LIFES50+ project development and results

Petter Andreas Berthelsen – SINTEF Ocean
Project Coordinator

Industry Meets Science
Trondheim, 24 October 2018

Qualification of innovative floating substructures for 10MW wind turbines and water depths greater than 50m

The research leading to these results has received funding from the European Union Horizon2020 programme under the agreement H2020-LCE-2014-1-640741.

LIFES50+ project overview

LIFES50+

Qualification of innovative floating substructures for 10MW wind turbines and water depths greater than 50m

Grant Agreement: H2020-LCE-2014-1-640741

Budget: 7.3 MM€

Start date: 1 June 2015.

End date: 30 April 2019.

Consortium: 12 partners

7 European countries

Project Coordinator: SINTEF Ocean

DTU Technical University of Denmark

University of Stuttgart Germany

POLITECNICO MILANO 1863

SINTEF

RAMBOLL

CATAPULT Offshore Renewable Energy

tecnalia Inspiring Business

DR. TECHN. OLAV OLSEN

nautilus floating solutions

ideol winning solutions for offshore wind

IREC Institut de Recerca en Energia de Catalunya Catalonia Institute for Energy Research

DNV·GL

LIFES50+ project overview

LIFES50+

Objectives:

1. Optimize and qualify to TRL of 5, two (2) innovative substructures designs for 10MW turbines
2. Develop a streamlined and KPI based methodology for the evaluation and qualification process of floating substrucures

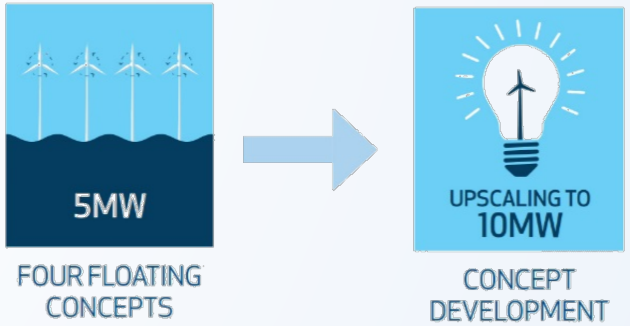
Focus:

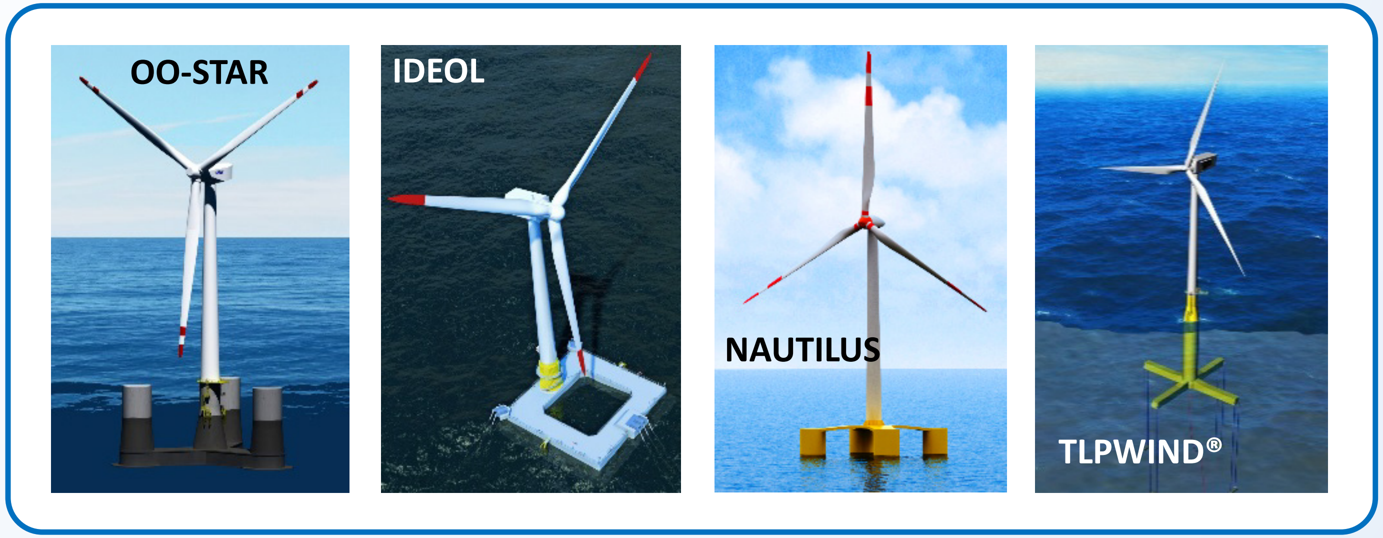
- Floating wind turbines installed in water depths from 50m to 200m
- Offshore wind farms of large wind turbines (10MW) – identified to be the most effective way of reducing cost of energy in short term

Project approach

First stage:

- Concepts design and upscaling
- Concept evaluation





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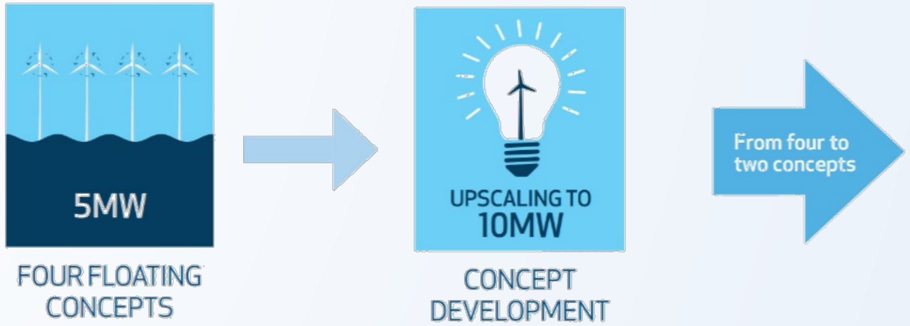

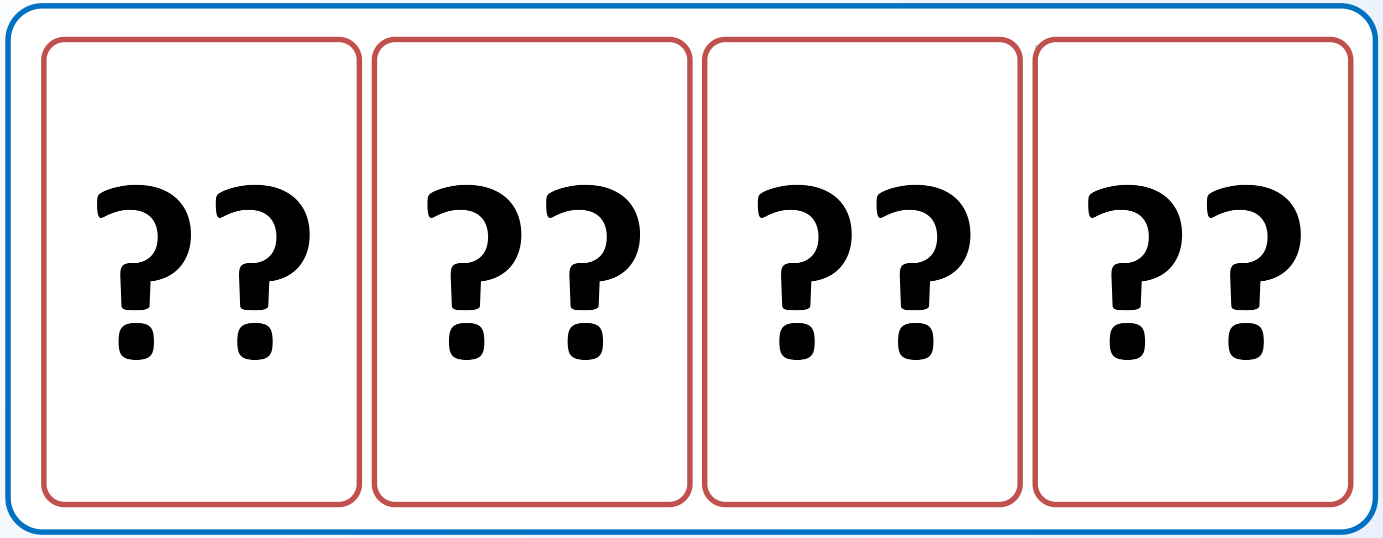

Project approach

First stage:
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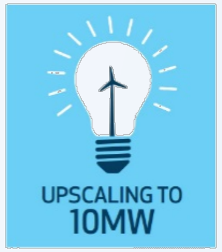
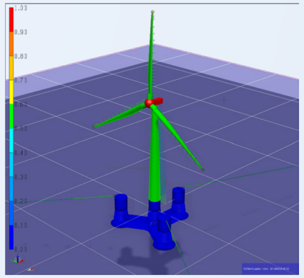
FOUR FLOATING CONCEPTS

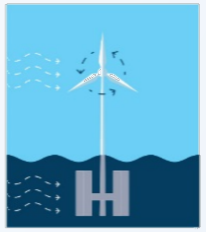


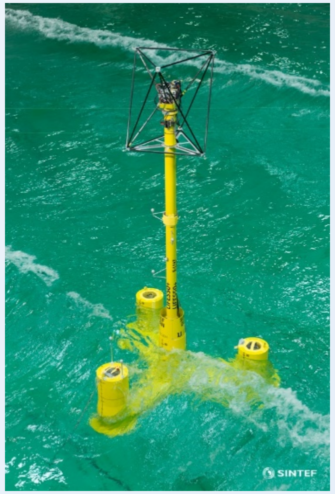
CONCEPT DEVELOPMENT

From four to two concepts



Second stage:
- Numerical modelling and experiments;


EXPERIMENTAL AND NUMERICAL INVESTIGATION



Project approach

First stage:

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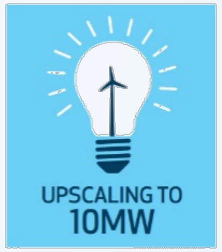
FOUR FLOATING CONCEPTS

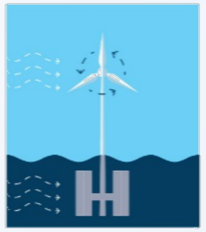


CONCEPT DEVELOPMENT

From four to two concepts

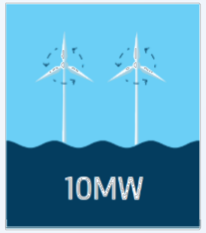
Second stage:

- Numerical modelling and experiments;
- Concept optimization
- Recommended practice and guidelines



EXPERIMENTAL AND NUMERICAL INVESTIGATION

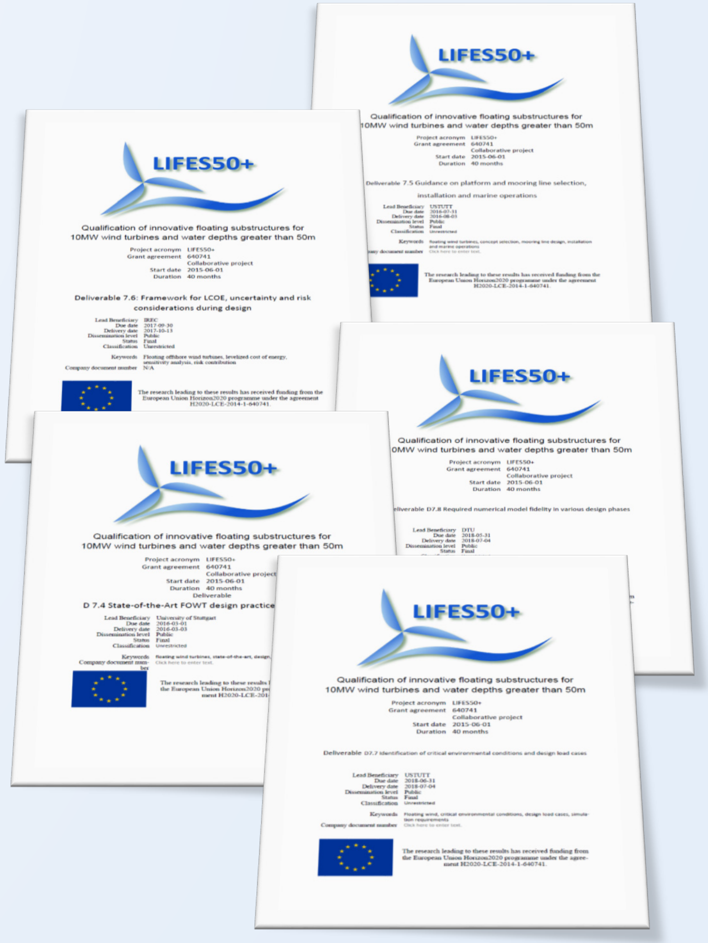
Final



TWO FLOATING CONCEPTS FOR:

- Large wind turbines (10MW)
- Large water depths (>50m)
- TRL 5

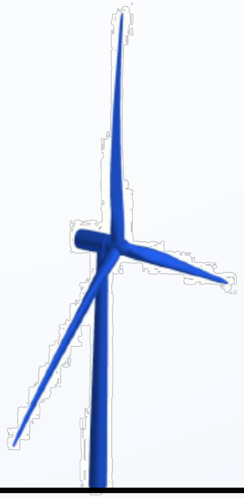
RECOMMENDED PRACTICE AND GUIDELINES



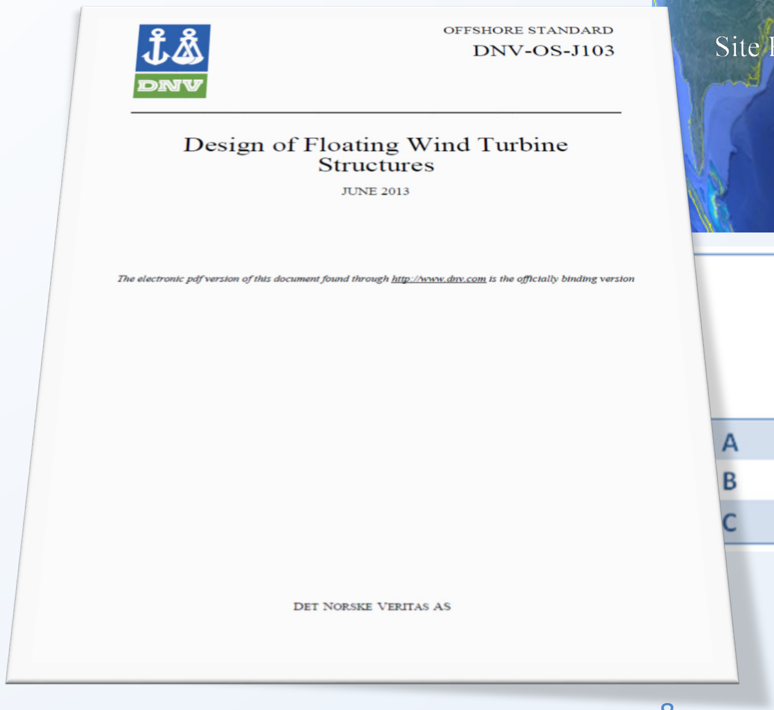
Project development and results: first stage

First stage of the project focused on concepts design & evaluation…

- **Definition of the Design Basis for the concepts design:**
  - Wind Turbine reference model
  - Identification of three sites
  - Design requirements and load cases – DLCs



DTU 10MW Reference Wind Turbine



OFFSHORE STANDARD
DNV-OS-J103

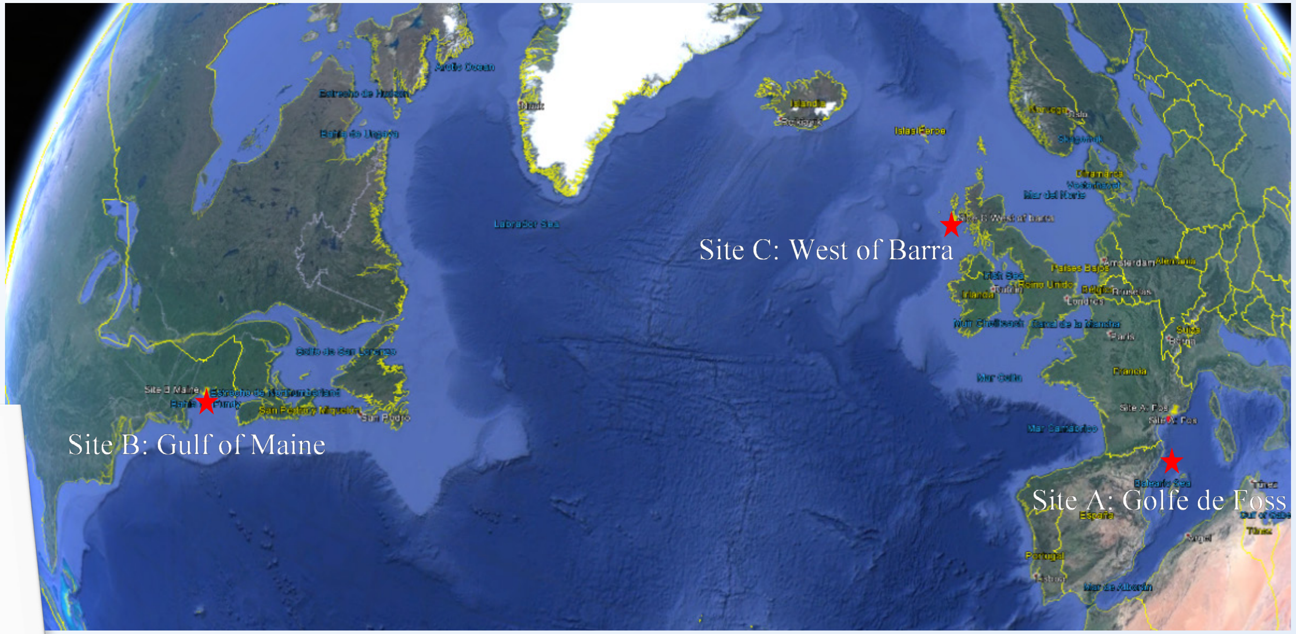
DNV

Design of Floating Wind Turbine Structures

JUNE 2013

The electronic pdf version of this document found through http://www.dnv.com is the officially binding version

DET NORSKE VERITAS AS



	50-year wind at hub height [m/s]	50-year significant wave height [m]	50-year sea-state peak period [s]	50-year current [m/s]	Extreme water level range [m]	Design Depth [m]	Soil Type
A	37	7.5	8-11	0.9	1.13	70	Sand/Clay
B	44	10.9	9-16	1.13	4.3	130	Sand/Clay
C	50	15.6	12-18	1.82	4.2	100	Basalt

Project development and results: first stage

First stage of the project focused on concepts design & evaluation…

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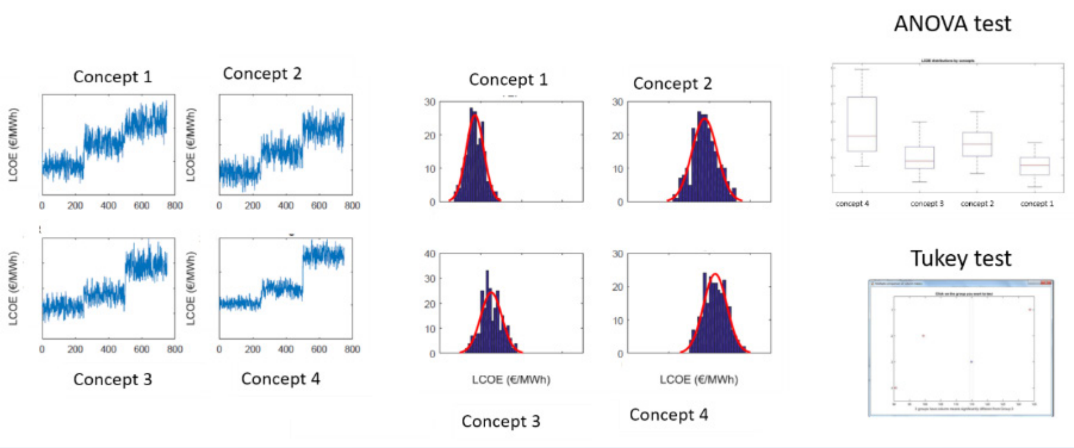
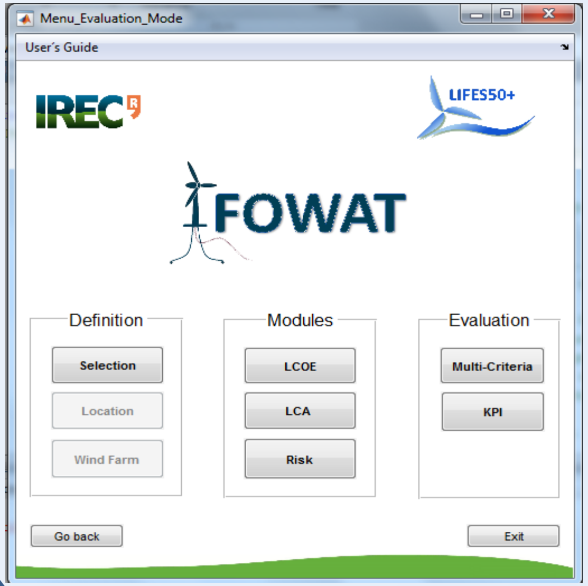
- **Definition of the framework for the concept assessment:**
  - Scope and development of the tools for the LCOE, LCA and risk analysis evaluation
  - Agreement on the evaluation procedure

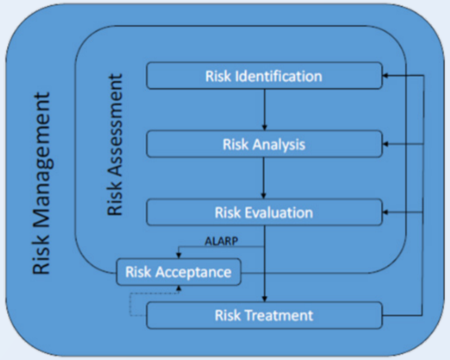




Risk score (20%)

LCA score (10%)

LCOE score (70%)



Project development and results: first stage

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  - Agreement on the evaluation procedure
- **Concepts design**
  - Sizing and structural design, mooring design, aero-hydrodynamic simulations
  - Adaptation of the WT controller
  - Analysis of marine operations, including manufacturing strategy

Design Basis

- Met-ocean condictions - DLCs
- Wind Turbine model, including WTG controller
- Standards
- Design restrictions and assumptions

SW becnhmark

- Definition of the benchmark: Load Cases
- Comparison of model results

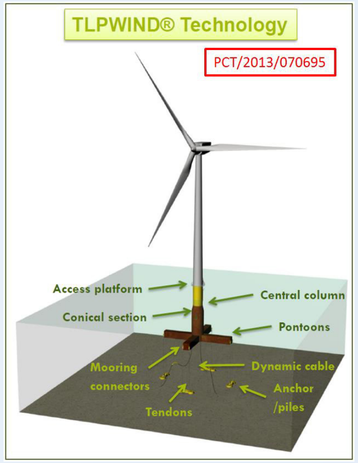
Design Briefs

- Review of the design procedures
- Qualitative assessment of the modelling approach

Concepts Design

- Design for the three sites
- Concept Developer provide figures: KPI, LCOE, LCA
- Evaluation Comittee review results and provide feedback
- Design summary collected in D1.3 to D1.5 deliverables

Evaluation Workshop and selection of concepts



Workshop hosted by IREC in Barcelona, 08-10 March 2017.

Evaluation Workshop and selection of concepts

LIFES50+

Workshop hosted by IREC in Barcelona, 08-10 March 2017.

END OF STAGE 1 …

- Concept design
- Concept assessment

… START OF STAGE 2

- Experimental and numerical investigation
- Concept optimization
- Recommended practice and guidelines

Public models

Public definition of selected floater concepts for the 10MW DTU wind turbine

- Public deliverable with the description of NAUTILUS steel semisubmersible and Olav Olsen concrete semisubmersible models for a 10MW wind turbine.
- FAST numerical models available on the project web site and DTU's repository.

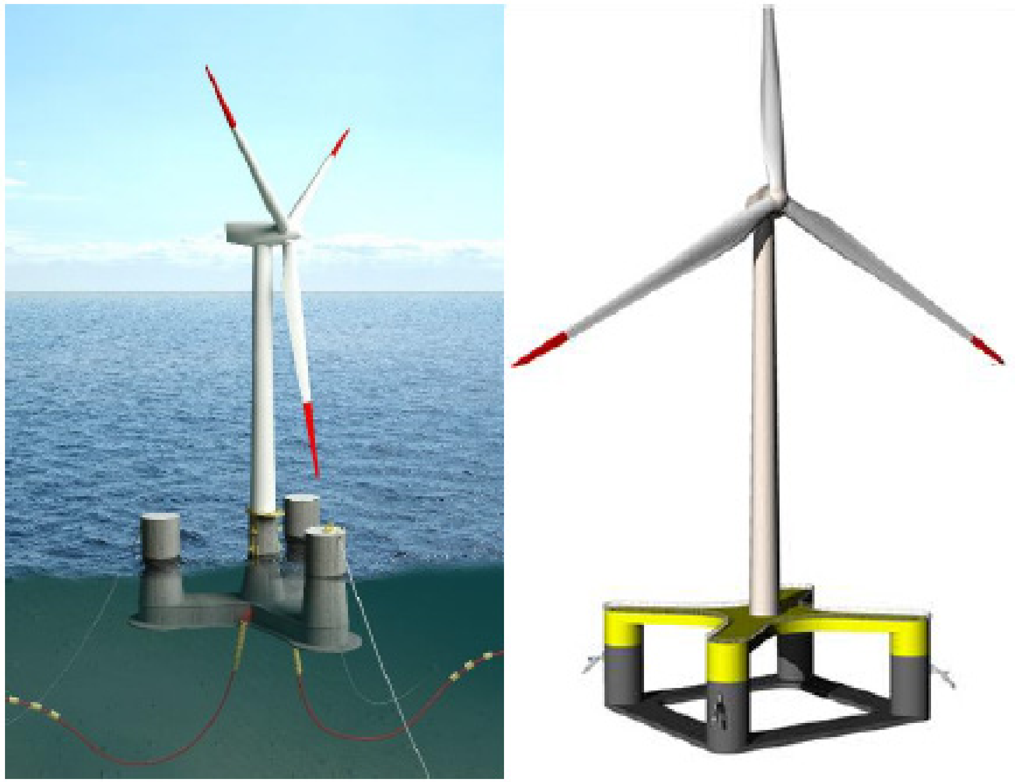


Figure 2: The OO-Star Semi floater (left) and the Nautilus floater (right). Figures provided by Dr.techn. Olav Olsen AS and Nautilus Floating Solutions, respectively.

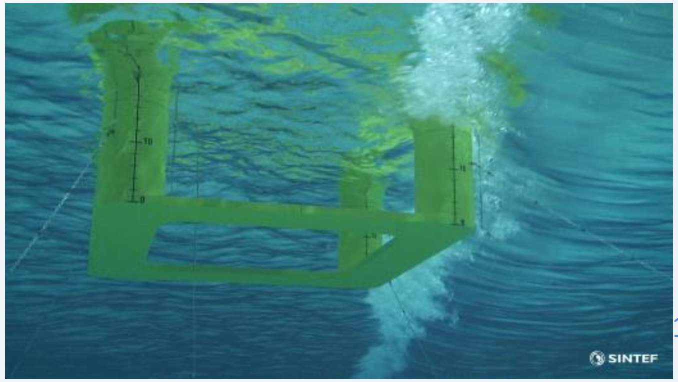
Wave tank experiments

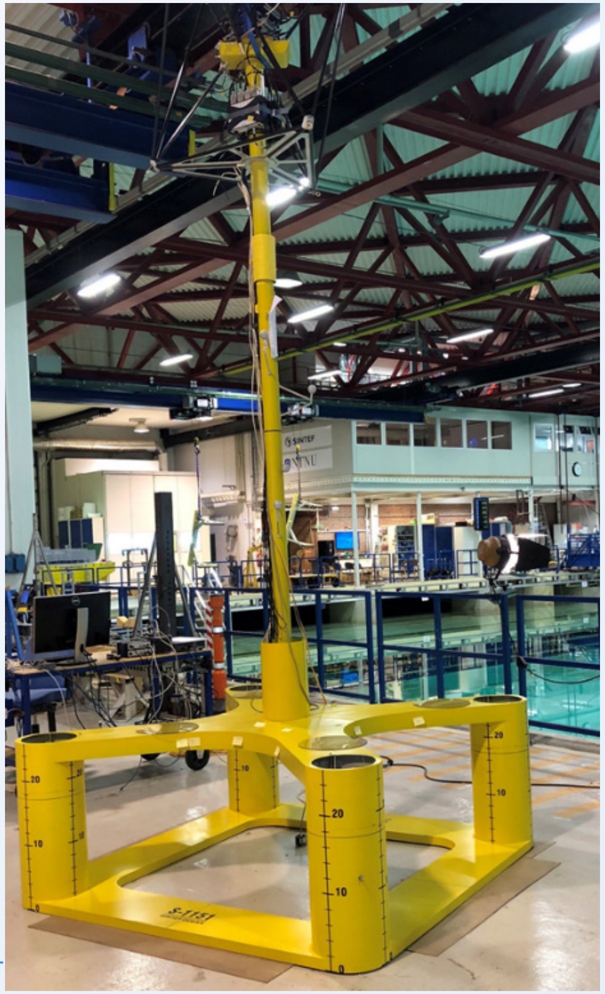
First step: scale models (1:36) preparation for Olav Olsen's OOstar and NAUTILUS semisubmersible concepts.

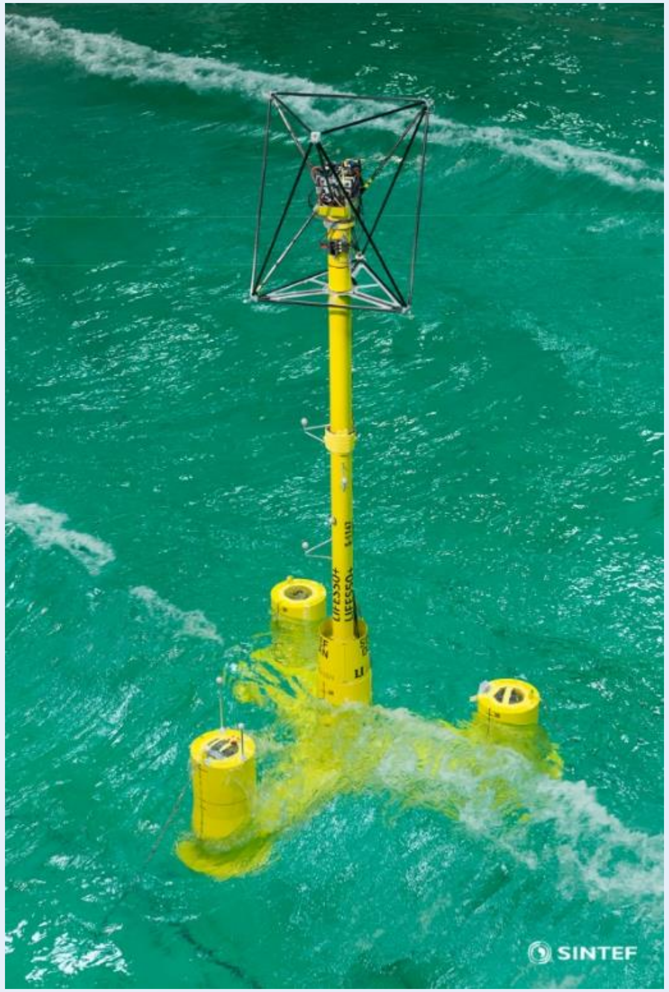
Numerical model adaptation for the Real-Time Hybrid Model testing (ReaTHM® testing) to generate realistic and controlled aerodynamic loads.

Load cases for the experiments.

- inclining tests,
- pullout tests,
- decay tests,
- pink noise (white noise) wave spectrum tests and regular wave,
- wind only tests,
- irregular wave tests, with/without wind, with/without current.





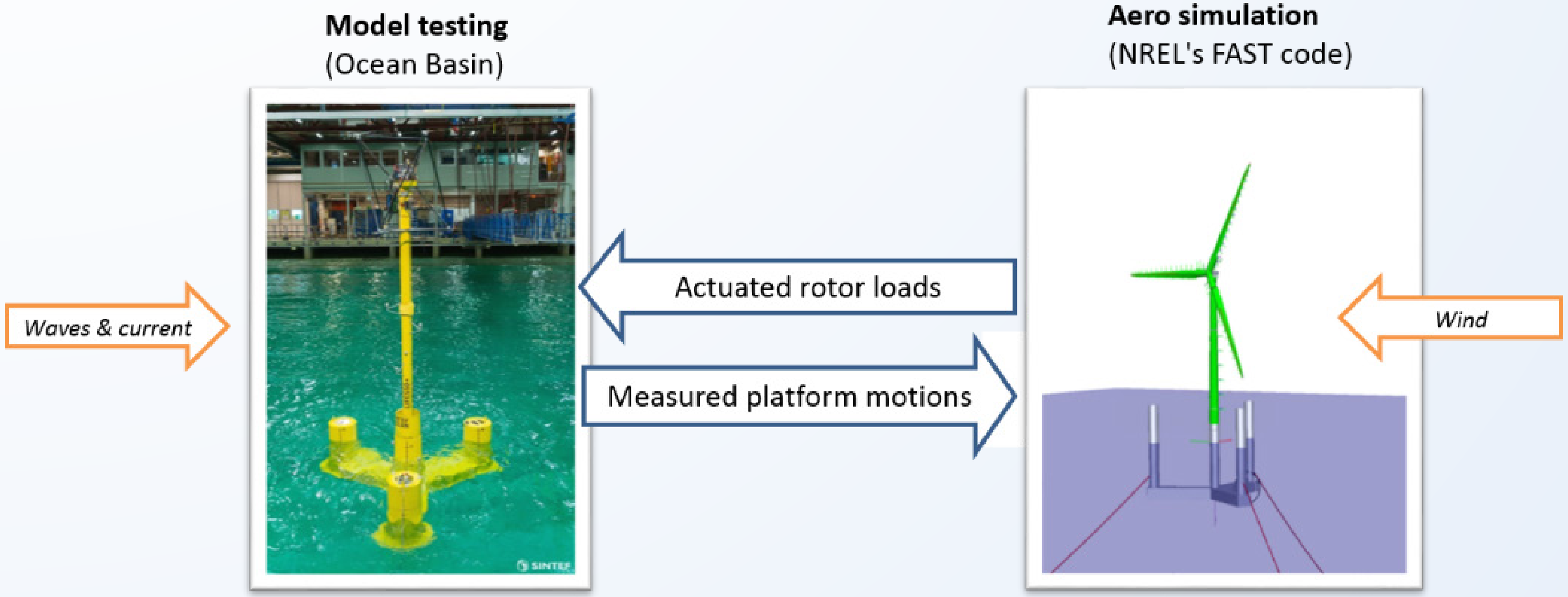


Experiments preparation

Wave Tank

Develop Real-Time Hybrid Model testing (Hardware in the Loop) for floating wind turbines:

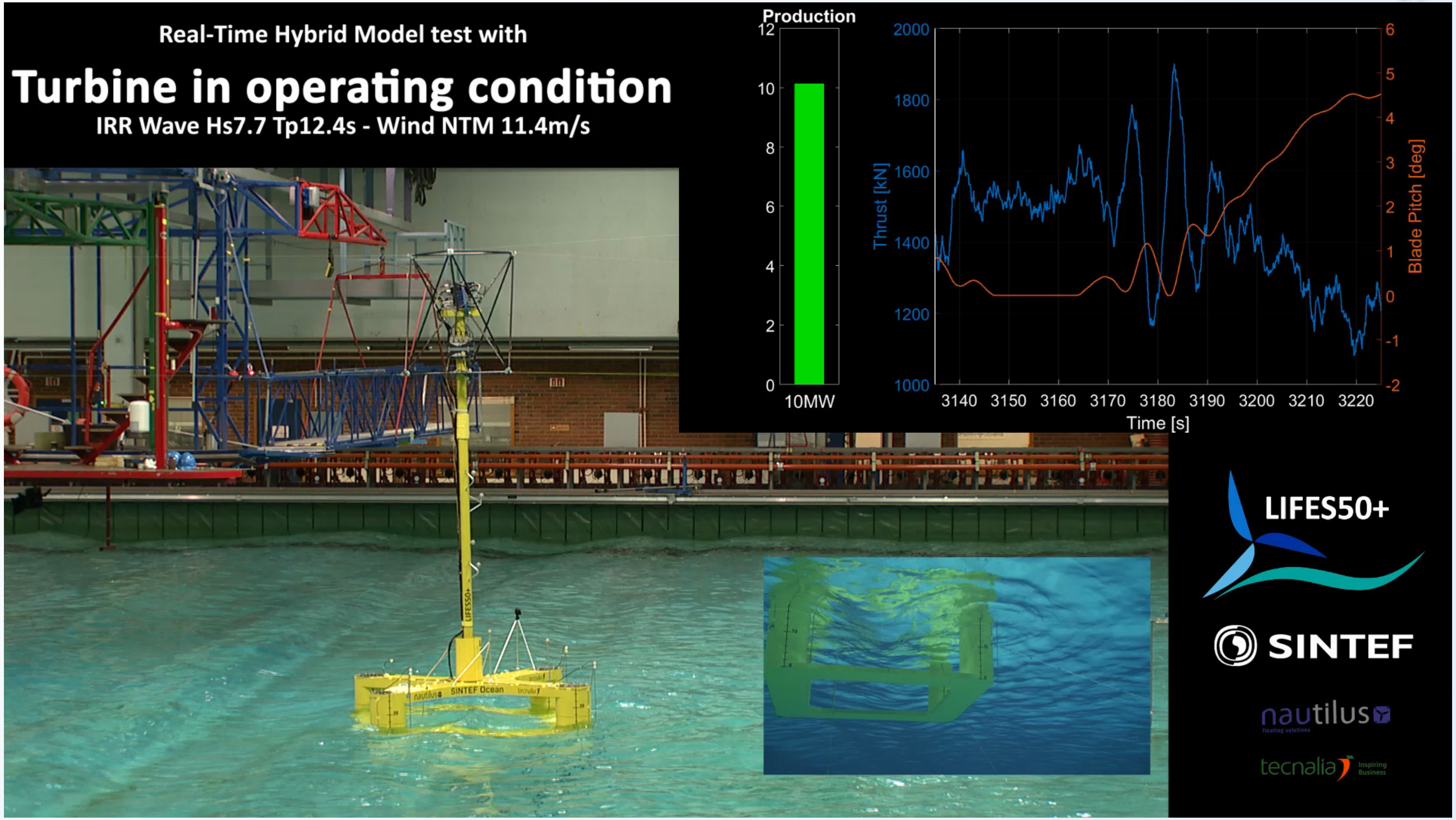
- Controlled environment
- Flexibility
- Overcome Froude-Reynolds scaling issues



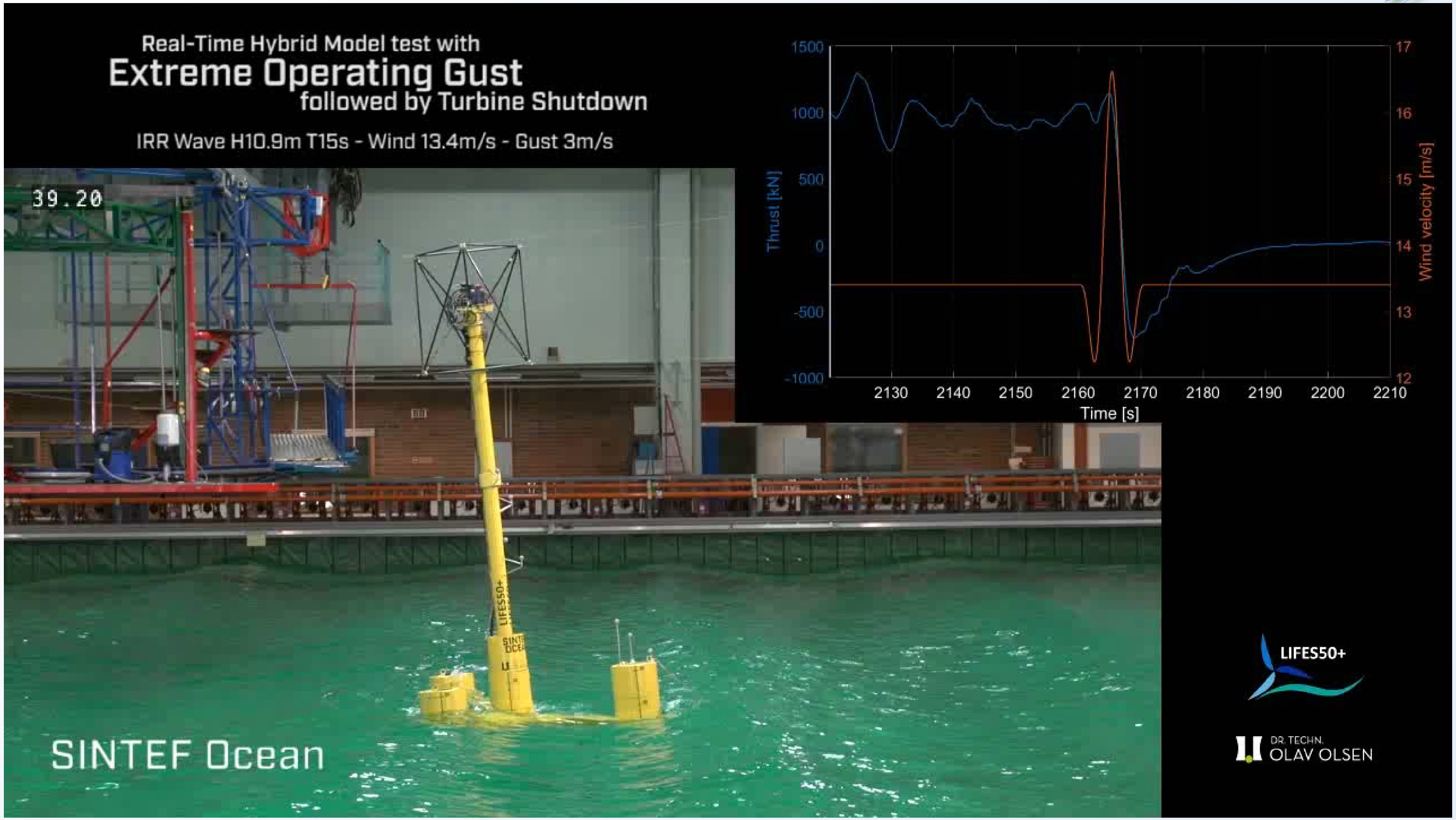
Physical model in ocean basin with physical waves coupled in real-time to aerodynamics simulations (FAST).

The aero loads are applied on the model by use of actuators and the position of the model is measured in the basin and used as input to the numerical simulations.

Ocean Basin Tests



Ocean Basin Tests

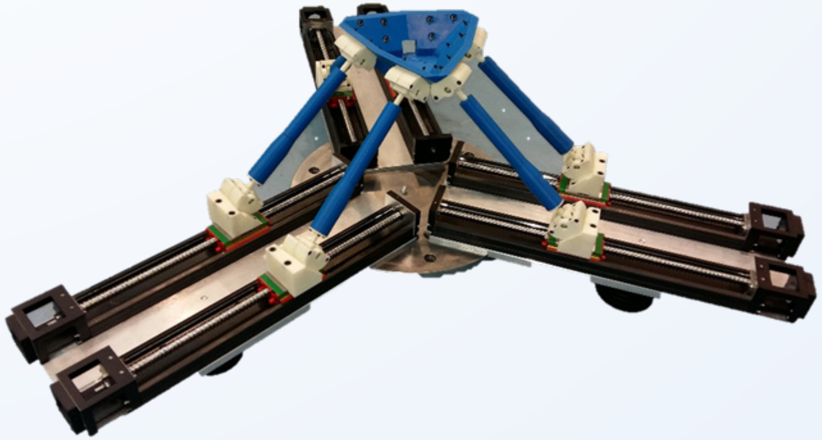


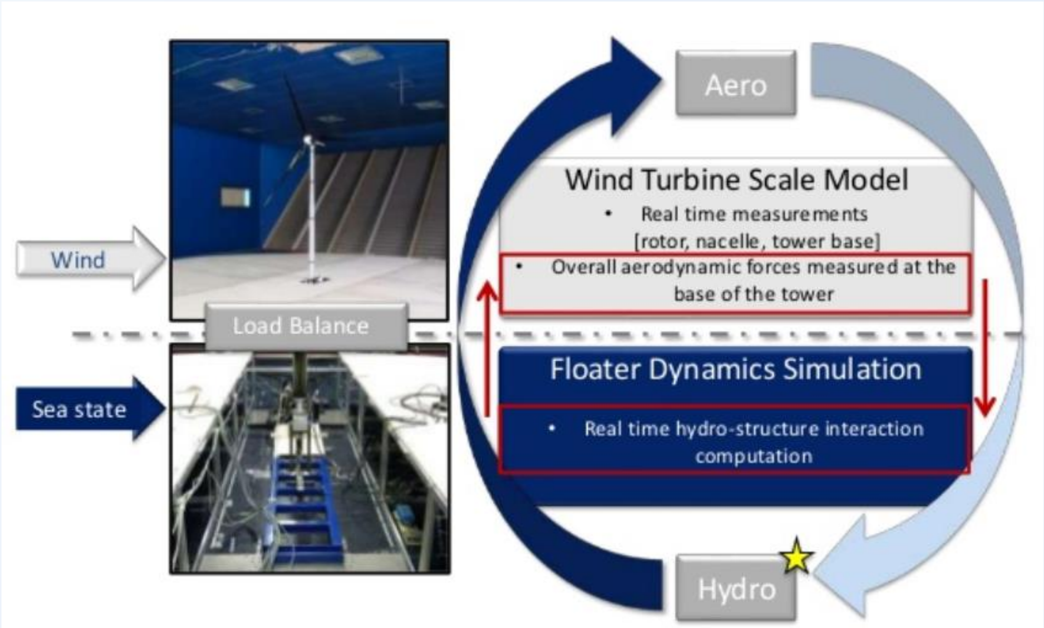
Experiments preparation

Wind Tunnel

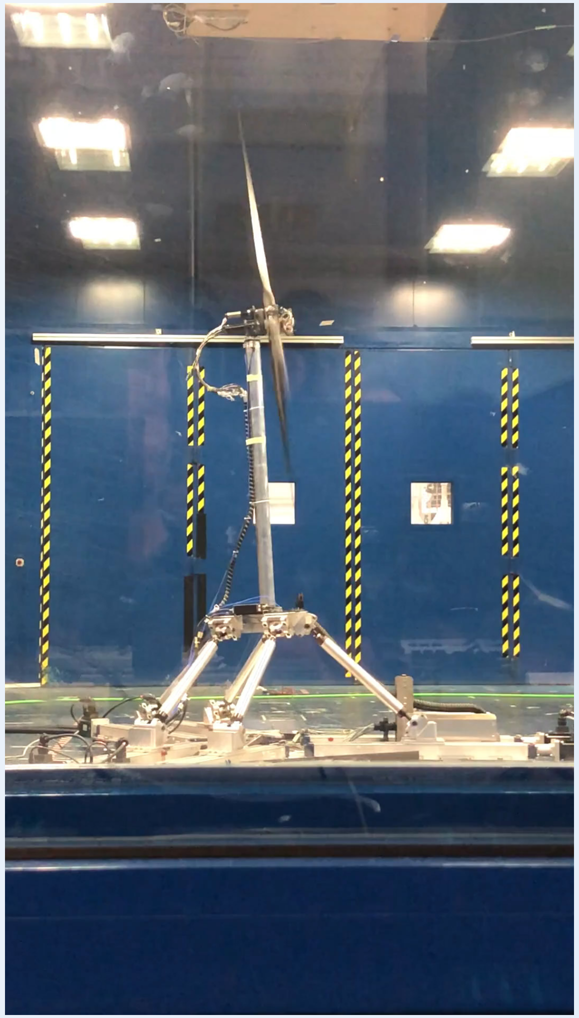
Physical wind and wind turbine connected in real time to numerical hydrodynamic simulator.

A 6DOF robot at the tower base imposes the simulated platform motions. The loads at base of tower measured in the wind tunnel are used as input to the numerical simulations. The output of the simulations is the floater position.



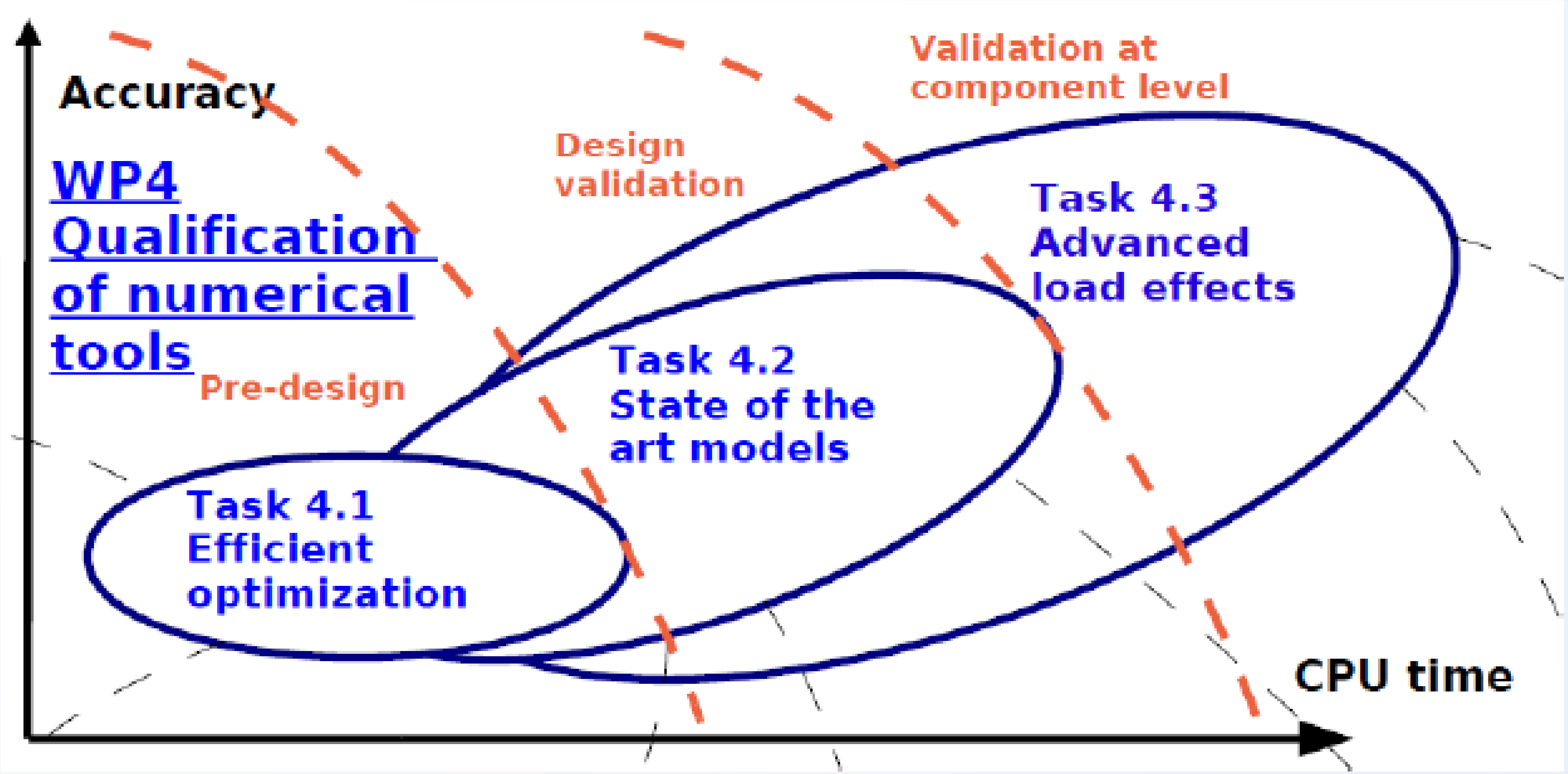


Wind tunnel tests



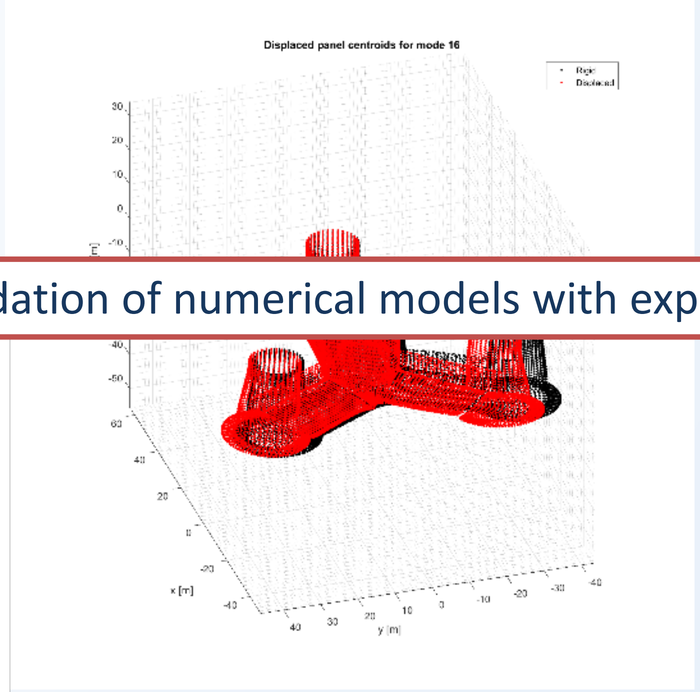
Numerical modelling

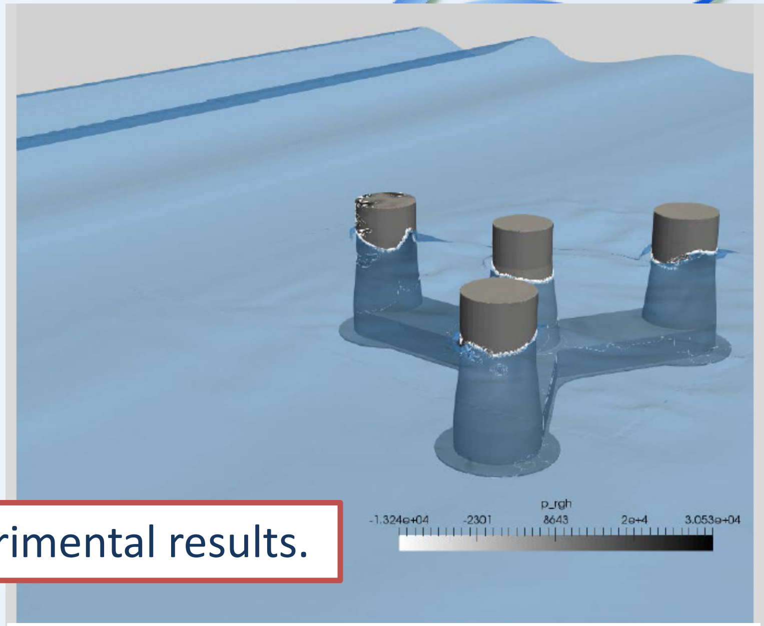
Research on advanced numerical modelling.



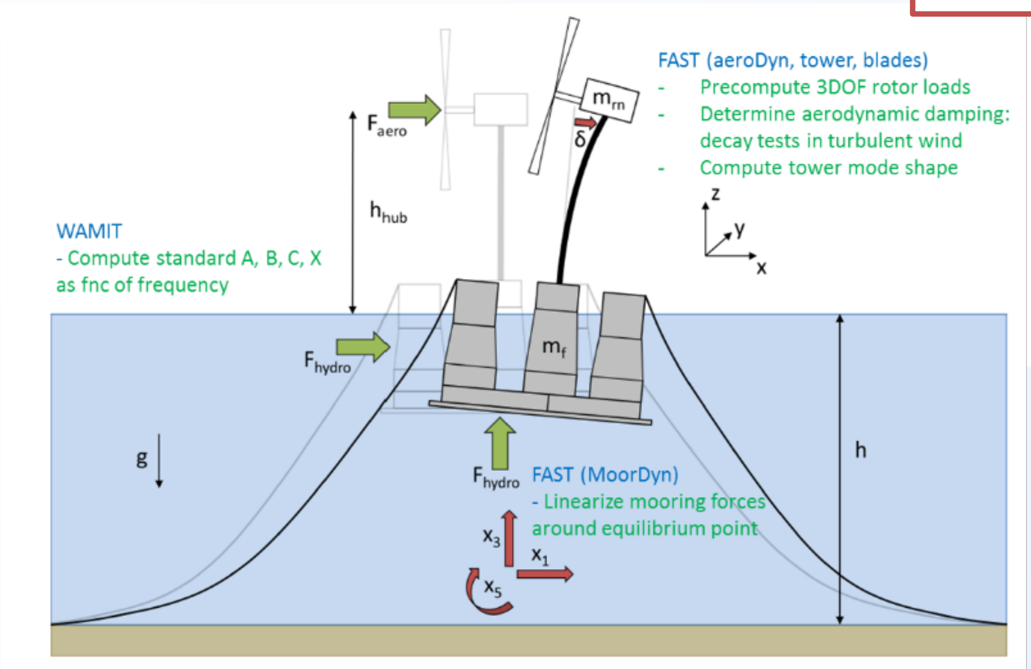
Numerical modelling

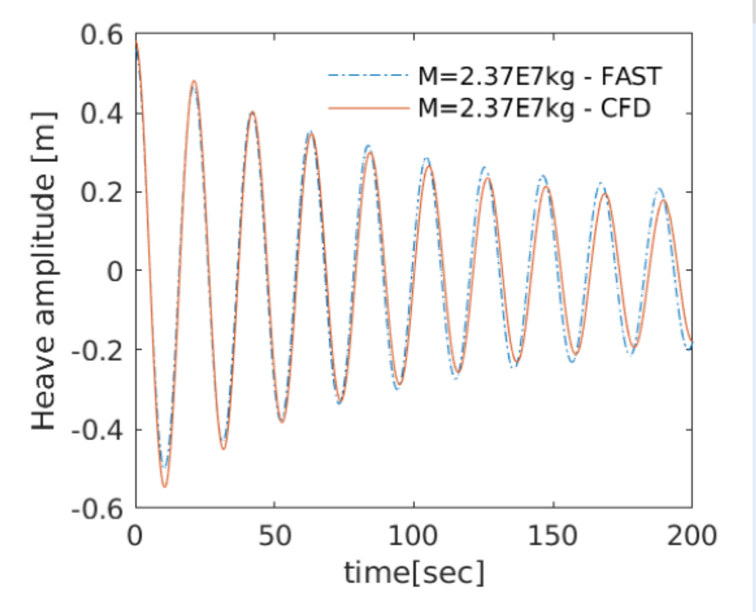
- Modelling of floater flexibility and second order forcing
- Hydrodynamic CFD analysis
- QuLAF accelerated frequency domain model
    - Accelerated model is ~1500 times faster than mother model





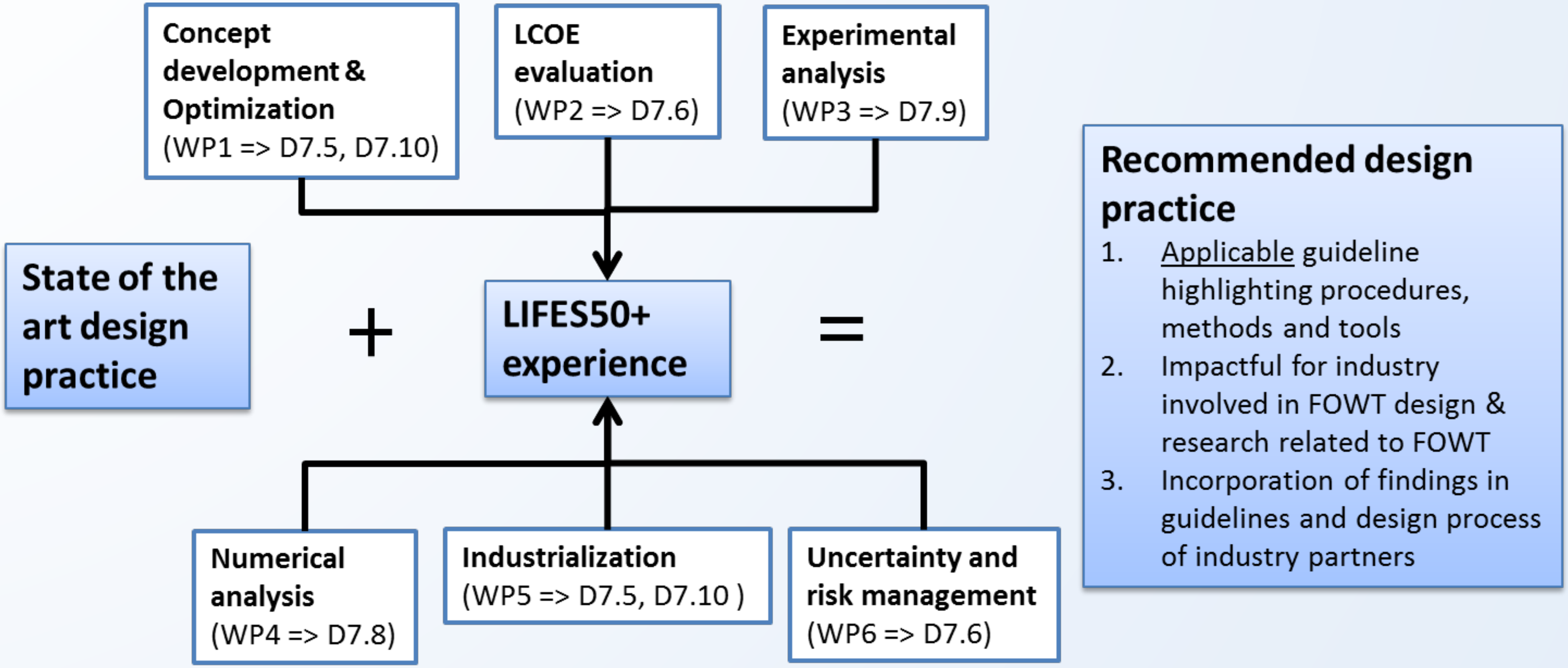
Validation of numerical models with experimental results.





Design Practices

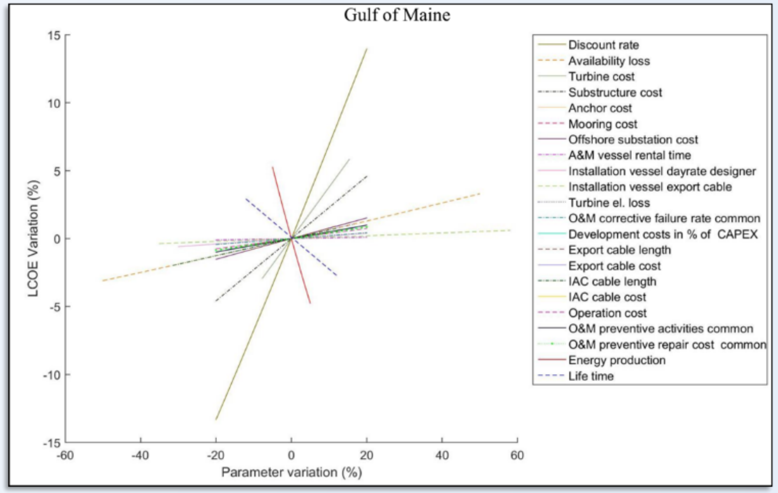
The aim it to develop recommended practices for FOWT design based on the state of the art and the project achievements in the design, modelling and experimental validation of the concepts.



Design Practices

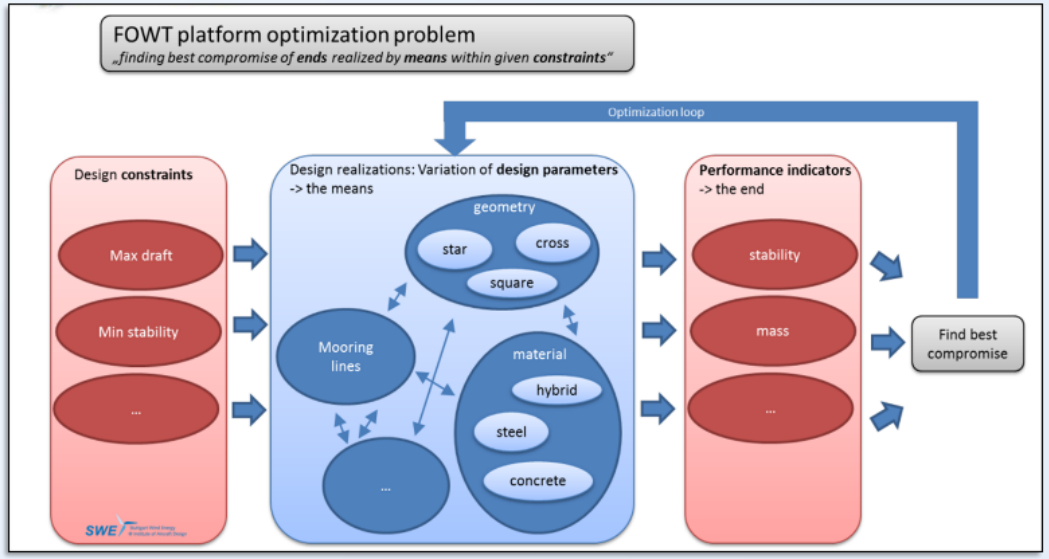
Several activities focused on the development of design practices for FOWT

- **Framework for LCOE, Uncertainty and risk consideration during design**
- **Identification of critical environmental condition and design loads cases**
- **Required numerical model fidelity and critical design load cases in various design**
- **Guidance on platform and mooring line selection, installation and marine operations**



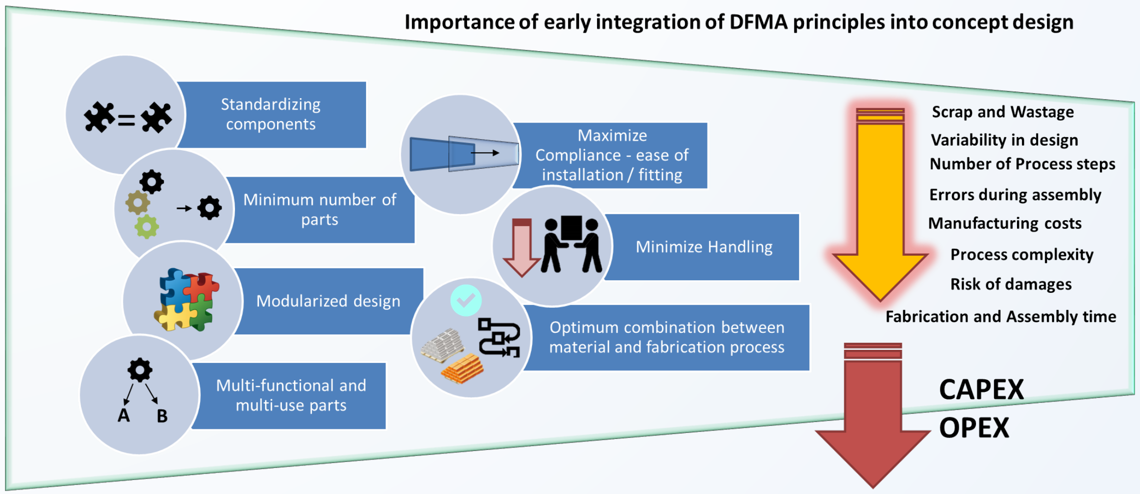
In preparation:

- Guidance and recommended methods for experimental testing
- Recommendation for platform design under consideration of O&M, logistics, manufacturing and decommissioning

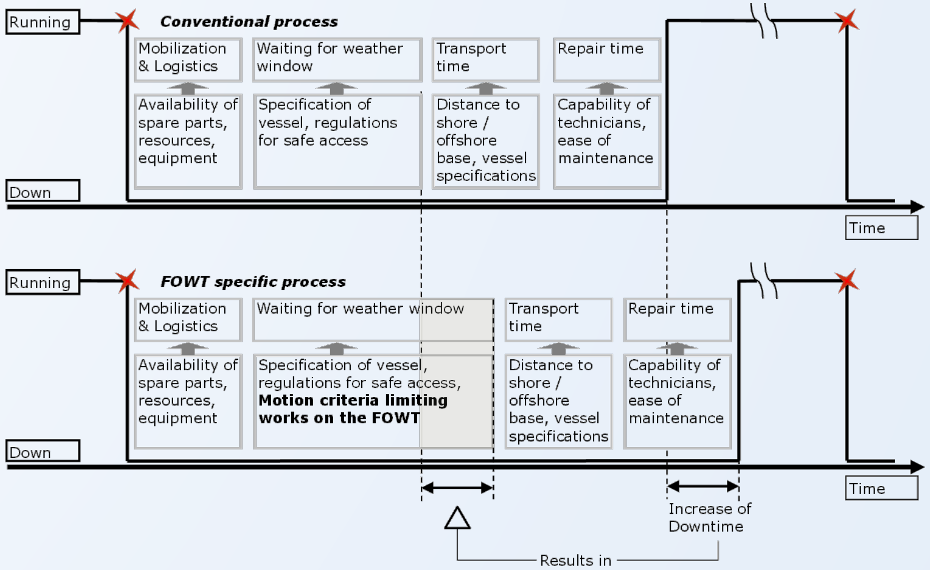


Next steps

- Industrialization, concepts design optimization and LCOE, LCA figures update



Workability study for FOWT O&M



- Final project workshop to present the results during WindEurope 2019 conference (2-4 April 2019, Bilbao)

Summary of results and dissemination

68 deliverables, 39 of them being public, including numerical models of the two selected floaters and DTU's 10 MW wind turbine. Public deliverables available on the project web site.

More than 80 dissemination activities carried out so far including:

- Posters and presentations in conferences
- Articles in different types of journals
- Project newsletter on the web site
- Workshop to present project results –wave tank-
- Press releases
- Youtube video
- … and much more coming soon!!

www.lifes50plus.eu

Concept development and optimization

Upscale innovative floating substructure concepts to a 10 MW wind turbine for water depths greater than 50 meters. During the process several reports regarding oceanographic and meteorological conditions for the design, wind turbine models for the design, concept design, wind turbine controller adapted to each concept, report on marine operations, up-scaling procedures, information for concepts evaluation and concept design optimization will be produced.

- Deliverable 1.1 Oceanographic and meteorological conditions for the design (Summary)
- Deliverable 1.2 Wind turbine models for the design (Summary)
- Deliverable 1.6 Upscaling procedures (Summary)

Experimental studies

This work package verifies the feasibility, safety, and performance of two selected substructures out of the four designed in the first work package. The reliability of existing techniques for floating offshore wind turbines will be increased. During the experiments the numerical models will be calibrated. Moreover, this work package works out how wind tunnel and ocean basin tests can be combined in an optimal way to validate substructure concepts efficiently and more accurately than today.

- Deliverable 3.1 AeroDyn validated model (Summary)
- Deliverable 3.2 Wind turbine scaled model (Summary)
- Deliverable 3.5 Hexafloat robot (Summary)

Design practice

This work package will scrutinize, examine and summarize the process and activities of all work packages related to design questions throughout the entire project to develop a recommended (industry-) design practice (RDP) for the design and qualification of large FOWT substructures to support the innovative process of the technology by creating a document to guide the reader through the design. In order to fulfill that objective, initially a review of existing design practice and guidelines for floating offshore wind turbine substructures will be performed. Additionally, relevant information, lessons learned, key findings and new knowledge generated within all design related work packages will be continuously analyzed at important milestones of the other work packages.

- Deliverable 7.1 Review of FOWT guidelines and design practice (Summary)
- Deliverable 7.2 Design basis (Summary)
- Deliverable 7.4 State-of-the-Art FOWT design practice and guidelines (Summary)
- Deliverable 7.5 Guidance on platform and mooring line selection, installation and marine operations (Summary)
- Deliverable 7.6 Framework for LCOE, uncertainty and risk considerations during design (Summary)
- Deliverable 7.7 Identification of critical environmental conditions and design load cases (Summary)
- Deliverable 7.8 Required numerical model fidelity and critical design load cases in various design phases (Summary)

Qualification of numerical tools

The work package focuses on the qualification of numerical models and their rational use in design optimization and design verification. A multi-fidelity approach is utilized, centered around state-of-the-art aero-elastic modelling which is nowadays used for design verification; simpler, efficient models which are turned into an optimizing pre-design tool, and advanced models at component level that predict physical load effects associated with large floaters beyond state-of-the-art. Schematically, these three levels of models are placed along the diagonal in the accuracy-CPU time diagram and the work package focuses on the increased efficiency of and accuracy potential associated with the combination and validation at models at all levels.

- Deliverable 4.1 Simple numerical models for upscaled design
- Deliverable 4.2 Public definition of the two LIFES50+ 10 MW floater concepts (Summary)
- Deliverable 4.3 Optimization framework and methodology for optimized floater design (Summary)
- Deliverable 4.4 Overview of the numerical models used in the consortium and their qualification (Summary)
- Deliverable 4.5 Public definition of the two LIFES50+ 10 MW floater concepts (Summary)
- Deliverable 4.7 Models for advanced load effects and loads at component level (Summary)

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LIFES50+

THANK YOU!

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