State-of–the-Art and Status of Offshore Wind Energy in Europe

Arno van Wingerde

ISOPE-2016 Conference, Rhodes, Greece

The 26th International Ocean and Polar Engineering Conference

Rhodes (Rodos), Greece, June 26–July 1, 2016: www.isope.org;

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Overview

- Facts & Numbers Wind Energy
- Onshore or Offshore?
- Examples of European Offshore Projects and Research
- Fixed or Floating?
- European Research Strategy

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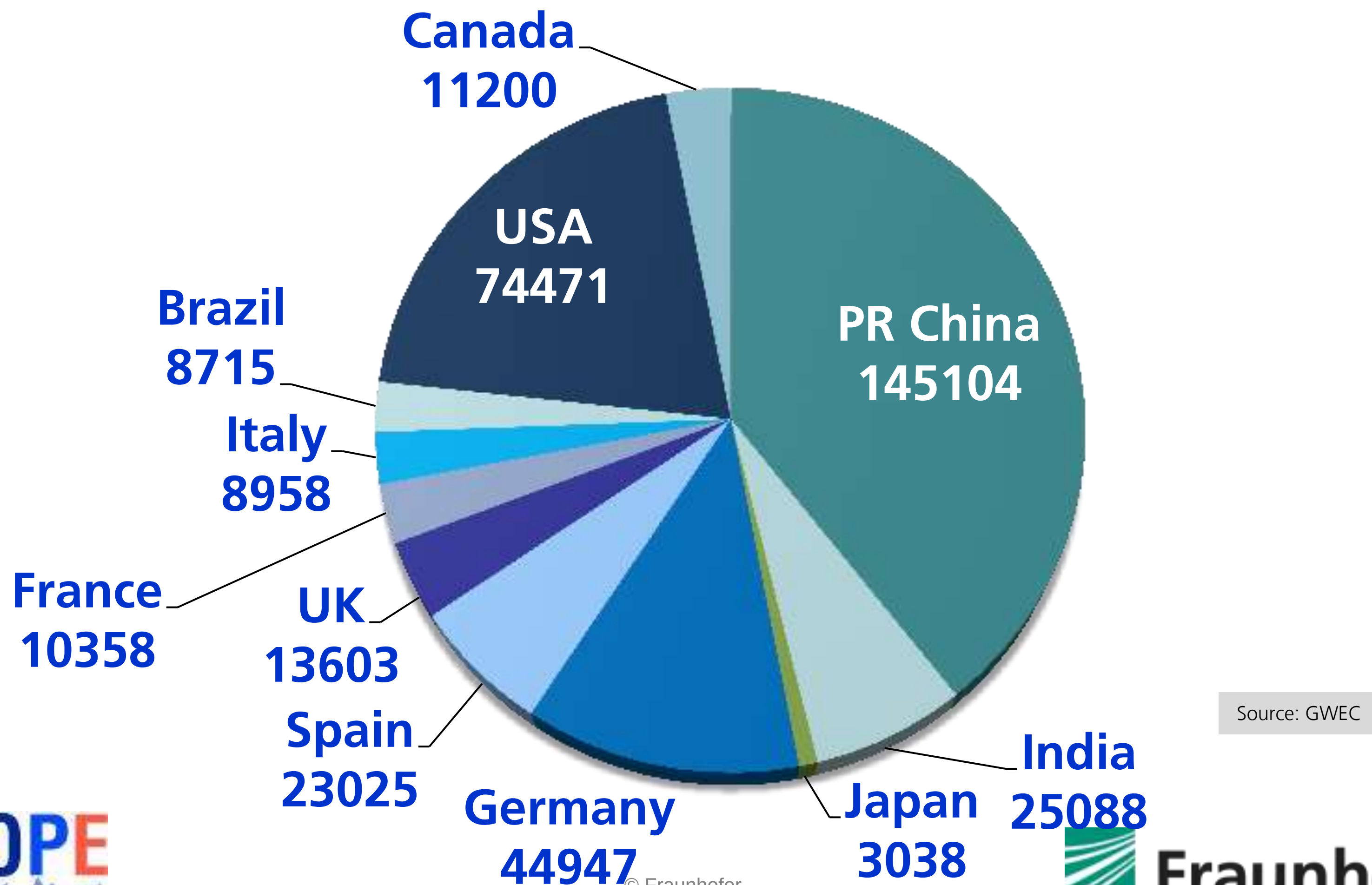
The 10 largest markets by the end of 2015 (cumulative MW)



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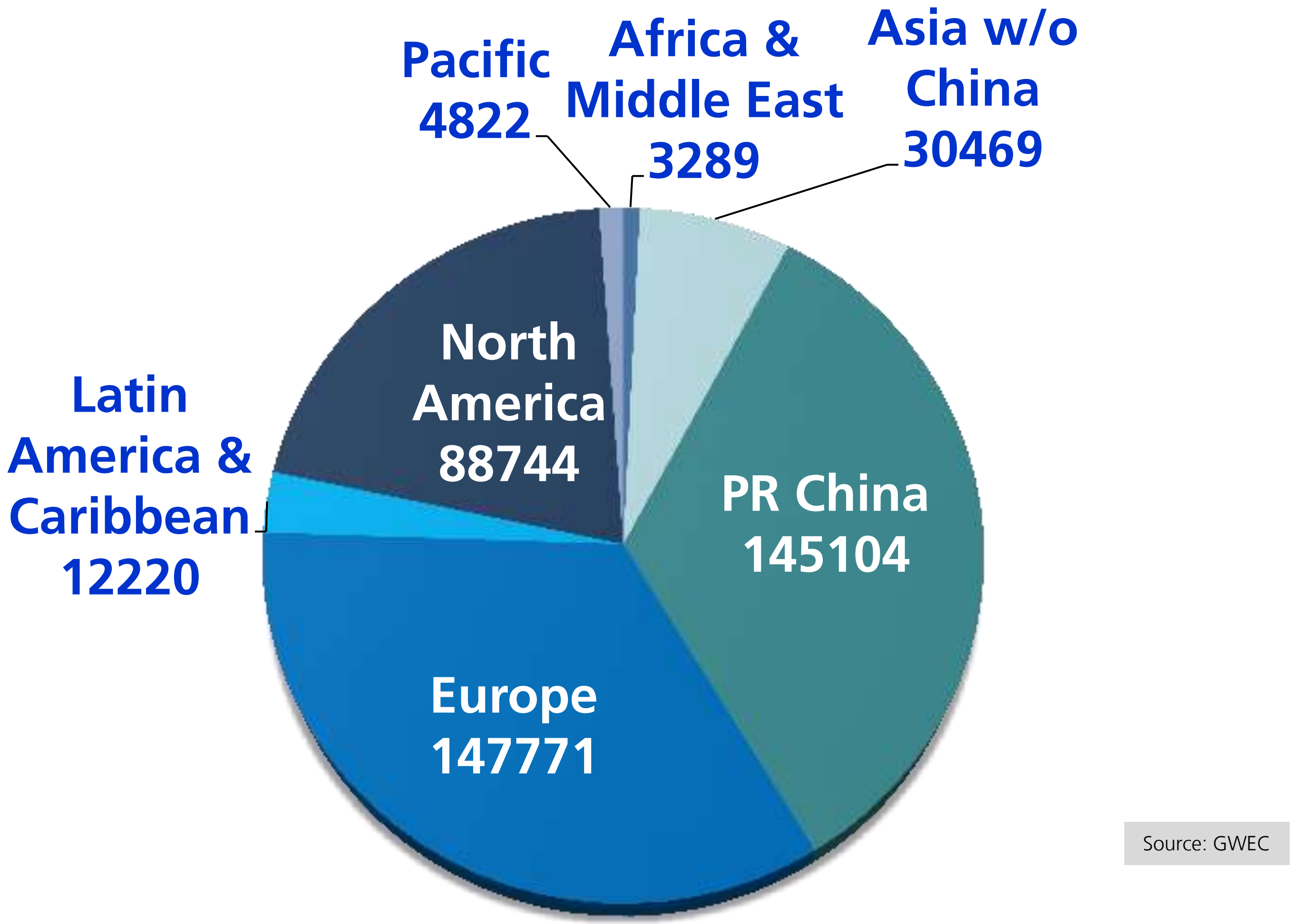
Wind Energy per Region by the end of 2015 (cumulative MW)



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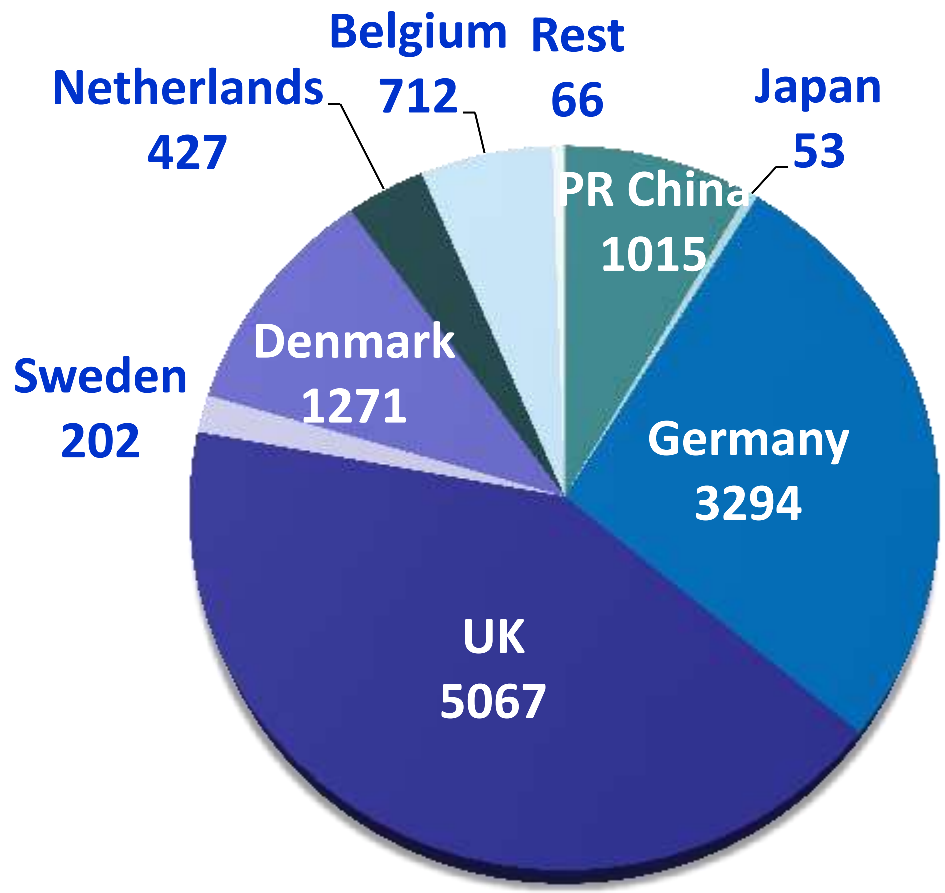
The 8 largest offshore markets by the end of 2015 (cumulative MW)

12 GW offshore vs. 432 GW total



Source: GWEC

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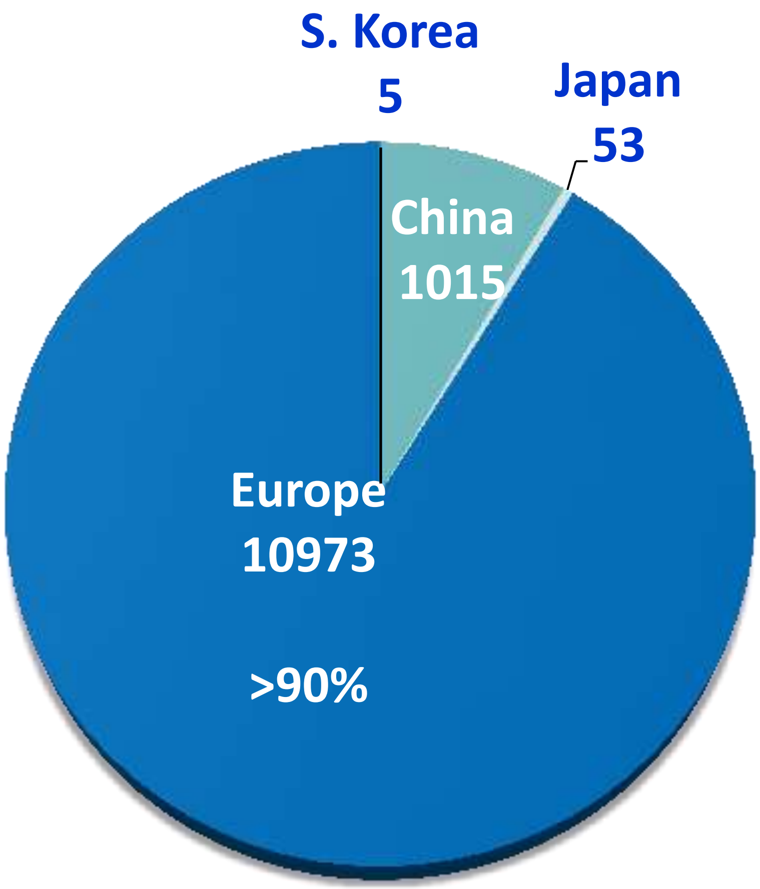
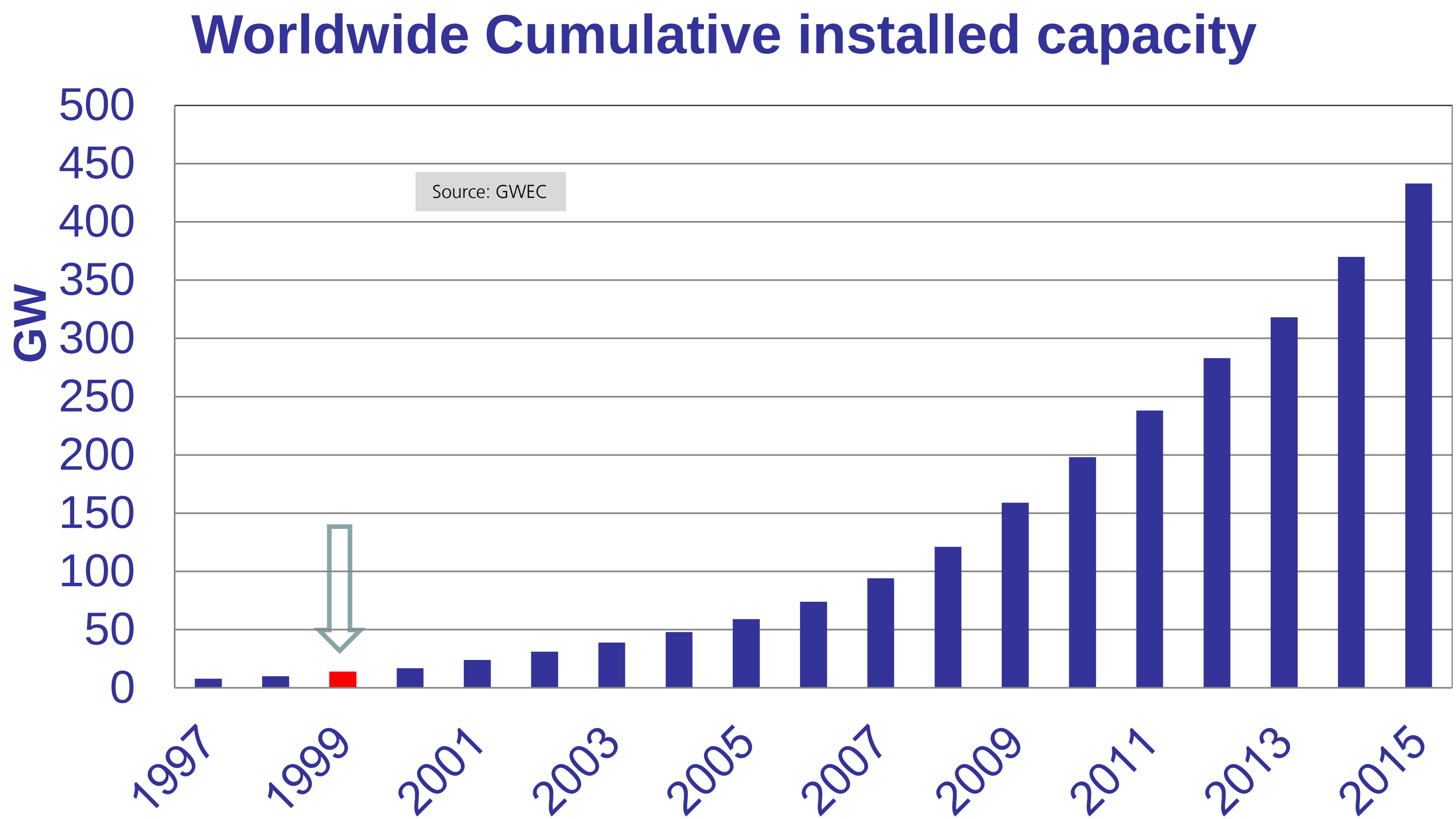
Offshore Wind Energy per Region by the end of 2015 (cumulative MW)

12 GW offshore vs. 432 GW total



Source: GWEC

Offshore wind in 2015 is where onshore wind was in 1999



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A GREAT SCIENCE AND ENGINEERING CHALLENGE!

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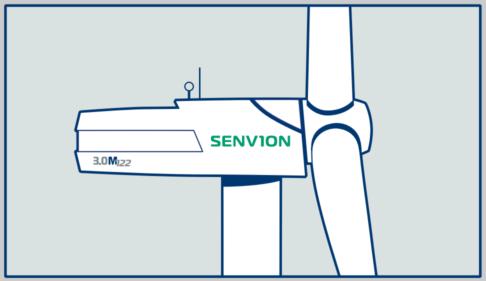
Onshore - Offshore: Capacity

Rated output:
3 megawatts (MW)

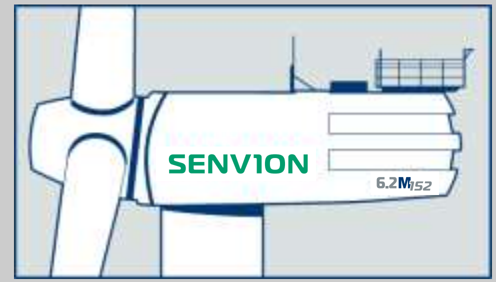


- Around 2,500 hours in full-load operation[1]
- 3,000 kilowatts
  x 2,500 hours

- = 7,500,000 kWh

- = **2,000 households**[2]

Rated output:
6.15 megawatts (MW)



- Around 4,000 hours in full-load operation[1]
- 6,150 kilowatts
  x 4,000 hours

- = 24,600,000 kWh

- = **6,500 households**[2]

[1] May vary strongly depending on location
[2] Model calculation based on a three person household with an average consumption of electricity of 3,800 kilowatt-hours (kWh) per year

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Onshore - Offshore: Logistics

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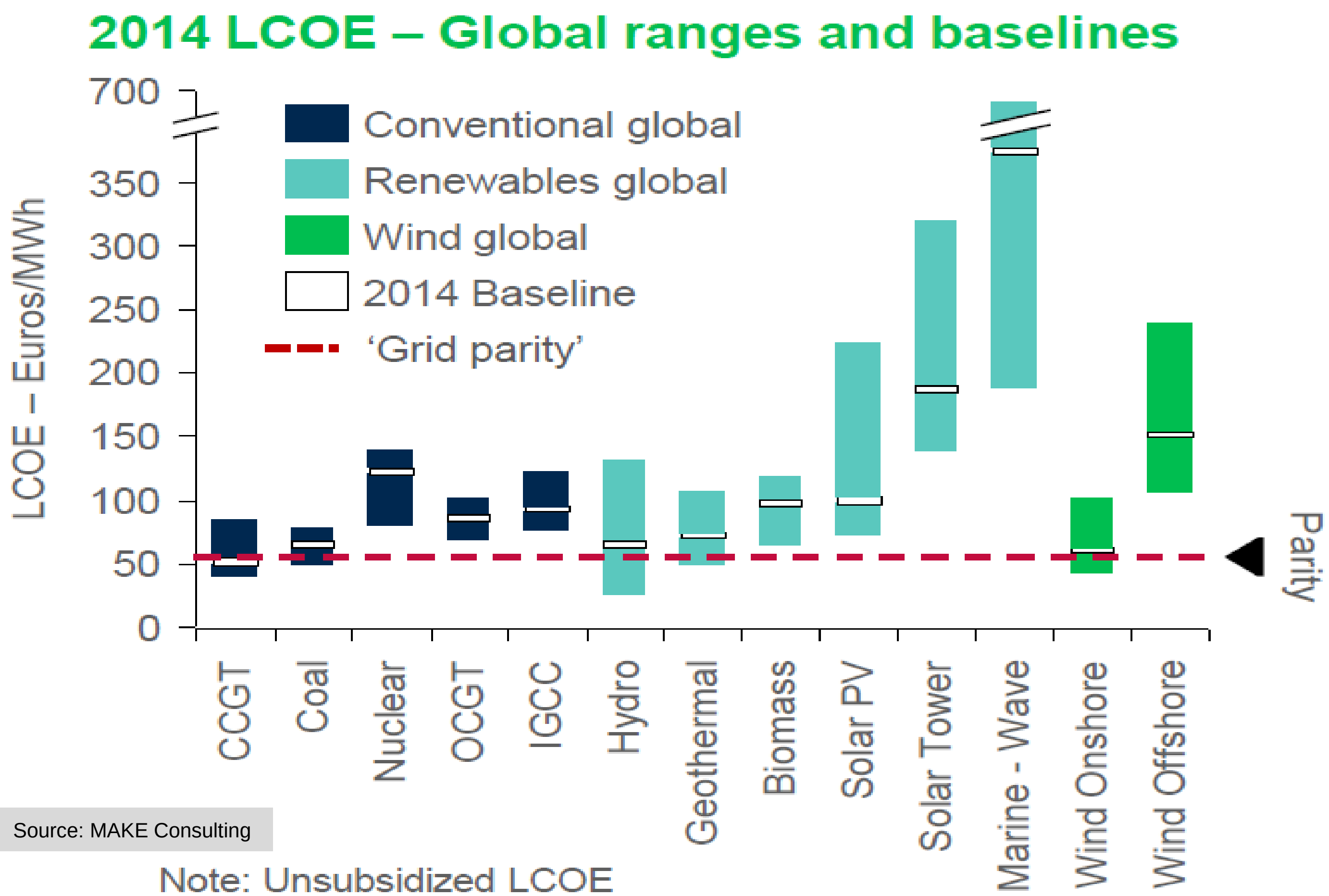
Wind Energy and other energy sources



Source: MAKE Consulting

Note: Unsubsidized LCOE

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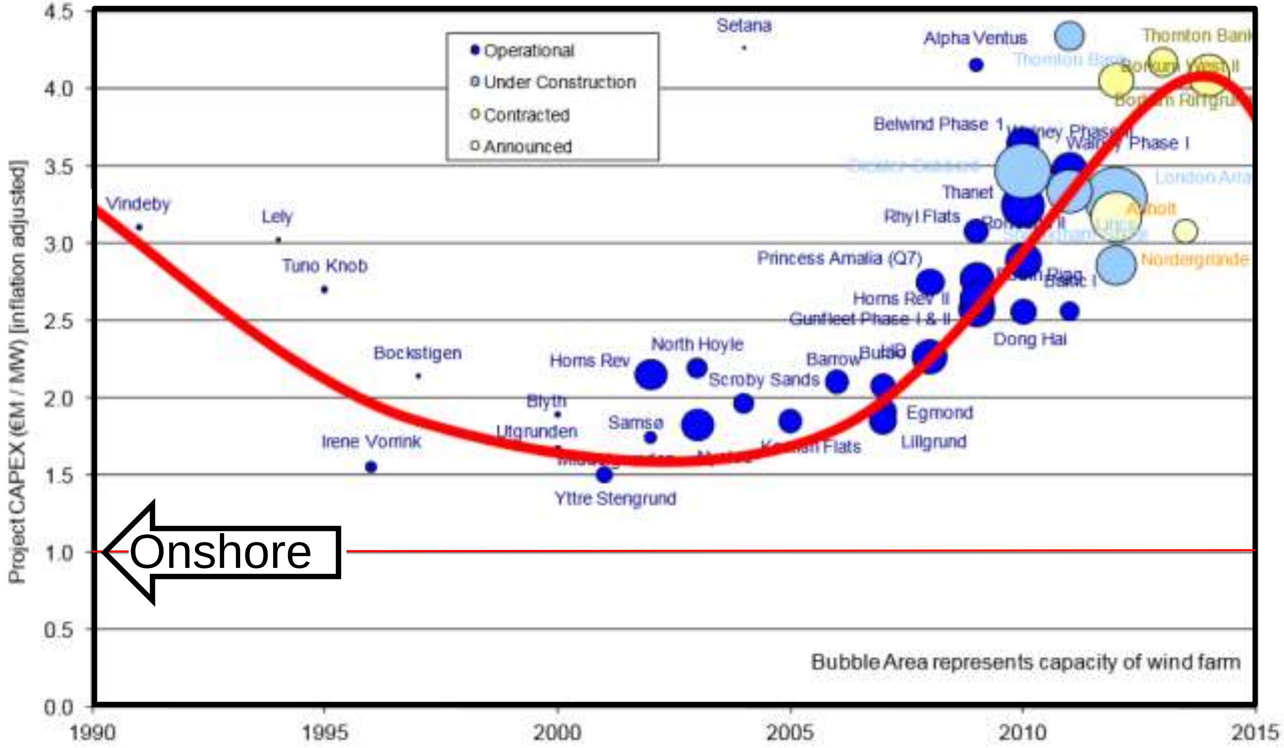
Offshore Wind levelised Cost of Energy



Source: DNV-GL

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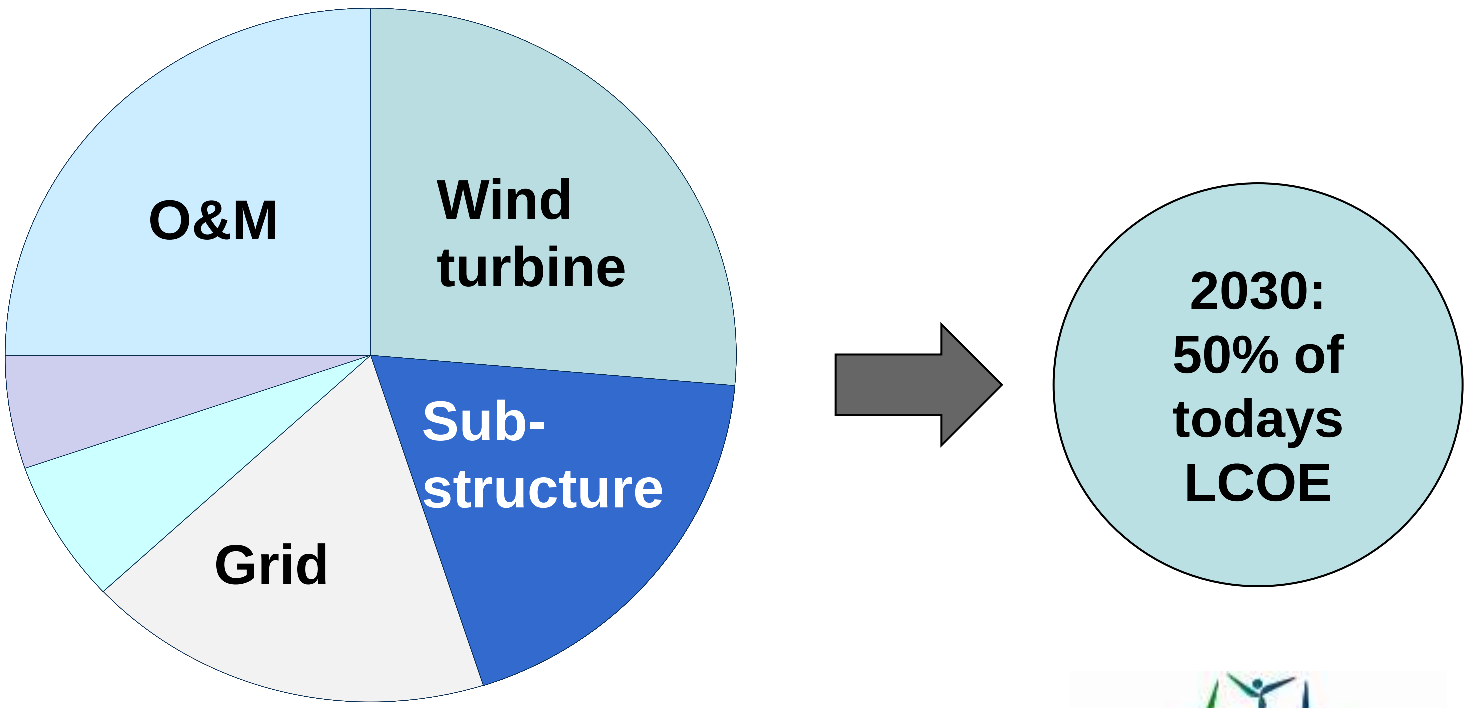
Offshore wind main challenge - Reduce Cost of Energy



European Wind Energy Technology Platform

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Offshore wind has cost reduction opportunities in multiple areas including scale effects

Turbines & plant

- Larger turbines and wind farms
- Increased reliability
- Scale effects and industrialisation

Substructures

- Standardised and optimised offshore foundation design and design criteria
- Industrialised manufacturing

Transmission

- eBoP optimisation of substation and transmission capex
- Innovative transmission solutions
- Improved grid access

O&M

- Low OPEX drivetrains
- Turbine and component quality
- Condition monitoring, diagnostics, preventive maintenance

Source: Siemens, MHI-Vestas, MAKE

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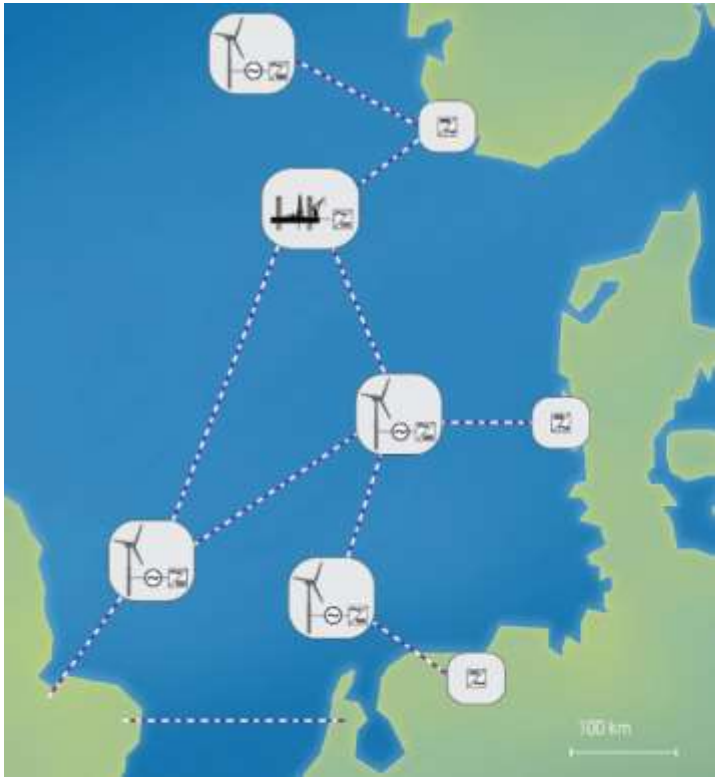
Moving towards an North-Sea offshore grid



Example of our supply chain footprint: production and logistics center in Bremerhaven

Senvion production hall for assembly of large nacelles and hubs

Source: Senvion

PowerBlades factory for Offshore blades

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Alpha Ventus – German offshore test field
6 Senvion 5M Turbines; 6 Adwen 5M Turbines

Completion of six Senvion 5M wind turbines on Nov. 16, 2009

Customer: DOTI GmbH

Location: German North Sea, 45 km off Borkum

Turbines: Six Senvion 5M

Total rated capacity: 30 MW

Rotor Ø: 126 m

Source: Senvion

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Senvion and Adwen Turbines at Alpha Ventus (formerly Areva … Siemens in the near future?)

Source: AREVA (ADWEN)

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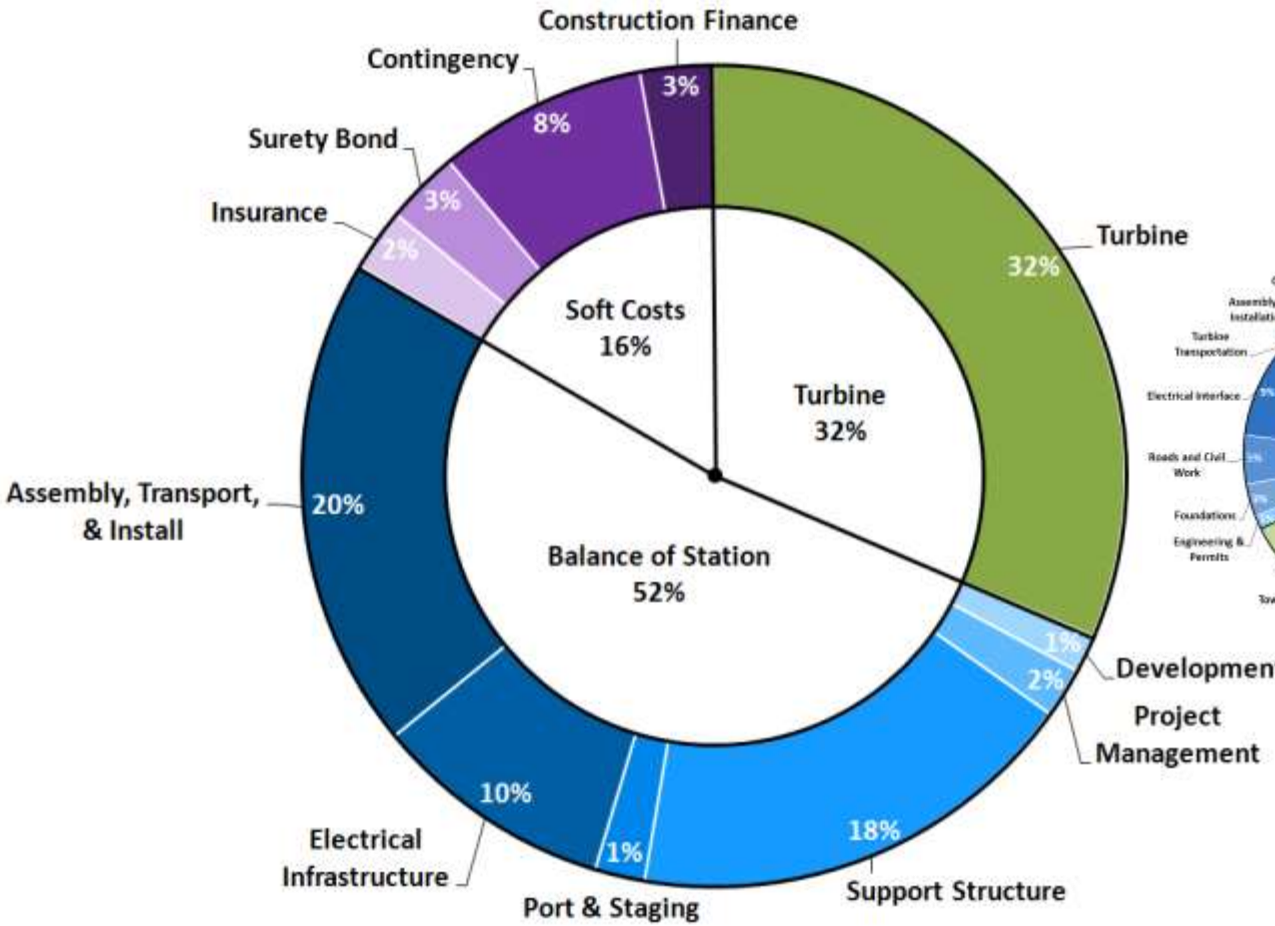
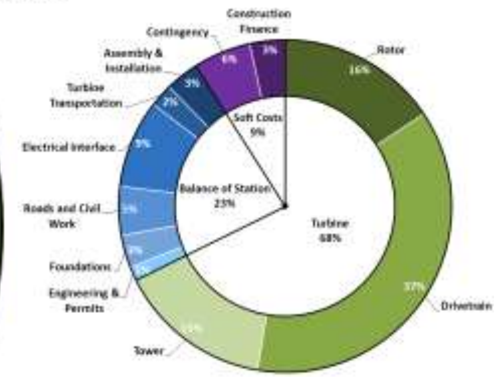
Costs of tower and support structures Offshore : 25%



Tower: 7% of total costs



Source: NREL

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RAVE Measurement program

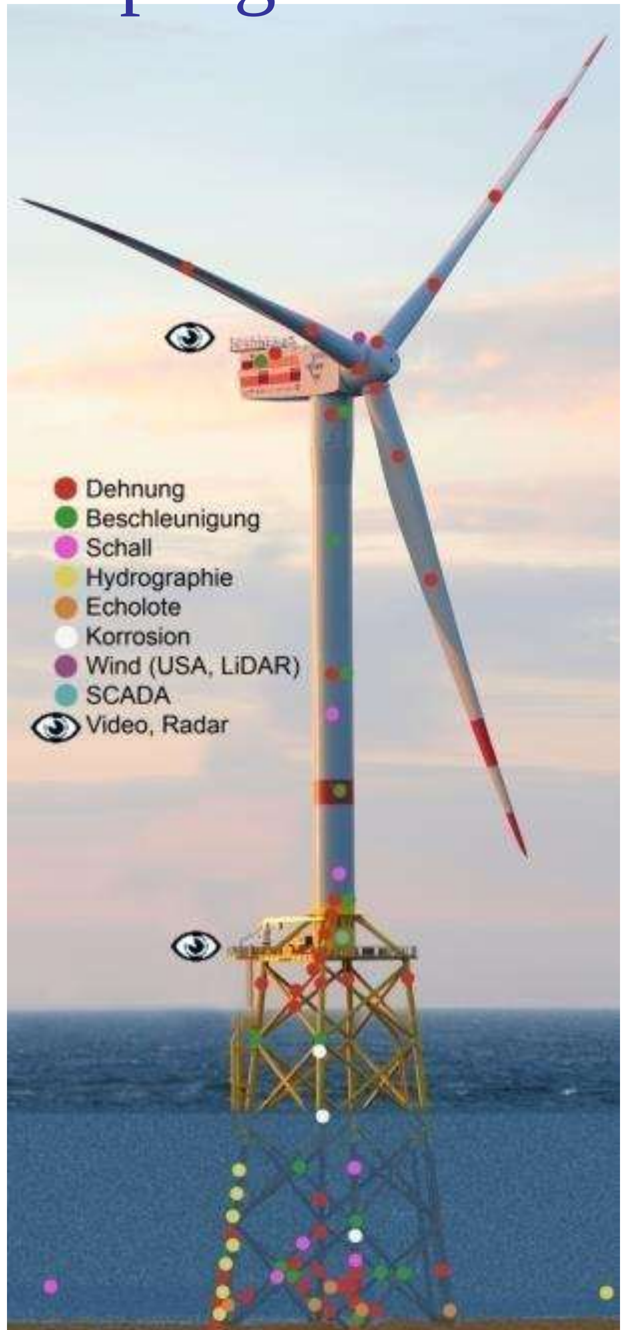
Struktural-
dynamics

Water-
pressure

Noise
emission

Corrosion

Electrical
parameters



Meteo-
rology

Hydrology /
Geology

Bird
migration

SCADA data

FINO 1

Offshore Site Assessment – Wind and Sea

Research topics:

- Offshore meteorology
- Offshore Lidar buoy
- Ship-based Lidar
- Wind, wave and current measurements

Services:

- Measurements
- Site conditions for design, construction and operation
- Wind ressource assessment

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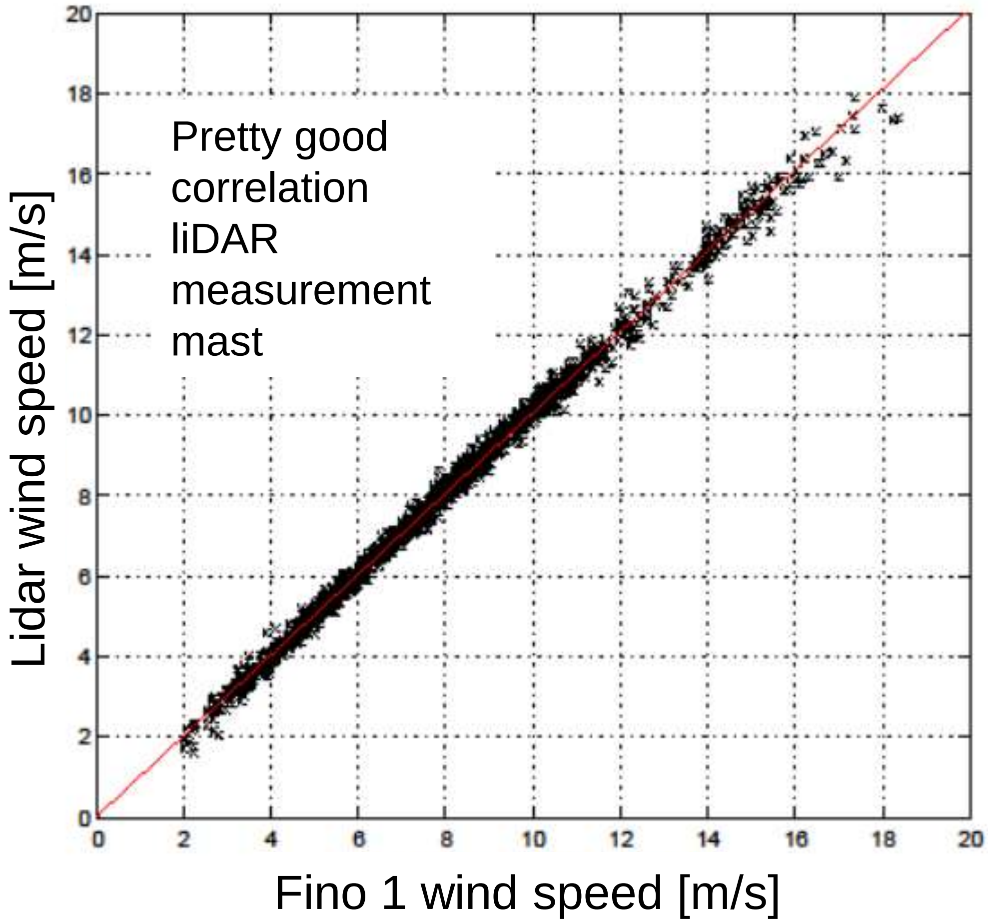
Validation Campaign Fino 1



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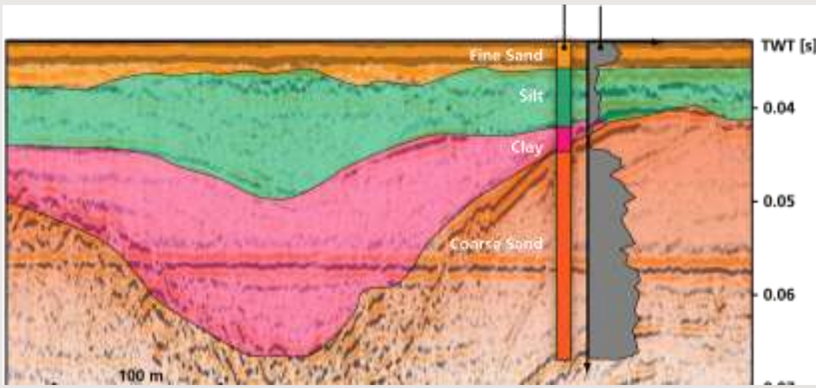
Offshore Site Assessment – Soil Conditions



Research topics:

- Seismic sea bed exploration with novel, digital streamer optimized for shallow water
- Geotechnical parameters
- Combination of seismic data with geotechnical surveys

Services:

- Seismic sea bed exploration
- Preliminary geotechnical investigations
- Laboratory measurements of soil parameters

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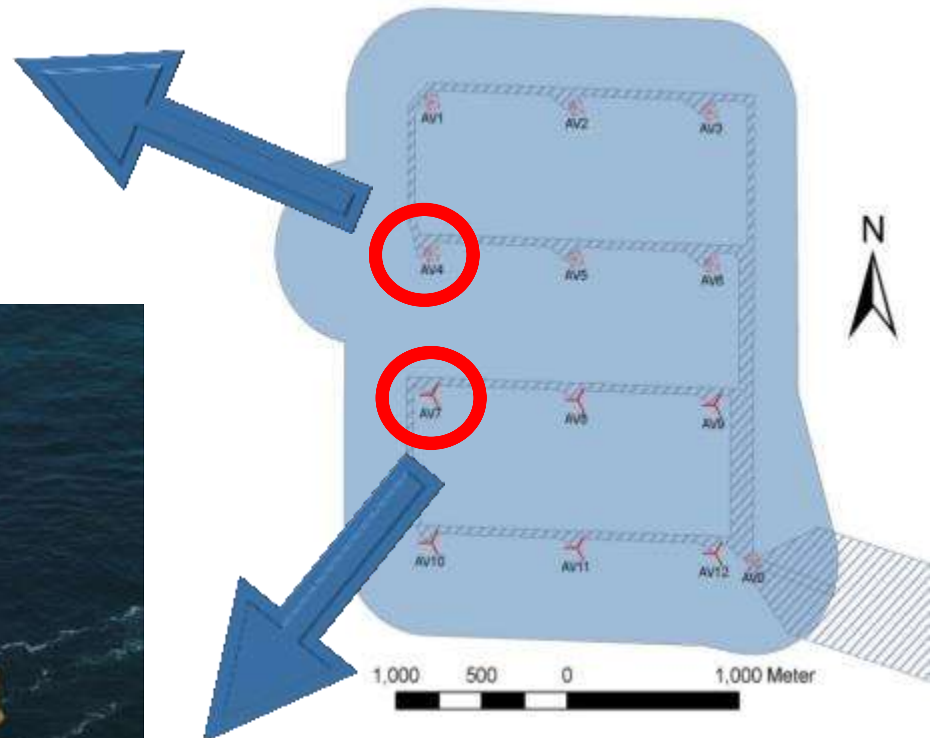
Scour and sediment transport

Source: bildarchiv.alpha-ventus.de

Source: BSH



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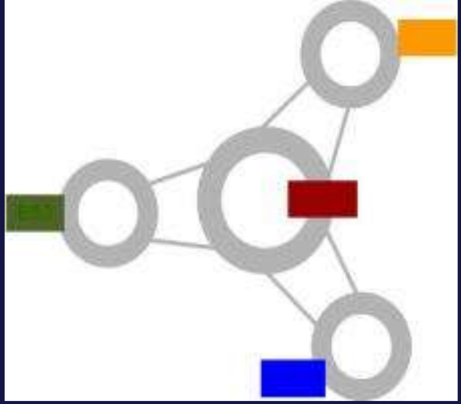
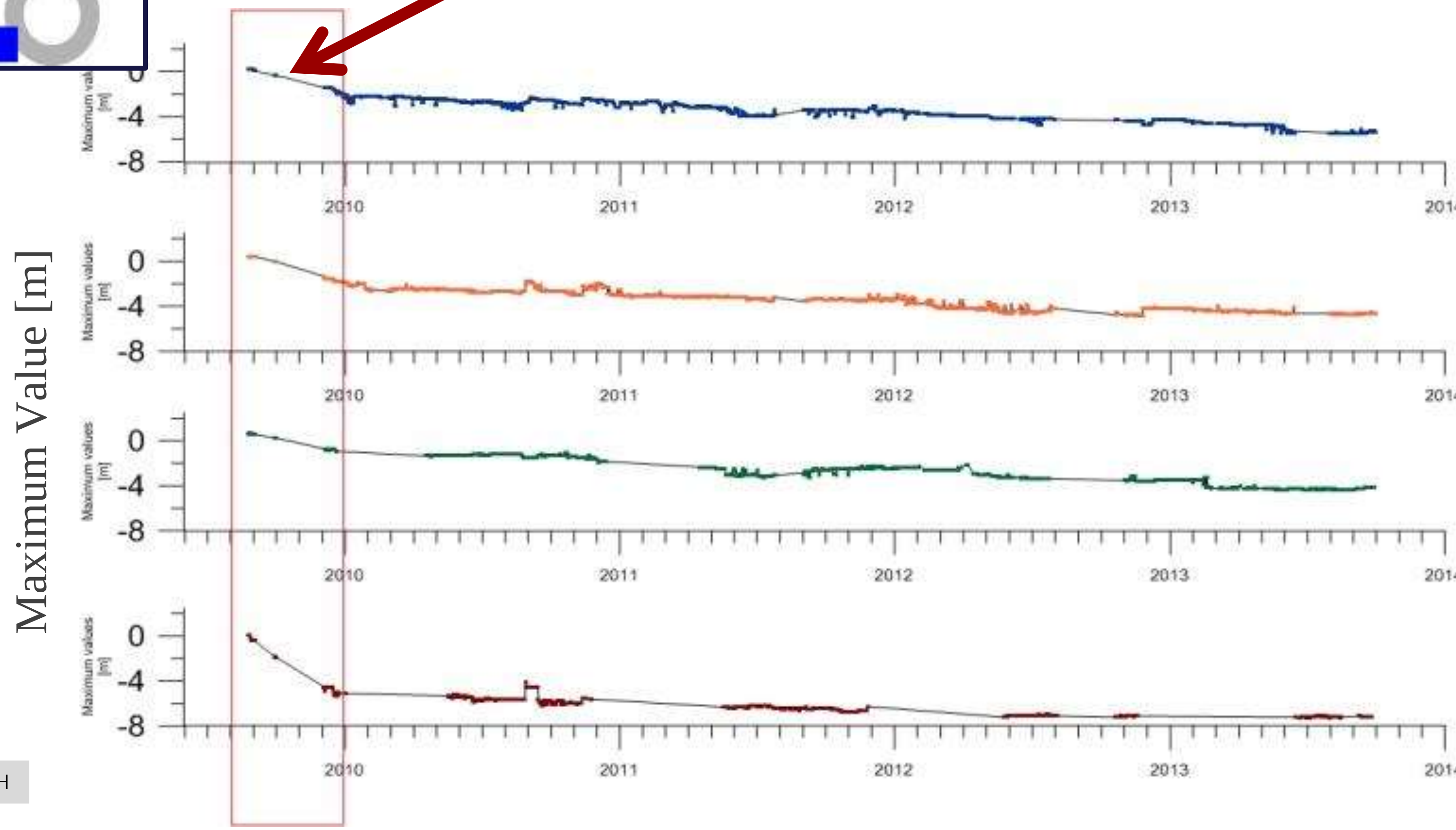


Scour development over time

Strong increase in scour in the first 5 months

Source: BSH



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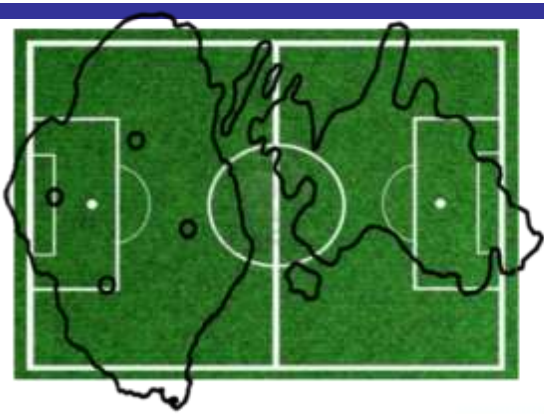
Scour geometry (AV4)



7140 m²
FIFA Standard

Accumulation volume: 200 m³
Accumulation area: 1400 m²

Scour volume: 1700 m³
Scour area: 2400 m²

Source: BSH

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Conclusions of Alpha Ventus

- Alpha Ventus and RAVE are major stepping stones for the deployment of offshore wind energy in Germany
- Manufacturers developed successful 5 MW turbines
- Coordinated and well networked research is an example for other major project clusters
- Measurement data can be used for further research (support structures, Loads, grid)
- Experience in cooperation between industry and research partners gained

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Exciting development of floating wind

Hywind SINTEF/ MARINTEK 2005

Hywind Norway 2009

Hywind Scotland 2017

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Introduction

What are floating offshore wind turbines?

Why build floating offshore wind turbines?

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Offshore Wind started out on fixed support structures

First offshore wind farms started here

You are here

Source: ACCIONA, 1-Tech

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State of the art: background

Fixed bottom OWT design

- Aero-servo-hydro-elastic loads simulation
- Experience since 1991 (Vindeby)
- Milestones like first jacket in 2006 (Beatrice Field)
- “Serial production”

Floater Design

- Frequency domain hydrodynamics simulation approaches and tank testing
- First Semi-Sub in 1960s
- Massive growth in size
- Design of single pieces

Source: Senvion

Source: Senvion

Source: Inpex, 2016

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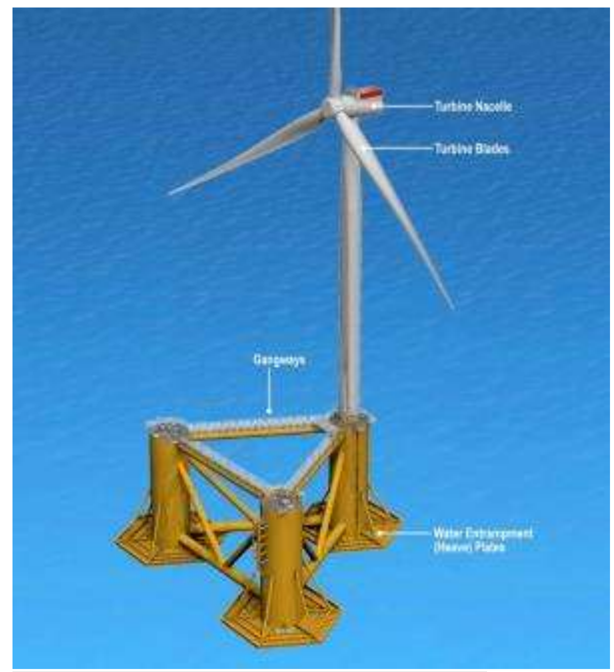
State of the art: most realistic / realized concepts

Ballast stabilized
Spar type

Mooring line stabilized
tension leg platform

Buoyancy and ballast stabilized
Semi-submersible concepts

- Vertical columns with large distance
- Buoyancy stabilized
- Relatively low CG
- Ballast stabilized



Source: Statoil, Glosten, Principle Power, 2016

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Specific design challenges: Uncertainties in hydrodynamic behaviour

- Offshore-Wind: aero-elastic time domain simulations, Morison approach
- Oil&Gas: Frequency domain, panel methods (diffraction problem)

- Diffraction in time domain
- Viscous damping hard to predict
- Challenging model tests necessary
- Fluid Structure Interaction (FSI) simulations can reduce uncertainty

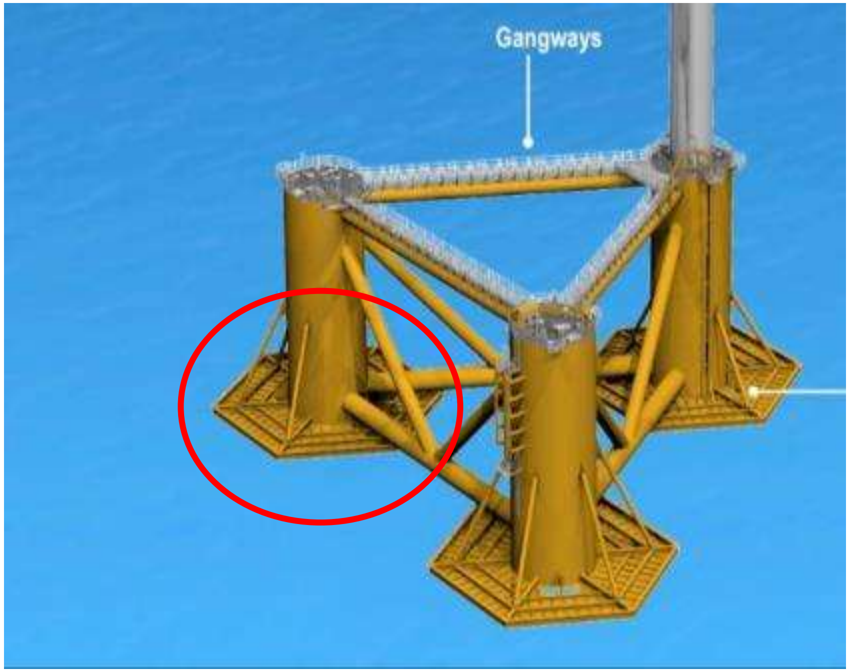

fig: Principle Power, 2016

Conclusion and outlook

Status

- Full scale prototypes
- Different Concepts
- Set of challenges
- Limited validation data available

But: Industrial experience

- Vestas MHI + Principle Power
- Siemens + Statoil
- Fukushima Forward consortium

Projects to come (?)

- Hywind Scotland: 5x 6 MW Siemens
- Fukushima Forward: 1 GW by 2020
- WindFloat Atlantic: 5x 6 MW Siemens
- Others

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European research

- Many leading wind turbine manufacturers:
  - Vestas/Mitsubishi
  - Siemens
  - Gamesa
  - Enercon
  - Nordex
  - … and many more
- Non-European manufacturers have major research centres in Europe
  - GE
  - Suzlon

Agreed strategic targets for offshore wind energy

- Agreed strategic targets for offshore wind energy
- Reduce the levelised cost of energy (LCoE) at final investment decision (FID) for fixed offshore wind* by improvement of the performances of the entire value chain to
  - Less than 10 ct€/kWh by 2020 and to
  - less than 7ct€/kWh by 2030;
- Develop cost competitive integrated wind energy systems including substructures which can be used in deeper waters (>50m) at a maximum distance of 50 km from shore with a LCoE* of
  - less than 12 ct€/kWh by 2025 and to
  - less than 9 ct€/kWh by 2030

* the costs for delivering the electricity to onshore substations are taken into account within the LCoE

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Discussion of the key priorities per pillar

Workshop
Brussels
Juni 2016

Wind Farm Management (O&M)

- Standardized and validated methods and sensor systems for performance measurement and condition monitoring
- Improvements in energy yield from wind farms through utilization of adaptive, and interactive and big data control
- Improvements in reliability and predictability of wind farms and data analysis to improve diagnostics and decision-making
- Lifetime optimization

Grid Systems, Integration and Infrastructure

- Energy management and balancing with other renewable sources
- Control, architectures for provision of ancillary services
- Standardization
- Improved long distance transmission systems for on- and offshore wind farms, incl. installation & O&M
- Energy storage

Industrialisation

- Standardisation
- Regulatory Market Requirement & Harmonisation
- Value chain development

Offshore Balance of Plant

- Floating offshore wind farms
- Industrialised transport and installation systems
- Innovative and industrialised offshore towers and foundations, incl. seabed interactions

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Thank you for your attention

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