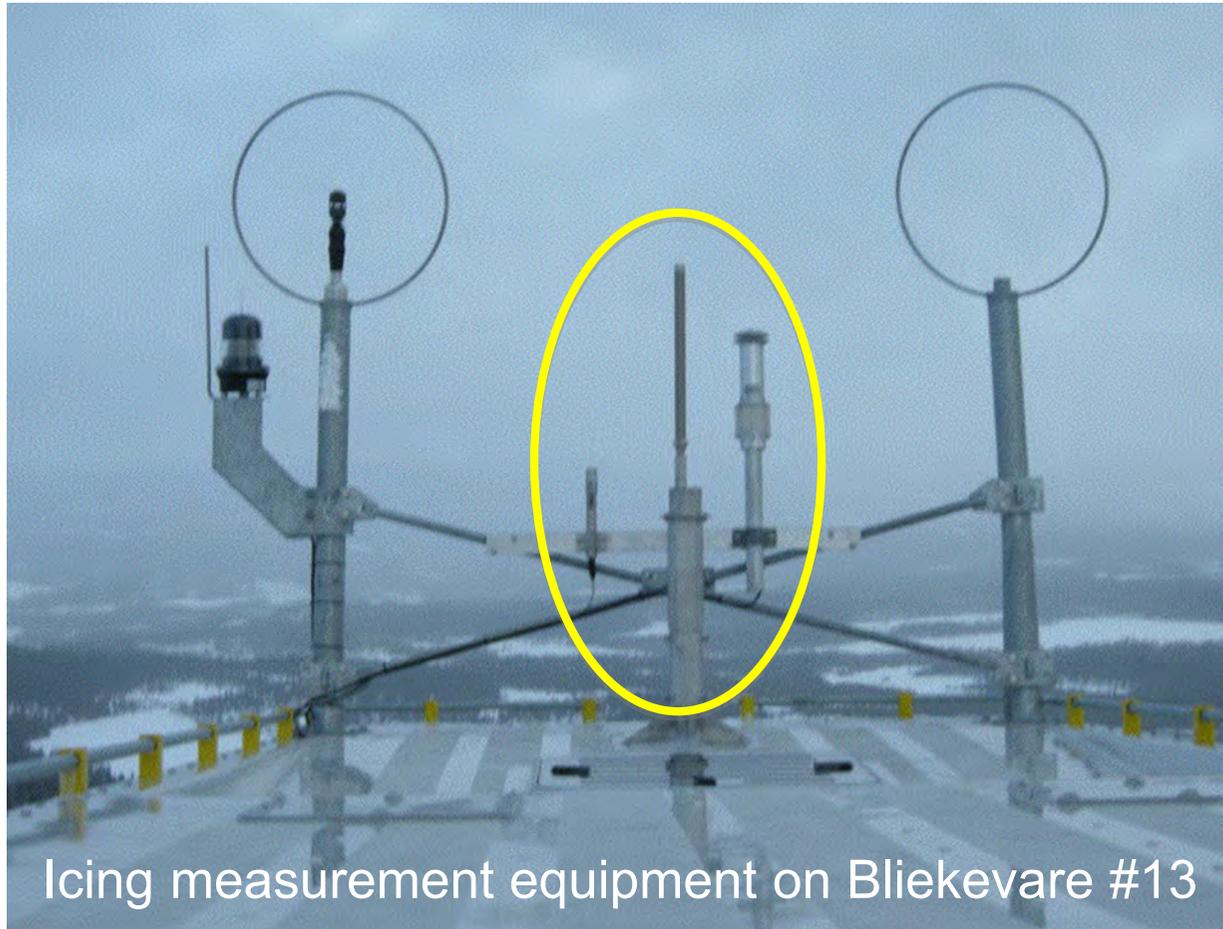


Icing measurements at 11 sites in 13 stations

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



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

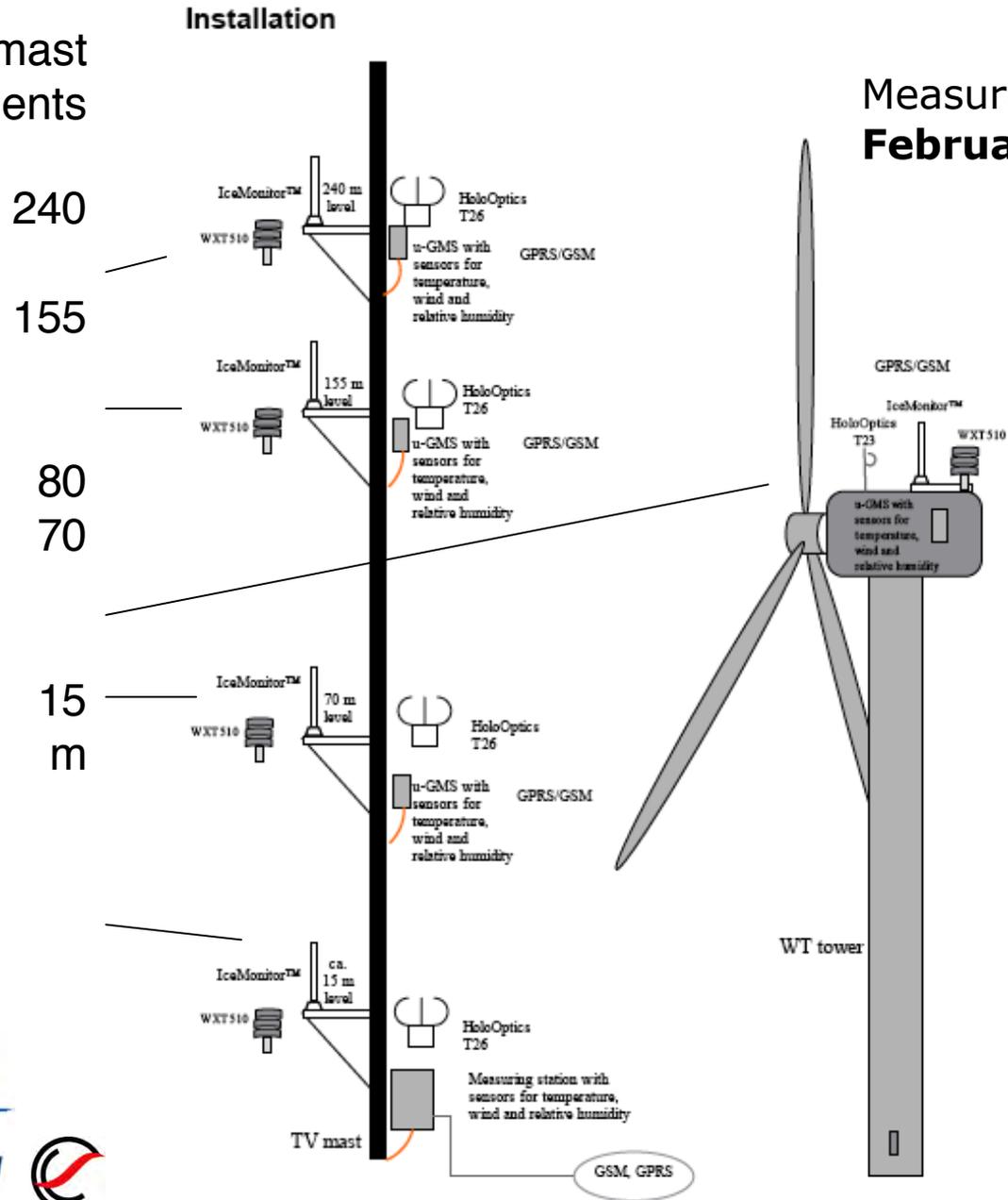




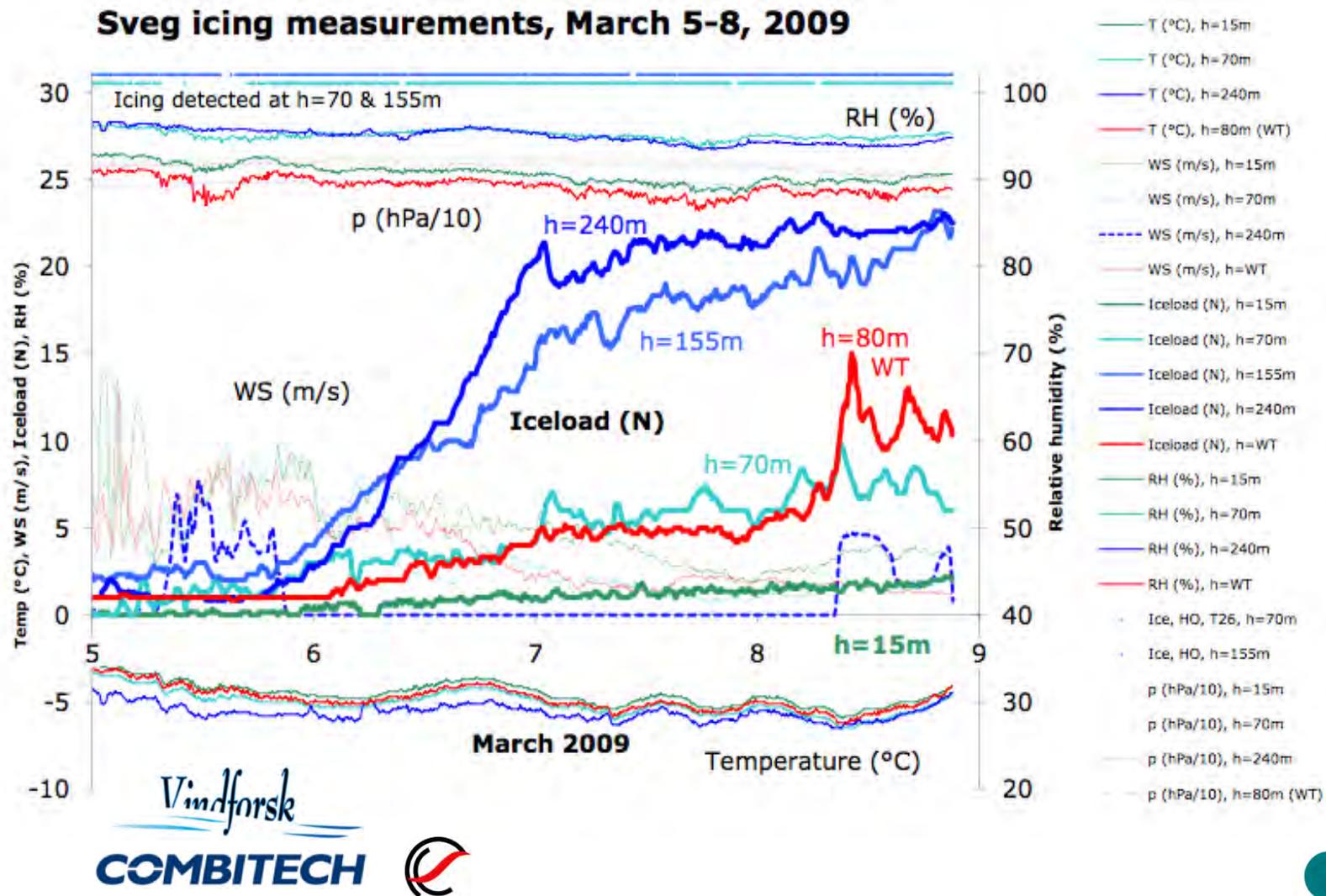
Sveg mast Measurements

WindREN AB

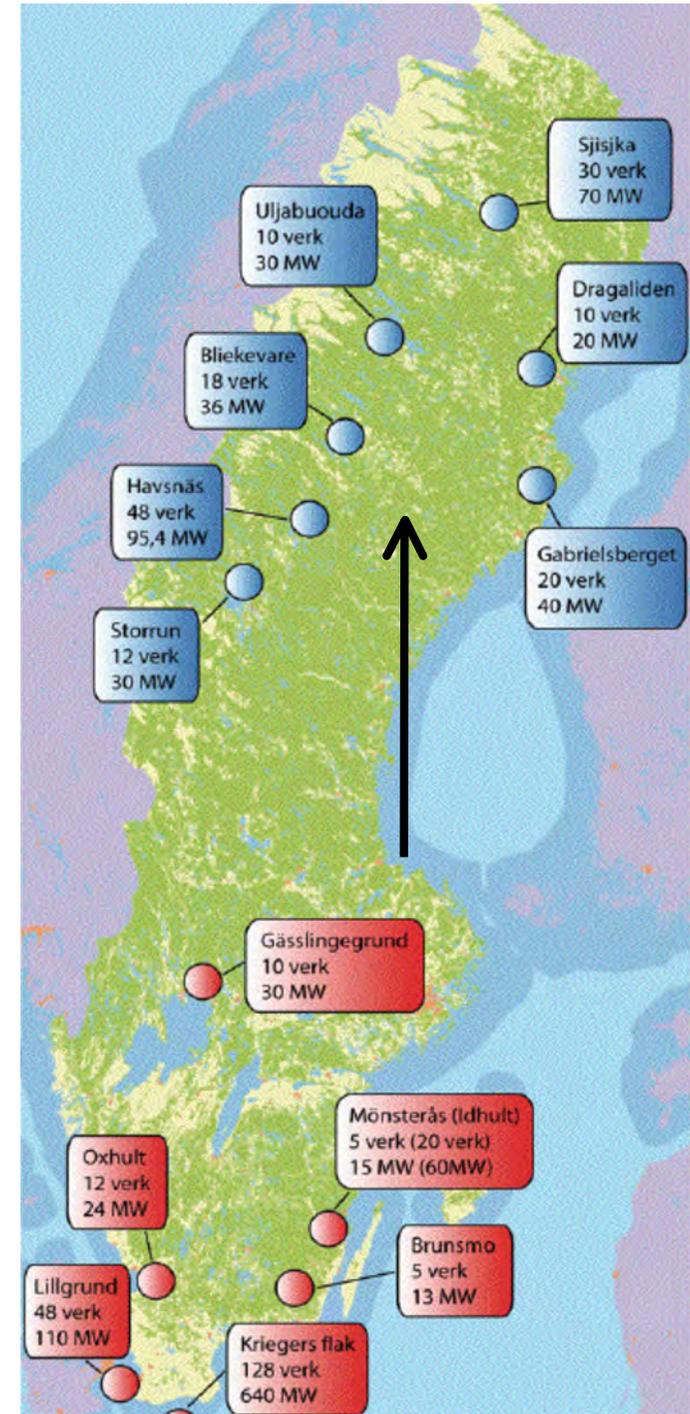
Measurements started
February 2008



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

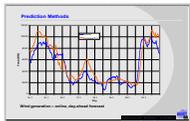
* not including work in kind, 1 Euro = 10 SEK

IEA Task 19 targets 1-3



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.



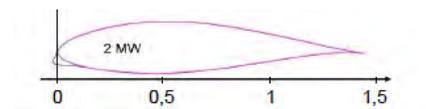
5. Review the current standards and recommendations from the cold climate point of view and identify the possible needs for updates.

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

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.



MAKE
CONSULTING


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,
dissemination

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



Modelling of Atmospheric Icing

An Introduction essay

Petra Thorsson

Vindforsk



Measuring routines of ice accretion for Wind Turbine applications

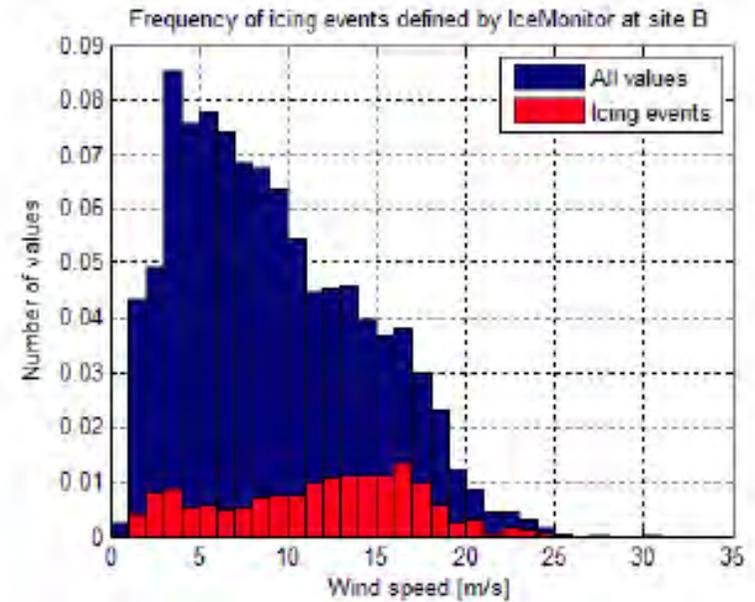
The correlation of production losses and detection of ice

Viktor Carlsson

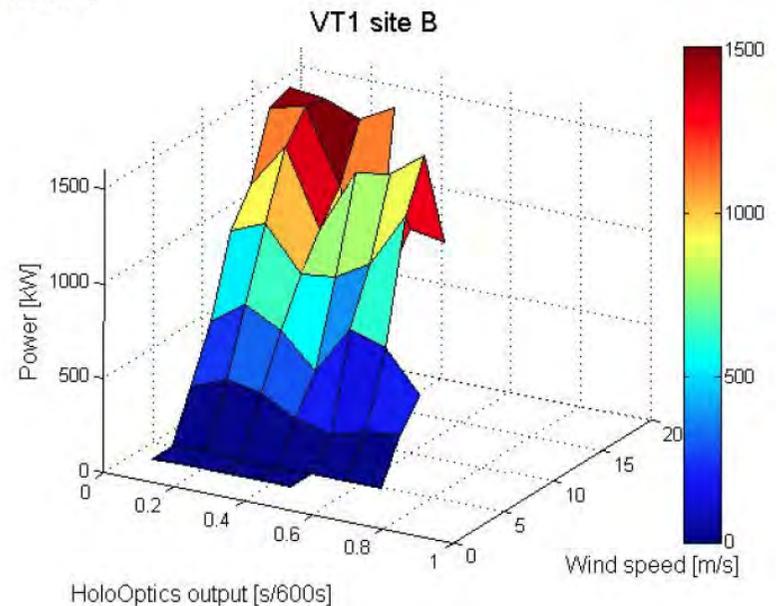
Viktor Carlsson
Ht 2009
Examensarbete, 30 hp
Civilingenjörsprogrammet inom Teknisk Fysik, 180 hp



Sep 2010



H.2 Site B



Jan 2011

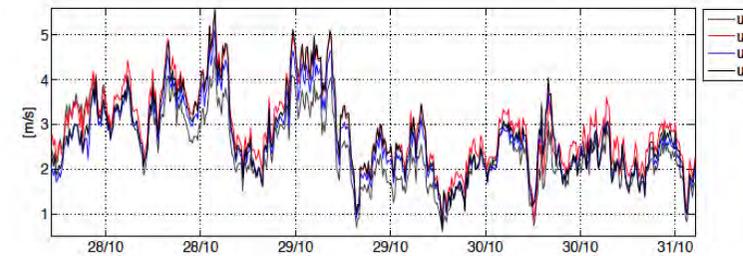
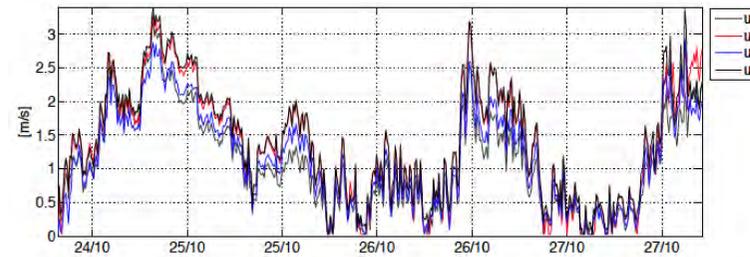
Master thesis: Evaluation of statistical analysis methods for the detection of partial icing of anemometers

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

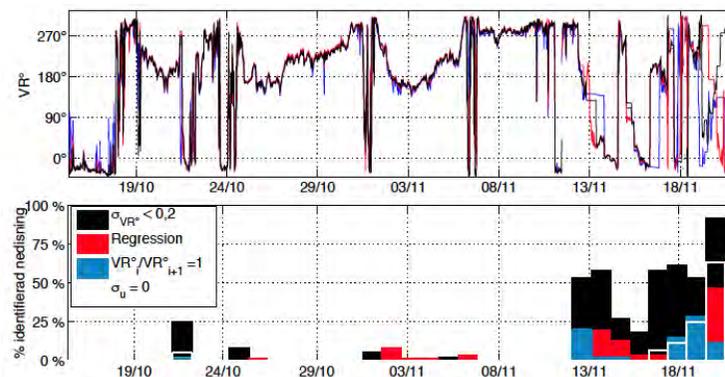
Examensarbete vid Institutionen för geovetenskaper
ISSN 1650-6553 Nr 209

Utvärdering av statistiska analysmetoder
för detektion av partiell nedisning
av anemometrar

Irene Helmersson



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.



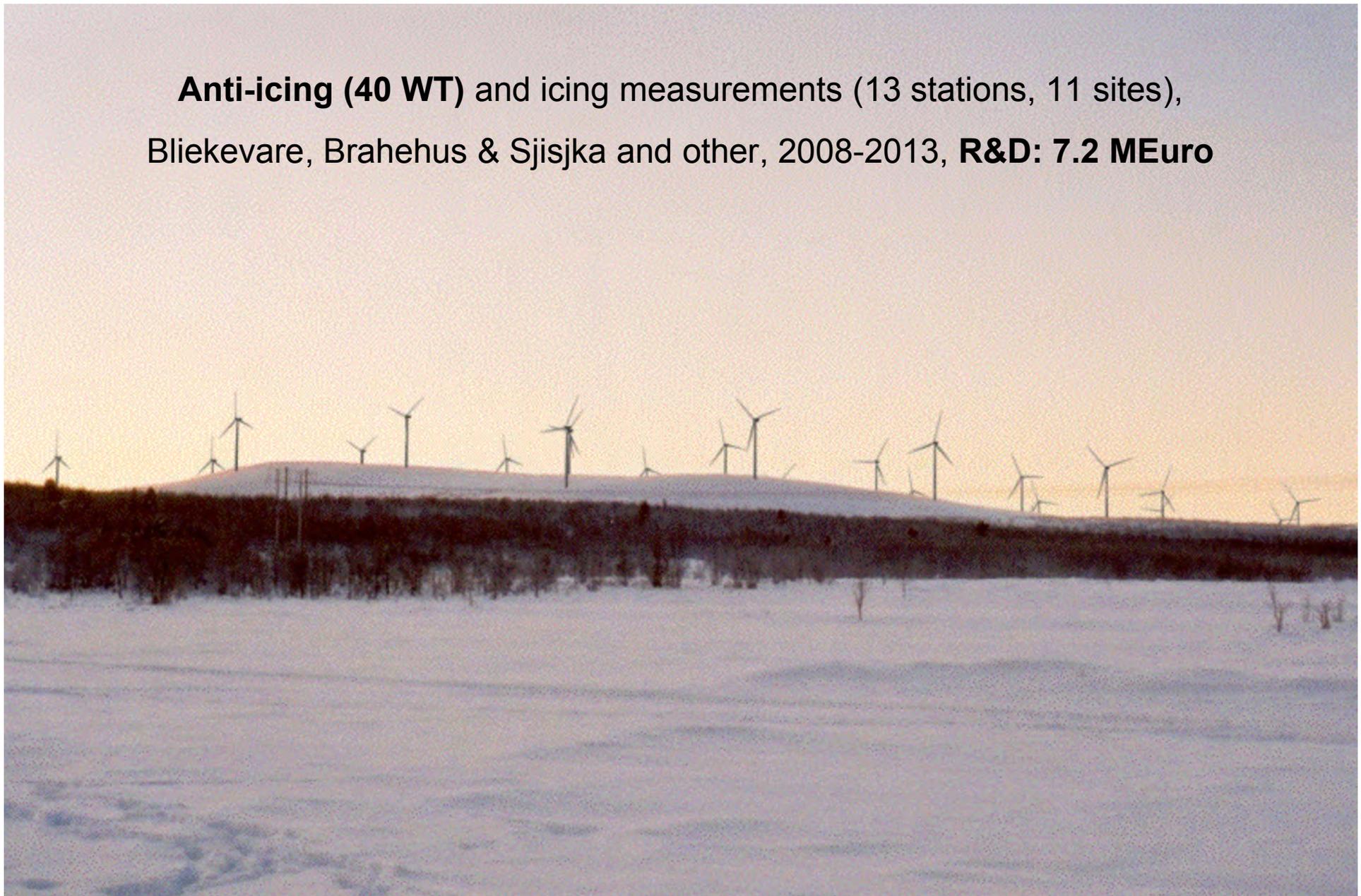
Figur 16. Vindhastighet, temperatur och vindriktningsförhållanden under mätperioden. Nedre bilden visar procentandel defekterad is på 10 femmarsperiod och i olika steg i algoritmer

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?

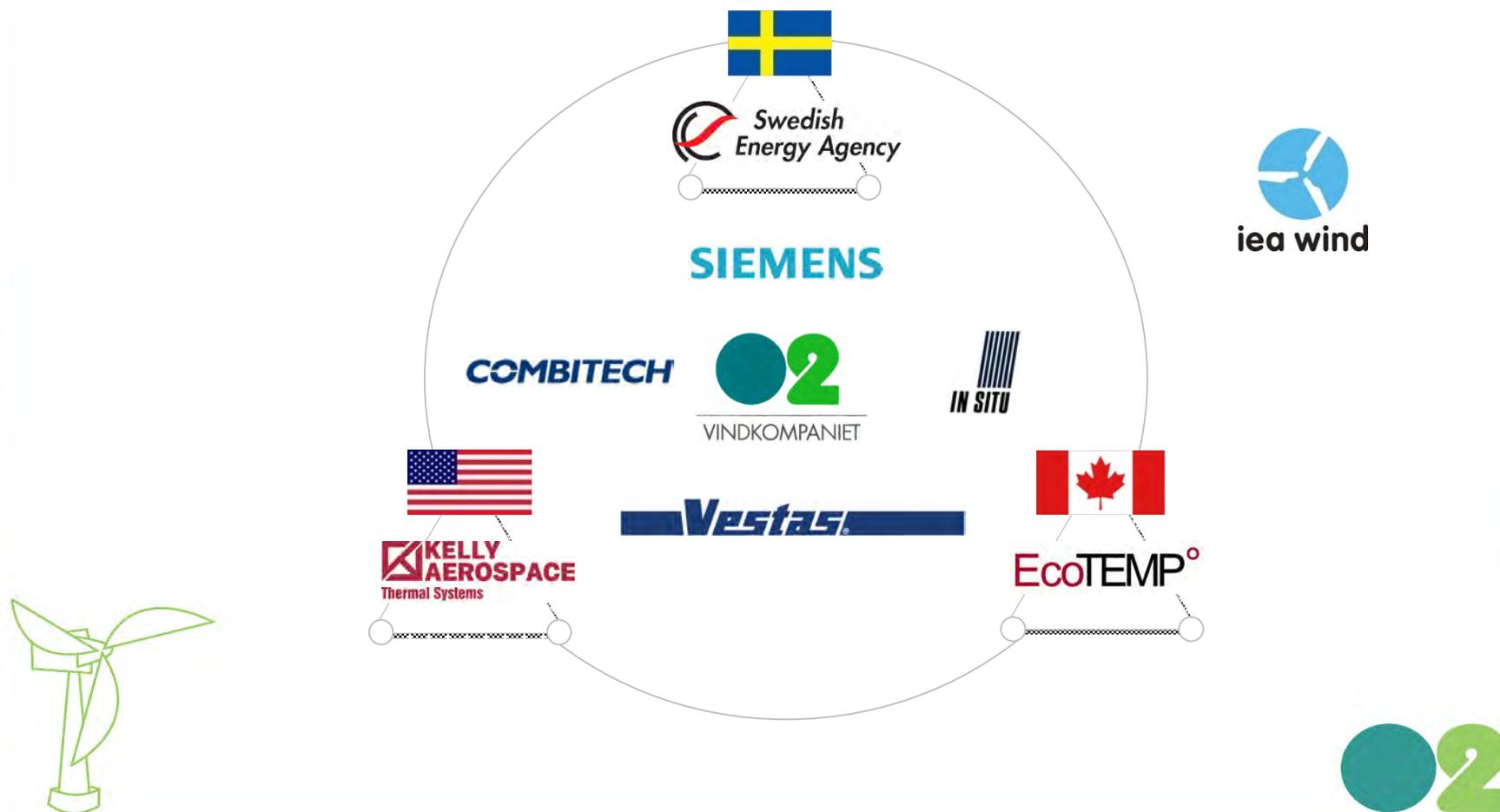
**Anti-icing (40 WT) and icing measurements (13 stations, 11 sites),
Bliekevare, Brahehus & Sjisjka and other, 2008-2013, R&D: 7.2 MEuro**



...



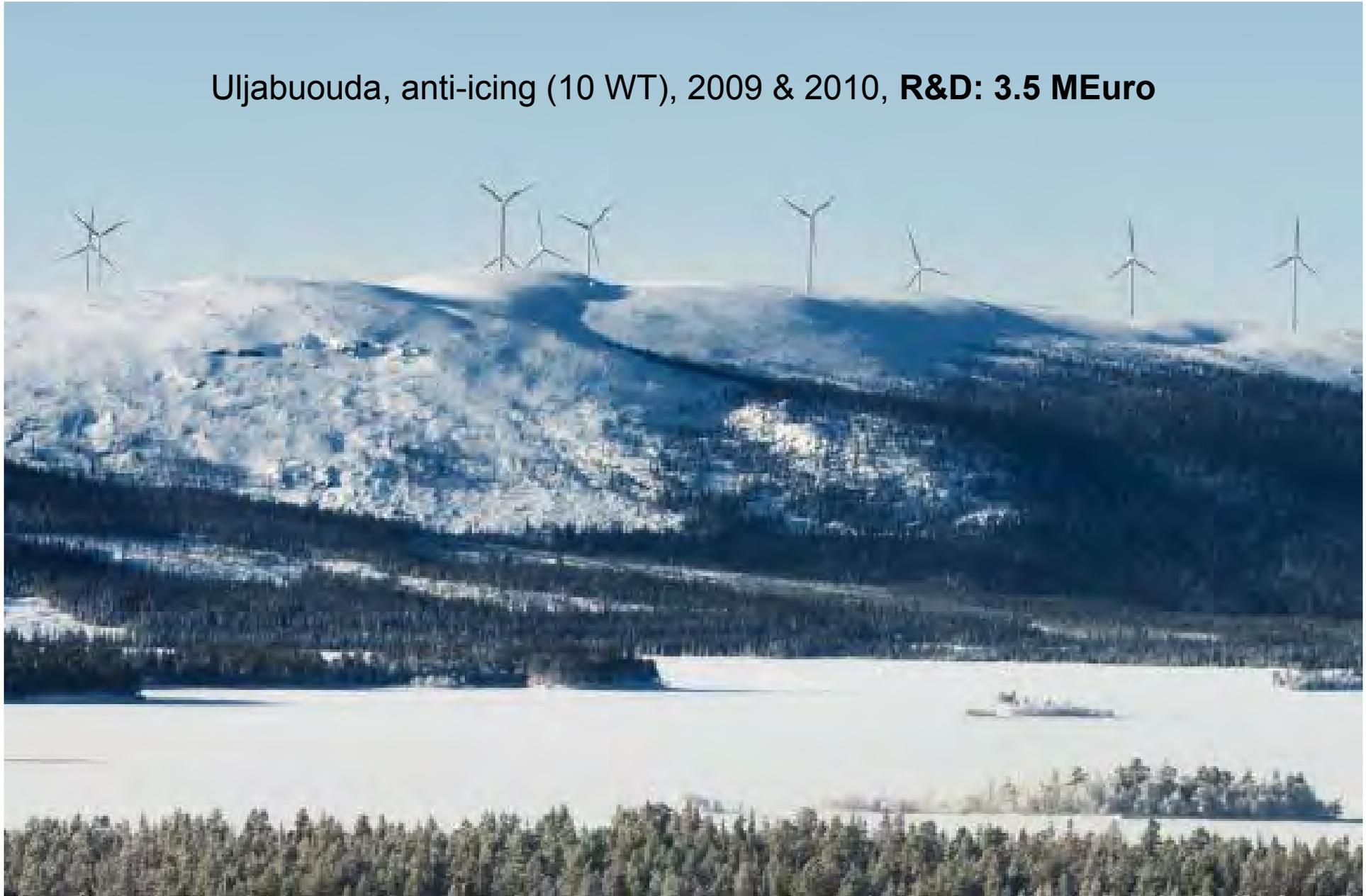
International support for o2 Vindkompaniet's wind pilot project



Exchanging blades - de-icing systems installed on Bliekevare



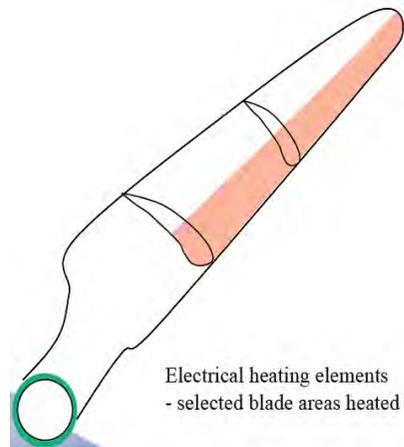
Uljabuouda, anti-icing (10 WT), 2009 & 2010, **R&D: 3.5 MEuro**



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.

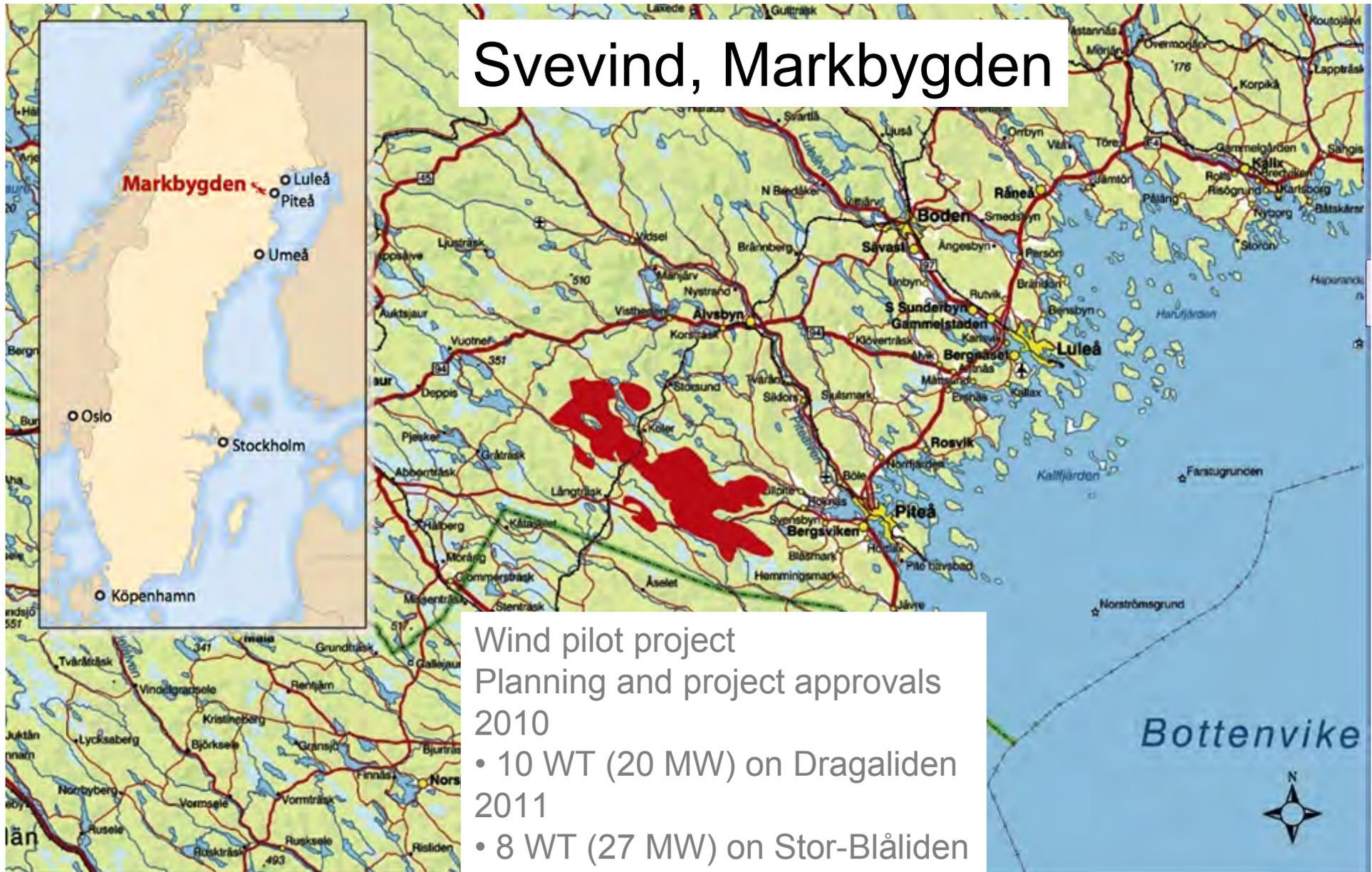


The anti-icing equipment consists of coal-fibre heating elements at the leading edge of the blade.

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



Svevind, Markbygden



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

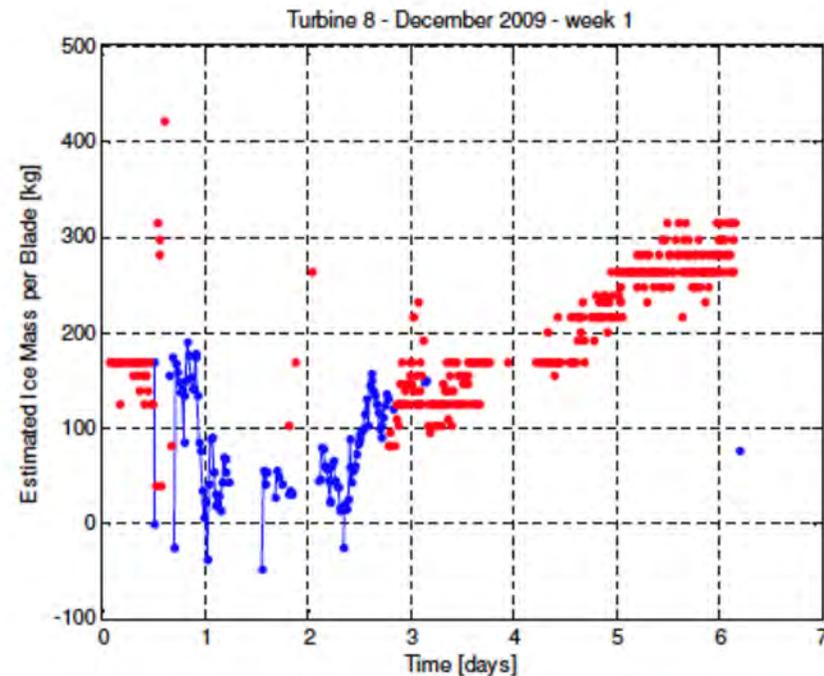
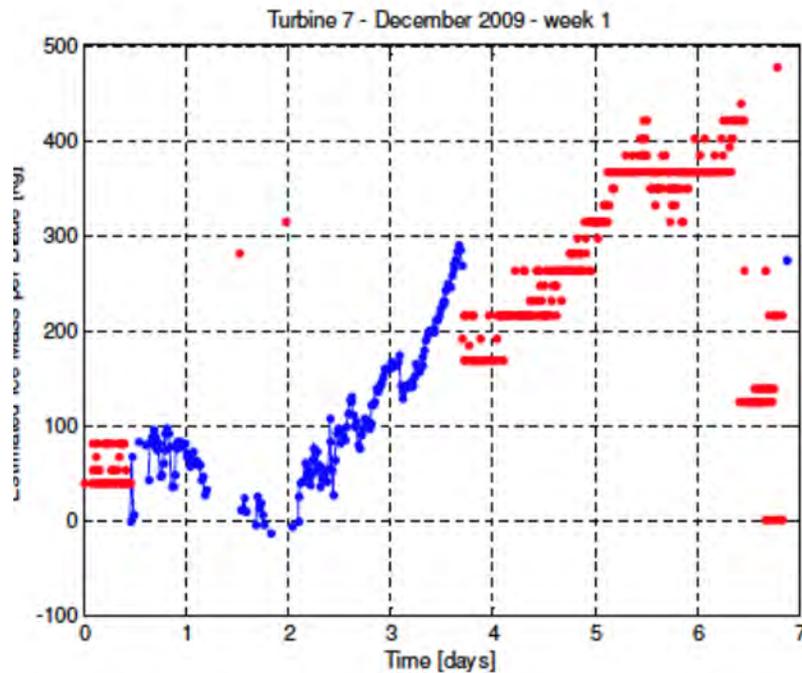


Preliminary results

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!



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

HAVSNÄS - FÖRST AV DE STORA



Driftuppföljning vindkraft

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Tabeller

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[Historia dag-3](#)

[Månad](#)

[Alla månader](#)

Alla verk, sorterade i nummerordning

Avläst 2010-10-10

[Förklaringar](#)

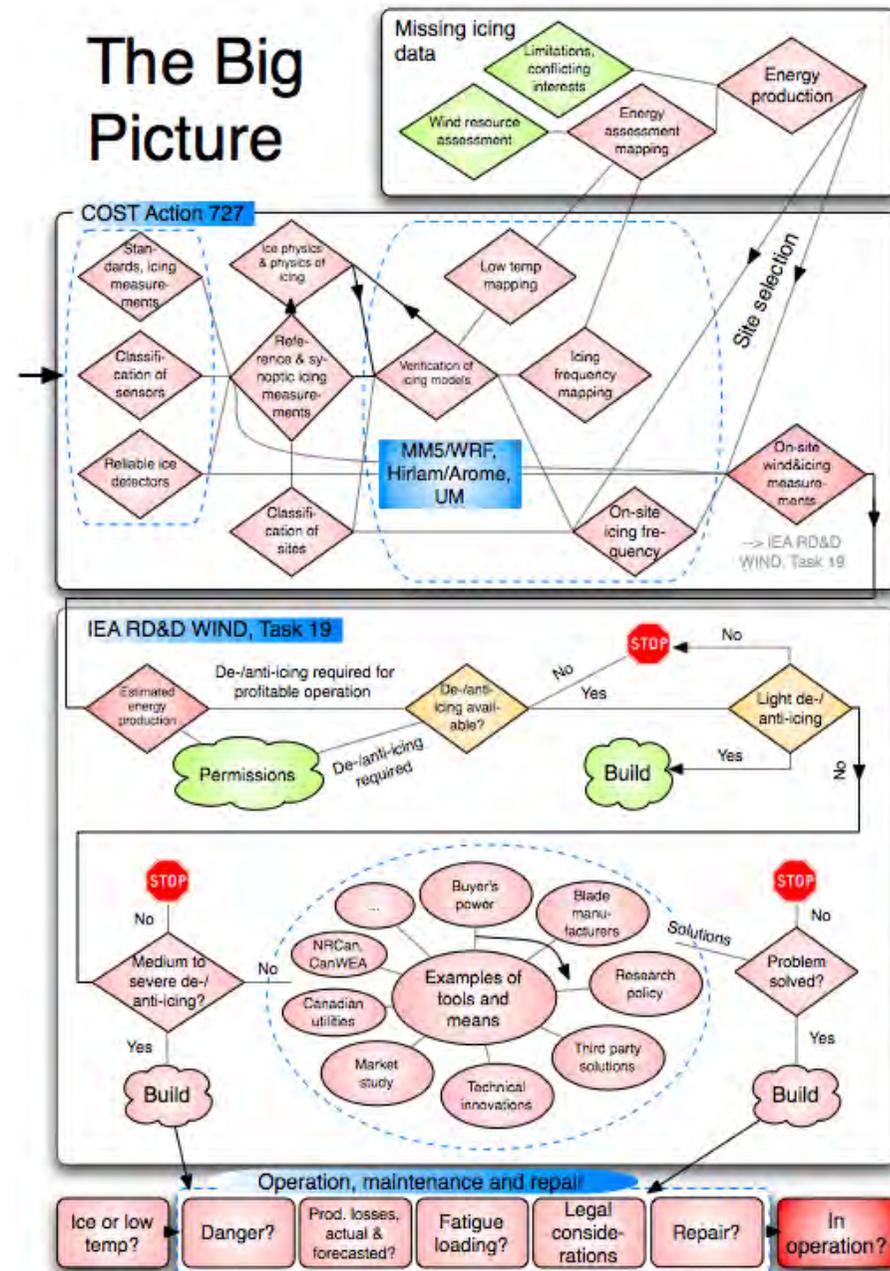
Storlek Typ	Namn	Nr	Status	Effekt	Vind	Temp	Prod	Prod
2000 Enercon	Skarstad	1260	-	0	1,1		19	1414
2000 Enercon	Stockebäck	1261	-	0	1,9		15	1071
2000 Vestas	Havsnäs D1	1262	-	2000	13,5	7	23	19410
2000 Vestas	Havsnäs D2	1263	-	2000	12,8	7	23	18801
2000 Vestas	Havsnäs D3	1264	-	2000	13,1	7	23	17451
2000 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

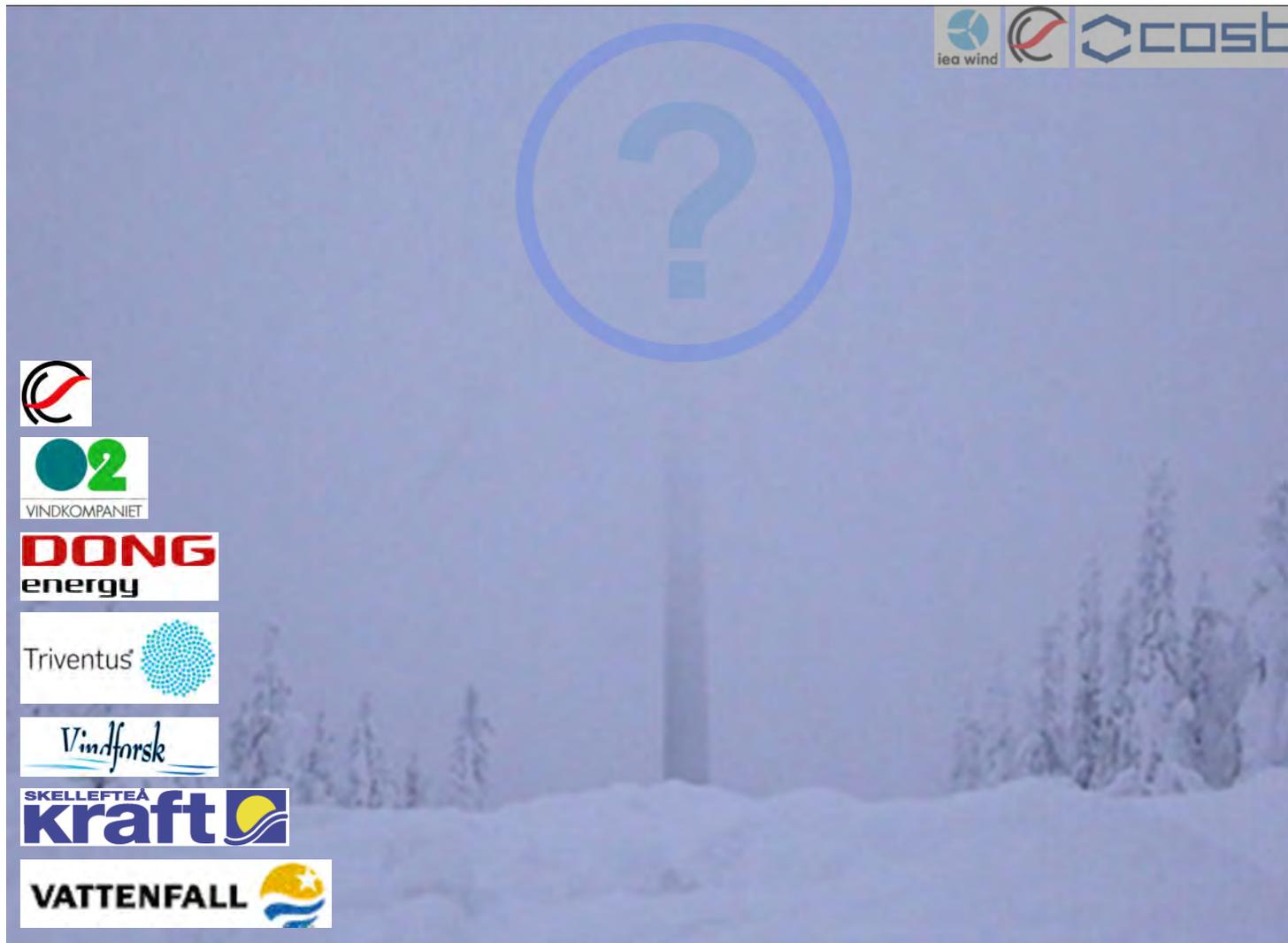
Conclusions with respect to icing

- **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**

The Big Picture



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



Samme hus ramt af fire biler



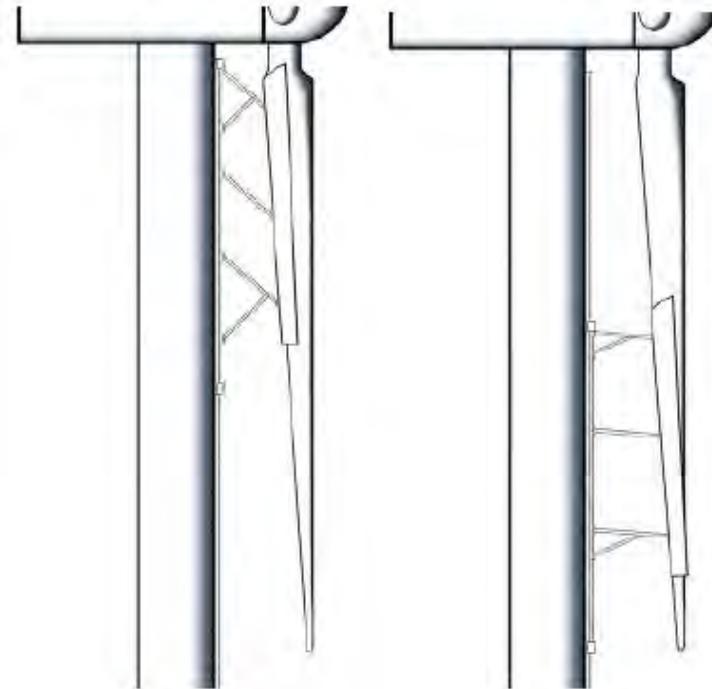
^ Benn Torkild Pedersen foran et af hullerne i muren på familiens staldbygning, der er blevet ramt af biler fire gange på 14 timer.

**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

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