Cost Effective Fixed and Floating Substructures

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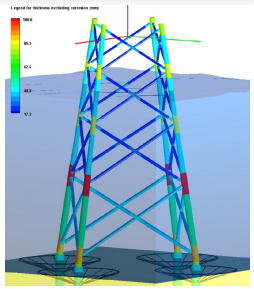
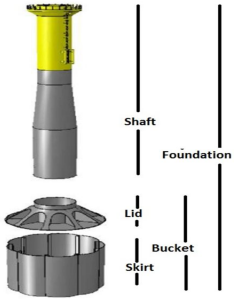
Support Structure Concepts

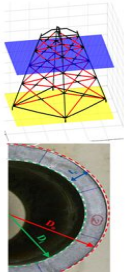
Bottom-fixed



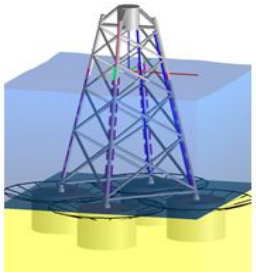
Jacket: 10MW and 20MW designs



Mono-bucket



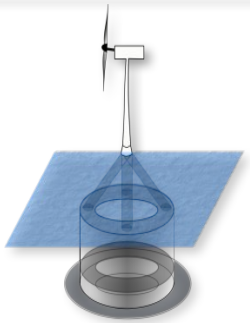
Hybrid jacket using sandwich material



Jacket with suction buckets

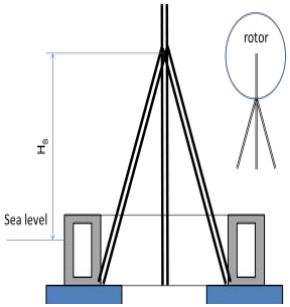
Floating

semi-floater



Concrete torus

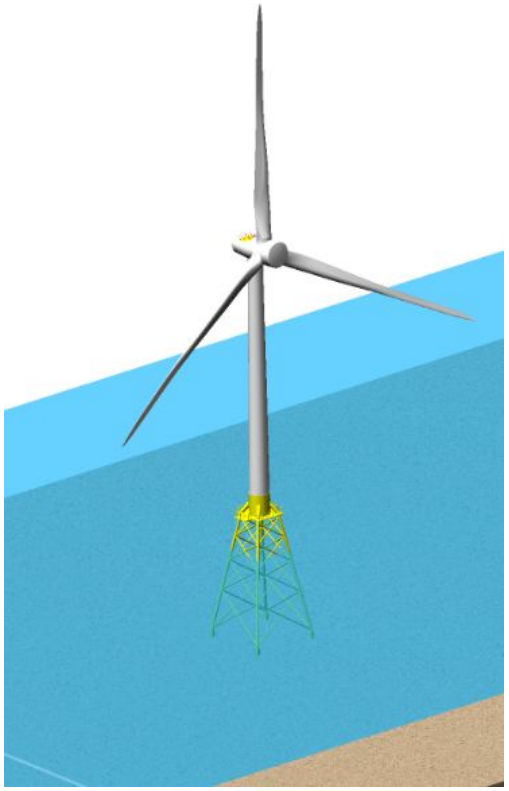
Semisubmersible



Concrete torus linked with floating bodies

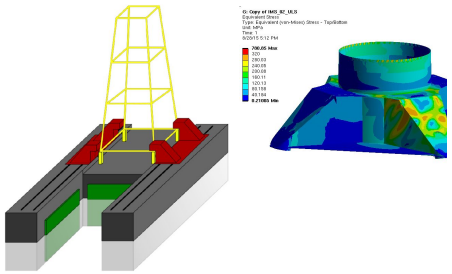
Main Objectives for Bottom-fixed Structures

Bottom-fixed

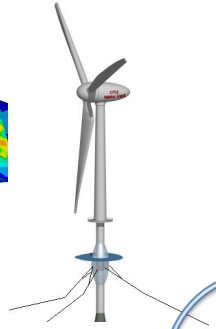


- Develop innovations on component level and scaled experiments
  - Addressing soil & structure, material & joining, component optimization and damping systems
- Cost reduction of 10 MW bottom fixed concepts by 20%
  - 17-43% demonstrated, i.e. 20% is realistic.
- Predesign of a foundation for 20MW
  - Jacket design developed (2170 t lifting mass, ~93€/MWh).

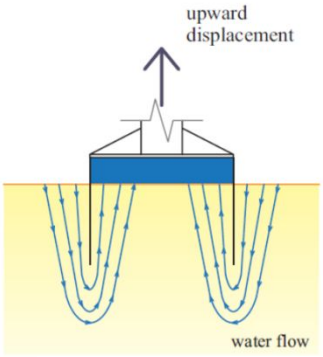
WP4 Achievements – Bottom-fixed Structures



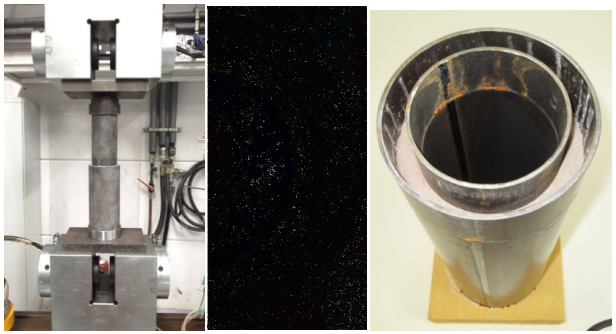
Innovative designs & installation



Innovative damping devices



Innovative foundations:
Buckets and vibro driven piles

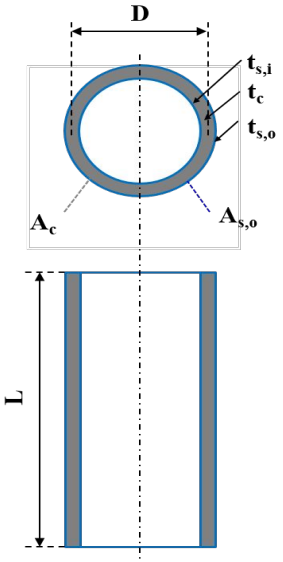


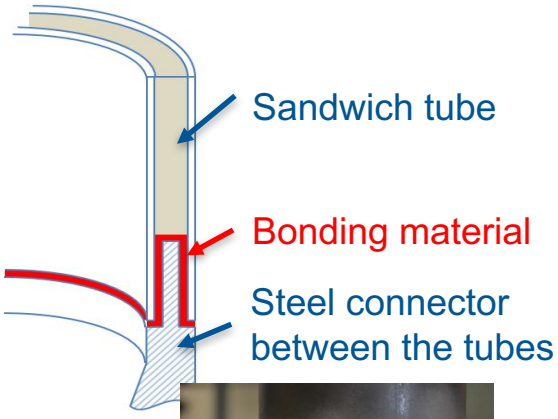
Sandwich materials and testing

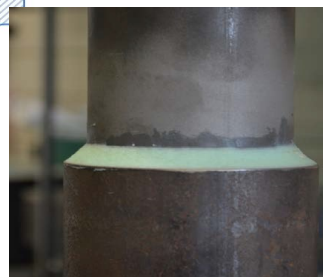
Resulting in a various bottom mounted design solutions for 10 and 20 MW wind turbine size

Example: Innovative Materials

- **Sandwich tubes** for chords and braces of the hybrid jacket
- Advantages:
  - ➢ Thin steel tubes made of high strength steel without stability issues or reduced quantity of steel
  - ➢ Reduced manufacturing time of steel tubes due to their small thickness







- **Adhesive hybrid joints** connecting chords and braces of the hybrid jacket
- Advantages:
  - ➢ Suitability with sandwich tubes
  - ➢ Replacement of time and cost consuming welding

Example: Innovative Foundations Buckets and Vibro-driven Piles

- **Results**
  - Reduced capacity in comparison to impact-driven piles
  - Significant set up effects
- **Outlook**
  - Extensive investigation on the influence of the penetration rate
  - Pile capacity under compression

Sand filling operations

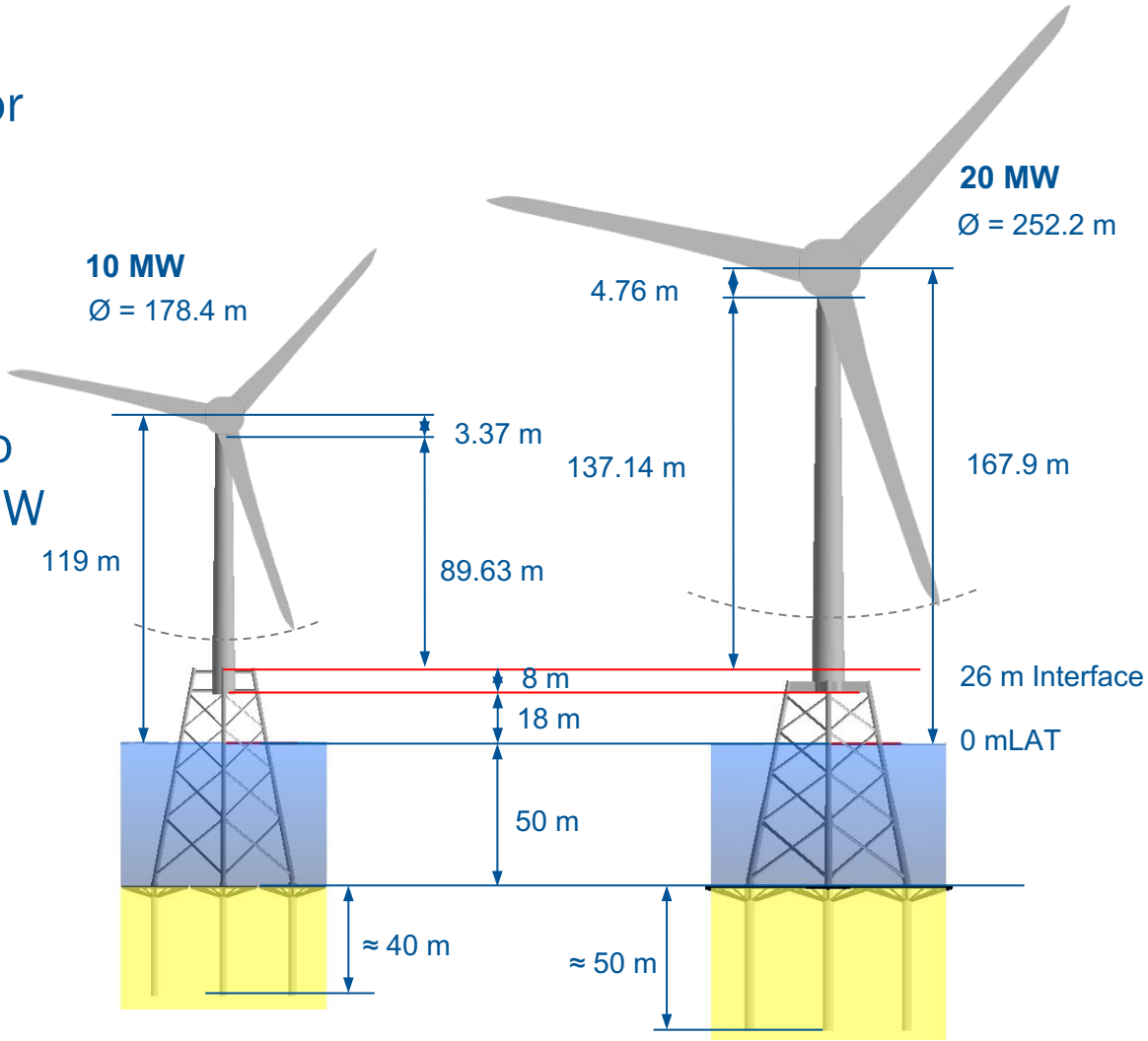

CPT campaign

Pile 1; end of the installation

Pile 1; pre-loading stage

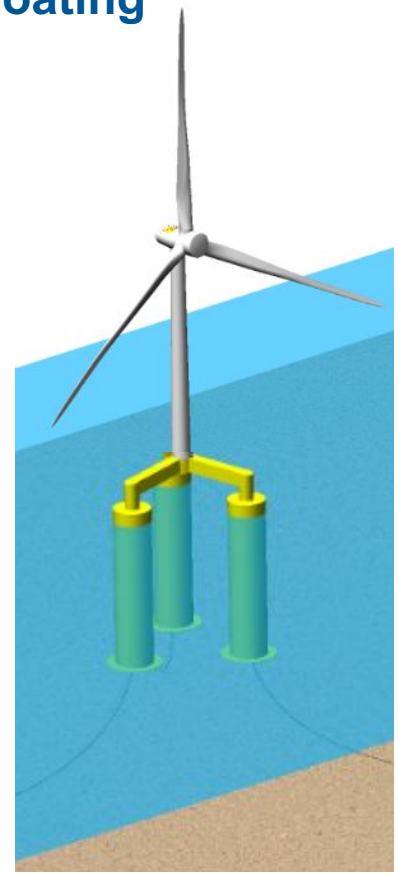
Overview of the 10MW and 20MW Designs

- Jacket design solutions for 10-20MW WTG
- Dynamic analysis of the concepts
- An exclusion zone is used to avoid excitations due to 3P frequency for the 10MW design
- 3P excitation is not anymore an issue for the 20MW design



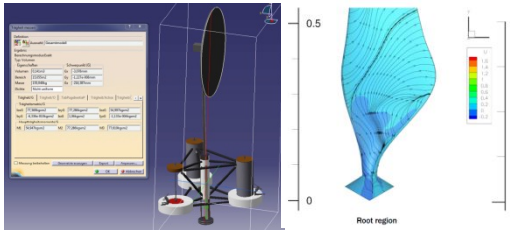
Main Objectives for Floating Structures

Floating



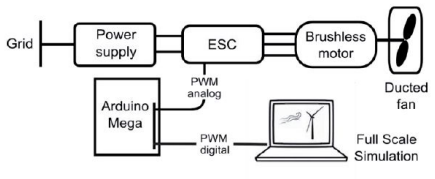
- Validate numerical tools using wave tank experiments
  - Addressing TLP and semi-sub in two wave tank tests.
  - Results public available.
- Develop reference floater designs for 10MW
  - Design of the “Triple Spar” floating support structure.

WP4 Achievements – Floating Structures

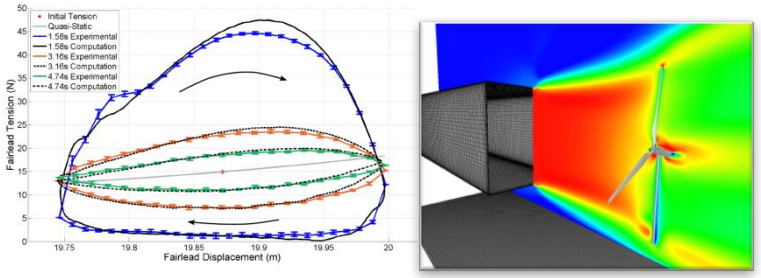


Development of methods and codes

Experiments: TLP, Semi-submersible, moorings, rotor



Methods for scaled tests



Code validation with experiments

Resulting in a various floating design solutions for 10 MW wind turbine size

Floating Offshore Wind Turbine Experiments

Test Campaign

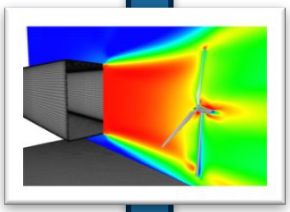
Model Tested

Codes Validated

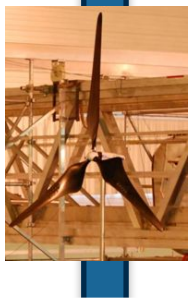
ECN Campaign

DHI

ECN Campaign #2



Air flow



Semisubmersible Low Reynolds Rotor

Semisubmersible HybridTesting (SiL)

TLP Low Reynolds Rotor

Mooring dynamics

Aerodynamic CFD

Integrated codes

Hydrodynamic CFD

Dynamic Mooring codes

Floating Offshore Wind Turbine Experiments

Database with INNWIND.EU experimental data:

Download von Messdaten

Name*

First name*

E-Mail*

Institution/Company*

Selection* Industry

Application* Software validation

Country*

How did you get to know about INNWIND.EU wave tank measurements?* Website

Alle Eingabefelder, die mit einem Stern (*) versehen sind, sind Pflichtfelder.

Senden Zurücksetzen

Index of /windenergie/innwind/DataBase

Name	Last modified	Size	Description
Parent Directory		-	
CalibrationFunctions/	15-Apr-2015 15:00	-	
CollectedData/	15-Apr-2015 15:00	-	
DataBase.zip	17-Apr-2015 15:04	3.8G	
DataIndex INNWIND ECN1409.xlsx	02-Apr-2015 15:46	93K	
INNWINDExportData.m	15-Apr-2015 14:59	2.3K	
INNWINDPlotTestData.m	15-Apr-2015 14:59	4.1K	
INNWINDReadData.m	15-Apr-2015 14:59	8.0K	
INNWINDReadDataIndex.m	15-Apr-2015 14:59	6.8K	
ReadASCIIFile.m	15-Apr-2015 14:59	1.0K	
ReplaceString.m	15-Apr-2015 14:59	1.5K	
figures/	15-Apr-2015 15:00	-	

Apache Server at www.ifb.uni-stuttgart.de Port 80

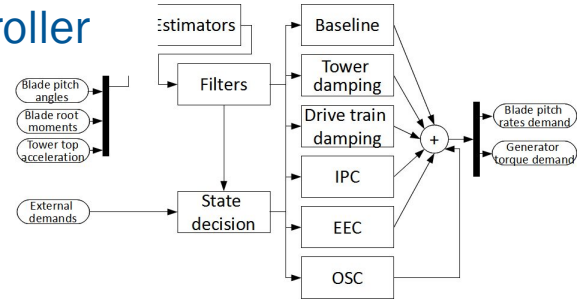
(http://www.ifb.uni-stuttgart.de/windenergie/download_messdaten.html)

Design of the 10MW Floater

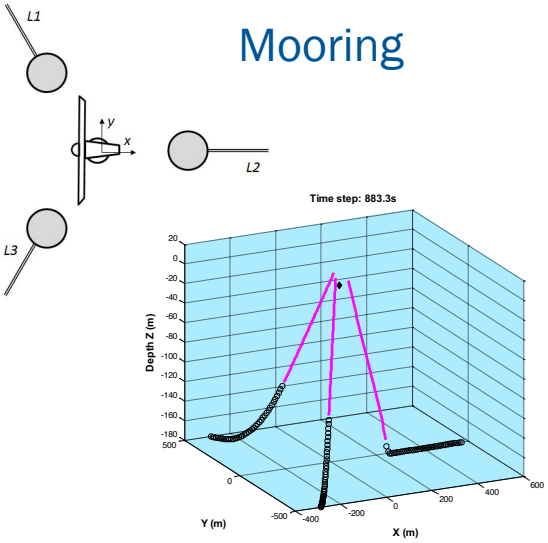
- Detailed analysis of the “Triple Spar” concept:

Concept Design

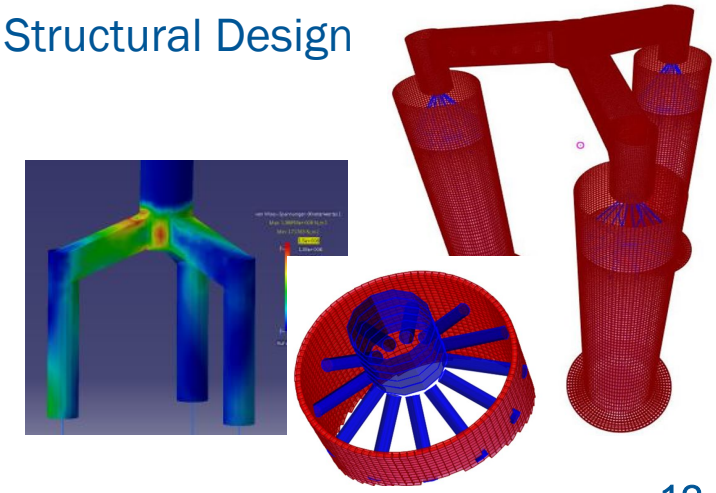
Controller



Mooring



Structural Design



10MW Triple Spar Geometry

Main properties:

Mass	Platform mass	**2.82e7 kg**
	Ballast mass	17 264 t
Main dimensions	Columns length	65 m
	Columns distance to the center	26 m
	Columns diameter	15 m
	Draft	56 m
Cost	Steel price	4 000 €/t
	Concrete price	236 €/t
	Ballast price	70 €/t
	Tripod cost	3.885e6 €
	Total platform cost	**1.029e7 €**

- Natural frequencies out of main wave spectrum energy range
- Design validation based on fully coupled simulations
- Moderate maximum pitch: 8.9°
- Structural design based on extreme loads
- Maximum tensions at mooring lines below breaking limit
- Successful control design for floating concept

Natural frequencies:

DoF	Td [s]	fd [Hz]
Surge	166	0.006
Sway	166	0.006
Heave	16.8	0.059
Roll	25.5	0.039
Pitch	25.5	0.039
Yaw	99.65	0.010

Summary of Outcomes

- Reference and evolutionary designs of 10MW and 20MW RWT models (different foundation concepts).
  - Various concepts studies
  - Hybrid jacket,
  - Reference jacket 10/20MW,
  - Reference floater 10MW
- Life-time extension of wind turbine & support structures as a result of integrating new innovations.
- Conducted experimental setups:
  - Hybrid joints and sandwich materials for the jacket and tower
  - Wave-tank tests for floating 10MW RWT
  - Suction bucket measurements for 10MW mono bucket
- More information on the INNWIND website:
  http://www.innwind.eu/work-packages/work-package-4
- Publications:
- http://www.innwind.eu/publications

Acknowledgment

The research leading to these results has received funding from the European Community's Seventh Framework Programme under grant agreement No.308974 (INNWIND.EU).

Thanks to all active partners within WP4 for their excellent contribution