Wind energy research in Denmark: An international perspective

Hansen, Jens Carsten

Publication date:
2011

Document Version
Publisher's PDF, also known as Version of record

Wind energy research in Denmark
an international perspective

Jens Carsten Hansen

Wind Energy Division, Risø DTU

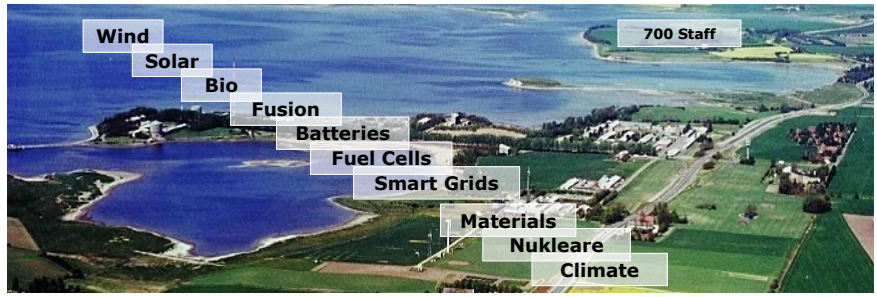
Technical University of Denmark

Outline

- Background and challenges
- Wind energy research
- International partnerships

Risø DTU history in brief

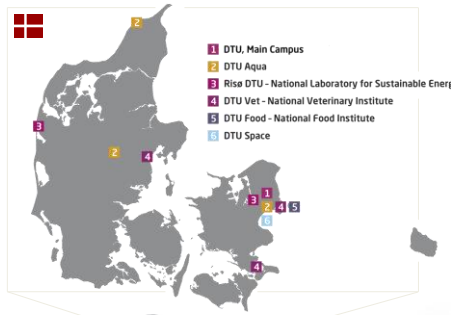
- **1954** Nuclear Energy Committee headed by Niels Bohr
- **1958** 3 nuclear reactors under construction
- **1976** ***Wind energy research starts***
- **1985** No Nuclear Power in Denmark energy plans
- **2000** Decommissioning of the last nuclear reactor is
- **2005** Sustainable energy central in strategy
- **2007** ***Part of Technical University of Denmark (DTU)***



Risø DTU, Technical University of Denmark

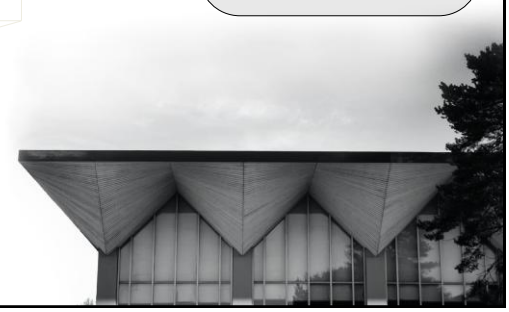
Technical University of Denmark

(founded 1829; first rector H.C. Ørsted)



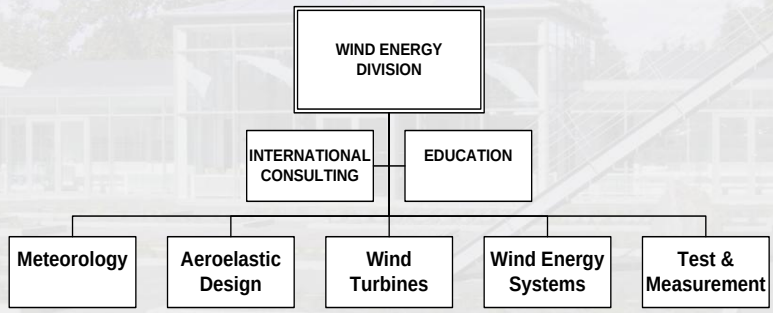
DTU areas of work

- Education (BSc,MSc,PhD)
- Research
- Consultancy for authorities
- Innovation



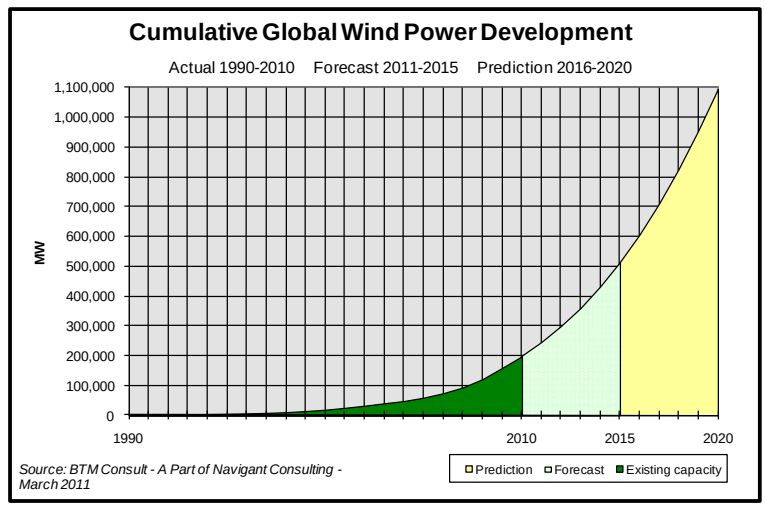
Wind Energy @ DTU

Risø DTU - Wind Energy Division (150 staff)



Risø DTU - Systems Analyses Division
Risø DTU - Materials Research Division
DTU-Mechanical Engineering
DTU-Electrical Engineering
DTU-Informatics

The challenge



Risø DTU, Technical University of Denmark

Denmark
a demonstration country for wind energy

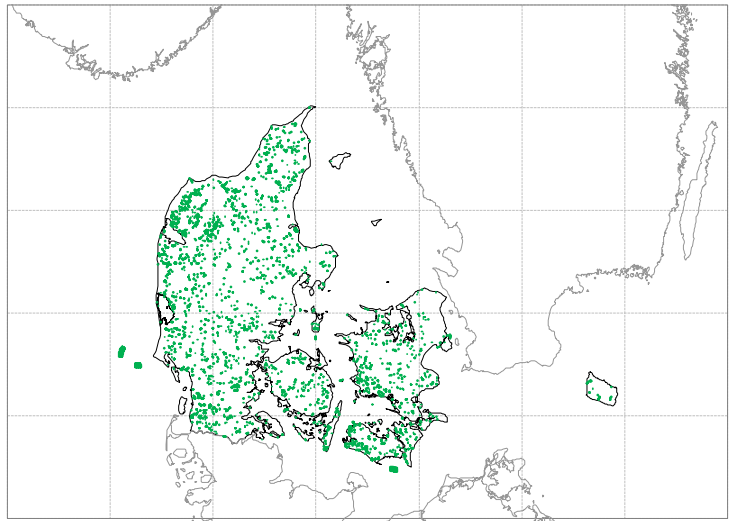
National targets and policy

25% of electricity from wind energy today
50% of electricity from wind energy by 2020 (in new government programme)

Innovation Partnership between Research and Industry (MegaVind)

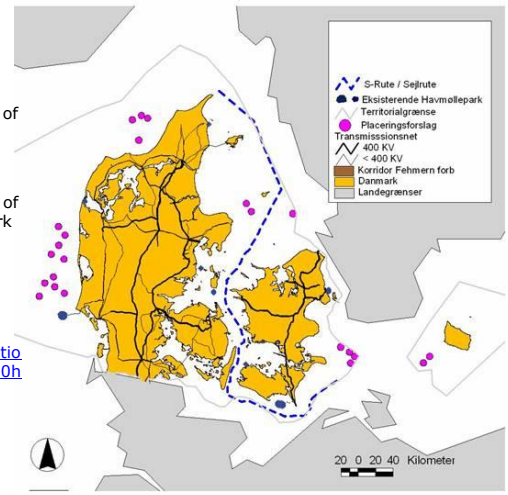
- world leading centre of competence in wind power
- **…** to provide the most effective wind power and wind power plants – that ensure the best possible integration of wind power …

Existing wind turbines in Denmark



Future Danish offshore sites

- Report on future Offshore sites
- Update of action plan from 1997
- 23 Sites each 44 km2 for a capacity of 4600 MW Wind Power
- Production 18 TWh, or just over 8% of total energy consumption in Denmark or approximately 50% of Danish electricity consumption
- http://www.ens.dk/graphics/Publikationer/Havvindmoeller/Fremtidens_%20havvindm_UKsummery_aug07.pdf



Wind Energy Research

Aeroelastic Design Methods
- Aerodynamic and aeroacoustic design
- Aero-servo-elastic design
- Wind farm design
- Innovative wind turbine design

Wind Turbine Structures
- Load and safety
- Structural design of blades
- Wind turbine structures and components
- Multi-disciplinary optimization

Wind Power Meteorology
- Atmospheric flow modelling and methods for verification
- Fundamental atmospheric processes
- Wind conditions for siting and design of wind turbines

Offshore Wind Energy
- Marine wind, wave and current conditions
- Wakes in offshore wind turbine farms

Wind power integration and control
- Wind power plants in the power system
- Variability, prediction and predictability of wind power
- Integrated design and control of wind turbines and wind farms
- Policies and strategies for wind energy research and innovation

Test and measurements

Objectives:
- To develop new opportunities and technologies for the global and Danish exploitation of wind energy;
- To improve the competitiveness of wind energy;
- To optimize the technical/scientific knowledge and competencies within the primary research areas for the development of wind energy; and
- To support the implementation and utilization of the research results in society through research-based consulting and services to industry and the public sector, innovation and education.

Key activities at Risø DTU

Problem-driven research and innovation in Wind Energy

- basic and applied research
- development and innovation
- Selected services & testing

Education and training:

- Master in Wind Energy
- Masters in Sustainable Energy
- Selected lectures
- PhD-programme and PhD-courses
- Training courses for industry

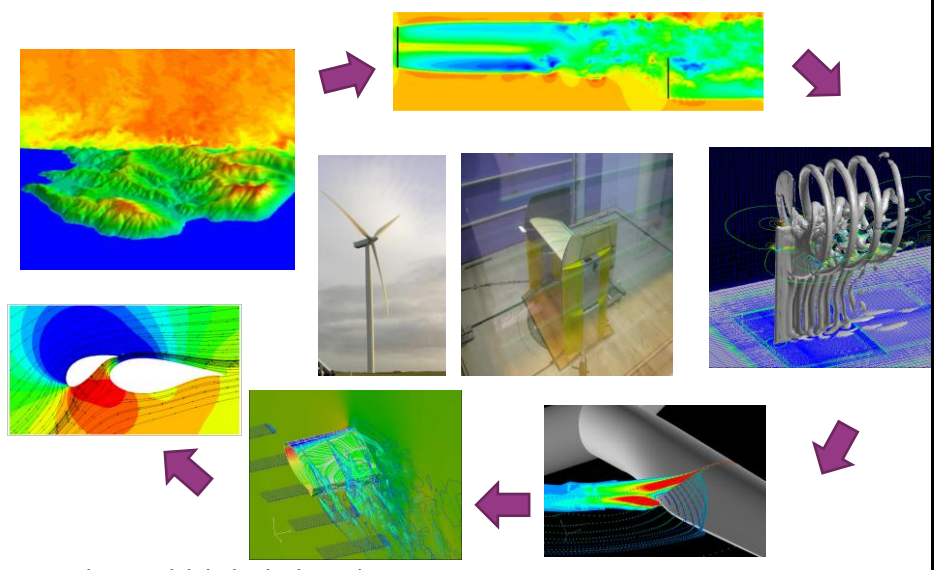
Experimental facilities

Large Projects

- Research programmes
- Development programmes
- Authorities
- Industry
- Power sector

Risø DTU, Technical University of Denmark

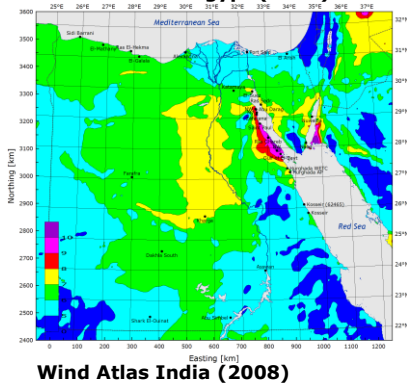
Advanced Wind Turbine Aerodynamics - modelling and experimental validation



Risø DTU, Technical University of Denmark

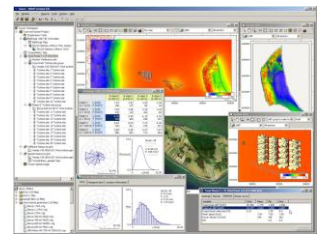
Wind Atlas Method and tools

Wind Atlas Denmark (1981)
Wind Atlas Europe (1989)
Wind Atlas for Egypt (2006)

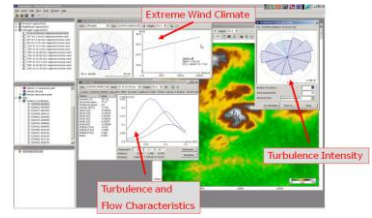


Wind Atlas India (2008)
Wind Atlas NE China (2010)
Wind Atlas South Africa (2011)
Global WA

WAsP – wind resource assessment

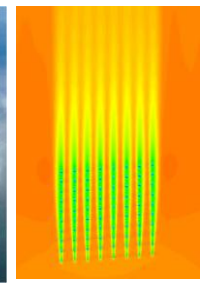


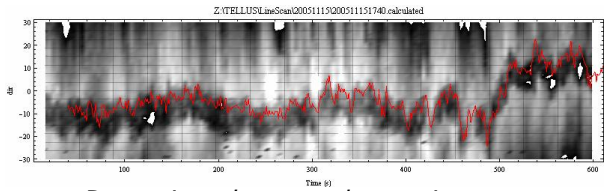
WAsP Engineering – design conditions



Wind Turbines in Complex Terrain
Do the models work here?

Offshore Wind Farms



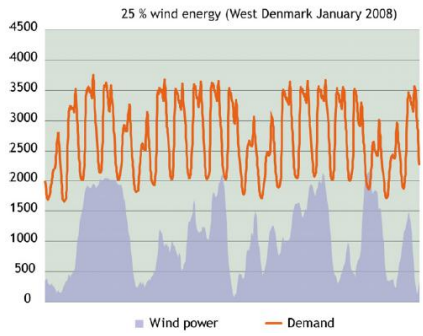


Dynamic wake meander motion

- Wind turbines wake effect
- Multiscale CFD turbulence models (ABL + wake)
- Wind farm data analysis
- Influence of atmospheric stability
- Dynamic wake meander model
- Wind farms shadow effect
- Micro-mesoscale interaction
- Wind farm layout optimization

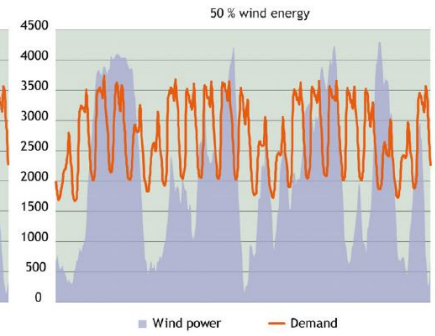
Wind integration: The Danish Target

2008



- Approximately 20% of electricity consumption met by wind power – annual average
- Around 3GW installed wind power capacity
- For a few hours in a year wind power covers the entire Danish demand

2020



- 50% of electricity consumption to be met by wind power – annual average
- Around 6GW installed wind power capacity
- Wind power production will often exceed the Danish demand

Source: Energinet.dk - EcoGrid

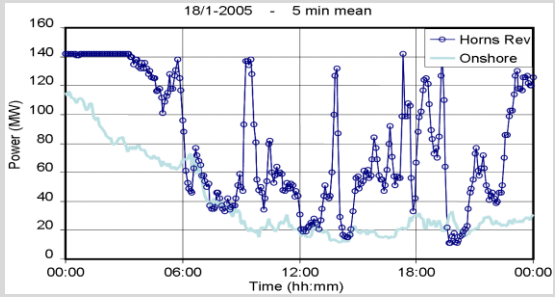
Wind power variability and prediction

Danish research efforts have as goal:

- to improve power system and wind power plant functionality
- to seek solutions to enable integration of large amounts of wind power
- to assure the security and reliability of power supply in power systems with large amounts of wind power

Relevance for planning, design and operation !

Example of Horns Rev wind farm



Source: DONG Energy and Vattenfall

Power fluctuations

- offshore more than onshore
- power gradients of 15MW/min
- from 0 to 160MW in 10-15 min**!**

Possible impact on:

- system power balancing
- deviations of the power exchanges between neighbouring countries

TWENTIES – WP16.2 (EU FP7)

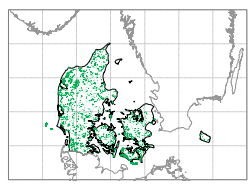
Twenties Transmitting wind

OBJECTIVES

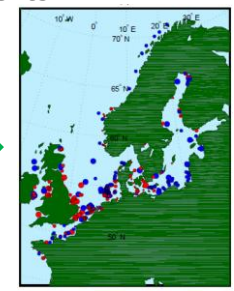
- Study power system balancing and reserve requirements with **massive offshore wind power**
- Special focus on sudden loss of wind power due to storm passages

RESULTS

- Time series of wind power generation and forecast errors in 2020 and 2030 – development and use of CorWind
- **Quantification of reserve requirements**



from large scale onshore to massive scale offshore



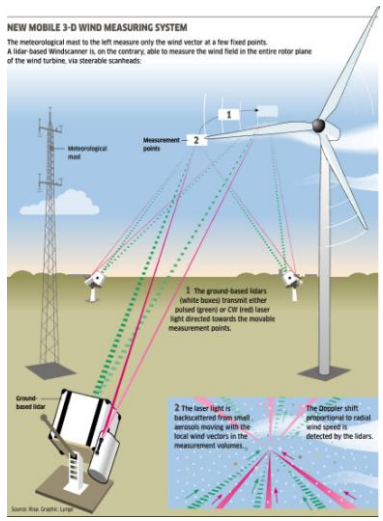
red: 2020
blue: 2030

Risø Test Stations – Prototype Testing

5 test beds
< 165 m
< 8 MW
Spacing 300 m

7 test beds
< 250 m
< 16 MW
Spacing 600 m

Windscanner.DK

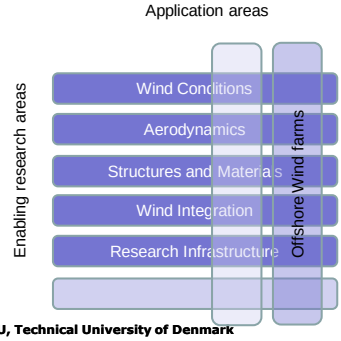


Lidar-based wind and turbulence measurements for research, siting and control

In global partnerships
such as e.g. TPWIND and EERA in Europe

The EERA Joint Programme on Wind Energy aims at accelerating the realization of the EU SET-plan goals and to provide added value through:

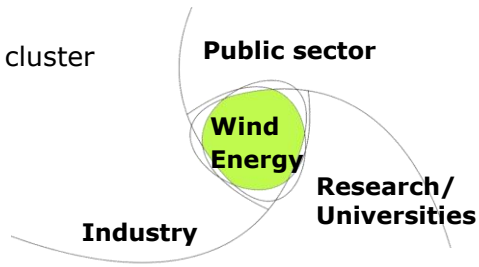
- Strategic leadership of the underpinning research
- Joint prioritisation of research tasks and infrastructure
- Alignment of European and national research efforts
- Coordination with industry, and
- Sharing of knowledge and research infrastructure.



EERA
European Energy Research Alliance

Potentials for Sino-Danish Cooperation

- Research cooperation
  - Wind resource mapping
  - Wind farm siting and performance
  - Flow modelling
  - Load conditions and design criteria; (standards)
  - Grid integration
- PhD and Graduate programs – SDC
- Software/training
- Part of the Danish wind cluster



SDC PhD in Wind Power Plants System Services

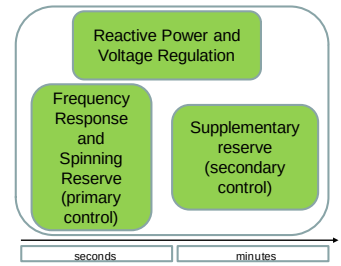
Ph.D project financially supported by
Sino-Danish Center for Education and research (SDC)

Overall goal:

- to analyze and assess the possibilities to exploit wind power plants capabilities to support the power system in a similar way as a conventional power plant does.

Focus on:

- integration of large wind power into the power system
- development and modelling of different technically viable solutions, which increase the ability of wind farms to provide system services
- study the impact on the power system of large and concentrated penetration of wind farms with controllers delivering ancillary services
- case studies – Denmark and China



Collaboration:

- CEPRI
- IEE CAS

Status:

- 57 applicants
- Candidate found / enrolment on-going
- Expected start date:15 dec. 2011

The Bolund Experiment

A. Bechmann, P-E Rethore, N.N. Sørensen, J. Berg, H.E. Jørgensen,
J. Mann, M. Courtney, P. Hansen, J. Johansen, K. Enevoldsen, L. Christensen, M. Rasmussen, S. Lund, S. Berner, K. Clemmensen, P. Hummeshøj, R. Kjærsgaard, A. Sogachev, S. Sørensen, A Jørgensen

Risø DTU
National Laboratory for Sustainable Energy
Risø DTU, Technical University of Denmark

Vestas

Purpose of Blind Comparison

1. **Make The Bolund Data Visible**
2. **Evaluate Flow Modeling Accuracy**
3. **Standardize Resource Assessment Modeling?**

Conclusions

The Experiment

1. Instrumentation and data acquisition worked well. Proximity to Risø – convenient
2. We have successfully captured the gross features of flow over a steep hill
3. Important to plan the experiment using the tools that are being validated

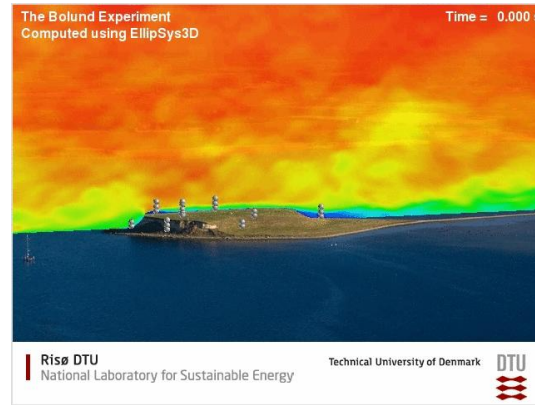
Conclusions

The Blind Comparison

1. Recommendation: RANS k-ε is today's main workhorse, LES has not matured yet.

2. 10% error on speed-up and 20% on TKE is what to expect in complex terrain?

3. 7 diff. CFD solvers in top 10: The user is more important than the solver.



Boundary-Layer Meteorology

Most downloads in September 2011

303 The Bolund Experiment, Part II: Blind Comparison of Microscale Flow Models
Bechmann, A.; Sørensen, N. N.; Berg, J. Show all authors (5)

188 The Bolund Experiment, Part I: Flow Over a Steep, Three-Dimensional Hill
Berg, J.; Mann, J.; Bechmann, A. Show all authors (5)

135 The Near-Calm Stable Boundary Layer
Mahrt, Larry

108 A Wind-Tunnel Investigation of Wind-Turbine Wakes: Boundary-Layer Turbulence Effects
Chamorro, Leonardo P.; Porté-Agel, Fernando

83 Modelling Near-Surface Low Winds over Land under Stable Conditions: Sensitivity Tests, Flux-Gradient Relationships, and Stability Parameters
Luhar, Ashok K.; Hurley, Peter J.; Rayner, Ken N.

Thanks to

- Danish Energy Counsel
- Vestas Technology R&D
- and the 60 participating companies:

3Tier	Geo-net	Tokyo Institute of Technology
ANSYS	Germanischer Lloyd	TUV Nord
Barlovento Recursos Naturales	Go Virtual Nordic AB	Univ Maryland
CENER	Kjeller Vindteknikk	Univ Berkeley
CERC	Megajoule	Univ Duke
CEsA Univ Porto	Meridian Energy	Univ Edinburgh
Chalmers Univ of Tech.	Metacomp Technologies	Univ Johns Hopkins
COWI	Meteodyn	Univ Madrid
CRES	MS Micro	Univ Nottingham
DMI Force	National Institute of Water & Atmospheric Research	Univ Southampton
ECOFYS	Natural Power	Univ Stanford
École de Technologie Supérieure	NCAR	Univ York (Toronto)
EMD	Nordex	Vattenfall
ENERCON	Normawind	Vijayant Kumar
EREDA	Numeca	Von Karman institute
ETH Zürich	RES	Wind Farm Grou
GAMESA	ReSoft ltd	Windlab Systems
Garrad Hassan	RWE npower renewables	WindSim
GE Infrastructure	Siemens Wind Power a/s	
DNV	Star-CD	
	Suzlon Wind Energy