

Wind and Wave Resource Estimation for the Baltic Sea Region

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Wind and Wave energy

Present Status and Future Development

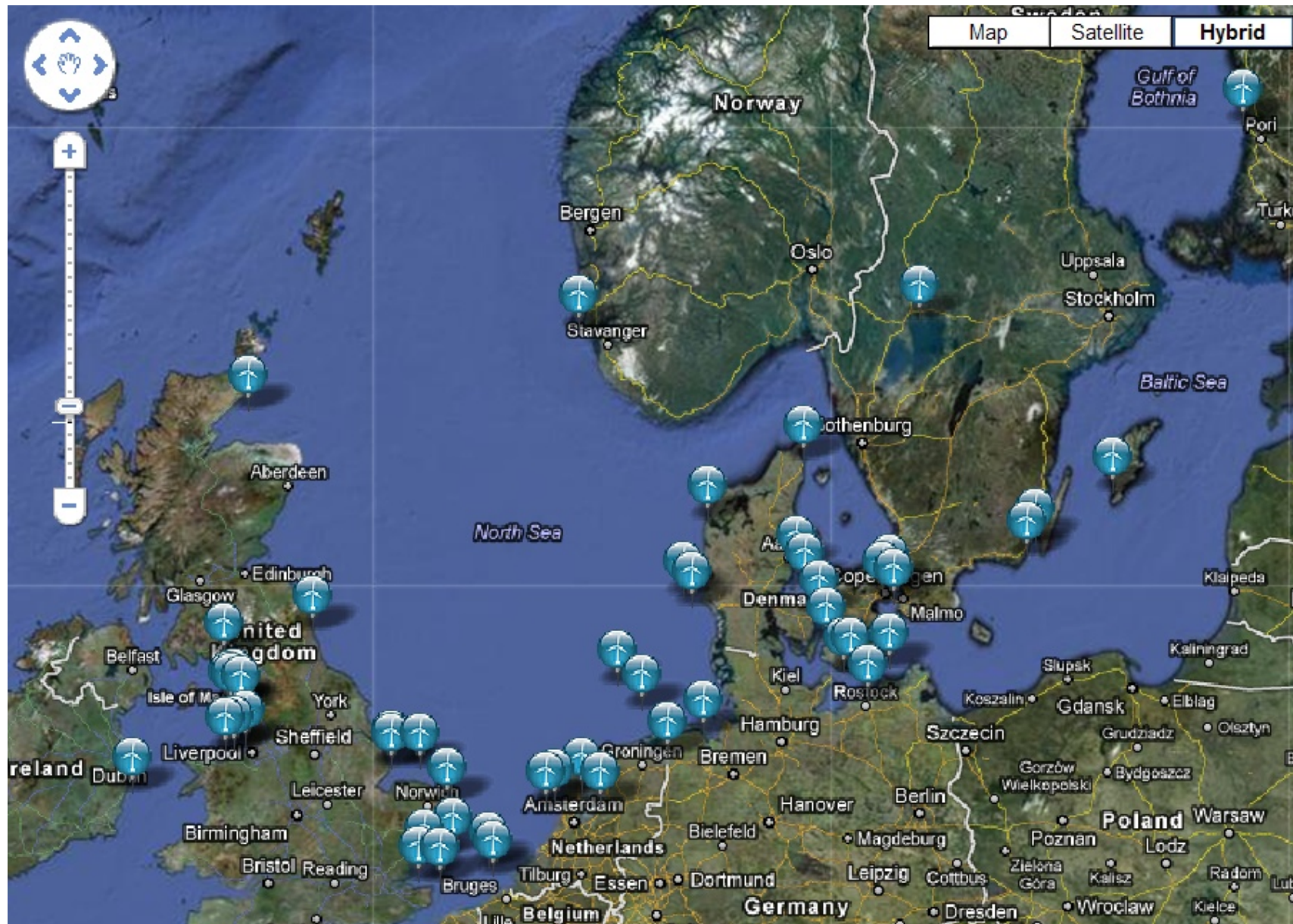
Wind energy is a mature technology , continuing to improve efficiency..

- Off shore wind energy is more expensive and in many aspects still a developing technology.

Wave energy is further away from maturity:

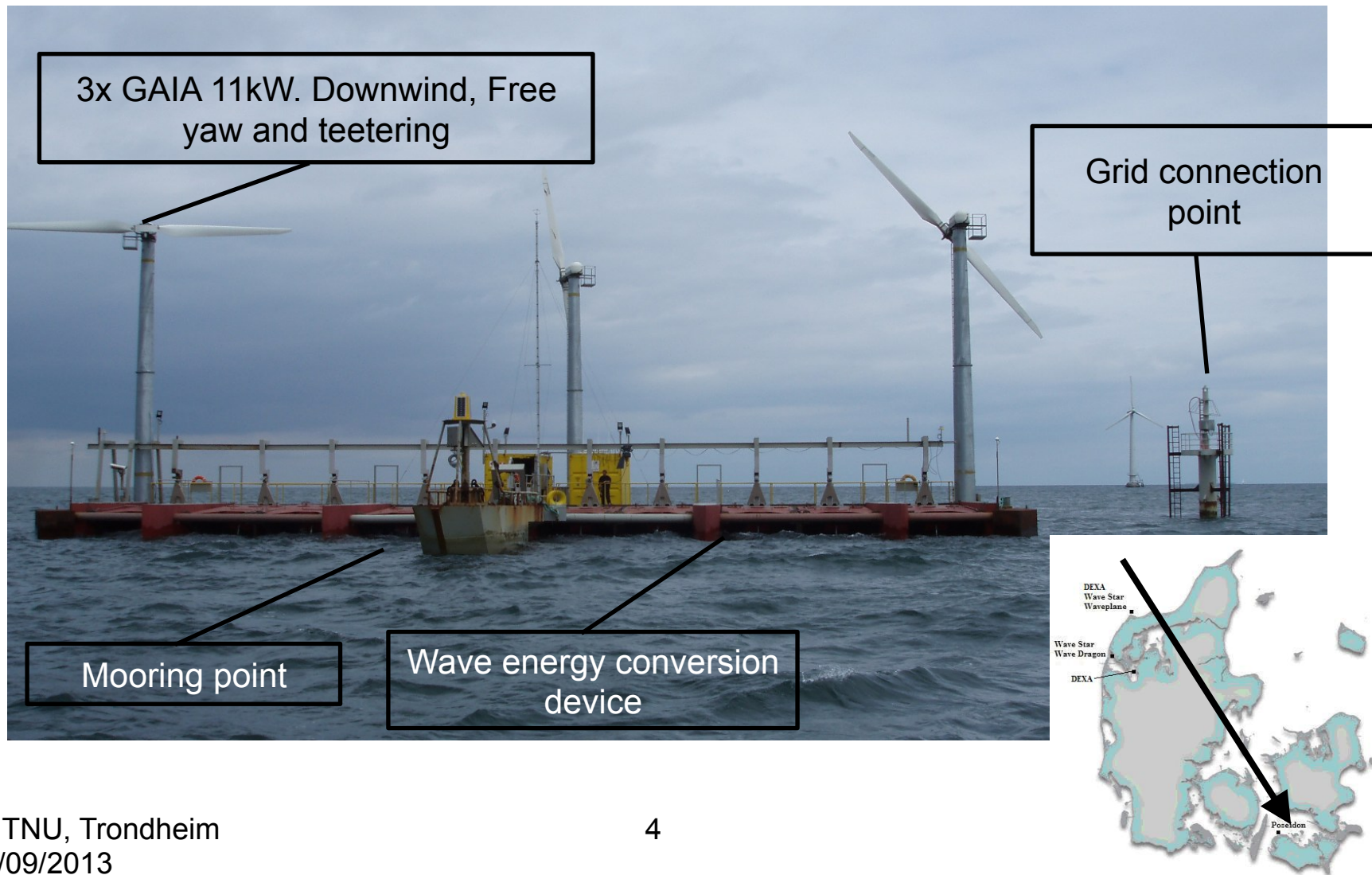
- Most of the offshore designs are still at a R&D or demonstration stage.
- The wave energy devices need to prove their integrity and reliability during normal operation as well as extreme conditions
- Especially the extreme conditions are challenging
- If they prove successful, some designs might achieve commercial status in 5-10 years (specially shoreline and near shoreline devices)

Offshore wind farms 2011



Floating power plant Poseidon

PSO project, measurements and modelling: DONG, FPP, DHI and DTU Wind Energy

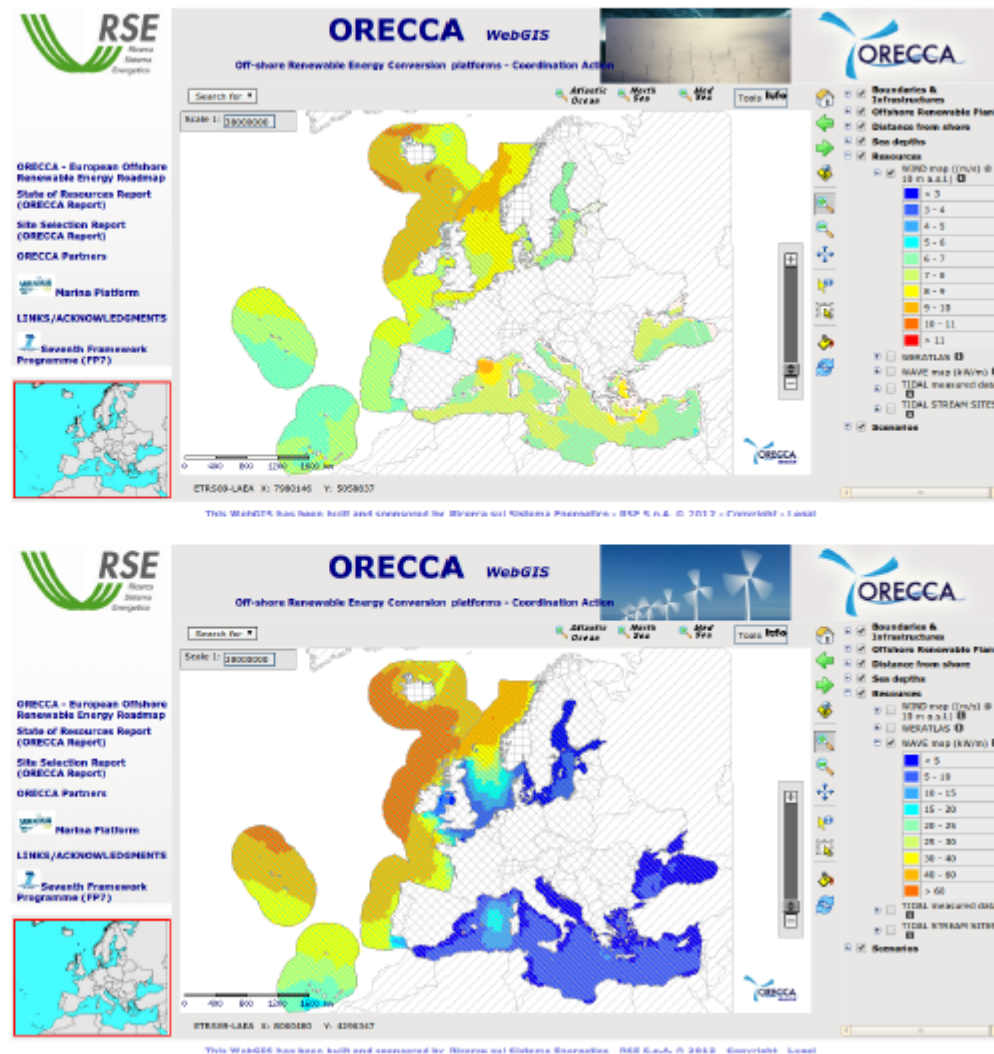


Wind and Wave Climates are strongly connected!

EU-ORECCA

Roadmap for research activities on offshore renewable energy conversion platforms for

- Wind
- Waves
- Other

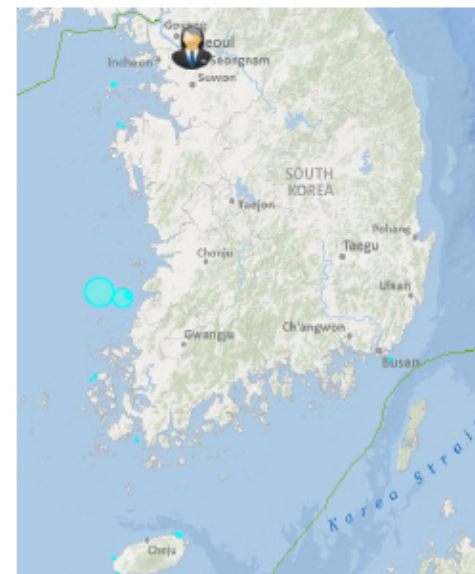


- Offshore Wind and Wave climatology are strongly related phenomena:
- The waves are generated by the surface wind !
- The necessary climate information for both offshore wind power and wave power plants involves both. Aside from wave resources for wave plants, wave loads are important for both wave and offshore wind power plants. Also both are relevant for Service and Maintenance.
- HOW TO OBTAIN THE RELEVANT INFORMATION?

Wind and Wave measuring sites are necessary but expensive to establish and operate.

Alternatives :

- LIDAR (remote sensing)
- Satellite observation
- Reanalysis data bases.
- Synoptic, Mesoscale, microscale models for wind and waves.



Significant Wave Height

$$H_s = 4\sqrt{\bar{\eta}^2}$$

- η : wave height
- Average crest-to-trough height of $\frac{1}{3}$ largest waves

Significant Wave height

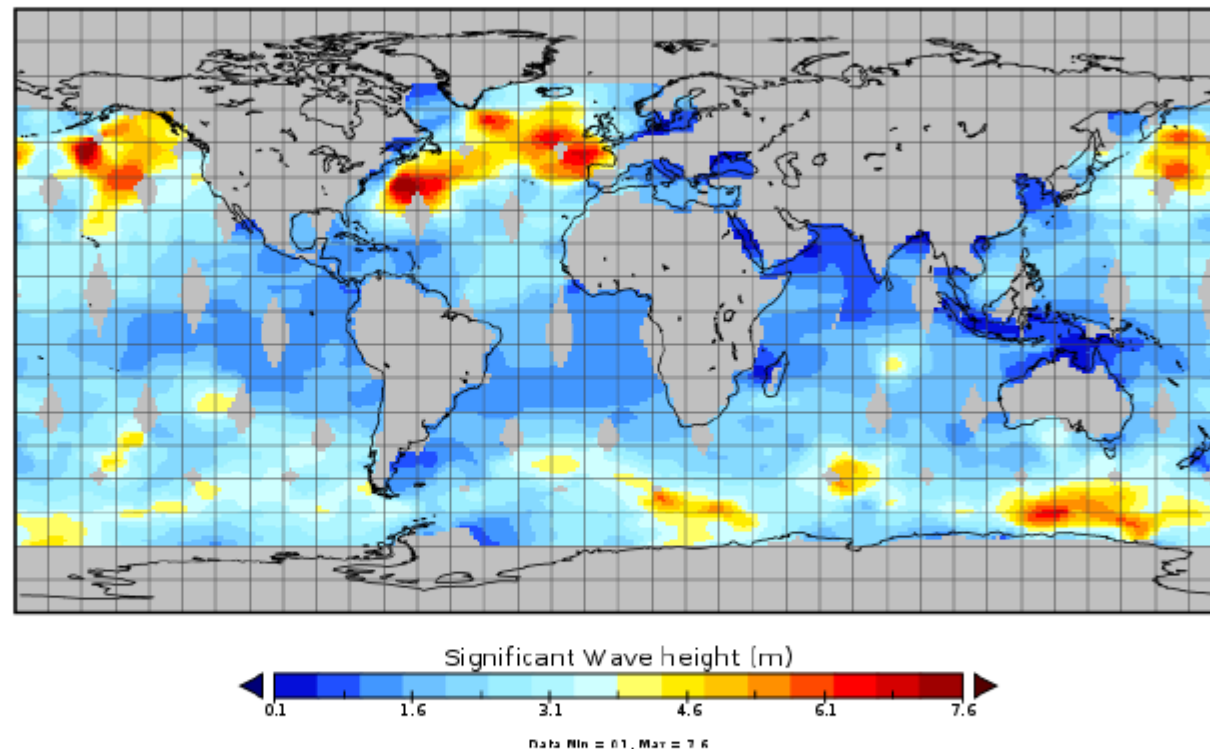


Figure: Latest NRT Significant Wave Height merged product, from Aviso (<http://www.aviso.oceanobs.com/en/data/products/wind-waves-products/mswhmwind.html>)

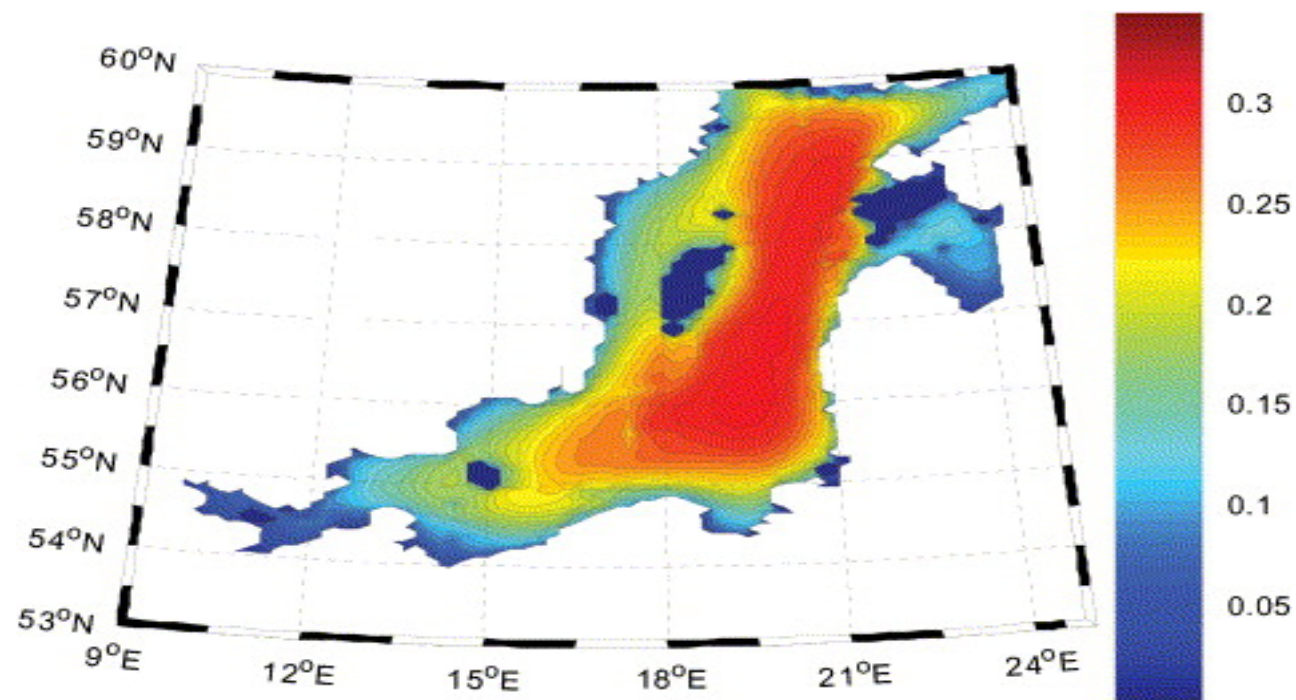


Fig. 1 Average annual wave energy density in the Baltic Sea (Wh/m^2), calculated from hindcasting data between 1994 and 2004. Data and map obtained from SMHI.

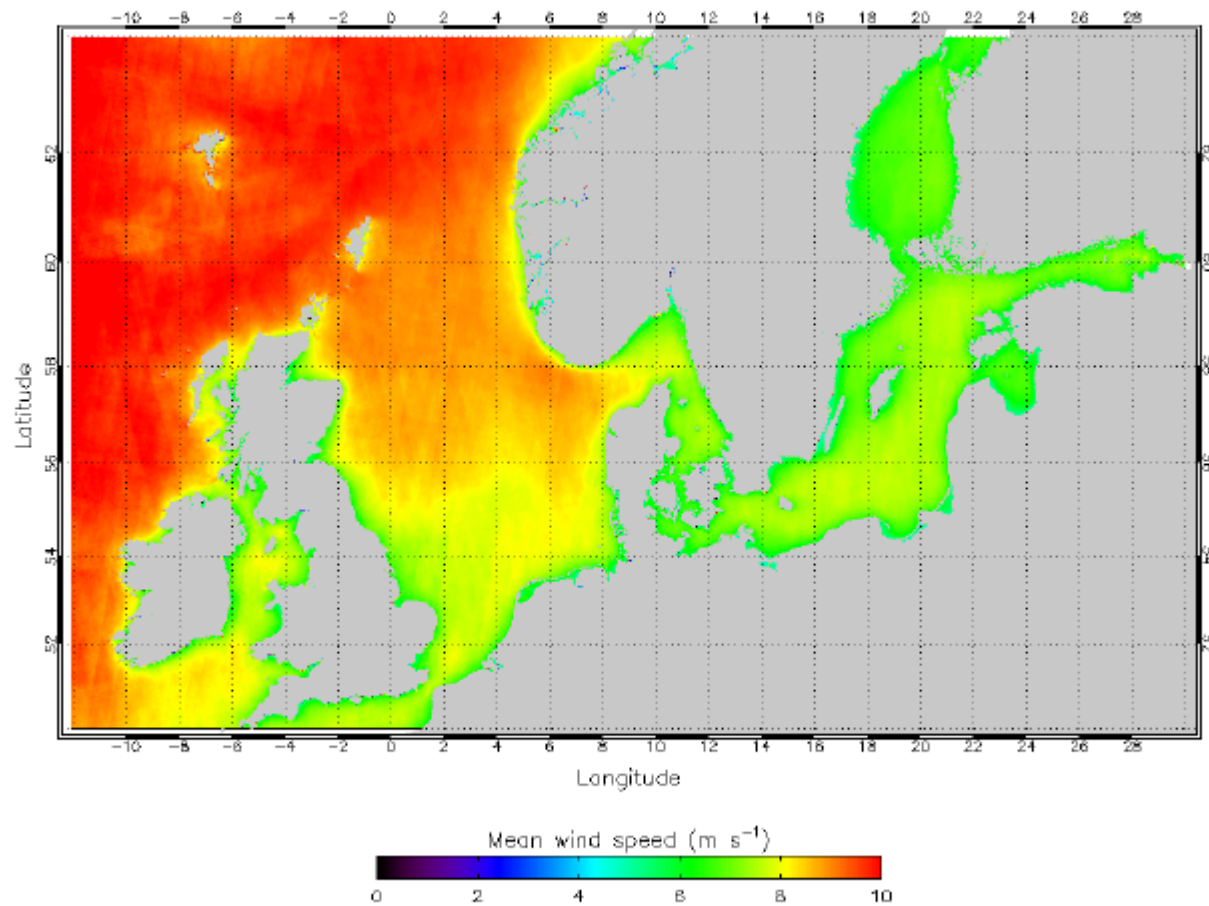
Urban Henfridsson , Viktoria Neimane , Kerstin Strand , Robert Kapper , Hans Bernhoff , Oskar Danielsson , Mats L...

Wave energy potential in the Baltic Sea and the Danish part of the North Sea, with reflections on the Skagerrak

Renewable Energy Volume 32, Issue 12 2007 2069 - 2084

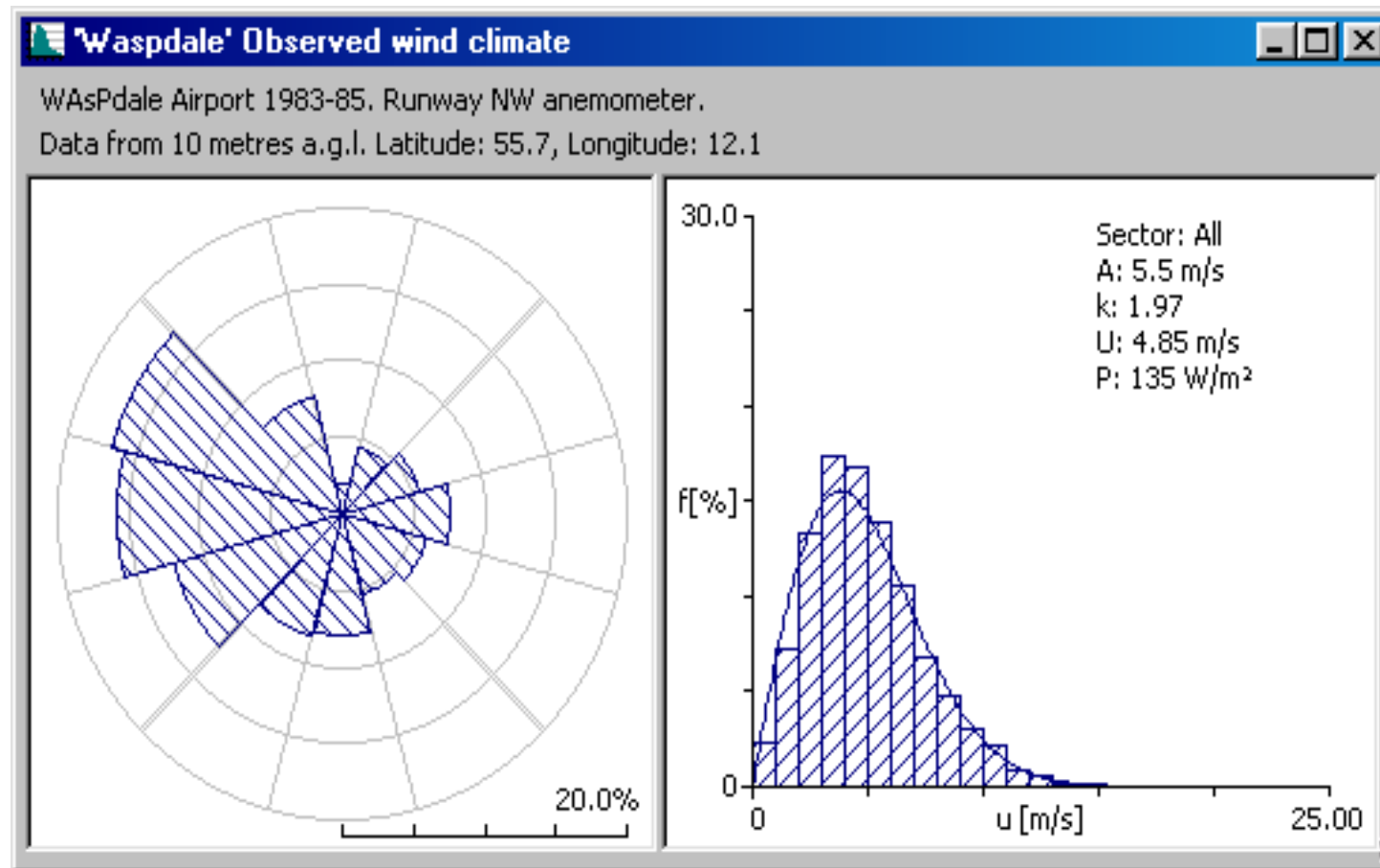
<http://dx.doi.org/10.1016/j.renene.2006.10.006>

NORSEWInD ASAR Wind atlas



Mean wind speed from the resource assessment atlas. Courtesy: DTU Wind Energy & CLS.

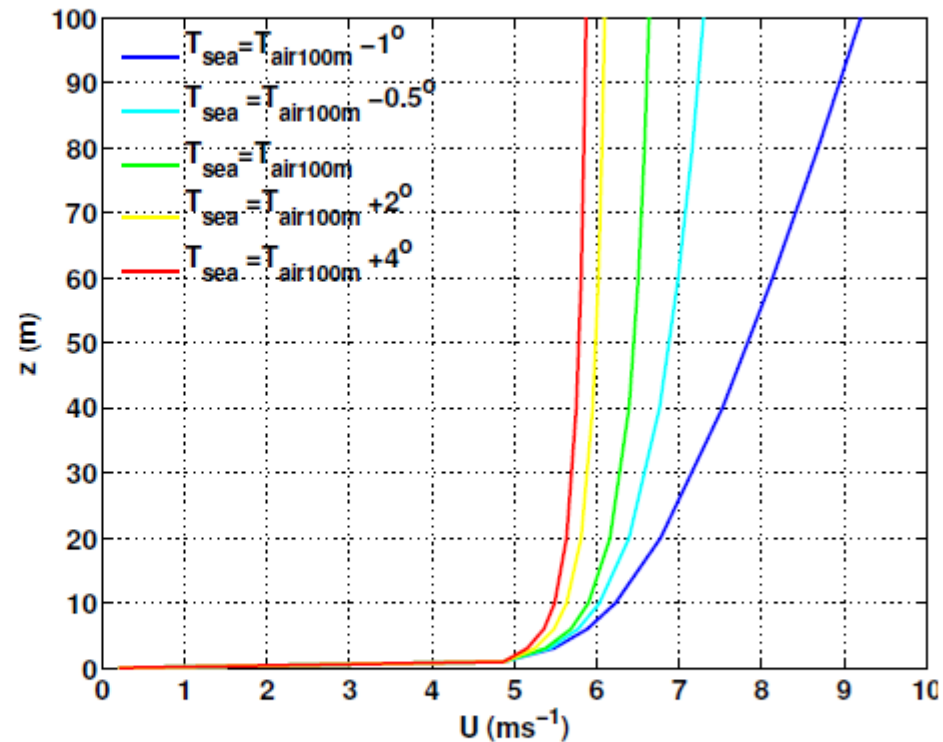
Distribution Functions



Wind Profiles

$$u = \frac{u_*}{\kappa} \left[\ln \left(\frac{z}{z_0} \right) - \Psi_M \right]$$

- u : wind speed at height z
- u_* : friction velocity
- κ : von Kármán constant (~ 0.4)
- z_0 : surface roughness
- Ψ_M : stability & height dependent

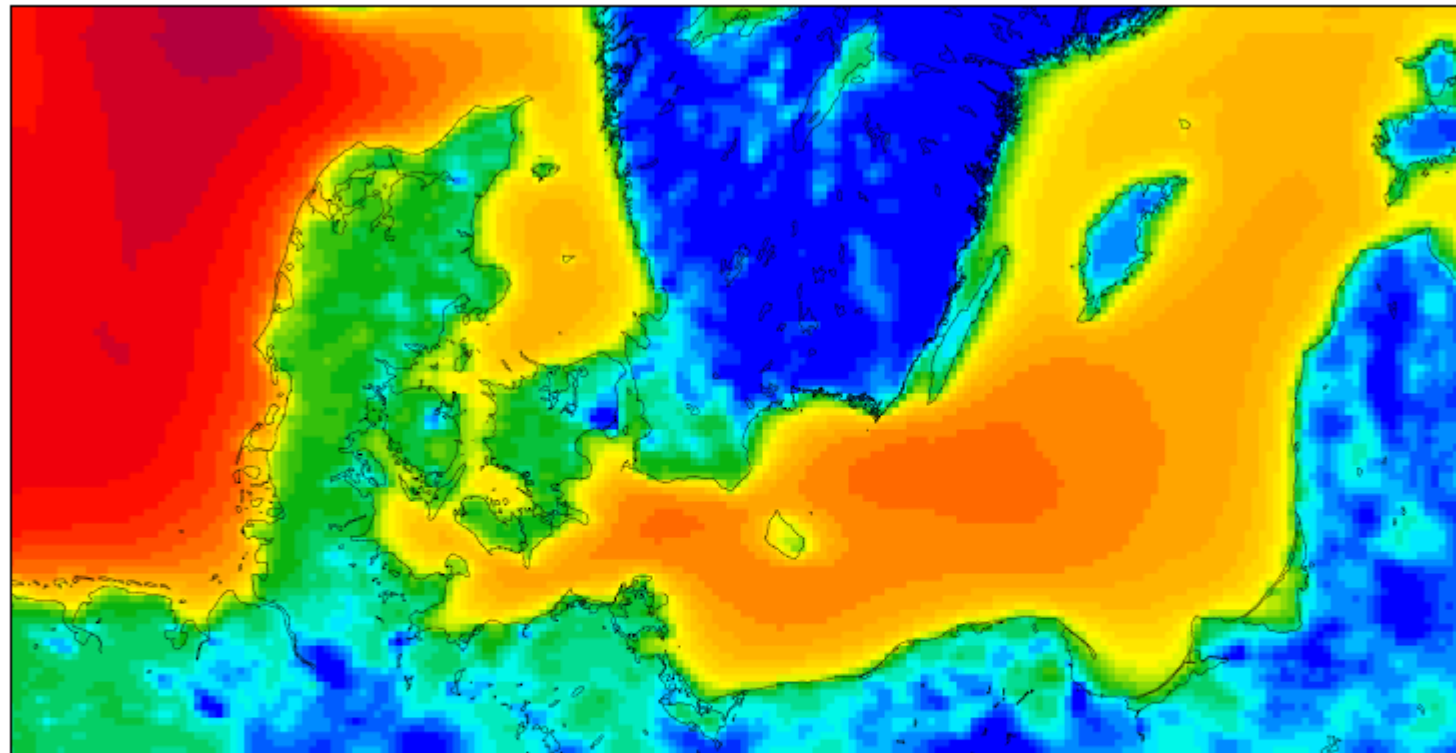


Compared to neutral case

- -1° : 39% increase of u_{100m} (167% for wind power density)
- $+2^\circ$: 8% decrease of u_{100m} (22% for wind power density)

Mean Wind Speed: Jan 2007 - Dec 2009

Height: 80 meters

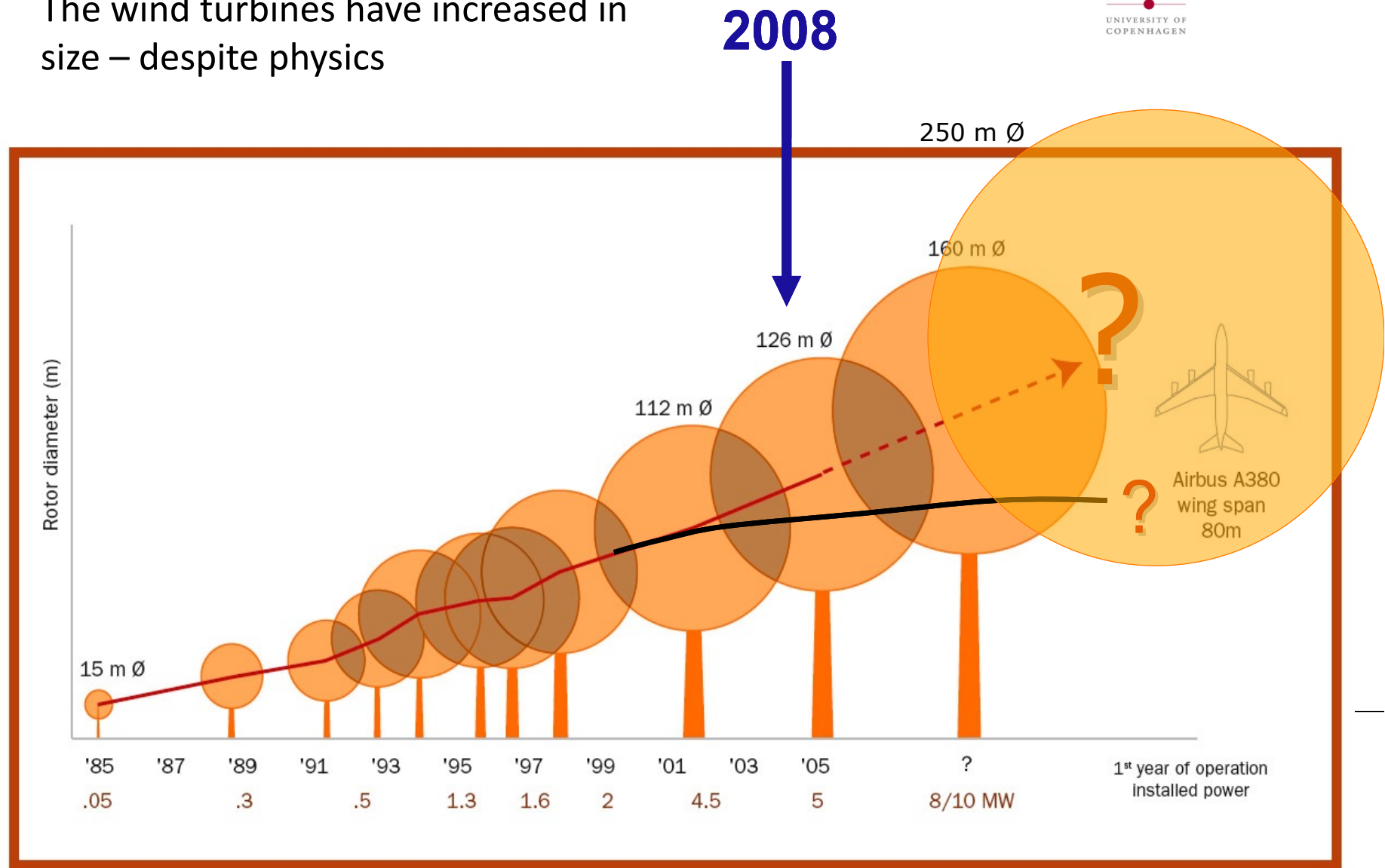


6.5 6.75 7 7.25 7.5 7.75 8 8.25 8.5 8.75 9 9.25 9.5 9.75 10 10.25 10.5

wind speed (m/s)

Up-Scaling

The wind turbines have increased in size – despite physics



Spatial planning at sea?



Driving forces for renewable energy

- Environment – global and local
- Security of supply (fuel supply & policy)
- High and increasing oil prices
- Industrial development – employment
- Export

Barriers

- Grid access
- Planning and permitting process
- Support mechanisms

Which parameters would you look for when choosing your offshore site?



Issues to be considered

A word cloud of various environmental and social issues. The words are arranged in a roughly circular pattern, with some words being larger than others. The words include:

- Hydrogeology
- Designated areas
- Tourism
- Morphology
- Benthos
- Fishery
- Landfill
- Oil and gas
- Dredging
- Birds
- Geology
- Waste water
- Shellfish
- Noise
- Archaeology
- Flora
- Protected species
- Visual
- Navigation
- Intertidal
- Aviation
- Military and munition
- Transportation
- Sediment chemistry
- Fish
- Flooding
- Marine
- Employment
- Coastal erosion
- Mammals
- Waste
- Electromagnetic fields
- Disposal
- Television and communication

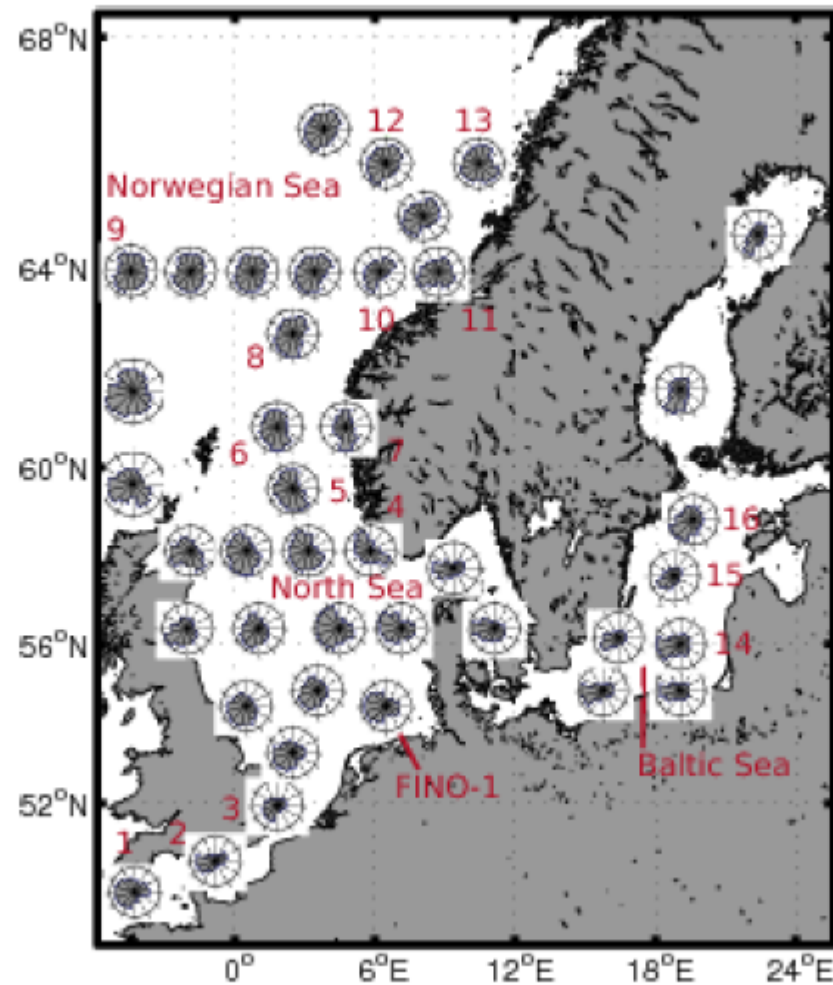
Total height 150 m – distance 2 km



Total height 150 m – distance 12 km

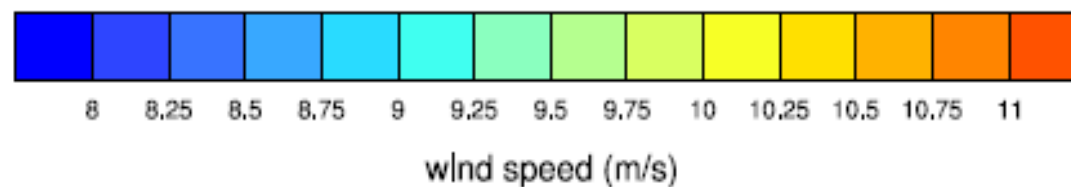
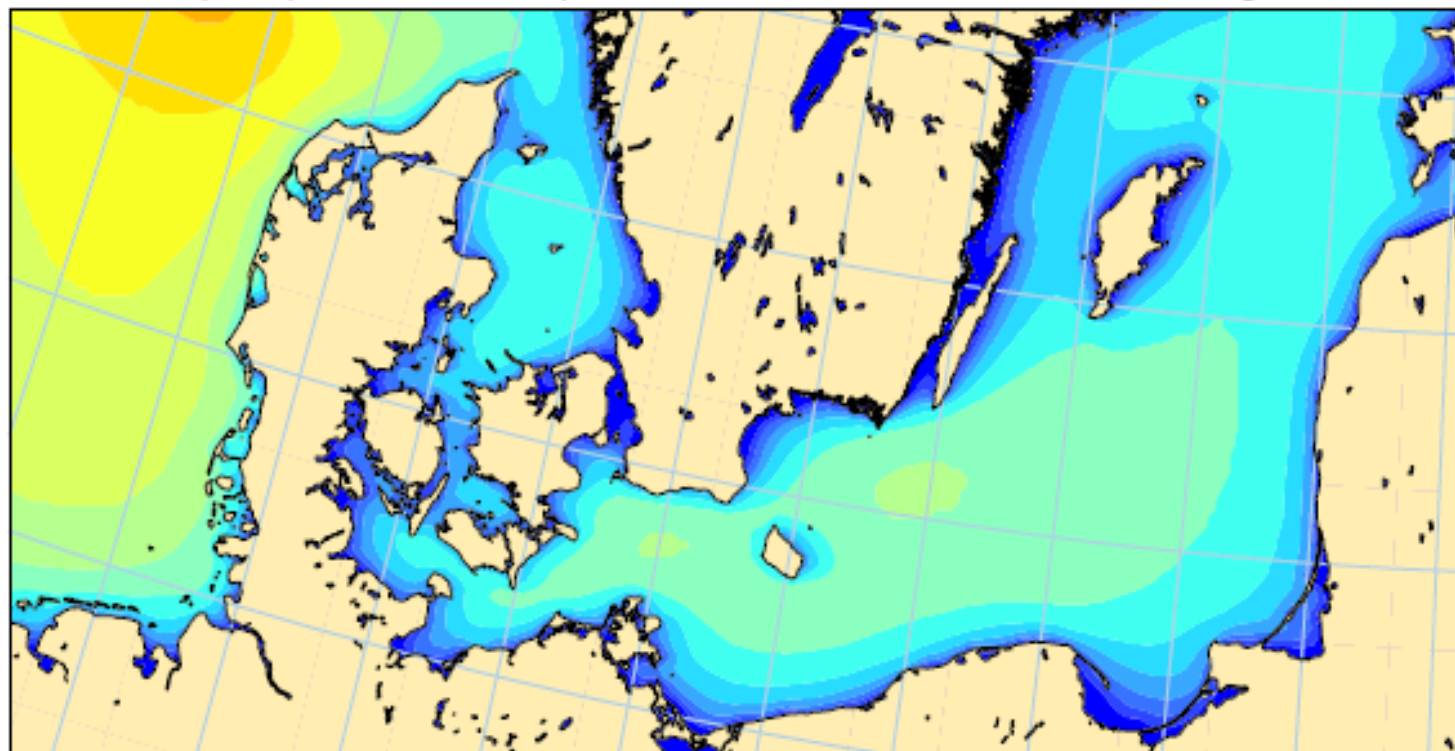


Wind Direction Distributions



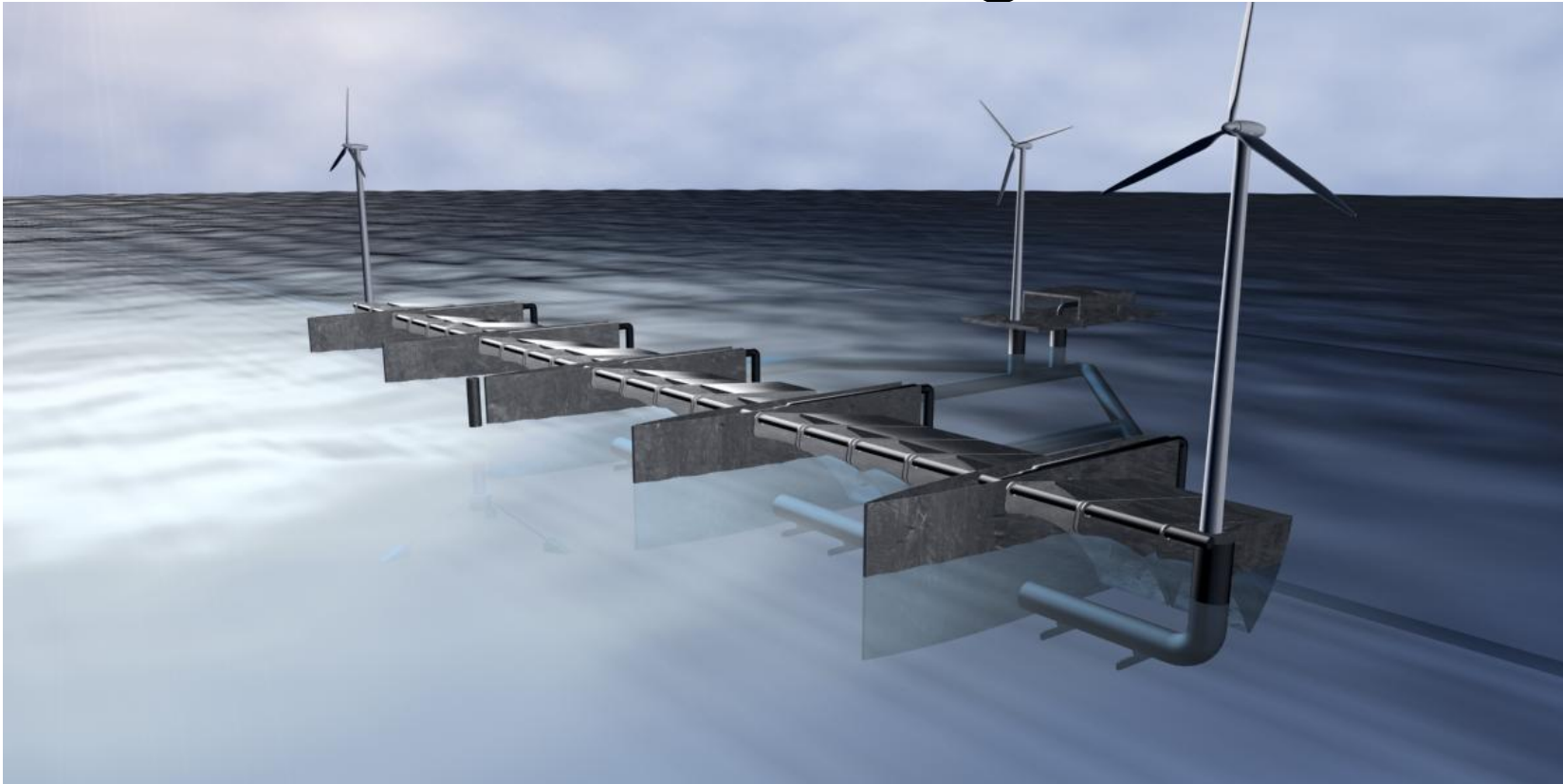
Mean Wind Speed (WRF+ERA Interlm): 2006-2011

Height: 100 meters



Combinations

Poseidons organ

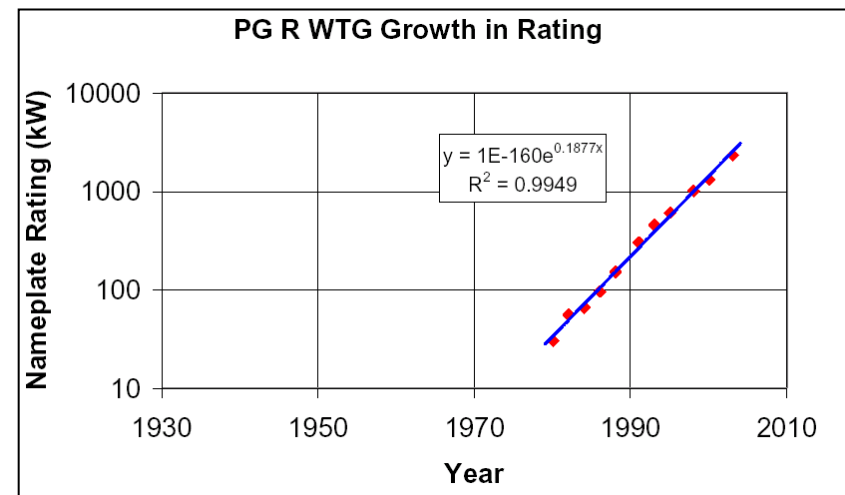
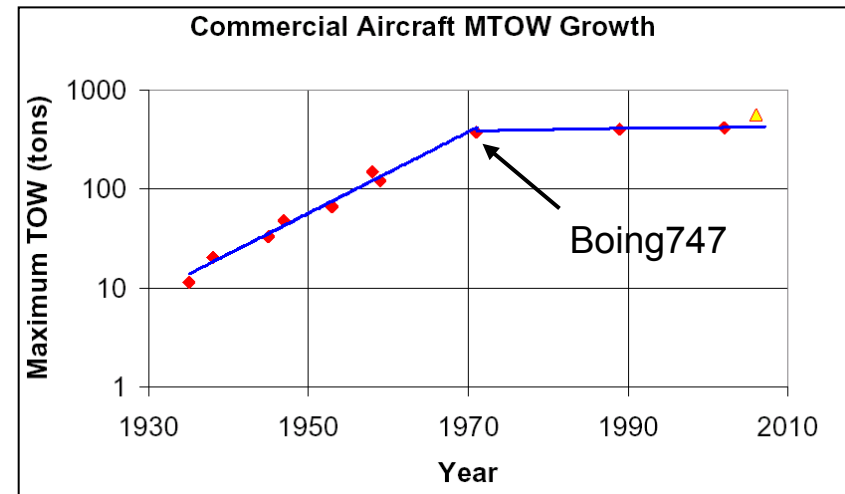
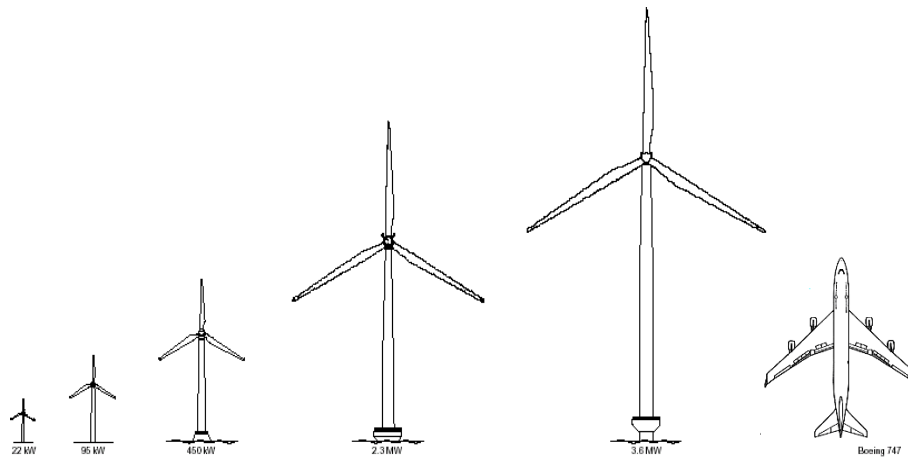


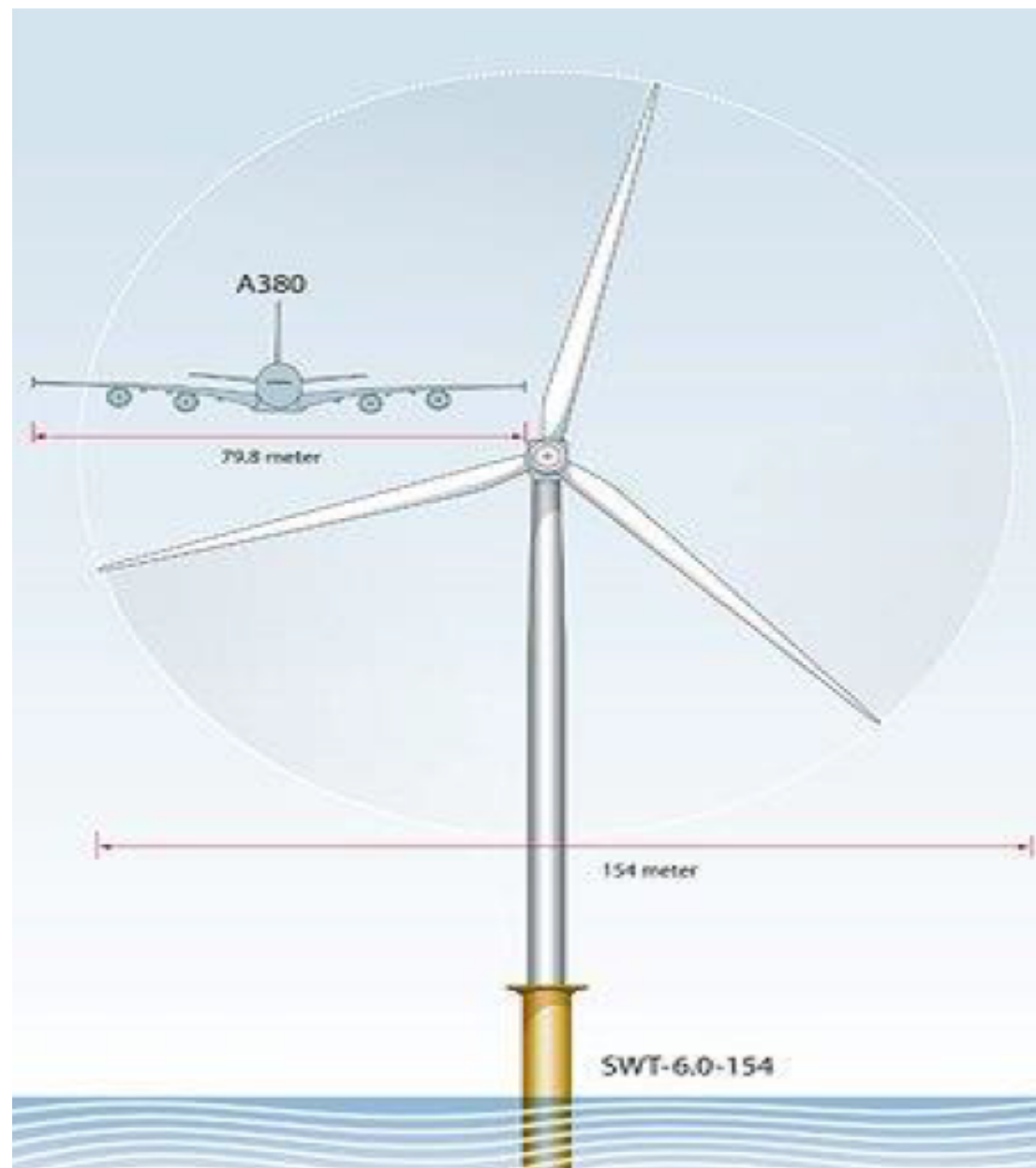
The first 30 MW demonstration plant will be 150 x 230 m and is expected to generate 50 GWh per year (CF =20%). It will serve as the foundation for three 2 MW wind turbines. A 80 kW prototype is being tested at Vindeby

Are wind turbines getting larger?

Until now exponential growth

- From 22 kW to 2.3 MW in 25 yrs
- Doubling in 4 yrs
- Will we see a plateau at 5-10 MW ?
- 3.6 MW wind turbine has 107 m diameter – Boeing 747 has 65 m wing span





Vestas V164

New offshore turbine from 2015
First prototype in 2013-2014
Medium speed gearbox
Permanent magnet generator



12500 January 2013



