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Offshore wind energy in Europe: Experiences and challenges

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Offshore wind energy in Europe: Experiences and challenges

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Presentation 30 July 2014 at

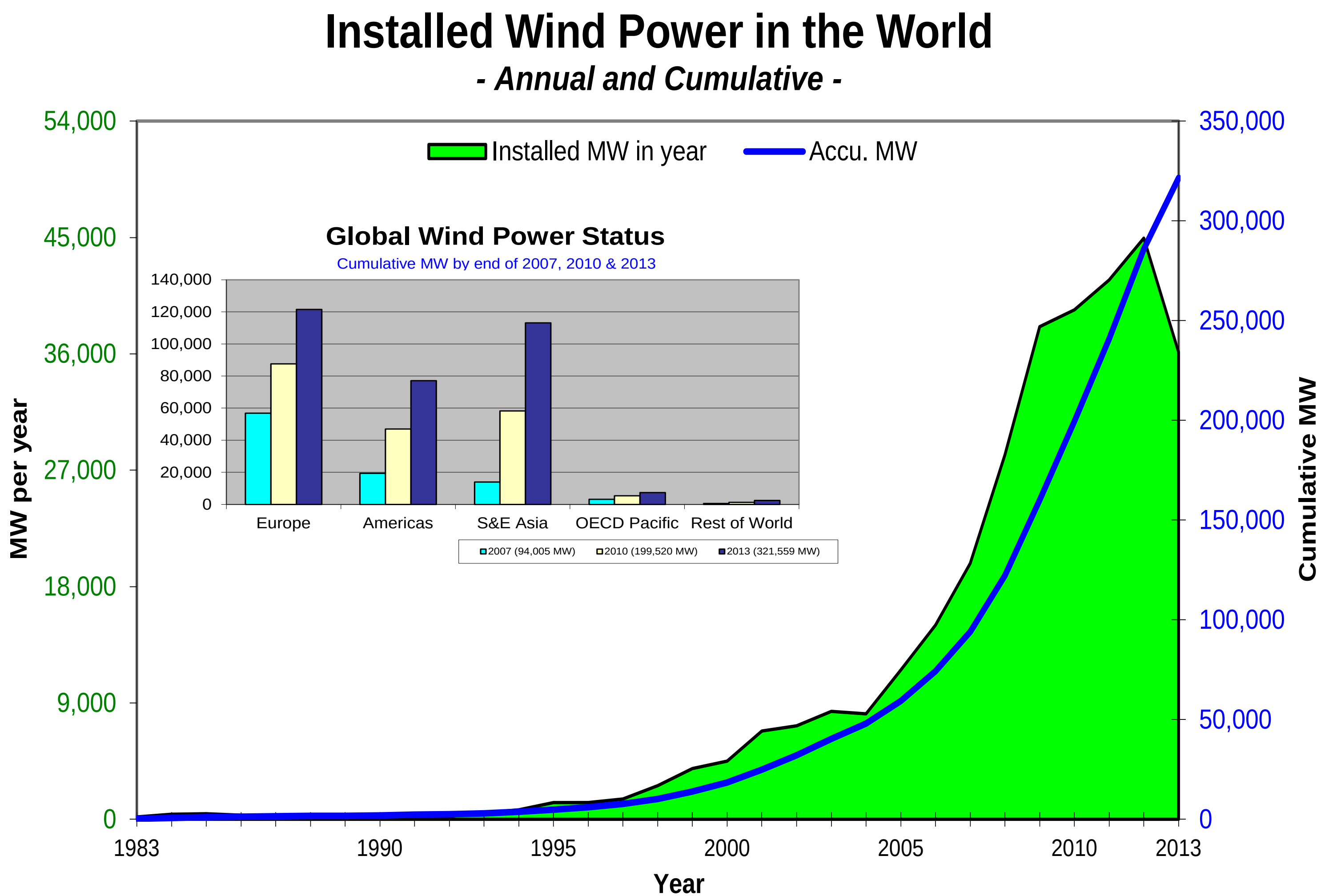
Grand RE2014 International Conference

July 27th – August 1st 2014

Outline

- Global and European development of wind energy
- Offshore wind energy in Europe
- The cost challenge
- International cooperation
- Research
- Technology development
- Validation and testing
- Standards and certification
- Concluding remarks

Global development of wind energy



Source: BTM Consult - A Part of Navigant - March 2014

Penetration Rate of Wind Power in Select Countries

Region	Country	Cumulative installation - end 2013 (MW)	Penetration rate %
Europe	Denmark	4747	33.20
	Portugal	4557	27.00
	Spain	22637	20.90
	Germany	34468	11.70
	The UK	10946	7.70
	Sweden	4474	7.00
	The Netherlands	2714	4.77
	Italy	8448	4.70
	France	8128	3.10
North America	The US	61292	4.13
	Canada	7813	3.00
Asia-Pacific	China	91460	2.60
	Australia	3489	2.40
	New Zealand	603	5.00

Source: BTM Consult - A Part of Navigant - March 2014

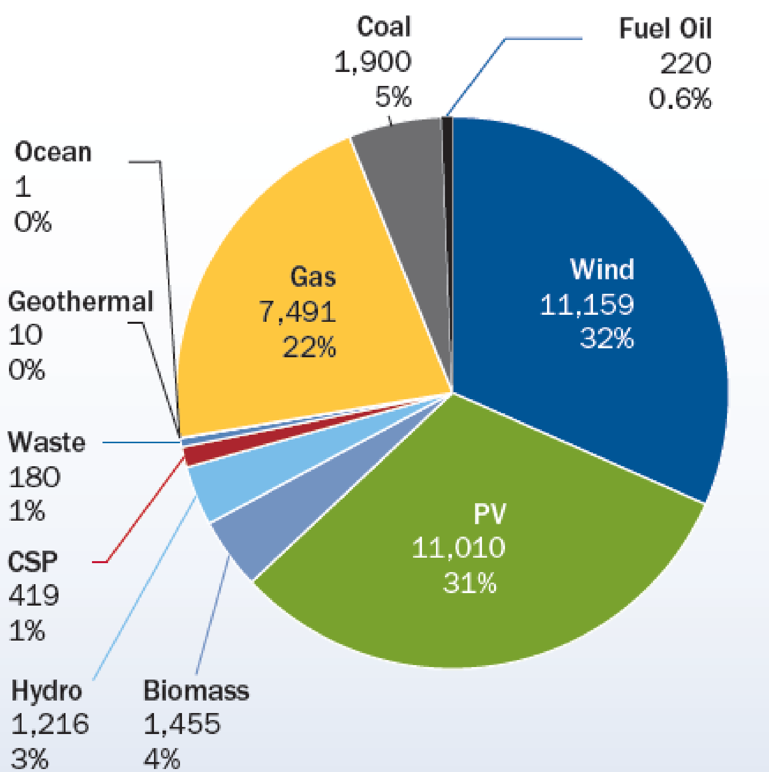
Penetration 2013:

Global 2,9 %

Europe 8%

Status 2013 in Europe

FIGURE 1.2: SHARE OF NEW POWER CAPACITY INSTALLATIONS IN EU, TOTAL 35,181 MW



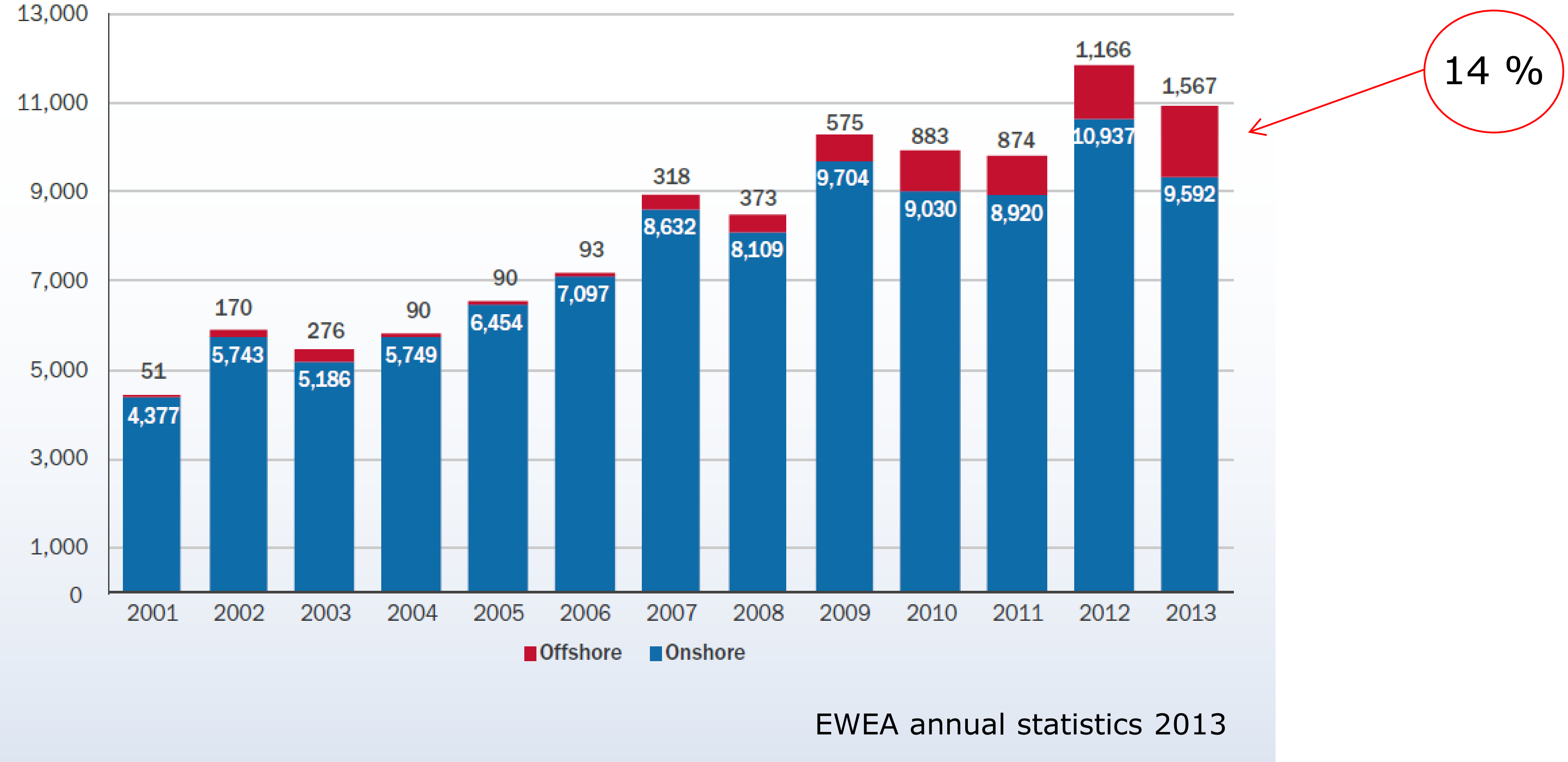
EWEA annual statistics 2013

11,159 MW of wind power capacity (worth between €13 bn and €18 bn) was installed in the EU-28 during 2013, a decrease of 8% compared to 2012.

The EU power sector continues its move away from fuel oil and coal continuing to decommission more than it installs.

The wind power capacity installed by the end of 2013 would, in a normal wind year, produce 257 TWh of electricity, enough to cover 8% of the EU's electricity consumption - up from 7% 2013.

Annual onshore and offshore installations in Europe (MW)

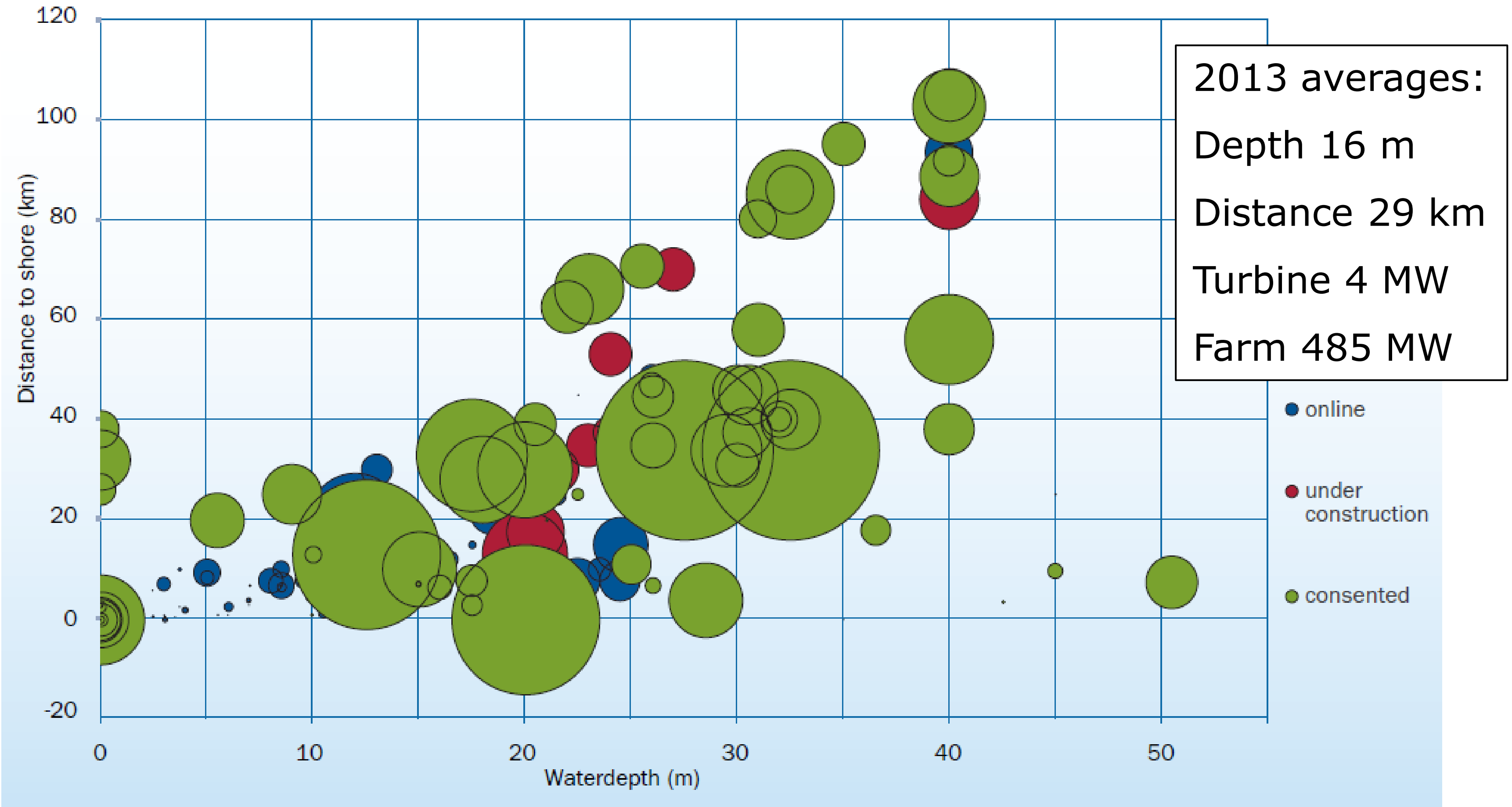


117.3 GW of installed wind energy capacity in the EU:
110.7 GW onshore and 6.6 GW offshore.

Cumulative offshore capacity end of 2013

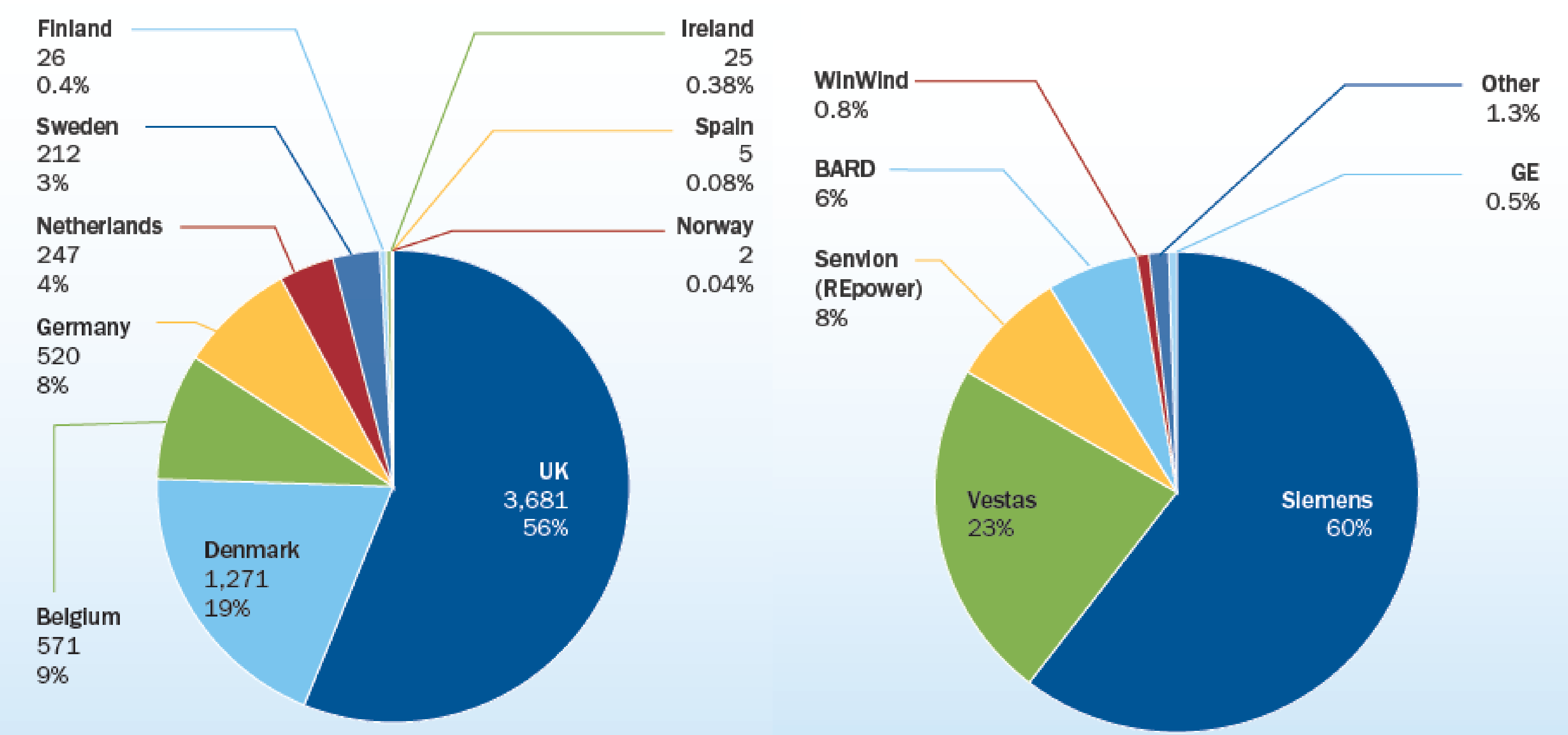
- 2,080 turbines are now installed and grid connected, making a cumulative total of 6,562 MW, in 69 wind farms in eleven European countries.
- This new total of 6,562 MW of offshore wind power is enough to provide 0.7% of the EU's electricity.
- 75% of substructures are monopiles, 12% gravity, jackets 5%, tripods 5%, and tripiles 2%.
- There are also two full-scale grid-connected floating turbines, and two down-scaled prototypes.
- 418 offshore turbines came online in 2013 in Europe, making a record 1,567 Megawatts (MW) of new capacity.

Water depth and distance to shore



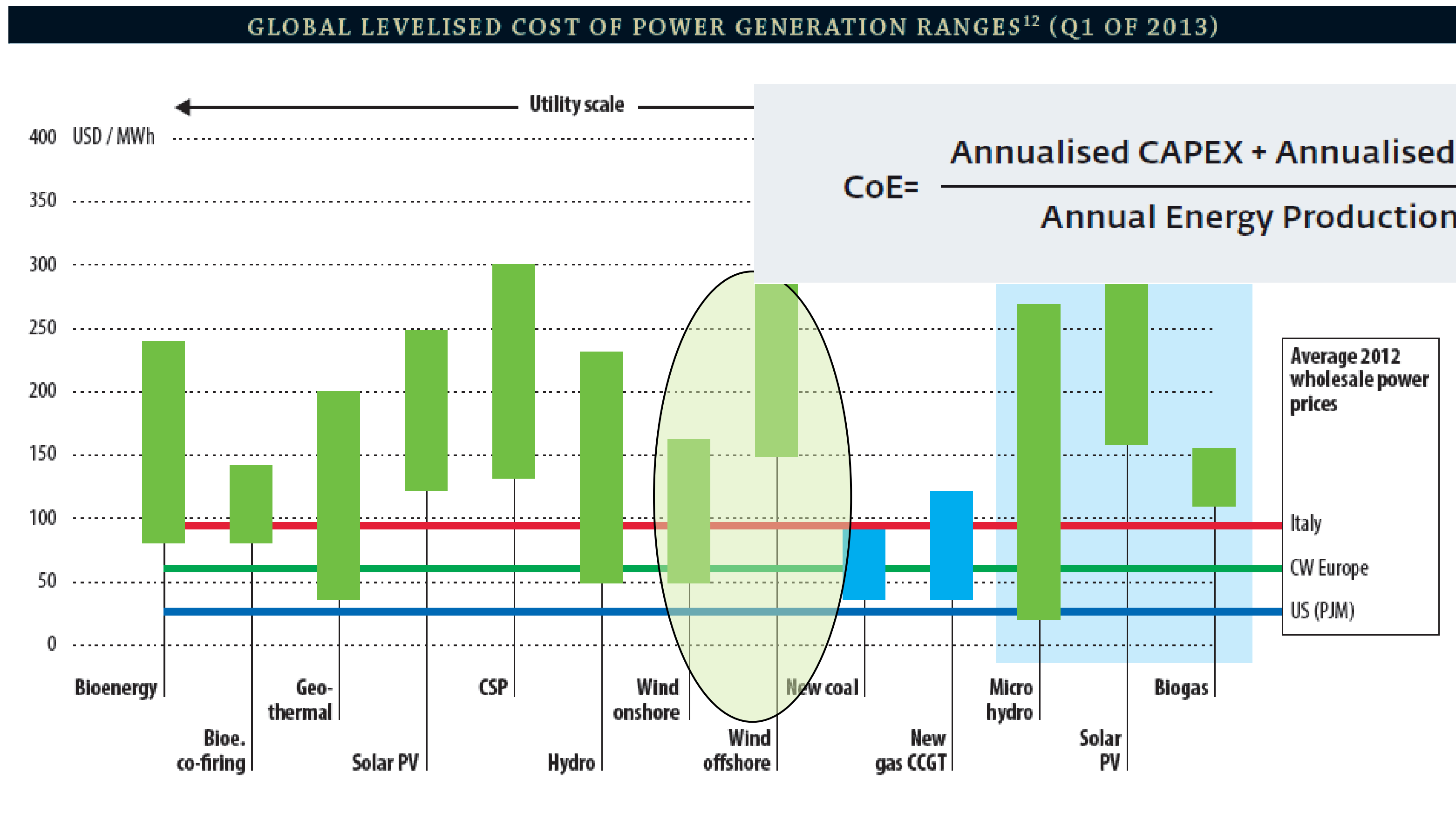
EWEA offshore statistics 2013

Cumulative installed capacity (MW), by country and manufacturer, 2013



EWEA offshore statistics 2013

The Cost Challenge



$$\text{CoE} = \frac{\text{Annualised CAPEX} + \text{Annualised OPEX}}{\text{Annual Energy Production}}$$

Notes: costs are indicative and ranges reflect differences in resources, local conditions and the choices of sub-technology.
CCGT = combined-cycle gas turbine.
Central-Western (CW) Europe = Austria, France, Germany, Switzerland. United States (US).
PJM = regional transmission organisation covering 13 states and the district of columbia (DC).

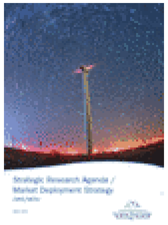
Source: IEA analysis with power price data from Bloomberg LP, 2013

How to meet the cost challenge

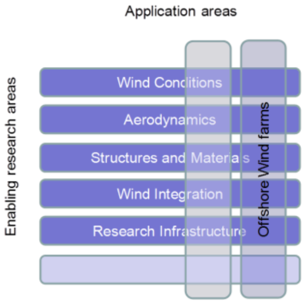
- International cooperation
- Research
- Technology development
- Validation and testing
- Standards and certification

R&D cooperation in Europe

- Technology Platform for Wind energy (TPWind)
  - SRA
  - EWI

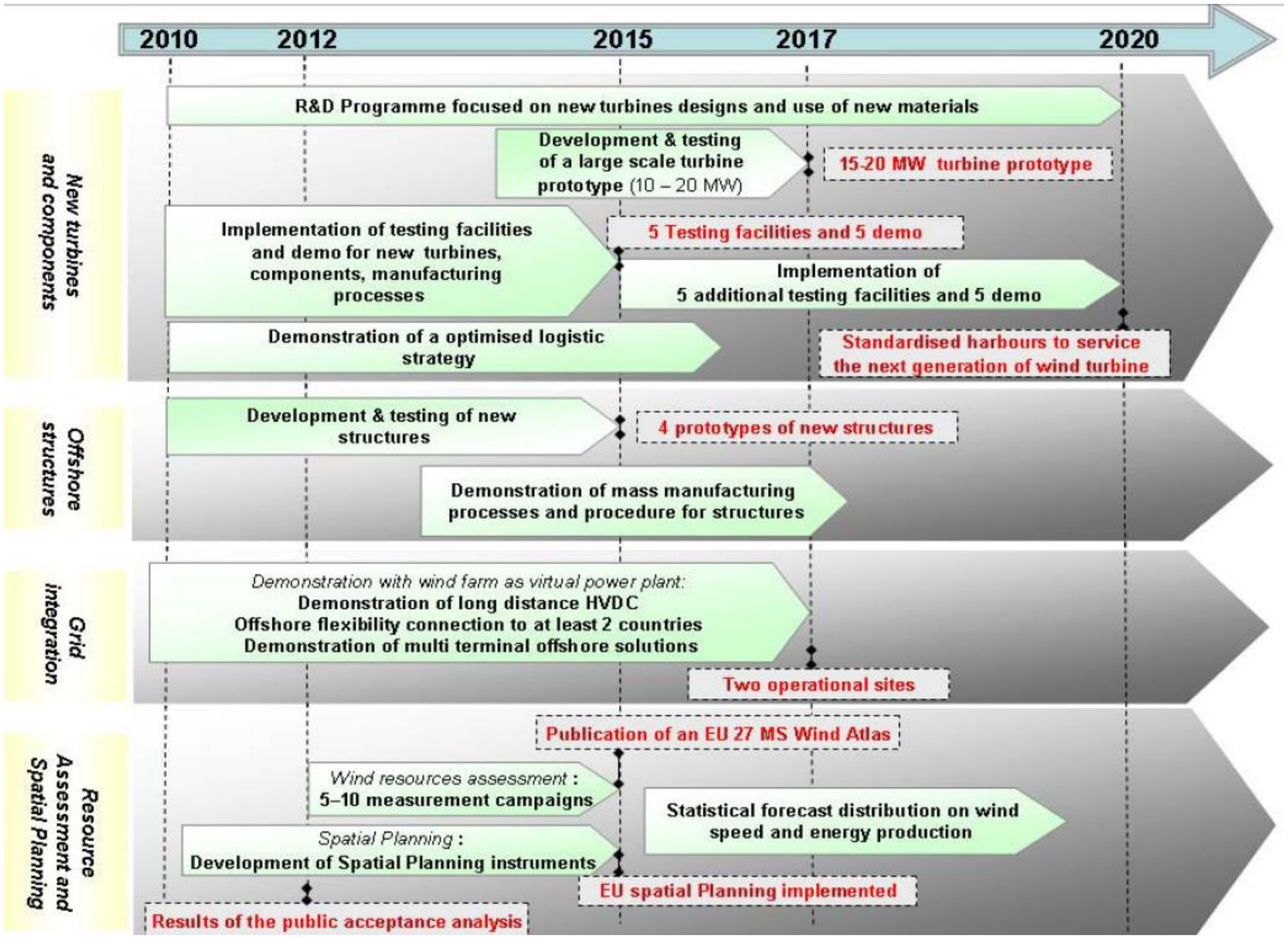


- European Energy Research Alliance (EERA)
  - Joint Programme for wind energy



- European Academy for Wind Energy (EAWE)
- European Wind Energy Master
- (IEA Wind R&D)
- ….

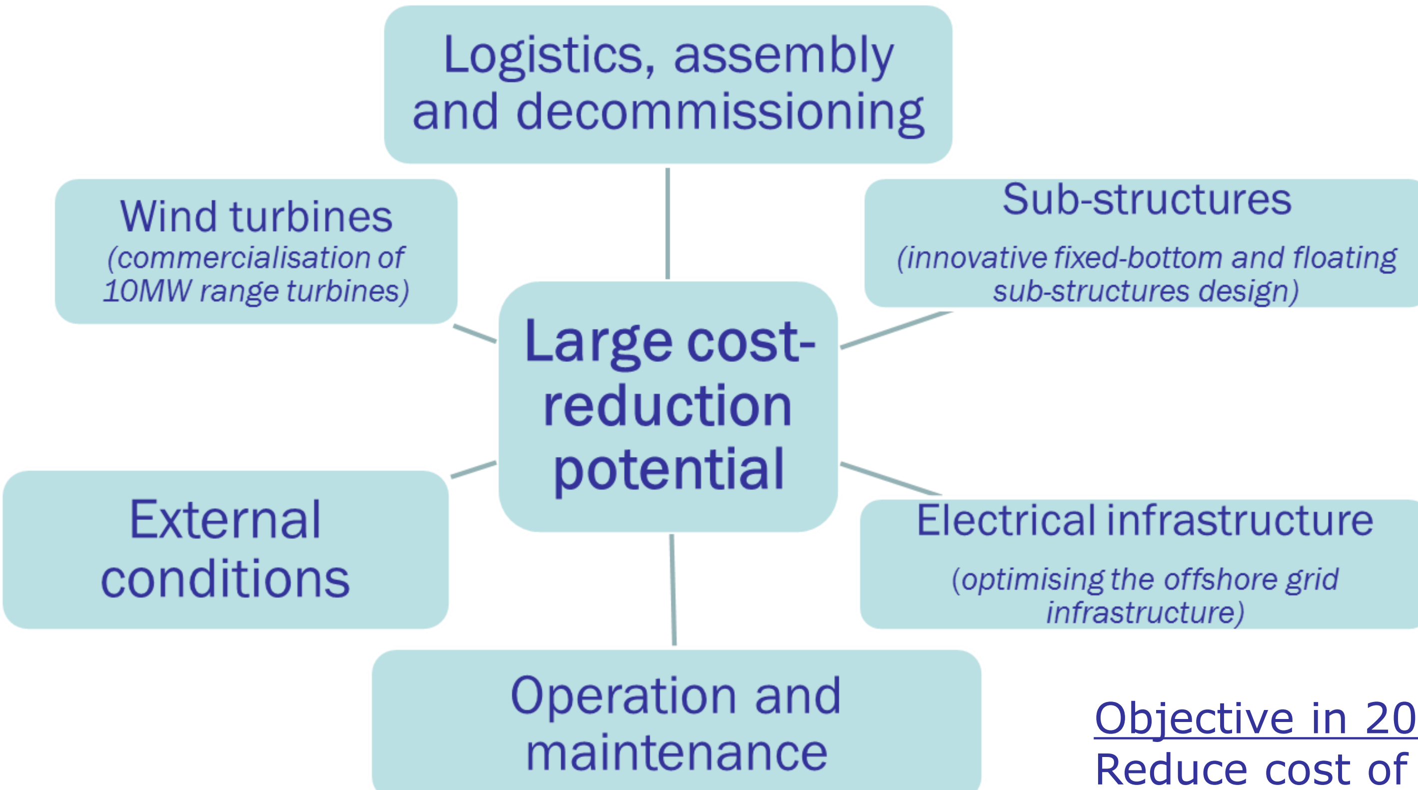
EC SET-plan – Technology Roadmap



Roadmap for the implementation of the SET Plan and the RES Directive:

- **Large scale integration** and
- **An accelerated offshore wind energy deployment**, including
- **Very large offshore wind turbines.**

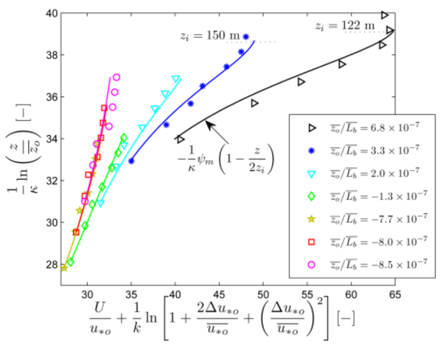
TPWind Strategic Research Agenda
Offshore Technology



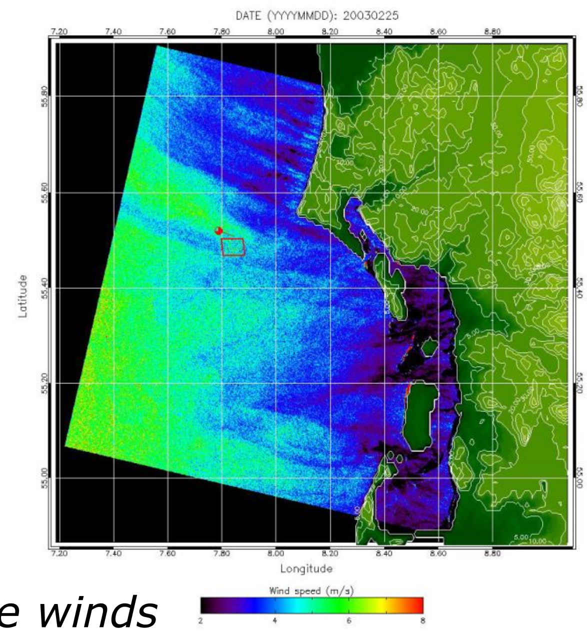
<u>Objective in 2014</u>:
Reduce cost of generating power from wind power plants in 2030 by:

- 20% onshore *and*
- 50% offshore

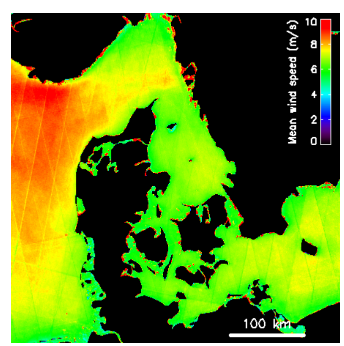
Offshore Wind Conditions



Lidar wind data and model from Horn's Reef offshore

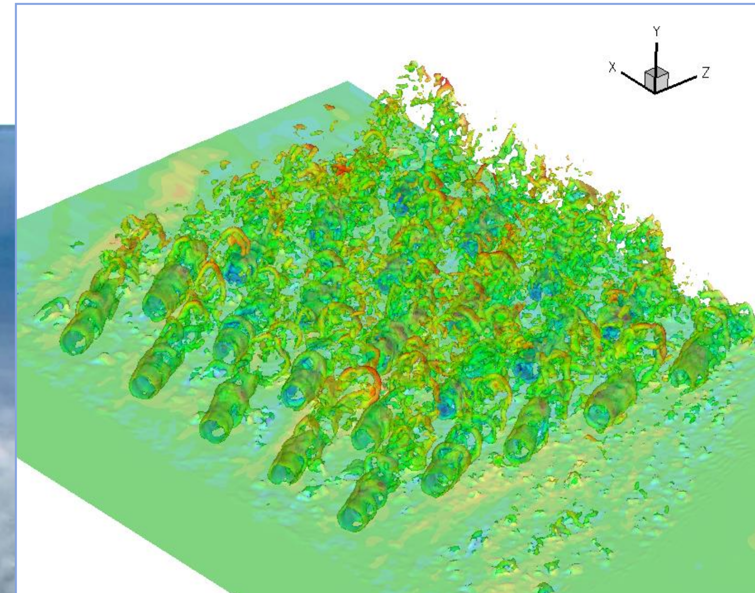


Satellite winds showing the wake at Horn Reef wind farm. Mean wind speed map using satellite Envisat ASAR.



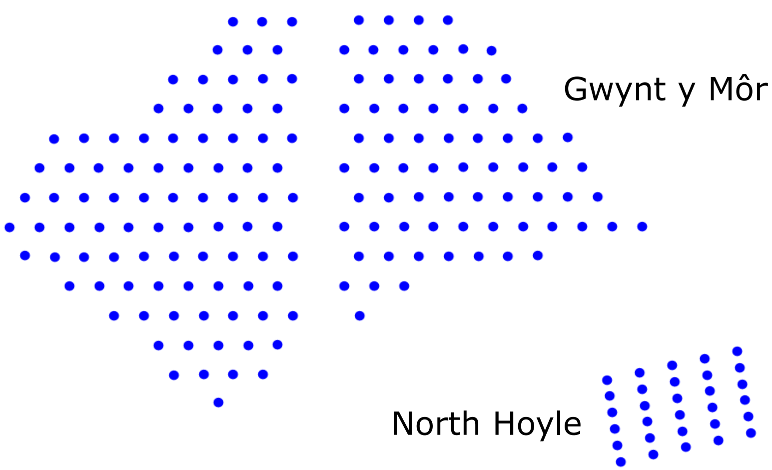
- Ocean winds
- Lidar observations and modelling
- Wind resource mapping using satellite data
- Mesoscale modelling
- Meteorological mast observations
- Wind farms shadow effect
- Satellite observations

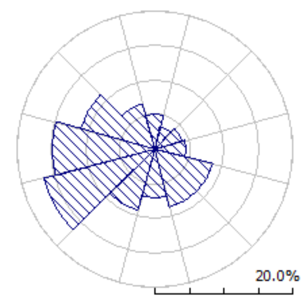
Wake effects – a complex flow essential for performance and loads

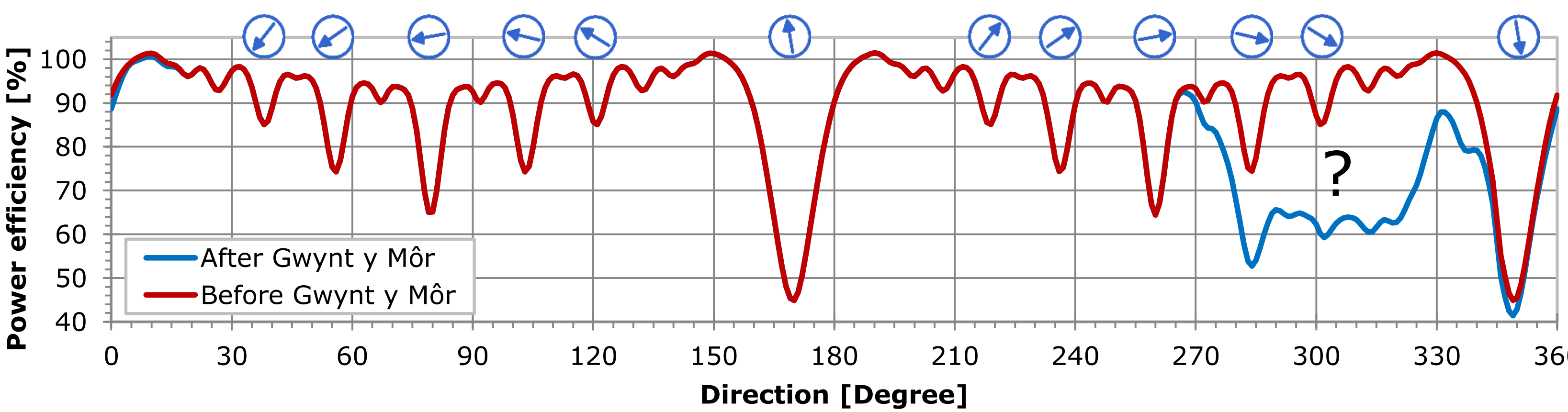


Vorticity shed from 5x5 turbines in a farm computed by actuator disk method

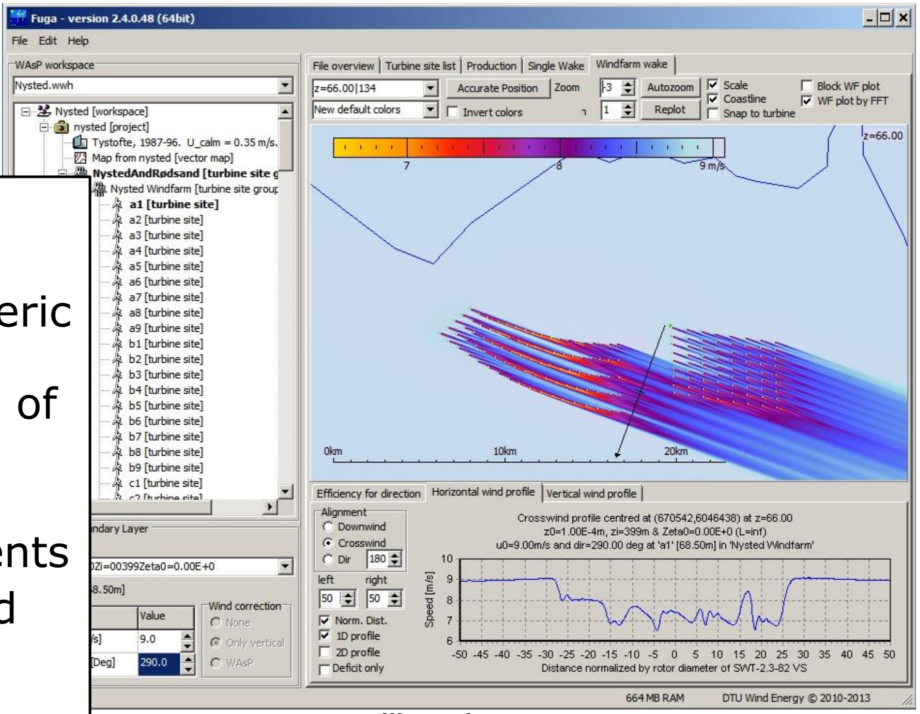
Wind farm efficiency of North Hoyle @ 10 ms^{-1}



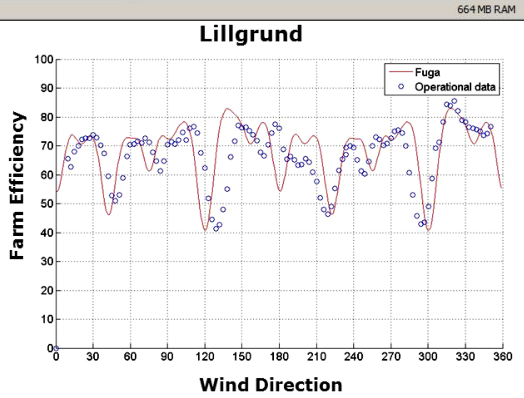




Fuga – a new wake model



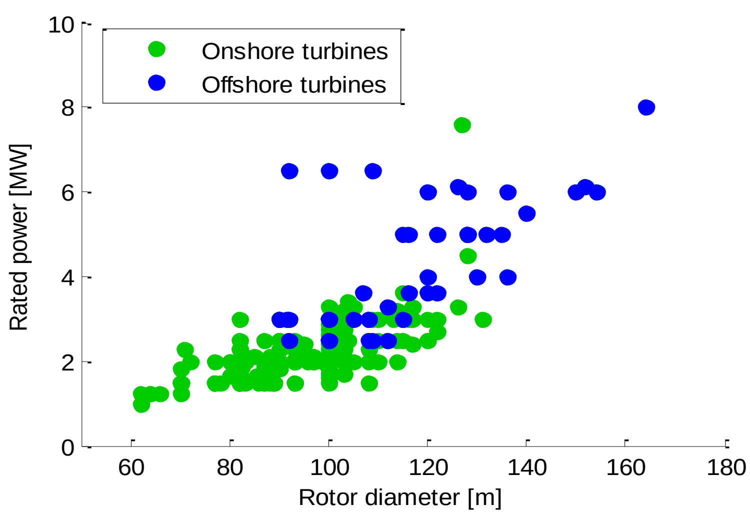
- Solves linearized RANS equations
- Latest version incorporates: atmospheric stability, meandering, effects of non-stationarity and spatial de-correlation of the flow field.
- No computational grid, no numerical diffusion, no spurious pressure gradients
- Integration with WAsP: import of wind climate and turbine data.
- Fast, mixed-spectral solver:
  - 10^6 times faster than conventional RANS!
  - 10^8 to 10^{10} times faster than LES!

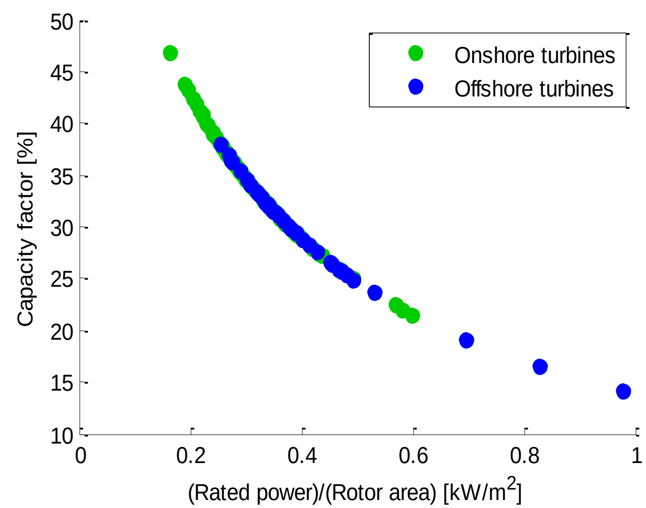


Upscaling – larger turbines, larger rotors

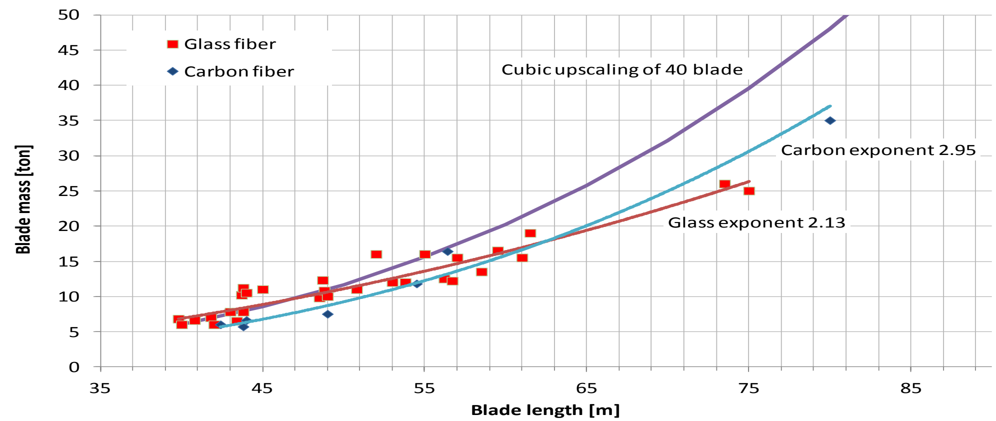
Year	2011	2012	2013
Total MW supplied	**40,495**	**43,134**	**37,478**
Product (Size range)	**% of total MW**		
"Small WTGs" <750 kW	0.6%	0.1%	0.1%
"One-MW " 750-1499 kW	6.6%	3.5%	2.8%
"Mainstream" 1500-2500 kW	85.7%	83.5%	79.6%
"Multi-MW Class" >2500 kW	7.2%	12.8%	17.5%
Total	**100.0%**	**100.0%**	**100.0%**

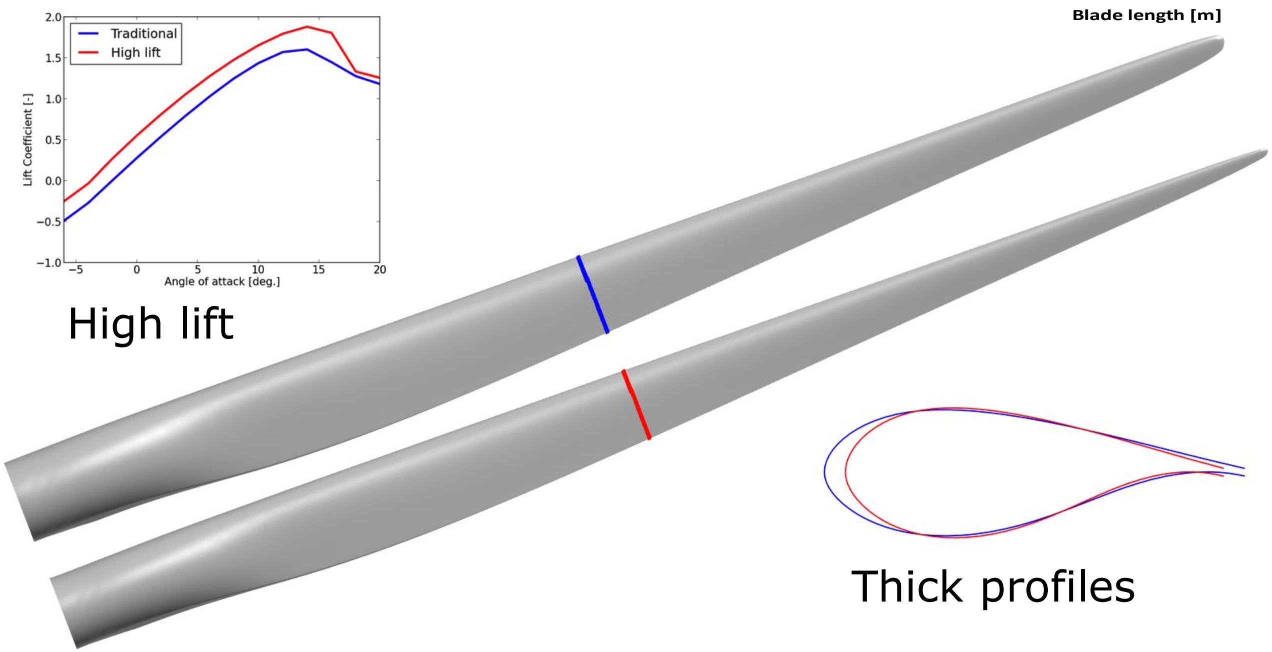
Source: BTM Consult - A Part of Navigant - March 2014





Larger rotors – slender blades to beat the cubic-law





High lift

Thick profiles

Advances in:

Aerodynamics

Stability

Dynamics

Structures

Materials

Validation

Grand RE2014 International Conference July 27th – August 1st 2014

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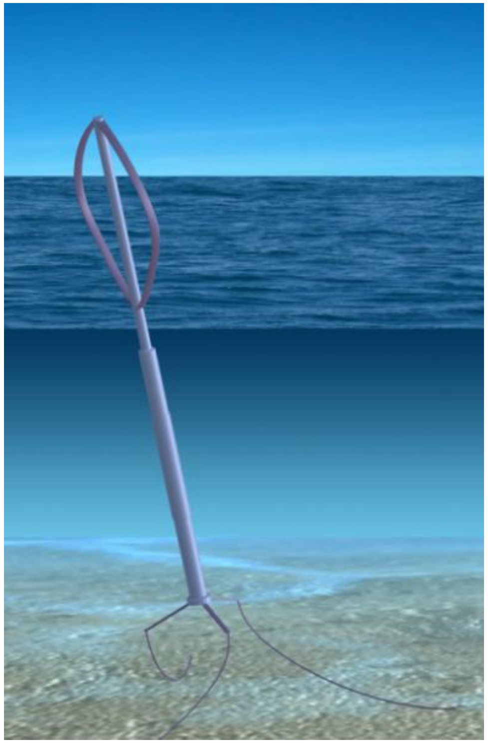
Offshore in deep water

Concept Hywind. Source: Norwegian Hydro and Solberg production

Combined wind and wave energy – Poseidon

DEEPWIND – a floating VAWT



VAWT Simulation suite finished

Achievement: Blade mass reduce significantly from about 800 kg/m to 230 kg/m

Pulltrusion process simulation

Generator + bearing design program

Control ready

Demonstrator tests finished

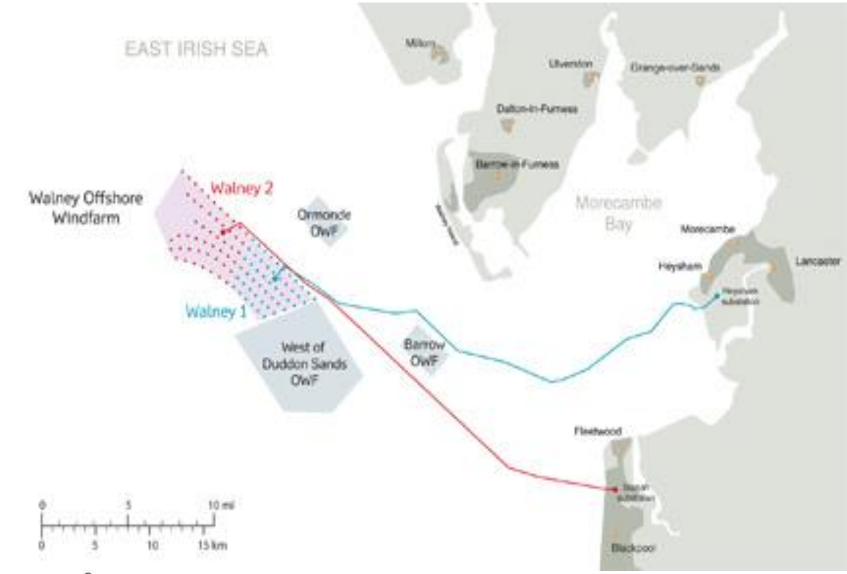
The Walney Offshore Wind (WOW) Project

Comprehensive loads validation on a state of the art 3.6MW wind turbine in cooperation with Siemens and DONG energy

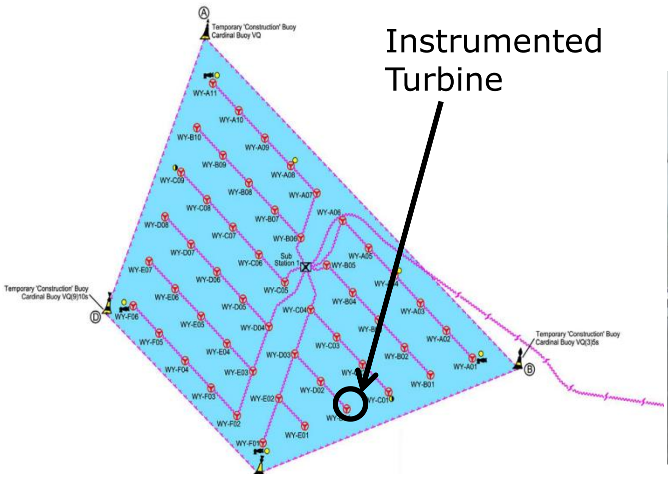
<u>Key Measurements</u>

- Nacelle mounted LIDAR for wind measurements
- Wave sonar and Buoy at turbine
- Accelerometers, strain gauges on
- Blade root, drive train, tower and foundation

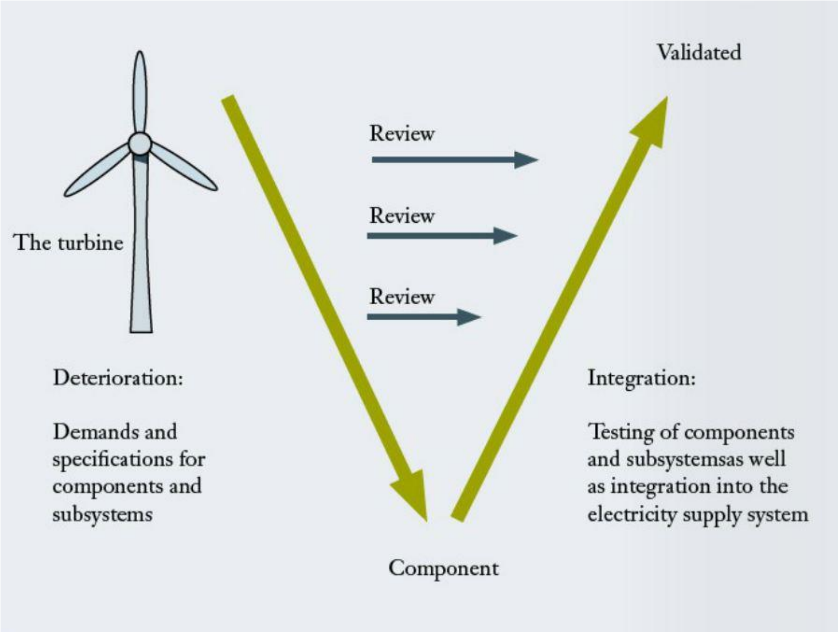
- <u>Scientific Objectives</u>
  - Validation of the dependencies of design loads
  - Prediction of turbine net damping
  - Advanced wind/wave correlati studies
  - Wake effects on loads

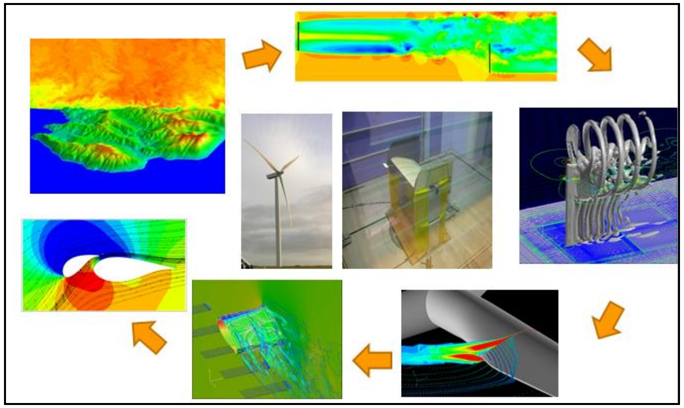


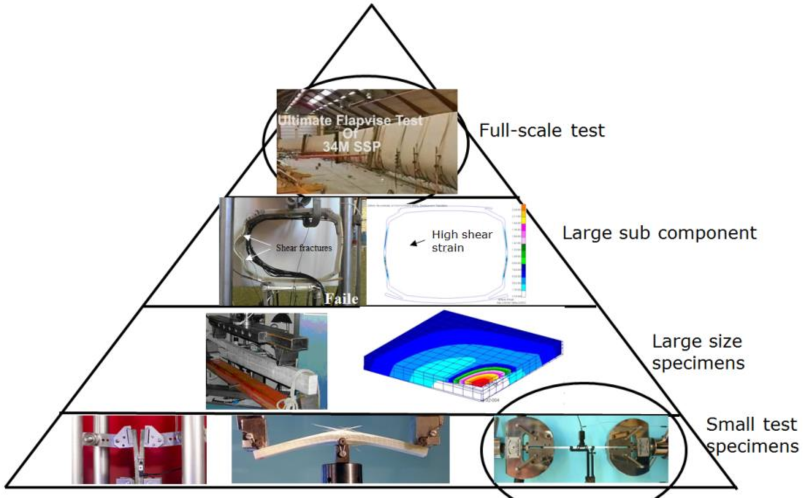
Instrumented Turbine



Validation – Products and research

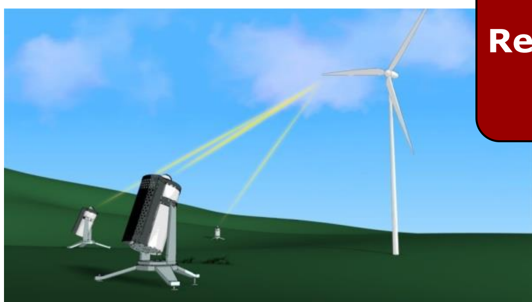


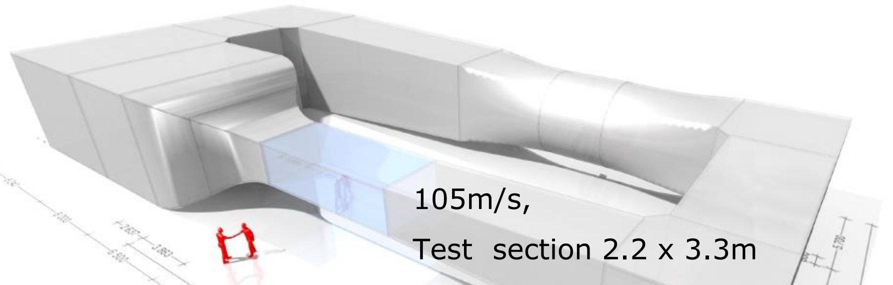




Experiments, Validation and Test

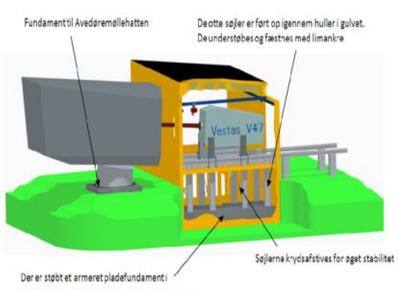
Research and test facilities





105m/s,

Test section 2.2 x 3.3m



The Testcenter in Østerild

Wind turbine testing:

- Tests acc. to international standards (IEC)
- Development tests

Research:

- Meteorology (Wind)
- Turbine technology
- Grid integration

International wind turbine standards - IEC

a) Safety & functional requirements

↓

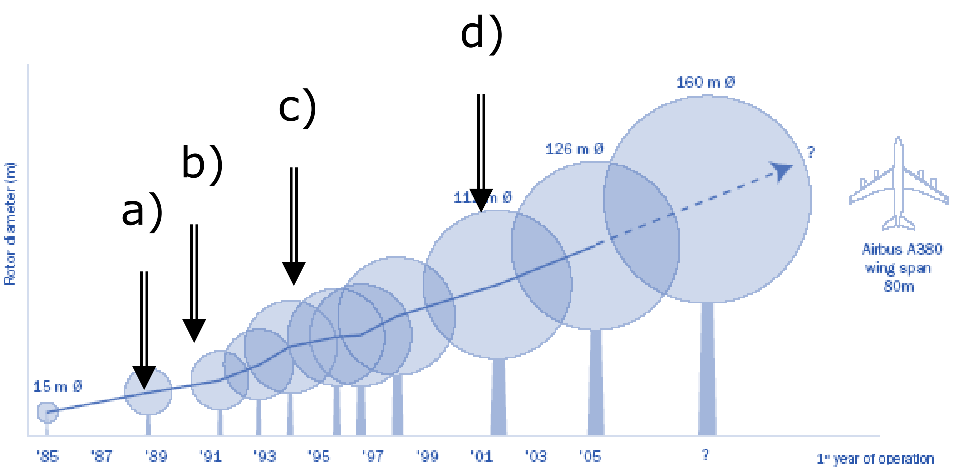
b) Test methods

↓

c) Certification procedures

↓

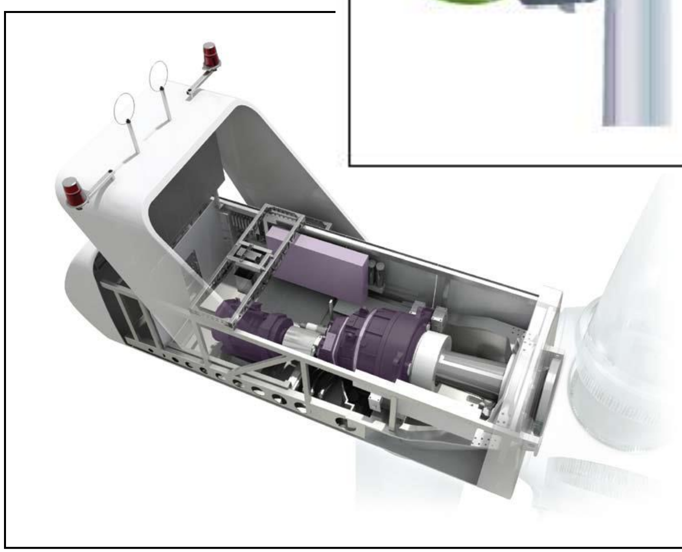
d) Interfaces & Component



IEC TC88: IEC 61400 series:

IEC 61400-1 Design requirements
IEC 61400-2 Small wind turbines
IEC 61400-3 Design requirements for offshore wind turbines
IEC 61400-4 Gears for wind turbines
IEC 61400-(5) Wind Turbine Rotor Blades
IEC 61400-11, Acoustic noise measurement techniques
IEC 61400-12-1 Power performance measurements
IEC 61400-13 Measurement of mechanical loads
IEC 61400-14 Declaration of sound power level and tonality
IEC 61400-21 Measurement of power quality characteristics
IEC 61400-22 Conformity Testing and Certification of wind turbines
IEC 61400-23 TR Full scale structural blade testing
IEC 61400-24 TR Lightning protection
IEC 61400-25-(1-6) Communication
IEC 61400-26 TS Availability
IEC 61400-27 Electrical simulation models for wind power generation

Offshore wind turbine installation – a series-produced machine or a custom built structure



Wind turbine generator system ~ Wind turbine structure

Revision of **IEC 61400-1**
Wind turbines - Part 1: Design Requirements

The revision scope shall include but not be limited to the following issues:

- External conditions:
- Cold climate conditions
- Structural Design
- Assessment of a wind turbine for site-specific conditions

Status

- 11 meetings held
- Committee draft to be submitted to IEC TC88 Sept. 2014

Sub-committees:

1. Assessment of site conditions (Thomas Hahm)
2. Wake effects (Graeme McCann)
3. Load cases/load calculation requirements (Enrique Gomez de Las Heras)
4. Safety factors (John Dalsgaard Sørensen)
5. Medium Wind Turbines (Julian Martin)
6. Cold Climate (Ville Lehtomäki)
7. Electrical systems (Tim Zgonena)
8. Tropical conditions (Hiroshi Imamura)

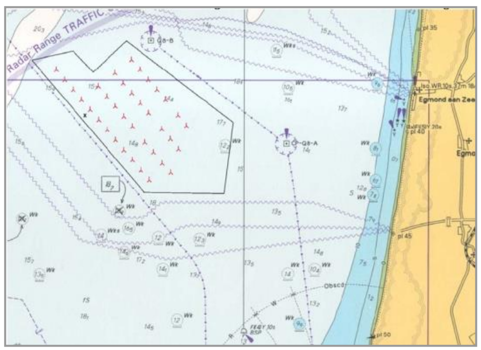
IEC 61400-1- Basic parameters for wind turbine classes

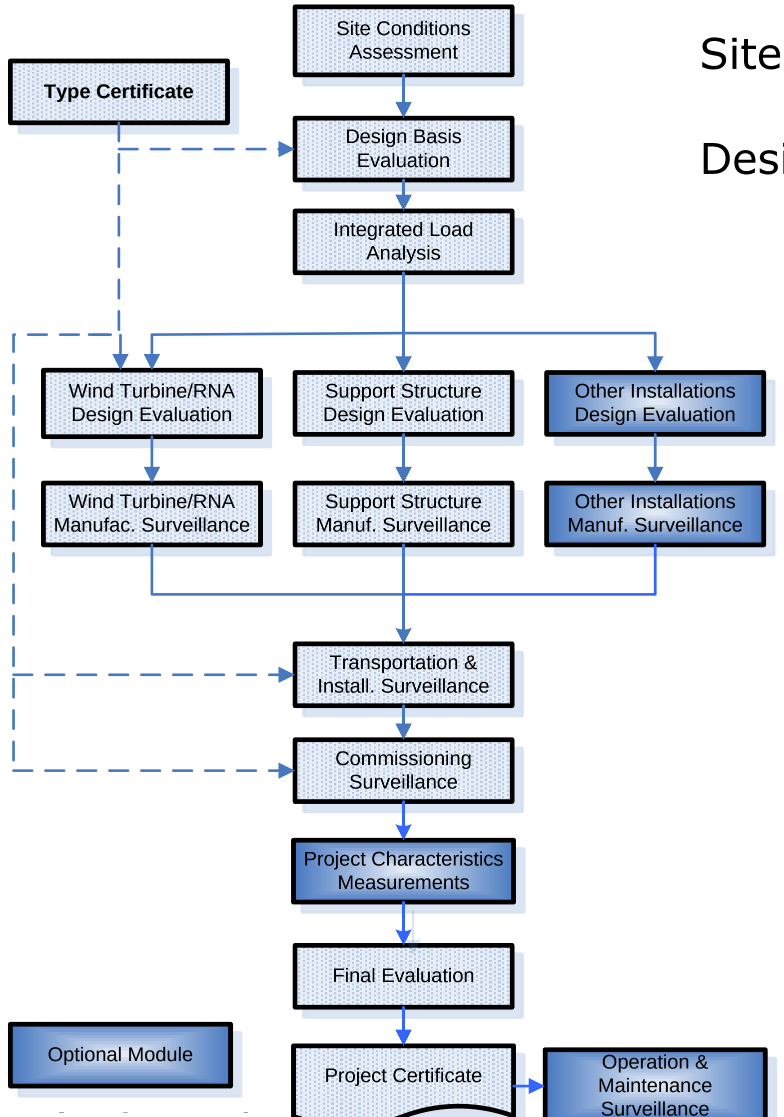
Wind turbine class		I	II	III	S
V_{ref}	(m/s)	50	42,5	37,5	Values specified by the designer
V_{ave}	(m/s)	10	8,5	7,5	
$V_{\mathrm{ref,T}}$	(m/s)	57			
A+	I_{ref} (-)	0,18			
A	I_{ref} (-)	0,16			
B	I_{ref} (-)	0,14			
C	I_{ref} (-)	0,12			

The load partial safety factors for DLC 6.1 and DLC 6.2 are derived by assuming that the coefficient of variation of the annual maximum wind speed, COV, is smaller than 15%. If COV is larger than 15%, they shall be increased linearly by a factor η from 1.0 at COV = 15% to 1.15 at COV = 30%.

Project Certification
(IEC 61400-22)

"Fit-for-Purpose"





Site-specific conditions

Design conditions

Load and design analysis

Surveillance

Certificate

Concluding remarks

- Expansion of wind energy installations has slowed down but is still going strong
- Wind energy plays a major role in Europe's energy mix
- Offshore wind energy expands but mostly in Europe

- But, offshore wind energy has a cost challenge

- The challenges must be met by
  - International cooperation
  - Research
  - Technology development
  - Validation and testing
  - Standards and certification


DTU
Thank you for your attention