Concerted Action on Offshore Wind Energy in Europe

State of the art - offshore wind turbine technology

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Funded by the European Commission

CA-OWEE

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CA-OWEE Project

17 European Partners from 13 Countries:

Principal partners:

- ***Delft University of Technology, NL (co-ordinator)***
- ***Garrad Hassan & Partners, United Kingdom ****
- ***Kvaerner Oil & Gas, United Kingdom ****
- ***Energi & Miljoe Undersoegelser (EMU), Denmark***
- ***Risø National Laboratory, Denmark***
- ***Tractebel Energy Engineering, Belgium***

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17 European Partners from 13 Countries:

Other Contributors:

- ***Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), Spain***
- ***Centre for Renewable Energy Sources (CRES), Greece***
- ***Deutsches Windenergie-Institut (DEWI), Germany***
- ***Germanischer Lloyd Windenergie, Germany **
- ***Netherlands Energy Research Foundation (ECN), The Netherlands***
- ***Espace Eolien Developpement (EED), France***
- ***Ente per le Nuove Tecnologie, l'Energia e l'Ambiente (ENEA), Italy **
- ***University College Cork, Ireland***
- ***Vindkompaniet i Hemse AB, Sweden **
- ***Technical Research Centre of Finland (VTT), Finland **
- ***Baltic Energy Conservation Agency (BAPE), Poland***

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Objective:

"to define the maturity of the technology currently available for offshore wind farms"

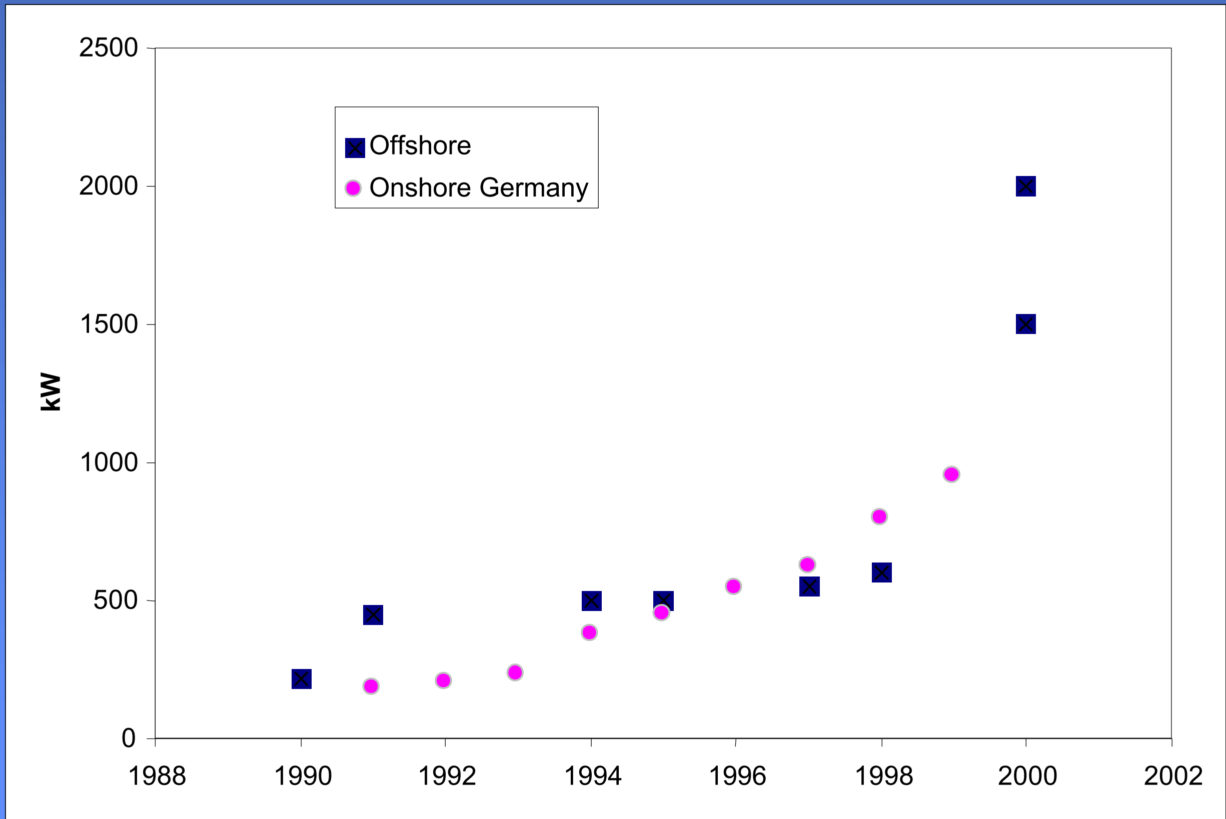
Scope:

- *Offshore wind turbine size and configuration*
- *Support structure*
- *Installation, decommissioning and dismantling*
- *Operation and maintenance, reliability*
- *Electrical transmission and grid connection*

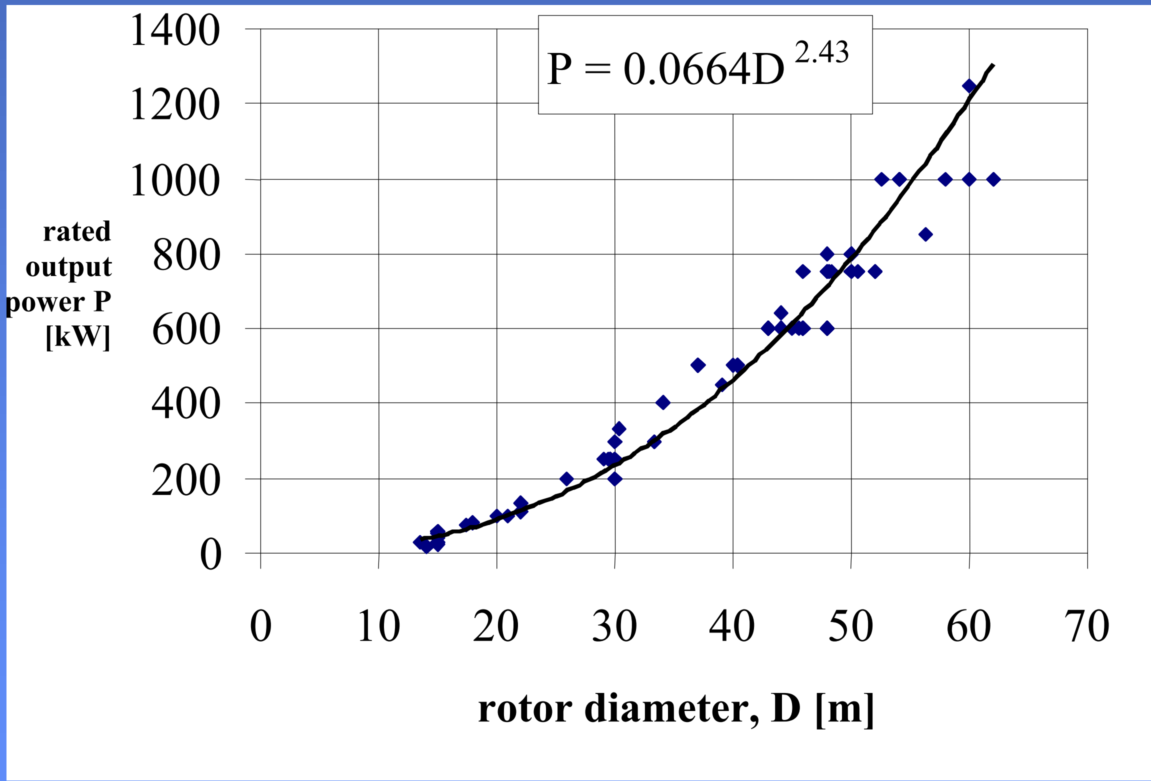
Wind turbine size and configuration

1. Scaling trends
2. Control
3. Rotor blades
4. Gearboxes

Growth of the technology



Power rating trend
- up to 62m rotor diameter



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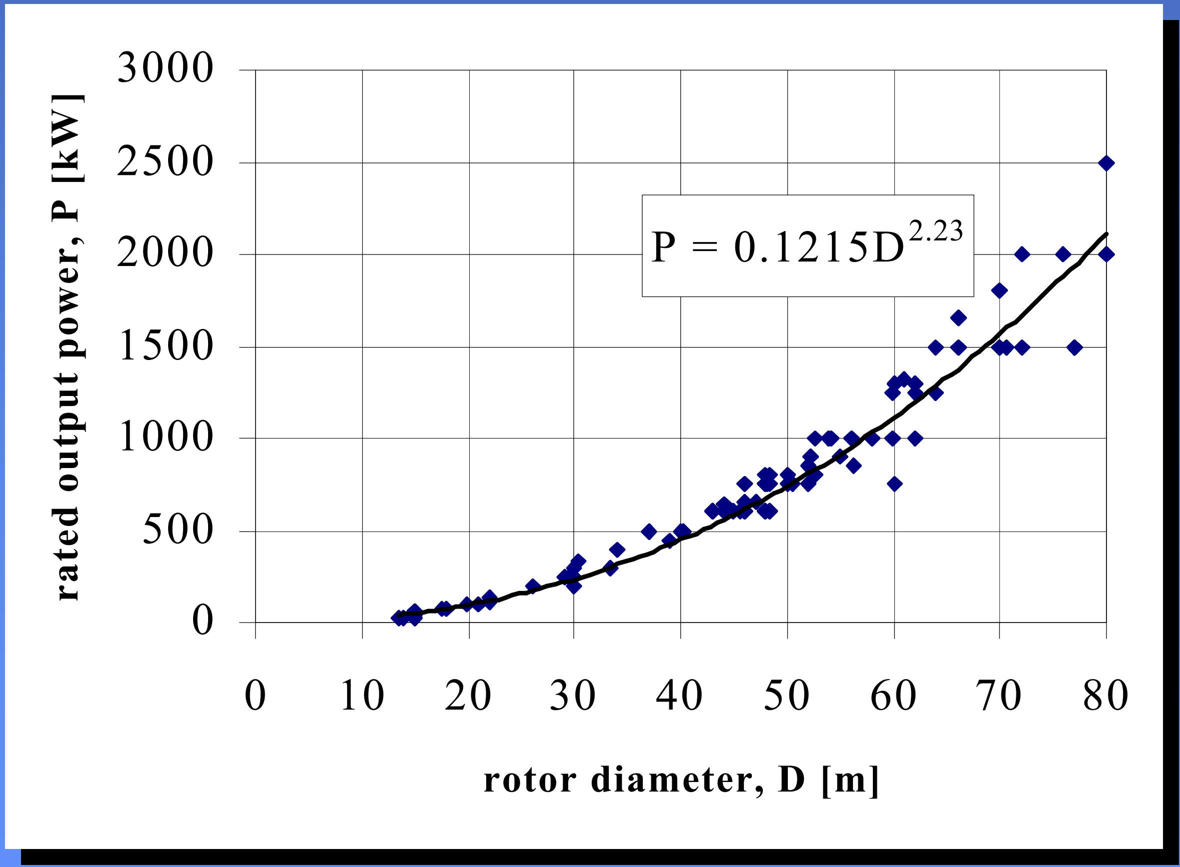
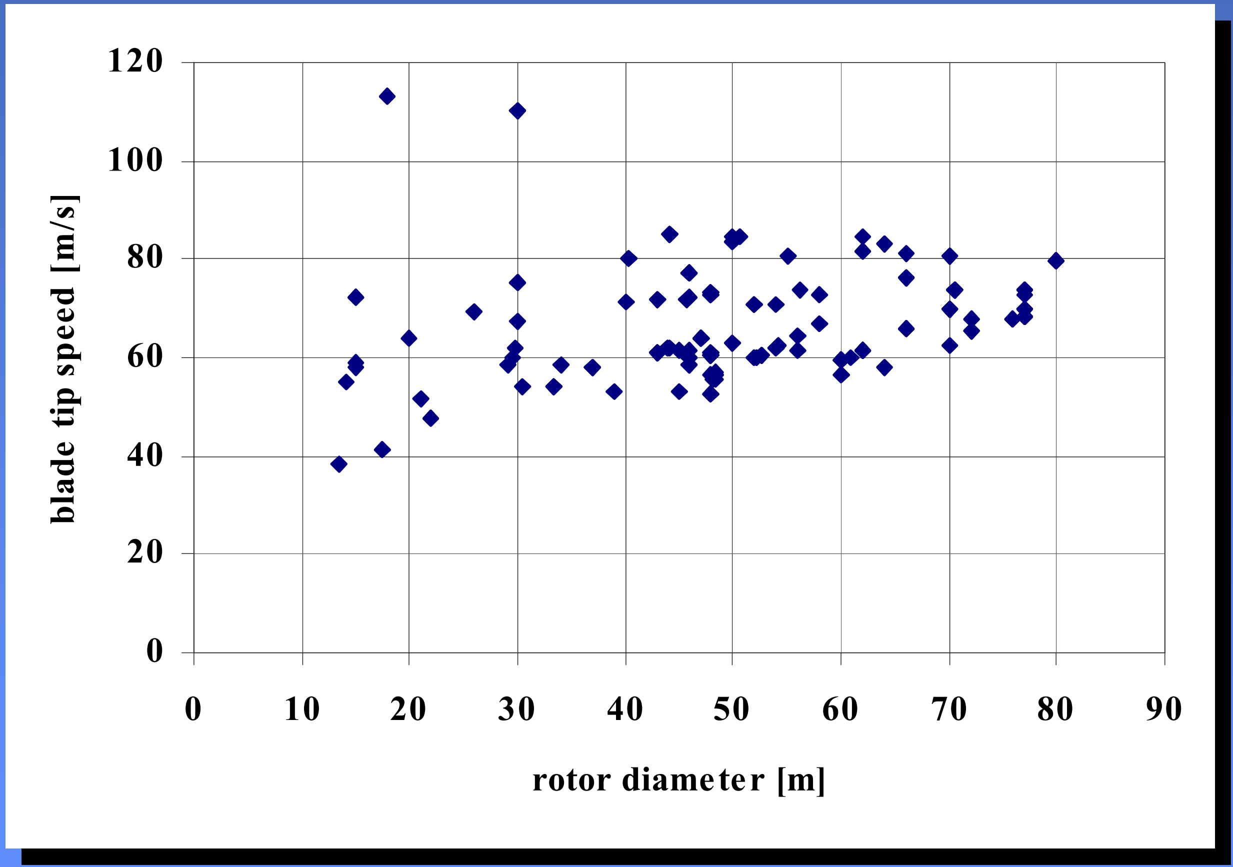
….. with larger machines



Design blade tip speed



Increasing tip speed

Design	Power [kW]	Control concept	Tip speed [m/s]	Ratio (offshore/land)
Vestas V66 (land)	1650	Pitch reg., variable slip	66	1.21
Vestas V80 (offshore)	2000	Pitch reg., variable speed	80	
Nordex N60	1300	Stall reg., fixed speed	60	1.33
Nordex N80 (offshore)	2000	Pitch reg., variable speed	80	
Bonus 1300 (land)	1300	Active stall, fixed speed	62	1.10
Bonus 2000 (offshore)	2000	Active stall, fixed speed	68	
NEG Micon 1000/60 (land)	1000	Stall reg., fixed speed	57	1.19
NEG Micon 2000/72 (offshore)	2000	Active stall, fixed speed	68	

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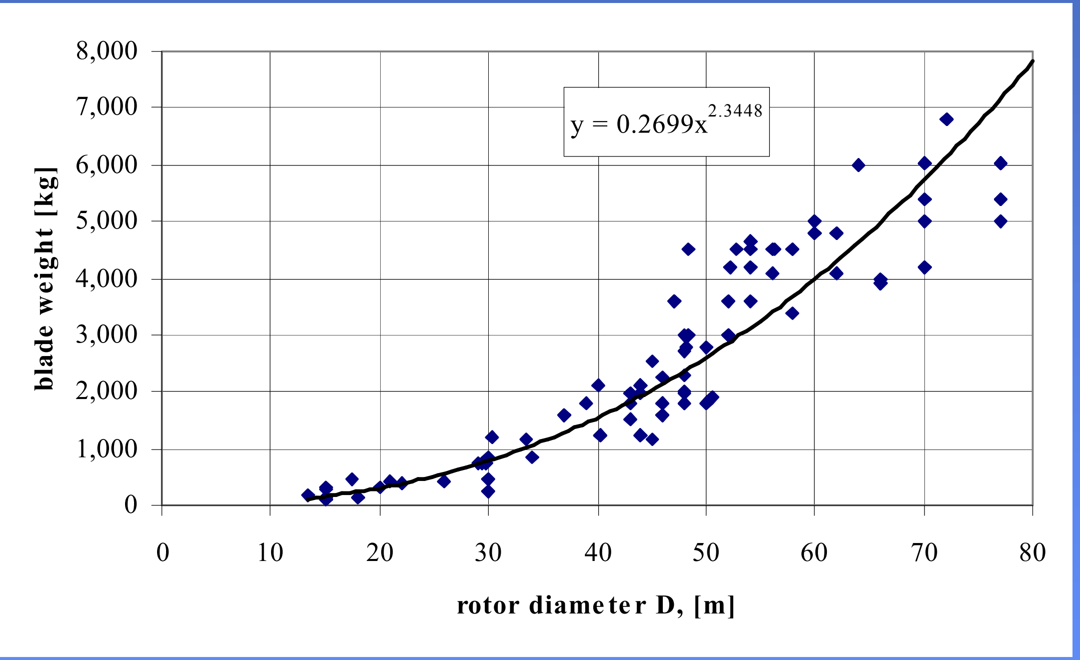
Control system trends

- **Pitch control**
  - Only around half of models historically
  - Predominant in turbines over 70m diameter
- **Variable speed**
  - Less than 10% of models historically are fixed speed
  - Dual-speed; high slip; moderate range variable speed; direct drive systems
  - Some form of variable speed predominant in large machines

Blade technology



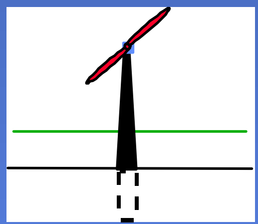
Gearboxes

- **Rotor speed approx. 20rpm; generator speed approx. 1500rpm**
- **Historically, 3 stage - 1 planetary, 2 parallel**
- **Larger machines likely to require 4th stage (>3MW onshore, larger offshore due to higher rotor speed)**
    - Marked increase in complexity, or,
    - Increased generator speed, or,
    - Direct drive approach

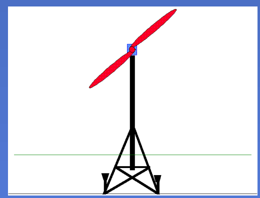
Future trends

- Higher tip speeds
  - Lower torque, less mass and cost of tower top
- Increased carbon fibre usage
  - Higher specific strength if solidity is to be maintained
- Direct drive
  - Less mechanical complexity
- Increasingly integrated design
  - Support structure
  - Grid connection (e.g. HVDC generator)
  - Design for installation & maintenance

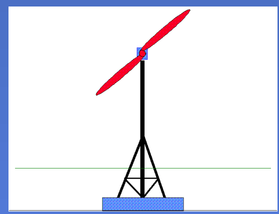
Support structures



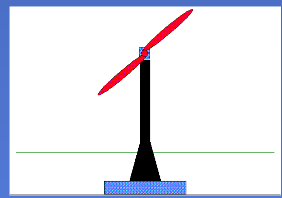
Monopile



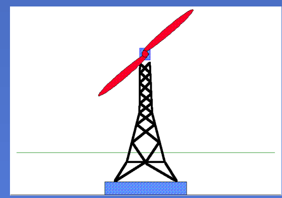
Piled-Braced Monotower



GBS-Braced Monotower



GBS Monotower



GBS-Lattice Tower

Monopile expected to be most common option for future offshore wind projects (but probably least stiff)

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Monopile design

- **_Well-established codes and practices (oil and gas)_**
- **_Structures typically supported by 3 or 4 legs_**
  - _Single pile through each leg_
  - _"Skirt" piles around each leg_
- **_But, unlike an offshore platform,_**
  - _Turbines exert much higher live loads (shear and bending)_
  - _Cyclic loading of near-surface soils more important_
  - _Potential for loss of soil contact near surface (post-holing)_
  - _Much higher volume jobs (i.e. not one-offs)_
- **_Nearshore works practice (jetties, etc.) important reference_**

Monopile installation

Four options:

- Above-surface hammering
- Underwater hammering
- Drill-drive
- Drill and grout

Trade-off:

- Installation speed
- Required pile capacity
- Geotechnical knowledge
- Risk of damage to pile
- Required placement accuracy

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