





O2's wind pilot project – Large-scale cost-effective wind energy development in icing climates, *Göran Ronsten, O2*



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2008–2013



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2008–2013

**72.5 MSEK**  
 $\approx 8 \text{ M€}$

## Vindkraftprojekt > 10 MW i Sverige, januari 2011

Under byggnad

4. Gabrielsberget, 40 verk, 92 MW

I drift

1. Uljabuouda, 10 verk, 30 MW

### In operation or under construction

- 32. Toftedalsfjället, 11 verk, 25 MW
  - 33. Östra Herrested, 9 verk, 18 MW
  - 36. Brahehus, 9 verk, 18 MW
  - 37. Töftedalsfjället, 11 verk, 25 MW
  - 39. Tavelberget, 5 verk, 10 MW
  - 40. Frösölä (Hytte), 6 verk 15 MW
  - 42. Vettäsen/Finnbergen, 10 verk, 23 MW
  - 46. Granberg, 5 verk, 10 MW
  - 48. Hedbodberget 2, 6 verk, 12 MW
  - 720 MW**
  - 65%**
- 
1. Storrun, 12 verk, 30 MW  
2. Haysnäs, 48 verk, 96,4 MW  
3. Hédbodberget 1, 5 verk, 10 MW  
4. Sältrådberget, 8 verk, 16 MW  
5. Fjällberget/Saxberget, 17 verk, 34 MW  
6. Gåsslingegrund, 10 verk, 30 MW  
7. Brattön, 10 verk, 25 MW  
8. Oxhult, 12 verk, 24 MW  
9. Lillgrund, 48 verk, 110 MW  
10. Hud/Kil, 10 verk, 23 MW  
11. Stentjärnåsen, 5 verk, 10 MW  
12. Röbergsfjället, 8 verk, 16 MW  
13. Häcksta, 5 verk, 10 MW  
14. Hornberget, 5 verk, 10 MW  
15. Silkomhöjden, 6 verk, 12 MW  
16. Sotared, 5 verk, 10 MW  
17. Höglberget, 5 verk, 10 MW  
18. Råbelöf, 5 verk, 10MW  
19. Utgrunden I, 7 verk, 10 MW  
20. Ytter Stengrund, 5 verk 10 MW  
21. Klinte vindpark, 5 verk, 10 MW  
22. Lundabukten, 10 verk, 16 MW  
23. Stora Istad, 5 verk, 10 MW  
24. Granberget, 6 verk, 12 MW  
25. Kyrkberget, 10 verk, 23 MW  
26. Källeberg, 5 verk, 10 MW  
27. Gårdslösa, 5 verk 12 MW  
28. Lövstaviken, 5 verk, 11,5 MW

**391 MW**  
**36%**

Totalt på land  
315 vindkraftverk, 655,8 MW, 1.331 TWh  
Totalt till havs  
60 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. Stornuddet, 53 verk, 985 MW

20. Hötiärmisklack, 7 verk, 14 MW

### Permissions granted (# excl. offshore)

- 5. Bösjövärden, 10 verk 25 MW
- 6. Mässingberget, 10 verk, 25 MW
- 7. Dingle-Skogen, 6 verk, 15 MW
- 8. Arjäng NV, 9 verk, 21,2 MW
- 9. Orsa Finnmark, 8 verk 20 MW
- 10. Tolvanastegen, 24 verk, 48 MW
- 11. Stora Middlegrund, 108 verk, 540 MW
- 12. Kriegers flak, 128 verk, 640 MW
- 13. Trolleboda, 30 verk, 150 MW
- 14. Utgrunden II, 20 verk, 80 MW
- 15. Knäred, 10 verk, 20 MW

**735 MW**  
**76%**



# Vindkraftprojekt > 10 MW i Sverige, September 2011

Under byggnad

4. Gabrielsberget, 40 verk, 92 MW



## In operation or under construction

32. Töftedalsfjället, 11 verk, 25 MW  
33. 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. Frösölä (Hytte), 6 verk 15 MW

**1265 MW**  
**64%**



**688 MW**  
**35%**

© Svensk Vindenergi

Svensk Vindenergi

# Vindkraftprojekt > 10 MW i Sverige, September

Med alla tillstånd/godkänd anmälan

Tillstånd för park, ej för vatten- och elanslutning

1. Storvindet, 53 verk, 295 MW



## Permissions granted (# excl. offshore)

5. Bösjövärden, 10 verk 25 MW  
6. Mässingberget, 10 verk, 25 MW  
7. Dingle-Skogen, 6 verk, 15 MW  
8. Årjäng NV, 9 verk, 21,2 MW  
9. Orsa Finnmark, 8 verk 20 MW  
10. Tolvansteggen, 24 verk, 48 MW  
11. Stora Middlegrund, 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. Knared, 10 verk, 20 MW



21. Blaiken, 90 verk, 225 MW  
22. Fallåsberget, 10 verk, 25 MW  
23. Brattön 2, 4 verk, 10 MW  
24. Stor-Blätsliden, 8 verk, 31 MW  
25. Raftsjöhöjden, 10 verk, 25 MW  
26. Stamåsen, 50 verk, 115 MW  
27. Verkanlidens, 8 verk, 24 MW  
28. Ås, 6 verk, 15 MW  
29. Stor Kvilla, 4 verk, 10 MW  
30. Övre Långan, 77 verk, 34 MW

**588 MW**  
**57%**



**437 MW**  
**43%**

Svensk Vindenergi

Q: A temporary decreasing share of projects in N Sweden due to grid limitations?



Wind pilot projects: 70 M€ over 10 years

**From offshore to cold climate and forests**

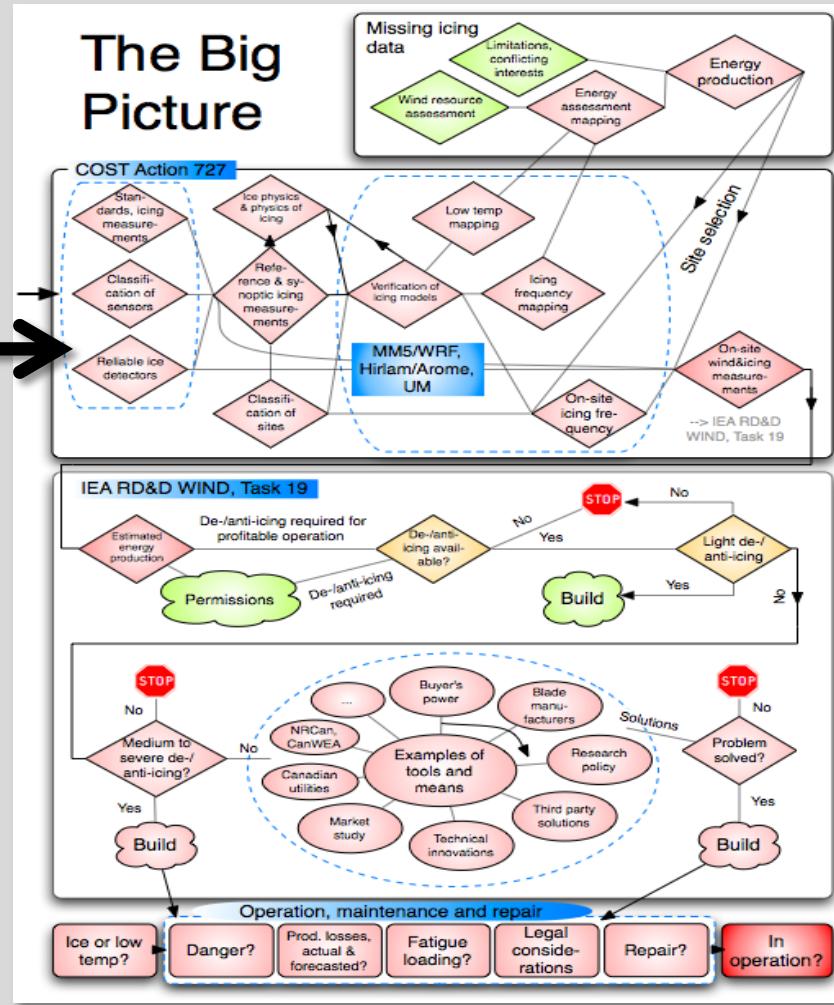




The main challenge in Sweden  
is icing, not low temperatures



A plan to keep  
WT in icing  
climates in  
operation



Planning  
Standards  
Sensors  
Models  
Measurements

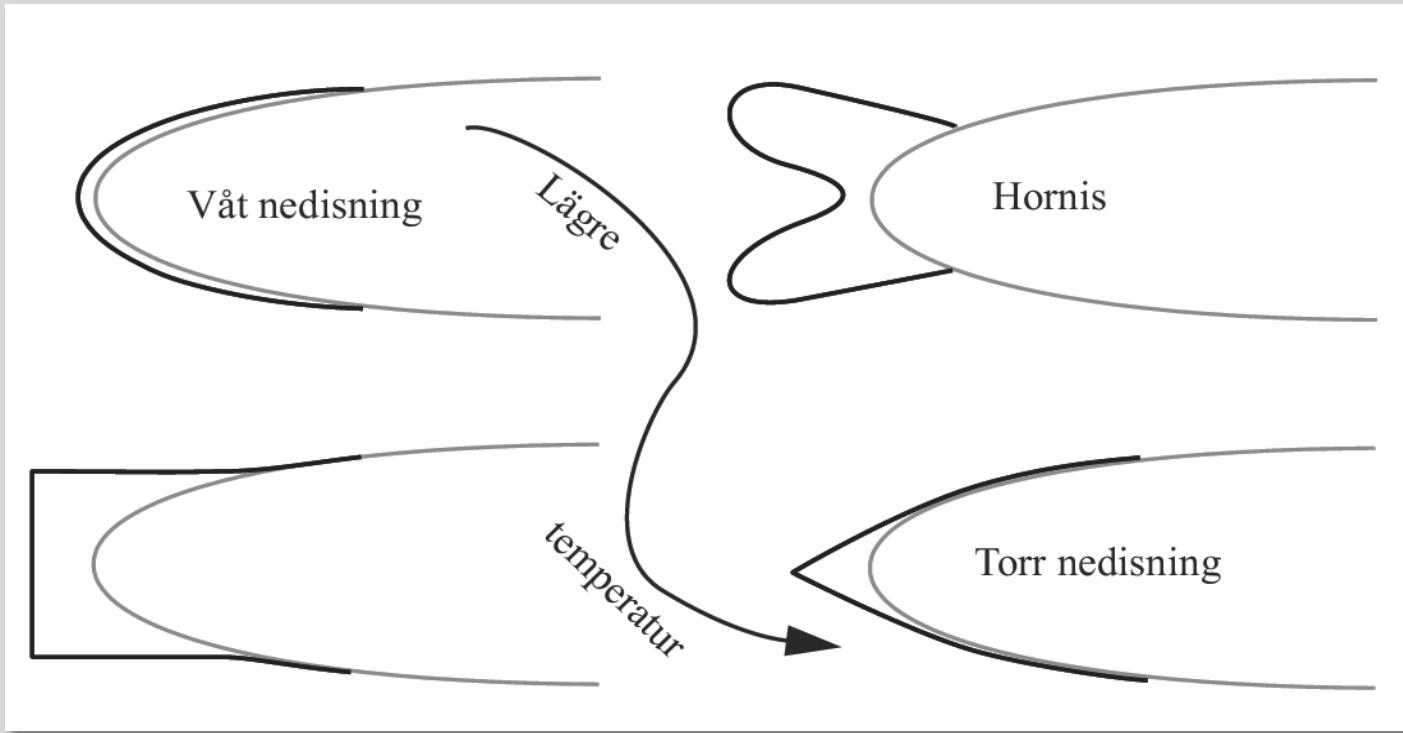
De-icing

Rules, O&M

Modern LED obstacle lights need heating to be seen



## Icing versus temperature





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# How to deal with practical issues?



**Anti-icing (40 WT) and icing measurements (13 stations, 11 sites),  
Bliekevare, Brahehus & Glötesvålen and other, 2008-2013, R&D: 8 MEuro**



...



# International participation in O2 Vindkompaniet's wind pilot project



# International participation in O2 Vindkompaniet's wind pilot project



# International interest in CC: IEA RD&D Wind, Task 19 meeting in 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





# 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 – today!
- State-of-the-art report - 2012
- Planned continuation 2013 - 2015

**WIND ENERGY IN COLD CLIMATES**

**Information (TO BE UPDATED...)**

- Publications
- Operational Experience
- Technical solutions in use
- Measurements & Instruments
- Information on climate conditions and resources

**IEA Wind R&D Task 19**

This is the home page of an International Energy Agency collaboration called Wind Energy in Cold Climates R&D Wind <http://Arcticwind.org>. The purpose of the project is to gather and provide information about wind turbine and low temperature operation.

Recommendations for wind energy projects in icing and cold climates can be found here ([left](#)). The recommendations report will give guidelines and information to wind energy developers to minimize the extra risks involved in wind energy projects in long and cold conditions.

State-of-the-art of wind energy in cold climates ([pdf](#)) summarizes existing experiences in wind energy in cold and long conditions.

**Wind turbines operating in cold or icing climate worldwide**



**What is a Cold Climate?**

Sites at which significant icing events or periods with temperatures lower than the operational limits of standard wind turbines may occur.

**Contact anemometer and wind vane at Oljastutturen, Jell, Finland**

- Send us information about icing and low temperature operation
- Add a low temperature or icing WTG site to our list and map

Index      Mail: [Tomas.Wetterling@vtt.fi](mailto:Tomas.Wetterling@vtt.fi)

# Technology development for WE in cold climates

## Requires market studies - **not available** :-(



**Business Study**  
By MAKE Consulting

**Offshore Wind Power**

**Global research – global markets**  
Independent desk knowledge of the industry  
Adding value to your renewable energy business

**October 2009**

This report provides an overview regarding the offshore wind power market in Europe. It highlights the opportunities and challenges for the development of the industry and the potential for growth in the future. The study also includes a detailed analysis of the current market situation and projections for the period from 2010 to 2020.

The report covers various aspects of the offshore wind power market, including the technical, economic, and political factors that influence its development. It also provides an analysis of the different segments of the market, such as onshore and offshore wind power, and the impact of government policies on the industry.

Overall, the report provides a comprehensive overview of the offshore wind power market in Europe, highlighting the opportunities and challenges for the industry and the potential for growth in the future.

**Market Report**  
By MAKE Consulting

**Wind Turbine Trends**

**Global research – global markets**  
Independent desk knowledge of the industry  
Adding value to your renewable energy business

**December 2009**

This report provides an overview of the wind turbine market in Europe. It highlights the latest trends and developments in the industry, including the introduction of new technologies and the impact of government policies on the market. The study also includes a detailed analysis of the different segments of the market, such as onshore and offshore wind power, and the impact of government policies on the industry.

Overall, the report provides a comprehensive overview of the wind turbine market in Europe, highlighting the latest trends and developments in the industry, and the impact of government policies on the market.

**World Market Update 2008**  
Forecast 2009-2013  
March 2009

**World Market Update 2009**  
Forecast 2010-2014  
March 2010

**World Market Update 2010**  
Forecast 2011-2015  
March 2011

**Offshore Report 2010**  
November 2010

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**International Wind Energy Development**

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November 2010

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# International participation in O2 Vindkompaniet's wind pilot project



Vestas

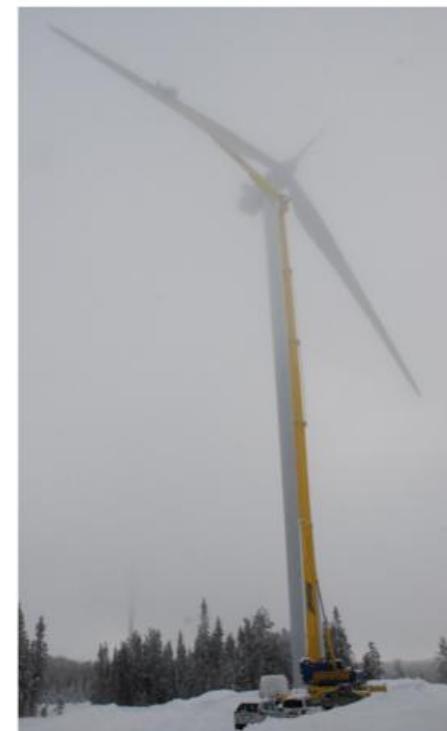
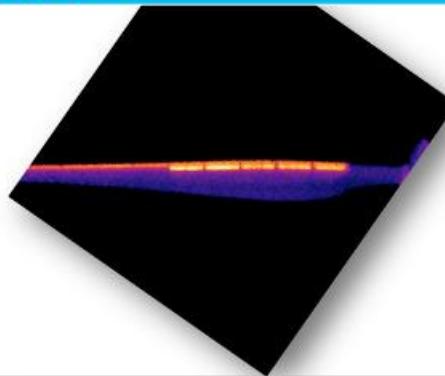


## Testing Active: Outside hot panels

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 to 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



Wind. It means the world to us.™

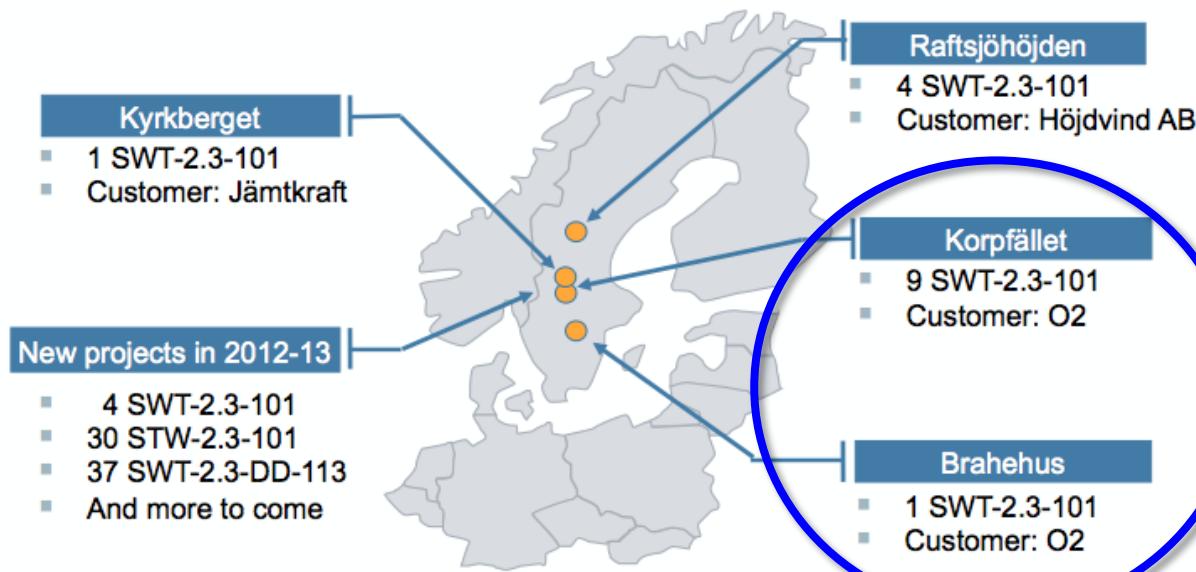
As  
presented  
by Vestas at  
Winterwind  
2012 on  
Feb 7, 2012

Applying  
external  
panels  
isn't a  
proven  
technology

# International participation in O2 Vindkompaniet's wind pilot project



## Turbines installed in Sweden and ongoing testing



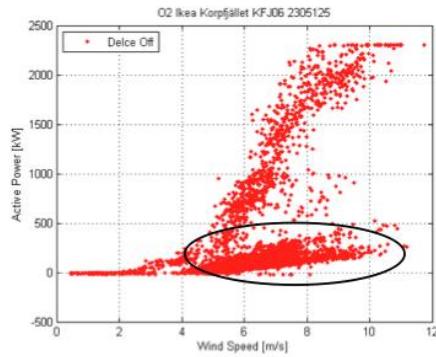
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As presented  
by Siemens at  
Winterwind  
2012 on Feb  
7, 2012

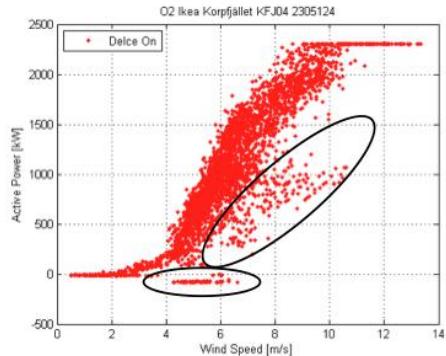
**Korpfjället  
and  
Brahehus are  
part of O2's  
wind pilot  
project**



**Power curve from reference turbine**

Page 11

February 2012

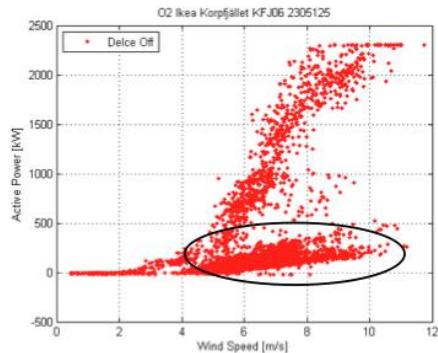
© Siemens AG. All rights reserved.  
E W CTO INNO**Power curve from turbine with de-icing**

Page 12

February 2012

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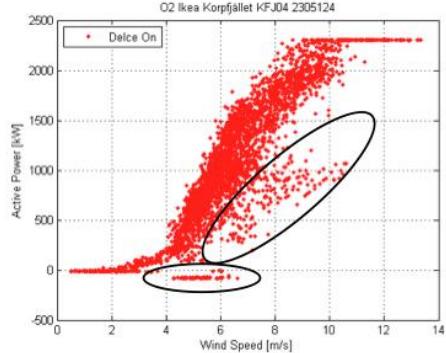
## Power curve from reference turbine



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## Power curve from turbine with de-icing



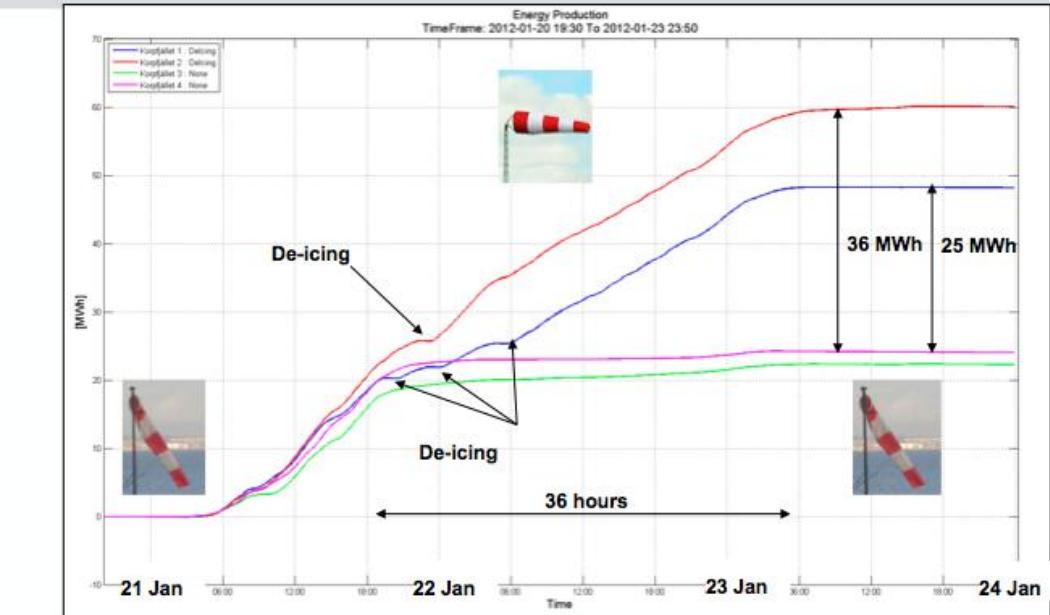
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## Turbines keep operating in spite of icing conditions

SIEMENS

## Power production in icy conditions



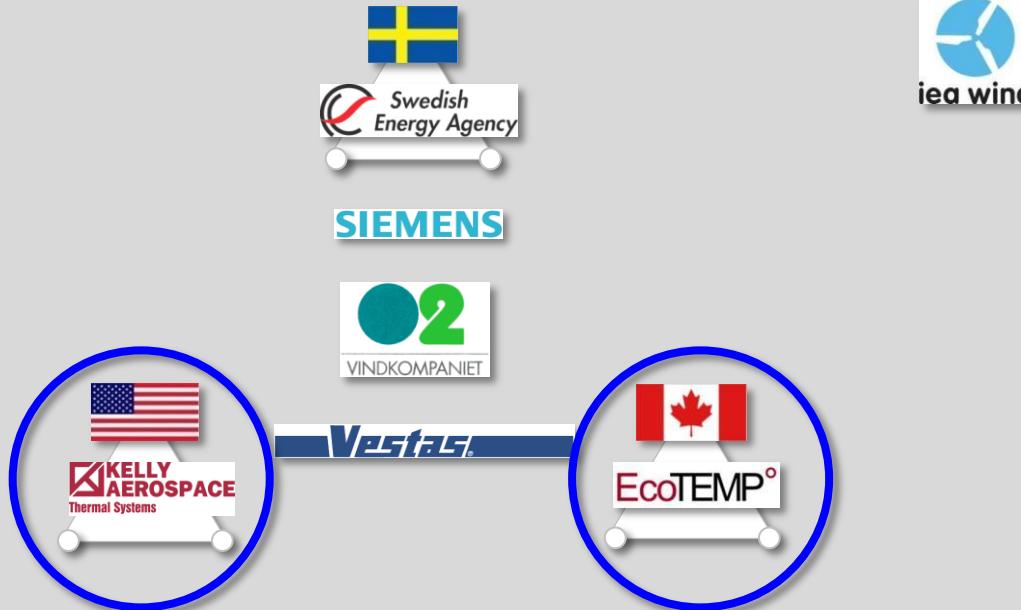
Page 13

February 2012

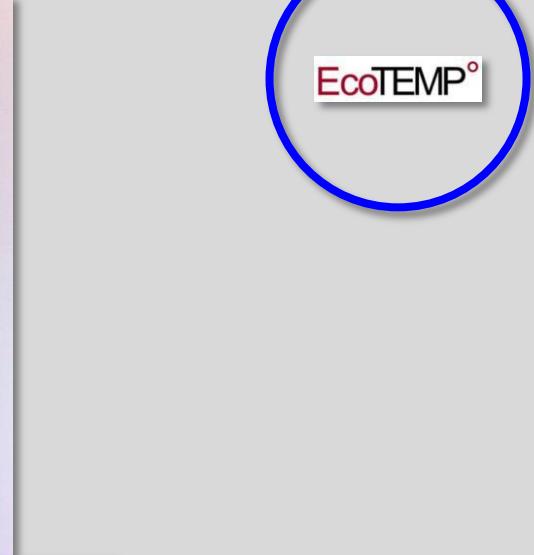
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# International participation in O2 Vindkompaniet's wind pilot project











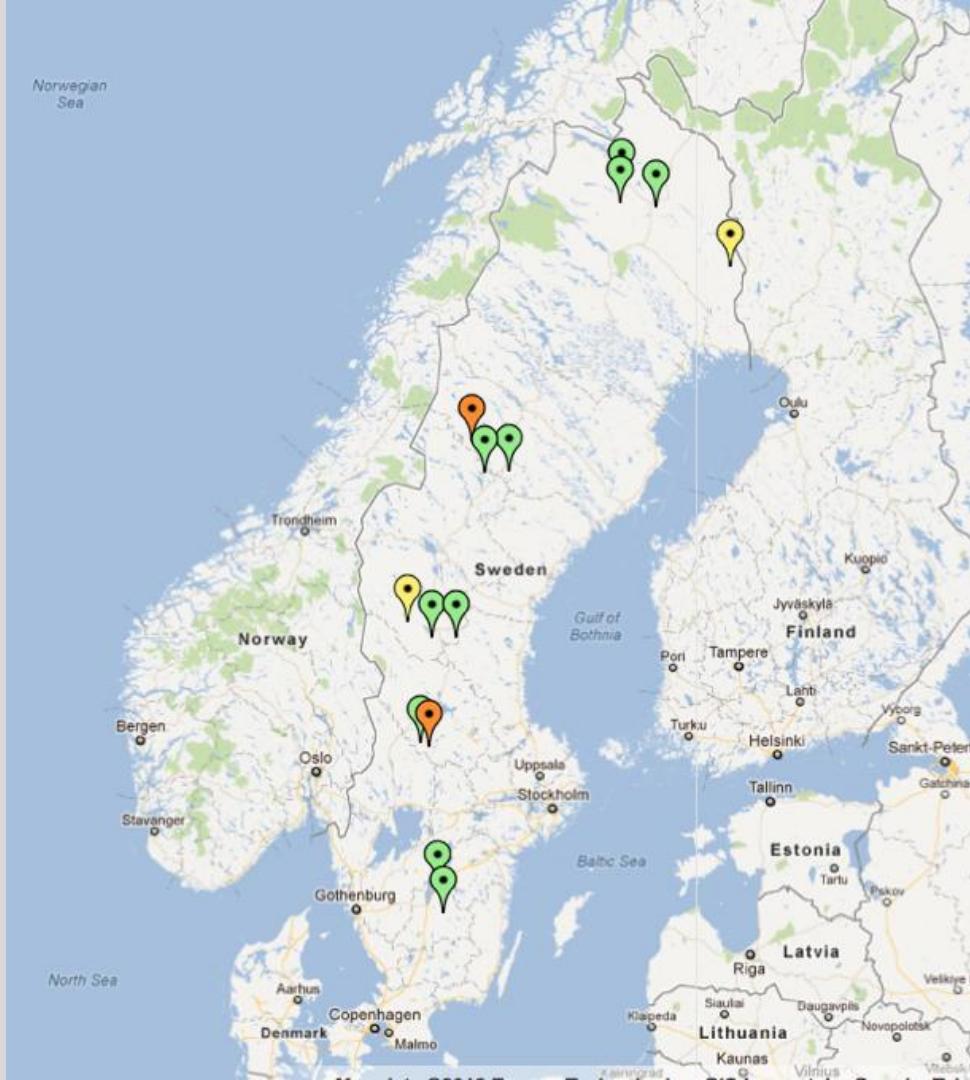


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O2's wind pilot project – Large-scale cost-effective wind energy development in icing climates • Göran Ronsten, O2 Vindkompaniet • Winterwind 2012• Skellefteå • Feb 7-8, 2012

Mapping of  
icing requires  
verification



Icing  
measurements  
are ongoing

# International participation in O2 Vindkompaniet's wind pilot project



## Metrology installation on the nacelle

Metrology test station mounted at Korpfället and Brahehus together with O2, IKEA and Gören Ronsten (Project manager on behalf of O2)

To learning and adjust the turbine controller for operating more efficient to improve energy production in cold climate



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# Equipment used on WT



Ice detector, ice load, met sensor

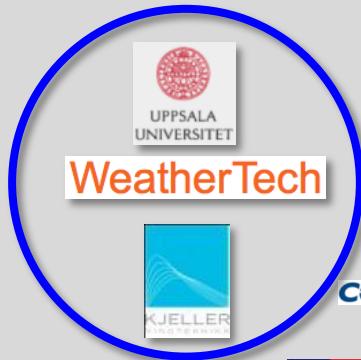
Long boom for WS

COMBITECH

# & in the masts (13 stations)



# International participation in O2 Vindkompaniet's wind pilot project



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COMBITECH



KELLY  
AEROSPACE  
Thermal Systems

Vestas



LEADING EDGE ATMOSPHERICS, LLC

FINNISH METEOROLOGICAL INSTITUTE



SMHI



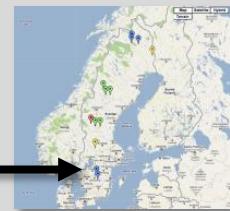
EcoTEMP°

	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

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



**Example:**  
 Number of  
 hours of icing  
 intensity  $> 10\text{g/h}$ ,  
 Nässjö



Site	max ice load kg/m	act icing hours no
Brahehus	0.7	167
Nässjö	0.9	184
Kiruna	0.7	154
Luongastunturi	1.2	357
Sjisjka	0.7	120
Bliekevare	1.2	240
Tåsjö	1.3	211
Sveg	0.9	244
Glötesvälen	3.1	619
Aapua	2.7	902
Röberg	2.5	640

**Example:**  
 Sum of monthly values,  
 201009-201104 Act icing hours: No of hours with icing intensity > 10g/m/h



## Example: Calculated and observed energy production in Dec 2011 on Aapua

Site	T <sub>mean</sub>	T <sub>min</sub>	T <sub>max</sub>	U <sub>mean</sub>	U <sub>max</sub>	Load <sub>avg</sub>	Load <sub>min</sub>	Load <sub>max</sub>	Rate>10	PwrPot PwrCln	PwrObs PwrIced	%LossObs %LossCln
AAPUA <sup>1</sup>	-	-	-	7.6	19.1	-	-	-	-	506	652	22.4%
671	-4.8	-16.5	0.9	8.1	18	2	0	7.7	279(42%)	729	593	18.7%

Table 3a: Subset of Table 2 for AAPUA.



## Example: Calculated and observed energy production in Dec 2011 on Aapua

SMHI

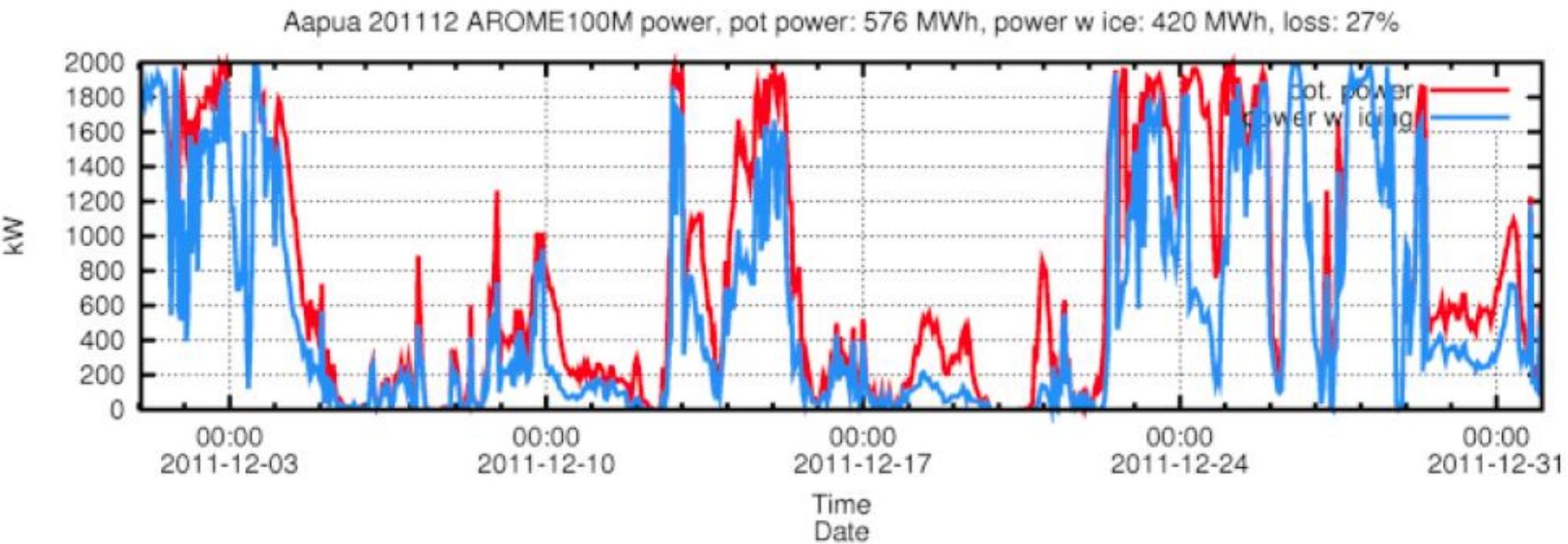


Figure 77. Ideal power production (red) and power production with ice (blue) (kW) at Aapua.

# International participation in O2 Vindkompaniet's wind pilot project



# International participation in O2 Vindkompaniet's wind pilot project





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

**Aim: Shorten the  
construction  
period**



Teknikgruppen AB

**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**



Teknikgruppen AB

**Prefabricated  
gravity foundation  
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**Aim: Shorten the  
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period**

**Structural  
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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**



# Large Scale, Cost Effective Wind Energy Deployment in Icing Climates

Welcome to O2's  
wind pilot project seminar

Sep 16, 2011, Elite Hotel Marina Tower,  
Stockholm

Internal

# Recap and kick-off 2011

09:00-09:30	Welcome, participants, background O2's current activities	Göran Ronsten Sónia Liléo, Kristina Lindgren
09:30-10:00	The foundation	Sten Forsström, SWECO
10:00-10:15	Ice measurement systems, portal	Mikael Töyrä, Jenny Ericson, Combitech
10:15-10:30	Ice measurement systems	Bengt Norén, Björn Östberg, In Situ
<b>10:30-10:45</b>	<b>Coffee</b>	
10:45-11:15	Weathertech	Stefan Söderberg
11:15-11:45	Kjeller Windteknikk	Erik Nordborg
11:45-12:15	Siemens de-icing	Finn D. Madsen
<b>12:15-13:15</b>	<b>Lunch ...</b>	



# Wind energy aerodynamics - icing and de-icing of WT blades

Welcome to an O2  
wind pilot project seminar

Sep 5 & 6, 2011, KTH and Chalmers (SWPTC)

External

# Wind energy aerodynamics - icing and de-icing of WT blades

**09:00-10:00** Cross-pollination of aircraft icing and wind turbine icing technologies,

**Prof. Wagdi Habashi**, Director, CFD Lab, Department of Mechanical Engineering, McGill University

NSERC-J-Armand Bombardier-Bell Helicopter-CAE Industrial Research Chair of Multidisciplinary CFD

Pratt&Whitney Canada Research Fellow, Editor-in-Chief, International Journal of CFD

**10:00-10:20** Challenges using composites in large rotor blades in arctic

environment, **Sören Nilsson**, Swerea SICOMP AB

**10:20-10:40** CFD in icing and deicing of WT, risk assessment of ice throw, increased noise due to iced up blades and cylindrical sound propagation, **Prof. Laszlo Fuchs**, KTH

**10:40-11:00 Pause**

**11:00-11:20** Detailed national mapping of icing, influence from icing on wind energy production and the benefits of forecasting of icing to improve profitability

**Øyvind Byrkjedal**, Kjeller Vindteknikk ...

<http://www.chalmers.se/ee/swptc-en/events/previous-events/wind-energy-aerodynamics>



# Thank you!

