INTERNATIONAL ENERGY AGENCY

Implementing Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems
ANNEX XI

48^{th} IEA Topical Expert Meeting

Operation and Maintenance of Wind Power Stations

Madrid, Spain, May 2006
Organised by: CIEMAT

Scientific Co-ordination:
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For more information about IEA Wind see www.ieawind.org

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Topical Expert Meeting #48

Operation and Maintenance of Wind Power Stations

TASK 11
BASE TECHNOLOGY INFORMATION EXCHANGE

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The objective of this Task is to promote wind turbine technology through cooperative activities and information exchange on R&D topics of common interest. These cooperative activities have been part of the Agreement since 1978.

The task includes two subtasks. The objective of the first subtask is to develop recommended practices for wind turbine testing and evaluation by assembling an Experts Group for each topic needing recommended practices. For example, the Experts Group on wind speed measurements published the document titled “Wind Speed Measurement and Use of Cup Anemometry”.

The objective of the second subtask is to conduct joint actions in research areas identified by the IEA R&D Wind Executive Committee. The Executive Committee designates Joint Actions in research areas of current interest, which requires an exchange of information. So far, Joint Actions have been initiated in *Aerodynamics of Wind Turbines, Wind Turbine Fatigue, Wind Characteristics, Offshore Wind Systems and Wind Forecasting Techniques.* Symposia and conferences have been held on designated topics in each of these areas.

In addition to Joint Action symposia, Topical Expert Meetings are arranged once or twice a year on topics decided by the IEA RD&D Wind Executive Committee. One such Expert Meeting gave background information for preparing the following strategy paper “Long-Term Research and Development Needs for Wind Energy for the Time Frame 2000 to 2020”. This document can be downloaded from source 1 below.

Since these activities were initiated in 1978, more than 60 volumes of proceedings have been published. In the series of Recommended Practices 11 documents were published and five of these have revised editions.

All documents produced under Task XI and published by the Operating Agent are available to citizens of member countries from the Operating Agent, and from representatives of countries participating in Task XI.

More information can be obtained from:

1. www.ieawind.org
2. http://www.ieawind.org/summary_page_xi.html

February, 2006

INTRODUCTORY NOTE

IEA TOPICAL EXPERT MEETING 48

ON

OPERATION & MAINTENANCE OF WIND TURBINE SYSTEMS

Marco A. Borja
Electrical Research Institute, Mexico

Background

Wind power is considered today as a mature industry. Nowadays, the majority of wind turbines used for the commercial generation of electricity, operate at acceptable levels of availability at most wind farms, especially those installed on land. Experiences with offshore turbines are hardly available but the first wind farms show figures of 90% or even lower. Over the last ten years, the investment costs for wind farms have been decreasing, as the trend in developing larger wind turbines brings as a consequence economies of scale. Therefore, the operation and maintenance cost of wind farms has become a significant component of the levelized production cost of electricity from wind energy (around 25 % in some cases, for offshore even more). Besides, wind power is moving towards the installation of wind farms in hostile environments (e.g., complex terrains, off-shore, special wind regimes). On one hand, heavy-duty wind turbines have been developed for applications in hostile environments; but on the other hand, preventive and corrective maintenance requirements could be increasing.

It is clear that the practices on O&M of wind turbines have a significant effect on the profitability of any wind farm. While investment and financial costs of a wind power project can be well known, O&M costs have to be projected over the entire life of the wind farm. Disregarding energy policy uncertainty, O&M costs becomes the most uncertain factor with regard to the economic success of a wind power project. Besides, there is a number of technical issues that entail specific best practices on operation (e.g., shutting down a wind farm when the wind speed exceeds the wind turbines' wind speed output). Therefore, in order to guarantee the profitability of wind power projects and to eliminate some adverse technical effects, emphasis is required on efforts aimed at lowering the O&M costs of wind farms.

Existing strategies for O&M are mainly based on experiences from other types of electricity production units. However, wind power plants require adoption of new methods and technologies as well as taking care of the challenges performing work in an unfamiliar environment especially off-shore.

Research and Development work related to wind power plants has so far been limited, except for information presented by Rademakers et.al.[1]. Their conclusion is that O&M approaches can be improved with R&D efforts, especially offshore. Examples of this are:

- demonstrate the added value of condition monitoring
- develop algorithms for predicting the remaining lifetime of components
- probabilistic cost modeling for the quantification of risks and uncertainties
- develop tools for better planning of O&M, that make use of operating experience (failure data) logistic information (availability of access systems, crew, spare parts, etc.) and weather forecast (for planning of maintenance actions and for predicting energy output and limiting unbalance).
- collect, analyze, and report operational experiences centrally and make information available for e.g. developers and investors to better estimate the risks related to O&M.

Industrial activities should (and do!) focus on improving the design and reliability of the turbines and on improving the accessibility of the turbines, even under harsh wind and wave conditions.

Present cost figures for O&M are reported in the range of 0.4-0.7 €cent/kWh for new turbines. Much higher values are indicated for lifetimes exceeding 10 years. Wind turbines of today are usually sold with service during the first 5 years. This is a business opportunity for the manufacturer, but may result in difficulties for the owner to see the actual cost for O&M which is required in the future. On the other hand it gives the owner reliable information of the near time cost.

Objectives

To hold a symposia meeting to discuss and gather information on:

- overview of existing knowledge and experience on economic and technical issues, regarding the O&M of wind farms
- overview of potential benefits from diverse elements targeted to reduce O&M costs as well as eliminating adverse technical effects
- challenges off-shore compared to on-shore work
- O&M strategies
- effects of preventive and corrective maintenance
- identify RD&D topics needed in order to lower O&M costs

Expected Outcomes

- Compilation of the most recent information on the topic
- Input to define IEA Wind RD&D’s future role in this topic

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[1] Rademakers L. W. M. M. et al, R&D Needs for O&M of Wind Turbines, http://www.ecn.nl/docs/library/report/2003/rx03045.pdf

Intended Audience

The national members will invite potential participants from research institutions, utilities, manufacturers and any other organizations willing to participate in the meeting by means of presenting proposals, studies, achievements, lessons learned, and others. This means then that the symposia will be wide open, taking into account that it is the first time that this subject will be discussed within the framework of the IEA Wind RD&D.

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B9 Energy O&M

Total Wind Farm Management

Welcome to B9 Energy O&M Ltd

Worlds first…

B9 Energy O&M Ltd is a leading wind farm operation and maintenance company, and the worlds first to achieve Integrated Management System accreditation to ISO 9001, ISO 14001 and compliance with OHSAS 18001.

B9 Energy O&M Ltd was formed in 1994 for the purpose of providing operation, maintenance, administration and general management services to developers and owners of wind farms. This was a logical evolution from the successful development work undertaken by its sister company, B9 Energy Services Ltd. The company is totally committed to renewable energy industries that are projected to show significant growth throughout the world over the coming years.

The organisation currently manages, operates and maintains wind farms in Northern Ireland, the Republic of Ireland, England, Scotland and Wales. Within the next few years the organisation is committed to undertaking the operation and maintenance of offshore sites as well as wind farms outside of the UK and Ireland. The organisation is currently in the process of establishing operations in North America.

We can offer full operation and maintenance services for completed plant throughout the UK, Ireland and north America. This work also involves general asset management, public relations and administration of wind farms.

"One-stop solution"

The company's philosophy is to offer the wind farm owner a "one-stop shop" solution to their O&M needs. This approach removes the complication of subcontracted responsibilities and ensures that the owner receives the "full story" in respect of any technical problems, which may arise from time-to-time.

B9 Energy O&M Clients

Based upon the guarantee of a professional service, we have experienced rapid growth and are currently contracted to operate, maintain and manage 533 turbines capable of generating up to 369.27MW.

With clients including ScottishPower and E.on, B9 Energy O&M Ltd is proficient at meeting the high standards required by major power companies.

Since August 2005 the company has been representing Spanish manufacturer Gamesa in the UK and Ireland carrying out service and maintenance work on their turbines during the warranty periods.

B9 Energy Client Base

England: 9 Sites

Site	Owner	Turbine Type	Turbine Capacity	No. of Turbines / MW	Start Date
Carland Cross Cornwall	Scottish Power	Vestas / WinDane WD34	400kW	15 (6MW)	June 2004
Coal Clough West Yorkshire	Scottish Power	Vestas / WinDane WD34	400kW	24 (9.6MW)	June 2004
St Breock Cornwall	E.on	Bonus	450kW	11 (4.95MW)	Feb 2005
Ovenden Moor West Yorkshire	E.on	Vestas / WinDane WD34	400kW	23 (9.2MW)	April 2005
Royd Moor West Yorkshire	E.on	Bonus	500kW	13 (6.5MW)	May 2005
Siddick Cumbria	E.on	Vestas V42	600kW	8 (4.8MW)	May 2005
Oldside Cumbria	E.on	Vestas V42	600kW	8 (4.8MW)	May 2005
Lowca Cumbria	E.on	Vestas V47	660kW	7 (4.62MW)	May 2005
Askham Cumbria	E.on	Vestas V47	660kW	7 (4.8MW)	June 2005
Coldham Cambridgeshire	ScottishPower	Vestas V80	2.3MW	8 (18.3MW)	Sept 2005
				124 (73.57MW)	

Scotland: 5 Sites

Site	Owner	Turbine Type	Turbine Capacity	No. of Turbines /MW	Start Date
Beinn an Tuirc Kintyre	Scottish Power	Vestas V47	660kW	46 (30MW)	Aug 2001
Deucheran Hill Kintyre	E.on	Vestas V66	1.75MW	9 (15MW)	Dec 2001
Cruach Mhor Cowal Peninsula	Scottish Power	Vestas V52	850kW	35 (29.75MW)	Feb 2004
Hare Hill East Ayrshire	Scottish Power	Vestas V47	660kW	20 (13.2MW)	Feb 2004
Dun Law Scottish Borders	Scottish Power	Vestas V47	660kW	26 (17.16MW)	Feb 2004
				136 (105.11MW)	

B9 Energy Client Base cont'd

Wales: 2 Sites

Site	Owner	Turbine Type	Turbine Capacity	No. of Turbines / MW	Start Date
Rhyd-y-Groes Anglesey	E.on	Bonus	300kW	24 (7.2MW)	May 2005
Tir Mostyn Wales	Gamesa	Gamesa G52	850kW	25 (21.25MW)	Aug 2005
				49 (28.45MW)	

Northern Ireland: 7 Sites

Site	Owner	Turbine Type	Turbine Capacity	No. of Turbines /MW	Start Date
Rigged Hill Co Antrim	Scottish Power	Nordtank 500 \ 37H	500kW	10 (5MW)	Nov 1994
Corkey Co Antrim	Scottish Power	Nordtank 500 \ 37H	500kW	10 (5MW)	Nov 1994
Elliott's Hill Co Antrim	Scottish Power	Vestas V39	500kW	10 (5MW)	Nov 1994
Bessy Bell Co Tyrone	E.on	Vestas V39	500kW	10 (5MW)	Mar 1995
Slieve Rusden Co Fermanagh	Quinn Concrete	Vestas V39	500kW	10 (5MW)	Dec 1997
Lendrum's Bridge Co Tyrone	RES	Vestas 47	660kW	20 (13.2MW)	Jan 2000
Altahullian Co L'Derry	RES	Siemens (Bonus)	1.3MW	20 (26MW)	June 2003
Callagheen Co Fermanagh	ScottishPower	Siemens (Bonus)	1.3MW	13 (16.9MW)	Dec 2005
				103 (81.1MW)	



B9 Energy Client Base cont'd

Republic of Ireland: 11 Sites

Site	Owner	Turbine Type	Turbine Capacity	No. of Turbines / MW	Start Date
Barnesmore Co Donegal	Scottish Power	Vestas V42	600kW	25 (15MW)	May 1997
Cark Co Donegal	RES	NEG Micon 600	600kW	25 (15MW)	Dec 1997
Beennageeha Co Kerry	RES	Vestas V47	660kW	6 (3.96MW)	Oct 2000
Milane Hill Co Cork	RES	Vestas V47	660kW	9 (5.94MW)	Oct 2000
Black Banks Co Leitrim	Waterfern	Vestas V52	850kW	4 (3.4MW)	Aug 2001
Drumlough Hill Co Donegal	Ecowind	Vestas V42	600kW	8 (4.8MW)	Feb 2004
Meenadreen Co Donegal	Ecowind	Vestas V52	850kW	4 (3.4MW)	Feb 2004
Arigna Co Roscommon	Ecowind	Vestas V42	600kW	8 (4.8MW)	Feb 2004
Largan Hill Co Roscommon	Ecowind	Vestas V47	660kW	9 (5.94MW)	Feb 2004
Moonetieve Co Leitrim	Gamesa	Gamesa G52	850MW	9 (7.65MW)	Aug 2005
Altagowlan Co Leitrim	Gamesa	Gamesa G52	850MW	5 (4.25MW)	Aug 2005
Geevagh Co Leitrim	Gamesa	Gamesa G52	850MW	6 (5.1MW)	Aug 2005
Anarget Co Leitrim	Saparito	Vestas V42	600kW	3 (1.8MW)	Dec 2005
				121 (81.04MW)	

B9 Energy Managed Sites

1.	Rigged Hill	10.	Milane Hill	19.	Cruach Mhor	28.	Siddick	37.	Callagheen
2.	Corkey	11.	Beinn an Tuirc	20.	Hare Hill	29.	Oldside		
3.	Elliot's Hill	12.	Deucheran Hill	21.	Dun Law	30.	Lowca		
4.	Bessy Bell	13.	Blacks Bank	22.	Ovenden Moor	31.	Moonetieve		
5.	Barnesmore	14.	Altahullion	23.	Royd Moor	32.	Altagowlan		
6.	Cark	15.	Drumlough Hill	24.	Carland Cross	33.	Rhyd-y-Groes		
7.	Slieve Rushen	16.	Meenadreen	25.	Coal Clough	34.	Tir Mostyn		
8.	Lendrum's Bridge	17.	Arigna	26.	St Breock	35.	Coldham		
9.	Beennageeha	18.	Largan Hill	27.	Askam	36.	Anarget		

The Services We Provide

B9 Energy O&M Ltd can ensure wind farm owners of the following:

- Engineering expertise in operating and maintaining a range of turbine designs and associated electrical equipment including HV/LV operation, maintenance and repairs
- Asset management which provides comfort to financiers by maintaining a rapid response time for plant faults, serial fault management and repairs
- Maintaining high availability and so maximising the owner's revenue, as well as extensive experience with data acquisition systems
- Clear, established procedures which meet Utility operational, health, safety and environmental standards
- High quality monthly reporting covering machine and financial performance, tailored to suit our clients' individual needs; which includes power curve analysis and an intelligent management information system
- Public relations, news, events and management skills, and a track record in enthusing local people

- A proactive and creative approach to problem solving, developing new ideas to enhance the value of the company's work
- Site communications, advice and trouble shooting including satellite, microwave and cell phone links.

Integrated Management System

In July 1999 B9 Energy O&M Ltd became the first wind farm company in the world to obtain accreditation to the International Environmental Management Standard ISO 14001. By July 2002 the company had risen to the challenge of triple certification, having consolidated ISO 9001:2000, ISO 14001:1996 and OHSAS 18001:1999 standards into an Integrated Management System (IMS).

The company continues to be the only wind farm operation and maintenance company in the world to have accreditation to all three standards.

Quality, value for money customer-focused service

The IMS is a demonstration of how the company delivers a quality, value for money customer-focused service. The philosophy behind the system is to keep it simple and applicable to all the company's activities, whilst meeting the technical and management requirements that a modern organisation demands. Internal controls and the development of successful strategies aim to address corporate, economic, social, environmental and health and safety responsibilities.

The IMS maximises the benefits achieved by the control of performance whilst optimising resource input. The system provides a framework which manages and controls the internal systems to ensure that our service is maintained at a satisfactory level to achieve the criteria set out for customer satisfaction.

The Policy Manual

The IMS is subdivided into several sections covering all of the company's activities. The Policy Manual outlines the Company's compliance with the standards and is structured around an adapted version of the Business Excellence Model (EFQM); it acts as a signpost document to other parts of the system.

The Management Procedures and Management Programme describe the contents of the system and how they are managed within the stated targets and objectives. The Operational Procedures and Work Instructions (also known as Safe Working Procedures or Method Statements) define the day-to-day activities of the company. A Register of Significant Impacts, which has been defined by risk assessments, details the current impacts of all the company's activities, whilst a Register of Regulatory Requirements details applicable statutory requirements specified by current legislation and regulations.

The system is audited both internally and externally to ensure that it continually meets the requirements of the international standards, the company and clients.

Contacts

If you have any questions regarding this brochure or queries regarding any aspects of B9 Energy O&M services please contact a member of our team for advice and information.

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Welcome to B9 Energy O&M

This presentation will provide information on the RCM2 services that
B9 Energy O&M offers to Wind Farm owners & developers

WIND POWER – RELIABLE, CLEAN AND INFINITE, LEADING THE WAY TO A LESS POLLUTED FUTURE

B9 Energy Group

- Fifteen years developing large wind farm projects in Ireland
- Manage, operate and maintain 39 wind farms across the British isles.
- Renewable Energy Systems are development partners in Ireland
- UK & Ireland's leading Wind Farm O&M company
- Only Wind Farm O&M company in the world to be accredited to ISO 9001, ISO 14001 and compliance with OHSAS 18001.

WIND POWER – RELIABLE, CLEAN AND INFINITE, LEADING THE WAY TO A LESS POLLUTED FUTURE

Historical View of Maintenance.

- First generation view up to the 1940's
- Fix it when it breaks

- Second generation view 1940's – 1970's
- Carry out scheduled overhauls to improve reliability & reduce costs.
- Work planning system

- Third generation view 1970's – 1980's (RCM)
- Condition monitoring
- Design for reliability and Maintainability
- Hazard studies
- Failure modes and effects analyses
- Multiskilling and Teamwork.

WIND POWER – RELIABLE, CLEAN AND INFINITE, LEADING THE WAY TO A LESS POLLUTED FUTURE

RCM as a tool to improve the performance of wind farms.

- RCM or Reliability Centred Maintenance is system of identifying the best way to operate and maintain plant and equipment.
- First developed for the Civil Aviation Industry in 1978 and has been under constant review ever since.
- Expanded to cover other industries since the early 1980's
- RCM 2 introduced in 1990 specifically for industries outside aviation.
- Goals of RCM2 are to improve reliability and reduce costs associated with maintenance
- "One-Stop Shop" solution to operational maintenance and management needs

WIND POWER – RELIABLE, CLEAN AND INFINITE, LEADING THE WAY TO A LESS POLLUTED FUTURE

What RCM achieves.

- Greater Safety and environmental integrity.
- Improved operating performance.
- Output, Product Quality and Customer service.
- Greater maintenance cost-effectiveness.
- Longer useful life of expensive items
- Better teamwork.

How RCM achieves its goals.

- Firstly: understand the assets function
- In a wind turbine its function is to capture energy from the wind and convert this into electricity.
- Secondly: understand how it does this.
- By converting the energy contained in the wind into rotation via the blades and hub and transmitting this rotational energy to a generator.
- Thirdly: understanding how it can fail to provide this function.
- It fails to convert wind energy into electricity

How RCM achieves its goals (cont).

- RCM provides a framework where it is possible to look at each individual component and how its failure will affect the turbines ability to perform its function.
- Within the framework a number of factors will be considered
- Safety & environmental consequences of the failure
- Cost of the failure.
- Cost of the repair.
- Cost of a scheduled task that may extend the life of the Component.

Patterns of Failure

- A  Traditional view with steady failure rate followed by a wear out zone. 4%
- B Bath tube curve. Infant mortality followed by constant failure ending in wear out zone. 2%
- C  Slowly increasing rate of failure with age. 5%
- D  Slow rate of failure when new followed by a constant rate of failure. 7%
- E  Random Failure no matter what age. 14%
- F  Infant mortality followed by a slow increase of random failure. 78%

Patterns of Failure (continued)

- These findings contradict the belief that there is always a connection between reliability and age.
- The belief that the more often an item is overhauled the less likely it is to fail is false.
- In fact scheduled overhauls can increase the failure rate due to "Infant Mortality" being introduced into stable systems.
- As a result of these findings, some organisations have abandoned "Proactive Maintenance" altogether.

Typical RCM example

- Analysis of Stall regulated 600kW WTG Transmission System.
- 2B4 Blade tip retaining cable failure due to fatigue
- Information Worksheet.
- Function: To capture power from the wind
- Functional failure: Fails to capture power from the wind
- Failure mode: Blade tip retaining cable fails due to fatigue
- Failure effects: Tip comes out & turbine faults with Vibration error or wind power measurement error.
- TTR: 2-7 days
- Manpower hours: 250
- Equipment: Cherry picker or Crane & man basket
- Cost of spare: £200
- Total cost of FE: £8500
- Proposed modification: Redesign of cable and reduce hydraulic pressure on cable.

Typical RCM example (Cont)

- From the RCM analysis of the total effects of the failure, it was deemed cost effective to carryout a redesign of this component and its operating parameters.
- The cable end was changed from a fabricated clevice to a forged clevice
- The hydraulic pressure applied to the cable was reduced from 106 bar to 84 bar.
- Result: No further failures of the cable since redesign.

Bottom Line:

- RCM has proved to be effective as a tool in helping to manage faults and their costs.
- It gives owners and operators a clear view of faults, their effects and the costs associated with failures.
- Allows the formation of an effective maintenance strategy

Summary

- We deliver increased value by recognizing the high cost of downtime. Our O&M team strives to keep each turbine operating and performing at optimum levels.
- B9 minimizes your operating costs and maximizes earnings through leverage of technology, state-of-the-art information systems, internationally accredited quality & safety standards and industry-effective competence.

WIND POWER – RELIABLE, CLEAN AND INFINITE, LEADING THE WAY TO A LESS POLLUTED FUTURE

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NORDEX : Worldwide Actor in Wind Energy

WTG manufacturer part of world leaders. Represents brands NORDEX and SÜDWIND.

More than 2500 WTGs running (more than 2400 MW)

About 800 employees

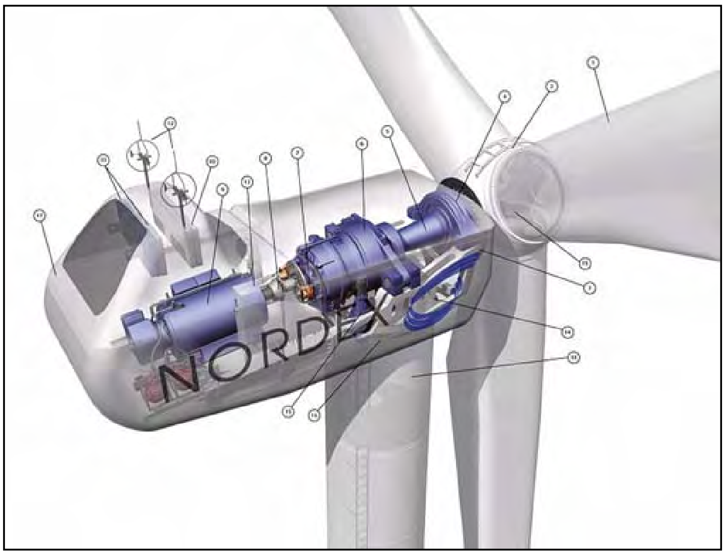
Production units in Denmark (Give), in Germany (Rostock) and in China (Beijing)

Worldwide subsidiaries (France, UK, Portugal, India, Brazil, Sweden, Japan, Italy, …)

Brief historic

- 1985 : Launching of the firm in Danemark, Large scale WTS connected to the grid
- 1992 : production units in Germany
- 1995 - 1996 : First WTS installed in France (Donzère, Lastours, Baie de la Somme)
- 2000 : Biggest onshore WTS available on the market (N80/2500 kW)

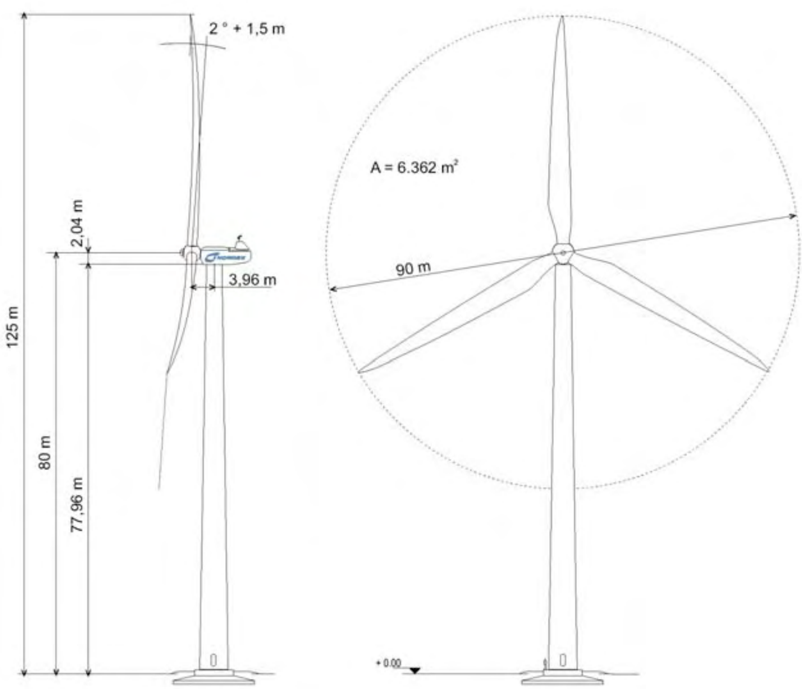
NORDEX N80 / N90



Rotor sweep m³)	5.025/6364
Output (kW)	2500 / 2300
In prod. since	2000/2002
Number comp.	108
Control type	pitch
Main markets today:	Germany, Scandinavia, Portugal, UK, France, Japan

N80 / N90 based on the same machine, but different blade length and regulations (control system)

NORDEX N80 / N90



NORDEX N90

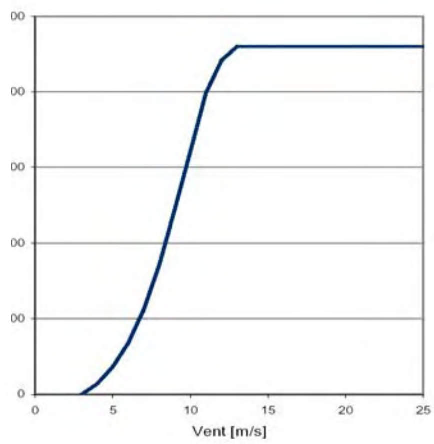
Blades : 45 m

Tower : 80 – 100 m

Rotor speed : 9,6 - 16,9 tr/mn

power : 2300 – 2500 kW

Cut in Wind Speed : 3 m/s



NORDEX : ACTIVITIES IN FRANCE

Office based in la Plaine-Saint-Denis
(43 employees) :

- Management and administration *(4 people)*
- Wind farm development *(10 people)*
- Sales *(3 people)*
- Project Management *(20 people)*
- Service Management *(6 people)*

Local Subdivisions
(20 technicians) :

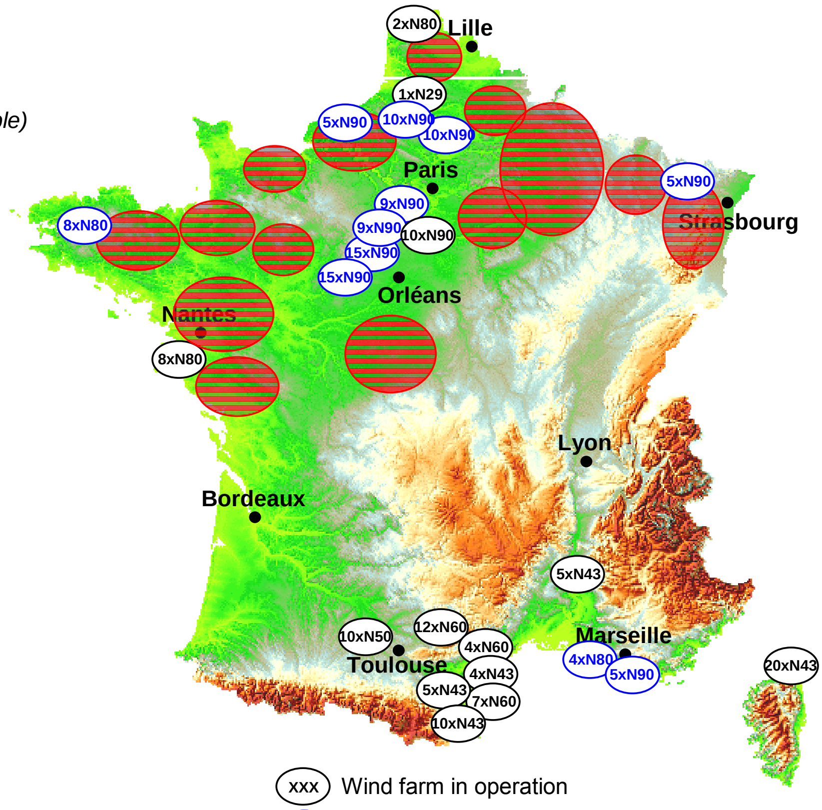
- Maintenance of Wind Farms

Growing resources

142 WTGs NORDEX in operation in France (210 MW)

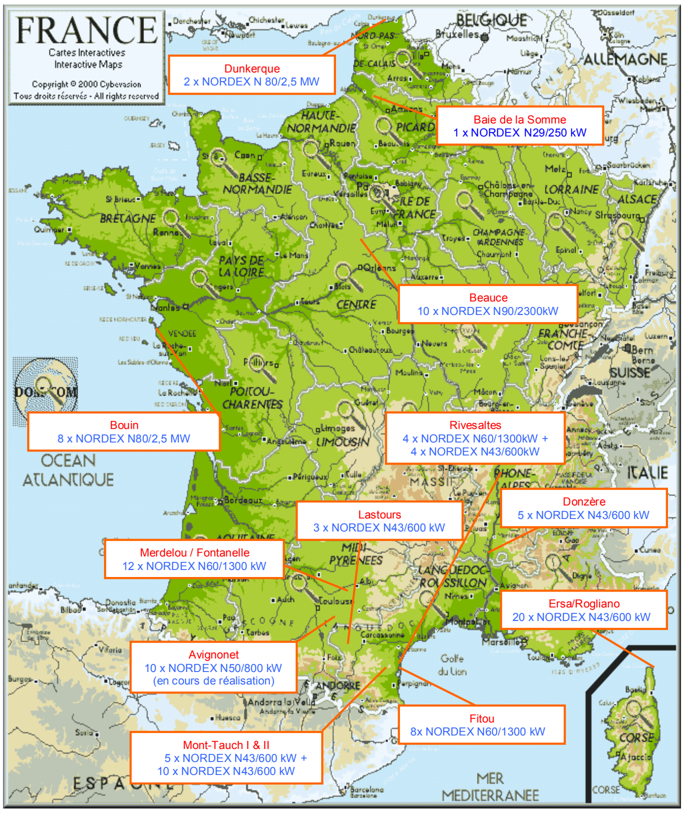
95 WTGs under construction in France (223 MW)

+ many project in development



xxx Wind farm in operation
xxx Wind farm under construction
Development zone

Nordex France History – Projects built



Situation in 12/2005:

- 1 x N29
- 47 x N43
- 10 x N50
- 24 x N60
- 10 x N80
- 10 x N90

102 turbines / 115,65 MW

(6 different types of WTG)

Nordex France – Resources Béziers

Fitou 8xN60

Rivesaltes 4xN43 4xN60

Donzère 4xN43

Lastours 3xN43

Merdelou / Fontanelle 12xN60

Avignonet 10xN50

Mont Tauch 15xN43

>>>>>

1 SC, 1 DP

7 technicians

Reminder: long distances…|___| 60km

Nordex France – Resources Bouin

BOUIN:

8 x N80 R60

>>>>

2 technicians for maintenance and technical operation

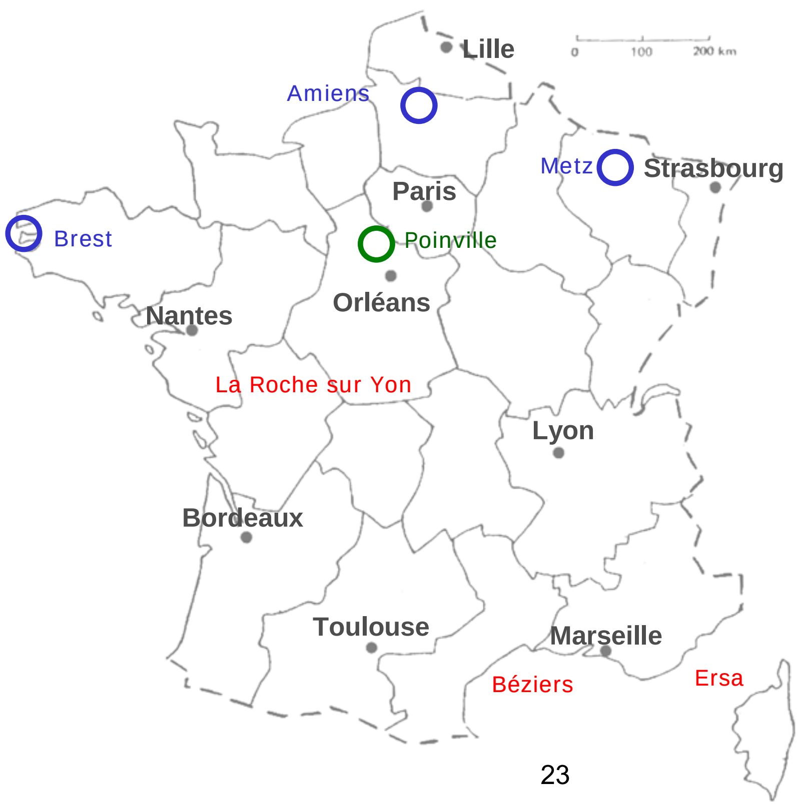
Nordex France – Resources Corsica

ERSA/ROGLIANO:
20 x N43 R40

>>>>

2 technicians for basic maintenance

Service Centres 2006

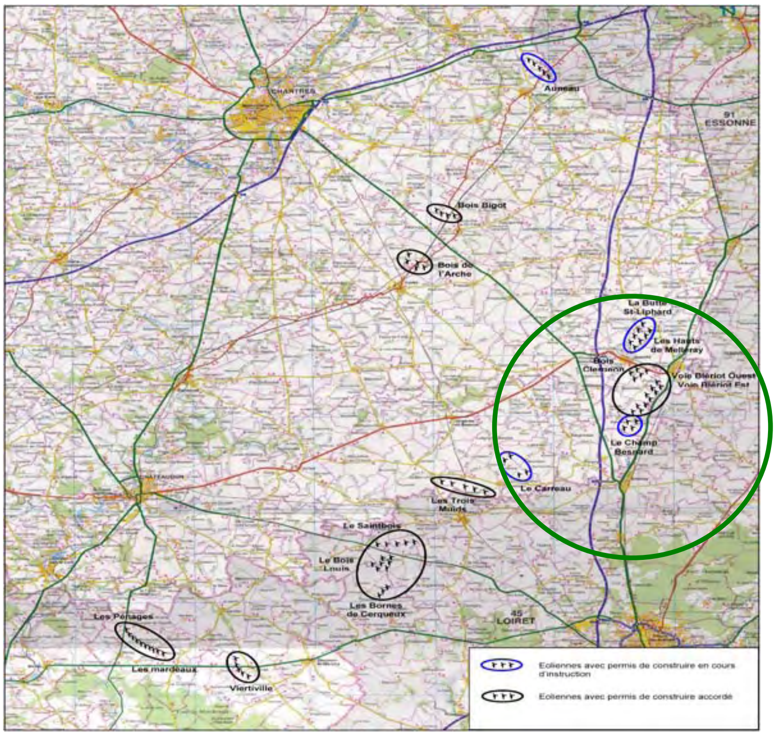


Existing :
- Béziers
- Ersa
- La Roche sur Yon

End 2005 :
- Poinville

Mid 2006 :
- Amiens
- Metz
- Brest

Example : Projects Beauce



Future
SC Poinville

NORDEX

Exploitation activities impacting project development (1)

Feedback and relation between operation and development activities in order to guarantee sustainability of wind energy

•Noise emission: problems with neighborhood giving a bad image of wind energy

➢*Better standards required in risk calculation*

• Landscape visibility: difficulties for social acceptance

➢*Nacelle design, architects and landscape designers involvements required*

NORDEX

Exploitation activities impacting project development (2)

- Wake effects: Problems in complex terrains
  - ➢*Standards?, Development of models?, CFDs?*
- Impacts of wind farms on radars: lack of experience and risk analysis
  - ➢*Global database on European experience?*
- Risk of fall of WTs or parts of wind turbines
  - ➢*European standards*
- Impact of WTGs on wildlife
  - ➢*Need of measurement, long term experience to predict impact on new Wind Farms*



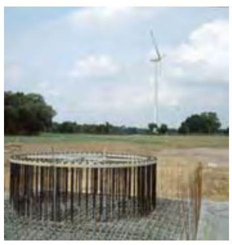

Exploitation activities impacting project development (3)

- Our experience could lead for the development to the following question :

=>Development of new sites that present strong but turbulent winds
- ➢*Interesting for upper energy productions*
- ➢*Reinforcement of the maintenance*

=>Development of new sites that present lower but more regular winds
- ➢*Less interesting regarding the energy production*
- ➢*Decreasing of the maintenance actions*



Operation and Maintenance Challenges

• Lower part of Corrective maintenance to more Preventive

➢*Better organization of work => lowering O&M Costs*

•Better adaptation of WTGs for maintenances interventions (ex. use of elevators)

➢*Capitalization of knowledge keeping technicians on long term*

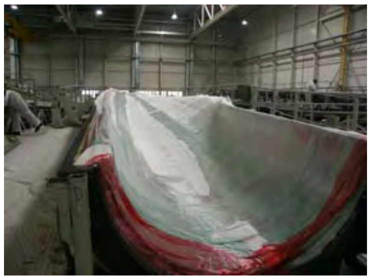
•Improve feedback of O&M to others activities (ex: design of WTGs, Project development, Research)

➢*Fluidity of information transfer and more communication*

NACELLE ASSEMBLING

BLADE MANUFACTURING






NORDEX

ERECTION



NORDEX


BACK

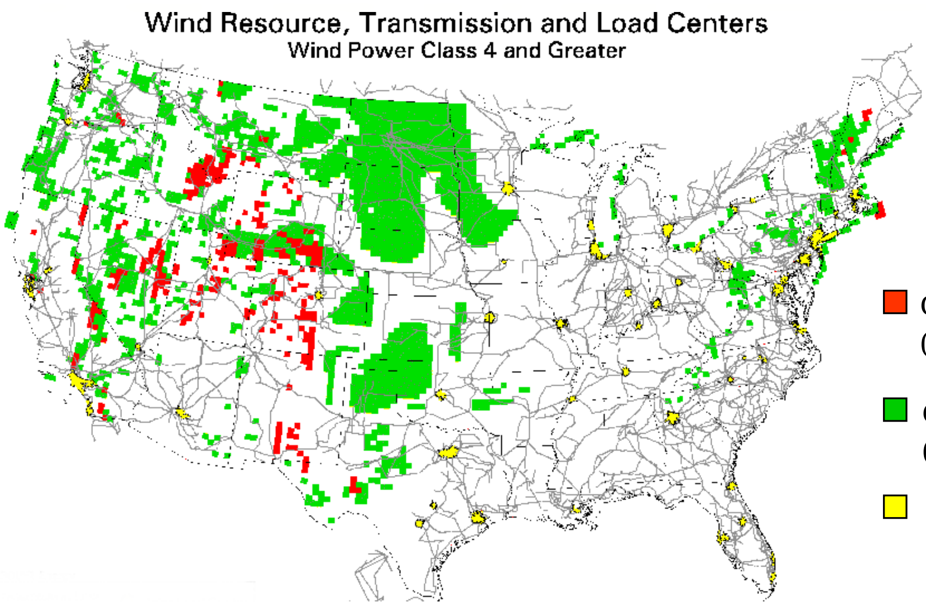
Background and Status of Wind Power O&M in the United States

Topical Experts Meeting on Operations and Maintenance of Wind Power Stations

Roger Hill
Sandia National Laboratories
rrhill@sandia.gov; 505-844-6111

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

U.S. Wind Resource



Class 6 (High Energy) Sites (6.4-7.0 m/s at 10m)

Class 4 (Good) Sites (5.6-6.0 m/s at 10m)

Load Centers

The U.S. National Wind Program

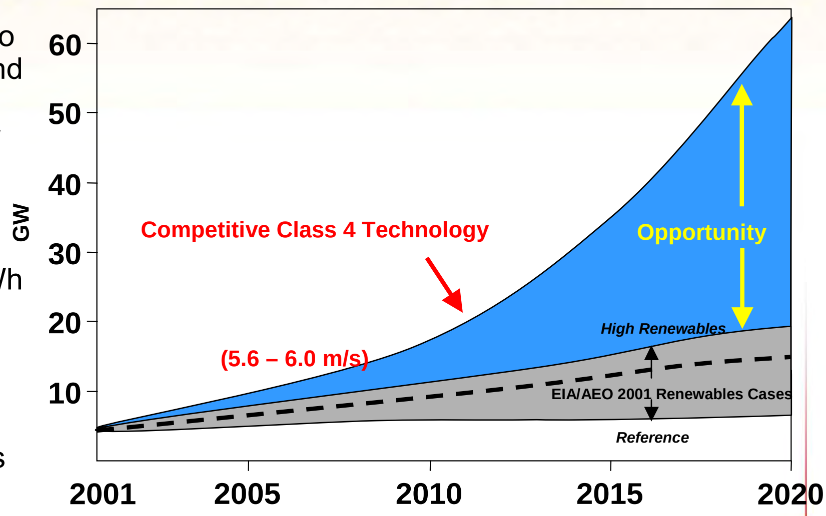
The program's mission is to:

- ***Lead the nation's efforts to improve wind energy technology***
- ***Work through public/private partnerships that enhance domestic economic benefit from wind power development, and***
- ***Coordinate with stakeholders on activities that address barriers to wind energy use.***

The U.S. National Wind Program Goals

- By 2007, reduce the cost of distributed wind systems to 10 to 15 cents per kWh in Class 3 wind resources.
- By 2010, facilitate installation of at least 100 megawatts of wind energy in 30 states.
- By 2012, reduce the cost in Class 4 winds to 3 cents per kWh for onshore systems or 5 cents per kWh for offshore systems.
- By 2012, complete program activities addressing:
  - electric power market rules
  - interconnection impacts
  - operating strategies, and
  - system

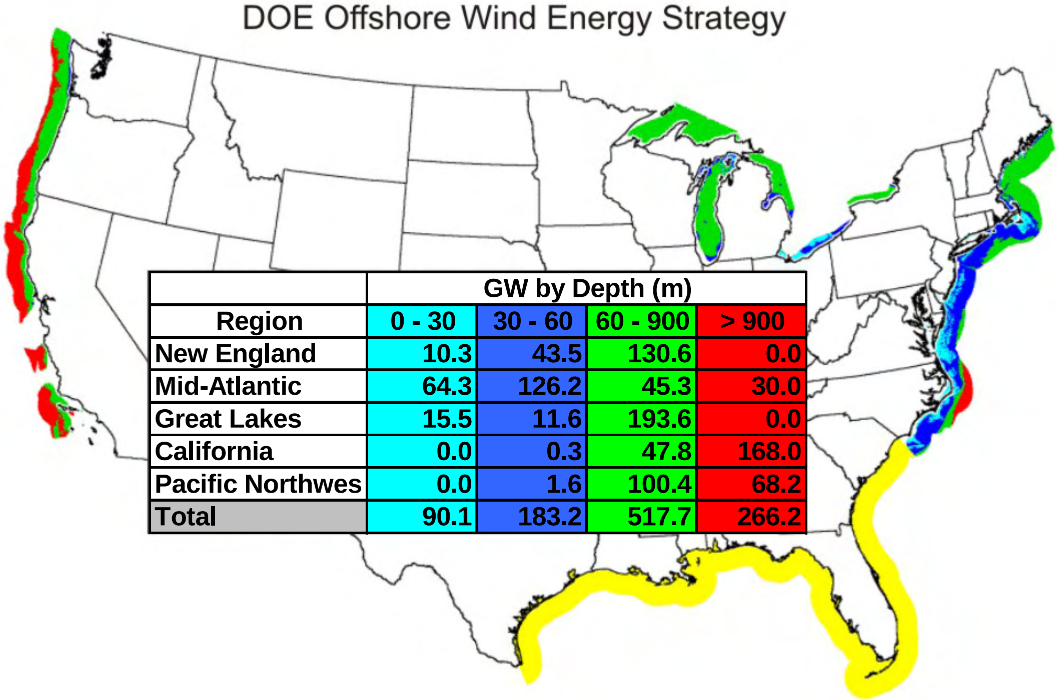
  needed for wind energy to compete without disadvantage to serve the Nation's energy needs.



Baseline (15 GW in 2020)
- No technology breakthrough
- *Class 6 Plateau*
- 6.4 – 7.0 m/s

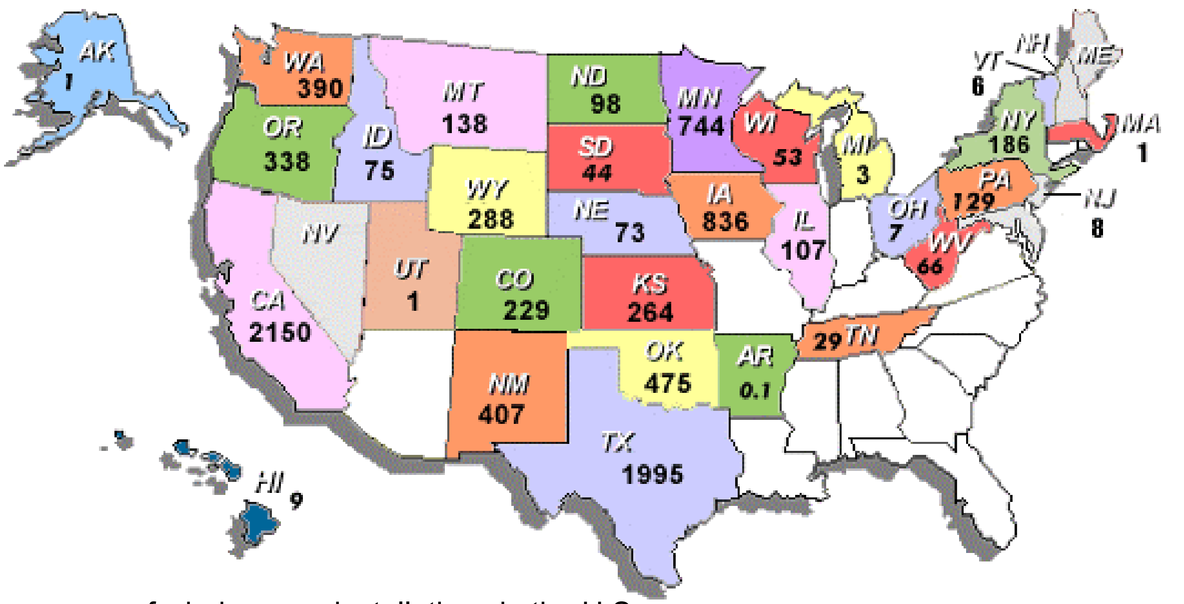
Offshore Resource Estimates

DOE Offshore Wind Energy Strategy



	GW by Depth (m)			
Region	0 - 30	30 - 60	60 - 900	> 900
New England	10.3	43.5	130.6	0.0
Mid-Atlantic	64.3	126.2	45.3	30.0
Great Lakes	15.5	11.6	193.6	0.0
California	0.0	0.3	47.8	168.0
Pacific Northwes	0.0	1.6	100.4	68.2
Total	90.1	183.2	517.7	266.2

Status of Wind Power in the US



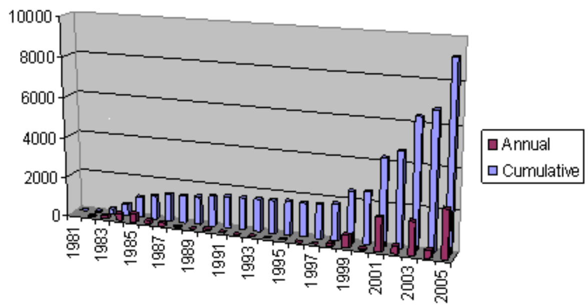
Leading owners of wind energy installations in the U.S.

Source: AWEA

#1 FPL Energy – 3,192 MW
#2 PPM Energy – 518 MW
#3 MidAmerican Energy – 360.5 MW
$4 Caithness Energy - 346 MV
#5 Edison Mission Group – 316 MW
#6 Shell Wind Energy - 315 MW

Manufacturers' Installed Capacity for the Past Five Years

2005	GE Energy 1,433 MW	Vestas 700 MW	Mitsubishi 190 MW	Suzlon 55 MW	Gamesa 50 MW
2004	GE Energy 171 MW	Mitsubishi 120 MW	Vestas 97 MW		
2003	GE Energy 903 MW	Vestas 359 MW	Mitsubishi 201 MW	NEG Micon* 129 MW	Gamesa 56 MW
2002	Vestas 175	NEG Micon* 98 MW	GE Energy 62 MW	Mitsubishi 61 MW	Bonus* 48 MW
2001	Vestas 653 MW	Enron Wind* 418 MW	Bonus* 278 MW	Mitsubishi 221 MW	NEG Micon* 119 MW



Source: AWEA

Sandia National Laboratories (SNL)

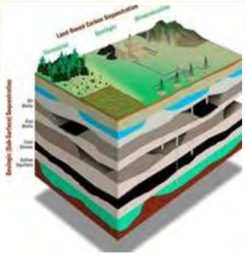
- **Multi-program research facility established in 1949**
- **Primarily funded by the U.S. Department of Energy (DOE)**

Albuquerque, New Mexico

Livermore, California

- **8600 full-time employees**
- **~$2.3 billion (€1.9 billion) annual budget**

Sandia Energy Programs



Technologies include Concentrating Solar Power, Photovoltaics, *Wind,* Geothermal, Energy Storage, Well Construction, Reservoir Evaluation and Production, Storage and Transmission, Energy and Water, Fuel Utilization

Sandia National Laboratories

Wind Energy Research at SNL

- **Began in the mid 1970's**
- **Initially focused on vertical-axis wind turbines**
- **Since 1993, the program has focused on industrial-sized horizontal-axis wind turbines (HAWT)**
- **Today , the focus is on HAWT blades**

Sandia National Laboratories

Sandia National Labs Research Focus

- ❖ Blades are the only uniquely wind-turbine component
- ❖ Blades capture all the energy
- ❖ Blades produce all the system loads

- SNL Blade Technology Research
  - Design innovations
  - Design tools
  - Materials & manufacturing
  - Sub-scale blade design & fabrication
  - Laboratory and field testing
  - Reliability

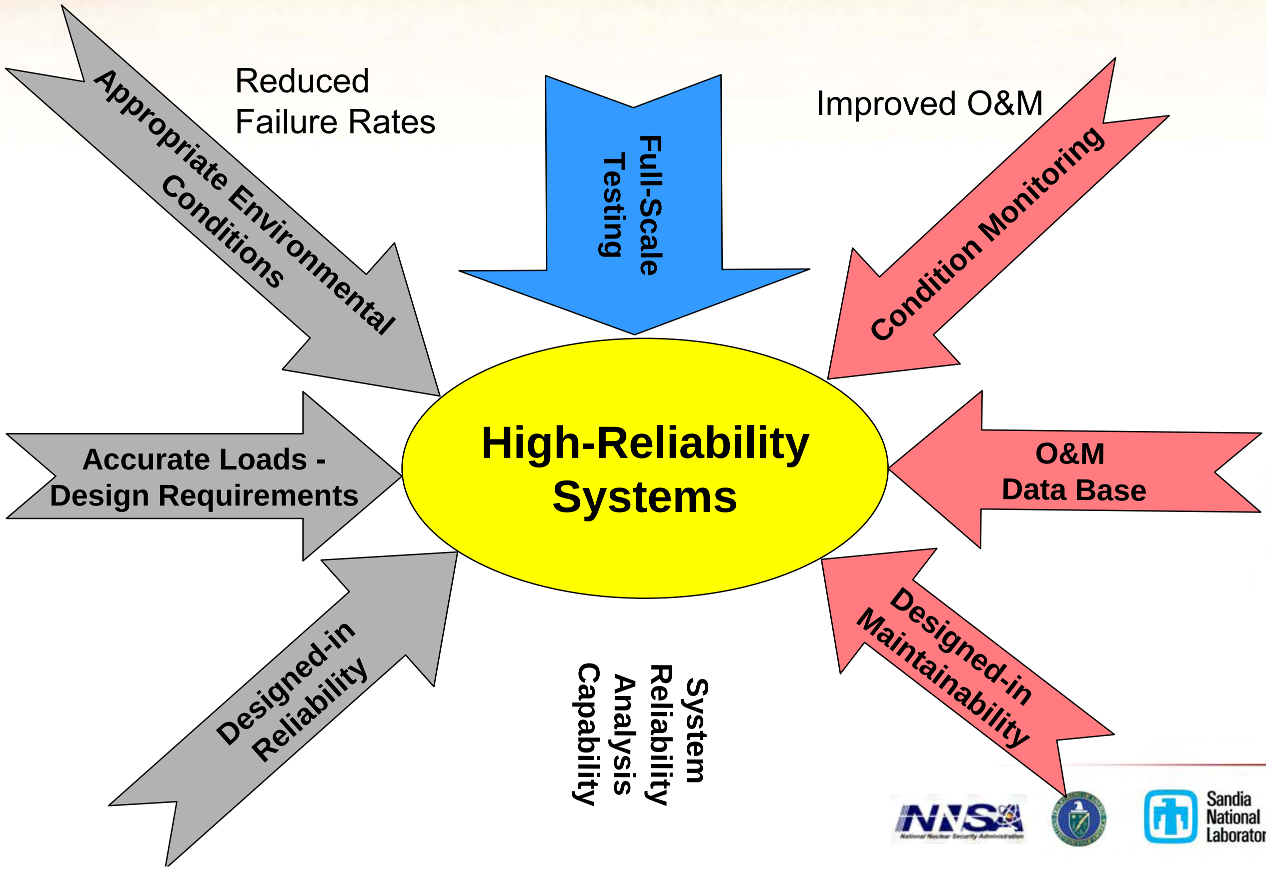
Reliability

Recognized Need for Improved Reliability

- Industry and others have acknowledged the importance of reliability in the continued growth and expansion of markets for wind turbine technology
- Critical for increasingly hostile environments such as off-shore and the impacts are broad, ranging from economics to advancement of designs.
- Increased efforts in reliability research and resultant R&D improvements to wind turbine design, operations, and maintenance

The value comes in having the opportunity to do something to prevent the failure from occurring…Thus prediction becomes part of the process of "designing the future"

What is Required to Develop High-Reliability Systems?



Goals for O&M/Reliability

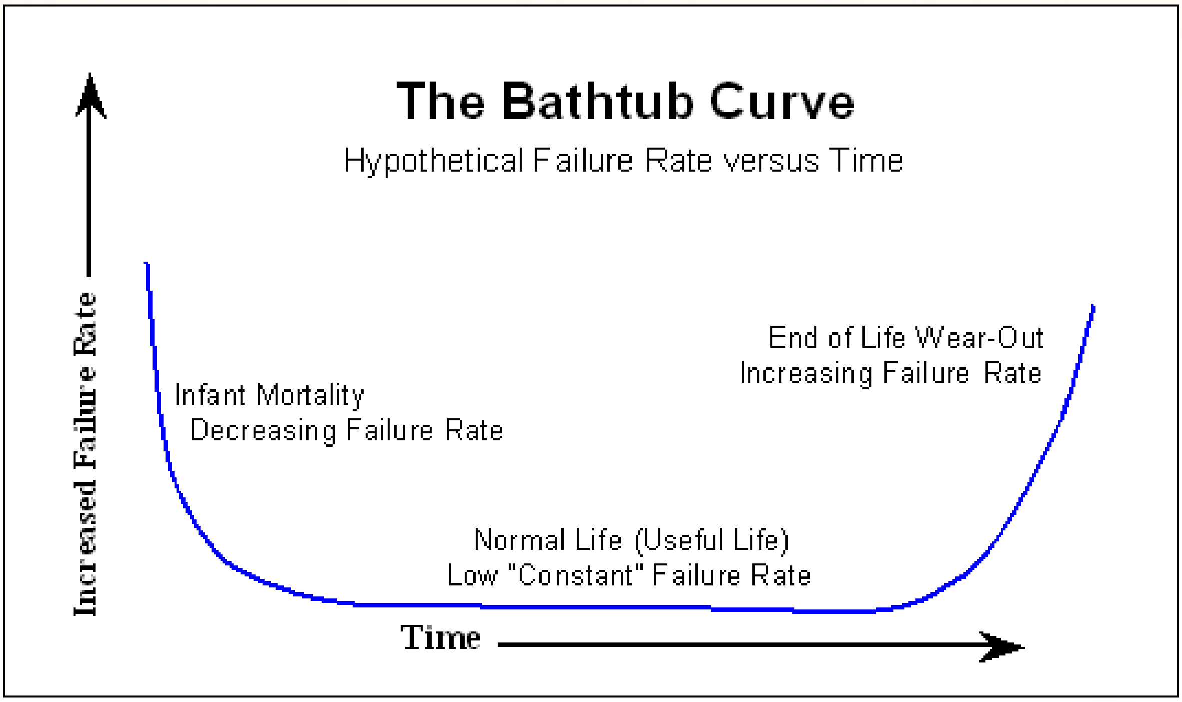
- Understand current O&M practices
- Reduce cost of O&M
- Increase fidelity of knowledge base (more complete knowledge of full operating condition of turbines and wind plant)
- Automate data interrogation and detection of abnormal operation
- Anticipate maintenance
- Optimize wind plant operation for site specific lowest COE
- Expand the concept and exploitation of condition monitoring
- Close the loop on the design process

Reliability Improvement Process

- **Reliability modeling is a long term activity involving testing or gaining new information, improving the reliability model, and improving system design**

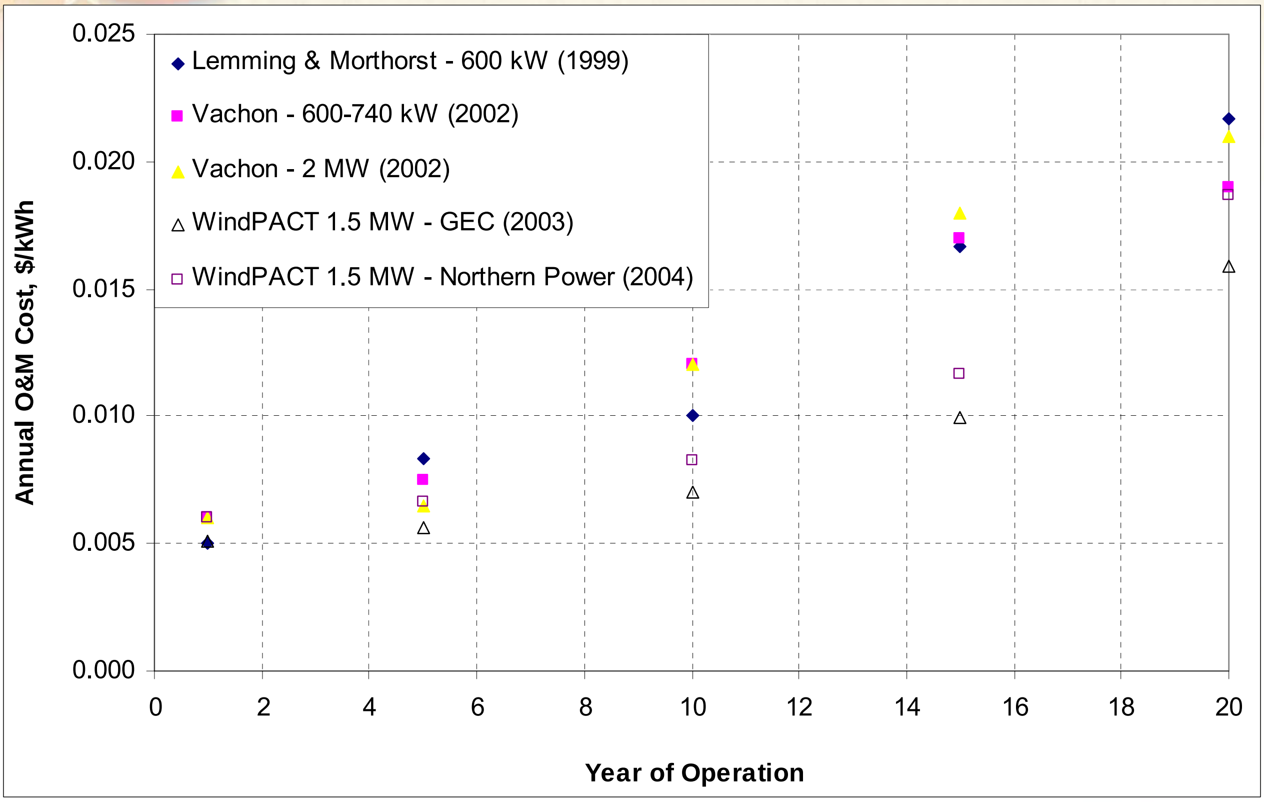
- **Reliability modeling:**
  - **Improves understanding of the system**
  - **Allows early evaluation of design alternatives**
  - **Identifies critical component failure modes and failure interactions**
  - **Guides resource allocations to parts of the system needing improvement**

Failure Rates



Source Weibull.com

Relative Cost of O&M?



SAND2005-5173

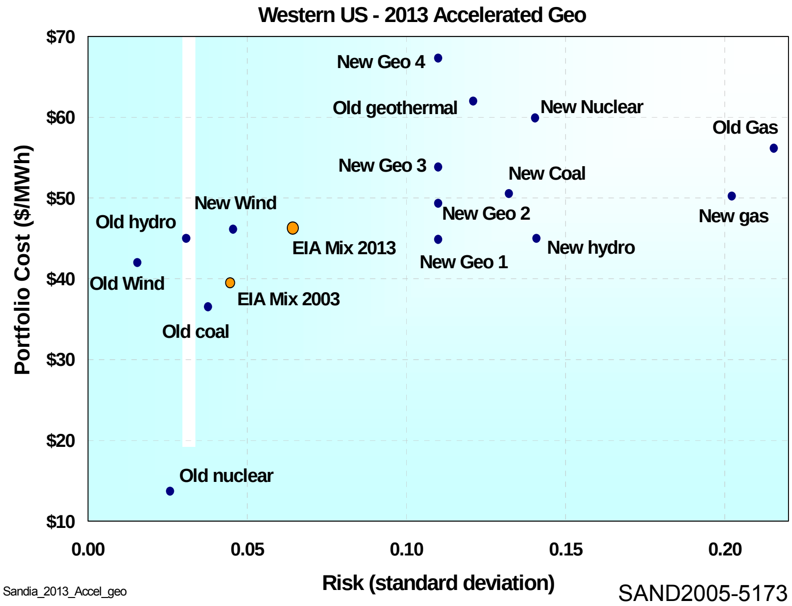
Reliability Modeling

Reliability assessments will have interfaces with all aspects of design, as well as O&M requirements and limitations, and life cycle costs

- **Initially, the system will be broken down into components, failures and understanding of failure modes and effects**
- **System reliability results are calculated using failures populated with real data**
  - **Recruit industry partners**
  - **Obtain data**
    - SCADA
    - Work Orders
    - Interviews
    - Maintenance steps/training
- **Results of model analysis include system mean time between failures, (MTBF), system mean time to repair (MTTR), availability, life cycle cost and sensitivity and uncertainty analyses**
- **Advanced stochastic techniques may be used**
- **This will be an iterative process with feedback throughout to partners**

Weighing Relative Risks Among the Technologies? The Western U.S. Region Generating Cost-Risk Trends

- 2013 EIA Mix has higher cost and risk relative to 2003
  - Driven by 32% demand increase, decommissioning existing plant, resource shortages and limitations on available options
- Move to larger gas/coal shares adds to portfolio cost and risk
  - Increases year-to-year expected volatility of generating costs



SAND2005-5173

- Renewables add Energy Diversity/ Security
- Wind and geothermal are ideally positioned to diversify the generating mix and reduce cost/risk

Summary

- The US Market is Growing
- Tremendous Wind Resource is available
- Sandia's Wind Energy Technology department conducts research in numerous areas to help achieve DOE goals and enable wide-spread utilization of wind energy
- Reliability is a Perceived Issue and Analysis Techniques will be Applied
- Reliability Workshop in September Will be Held with Stakeholders

Basic Research → Commercial Viability

IEA Topical Expert Meeting
”Operation and Maintenance of Wind Power Stations”
Madrid
May 9-10, 2006

Anders Andersson

VATTENFALL

Operation & Maintenance

Introduction

SCADA & Supervision

VATTENFALL

Intro

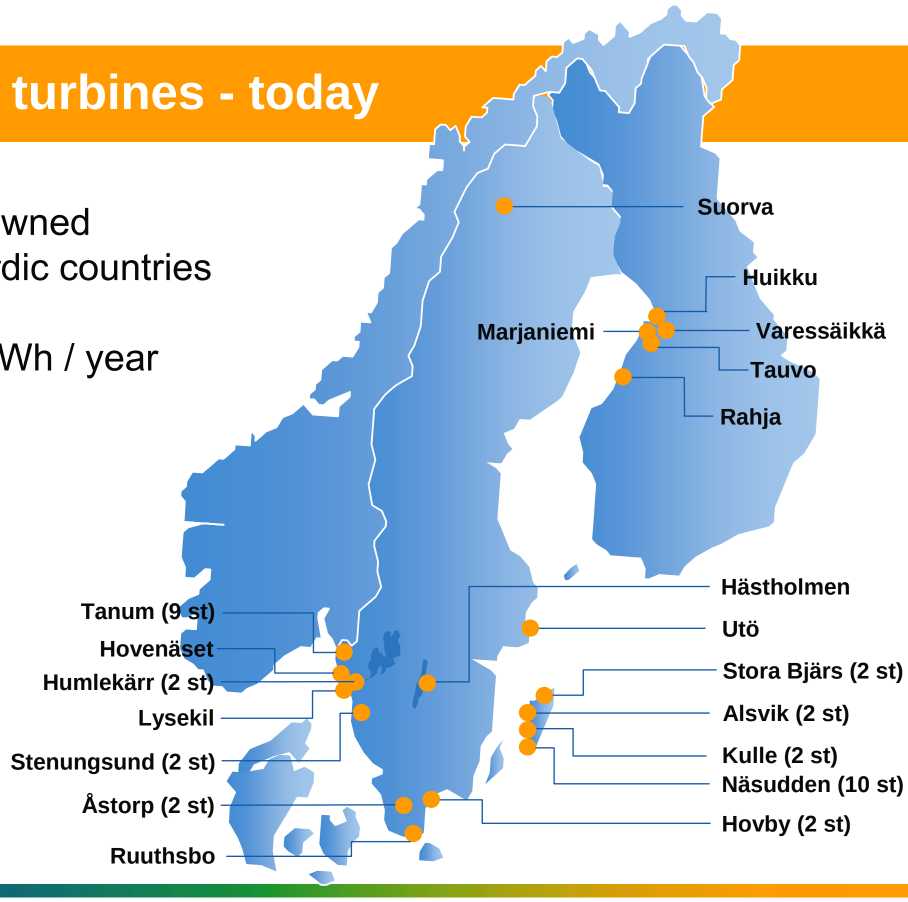
Anders Andersson
Working for Vattenfall with wind power since 1983

VATTENFALL

Vattenfalls wind turbines - today

49 full and partly owned
turbines in the Nordic countries

Production ~ 60 GWh / year



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Näsudden – Vattenfalls O&M center

Sigvards 2, 1000 kW

Sigvards 1, 1000 kW

Näsudden II, 3000 kW

3 persons
Supervision
Operation
Maintenance

VATTENFALL

Näsudden II

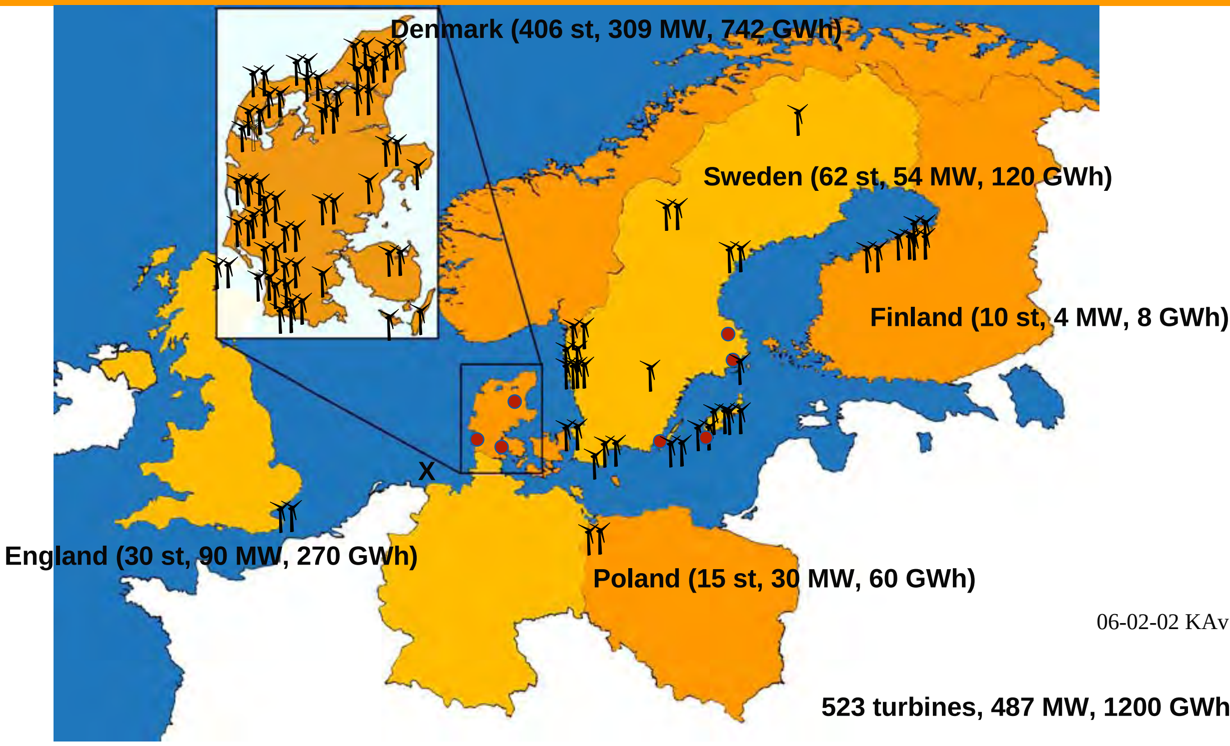
World Production Record!

2006-05-09

58.3 GWh

VATTENFALL

Vattenfalls wind turbines 2006-07-01



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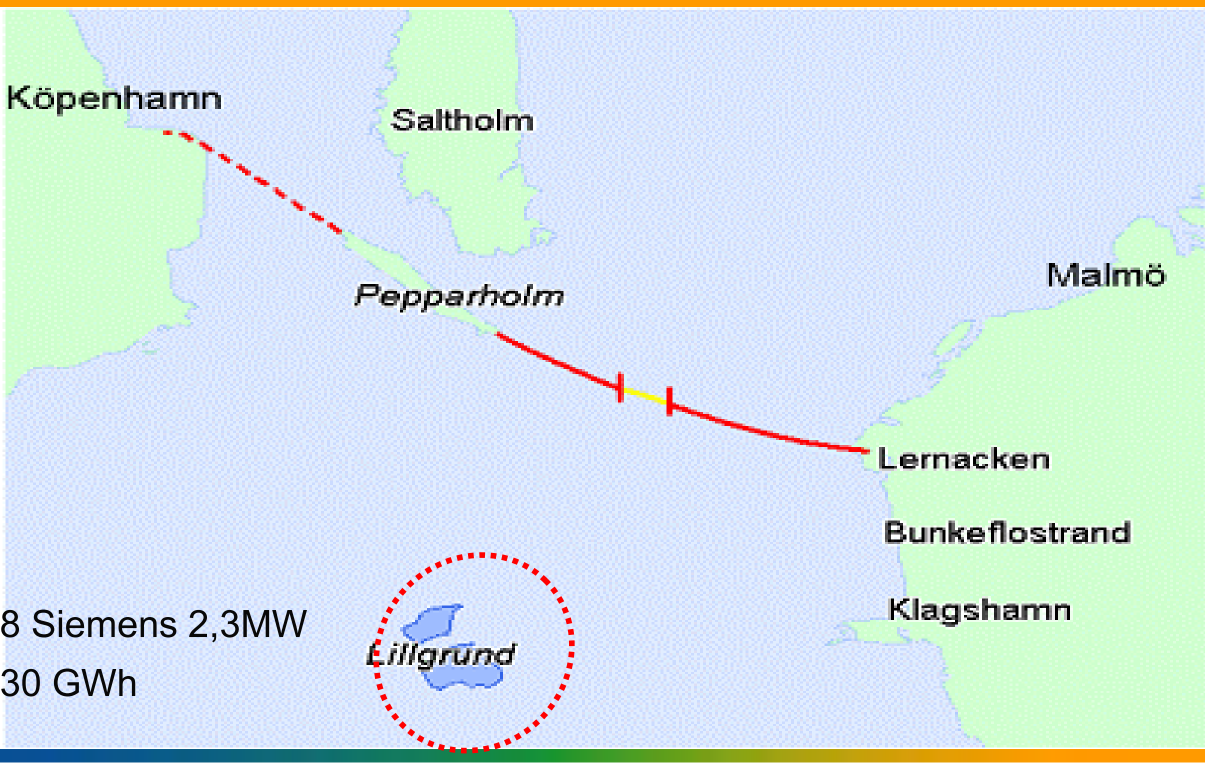
Lillgrund Offshore project



- 48 Siemens 2,3MW
- 330 GWh

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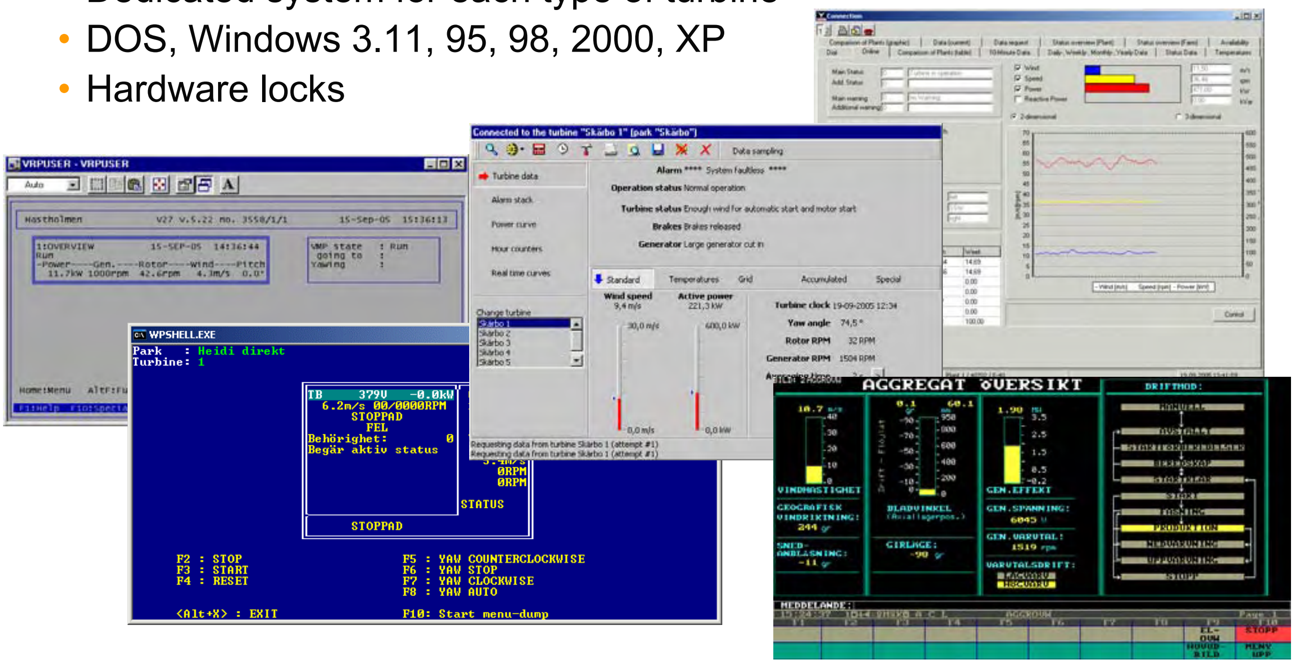
Supervision

Year 2000, turbines from 7 manufacturers
Danwin
NWP400
NWP1000
Vestas
Bonus
Enercon
Kvaerner
Micon

VATTENFALL

Vendor specific programs

- Dedicated system for each type of turbine
- DOS, Windows 3.11, 95, 98, 2000, XP
- Hardware locks



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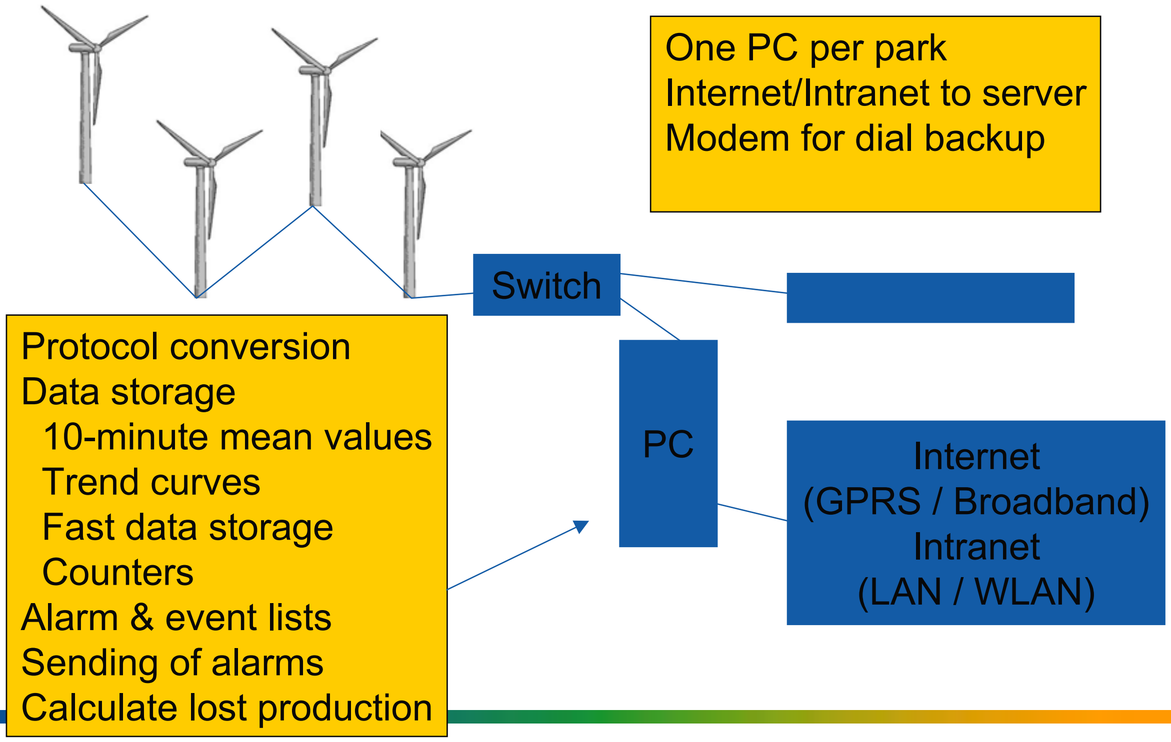
Disadvantages

- Dial-up modem connection
- Some systems was able send alarms from the turbines to the PC
- No alarms ”outside” the PC
- One PC + modem + phone line for each turbine type

New SCADA

- Common system for all types of turbines
- Online data
- Logging of all signals
- As much WEB-based as possible
- One central database for alarms and statistical data
- Automatic logging of downtime (stop time and start time)
- Modem backup connection
- Possible to use the manufacturers program

Park PC



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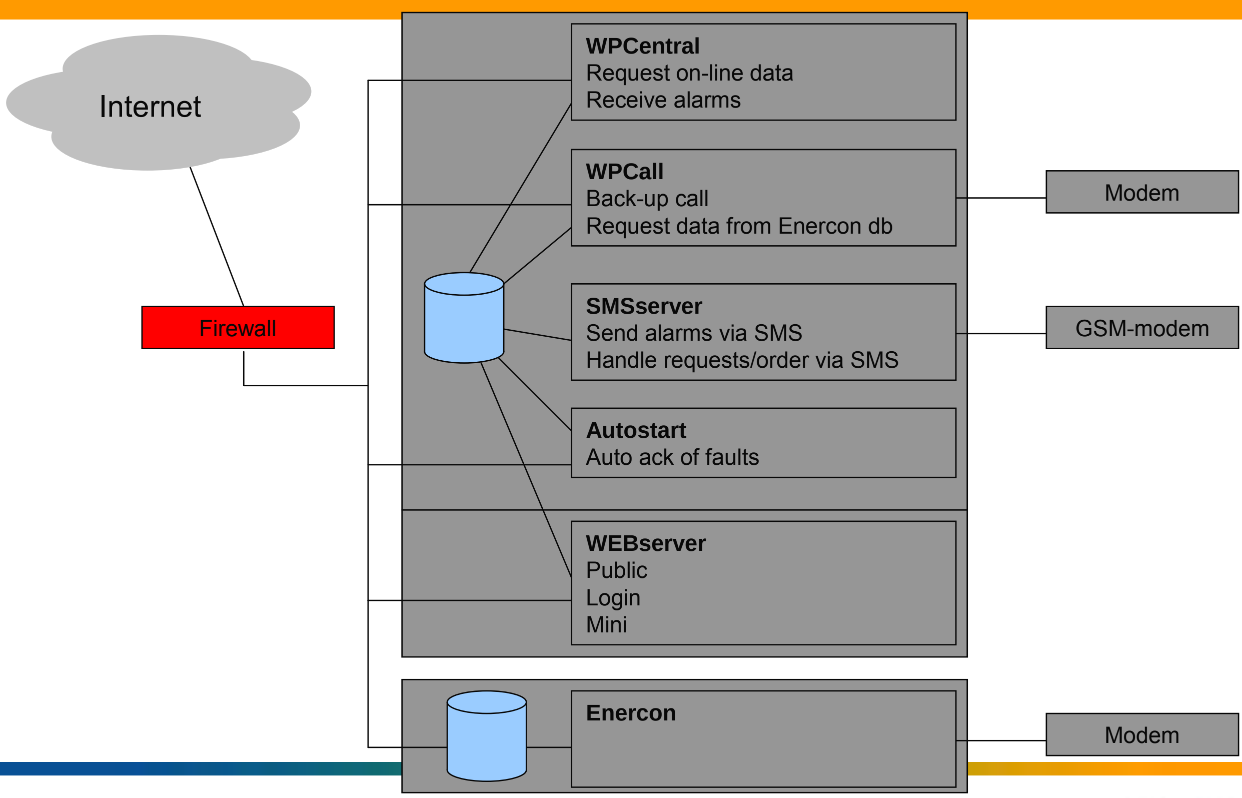
Server/Database



VATTENFALL

Advantages

- Common presentation of data for all types of turbines
- Mobile control center
- Control the turbines via WPClient, WEB, SMS
- Automatic compilation of reports
- Etc.

VATTENFALL

WEB public

Hem

Driftläge
> Alla verk

Larm
> Larmlista

Statistik
> Dygn acc
> Dygn
> Vecka
> Månad
> Total

Mätmast
> Aktuellt
> Historia

Driftuppföljning
> Sammanfattning
> Tabell (storlek)
> Tabell (nummer)
> Tabell (prod 1)
> Tabell (prod 2)

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

> Månad

Aktuella driftdata

Effekt kW	Namn	Typ	Status	Effekt (kW)	Vind (m/s)	Rotor (rpm)	Utetemp (°C)
180	Alsvik 3	Danwin 23D	-	-10	4,8	0	13
180	Alsvik 4	Danwin 23D	-	-10	2,1	0	20
225	Hovby 1	Vestas V29	-	28	5,3	40	16
225	Hovby 2	Vestas V29	-	34	6,6	41	15
225	Hästholmen 1	Vestas V27	-	6	3,8	32	22
225	Stora Bjärs 1	Vestas V29	-	1	3,6	30	21
225	Utö	Vestas V27	-	2	2,6	32	12
450	Lyse Bonus	Bonus MKII	-	12	5,3	35	23
500	Hog 1	Enercon E-40	-	59	5,5	22	.
500	Hog 2	Enercon E-40	-	179	8,2	31	.
500	Humlekärr 1	Enercon E-40	-	174	7,2	31	.
500	Humlekärr 2	Enercon E-40	-	134	7,3	28	.
500	Ruuthsbo	Enercon E-40	-	171	6,6	31	.
500	Hogenäset	Vestas V39	-	30	5,5	30	22
500	Åstorp 1	Vestas V39	-	380	11,4	30	29
500	Åstorp 2	Vestas V39	-	301	8,9	30	20
600	Olsvenne 1	Bonus MkIV	-	10	3,6	18	15
600	Skärbo 1	Bonus MkIV	-	29	4,4	32	19
600	Skärbo 2	Bonus MkIV	-	47	5,5	17	19
600	Skärbo 3	Bonus MkIV	-	41	5,4	18	20
600	Skärbo 4	Bonus MkIV	-	30	4,6	18	21
600	Skärbo 5	Bonus MkIV	-	23	3,9	18	18
600	Skärbo 6	Bonus MkIV	-	55	6,7	18	19
600	Suorva	Bonus MkIV	-	-7	2,6	11	10
600	Dusgård	Micon M1500	-	153	6,1	27	17
600	Tannam	Micon M1500	-	32	4,2	27	19
600	Torseröd	Micon M1500	-	60	4,6	18	20
600	Kulle 14	Vestas V44	-	35	4,9	29	17
600	Kulle 16	Vestas V44	-	22	4,1	29	17
600	Stora Bjärs 2	Vestas V44	-	36	4,4	28	20
660	Levide 1	Vestas V47	-	22	3,7	20	18

VATTENFALL

WEB public

Hem

Driftläge
> Alla verk

Larm
> Larmlista

Statistik
> Dygn acc
> Dygn
> Vecka
> Månad
> Total

Mätmast
> Aktuellt
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Driftuppföljning
> Sammanfattning
> Tabell (storlek)
> Tabell (nummer)
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> Tabell (prod 2)

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

> Månad

Aktuella larm

Larmtext	Tid
Alla verk i drift	

Senaste 50 händelserna

Larmtext	Tid till	Tid från
Skåls 1, Service (994) 3,2 m/s, oljebyte hyd	2006-05-04 09:29	2006-05-04 13:46
Sigvards 2, Fjärrstopp (9) 4,5 m/s, kontroll 10kV frånskiljare	2006-05-04 08:07	2006-05-04 09:47
Skåls 1, Service (994) 3,7 m/s, oljebyte vx	2006-05-03 13:21	2006-05-03 17:04
Sigvards 2, Manuellt stopp (13) 2,2 m/s Visning Deltawind	2006-05-03 14:30	2006-05-03 15:36
Skåls 1, Service (994) 0,0 m/s, oljebyte vx	2006-05-03 09:50	2006-05-03 13:09
Sigvards 2, Vindfana fel (218) 5,5 m/s /Autostart	2006-05-03 00:14	2006-05-03 00:25
Sigvards 2, Manuellt stopp (13) 3,0 m/s, service	2006-05-02 09:44	2006-05-02 15:42
Skåls 1, Nödstoppskrets bruten (102) 3,4 m/s	2006-05-02 14:24	2006-05-02 14:36
Skåls 1, Nödstoppskrets bruten (102) 2,8 m/s	2006-05-02 13:40	2006-05-02 13:49
Hog 2, Skyddsbrytare utlöst strömriktare 1(90:5)	2006-05-02 09:10	2006-05-02 09:30
Näsudden II, MDK01, Hög vibr. vinkelst., signal	2006-05-01 19:06	2006-05-02 08:26
Hog, Aut. Provlarm	2006-05-01 17:00	2006-05-01 17:00
Näsudden II, MDK01, Hög vibr. vinkelst., signal	2006-05-01 14:23	2006-05-01 16:10
Kulle 16, Extern 24V glättad saknas, F33 utl./Ingvar	2006-04-30 21:09	2006-05-01 09:35
Åstorp 1, Negative power Gen1: -295,6 kW (115) 3,6 m/s/Göran K	2006-04-30 23:29	2006-05-01 09:33
Näsudden II, MDK01, Hög vibr. vinkelst., signal	2006-04-30 22:31	2006-04-30 23:18
Näsudden II, MDL01, Gir felaktigt detekterad (34) 14,5 m/s /Autostart	2006-04-30 21:09	2006-04-30 21:20
Näsudden II, MDY01, Hög hor. vibr. ???? 12,5 m/s	2006-04-30 17:58	2006-04-30 18:51
Näsudden II, MDY01, Hög hor. vibr. (51) 12,4 m/s/ej auto.kvitt?	2006-04-30 14:46	2006-04-30 15:40
Olsvenne 2, Torn acc. Y, larm:0,37 m/s2 (297) 14,2 m/s	2006-04-30 13:16	2006-04-30 13:25
Olsvenne 2, Extern varvtalsvakt 2046RPM (159) 12,7 m/s, Vestas	2006-04-30 07:48	2006-04-30 09:47
Näsudden II, MDY01, Hög hor. vibr. (51) 11,6 m/s/gol	2006-04-30 07:37	2006-04-30 08:30
Näsudden II, MDK03, Fel filtertryck i (145)	2006-04-29 09:55	2006-04-29 20:19

VATTENFALL

WEB public

Hem

Driftläge
> Alla verk

Larm
> Larmlista

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

> Månad

Månadsrapport april 2006

Energiproduktion	3749,0	MWh	20	%
Produktionstid	73	%		
Tillgänglighet	98,6	%		
Hinder	1,4	%		
Förlorad produktion	81	MWh		

Effekt kW	Namn	Typ	Energi (kWh)	Energi (%)	Tid (tim)	Tid (%)	Hinder (tim)	Hinder (%)	Tillg (%)	-Energi (MWh)
180	Alsvik 3	Danwin 23D	26449	20	420	58	0	0,0	100,0	0,0
180	Alsvik 4	Danwin 23D	23940	18	424	59	0	0,0	100,0	0,0
225	Stora Bjärs 1	Vestas V29	23640	15	463	64	0	0,0	100,0	0,0
225	Hovby 1	Vestas V29	20258	13	451	63	0	0,0	100,0	0,0
225	Hovby 2	Vestas V29	19821	12	455	63	0	0,0	100,0	0,0
225	Utö	Vestas V27	16390	10	420	58	9	1,2	98,8	0,3
225	Hästholmen 1	Vestas V27	26172	16	541	75	5	0,6	99,4	0,4
450	Lyse Bonus	Bonus MKII	66607	21	504	70	17	2,3	97,7	3,1
500	Ruuthsbo	Enercon E-40	82829	23	649	90	35	4,8	95,2	0,0
500	Humlekärr 1	Enercon E-40	84075	23	643	89	0	0,0	100,0	0,0
500	Humlekärr 2	Enercon E-40	85160	24	626	87	0	0,0	100,0	0,0
500	Hog 1	Enercon E-40	53488	15	622	86	1	0,2	99,8	0,0
500	Hog 2	Enercon E-40	60550	17	624	87	2	0,2	99,8	0,0
500	Hogenäset	Vestas V39	71550	20	524	73	6	0,9	99,1	0,0
500	Åstorp 1	Vestas V39	56257	16	476	66	13	1,8	98,2	1,6
500	Åstorp 2	Vestas V39	58942	16	481	67	1	0,2	99,8	0,0
600	Olsvenne 1	Bonus MkIV	92378	21	574	80	6	0,8	99,2	0,0
600	Skärbo 1	Bonus MkIV	61673	14	571	79	10	1,4	98,6	0,1
600	Skärbo 2	Bonus MkIV	57902	13	579	80	3	0,4	99,6	0,3
600	Skärbo 3	Bonus MkIV	63139	15	582	81	12	1,6	98,4	0,1
600	Skärbo 4	Bonus MkIV	56349	13	560	78	6	0,9	99,1	0,1
600	Skärbo 5	Bonus MkIV	59941	14	568	79	5	0,7	99,3	0,1
600	Skärbo 6	Bonus MkIV	50839	12	552	77	4	0,5	99,5	0,1
600	Suorva	Bonus MkIV	130383	30	613	85	26	3,6	96,4	0,4

VATTENFALL

WEB public

Hem

Driftläge
> Alla verk

Larm
> Larmlista

Statistik
> Dygn acc
> Dygn
> Vecka
> Månad
> Total

Mätmast
> Aktuellt
> Historia

Driftuppföljning
> Sammanfattning
> Tabell (storlek)
> Tabell (nummer)
> Tabell (prod 1)
> Tabell (prod 2)

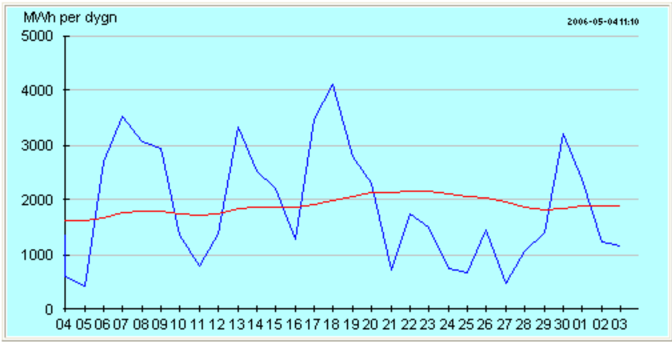
> Historia dag-1
> Historia dag-2
> Historia dag-3

> Månad

Översikt

Antal verk	643			
Ej rapporterade	45		7,0	%
Ur drift	10		1,6	%
Installerad effekt	425	MW		
Aktuell effekt	63	MW	15	%

Senaste 30 dygnens produktion



Blå linje = dygnsvärden, röd linje = medelvärde av de senaste 30 dygnen

Uppdaterad 2006-05-04 11:08

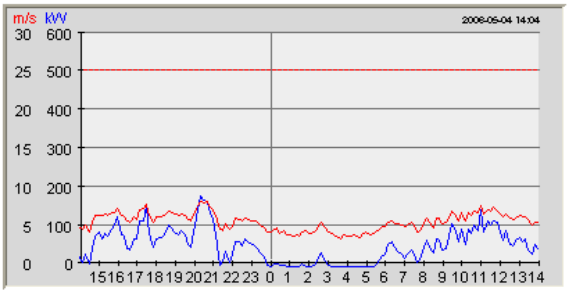
WEB login

Storlek (kW)	Namn	Typ	Status	Effekt (kW)	Vind (m/s)
180	Alsvik 3	Danwin, 23D	-	-10	4,7
180	Alsvik 4	Danwin, 23D	-	-10	2,7
225	Hovby 1	Vestas, V29	-	27	6,0
225	Hovby 2	Vestas, V29	-	34	6,2
225	Hästholmen 1	Vestas, V27	-	10	3,4
225	Stora Bjärs 1	Vestas, V29	-	23	5,3
225	Utö	Vestas, V27	-	1	2,3
450	Lyse Bonus	Bonus, MKII	-	12	5,3
500	Hog 1	Enercon, E-40	NC		
500	Hog 2	Enercon, E-40	NC		
500	Humlekärr 1	Enercon, E-40	NC		
500	Humlekärr 2	Enercon, E-40	NC		
500	Ruuthsbo	Enercon, E-40	NC		
500	Hogenäset	Vestas, V39	-	31	5,0
500	Åstorp 1	Vestas, V39	-	271	9,7
500	Åstorp 2	Vestas, V39	-	288	9,7
600	Olsvenne 1	Bonus, MkIV	-	16	3,7
600	Skärbo 1	Bonus, MkIV	-	206	7,2
600	Skärbo 2	Bonus, MkIV	-	31	4,8
600	Skärbo 3	Bonus, MkIV	-	34	5,2
600	Skärbo 4	Bonus, MkIV	-	192	7,8
600	Skärbo 5	Bonus, MkIV	-	156	8,0
600	Skärbo 6	Bonus, MkIV	-	164	7,1
600	Suorva	Bonus, MkIV	-	-7	1,3
600	Dusgård	Micon, M1500	-	5	3,5
600	Tannam	Micon, M1500	-	161	6,3
600	Torseröd	Micon, M1500	-	0	2,0
600	Kulle 14	Vestas, V44	-	26	4,0
600	Kulle 16	Vestas, V44	-	32	4,2
600	Stora Bjärs 2	Vestas, V44	-	32	4,3
660	Levide 1	Vestas, V47	-	22	3,9
660	Levide 2	Vestas, V47	-	22	4,1
660	Levide 3	Vestas, V47	-	-10	3,8
660	Skåls 1	Vestas, V47	-	3	3,3
1000	Sigvards 2	Nordic, 1000s	-	-9	4,6
1500	Sigvards 3	Vestas, V66	-	46	3,8
3000	Näsudden II	Kvaerner, II	-	2	4,2
3000	Olsvenne 2	Vestas, V90	-	235	5,8

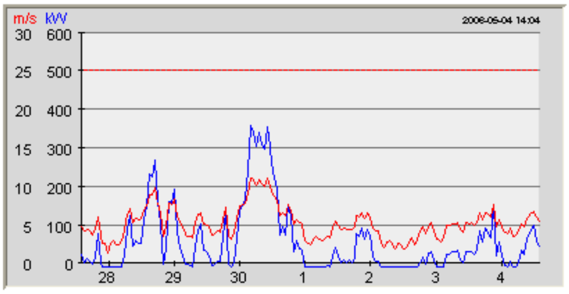
WEB login

Alsvik 4
Hovby 1
Hovby 2
Hästholmen 1
Stora Bjärs 1
Utö
Lyse Bonus
Hog 1
Hog 2
Humlekärr 1
Humlekärr 2
Ruuthsbo
Hogenäset
Åstorp 1
Åstorp 2
Olsvenne 1
Skärbo 1
Skärbo 2
Skärbo 3
Skärbo 4
Skärbo 5
Skärbo 6
Suorva
Dusgård
Tannam
Torseröd
Kulle 14
Kulle 16
Stora Bjärs 2
Levide 1
Levide 2
Levide 3
Skåls 1
Sigvards 2

Produktion senaste dygnet



Produktion senaste veckan

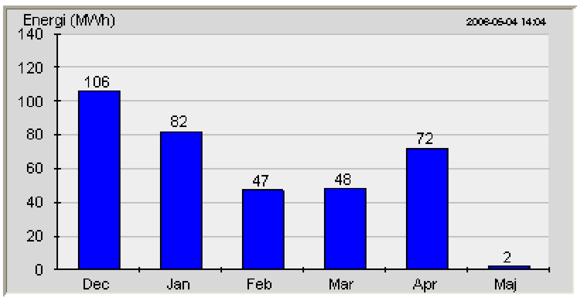


VATTENFALL

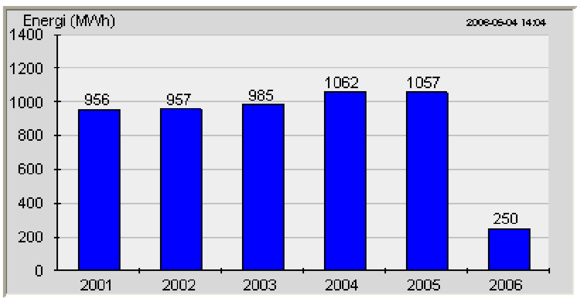
WEB login

Näsudden II
Olsvenne 2

Månadsstatistik



Årsstatistik



VATTENFALL

WEB login

Händelser   Lägg till ny händelse

Händelse start	Händelse slut	Tid	Händelse
2006-04-04 11:29	2006-04-04 17:41	6,2	Kommunikation bruten (996) 0,0 m/s, service
2006-03-06 14:24	2006-03-06 14:24	0,0	Byte PC /Anders
2006-02-14 09:25	2006-02-14 09:45	0,3	Max autoyawtime 600 sec. (136) 4,1 m/s
2006-02-14 08:41	2006-02-14 08:47	0,1	Max autoyawtime 600 sec. (136) 4,1 m/s
2006-02-14 01:10	2006-02-14 07:49	6,6	Max autoyawtime 600 sec. (136) 4,6 m/s
2006-01-30 16:37	2006-01-30 18:26	1,8	Max autoyawtime 600 sec. (136) 5,2 m/s
2006-01-30 15:44	2006-01-30 16:27	0,7	Max autoyawtime 600 sec. (136) 4,9 m/s
2006-01-30 15:15	2006-01-30 15:35	0,3	Max autoyawtime 600 sec. (136) 3,9 m/s
2006-01-11 21:05	2006-01-11 21:24	0,3	Ctrl:-10,V PitchVel:0,°/s (281) 12,6 m/s /aa
2005-12-08 13:20	2005-12-09 09:00	19,7	Kommunikation bruten (996) 0,0 m/s, nätstörning, Q8 utlöst /Roger
2005-12-06 20:11	2005-12-06 20:11	0,0	Service (994) 3,9 m/s
2005-11-25 15:18	2005-11-25 15:18	0,0	Aktivering kontantkort mobil/Roger
2005-11-24 22:38	2005-11-25 07:07	8,5	Ctrl:10,V PitchVel:0,°/s (281) 10,0 m/s
2005-11-15 07:58	2005-11-15 08:24	0,4	High windspeed: 20,6 m/s (170) 21,0 m/s
2005-11-15 07:51	2005-11-15 07:58	0,1	Ctrl:10,V PitchVel:0,°/s (281) 18,9 m/s
2005-11-14 23:47	2005-11-15 00:10	0,4	Ctrl:-10,V PitchVel:0,°/s (281) 13,5 m/s
2005-11-14 15:46	2005-11-14 18:01	2,2	High windspeed: 25, m/s (170) 29,1 m/s
2005-11-14 13:20	2005-11-14 13:24	0,1	Ctrl:10,V PitchVel:0,°/s (281) 18,9 m/s
2005-11-14 11:43	2005-11-14 12:57	1,2	High windspeed: 23,2 m/s (170) 19,2 m/s

VATTENFALL

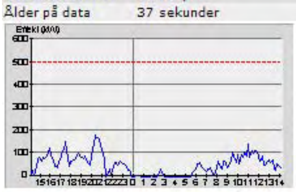
WEB mini

Larmlista   Statistik   Logga ut   14:10

kW	Verk	Status	Effekt	Vind
180	Alsvik 3	-	-10	4,8
180	Alsvik 4	-	-10	2,8
225	Hovby 1	-	5	3,9
225	Hovby 2	-	29	5,9
225	Hästholmen 1	-	34	5,0
225	Stora Bjärs 1	-	-7	2,8
225	Utö	-	3	2,6
450	Lyse Bonus	-	-19	4,3
500	Hog 1	NC		
500	Hog 2	NC		
500	Humlekärr 1	NC		
500	Humlekärr 2	NC		
500	Ruuthsbo	NC		
500	Hogenäset	-	20	5,3
500	Åstorp 1	-	306	10,1
500	Åstorp 2	-	299	9,6
600	Olsvenne 1	-	10	3,5
600	Skärbo 1	-	44	6,4
600	Skärbo 2	-	47	5,2
600	Skärbo 3	-	84	6,7
600	Skärbo 4	-	113	6,5
600	Skärbo 5	-	52	5,8
600	Skärbo 6	-	171	6,7
600	Suorva	-	-7	0,8
600	Dusgård	-	6	2,7
600	Tannam	-	18	4,1
600	Torseröd	-	41	3,4
600	Kulle 14	-	17	4,1
600	Kulle 16	-	39	4,5
600	Stora Bjärs 2	-	-10	3,2
660	Levide 1	-	20	3,9

Översikt   Larmlista   14:12

Hogenäset	Vestas 500 kW
Status	OK (0)
Status text	System OK
Effekt	64 kW
Vindhastighet	6,7 m/s
Rotorvarvtal	30 rpm
Generatorvarvtal	1500 rpm
Ålder på data	37 sekunder

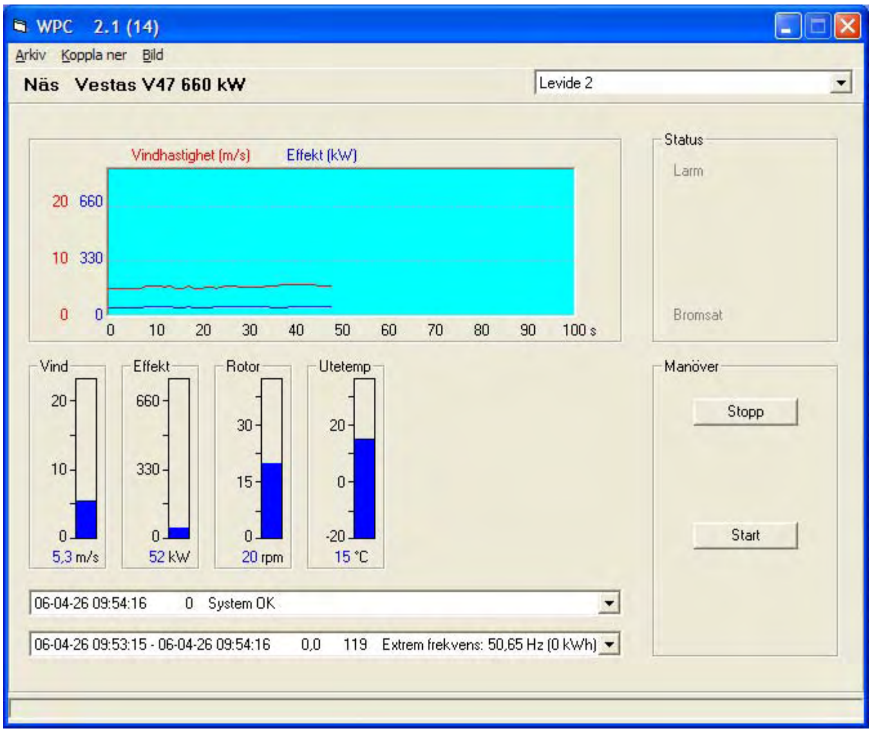


Manöver   Lösenord

Larmhistoria	Start	Slut
Kommunikation bruten (996) 0,0 m/s, service	06-04-04 11:29	06-04-04 17:41
Byte PC /Anders	06-03-06 14:24	06-03-06 14:24
Max autoyawtime 600 sec. (136) 4,1 m/s	06-02-14 09:25	06-02-14 09:45
Max autoyawtime 600 sec. (136) 4,1 m/s	06-02-14 08:41	06-02-14 08:47
Max autoyawtime 600 sec. (136) 4,6 m/s	06-02-14 01:10	06-02-14 07:49
Max autoyawtime 600 sec. (136) 5,2 m/s	06-01-30 16:37	06-01-30 18:26
Max autoyawtime 600 sec. (136)	06-01-30	06-01-30

VATTENFALL

WPClient



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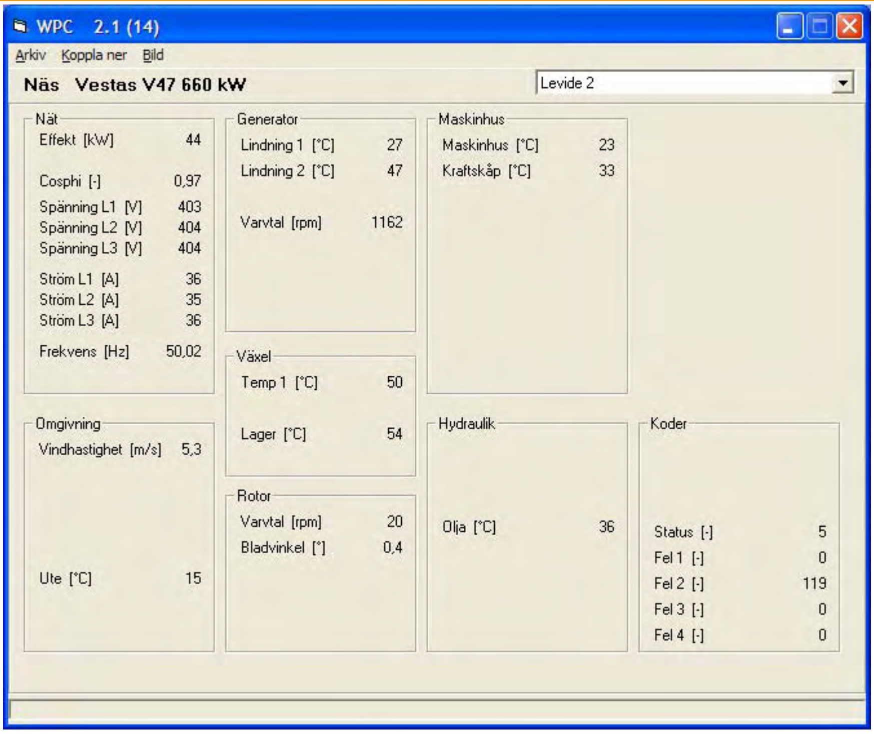
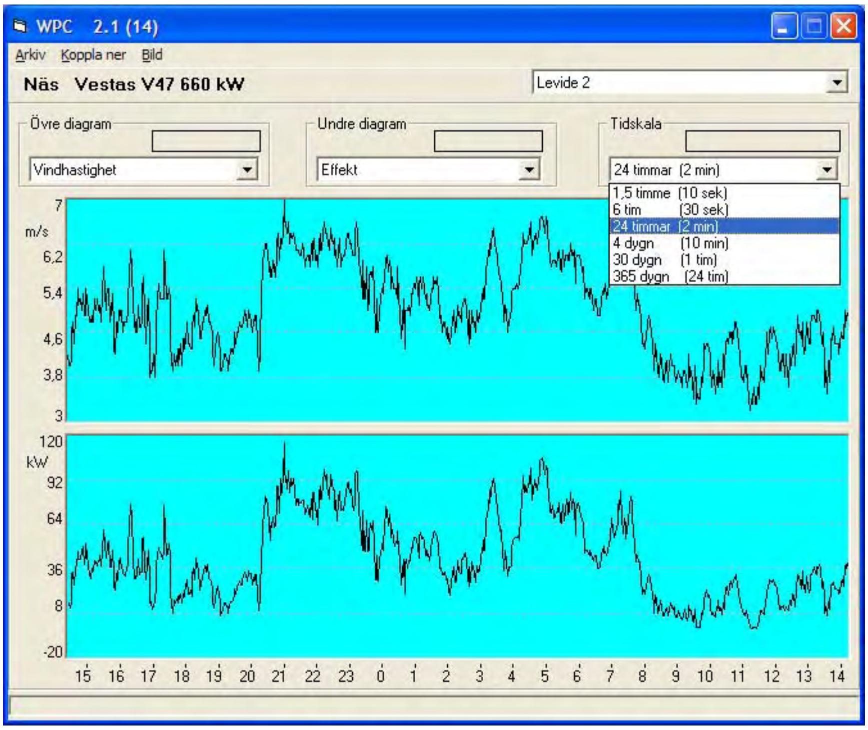
WPClient



VATTENFALL

WPClient


WPC 2.1 (14)
Arkiv Koppla ner Bild
Näs Vestas V47 660 kW
Levide 2
Övre diagram
Vindhastighet
Undre diagram
Effekt
Tidskala
24 timmar (2 min)
1,5 timme (10 sek)
6 tim (30 sek)
24 timmar (2 min)
4 dygn (10 min)
30 dygn (1 tim)
365 dygn (24 tim)
m/s
7
6,2
5,4
4,6
3,8
3
kW
120
92
64
36
8
-20
15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

ECN

Energy research Centre of the Netherlands

O&M Cost Estimator

Luc Rademakers
ECN Wind Energy, Group Operations & Experiments

www.ecn.nl

ECN

Contents

- Introduction to ECN Wind Energy and O&M research
- O&M Cost Estimator
  - Background: Why developing an O&M Cost Estimator
  - General Approach
  - Practical work and first results

The Petten Site

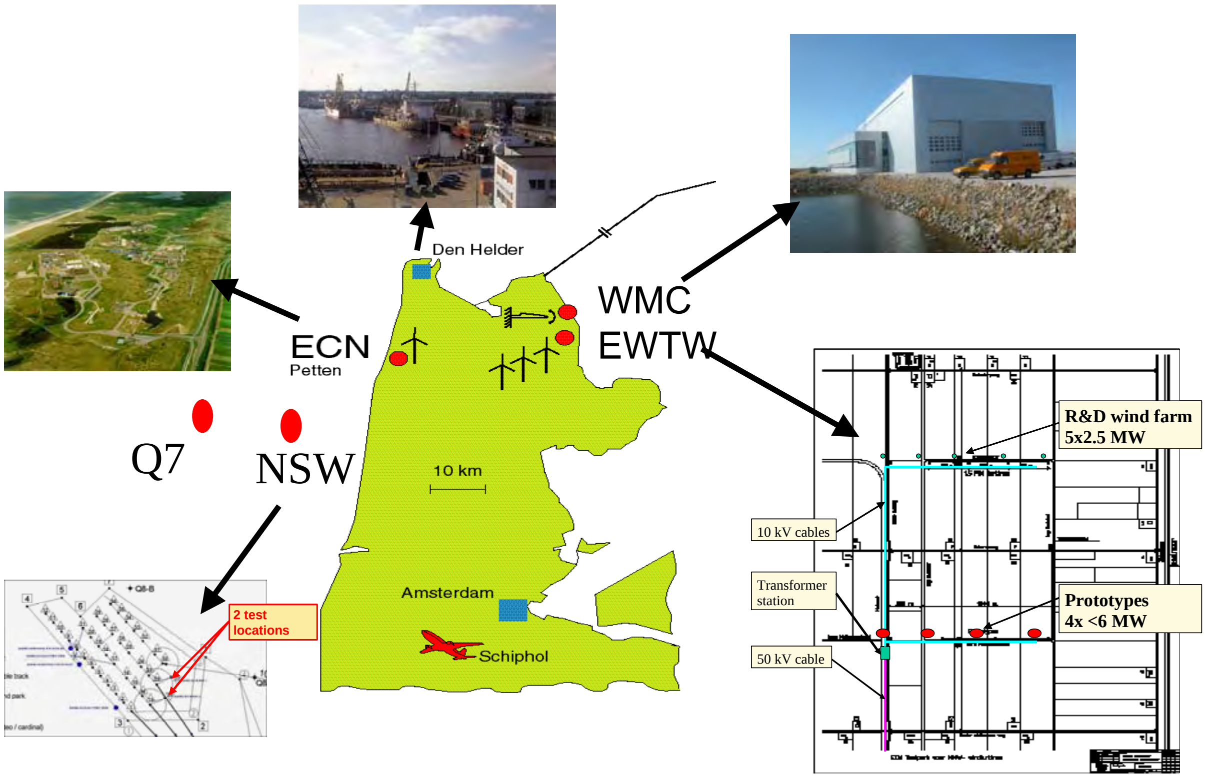
Research areas

- Biomass, Coal & Environmental Research
- Solar energy (PV)
- Wind energy
- Energy in Built Environment
- Hydrogen & Clean Fossil Fuels
- Fuel cells
- Energy Efficiency in Industry
- Policy Studies
- Engineering and Services

ECN in figures 2004

Number of employees:	**650**
Turn over:	**65 M euro**
Governmental subsidy:	**23 M euro**
Contract research:	**32 M euro**
Patents 2004:	**4**
Number of publications 2004:	**617**

ECN



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ECN Wind Energy Market Orientation

(Process)	*(Group)*	*(Market)*
Location ↓ Farm design	Wind Farm Design	Project designers/ Developers/ Offshore operators
↓ Realisation ↓ Commissioning	Wind Turbine Technology	Manufacturers of turbines and components
↓ Operation ↓ Dismantling	Wind Farm Operation	Owners/ Operators/ O&M specialists

Experiments

Total number of employees: 40

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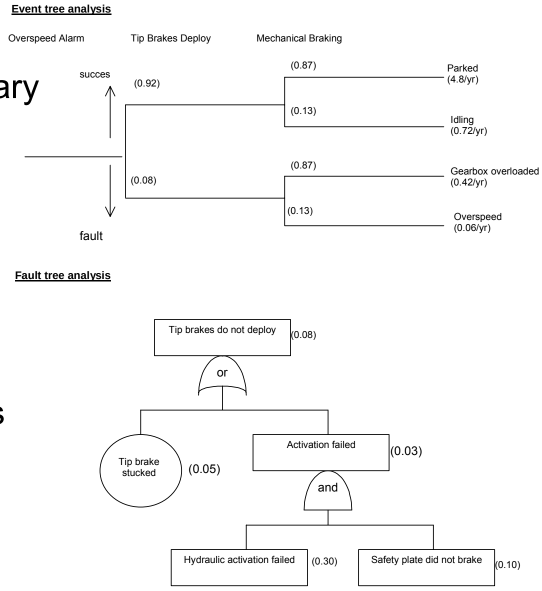
Operation and Maintenance: Past, Present, and Future

History 1990

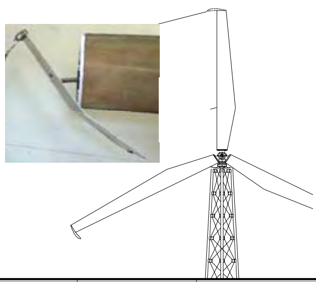
- Probabilistic Safety Assessment complementary to deterministic design standards (IEC, NVN)
- Introduction of "nuclear" methods into windenergy
  - Fault Tree Analysis
  - Event Tree Analysis
  - Failure Mode, Effects and Criticality Analysis
- Applied in design phase
- Lack of data (MTBF, MTTR, etc.)
- Lagerwey 15/75, HMZ 1MW,
  AOC 15/50, Certification and Standardisation



Operation and Maintenance: Past, Present, and Future

History 1992 - 2001

- Apply same methods for improvement of reliability (qualitative)
- - Fault Tree Analysis
  - Event Tree Analysis
  - FMECA
- Applied during design reviews
- Lack of data (MTBF, MTTR, etc.)
- Lagerwey 15/75, NedWind 40
  WindMaster 300 kW, **AOC 15/50**



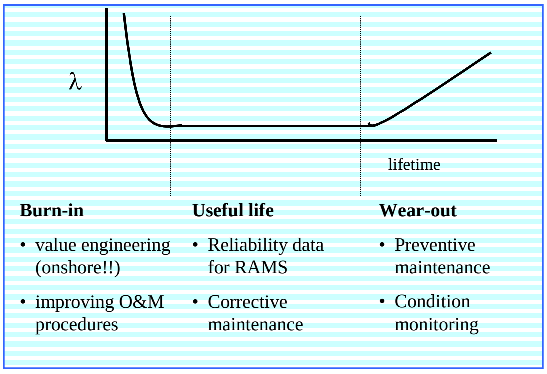
Name	TAG number	Description	Function Description	Failure Mode	Failure Cause
damper bracker ass.	TB-db1	damper bracket assembly	connect damper with hinge block	clevis pin failure	play in connection
					structural failure
				damper bracket loose	play in bolt connection
				damper bracket fracture	structural failure
					failure of bolt

#Failures (Min)	#Failures (Max)	Preventive measures	Failure rate (Present) [#/yr]	MTBF [yr]	Likeli-hood	Remarks
2	3	Solved by locktite, no more failures observed.	0,021	48,0		
2	5	Putting additional screws inside of hinge block. No more failures	0,029	34,3		

Operation and Maintenance: Past, Present, and Future

History 1997 - ……

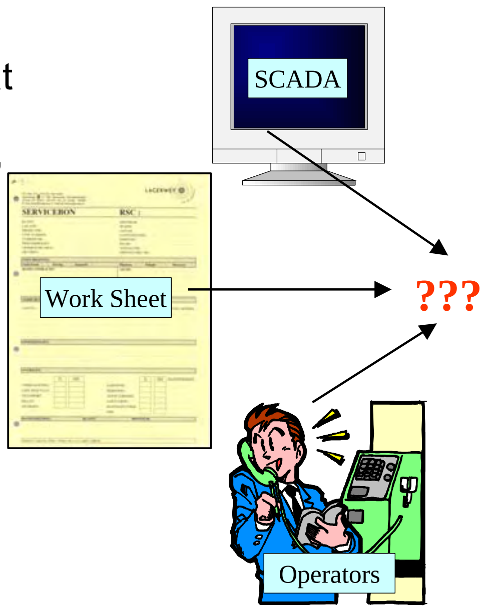
- Development of method to collect, analyse and feedback of O&M data for RAMS, LCCM, …
- Close collaboration with O&M dept.'s.!!!
  - improvement of daily practices of technicians
  - less forms to fill in, connection to invoicing
  - configuration control
  - preventive maintenance program
  - guide for troubleshooting
  - ……



Operation and Maintenance: Past, Present, and Future

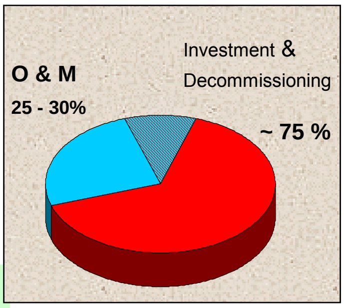
History 1997 - ……

- Data collection based on FMECA format
- <u>Definition part:</u> to uniquely define farms, turbines, main systems, and components
- <u>Logbook part:</u> to collect operational and failure data unambiguously
- <u>Analysis part:</u> reporting and (technical) feedback

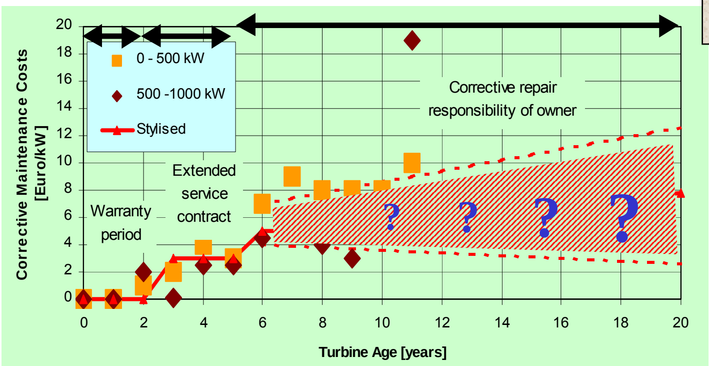


Why O&M Offshore Research?

Offshore
- preventive maintenance 0,003 to 0,009 (€/kWh)
- corrective maintenance 0,005 to 0,010 (€/kWh)
- 25 to 30 % of kWh price
- revenu losses = repair costs



2001 (CA-OWEE)



High costs, high uncertainties

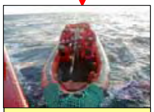
ECN's Topics for O&M Research

Planning phase	Operational phase (Short Term)	Operational phase (Long Term)
Cost model and O&M aspects - model wind en wave conditions - model availability and costs	*Failures and maintenance* - SCADA/diagnostics - logistics - weather conditions (predictions) - O&M equipment - condition monitoring	*Failures and maintenance* - (trend)analyses failure data, logbooks - analysis O&M actions & equipment - modelling aging and maintenance costs - analysis weather conditions
Contracts - LCCM	*Imbalance en Energy Trading* - power predictions - *Energy Trading* (day-ahead, intraday, imbalance)	*Contracts* - check performance (P-V curve, availability, production
Park effects and loads - wind and turbulence - loads - production	*Fault Tolerant Control* PHD@SEA	*Park effects and loads* - condition monitoring and load measurements - aging algorithms

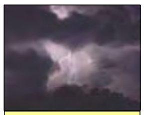
Planning phase: Modelling of O&M aspects

Collecting and analysing O&M data

1) Failure behaviour and maintainability



2) Characterisation of access and hoisting systems



3) Characterisation of weather conditions
- wind
- waves
- lightning
- visibility

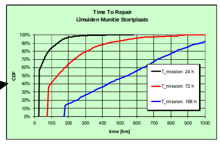
Corrective Maintenance (Probabilistic Model)

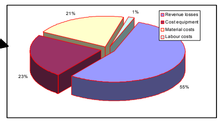
Preventive Maintenance

Optimisation

Results
- High availability
- Low price per kWh

Additional results
- Waiting time
- Cost drivers
- Recommendations for improvement

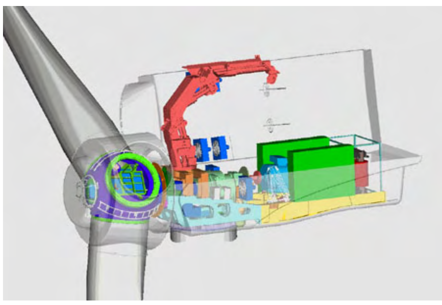




Modelling of O&M costs and downtimes (incl. uncertainties)

Collecting and analysing O&M data

Generator		Repair Classes	
1. Overheating alarm	→	1. Alarm with remote reset	(0,5 /yr)
2. Carbon brushes	→	2. Repair and consumables	(0,2 /yr)
3. Fan cooling broken	→	3. Replacement (internal crane)	(0,05 /yr)
4. Bearings damaged	→	4. Replacement (hoisting outside)	(0,011/yr)



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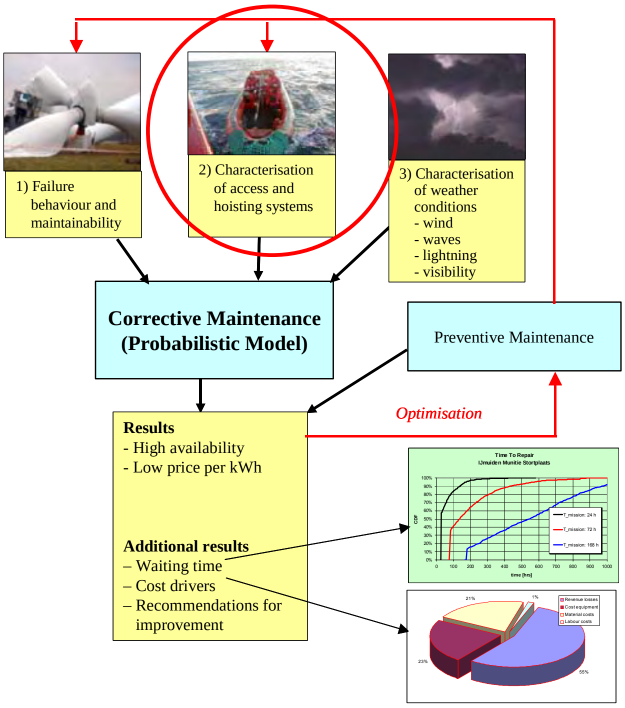
Planning phase: Modelling of O&M aspects

Specifying lifting and access systems



ECN

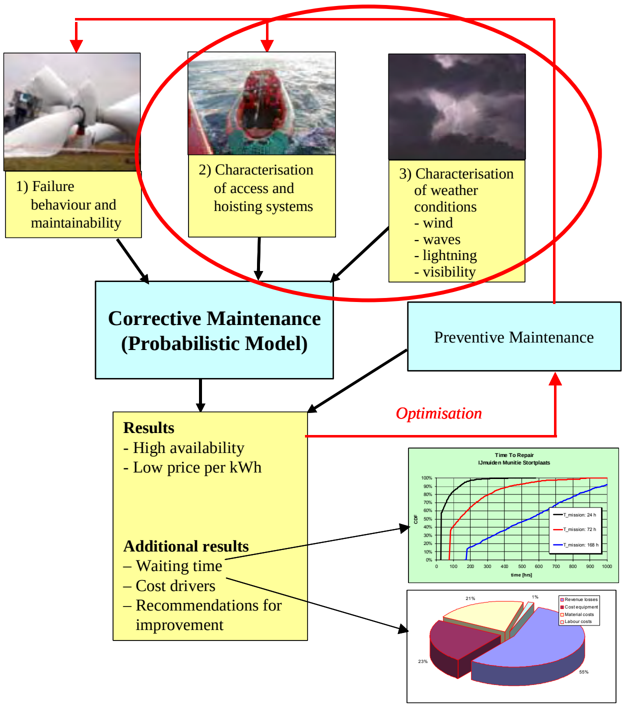
Modelling of O&M costs and downtimes (incl. uncertainties)

Specifying lifting and access systems

Supplier with Zodiac		
Specification	**Value**	**Remarks**
H max at transfer	0. 5 m (- 0.75 m)	
V max at transfer	6 m/s	
Travel time to turbine (one way)	2 hrs	Supplier remains at site
Mobilisation time	1 to 4 hrs	
Availability	Good	
Maximum size of repair crew	10-20	
Maximum weight of load	Medium size (with crane)	
Hourly rate	1.200,- Euro	Rates may vary: 850,- to 1.600,- Euro
Mob/demob costs	Depends on contract	
	Data:	

ECN

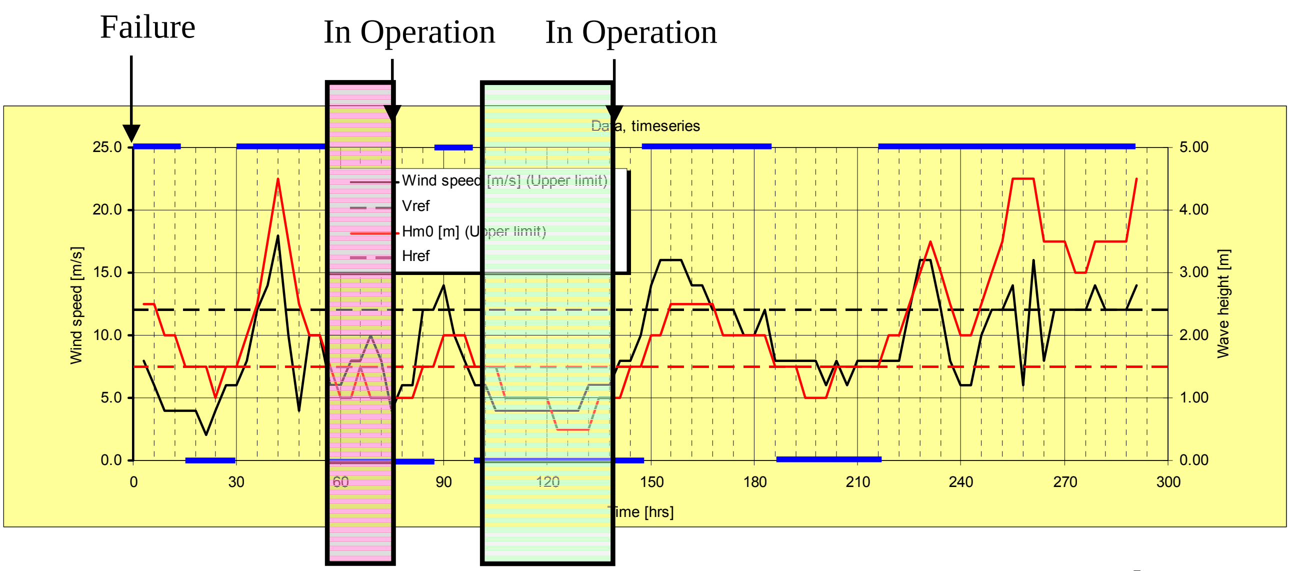
Planning phase: Modelling of O&M aspects



Analysis of weather windows and waiting time

ECN

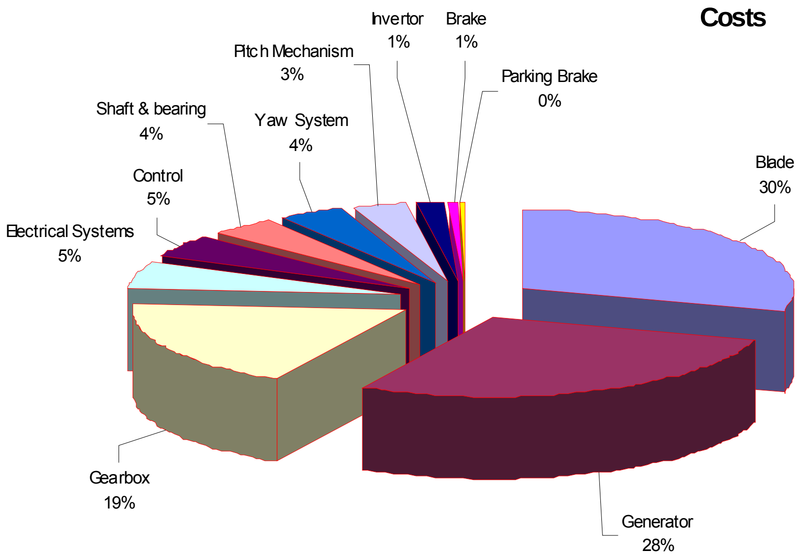
Modelling of O&M costs and downtimes (incl. uncertainties)



$$T\_wait_{40\ uur} = 96 \text{ hr}$$

$$T\_wait_{20\ uur} = 56 \text{ hr}$$

Planning phase: Modelling of O&M aspects

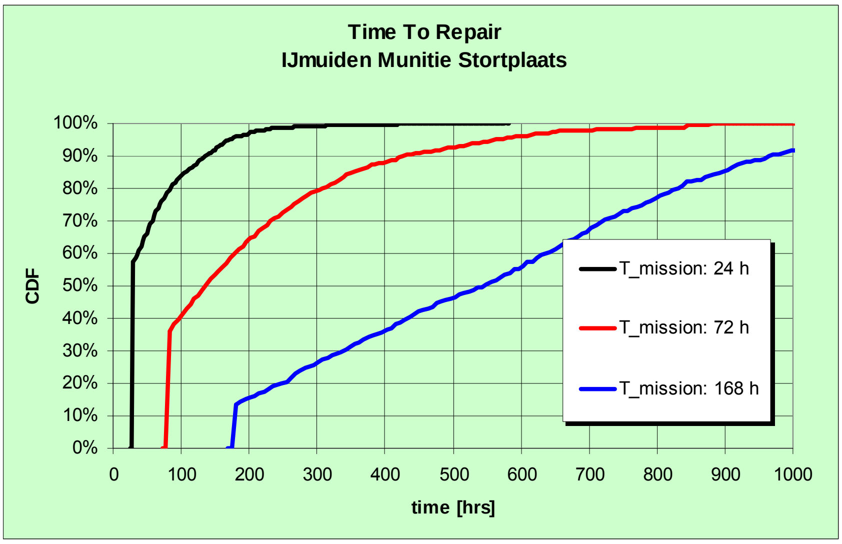


Cost Model

Typical Results

- Cost Drivers

Planning phase: Modelling of O&M aspects



Cost Model

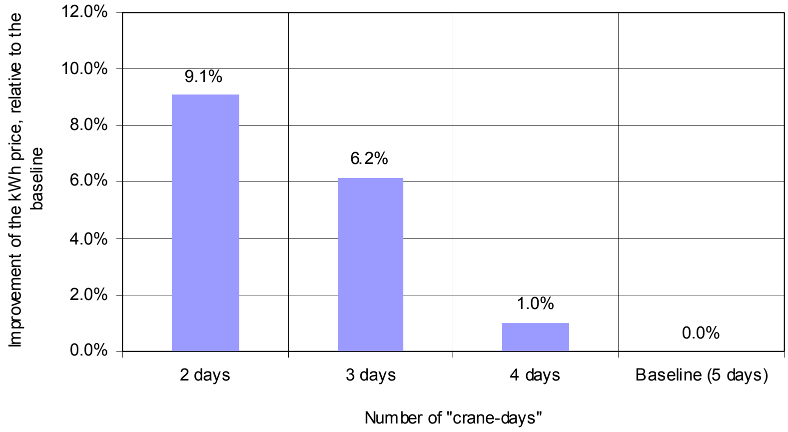
Typical Results

- Cost Drivers
- Waiting Time

Case study

- H_{max} = 1.5 m
- V_{max} = 12 m/s
- *T_logistics* = 0
- *T-mission* = 24, 72, 168 hr

Planning phase: Modelling of O&M aspects



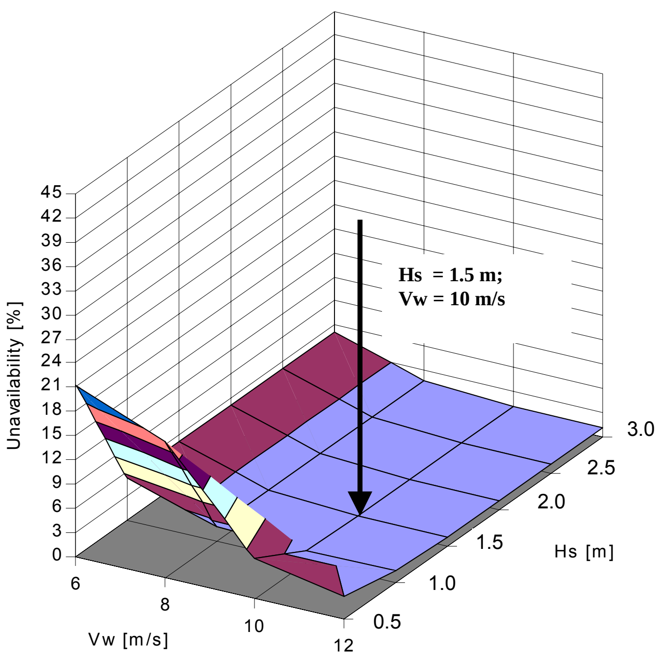
Reduction of the kWh price, relative to the baseline

Cost Model

Typical Results

- Cost Drivers
- Waiting Time
- Price (per kWh)
- Scenario studies

Planning phase: Modelling of O&M aspects



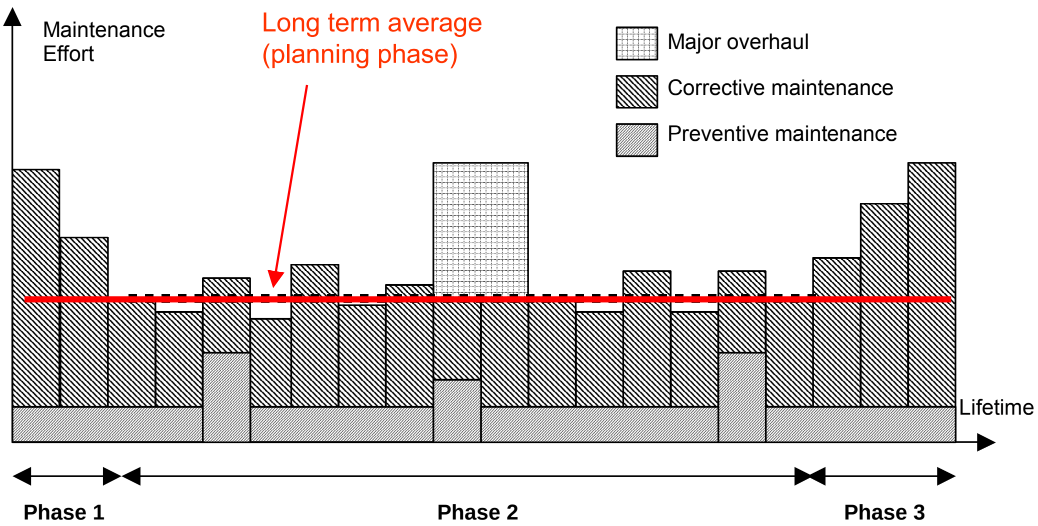
Cost Model

Typical Results

- Cost Drivers
- Waiting Time
- Price (per kWh)
- Scenario studies
- Optimisation of access systems

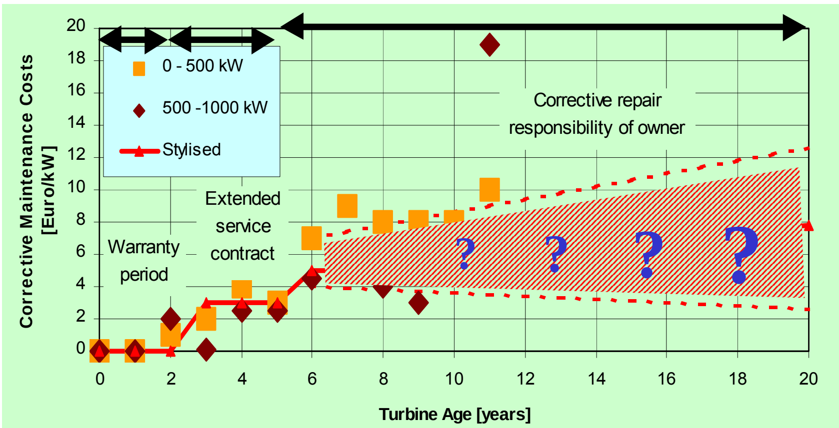
Planning phase: Modelling of O&M aspects

Typical results



Long Term O&M Cost Estimator: The problem

"How Many Gearboxes Do We Need To Replace in the Next 5 Years??"



ECN

O&M Optimisation: Long Term O&M Cost Estimator

Looking for <u>key parameters</u> that determine

1. trends in failure behaviour (components of which condition cannot be measured, e.g. yaw system, pitch system)
2. degradation of components (blades, drive trains, etc)

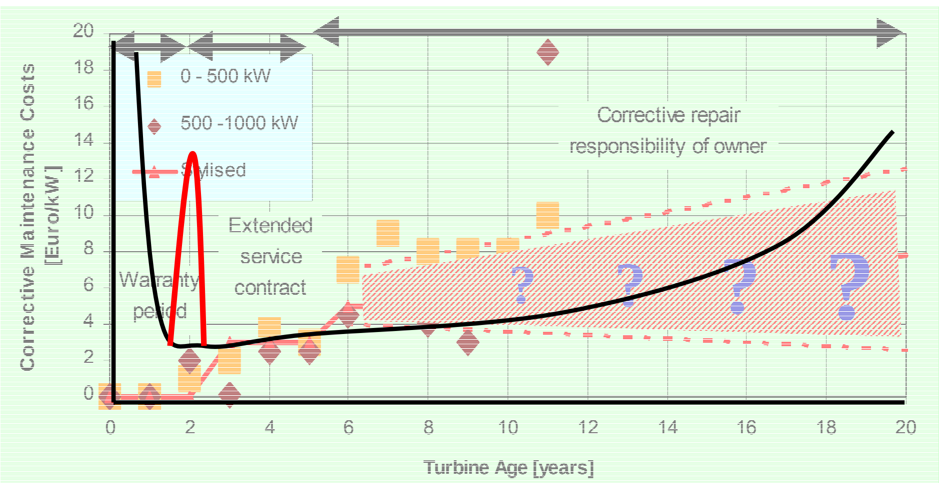
Developing “Flight leader” principle to avaoid extensive measurement campaigns for all turbines

ECN

O&M Cost Estimator: Which key parameters?

1. Failure rate of main components and systems

- components that are not being monitored
- number of failures (per year) determines corr. miant. costs



Theory: Bathtub curve

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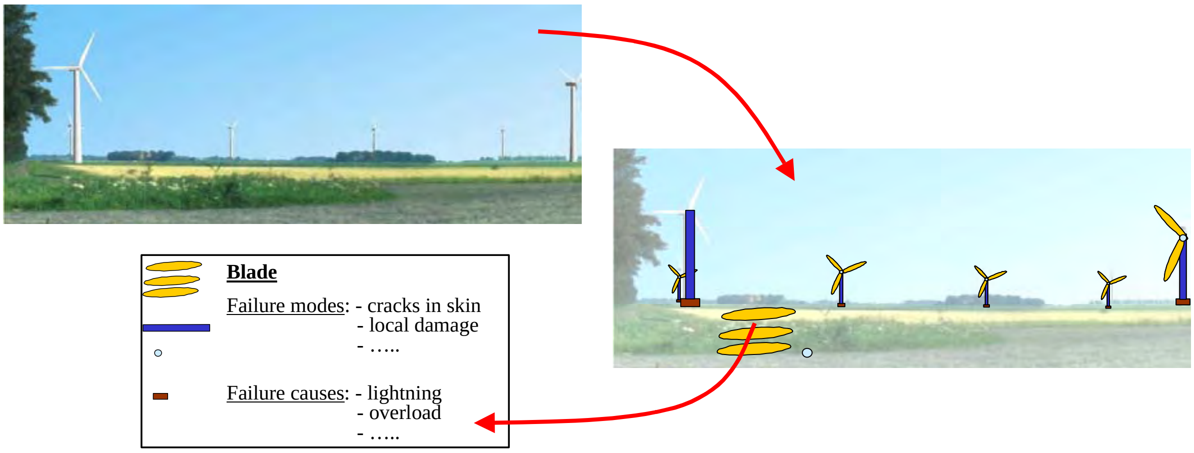
O&M Cost Estimator: Which key parameters?

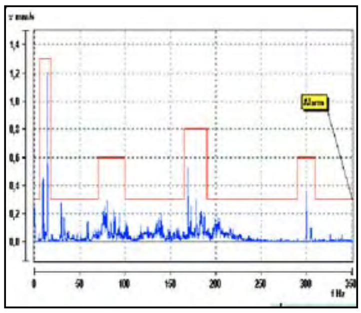
1. Failure rate of main components and systems

- "Predicting" failure behaviour based on observed failures and key parameters
- Collecting O&M data in a structured manner to allow feedback



ECN

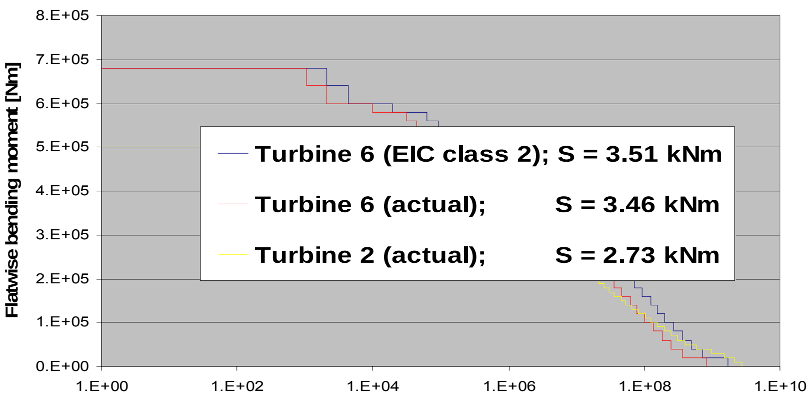
O&M Cost Estimator: Which key parameters?



2. Degradation of components and monitoring:

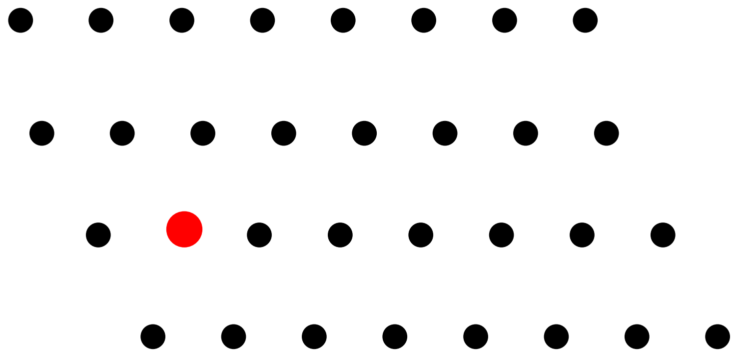
- condition based maintenance, fault prediction
- avoiding consequence damage
- "flight leader principle"
- prioritising maintenance

$$L_{eq} = \left[\frac{\sum_i n_i . L_i^m}{n_{eq}} \right]^{-\frac{1}{m}}$$



O&M Cost Estimator: Which key parameters?

3. Flight leader principle



- Wind farm modelling
- Wake effects
- Loading patterns different for different components

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Practical work

- N80 turbines ECN test station
  - extensive measurement campaign (loads, CM, PLC)
  - extensive collection other information (SCADA, O&M)
  - developing "flight leader principle"
- Case study N80 turbines offshore
  - O&M model ready
  - feedback of O&M data from ECN test station data

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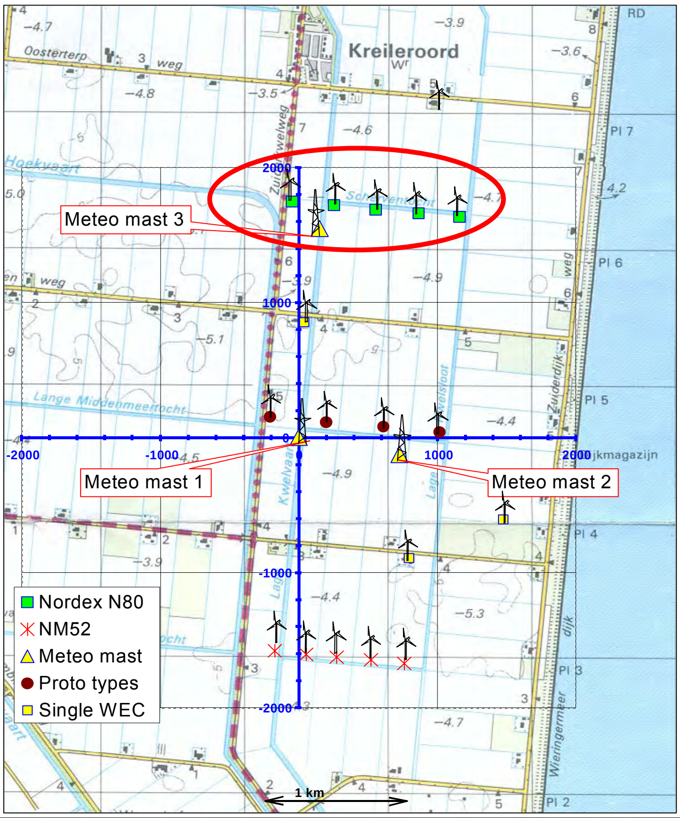
Practical work



Practical work

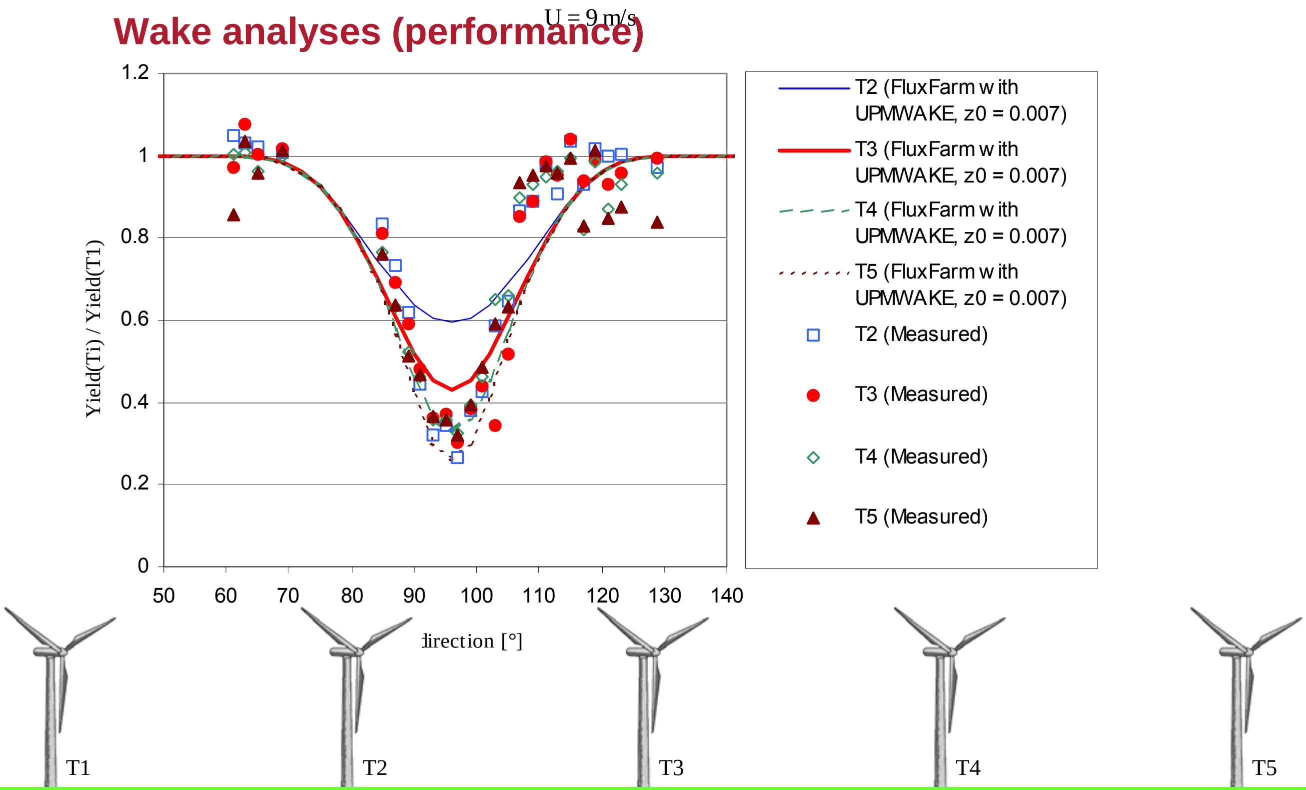
Quantification of future O&M costs and uncertainties based on a.o.:

- condition monitoring data
- observed failures
- operational experience
- SCADA data
- repair strategy

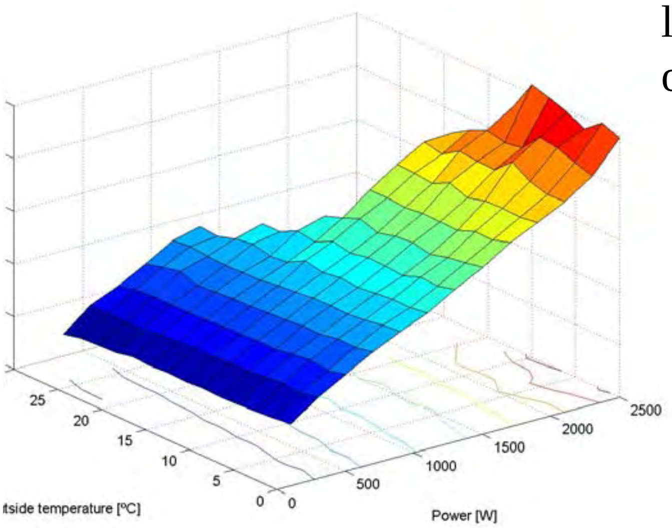
Flight leader

extensive measurement campaign

Wake analyses (performance)



Example – difference cool water temperature before and after generator



Determine most common trend line for turbines under 'normal' operation

ECN

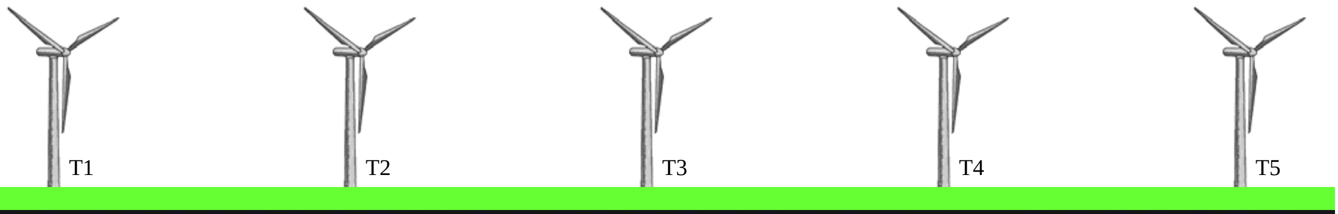
Loads analyses (in preparation)

Investigate effects of

- turbulence
- wakes
- power

For different components, and compare:

- mutual
- load calculations (single turbine and wind farm effects)



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Condition Monitoring (Objectives)

- Changing from corrective maintenance to condition based maintenance
- Less consequence damage
- Better planning of maintenance actions
- Design verification
- Alarms (green, yellow, red)
- Insurance companies ask for it

White spots:

(1) Development of algorithms for predicting remaining lifetime

(2) Blade monitoring

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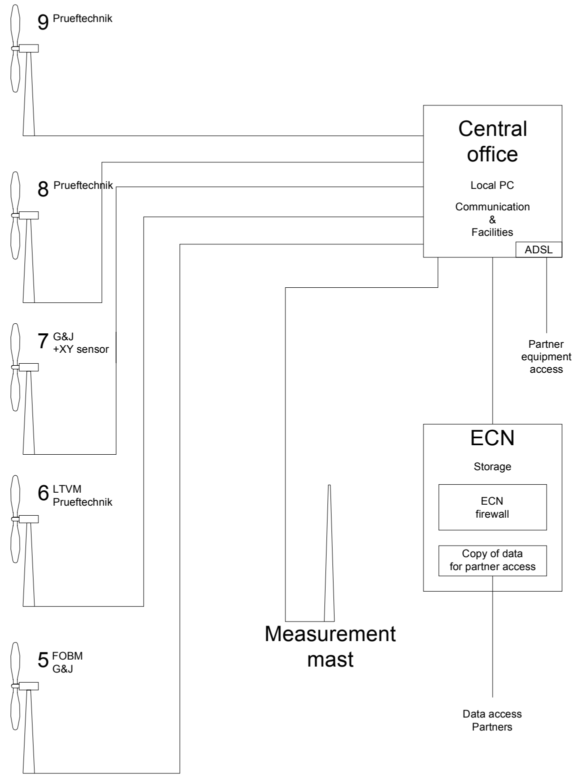
CM Lay-out on EWTW

On each turbine, a condition monitoring system will be installed:

- G&J on Turbine # 5&7
- Prüftechnik on Turbine # 6, 8 and 9

ECN is within CONMOW project responsible for installation, measurements, etc. and determining added value for offshore wind energy



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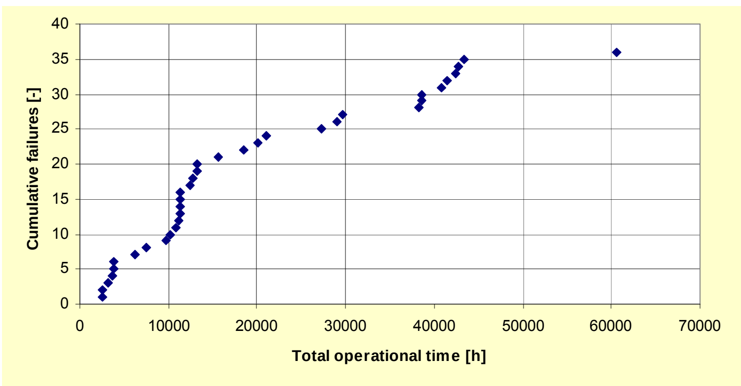
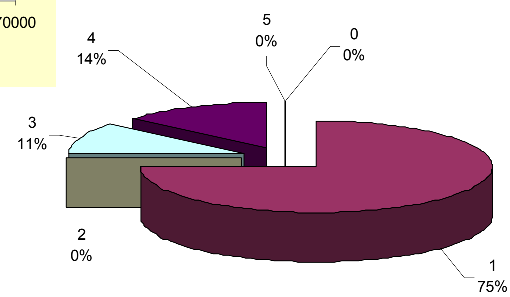
Feedback of O&M data





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Acknowledgement

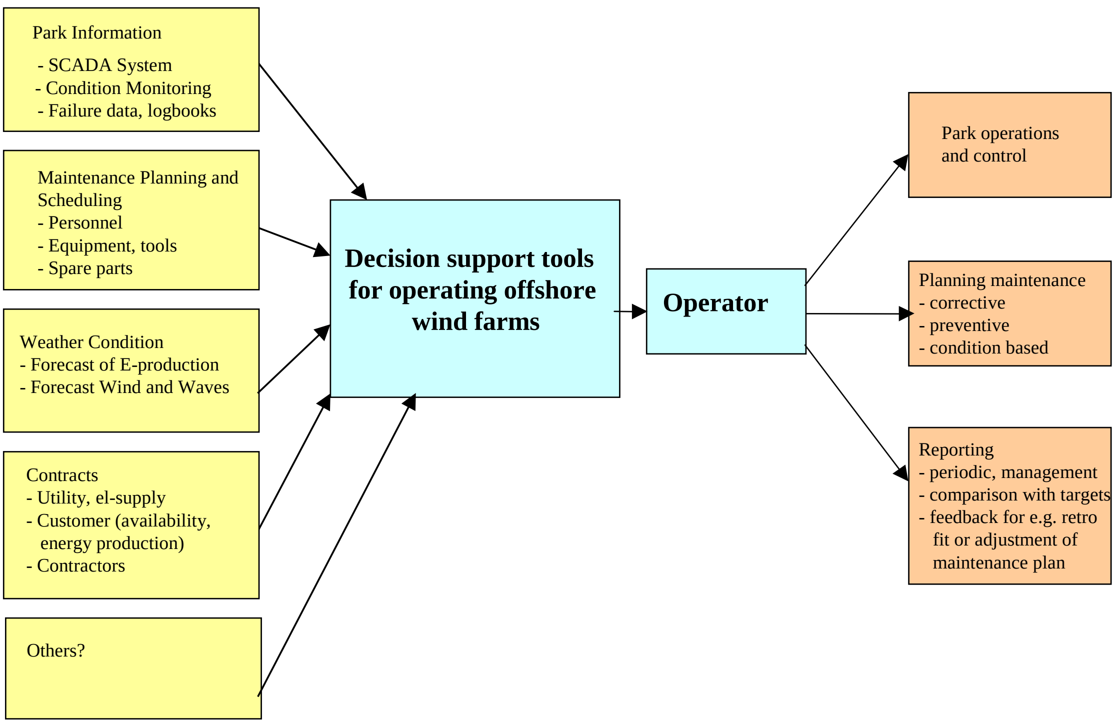
Wea@Sea project O&M Cost Estimator

Senter-Novem project: Long Term Validation Measurements

EU project: Condition Monitoring Offshore Wind Turbines

Nordex

O&M Optimisation: Short Term < 72 hrs



Examining Operational Risks Through Simulation

Presented by:

Unai Otazua at CIEMAT May 9, 2006

Adapted from:

Presentations made by Joe Phillips and Colin Morgan

Overview

- Differences between onshore and offshore - impact on operational economics
- Key questions an optimization tool can help answer
- Overview of "Optimization of Operations & Maintenance" (O2M) code
- Examples of applications of O2M

Risks and Associated Uncertainties of Wind Projects

"Wind" risk is the biggest risk and common to both onshore and offshore.

Uncertainties include:

- measurement accuracy
- data correlation uncertainty
- historical wind variability
- future wind variability
- wind flow modeling – in complex terrain

Onshore: Operational uncertainty generally not considered since O&M cost impact on economics is relatively weak

Offshore: Operational risk is a major consideration.

- mitigated in early years by warranty – but trend suggests owner may end up owning non-access / "weather" risk anyhow.

Accessibility Differences:

Major Cost of Crane Differences:

GARRAD HASSAN

GARRAD HASSAN

Garrad Hassan have developed a modeling tool to help analyze O&M challenges and minimize costs

"Optimization of Operations & Maintenance" or O2M

Closely based on work of Bossanyi and Strowbridge (ETSU 1994)

Questions that a modeling approach can help to answer

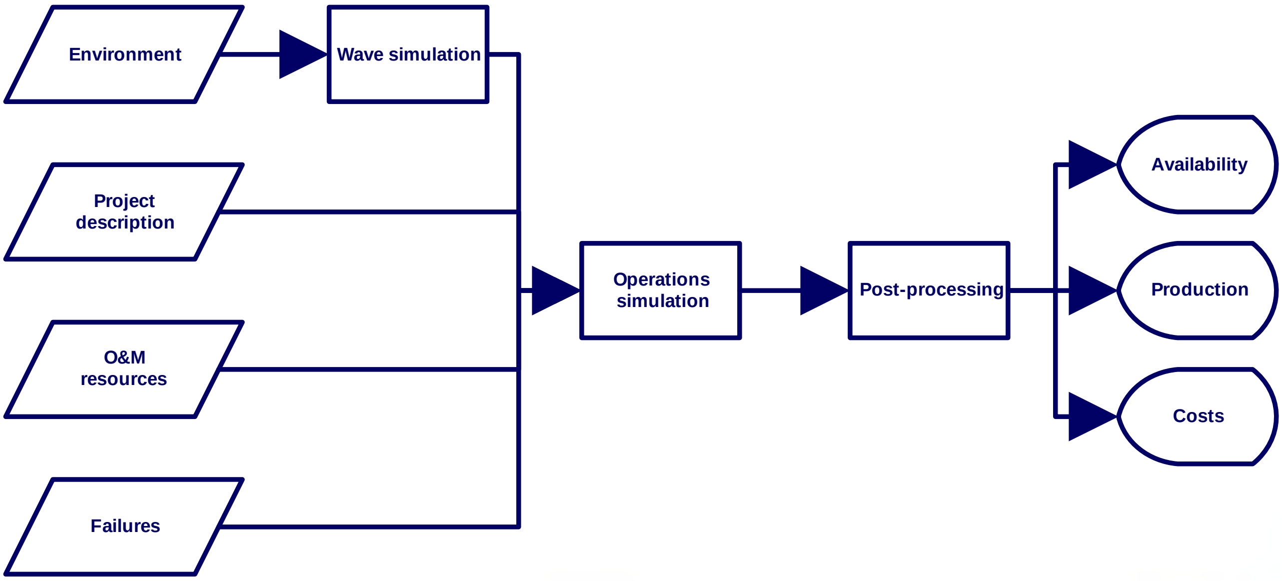
Banks and Owners:

- *What levels of wind farm "Availability" can be expected after the warranty period ?*
- *Is it worth investing more / less in O&M resource ?*

O&M Contractors / Turbine Manufacturers:

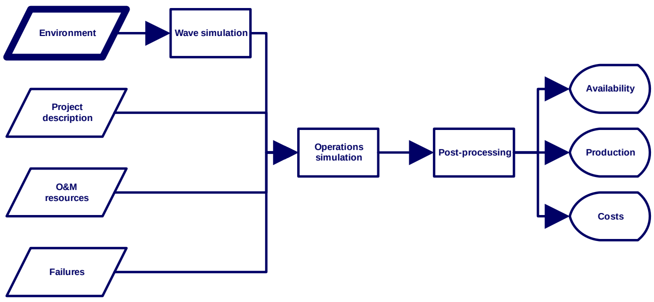
- *Is our O&M strategy adequate to meet warranted availability level ?*
- *What is the value of our O&M contract ?*

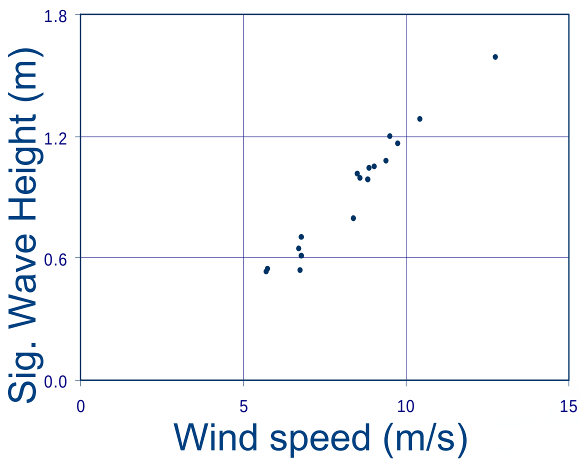
O2M Structure



Inputs: Environment

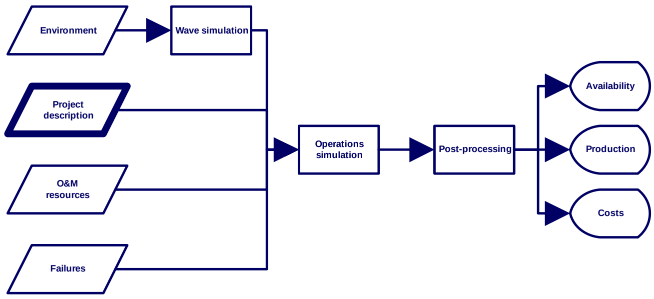
- Wave time series, if available
- Wind – wave relationship





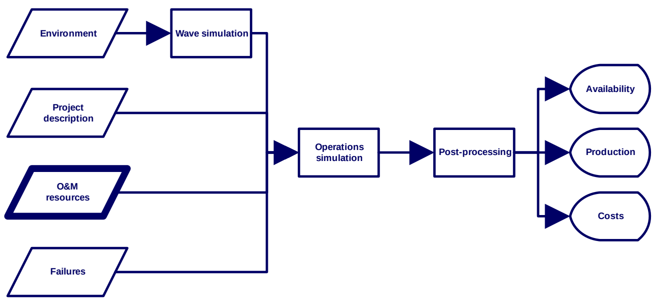
Inputs: Project Description

- No. of wind farm sites
- No. turbines on each site
- Stores and service locations
- Mobilization + Travel times
- LT energy prediction
    - (seasonal breakdown)



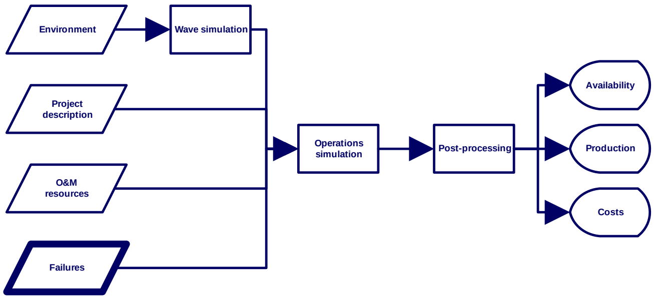
Inputs: O&M Resources

- Staffing
- Shift system
- Vessel capability
- Spares holding
- Spares lead times



Inputs: Turbine Reliability

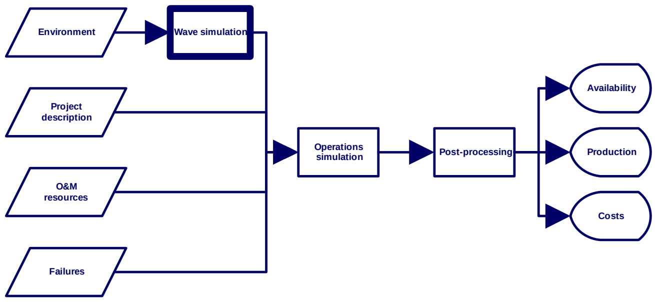
- Define several failure categories
- For each category define
  - Mean Time Between Failure (MTBF)
  - Mean Time To Repair (MTTR)
  - Spares requirement
- Example schedule of faults:

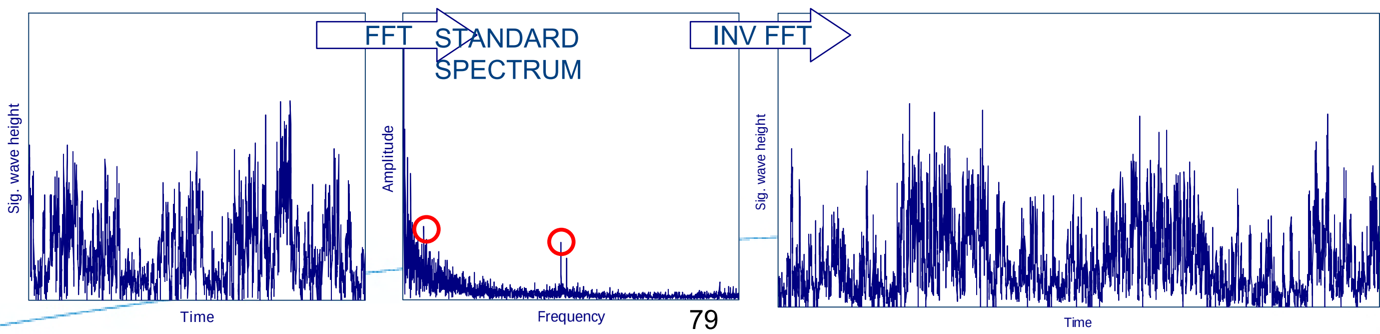


	DESCRIPTION	MTBF (HRS)	MTTR (HRS)
1	Manual restart	4000	2
2	Small component change-out	2500	8
3	Major component repair	15000	30
4	Major component change-out	50000	45

Wave Synthesis

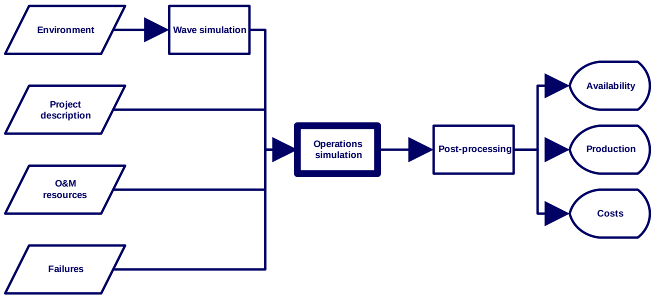
- Input time series
- Fast Fourier Transform (FFT)
- Wave Spectrum, includes
  - Seasonal phasing
  - Tidal phasing
- Inverse FFT
- Synthesized time series of desired length





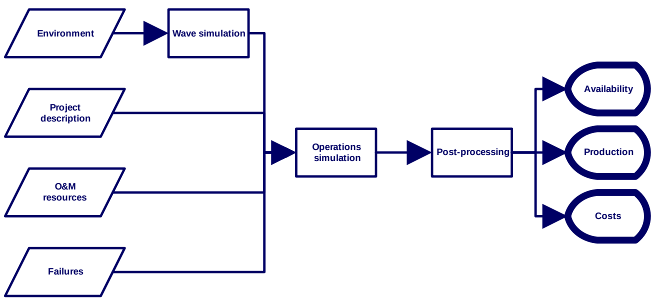
Operations Simulation

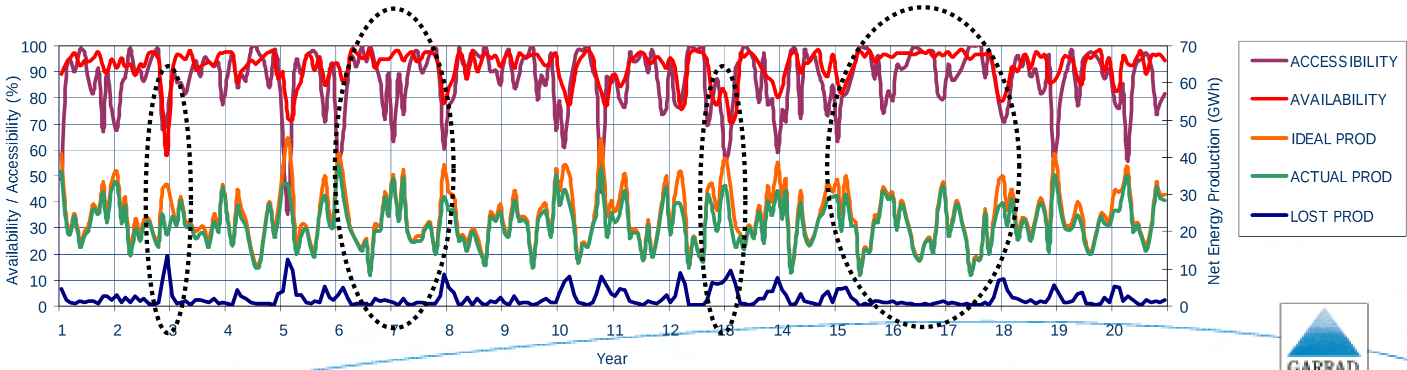
- Hourly time step, run for N years
- At each time step:
  - Failures (Monte Carlo)
  - Actions
  - Status updated
    - Turbines
    - Crews
    - Parts
  - Results recorded



Outputs

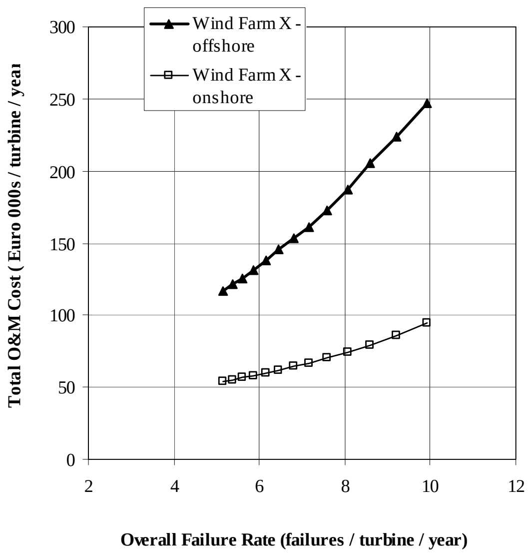
- Availability
- Production and Lost Production
- Costs, resource and spares usage
- Example output plot
  - “Low avail.-Low access” periods
  - “Lucky” periods





Examples of Analyses using O2M

O &M Cost Comparison

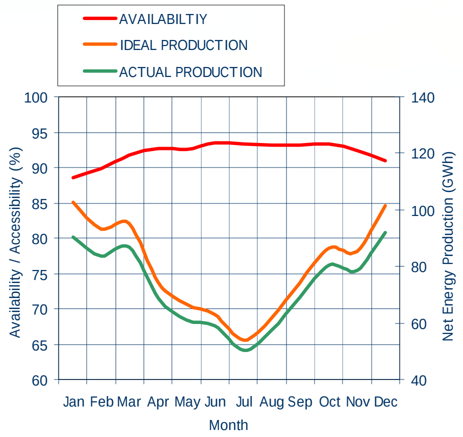


Offshore vs. Onshore

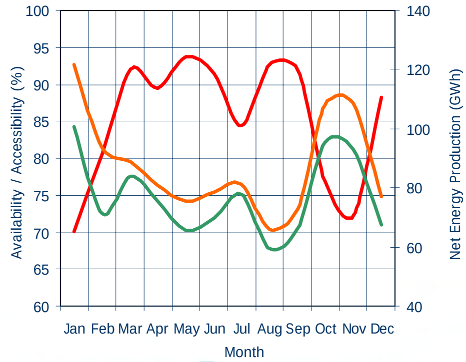
Sensitivity of cost to failure rates

Example Applications (1)

- Seasonal Analysis
  - Mean seasonal trend
  - "Worst" expected year



- Scenario Modeling
  - Serial defects in years 1-5
  - Wear-related failures in years 10-20



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Example Applications (2)

- Cost Benefit Analysis
  - Example: Access Method Capability

	Capex M €	Access Limit (Hs)	Accessibility (%)	Availability (%)
Method 1	0.4	< 1.5 m	68.8	86.7
Method 2	0.6	< 2.0 m	80.6	92.4
Method 3	1.2	< 2.5 m	88.3	94.8

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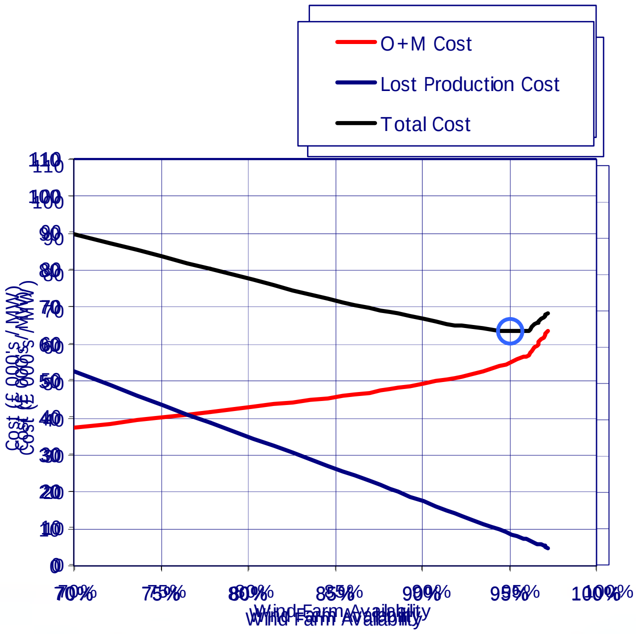
Example Applications (3)

- O&M Optimization

O&M Direct Costs

+ Lost Production Cost

= Total Cost



Summarizing

Onshore O&M:

- Worth more attention than it often gets – room for optimization?

Offshore O&M:

- Access and higher cost risks
- Shortage of relevant project experience
- Much reduced scope for trial and error

Common factor is turbine reliability

Optimization of Operations & Maintenance code "O2M" can help

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Research Concept On **Self Maintenance Machines** To Be Applied To O&M Of Large Scale Offshore Wind Turbines

Topical Expert Meeting on Operation and Maintenance of Wind Power Stations
IEA RD&D Wind, Annex XI

Erika Echavarría Uribe
PhD @ Sea
Intelligent Mechanical Systems Group
Bio Mechanical Engineering Department
3mE Faculty
Email: E.EchavarriaUribe@TUDelft.nl

Content

- Introduction **we-at-sea**
- Offshore industry
- Offshore maintenance overview
- Maintenance Strategy: Self Repair Design Methodology
  - Intelligent Maintenance & Operation Support
  - Design for Re-Configuration
- Conclusions

Reliability, Availability and Maintainability

access systems
operation
tools and models
maintenance
repair

cost-benefit ratio

higher wind farm availability and lower costs

TU Delft
PhD @ sea:
Scenarios
Wind & Waves
Large Blades
Concepts
Park-Grid Interaction
Morphology
Grid Stability
Site Data
RAMS
Verification

Offshore industry

- Already developed **Offshore** industry
  - Equipment,
  - Procedures,
  - Wave and tidal information,
  - Models, etc.

- Onshore **wind energy**:
  - 98% availability
  - Commercial wind turbines

Offshore wind energy

Lack of experience and maintenance records for offshore wind energy.

Tools, equipment and solutions should be derived, if possible, from already developed offshore industries.

Offshore maintenance overview

High installation, O&M and decommissioning costs

O&M is about 25%-30% of kWh cost

- ❑ Required maintenance cannot be predicted yet

uncertainty leads to higher financial and insurance costs

- ❑ Corrective maintenance: ~ 2x preventive maintenance
- ❑ Accessibility affects directly the availability
- ❑ Weather conditions
  - —salt water
  - —Ice
  - —low visibility
  - —high wind speeds
  - —and high waves

Force changes in technology/structure of wind turbines.

- ❑ RESULT: Need of a Maintenance Strategy

Maintenance Strategy

Self Repair Design Methodology …

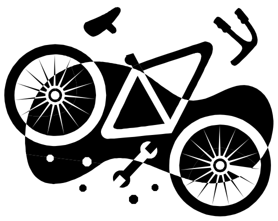
fault tolerance

Objective

to increase reliability and availability for offshore wind farms, without sacrificing economy and complexity.

Offshore Maintenance Problems
Failure Modes

Design for Re-Configuration → Intelligent Maintenance and Operation Support



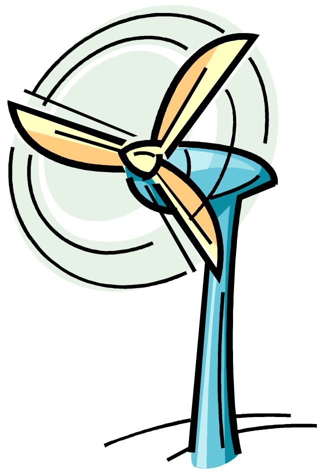
Faults happen!

- ❑ Decreased stoppage rate.
- ❑ Reduced number of failure events.
- ❑ Maintained energy output.
- ❑ Reduced maintenance visits.

Intelligent Maintenance & Operation Support

Improve FAULT TOLERANCE

"A machine ca be made self-maintaining by taking advantage of functionally similar components when faults occur. The performance of the machine might degrade, but the required functions will continue".



A Self Maintenance Machine [SMM] should:

- Constantly monitor its state
- Judge status: normal/faulty
- Carry out a diagnose, even for unknown faults
- Generate a repair plan: to allow the machine to performed at least some of the required functions
- Execute repair plan

Computer usage

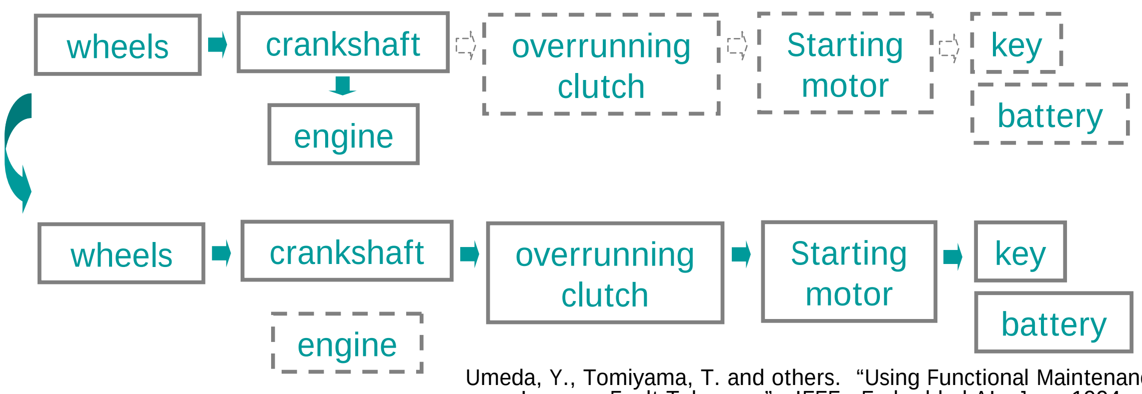
Sensors and Actuators

Umeda, Y., Tomiyama, T. and others. "Using Functional Maintenance to Improve Fault Tolerance". IEEE. Embedded AI. June 1994. p.p. 25-31

SMM vs. TCS (Traditional control strategy)

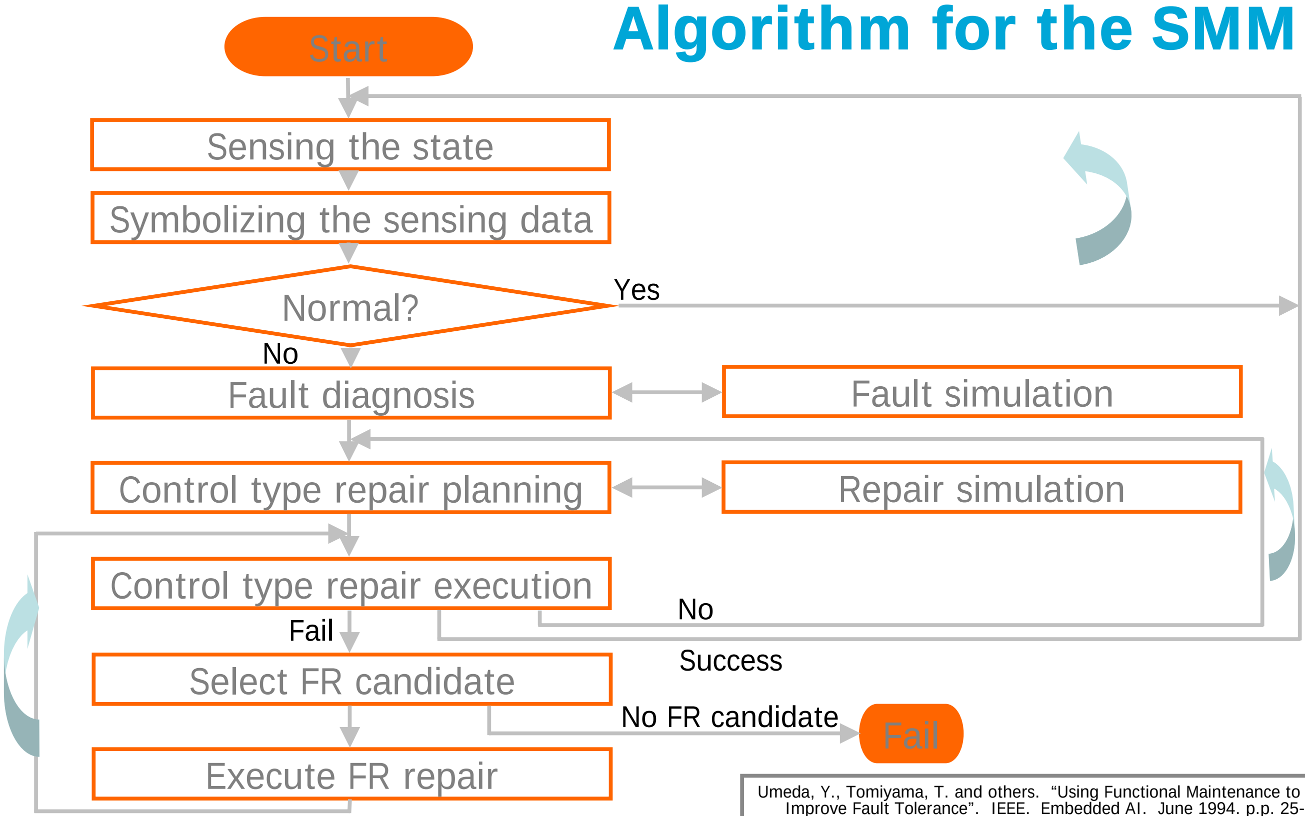
- TCS aims to keep the machine in a given state
- SMM aims to keep the machine operating

Example: Functional Redundancy in a car



Umeda, Y., Tomiyama, T. and others. "Using Functional Maintenance to Improve Fault Tolerance". IEEE. Embedded AI. June 1994. p.p. 25-31

Algorithm for the SMM



Umeda, Y., Tomiyama, T. and others. "Using Functional Maintenance to Improve Fault Tolerance". IEEE. Embedded AI. June 1994. p.p. 25-31

SMM concept for a photocopy machine

- Control Type
  - Adjustment of parameters by means of actuators based on sensor data collected
  - It can recover from faults, even from unknown cases
  - Repair planning reasons out multiple repair methods simultaneously. A repair plan needs to be carried out with each parameter that requires adjustment.

- Functional Redundancy
  - i.e. Main charger fails:
    - Function — to charge the drum
    - Redundancy — the transfer charger has the same working principle
    - Requirements — to replace a transformer in the transfer charger + additional control program
    - Trade-off — reduced copying speed and quality

Maintenance Strategy

Self Repair Design Methodology …

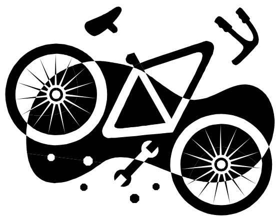
fault tolerance

Offshore Maintenance Problems
Failure Modes

Design for Re-Configuration

Intelligent Maintenance and Operation Support

- ❑ Non-stop operation.
- ❑ Reduced number of failure events.
- ❑ Maintained energy output.
- ❑ Reduced maintenance visits.



Design for re-configuration

towards a SMM

Umeda, Y., Tomiyama, T. and others. "Using Functional Maintenance to Improve Fault Tolerance". IEEE. Embedded AI. June 1994. p.p. 25-31

- ❑ Sensors: monitor the machine
- ❑ Functional Redundancy Designer
- ❑ Model Based Reasoner
- ❑ Repair Methods

Function-Behavior-State Model

Knowledge Base

Object Model
oFunctional Model
oEntity Model
oParameter Model
oRepair Model

Qualitative Simulator

Knowledge about Principles and Laws

Fault Diagnosis

Repair Method

Control Type

Functional Redundancy Type

Design for re-configuration

- RESEARCH OUTLINE: Design Methodology combining Re-Configuration and Functional Maintenance

Object Model

Define main offshore wind turbines architectures

Identify system components, systems and subsystems:
- Component level
- Wind turbine level
- Wind farm level

Generate function model
F-B relations [connectivity]

Identify existing redundancies

Failure Mode Identification

Alternative Structural Configuration

Control Strategy

Identify required redundancies

Design for re-configuration

Sensors + actuators

Intelligent monitoring

Object Model

Knowledge about physical Laws

System level ramification

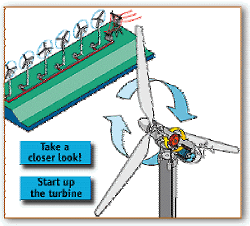
operation under extreme conditions

Repair execution

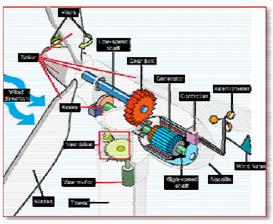
Control Type

Functional Redundancy

Intelligent Maintenance

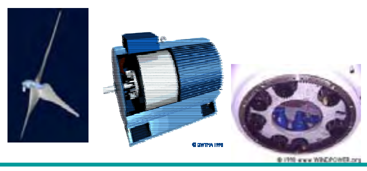


Wind Farm Level



Wind Turbine Level

Component Level



www.windpower.org

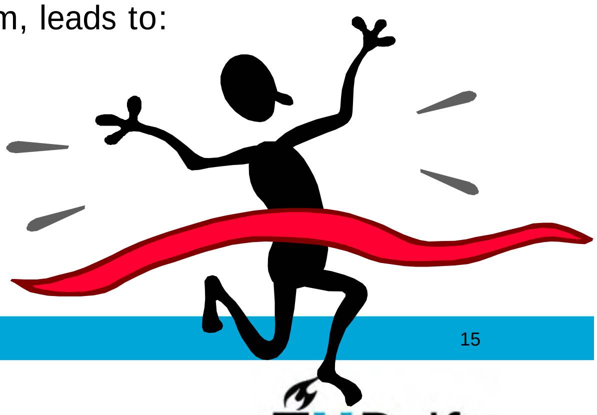
Design for the best way to allocate required redundancies for alternative configurations.

Conclusions

- O&M represent a large percentage of an offshore wind farm kWhcost.
- Economics of O&M strongly depend on failure behavior of WTs.
- Offshore wind energy has enough differences with onshore wind energy and offshore industry in general to call for different technological solutions.
- Offshore accessibility affects considerably the availability of the plant.

A new approach for offshore O&M is needed

- Design for Re-Configuration together with Functional Maintenance through the use of existing redundancies of the system, leads to:
  - Almost no-stop operation
  - Fault tolerance operations
  - Maintained energy output
  - Reduced # of hard failure events
  - Reduced # of MTTO visits



Questions and Discussion

Operation & Maintenance of Wind Turbine Systems

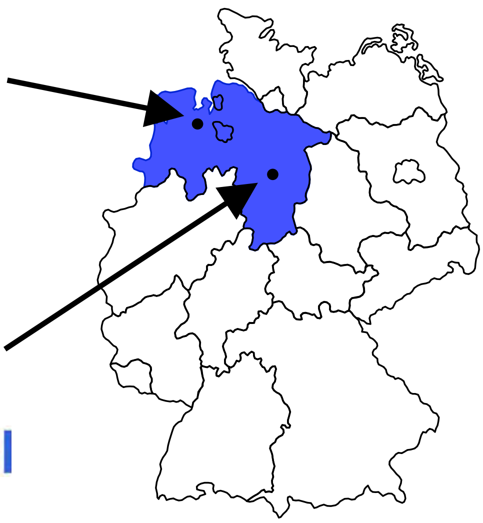
Is there a need for basic research?

Joachim Peinke

ForWind

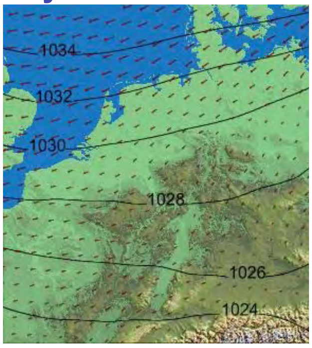
- Common centre for wind energy research (ForWind)
- Carl von Ossietzky University Oldenburg
- University of Hanover.

Universität Hannover



ForWind

Physics



Civil engineering

Electric engineering

Research topics:
-energy forecasting
-turbulence and stochastics
-Mechanical effects and loads
-Grid integration

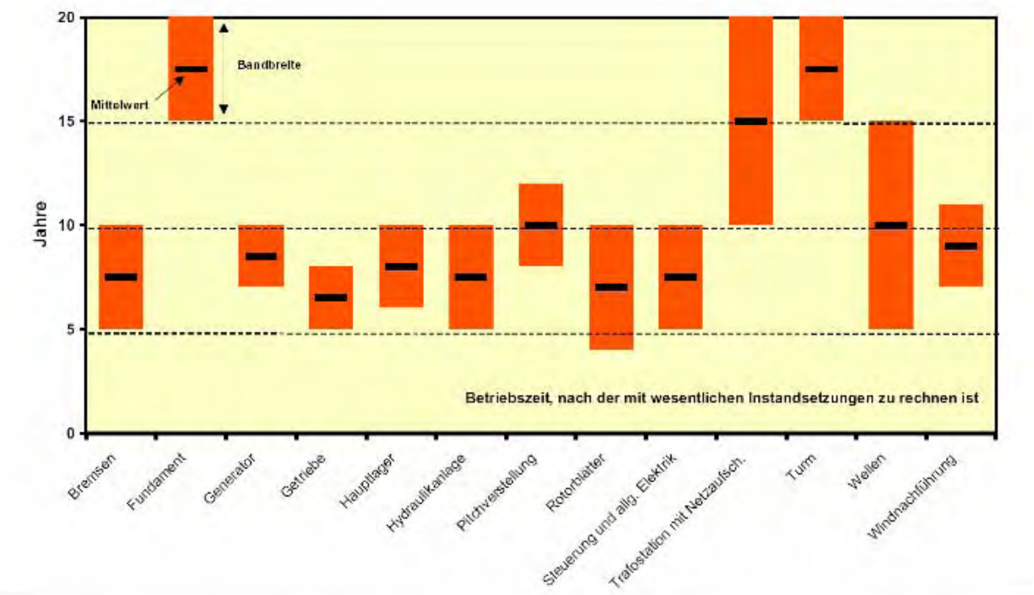
My point of view - open for discussion

Operation & Maintenance -

there is the problem of many unknown loads for wind turbines

Life cycles of main components

- „End User“ (Twele et.al. Ispra 2005)



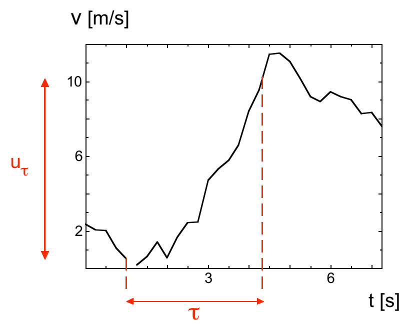
Wind energy - with some specific unknown loads
- fluctuating wind, heavy tail statistics
- blade turbulence
- WEC a interacting dynamical subsystems

Scientific problems / challenges
- correct knowledge of load and production statistics
- to understand the WEC dynamics in real time
- no first principles description (Bottom-up) possible
- to find the correct simplifications

Three topics:

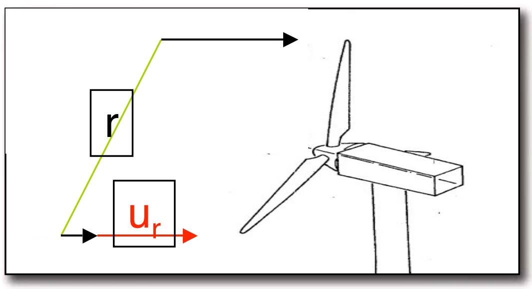
- wind field and its fluctuations
- blade turbulence
- interacting dynamical subsystems

Wind turbulences

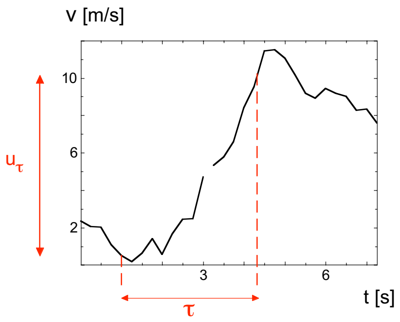


Windfluctations - gusts:
Spatial and temporal aspects

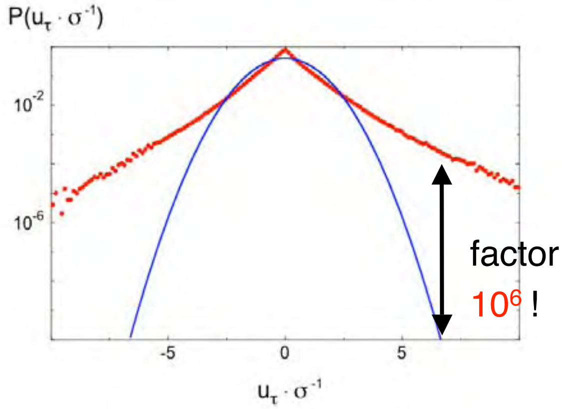
$$u_\tau = U(t+\tau) - U(t)$$



Wind turbulences



statistics of wind fluctuations / wind gusts



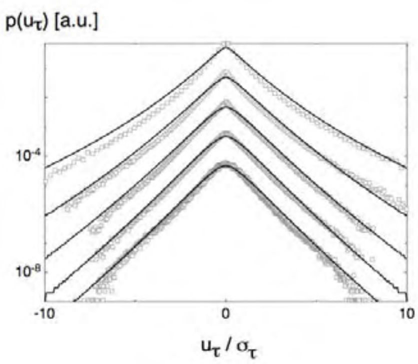
Heavy tail statistics once a minute / a year

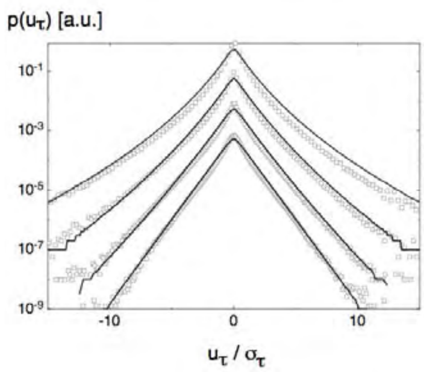
Wind turbulences

Model of superporstion of ideal turbulence

offshore

Complex terrains





τ = 0,25s 2,5s 25s 250s

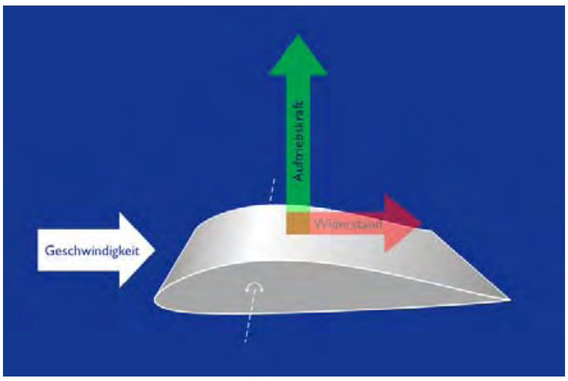
F. Böttcher et.al. Boundary Layer Meteo. 108 (2003)

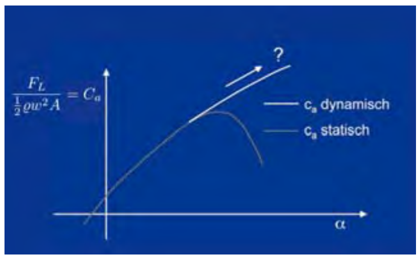
Three topics:

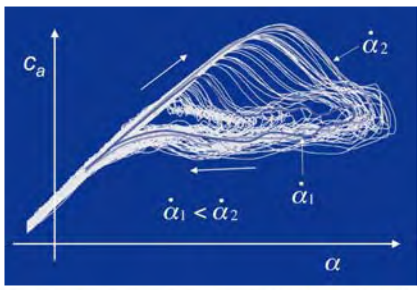
- wind field and its fluctuations
- blade turbulence
- interacting dynamical subsystems

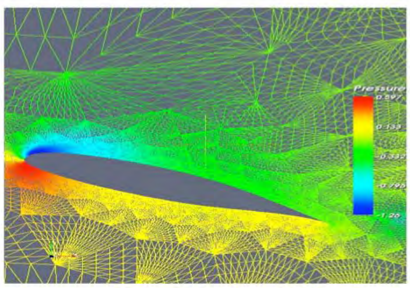
Blade aerodynamics

Loads on a blade
Dynamic lift force









Flexibler hp Spektral-Code

Three topics:

- wind field and its fluctuations
- blade turbulence
- interacting dynamical subsystems
  - coupled dynamical systems
  - nonlinear dynamics; Chaos
  - challenge to find the right simplification,
  - slaving principle and order parameter selection -
  - mechanism of synergetics

- interacting dynamical subsystems

method how to extract from given measured data the effective dynamics

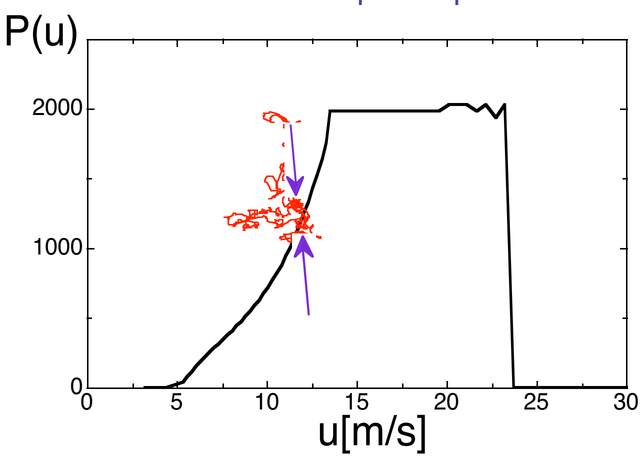
universität OLDENBURG
IEA Madrid 2006
ForWind Zentrum für Windenergieforschung

Wind - power dynamics

Power production of a wind turbine

a nonlinear dynamic process

Wind - power relation is
A response problem

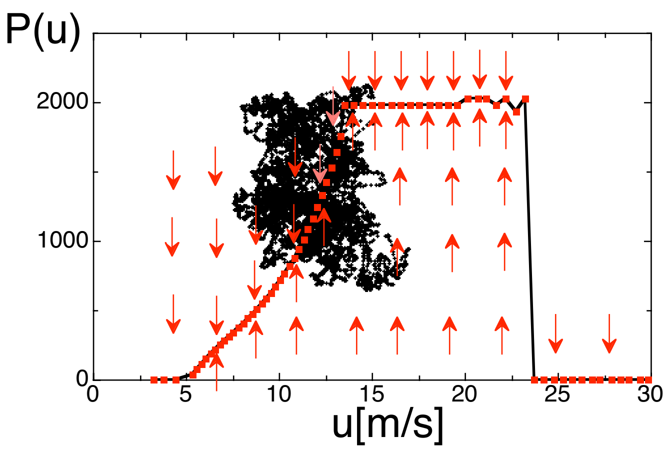


- IEC averaging
- understanding of the dynamics

Dynamics power characteristics

New method of **time series analysis**
enables to reconstruct the dynamics in a parameter free way

$$M^{(k)}(u,r,\Delta r) = \int_{-\infty}^{+\infty} (\tilde{u}-u)^k p(\tilde{u}, r-\Delta r | u, r) d\tilde{u} \qquad D^{(k)}(u,r) = \lim_{\Delta r \to 0} \frac{r}{k!\Delta r} M^{(k)}(u,r,\Delta r),$$

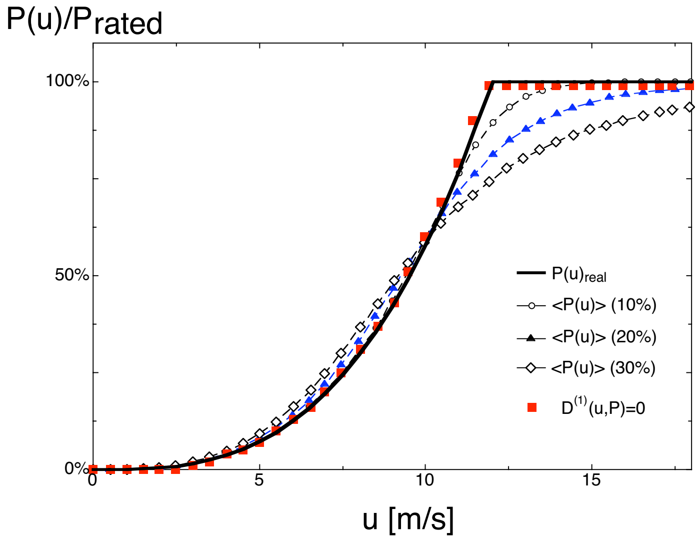


Data from a 2MW
Turbine at Tjaereborg DK

E. Anahua et.al. EWEC 2006

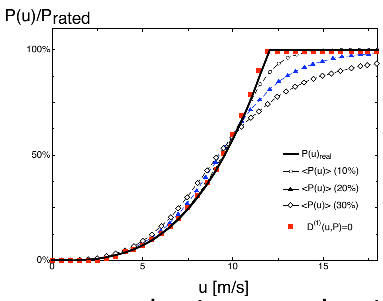
Dynamics power characteristics

example: comparision between IEC norm and dynamic characteristic



F. Böttcher in Wind Energy, eds. J. Peinke et.al (Springer 2006)

Dynamic characteristic of a WEC



- **efficient:** data in sec => short measuring time
- **robust:** direct use of the measured data
- **universal:** independent of complexity of the terrain
- **monitoring:** overall performance monitoring

Other dynamical relationships can be modeled, too

Basic research

- ➤ wind field with correct correlation
- ➤ transition to turbulence
- ➤ improved load modeling
- ➤ improved modeling of power production

- ➤ real time dynamic understanding/model

All this basis for

➤ improved technical parts

Thank you

ForWind
Zentrum für Windenergieforschung

Further informations www.physik.uni-oldenburg.de/hydro

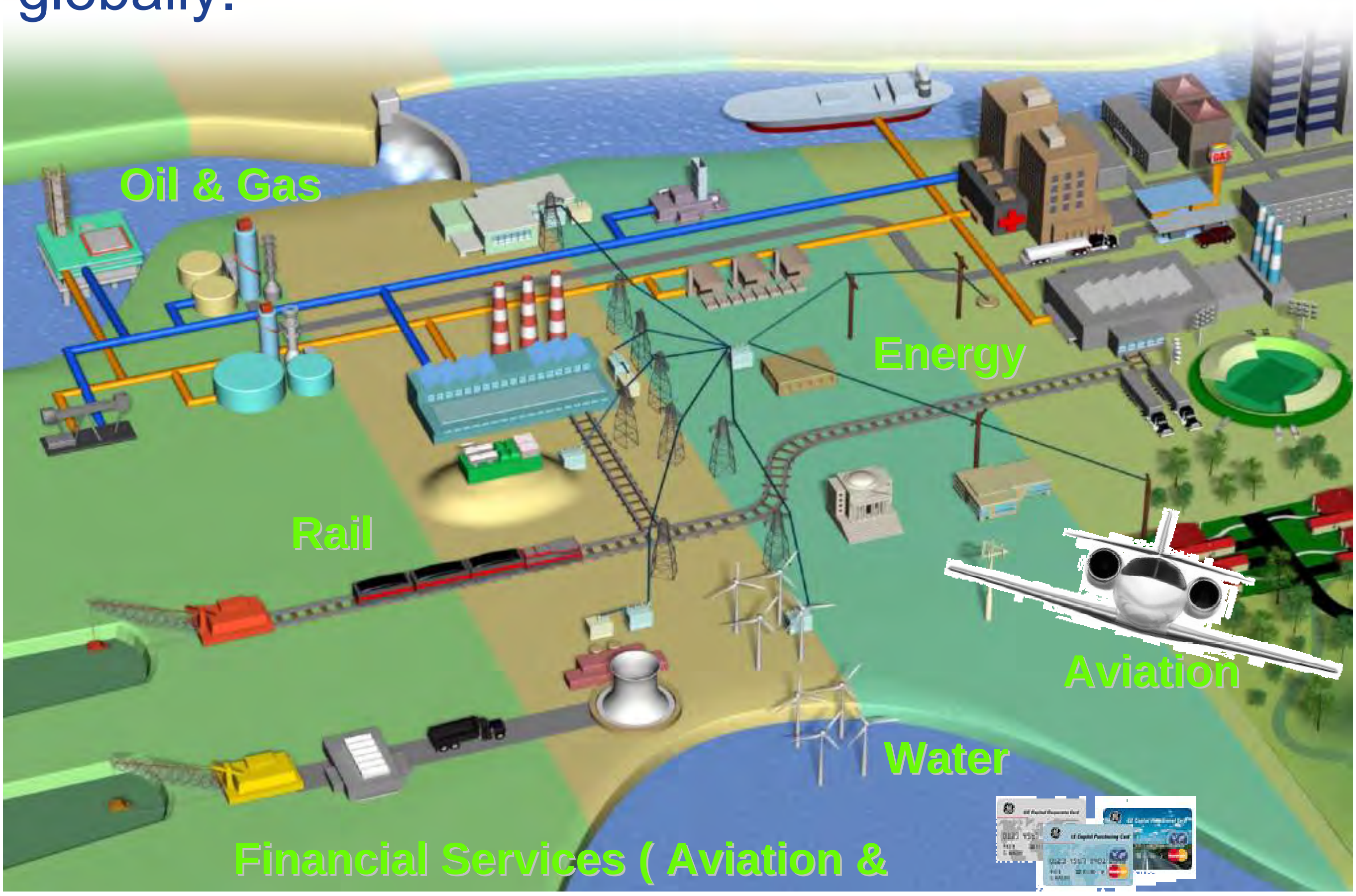
GE Energy
Wind Parts & Maintenance

Axel Buehler
Philippe Kavafyan
May 10, 2006

imagination at work

GE Infrastructure

Provide unified approach to key customers globally.



GE Infrastructure's Businesses

Oil & Gas

Energy

Rail

Aviation

Water

Fin. Services
(Aviation & Energy

Infrastructure Revenue is ~25% of GE Sales

Imagination Breakthroughs

- **Cleaner Coal™**

  Converts coal into a gas which burns in a gas turbine — cleaner burning of coal

- **Very Light Jet**

  New generation of very Light Jets including the potential "Air Taxi" segment of business travel ranging from 300 to 500 miles

- **Desalination**

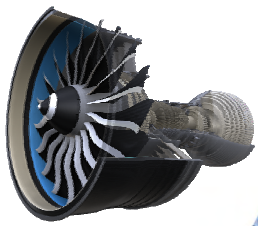
  Removes the saline from sea or brackish water to provide fresh water for drinking, irrigation or industrial applications

- **Digital Rail**

  Automates the millions of human decision points in rail traffic control, optimizing how the rails run and maximizing freight capacity

Green Solutions

- **GEnx - 35% reduced pollutants, 50% quieter**



- **Evolution Series Locomotive - 40% less emissions**

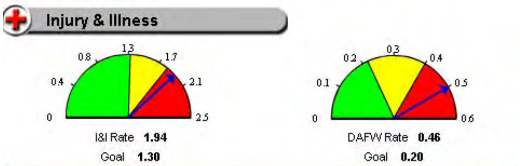
- **Wind – 3.6MW offshore turbine powering 1200 homes**

- **Water - 3 Billion gallons conserved**

- **Equipment Rentals for Disaster Relief Efforts**

Wind Challenges

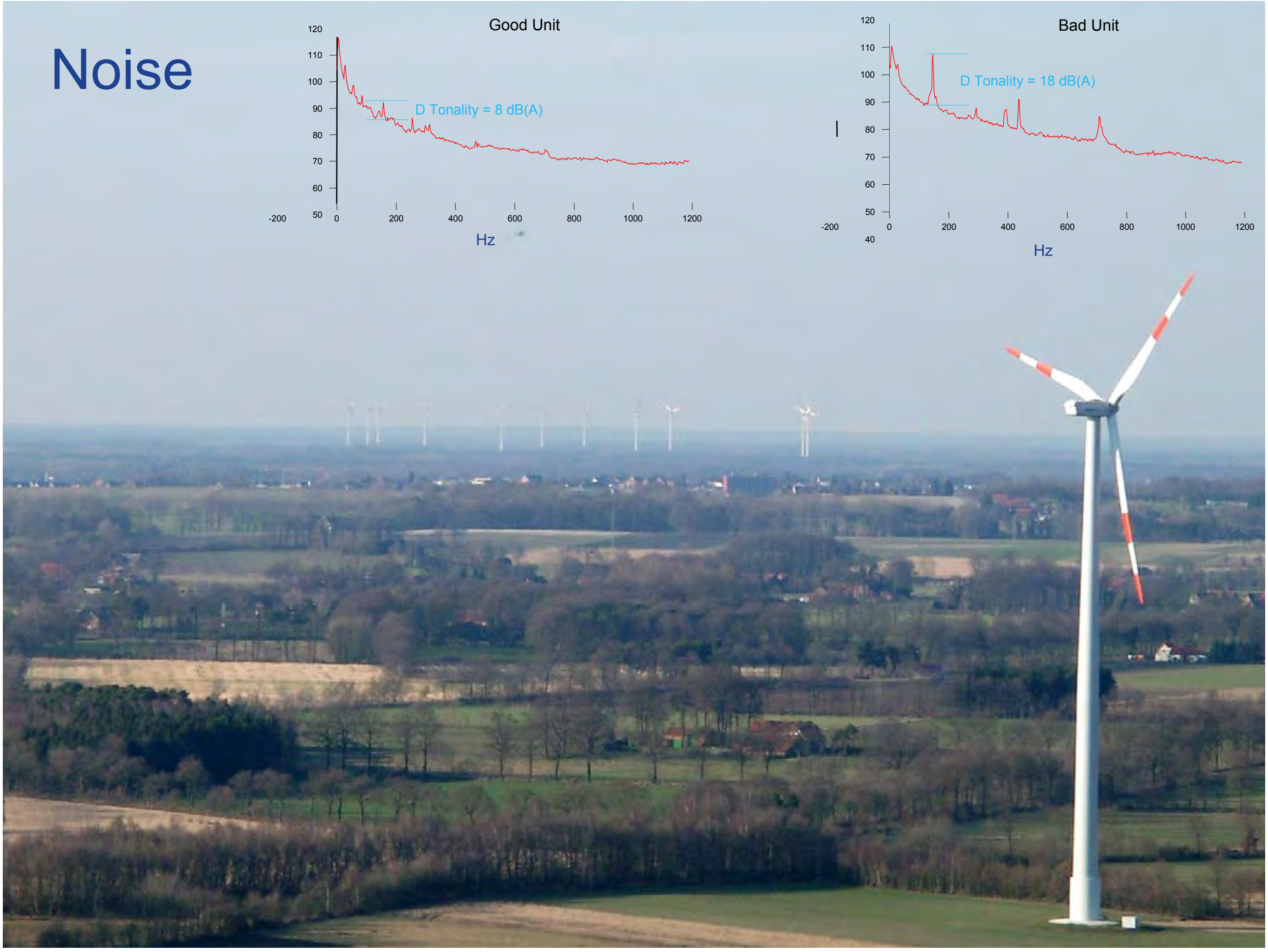
Safety



	?	2004	2003	%V
Total Number of Injuries/Illnesses		34	57	-40.4 %
Total Days Away From Work		8	17	-52.9 %

imagination at work

GE Proprietary Information


Noise
Good Unit
D Tonality = 8 dB(A)
Hz
Bad Unit
D Tonality = 18 dB(A)
Hz


Accessibility

Reliability

Failure Modes
- Micropitting – Gears & Bearings
- Gear Tip-to-Root Interference (gouging)
- Gear macropitting /spalling
- Gear fretting /brinelling /scuffing

Logistics

(Logistics)^2

Parts / Logistics
Expertise / Technology

Service Technologies for Effective O&M

Product Reliability (Prevention)

- Enhanced Offshore Equipment Designs
- Advanced Controls for Load Mgmt & Performance
- Design for Serviceability

Field Services

- High Quality Planned & Unplanned Maintenance
- O&M Asset Management
- EHS Trained

Customer Benefits

Revenue ↑
COE ↓
Reliability ↑
Availability ↑
Production ↑

Product / Customer Support

- 24/7 Remote Operations, Monitoring and Diagnostics
- Predictive & Condition Based Maintenance
- Contractual Services/Warranty Mgmt

Continuous Improvement

- Reliability & Performance Modifications & Upgrades

Product Reliability (Prevention)

Goal: Design turbines to deliver very high availability …. Breaks Down Rarely

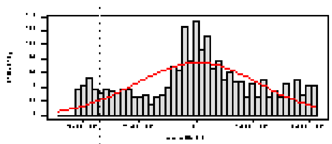
Approach:

- Utilize "Design for Reliability" & Serviceability
- Extended FMEA analysis to define causal events and impacts of failures
- Physics-based Reliability Models to understand true design and operational limits
- Redundancy of selected components to reduce availability impact of failures
- Advanced Controls for Load Management & Performance enhancement

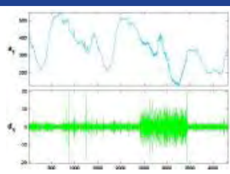
Serviceability

Extended FMEAs

Physics-based



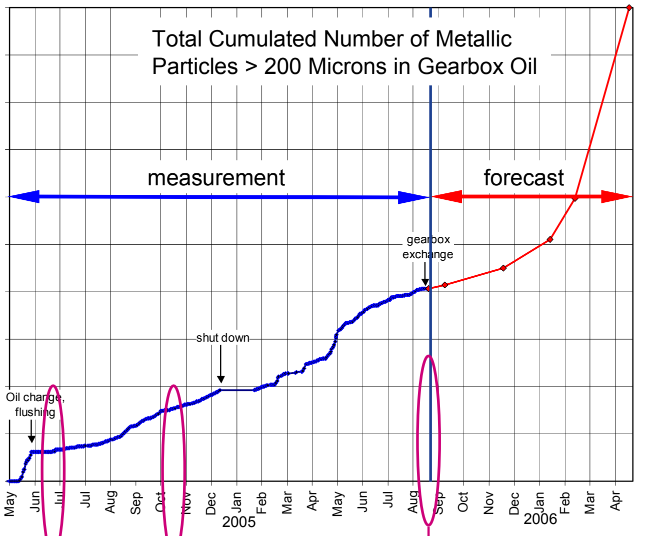
Advanced Controls



Condition Based Maintenance

Goal: Increase Damage <u>Predictability</u>

Approach: Gearbox Metallic Particle Monitoring



Aug '05

Offshore Field Services

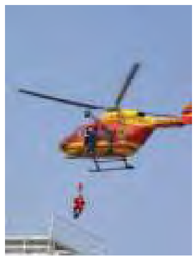
Goal: Effective Access System & Logistics for rapid field response

- Offshore Access Systems
  - Commissioning
  - Regular O&M duties
  - Overhaul tasks
- Access/Weather Modeling

Project	% Wave Height > 2.0 Meters
Project 1	48%
Project 2	3.5%
Project 3	8.1%

- Jack-up Barge Logistics
- Service Friendly Equipment
- Asset Management



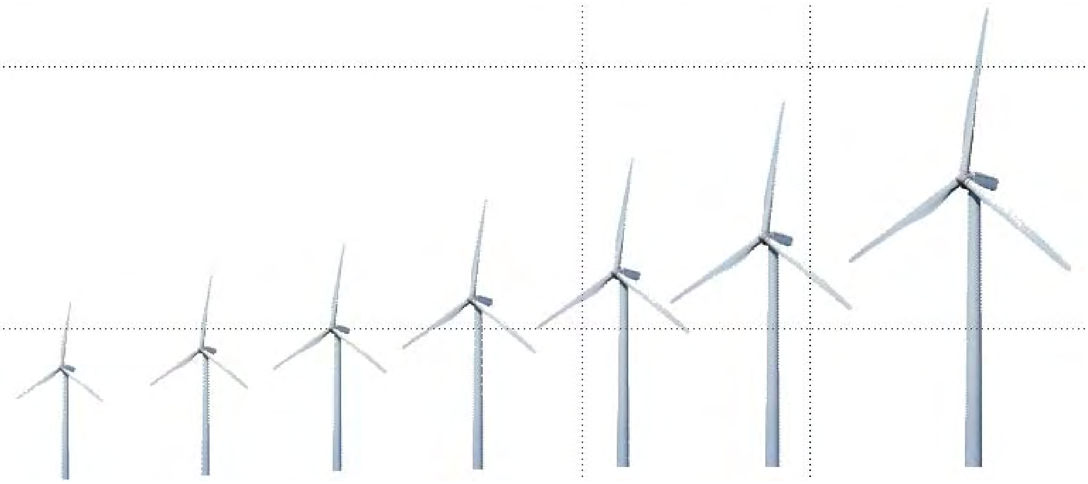

Driving Productivity in O&M

- Larger Turbines
  => shorter maintenance time / MW
- Remote Operations
  => reduce manual resets
- Parts refurbishment
  => control costs / obsolescence risk
- Condition Monitoring
  => (un)planned events
- Reliability improvement
  => less replacement
- Serviceability
  => reduce logistics costs

imagination at work

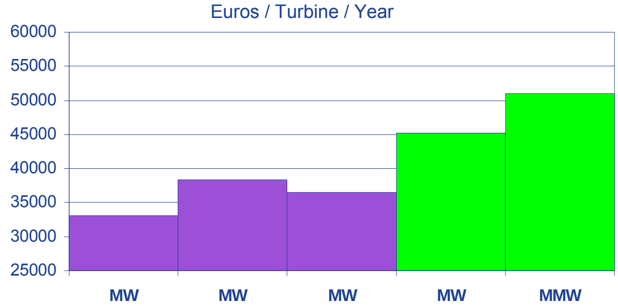
Wind farm total life cycle

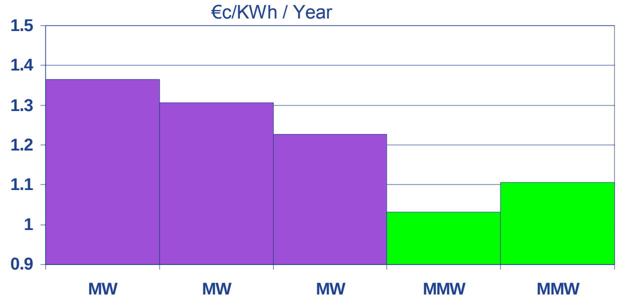
Cost of Installed MW … what about O&M ?



	1981	1985	1990	1996	1999	2001	2005
Rotor (Meter)	**10**	**17**	**27**	**40**	**50**	**71**	**88**
KW	**25**	**100**	**225**	**550**	**750**	**1,500**	**2,500**
Total Price	$65	$165	$300	$580	$730	$1,300	$ 2,000
Price/kW	$2,600	$1,650	$1,333	$1,050	$950	$866	$800
MWh	**45**	**220**	**550**	**1,480**	**2,200**	**5,600**	**9,690**

Reduction of Operating Expenses / kWh

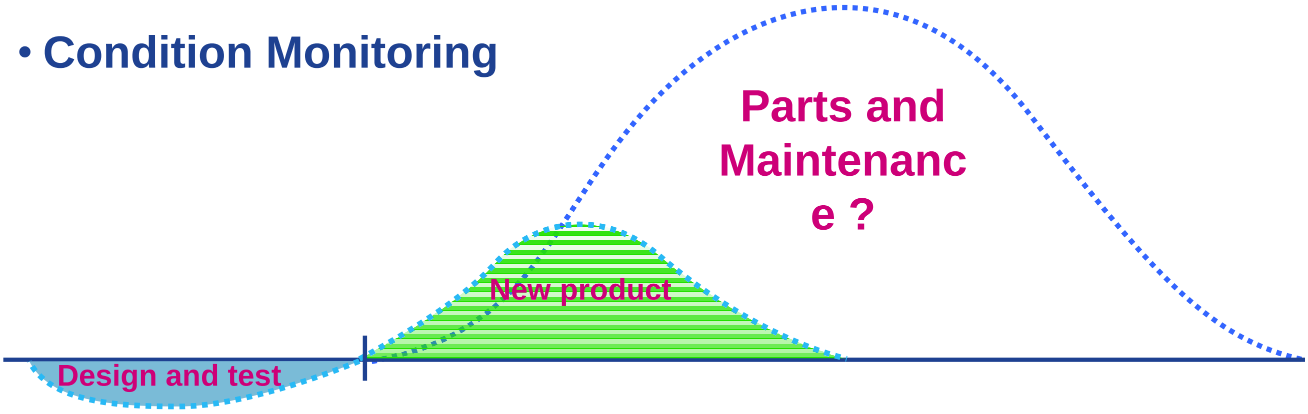




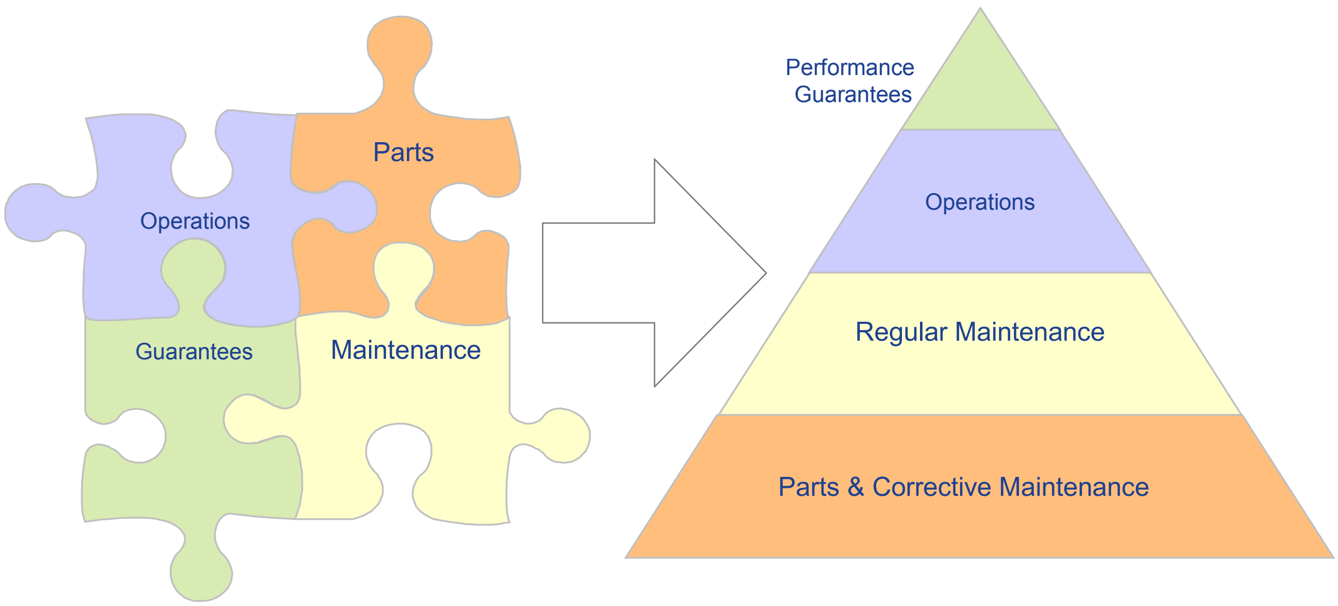
Assuming Similar Logistics Cost

Does traditional business model apply to Wind?

- Parts Sourcing & Logistics
- Specialized Maintenance
- Remote Monitoring & Diagnostics
- Condition Monitoring



Risk Allocation & Roles under definition in Industry



Effective Solutions will be found because…

the world wants

More Wind!

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IEA RD&D Wind, Annex XI
Operation and Maintenance of Wind Power Stations - 9th and 10th of May 2006, Madrid, Spain

Reliability of Wind Turbines

Experiences of 15 years with 1 500 Wind Turbines (WT)

Paul Kühn
Berthold Hahn

ISET
Institut für Solare Energieversorgungstechnik
Kassel/ Hanau, Germany

- ISET, Introduction and Data Base
- Availability and Causes for Failure
- Affected Components and Downtime
- Frequency of Failure
- Conclusion and Outlook

ISET - Institut für Solare Energieversorgungstechnik

Applications-oriented Research and Development in Electrical Engineering and Systems Technology for the Use of Renewable Energies and Decentralised Power Supply

- Wind Energy
- Photovoltaics
- Use of Biomass
- Hydro Power and Marine Energies

- Energy Conversion and Storages
- Static Converters
- Hybrid Systems
- Energy Economy

ISET has been monitoring the development of wind energy use in Germany since 1989, in the framework of the "250 MW Wind" programme.

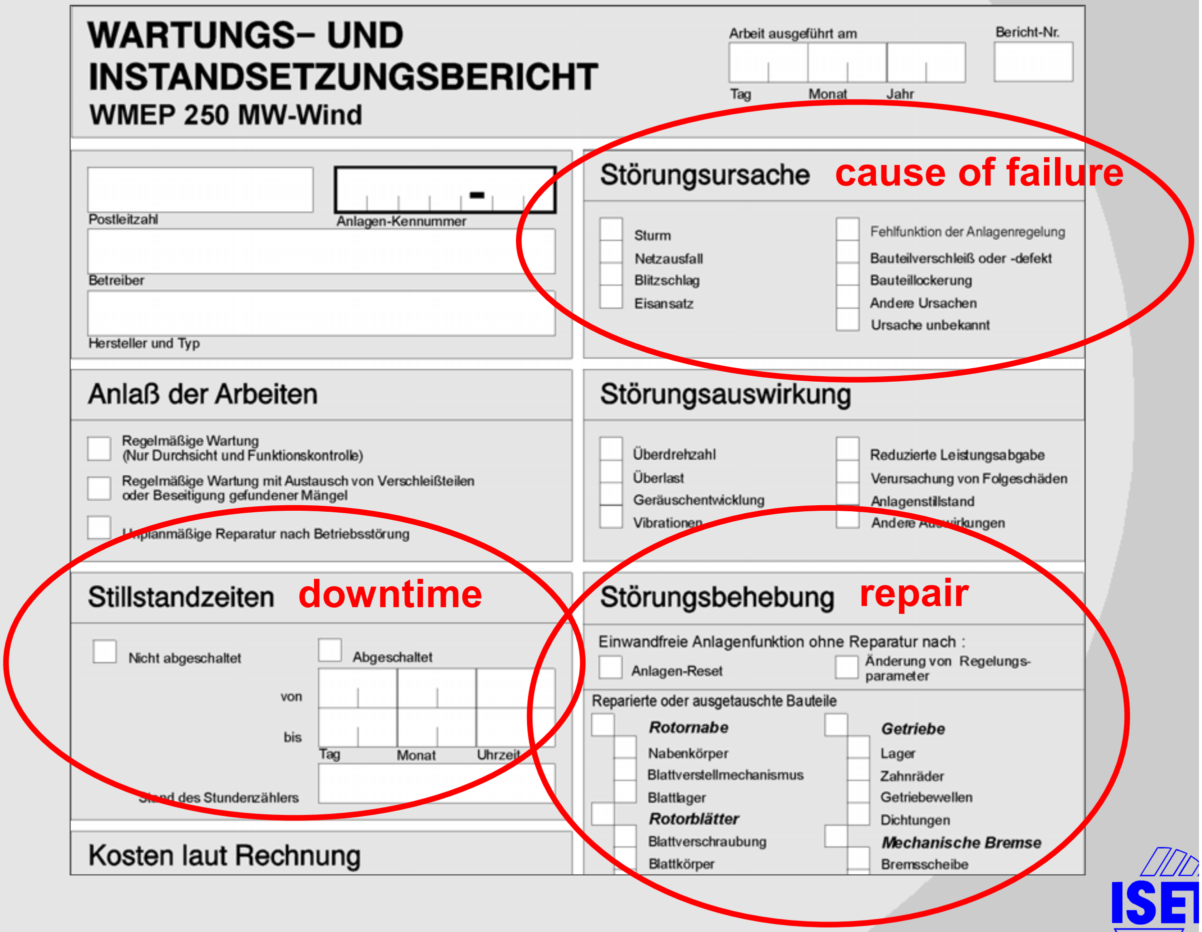
Operational results gathered by questionnaire and measurements (200 sites) about
- effects by external conditions
- energy yields
- fluctuation of fed in wind power
- reliability of WT
- economy of wind energy

This contribution: Particularly Reliability

Damages to Wind Turbines...

- **cause costs for repair of primary and consequential damages**
- **result in periods of downtime and in production losses**
- **affect the security of supply**

More than 62 000 reports concerning maintenance and repairs


WARTUNGS- UND INSTANDSETZUNGSBERICHT
WMEP 250 MW-Wind

Arbeit ausgeführt am: Tag / Monat / Jahr — Bericht-Nr.

Postleitzahl — Anlagen-Kennummer
Betreiber
Hersteller und Typ

Störungsursache
- Sturm
- Netzausfall
- Blitzschlag
- Eisansatz
- Fehlfunktion der Anlagenregelung
- Bauteilverschleiß oder -defekt
- Bauteillockerung
- Andere Ursachen
- Ursache unbekannt

Anlaß der Arbeiten
- Regelmäßige Wartung (Nur Durchsicht und Funktionskontrolle)
- Regelmäßige Wartung mit Austausch von Verschleißteilen oder Beseitigung gefundener Mängel
- Unplanmäßige Reparatur nach Betriebsstörung

Störungsauswirkung
- Überdrehzahl
- Überlast
- Geräuschentwicklung
- Vibrationen
- Reduzierte Leistungsabgabe
- Verursachung von Folgeschäden
- Anlagenstillstand
- Andere Auswirkungen

Stillstandzeiten
- Nicht abgeschaltet
- Abgeschaltet

von / bis — Tag / Monat / Uhrzeit
Stand des Stundenzählers

Störungsbehebung
Einwandfreie Anlagenfunktion ohne Reparatur nach :
- Anlagen-Reset
- Änderung von Regelungs-parameter

Reparierte oder ausgetauschte Bauteile
- ***Rotornabe***: Nabenkörper, Blattverstellmechanismus, Blattlager
- ***Rotorblätter***: Blattverschraubung, Blattkörper
- ***Getriebe***: Lager, Zahnräder, Getriebewellen, Dichtungen
- ***Mechanische Bremse***: Bremsscheibe

Kosten laut Rechnung

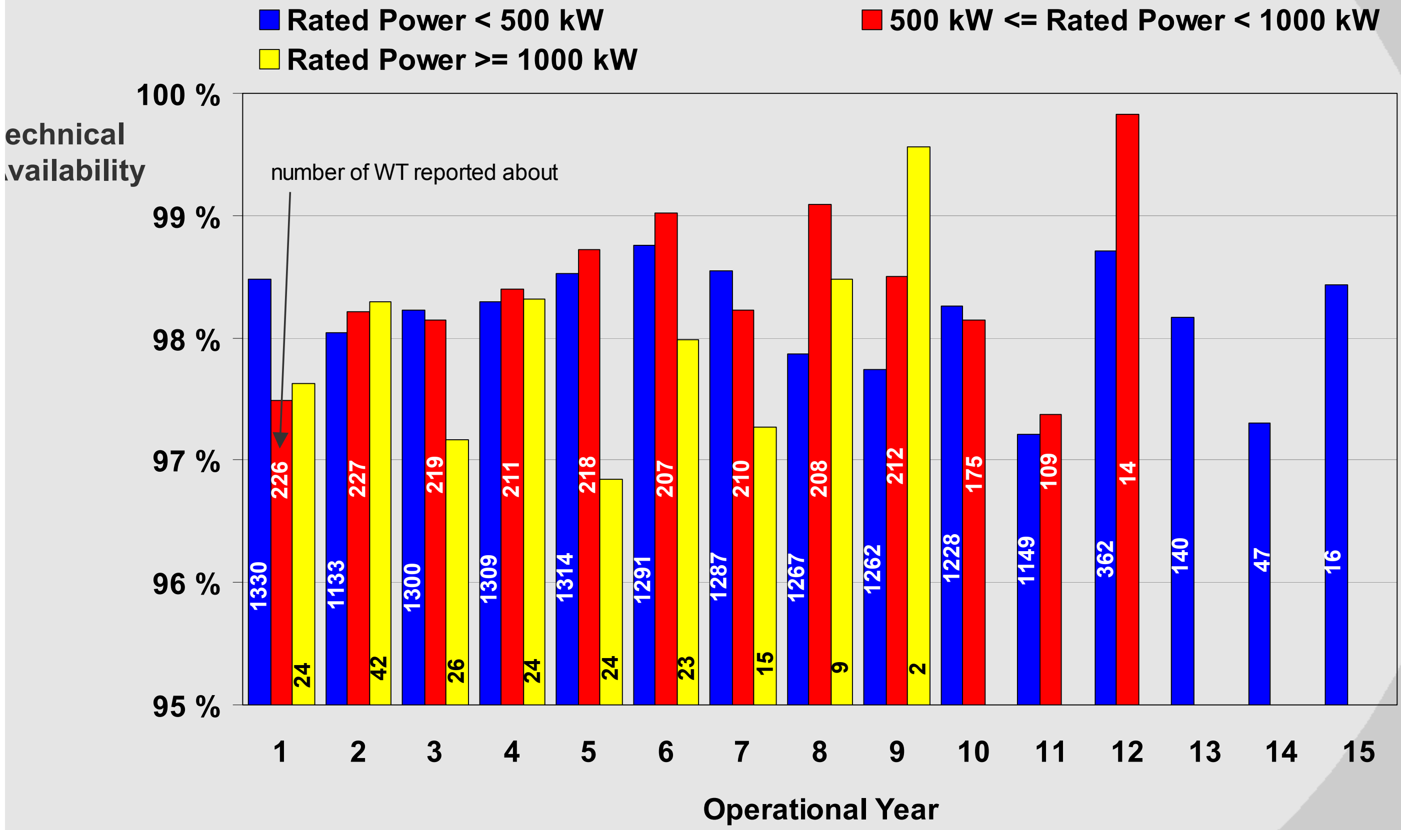

Störungsbehebung

Einwandfreie Anlagenfunktion ohne Reparatur nach :
- Anlagen-Reset
- Änderung von Regelungs-parameter

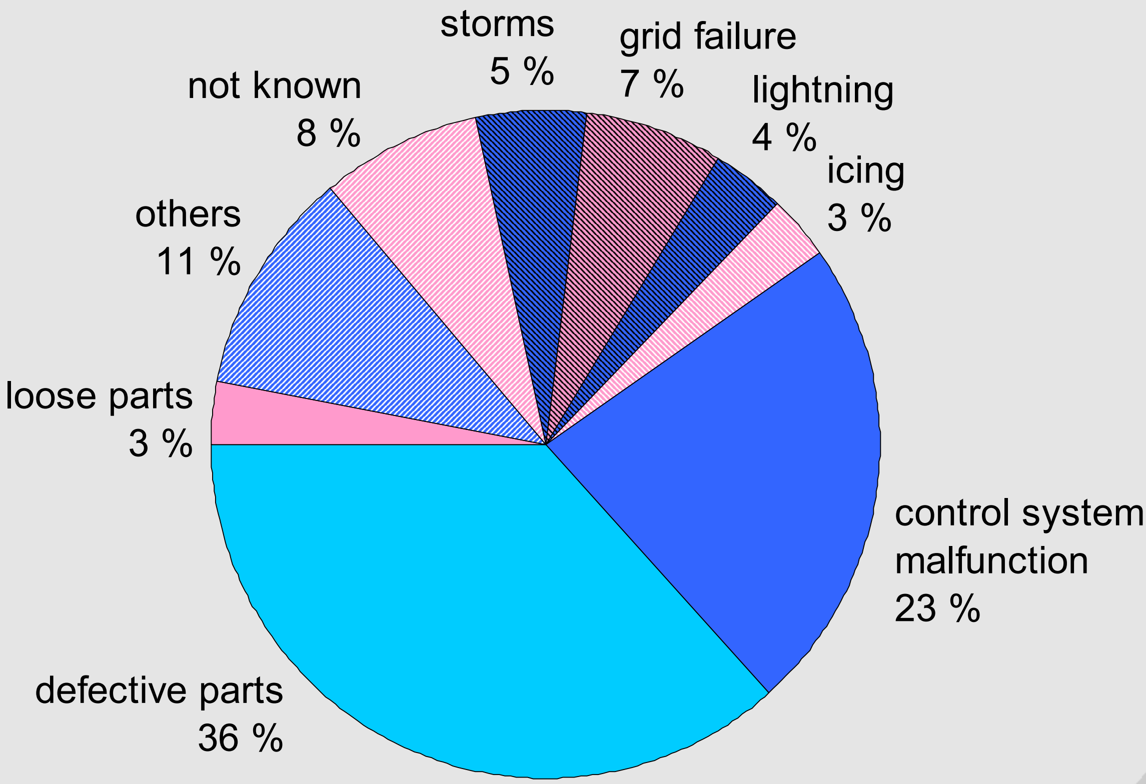
Reparierte oder ausgetauschte Bauteile
- ***Rotornabe***: Nabenkörper, Blattverstellmechanismus, Blattlager
- ***Rotorblätter***: Blattverschraubung, Blattkörper, Aerodynamische Bremsen
- ***Generator***: Wicklung, Schleifringe/Bürsten, Lager
- ***Elektrik***: Stromrichter, Sicherungen, Schütze/Schalter, Leitungen/Anschlüsse
- ***Geber***: Anemometer/Windfahne, Rüttelschalter, Temperaturfühler, Öldruckschalter, Leistungsmesser, Drehzahlmesser
- ***Regelung***: Elektron. Regelungseinheit, Relais
- ***Getriebe***: Lager, Zahnräder, Getriebewellen, Dichtungen
- ***Mechanische Bremse***: Bremsscheibe, Bremsbeläge, Bremssattel
- ***Antriebsstrang***: Rotorlager, Antriebswellen, Kupplungen
- ***Hydraulikanlage***: Hydraulikpumpe, Pumpenantrieb, Ventile, Hydraulikleitungen
- ***Windrichtungsnachführ.***: Azimut-Lagerung, Antriebsmotor, Zahnkranz/Ritzel
- ***Tragende Teile/Gehäuse***: Fundament, Turm/Turmverschraubung, Gondelrahmen, Gondelverkleidung

Repairs: categorisation with respect to main component groups and their individual parts

Availability and Causes for Failure

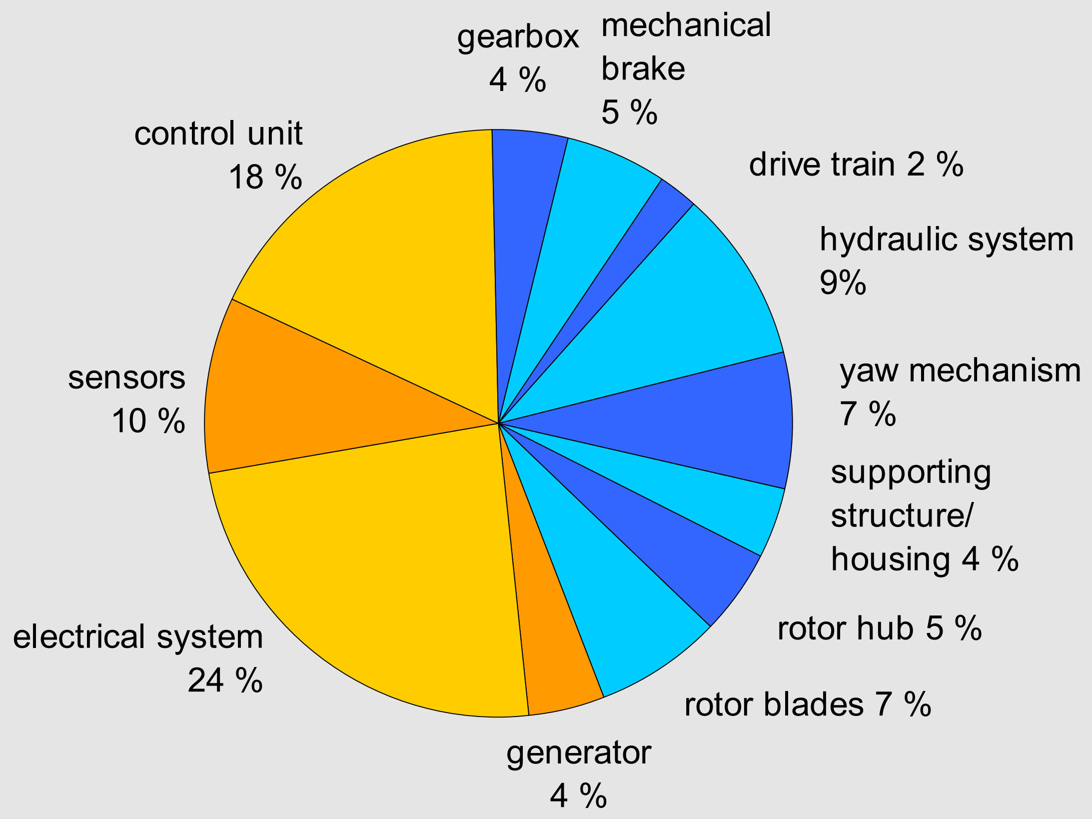


Technical Availability



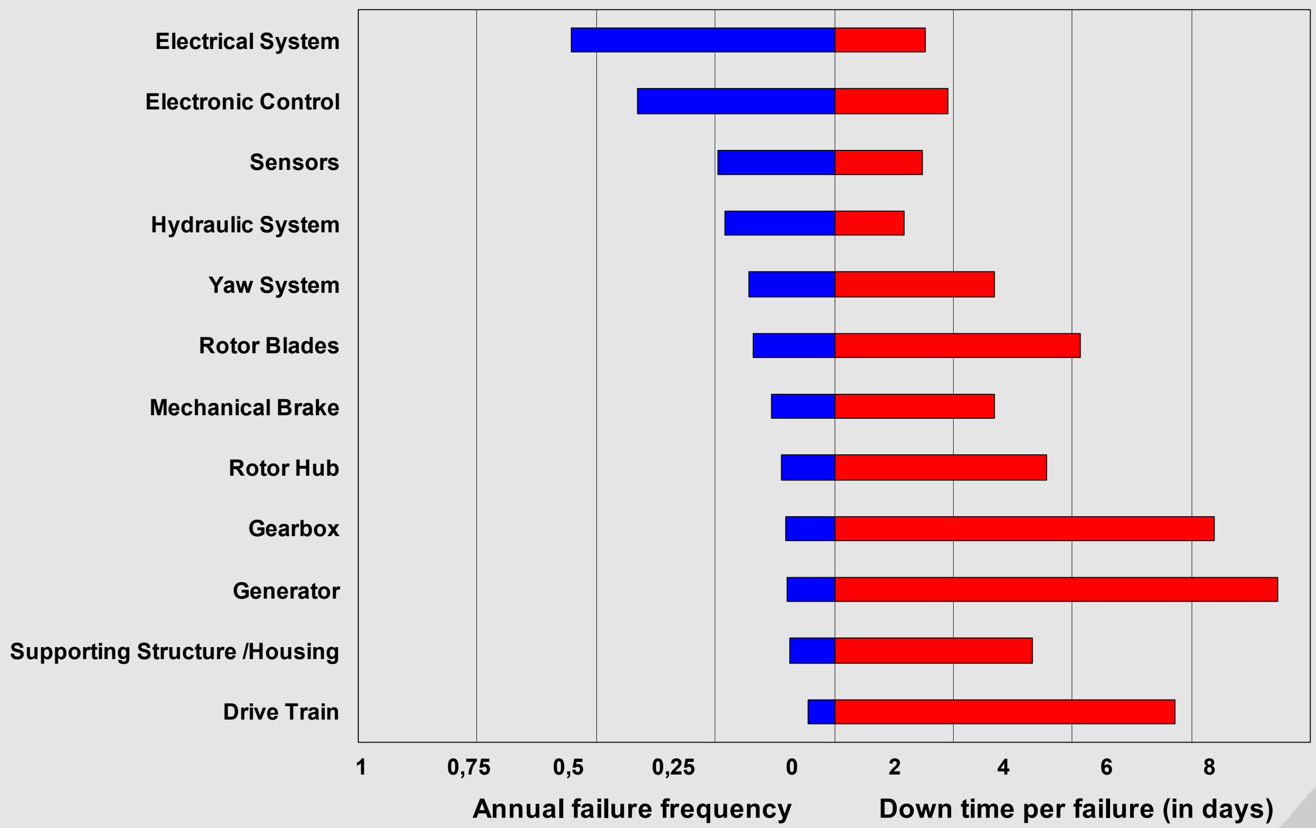
Causes for Failure

Affected Components and Downtime



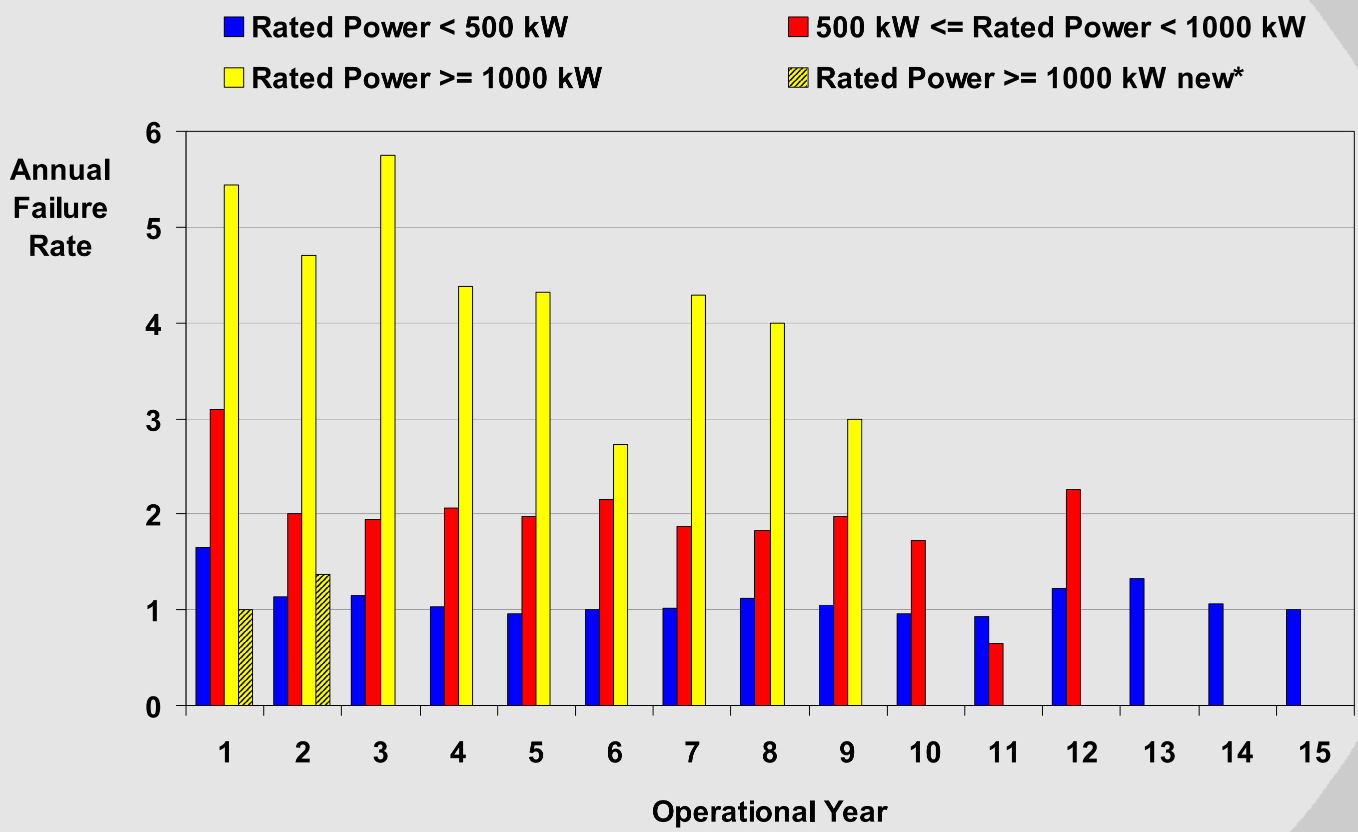
Breakdown of Components Affected by Failures

Affected Components and Downtime



Failure Rates and Downtimes

Frequency of Failure



* 1 windfarm, 1 type of WT, year of installation: 2004

Annual Number of Failures

Reliability of Wind Turbines

- 98 % technical availability is remarkably high
- causes for failure mainly internal problems
- in half of the cases the faults were based on mechanical, in the other half they were based on electrical components
- downtimes of susceptible components are short
- on average each WT suffers from more than one failure per year
- WT in the megawatt class tend to a higher malfunction frequency
- no significant increase in failure frequency up to an operational age of 15 years

Summary

Reliability of Wind Turbines

Outlook:

Given 1 failure per year: 25 % of an offshore windfarm will stand still after 3 months of inaccessibility of the WT sites.

- Optimisation of WT regarding reliability and low maintenance
- Health monitoring systems for all components
- Health monitoring systems able to evaluate the remaining lifetime of pre-damaged components
- Optimisation of strategies for maintenance and repair
- Continuation of monitoring of the development of reliability, availability, maintainability and safety (RAMS)

R&D Needs

ISET

Thank you for your attention!

Contact: pkuehn@iset.uni-kassel.de

www.iset.uni-kassel.de
http://reisi.iset.uni-kassel.de

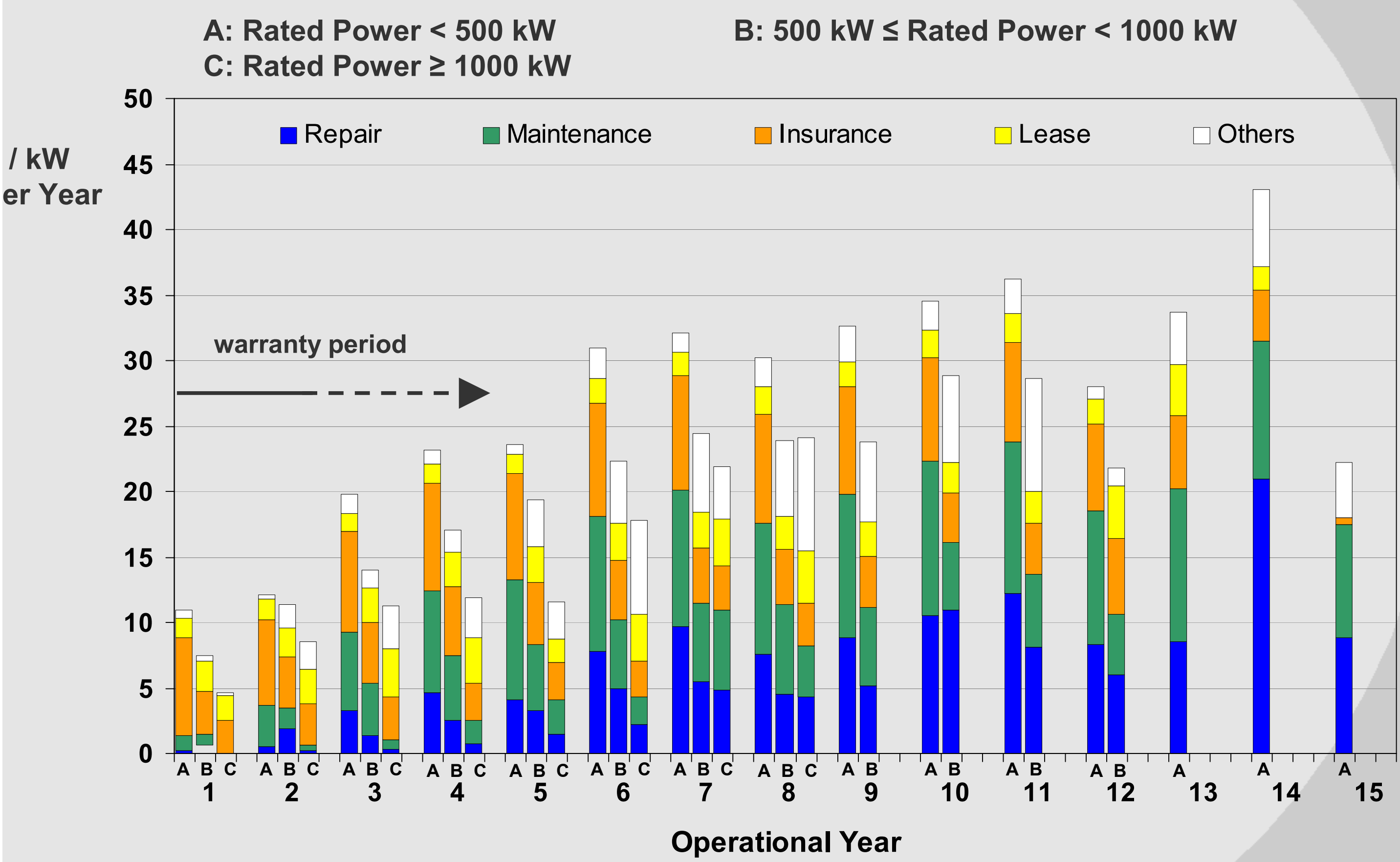
Institut für Solare Energieversorgungstechnik e.V.

Electrical systems technology for the use of renewable energies and for the decentral power supply

Applications-oriented R&D

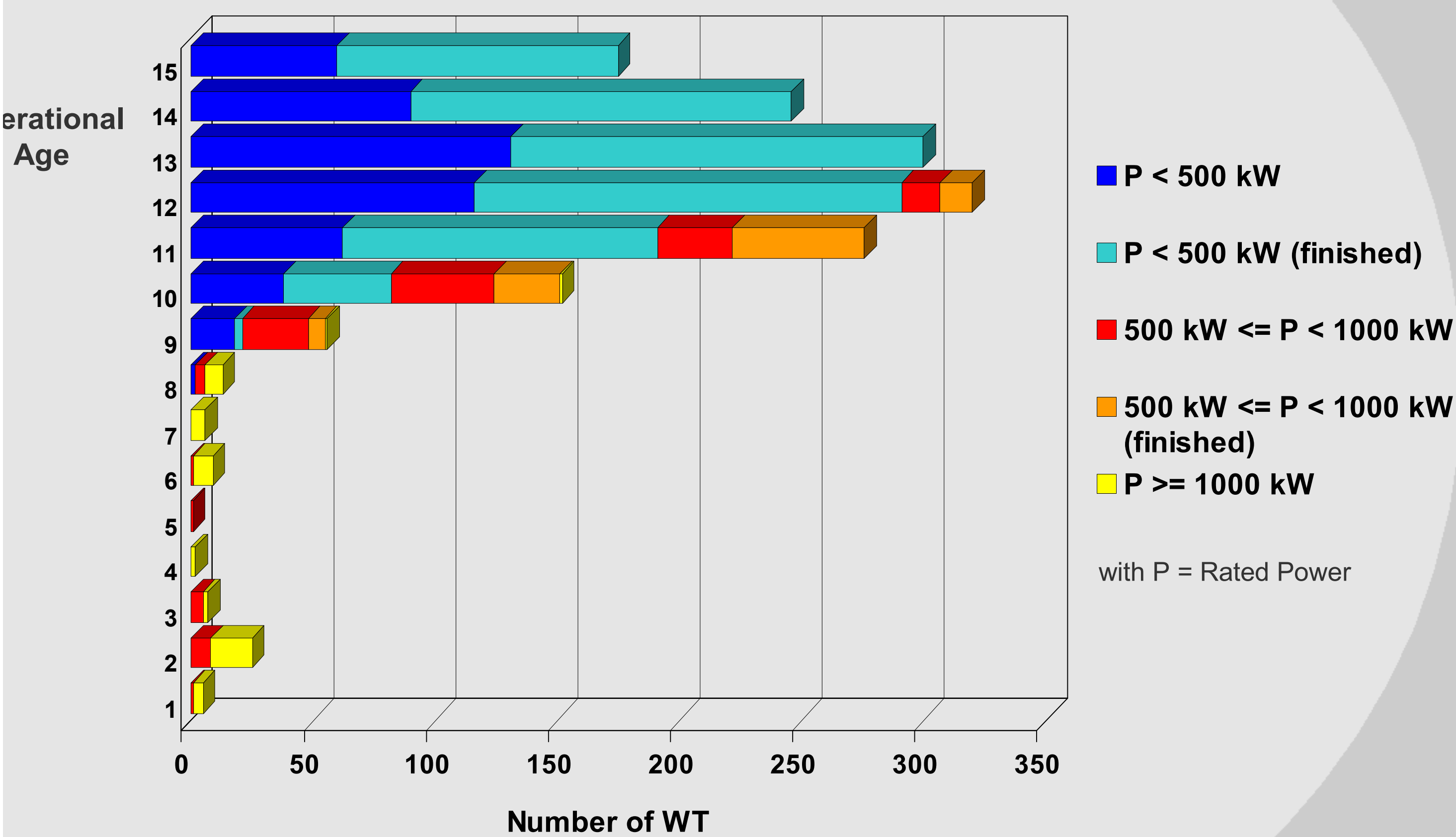
- Wind Energy
- Photovoltaics
- Bio Energy
- Hydro Power and Marine Energies
- Energy Conversion and Storage
- Hybrid Systems
- Energy Economy

ISET



Development of Operational Cost

Paul Kühn 04/2006



Operational Age of WT in the WMEP

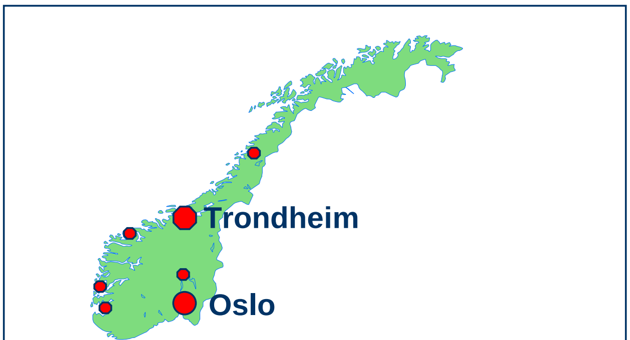
Condition based maintenance system for wind turbines

Arnt Ove Eggen
SINTEF Energy Research

IEA R&D Wind, Annex XI, Topical Expert Meeting
Operation and Maintenance of Wind Power Stations
Madrid, May 2006

SINTEF - The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology

SINTEF is one of the largest independent research organisations in Europe



Social perspective
SINTEF wishes to contribute to the creation of value and to a society in healthy sustainable development.

Business concept
SINTEF sell research-based knowledge and related services to Norwegian and international clients.

Fundamental values
Honesty, Generosity, Courage and Unity

SINTEF has 1763 employees, 1400 situated in Trondheim and 363 in Oslo with offices in Bergen and Stavanger.

Annual turnover in 2005: 230 mill. €
15 % from international contracts

GLØSHAUGEN CAMPUS (Trondheim)

SINTEF and NTNU, The Norwegian University of Science & Technology

Number of employees:

NTNU	3.300
Scientific	1.800
(incl. Post.doc and PhD Students)	
SINTEF	1.400
(Scientific	1.100)
Students:	20.000
Around:	8.000
in Engineering & Sciences	

This is SINTEF Energy Research

- Vision
  With the energy industry for a better environment.

- From our articles of corporation…..
  " … SINTEF Energy Research is a general purpose research institute that will

focus on

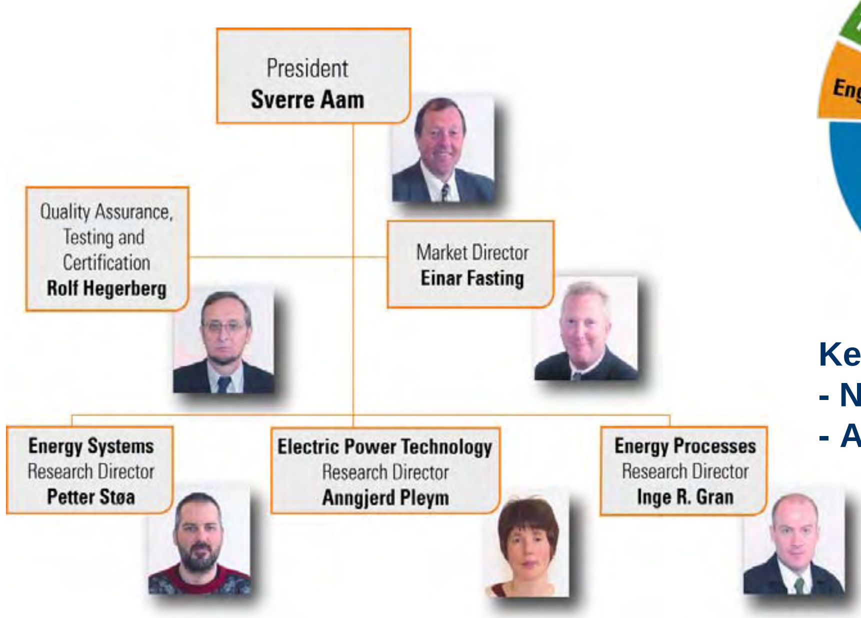
- **research and development**
- **dissemination and information**

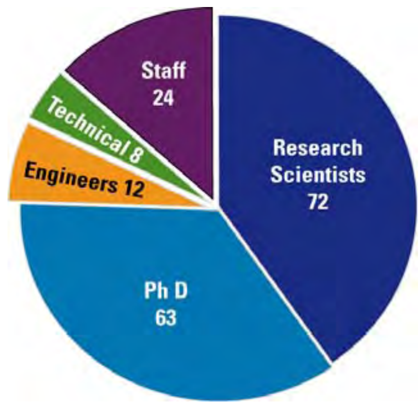
concerning the

- **production**
- **generation**
- **transmission/distribution**
- **consumption of energy**
- **industrial processes and commercial products**

in order to stimulate developments in industry and the public sector …"

SINTEF Energy Research





Key figures per 2005-12-31
- Number of employees: 179
- Annual turnover: 26 mill. €

SINTEF Energy Research

Areas of expertise

- Combustion
- Gas technology
- CO_2-technology in refrigeration and heat pumping
- Cable technology
- Energy system analysis
- Electric supply system planning, operation and maintenance

Growth areas

- Hydrogen technology
- Sub sea oil- and gas production technology
- Converters
- Deregulated and extended energy market
- Incorporation of renewable energy
- Energy related to industrial processes

Main group of clients

Utilities, oil and energy companies, heavy manufacturing industries, power installation companies and consultants, energy sector organizations, the Research Council of Norway, state authorities/public sector, offshore industry

Condition based maintenance system for wind turbines

- Duration 2006 – 2008
- Budget NOK 4.0 mill (~ 0,5 mill. €)
- Funding
  - NOK 3.0 mill Norwegian Electricity Industry Association (EBL), Norwegian power companies
  - NOK 1.0 mill The Research Council of Norway
- Participants
  - Norwegian Electricity Industry Association (EBL) (project owner)
  - SINTEF Energy Research
  - Norwegian power companies
  - The Centre for Renewable Energy (NTNU - SINTEF - IFE)
  - Elforsk, Sweden
  - The Royal Institute of Technology (KTH), Sweden
    "Optimal maintenance management for wind turbine systems using condition based monitoring systems with aspect to reliability and cost"

Relevant maintenance projects from the Norwegian hydro power industry

- Mid 1990s
  - Maintenance philosophy
  - Reliability Centred Maintenance
  - Condition monitoring guidelines for hydro power stations
    - Dams, Waterways, Turbines, Generators, Control systems
  - Norwegian Electricity Industry Association component coding system
- Late 1990s
  - Maintenance strategy
  - Specifications of data needed for maintenance planning, including predefined codes for failure descriptors, failure causes, maintenance actions and other important failure-related data (ensure that necessary data can be recorded)
- Early 2000s
  - Necessary functionality implemented in CMMS (Computerized Maintenance Management Systems)
    - Data fields, Predefined value lists, Export to specified data exchange format (XML)
  - Prototype of national failure database (collection of data already available)
  - Case studies
  - Lifetime modelling

Objectives

- The main objective of the project is to transfer technology, systems and experience from the hydro power industry in order to develop a condition based maintenance system to optimise operational and maintenance cost and reduce downtime for wind power systems

- The main objective will be reached through the following goals:
  - Common coding system for wind turbines
  - Conditions monitoring guidelines for wind turbine components
  - Systematic approach for recording operational data and experience
  - Lifetime prediction model for critical components
  - Recommendations related to how expected future maintenance should be included in the negotiation and contract signing process
  - Develop educational framework

Reference designation system for wind turbines

- Extending the existing Norwegian Electricity Industry Association coding system to cover modern, larger and offshore wind turbines

- This coding system is implemented in commonly used CMMS

- The Norwegian coding system is not related to IEC 61346 and the KKS/RDS
  It may be necessary to make a mapping between the two systems

Conditions monitoring guidelines for components in a generic wind turbine

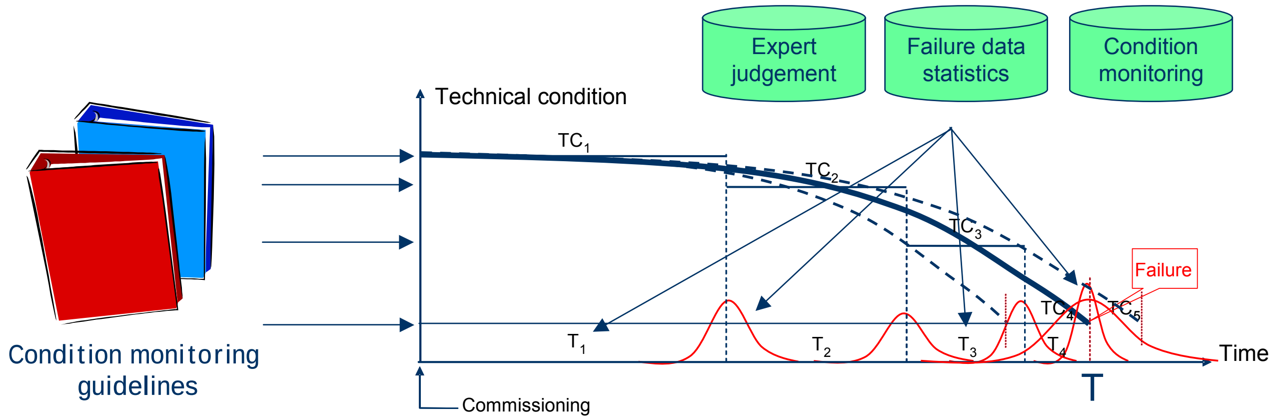
- Component description
  - Focus on elements important for maintenance and condition monitoring
- Failure mechanisms
  - Failure causes
  - Consequences
  - Measurements
- Condition monitoring methods
  - Schemes
  - Condition classification
  - Decision aiding flowcharts
  - Evaluate the feasibility of online condition monitoring system
- Condition monitoring program

Class	Description	Example
1	No degradation	Smooth surface
2	Incipient degradation	Rough surface
3	Severe degradation	Cracks
4	Critical degradation	Critical cracks
5	Failure	

Systematic approach for recording operational experience in wind turbines

- Describe data needed for maintenance planning (optimize inspection intervals, preventive actions, rehabilitation intervals)
  - Component data (ID / tag, manufacturer, technical solution, rated values, commissioning date)
  - Environmental data (external stress from wind, ice)
  - Operational data (SCADA)
  - Maintenance data (preventive maintenance interval and costs)
  - Condition monitoring data (classifications, measurements, trends)
  - Failure data / event data (failure cause, failure consequences, corrective maintenance actions and costs)
- Code failure descriptors, failure causes and other data
- Establish requirement specification for implementing in CMMS
- Establish a failure database prototype
- Case study

Lifetime prediction model for critical components



- Expected lifetimes based on statistics and expert judgements
- Lifetimes are traditionally modelled by a probability distribution
- Degradation can often be observed
- Information on observed condition (degradation) can be used to give a better estimate on residual lifetime
- State lifetimes are modelled by a probability distribution

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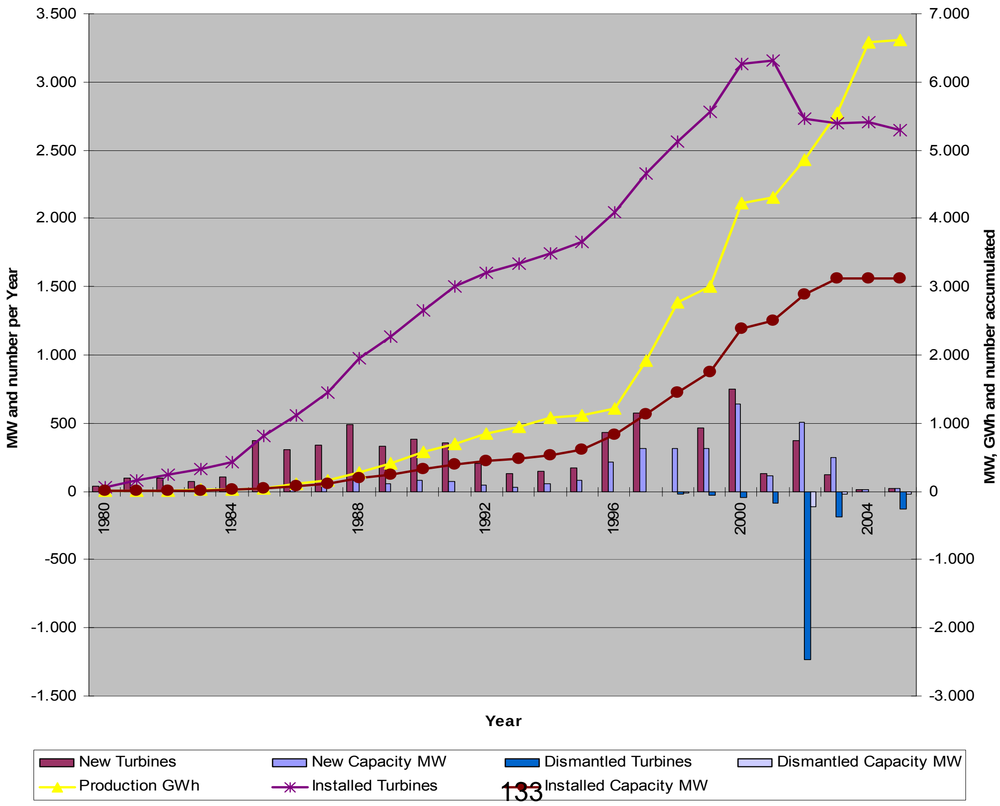
RISØ

Risoe Activities within O&M for Wind Turbines

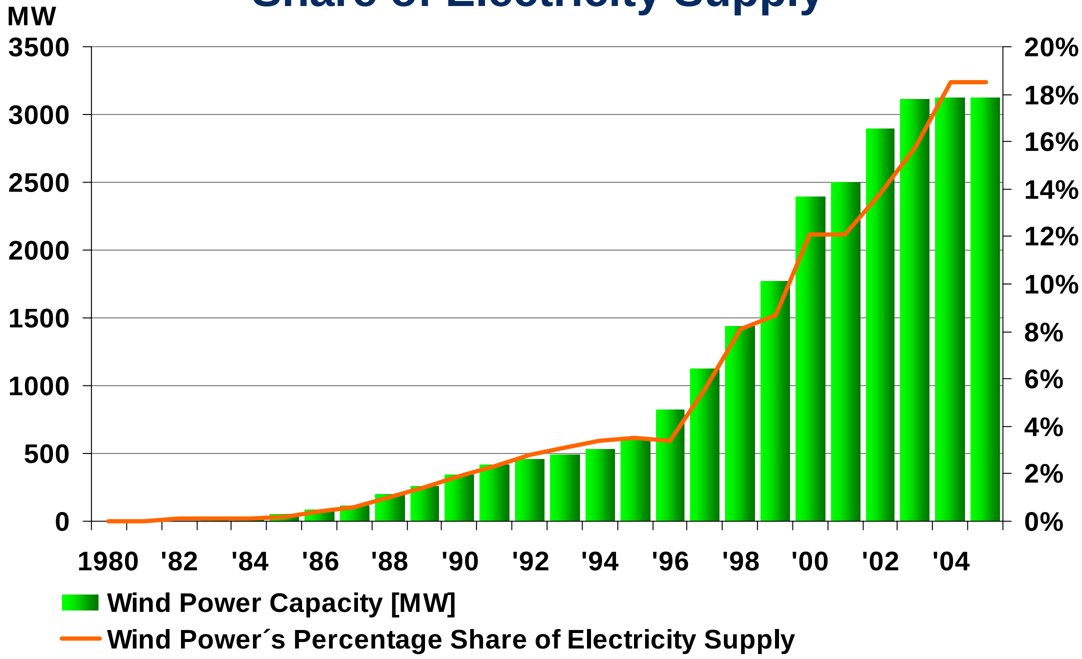
Jørgen Lemming
Risoe National Laboratory
4000 Roskilde

RISØ

Development of Wind Power in Denmark



Wind Power Capacity and Percentage Share of Electricity Supply



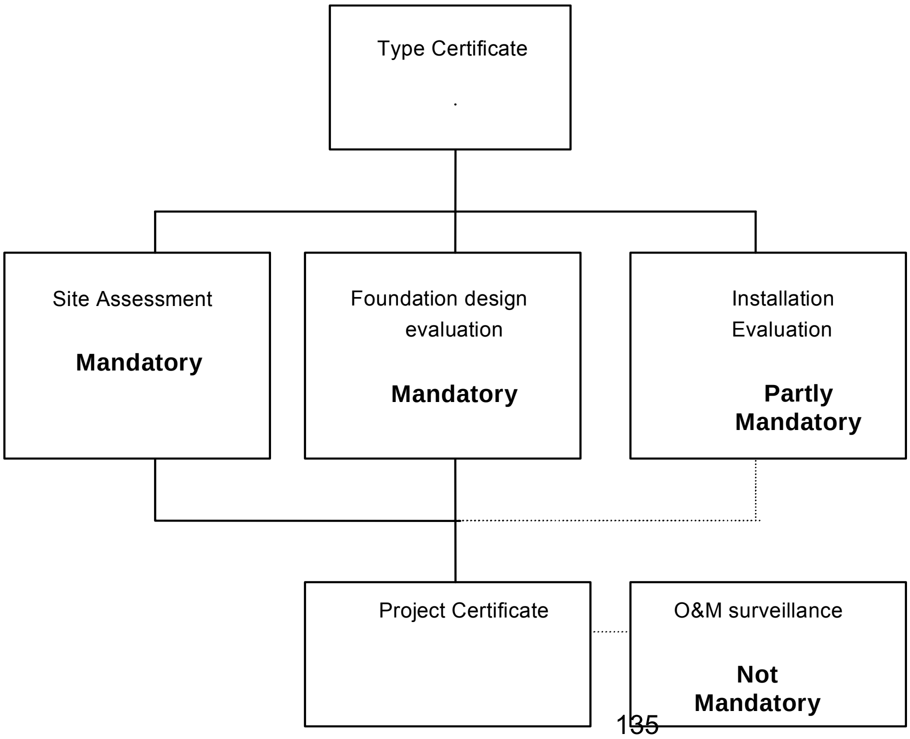
Risø National Laboratory

www.risoe.dk

Test centre for large-scale wind turbines

At Høvsøre, wind turbine manufacturers can test the multi-megawatt wind turbines of the future

Project Certification within IEC WT01
IEC System for Conformity Testing and Certification of Wind Turbines (Rules and procedures)



O&M surveillance ensures that a specific wind farm is operated and maintained in conformity with the relevant manuals included in the design documentation

Current O&M R&D activities at Risoe

CleverFarm®

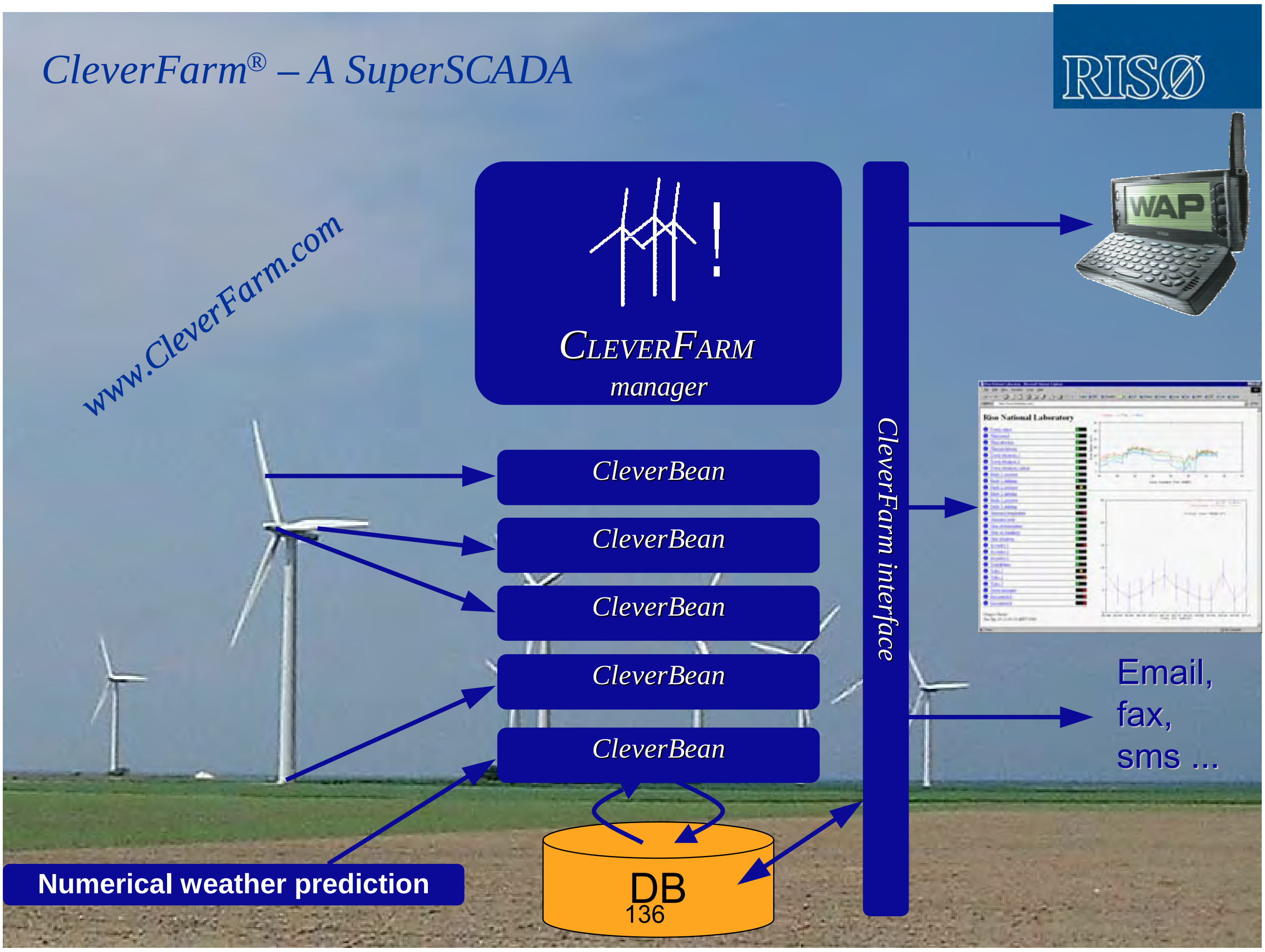
ConMOW

- **“Condition Monitoring for Offshore Windfarms”**
- **ECN leader**
- **Initially 4-year project, now extended to 54 months (2002 – 2007)**

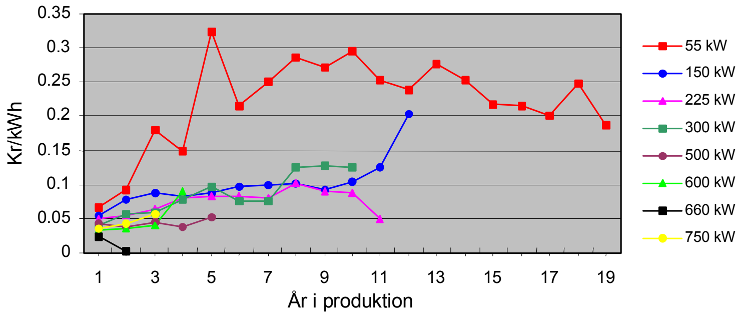
IEC 61400-25-6

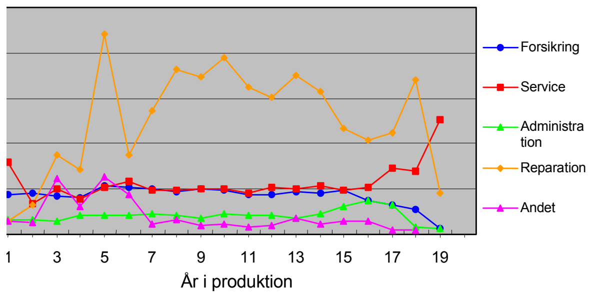
- TC88 has a subgroup for the development of a standard for communication with condition monitoring equipment

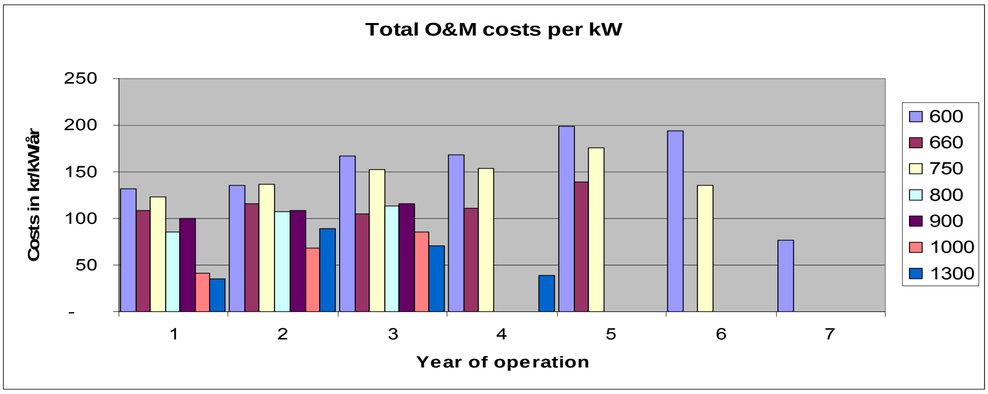
www.risoe.dk



Example of O&M costs of turbines in DKK pr. kW







For a 750 kW turbine
Production
1.300.000 kWh
0.087 DKK/ kWh
Production
1.700.000 kWh
0.066 DDK/ kWh

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IEA Offshore Wind Energy

Current Offshore Wind Energy Technology and Deployment Activities

Jørgen Lemming
Risoe National Laboratory
National Wind Technology Center, Director

Operating Agents
Jørgen Lemming
Walt Musial

Supported by Sandy Butterfield and Flemming Øster

Annex XXIII Offshore Wind

Annex 23 Operating Agents
Risø and NREL

Subtask 1 (Risø Lemming/Øster)
Experience with critical deployment issues

- **Research Area # 1** – Ecological Issues and Regulations – TBD
- **Research Area # 2** – Electrical System Integration – John Overton - UK
- **Research Area # 3** – External Conditions, Layouts and Design of Offshore Wind Farms – Flemming Øster - DK

Subtask 2 (NREL Musial/Butterfield)
Technical Research for deeper water

- **Research Area # 4** - Offshore Code Comparison Collaboration – Sandy Butterfield - USA

Subtask 1: Experience With Critical Deployment Issues

Workshops with proceedings in order to

- **Exchange information, data and experiences**
- **Perform R&D gap analysis**
- **Identify and propose joint research tasks**

For the research areas

#1 - External Conditions

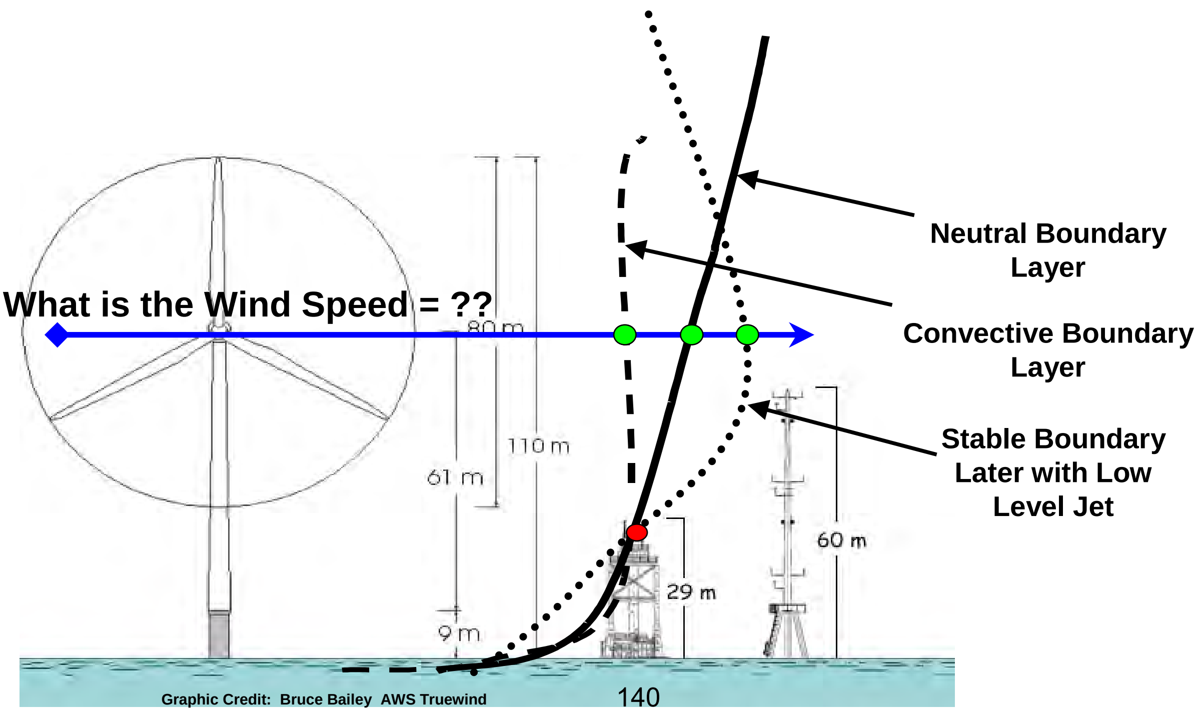
#2 - Operation and Maintenance

#3 - Ecological Issues and Regulations

#4 - Electric system integration

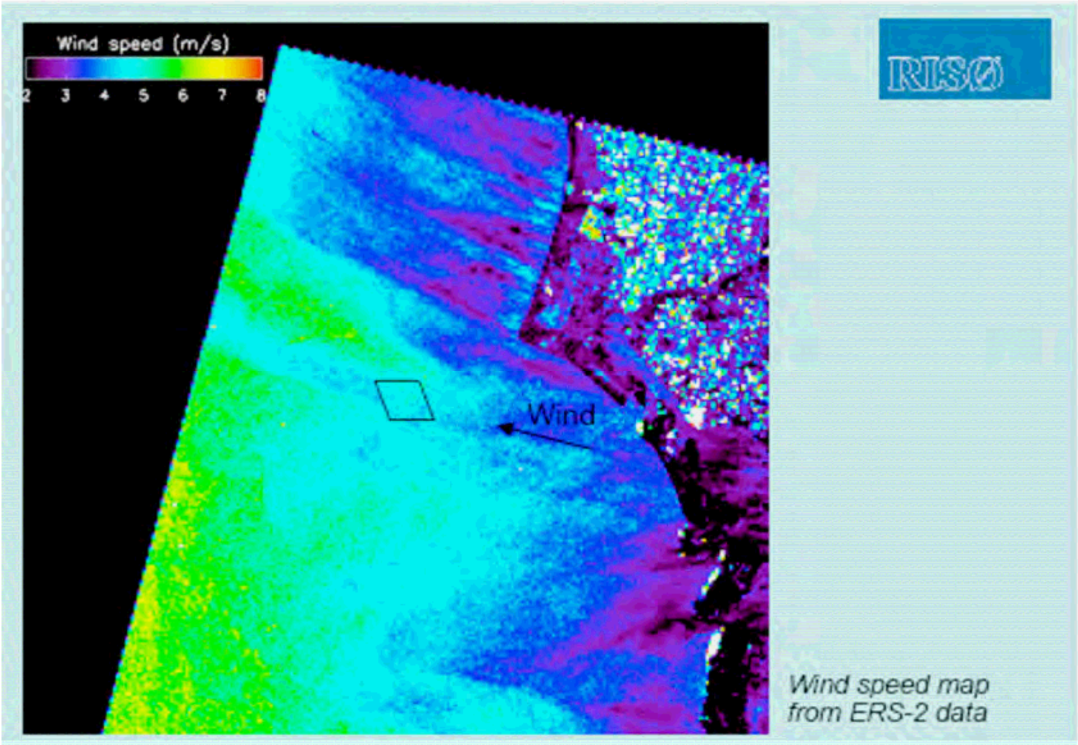
#5 – Wind Facilities Technology and Design

Marine boundary layer characteristics



Wake loss Assessment at Horns Rev

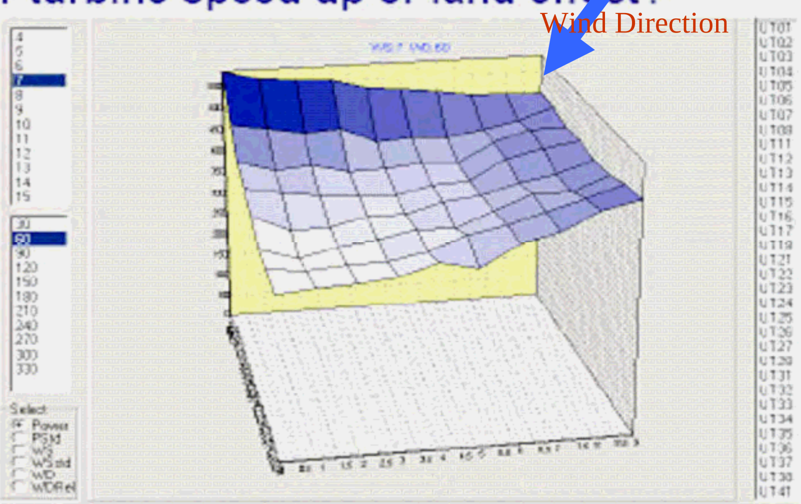
European Remote Sensing Satellite -2 Global Measurements and Images including Sea State, Sea Surface Winds, Ocean Circulation, and Sea and Ice Levels.



Wind speed map from ERS-2 data

Wake losses at Horns Rev

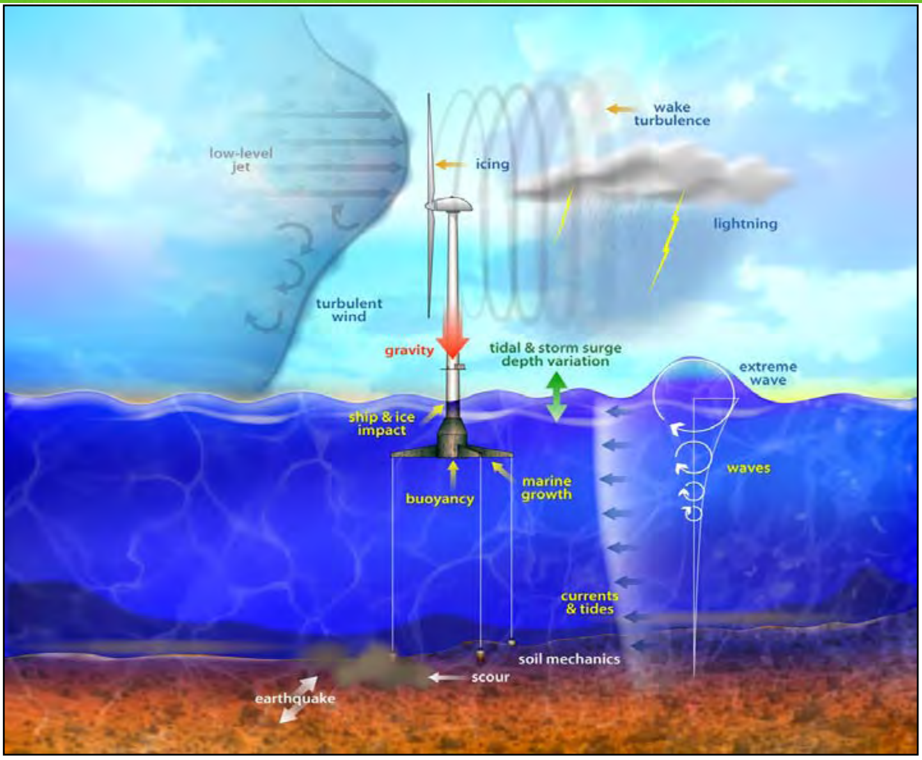
Corner turbine speed up or land effect?



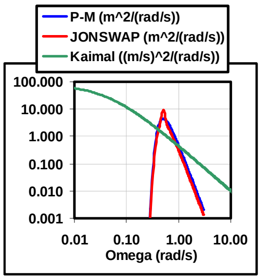
118.18	113.34	112.43	111.47	106.71	105.35	103.59	101.34	101.30	130.00
101.31	97.57	94.65	95.92	98.61	99.42	99.99	91.54	95.19	110.02
91.20	85.13	86.90	82.77	83.32	84.76	83.93	92.93	97.96	97.50
81.91	82.75	80.46	79.55	78.48	82.18	83.21	92.38	95.76	98.34
81.17	73.41	74.15	77.91	77.89	82.22	84.29	88.58	91.90	97.06
74.76	69.77	73.42	75.43	79.06	78.10	84.99	91.19	91.10	97.47
74.27	72.62	74.17	74.99	77.39	92.41	86.55	91.44	95.94	101.02
73.94	73.73	74.31	76.14	81.28	77.74	86.70	90.70	98.45	102.40

Elsam

Met-ocean data and loads



- Turbulent winds
- Irregular waves
- Gravity / inertia
- Aerodynamics:
  - induction
  - skewed wake
  - dynamic stall
- Hydrodynamics:
  - scattering
  - radiation
  - hydrostatics
- Elasticity
- Mooring dynamics
- Control system
- Fu



Wind and Wave Spectra

Offshore Code Comparison: Collaboration (OC^3)

Goal

1. Quantify offshore load prediction capability
2. Identify critical modeling deficiencies common to all codes.

Scope

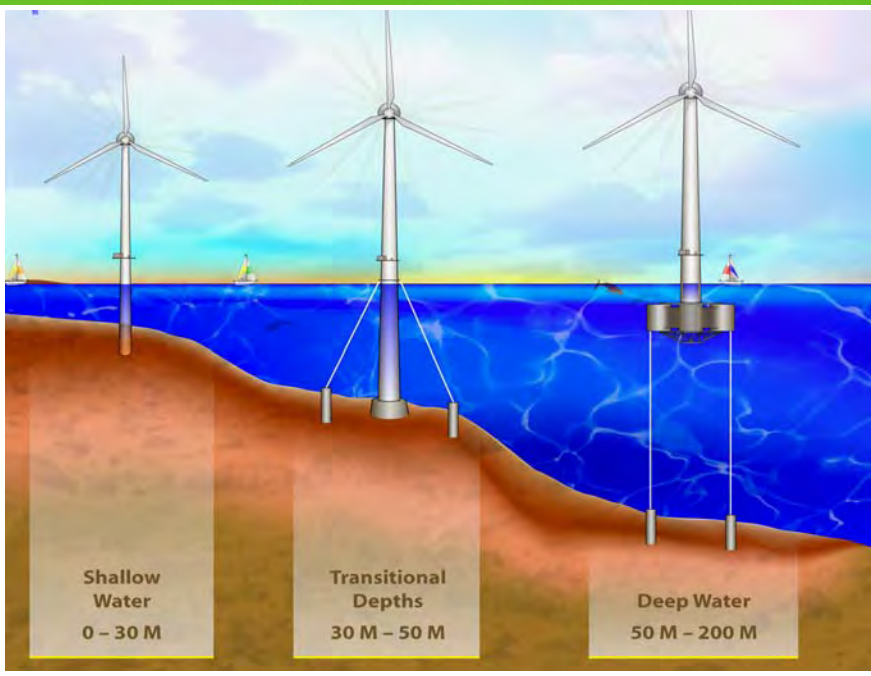
Code Comparisons for:

•Wave loading

•Support structures

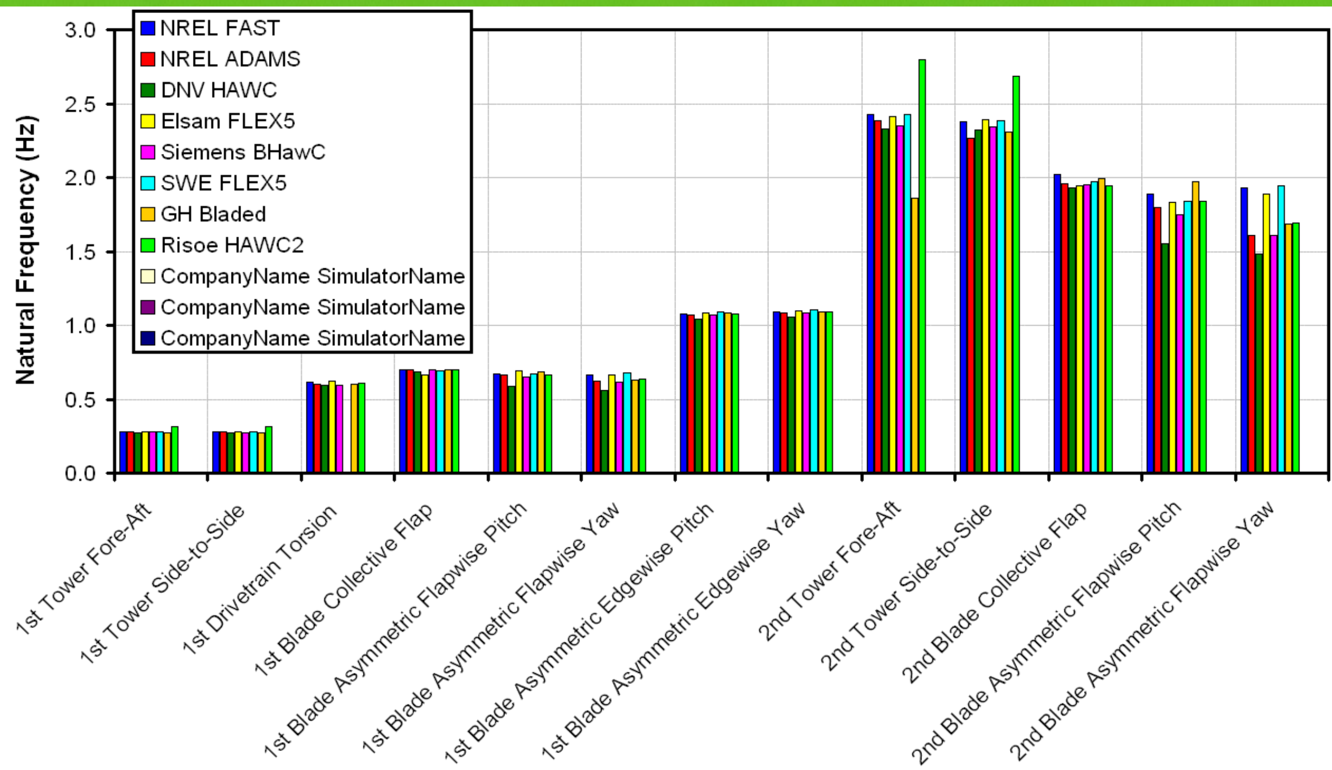
•Geotechnical

•Coupled system dynamics



Lead: Sandy Butterfield-US DOE/NREL

Status: Phase 1.1: Baseline Model dynamics Comparisons (8 codes)



Annex 23 Participation

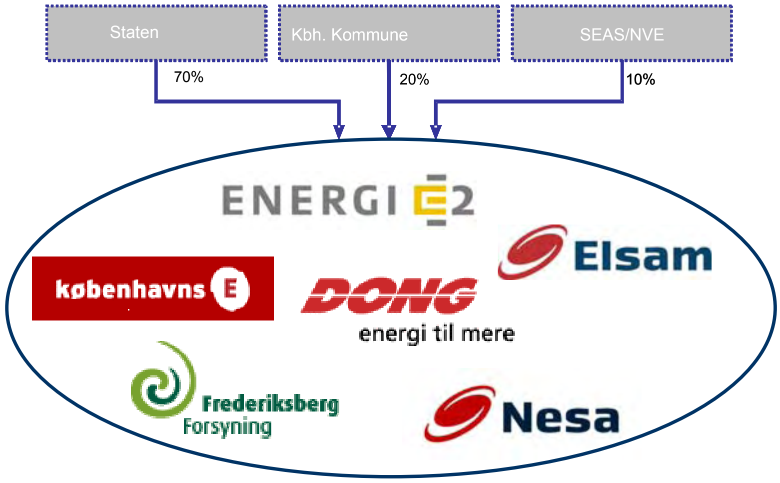
Country	Membership Status/ Contracting Party	Organization
United States	Committed/US Department of Energy	▪ NREL • MIT • University of Massachusetts • GE Energy
Denmark	Committed/RISØ National Laboratory	▪ RISØ National Laboratory • Vestas • Elsam • Carlbro
Norway	Committed/Enova SF	▪ NTNU-BAT
United Kingdom	Comitted/Department of Trade and Industry	▪ Garrad Hassan • Ceasa
Netherlands	Committed	▪ ECN
Germany	Committed	▪ University of Stuttgart • GE Energy
South Korea	Committed	▪ Inha University
Finland	TBD	▪ VTT
Sweden	TBD	▪ Chalmers
Japan	TBD	▪ MITI
Spain	TBD	▪ Ciemat

Annex 23 Summary

Current Status:

- 4 research areas are planned with 3 making good progress starting the second year (4 year time line)
- Active collaborative technical working groups are formed with seven countries currently participating and three pending
- Offshore O&M to be decided on

Mulig ejerstruktur – januar 2006



Installeret produktionskapacitet på i alt 7.300 MW, hvoraf 616 MW er vindkraft

Kilde: E2 Online, 1. juni 2005

ENERGI E2 and offshore wind

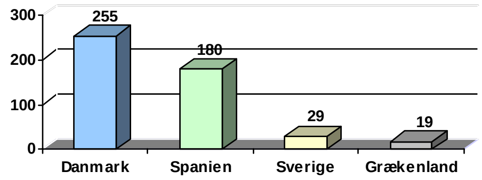
- **ENERGI E2 operates**
  - 600 MW onshore wind
  - 210 MW offshore wind
- **ENERGI E2 offshore**
  - Vindeby 5 MW installed 1991
  - Middelgrunden 40 MW installed 2000
  - Uttgrunden 10 MW installed 2000
  - Yttre Stengrund 10 MW installed 2001
  - Nysted 165 MW installed 2003

E2 ejer en anseelig europæisk portefølje af vindmøller

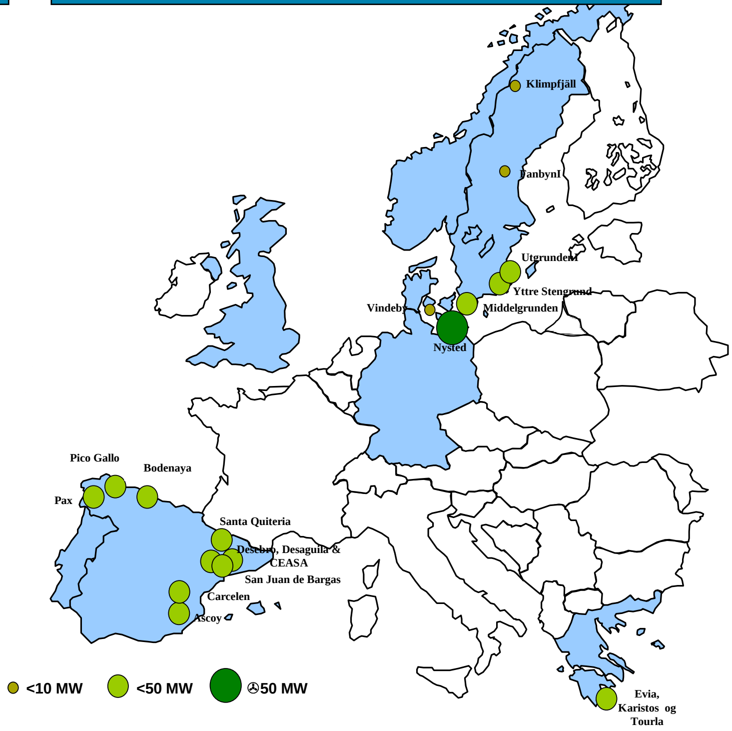
E2's portefølje af vedvarende energiproduktion (i funktion)

	Nettoeffekt, MW
■ Vindmøller, Danmark	255
■ Vindmøller, Grækenland	19
■ Vindmøller, Sverige	28
■ Hydro Indalselven, Sverige	205
■ Hydro Narvik Energi (33%), Norge	76
■ Hydro SKS Energi (20%), Norge	55
■ ENERGI E2 Renovables Ibéricas, Spanien	
■ Vind	180
■ Biomasse	5
■ Mini-vandkraft	6
	482
E2's totale vindkraftproduktion	829
E2's totale vedvarende energiproduktion	

Total installeret vindkraftkapacitet primo 2005
Total: 473 MW (netto)



Vindmølleparker i Skandinavien, Spanien og Grækenland

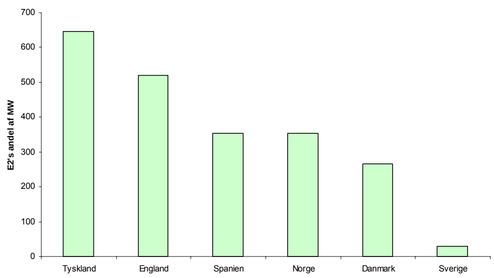


ENERGI E2

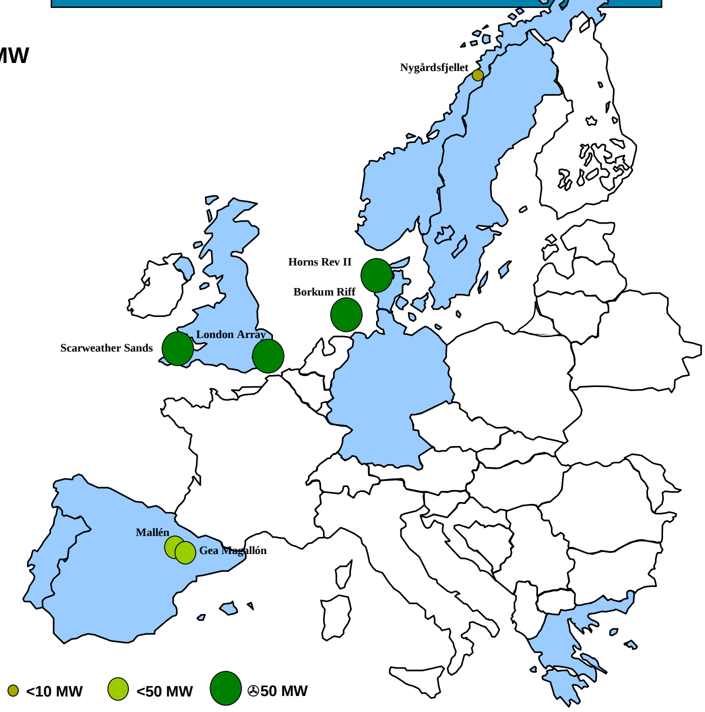
E2 Vindkraft udvikler focuseret europæisk pipeline for projekter

E2 Vindkrafts pipeline

Projekter under udvikling eller udførelse	**Netto effekt, MW**
■ Havvindmølleprojekter i Danmark	200
■ Havvindmølleprojekter i Tyskland	645
■ Havvindmølleprojekter i England	521
■ Havvindmølleprojekter i Norge	117
■ Havvindmølleprojekter i Norge	47

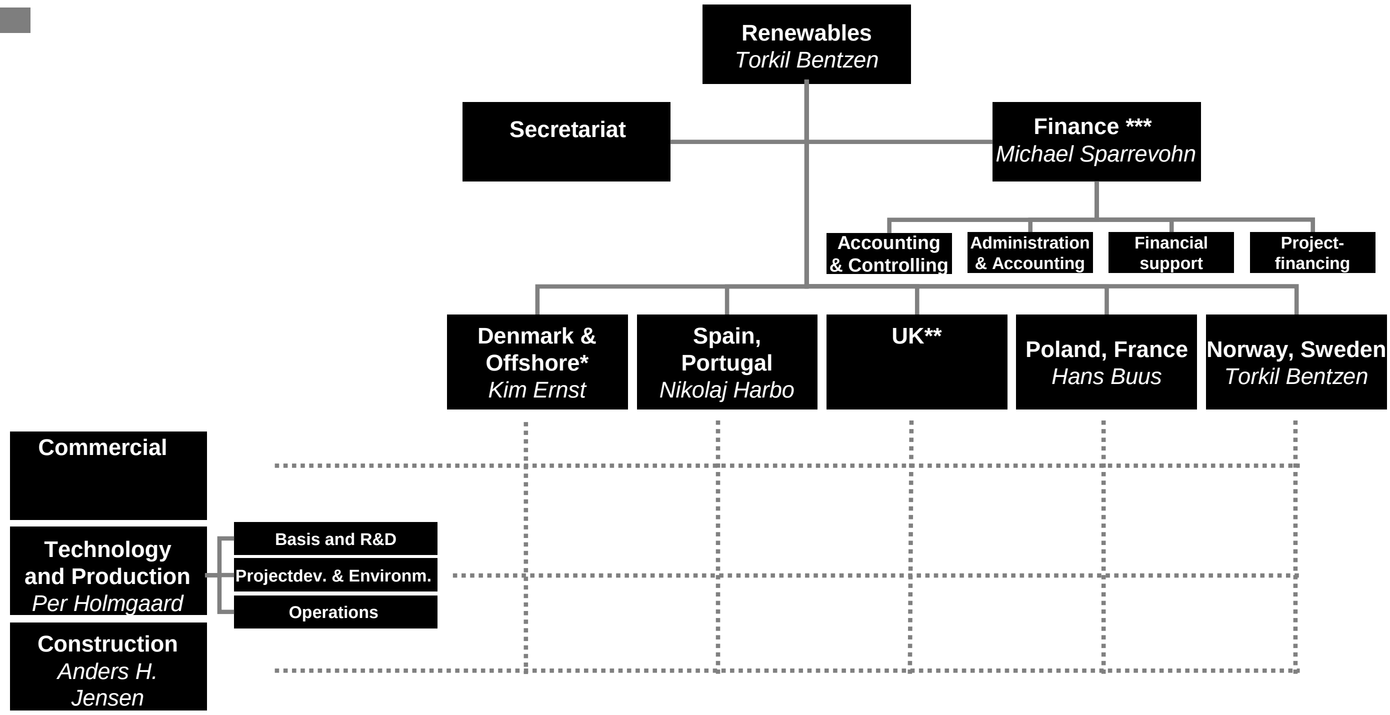


Pipeline i Skandinavien, Spanien, England og Tyskland



ENERGI E2

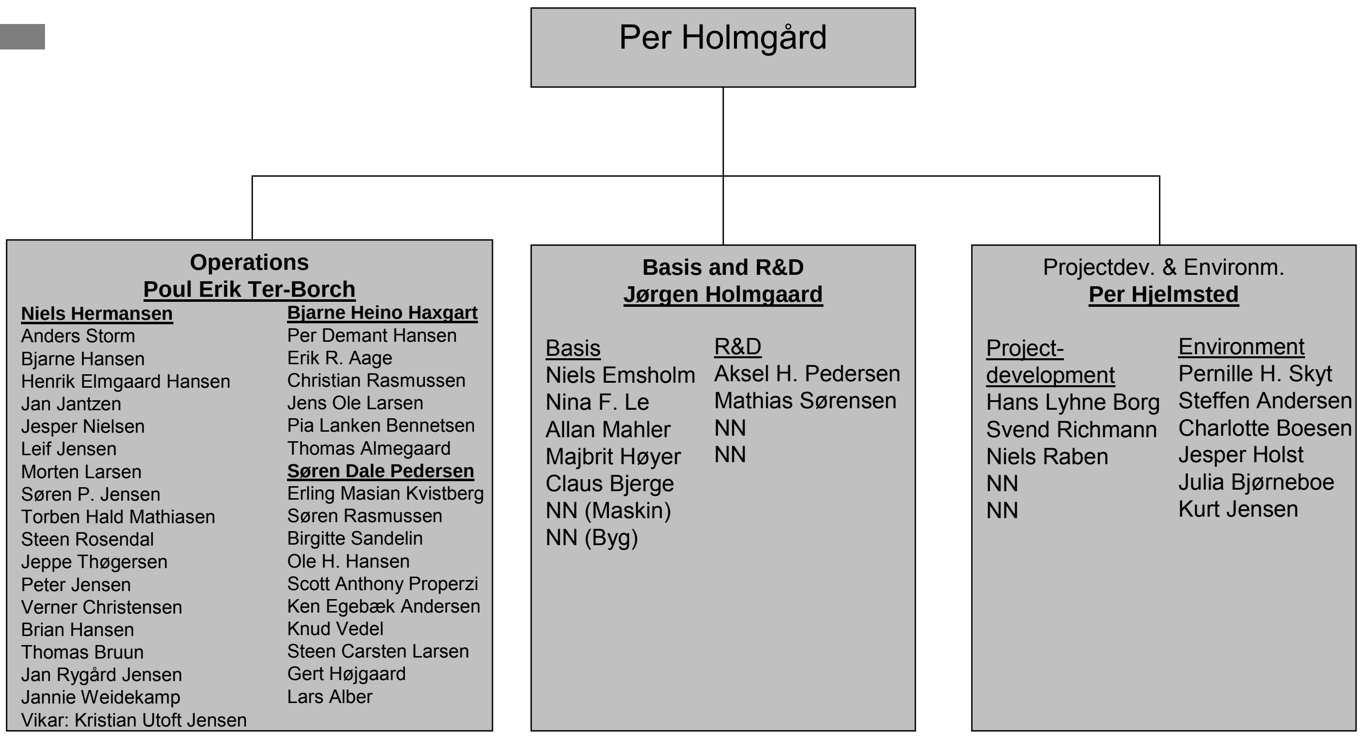
Organisation



* Offshore udenfor regionernes område
** Undtagen E-on projekter, som varetages at region DK
*** Økonomi fungerer som shared service center med Kraft Øst

ENERGI E2

Technology & Production

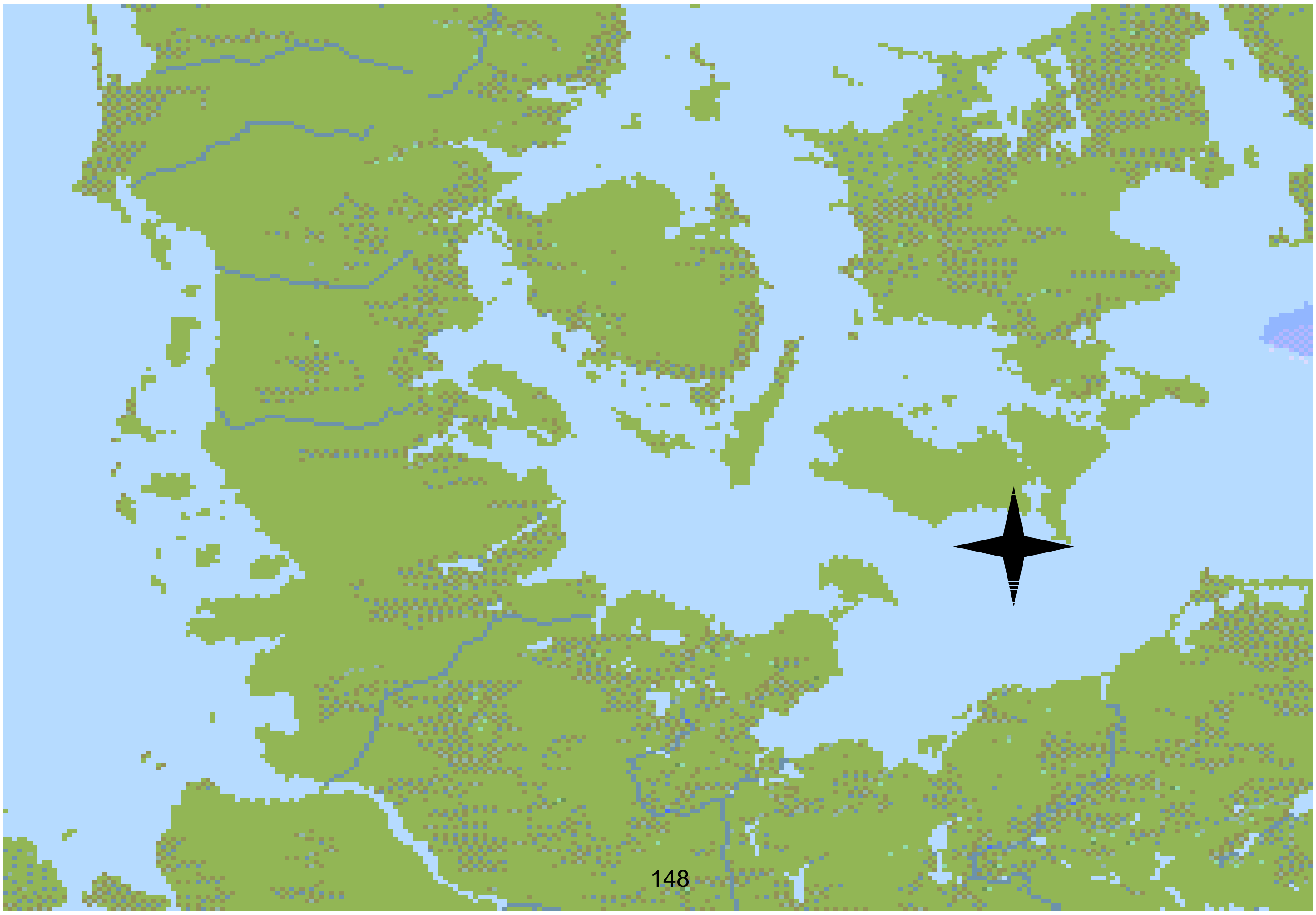


ENERGI E2

Risk management and ENERGI E2's responsibility during installation, commissioning, and operation and maintenance of Nysted Offshore Wind Farm

Poul Erik Ter-Borch, Production Manager, E2 Wind Energy, Denmark

The Danish training ship "Skoleskibet Danmark" at Nysted Offshore wind farm July 2003



Experience gained from 2 years of operation

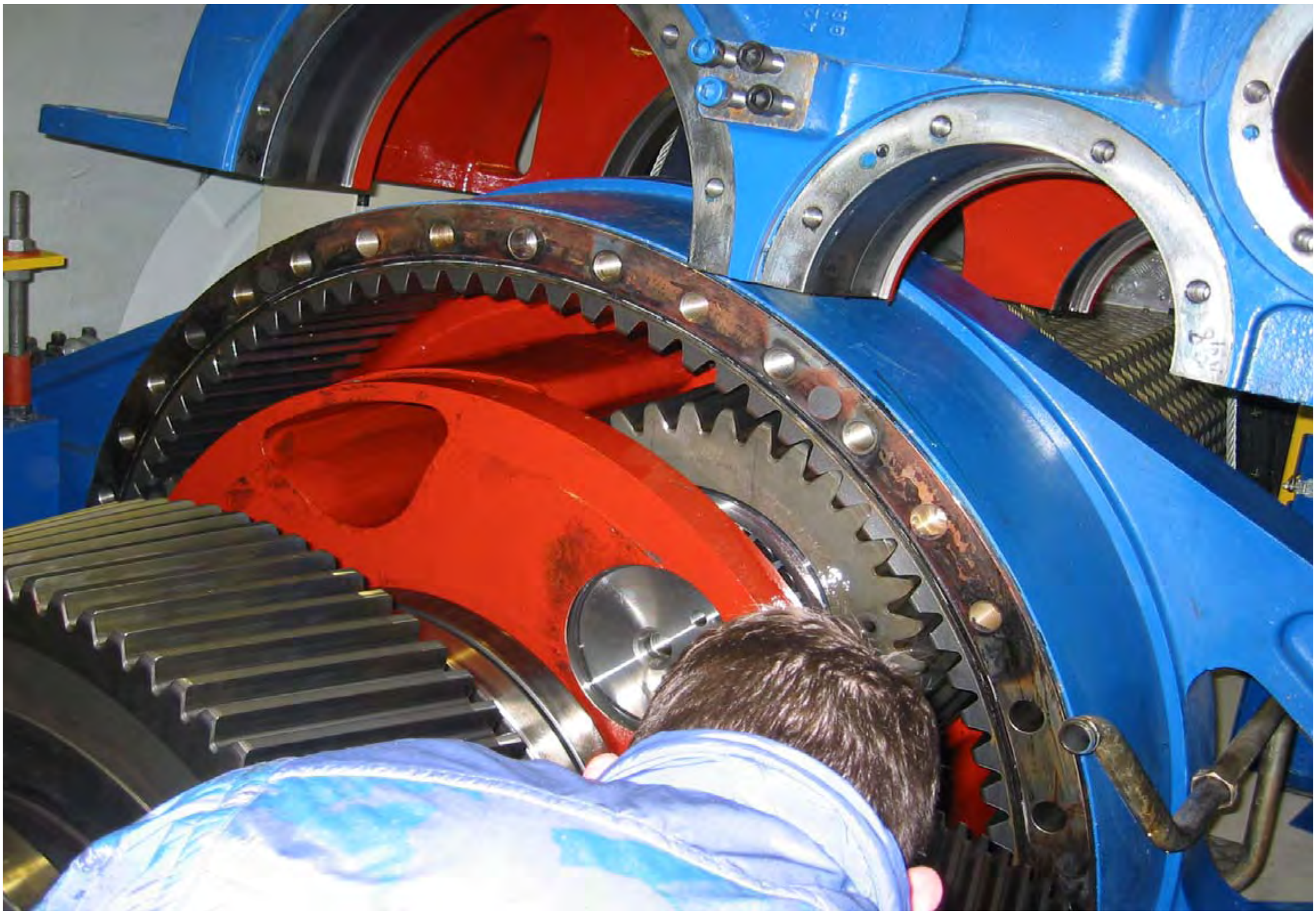
- O&M organisation
  - E2's staff is gradually taking over the O&M tasks
  - E2 provides the site manager
  - E2 is in charge of the risk management
  - E2 has a fruitful partnership with Siemens
- Demonstration turbine
  - Several details have been changed to facilitate the O&M work

ENERGI E2

Experience gained from 2 years of operation

- Nacelle
  - 2 gearbox bearings have been redesigned
  - 20 gearboxes have been repaired or replaced due to cracks in teeth
- Blades
  - Lightning protection is functioning perfectly
- Tower
  - The lifts must be commissioned on shore

ENERGI E2



Experience gained from 2 years of operation

- SCADA
  - One common SCADA system is preferred instead of two
- Machine transformer
  - Additional cooling fans have been installed
  - Vibration dampers will be installed to minimise vibrations
- Main transformer
  - Additional cooling fans have been installed

Survey shows that the concrete on the foundation is in perfect condition
Boat landing and vessel design provide access to the wind farm 80% of the year

ENERGI E2

Experience gained from 2 years of operation

- Marine cables
  - Survey shows perfect condition, few holes in the seabed have been filled
- Port and onshore facility
  - Functions well, limited use due to few repair jobs
- Service
  - Only one annual service visit as planned
  - Mixed service teams

ENERGI E2

Experience gained from 2 years of operation

- Maintenance management
  - VKS identification system has been implemented
  - SAP PM maintenance management system has been implemented recently
- Environmental protection and H&S
  - Nysted Offshore Wind Farm is certified by BWQI, regular audits
  - Offshore wind farms require firm rules to minimise the risk of accidents

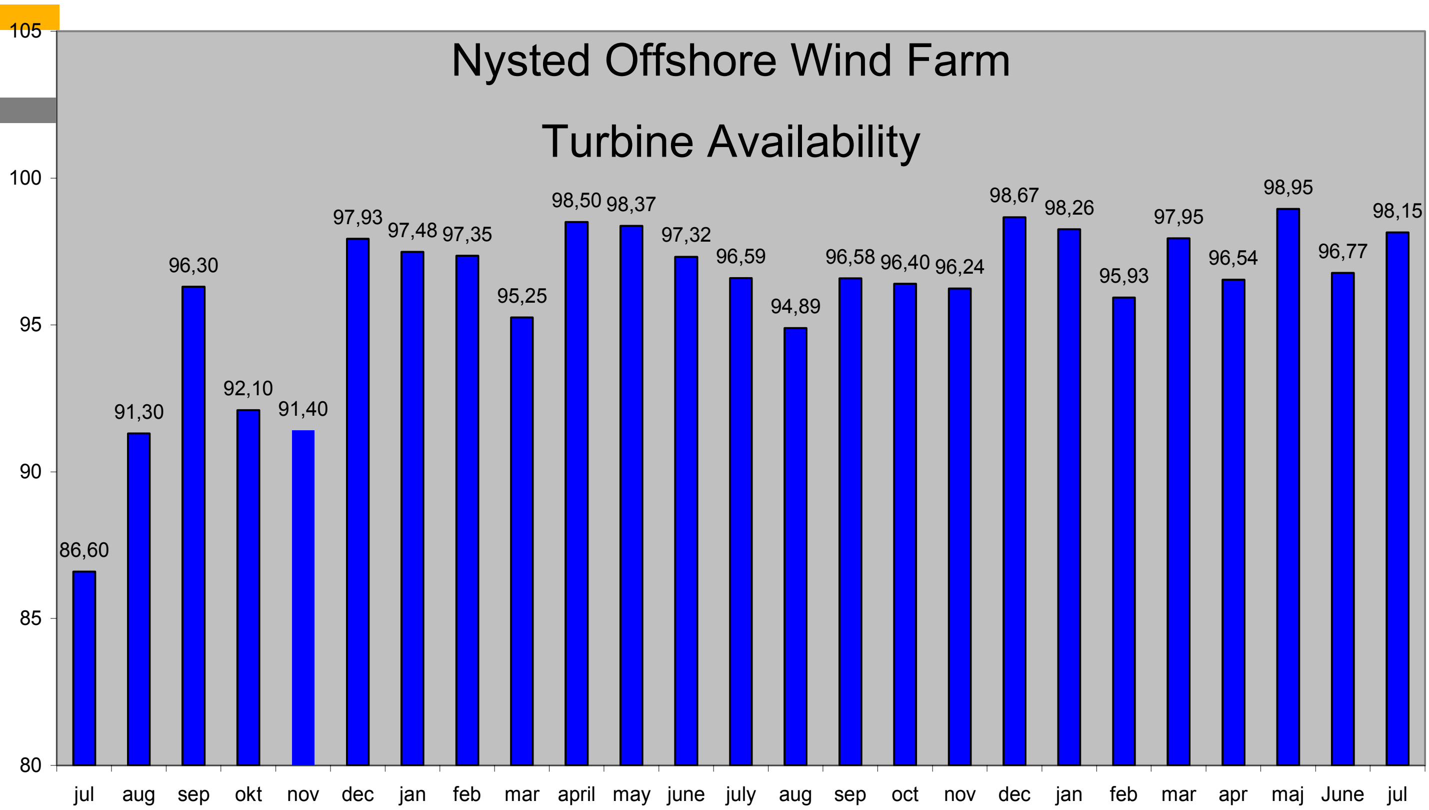
ENERGI E2

Experience gained from 2 years of operation

- Operating results
  - Establishing costs below budget
  - Annual production as planned 600.000 MWh
  - Turbine availability is 97%
  - Operating cost below budget

ENERGI E2

Turbine availability NHP (SWP - Real time hours - Timer errors / Real time hours / 100))
Juli 03 - Juni 05



ENERGI E2

Experience gained from 2 years of operation

The favourable operating results and the minimum of problems occurred during the erection period are the result of:

- Multi contracting with strong involvement and risk management by ENERGI E2
- Great attention and support from DONG and E.ON Sweeden
- Fruitful co-operation and competent performance from the suppliers Bonus/Siemens, Aarsleff, ABB, A2SEA

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Thank you for your attention

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Summary of IEA RD&D Wind – 48th Topical Expert Meeting on

OPERATION AND MAINTENANCE OF WIND POWER STATIONS

May 2006, Madrid, Spain

Anders Andersson and Sven-Erik Thor

General observations

In the future there is an urgent need to lower the corrective maintenance and find strategies and methods for preventive maintenance. It is assumed that there is a great potential for lowering the O&M costs by doing so. Presently it is quite difficult to develop such general strategies due to the limited number of wind turbines of a specific model and also that fault statistics is in the hands of the owners/operators.

The attendees discussed the magnitude of the O&M costs. It seems as if those are in the following range:

- Offshore 1-2c€/kWh
- Onshore 1c€/kWh

O&M cost estimators are offerd by at least two companies: ECN and Garad&Hassan. These tools are considered interesting, but the crucial statistical input is an issue of great importance.

At the end of the meeting there was a discussion on a number of different aspects of Operation and Maintenance.

- Health &Safety
- O&M costs
- On shore compared to off shore

Below is a short summary of the discussions.

Health & Safety

Ford-Hutchinson, B9Energy Ltd.
In Ireland a number of turbines was investigated regarding Health & Safety issues. No one of the inspected turbines fulfilled the requirements for fall arresting equipment. No one of the manufacturers of fall arresting systems has answered a questionnaire on this issue from B9. This is quite disappointing!

There is a need for cooperation in the wind power business to create a standard.

The cooperation can be started in the BWEA. What are the requirements in other countries?

O&M costs

Poul Erik Ter-Borch, E2 Wind Energy
Nystedt off shore wind farm is still in the warranty period, therefore the cost for a number of gearbox damages are unknown.

It is important to find the optimum size for the service vessel. The lack of larger vessels like crane ships, on the world market, can lead to long stand stills.

Philippe Kavafyan, GE
The long time O&M costs seems to be underestimated. Urgent repair seems to be a larger share of the O&M costs than expected.

Important to use CMS (Condition Monitoring System), inspections etc. to decrease the number urgent repairs and minimize the loss of production.

Henk Braam, ECN
The up scaling of WTs often cause problem due to step effects. This is most often covered by the warranty period.

Poul Erik Ter-Borch, E2 Wind Energy
Some faults often occur after 5 years or more, for example gearboxes in the range 500-700 kW.

Luk Rademakers, ECN Wind Energy
Important that the TCMS (Turbine Condition Monitoring System) predictions are accurate.

Paul Kuehn, ISET
Most likely, ISETs ongoing work with collection of operational data will continue after 2006. International comparisons is of great importance.

Philippe Kavafyan, GE
It is hard to keep up the quality of the fault reports. How to make data with different level of quality comparable? Most of the collected data covers turbines that are not manufactured any more. It is easier to get quality data from smaller population than general investigations.

Poul Erik Ter-Borch, E2 Wind Energy
To make reports comparable, we need a common identification system like the VKS/KKS. It is important to find the balance of enough data and accuracy compared to usefulness of the reporting system.

On shore compared to off shore

Philippe Kavafyan, GE
It is risky to bring experiences from on shore to off shore without identifying the specific problems. Saline air and ventilation has to be considered.

Ericka Echevara, TUDelft
Maybe different vessels for transportation and boarding.

Luk Rademakers
TCMS may be totally different compared to similar systems in other industries.

Philippe Kavafyan, GE
Many users have developed systems for their needs. How to merge the knowledge from different users.

Roger Hill, Sandia
Who wants longer service interval?

Poul Erik Ter-Borch, E2 Wind Energy
Mostly the customers. TCMS of great importance at extended service intervals.

Jørgen Lemming, RISØ
Transportation and accessibility is of great importance.

Philippe Kavafyan, GE
What is the long-term degradation of blades and other components?

Is there a need to collect O&M data – in cooperation?”

After the meeting Paul Kühn from ISET submitted the following text on
“Is there a need to collect O&M data – in cooperation?”

The presentations and discussions proved that sound O&M data is essential when dealing with O&M of wind turbines (costs, logistic problems, O&M strategies, reliability, accessibility etc.).

We at ISET are confident that there is a considerable need to collect O&M data. The data base at ISET has already turned out to be a valuable source of information which was and still is used in national and international research projects, political decision making and commercial applications.

Two of ISET’s upcoming projects will be concerned with the acquisition of O&M data:

The first is the subsequent project of the WMEP (Scientific Measurement and Evaluation Programme). Within the scope of that project ISET will, among others, continue to monitor the development of the reliability, availability, maintenance and repair activities etc. of onshore wind turbines. This monitoring and evaluation project will be concerned with older turbines as well with modern multi-megawatt turbines.

In the second project we are planning to collect and evaluate the O&M data of the first German offshore wind farm “Borkum-West”. This pilot wind test field, promoted by the German government, will be erected 45 km offshore the German coast in 2008. It will have a rated power of about 60 MW (12 wind turbines with app. 5 MW each, several manufacturers).

However, the amount of O&M data which will be acquired within the described projects will be limited. Therefore we at ISET would welcome to collect O&M data in cooperation by bundling efforts to gain adequate experience regarding O&M of wind turbines (especially multi-megawatt wind turbines and offshore applications). Two fundamental questions arise when considering this idea:

1. In what framework will this O&M data be collected and exchanged? (on an international level: i.e. integrated in an IEA annex, European research projects etc.)
2. What data is to be measured? (level of detail, questions of methodology etc.)

These problems, among others, will be crucial if one wants to acquire O&M data in cooperation.

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IEA RD&D Wind Annex XI, Topical Expert Meeting
Operation and Maintenance of Wind Power Stations
CIEMAT, Madrid, Spain
9-10 May 2006

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