Offshore wind potential in Europe and review of offshore resource modelling techniques

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Objectives and approach

Part of the EU Concerted Action for Offshore Wind Energy in Europe

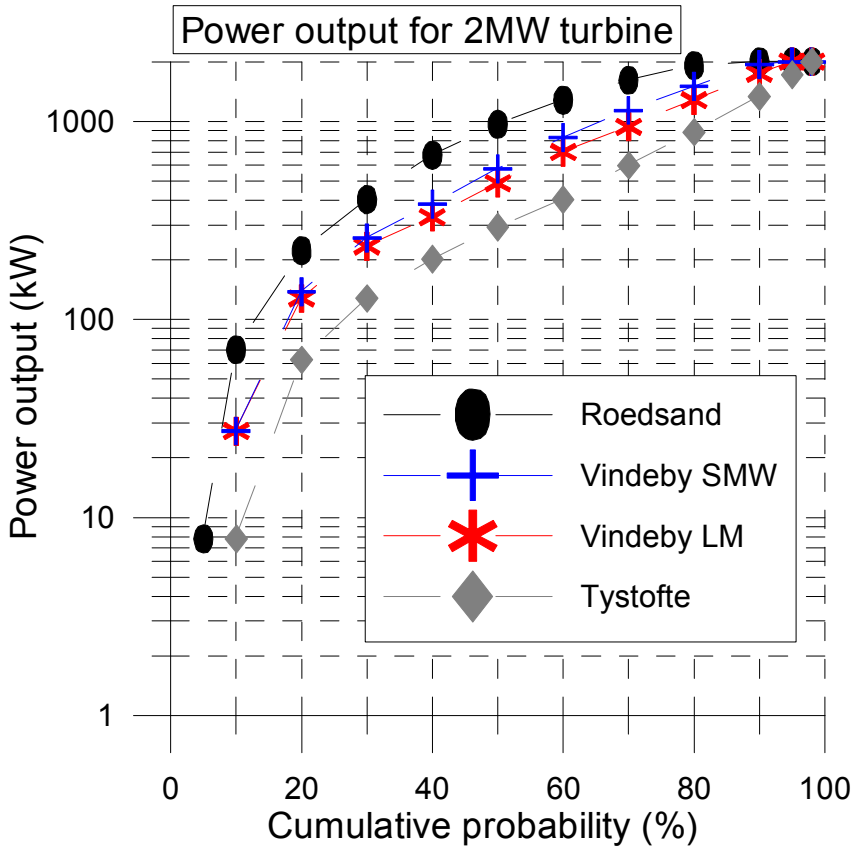
- Review of offshore measurements
- Review of offshore modelling
- Country by country survey of resources
- Estimates regarding the offshore wind potential in Europe

- The full report is available on-line:

http://www.offshorewindenergy.org/

What do you gain offshore?

- E.g. Data from 1996-2001
- Danish sites:
  - Inland =Tystofte
  - Coastal = Vindeby LM & SMW
  - Offshore=Rødsand
- For 2 MW turbine > 50% probability of 1 MW power output offshore cf. <20% on land



Offshore measurements - existing

Data sources:

- Ship data
  - Voluntary observers force
  - National Weather Ships (few remaining)
- Buoys
  - Mainly US
  - Observations 3-8 m
- Platforms and barges
  - Tend to be short term
  - Data are difficult to access
- Coastal sites
  - Not offshore!

General issues:

- Data quality
- Data recovery rates
- Temporal resolution
- Site representativeness
- ~ 3-20m from surface (i.e. not hub-height)
- Available now (but maybe expensive to purchase)
- Not always accessible
- Some long time series

Offshore measurements - on-site

Purpose built masts:

- Good quality and site representative
- High cost to install and maintain
- Usually short time series
- Time investment for planning/installation and data recovery - delay to project?
- Not always measurements to hub-height
- Often required for project financing

Offshore site resource modelling

1) Statistical - requires on-site measurements

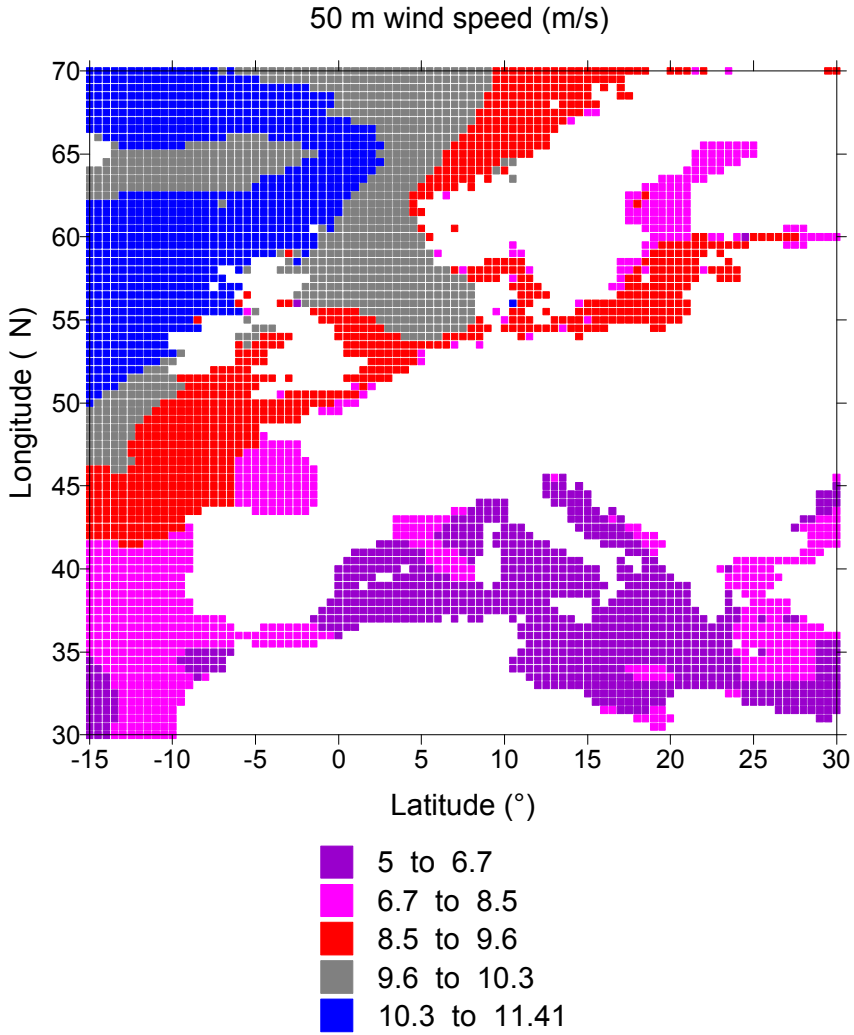
2) Physical - can be run climatologically i.e. without on-site data

- Linear e.g. WAsP
  - Straightforward to apply
  - Low data requirement
  - Typically give good results for offshore sites
- Mesoscale models
  - More comprehensive & better adapted to coastal areas
  - Include thermal effects e.g. sea breeze
  - Difficult/expensive to run
  - High data requirement

Resource modelling

E.g. POWER project

- Based on sea level pressure data i.e. independent of near-surface data
- Data sets from 1985-97
- WAsP runs at 0.5 x 0.5 ° grid
- Good agreement with observations in Northern Europe
- Less accurate in Mediterranean - impact of thermal flows and surface decoupling



Resource assessment by country

- Combination of national and European assessments
- The technical potential is usually very large
- Different physical, environmental & social constraints used giving very different estimates country by country
- Estimates from DEA/CADDET were used if not supplied by the individual countries
- Resource supplied converted if necessary assuming 1000 MW ~ 3.3 TWh/y

Resources by country

	Resource estimate		Target installation	
	MW	TWh/y	MW	YEAR
BE	1200	4	200	2004
DK	8000	26	4000	2030
FI	6000	20		
FR	13000	44		
D	13000	45		
GR	1500	5		
EI	3300	11		
I	3000	10	1000	2030
NL	10000	33	1250	2020
PL	600	2-3		
PT	600	2		
ES	2000	7		
SE	7000	22.5	650	2005
UK	70000	80-334	2600	2010

Plans by country

BE Target 3% electricity from renewables. Offshore wind energy is not yet eligible for green certificates (under discussion).

DK Government target set and plans for large scale developments in five areas mandated.

FI Plans to develop one wind farm

FR Several plans discussed.

D Target 5-6% electricity from renewables by 2010 and 50% by 2050. In spring 2001 a number of sites were announced.

GR None publicly available

EI Measurements underway.

I Discussion of 1000 MW target installation. Local feasibility studies.

NL Targets set of about 1250 MW for offshore wind. Wind farms developed in Ijsselmeer. Demonstration wind farm 100MW planned

PL Two wind farms of ~100 MW have consent near Bialogóra and near Karwia

PT None publicly available

ES Some monitoring studies.

SE No target set but construction of wind farms undertaken by private developers.

UK Targets set. One site developed. In April 2001 preliminary licences for 18 offshore sites were awarded.

European resources & plans

- Summing national resources gives a lower estimate of 460 Twh/y which is greater than the BTM Consult estimate of 327 TWh/y
- Largest estimates are around 3000 TWh/y
- Differences are due to the physical/environmental & social constraints applied
- Current electricity demand is ~320 TWh/y
- Overall resource of 140 GW is much larger than the EU White paper target of 10 GW in 2010
- Currently installed offshore ~ 80 MW
- Specific site plans to 2010 ~ 1800 MW

Overview

On site data	Necessary because of project financing
	Resource has to be quantified with high degree of confidence
Available data	Typically useful for broad assessment (Ships, satellites etc)
Models	Useful tools, under development, still uncertainties
Physical limits	Maritime data (sea depth etc) - available for most countries
	Typically > 5 km from shore
	Water depth limit 20-30 m?
	North Sea: Large tidal range, water depth
	Baltic Sea: Ice and ice floes
	Mediterranean: Sea bed slope, water depth
Planned activity	Highly variable by country
	Targets set, plans in place: DK
	Targets set, feasibility studies: UK, NL, I
	No target set, monitoring underway ES, FI, EI
	No target set, wind farms underway SE, FR
	Preliminary consents given: PL
	No plans publicly available: GR, PT
Comparison with national consumption	Not a major issue
	Varies from 2-40%
	Grid compatibility and penetration is more of a problem

Uncertainties

- Resource estimation - complex in coastal areas
  - Thermal flows (jets,sea-breeze)
  - Local stability effects (vertical profiles, internal boundary layers)
- Vertical profiles
  - Not currently measured to hub-heights
  - Internal boundary layer effects
- Extremes and combined wind/wave loading
- Wake losses
  - Larger wind farms
  - Less knowledge of wake propagation offshore
  - Effects of stability may be important at low turbulence
- Farm losses
  - If large clusters are located within 50 km of each other

Future trends/requirements

- Measurements
  - Vertical profiles to hub-height
  - Offshore wakes
  - Use of 'new' techniques such as SODAR
- Modelling
  - Improved wake & wind farm models
  - Improved boundary-layer models
  - Linked models
  - Use of mesoscale models

Summary

- Offshore is complicated!
- Both measurements and modelling have a role
- Specific site resource estimation still requires on-site measurements
- Constraints are not applied uniformly: difficult to make a European comparison
- The offshore resource is uncertain but probably at least as large as current EU electricity consumption ~ 320 TWh/y
- Overall estimate of 140 GW is much larger than the EU White paper target of 10 GW in 2010

Acknowledgement & Sources

- Acknowledgement: EC funding through CA-OWEE

- Main sources:
  - Danish Wind Industry Association web site www.windpower.org.
  - OPTI-OWECS/ Kuhn (2001)
  - BWEA
  - DEA/CADDET
  - Greenpeace
  - Prospects for offshore wind energy (Altener report)