MAJOR OPPORTUNITIES FOR CONCRETE STRUCTURES TO SUPPORT LARGE WIND TURBINES

INNOVATIONS IN CONCRETE SUPPORT STRUCTURES FOR OFFSHORE WIND TURBINES

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- Offshore wind energy is important

- Offshore wind energy structures require marine structures

- Concrete has proven well suited for marine structures

- Marine concrete structures have some peculiarities that need to be addressed
    - Loading
    - Design
    - Construction

- We know how to deal with these peculiarities fib CEB-FIP

Floating concrete structures

Contents

International Federation for Structural Concrete
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www.fib-international.org

Floating concrete structures

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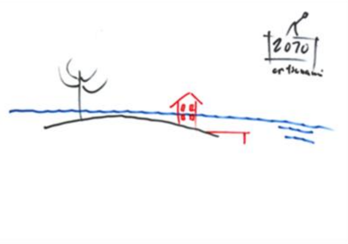
Bulletin 91

Floating concrete structures

State-of-the-art report

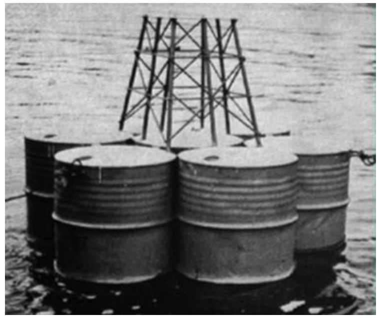
The Bulletin 91 identifies 12 areas of potential useful applications:

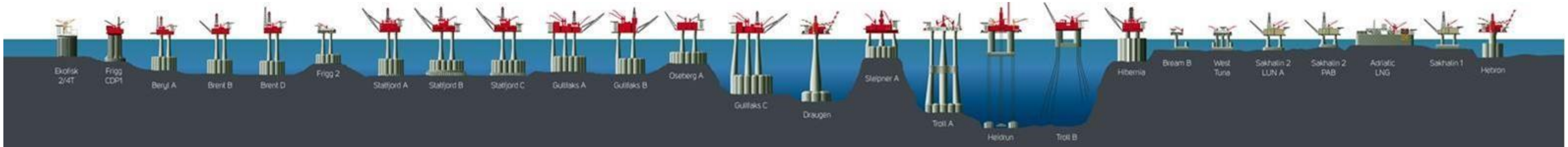
- Food production
- Infrastructure
- Energy
- Environment
- Dwellings and urban development
- Nearshore industrial development
- Offshore industrial development
- Storage
- Vessels
- Recreation
- Aid in catastrophes
- Military actions



There may be more. Note that several of these relate to environmental issues.

MARINE STRUCTURES FOR OIL & GAS DURING 50 YEARS





World-leading competence in design of marine concrete structures for the Oil & Gas industry

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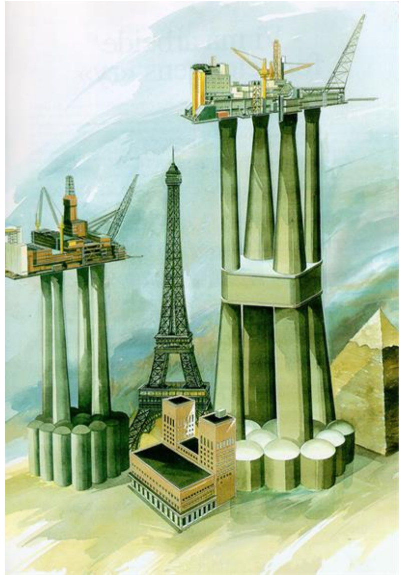
Challenging gravity; the beauty of buoyancy



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CONSTRUCTION

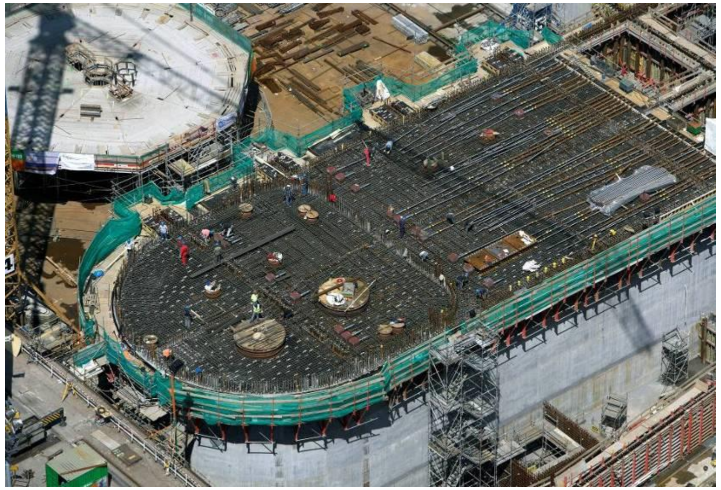
Large structures need a graving dock, to build at least a part of the structure. This graving dock requires space and represents a major cost.

For smaller structures there are alternative ways of construction:

- On a dock, with subsequent wheeling to a barge for submergence
- On a dock, for subsequent lift out by a crane, floating or land based
- In a ship dry dock, or floating dry dock
- On a barge for subsequent submergence
- Built by elements lifted together by crane
- Built by purpose-built structures

Obviously, the facility of the contractor is important, for the execution of the project, and also for the design. Therefore, integration of design and construction is important.

Offshore Concrete Stuctures – Relevant Construction Experience



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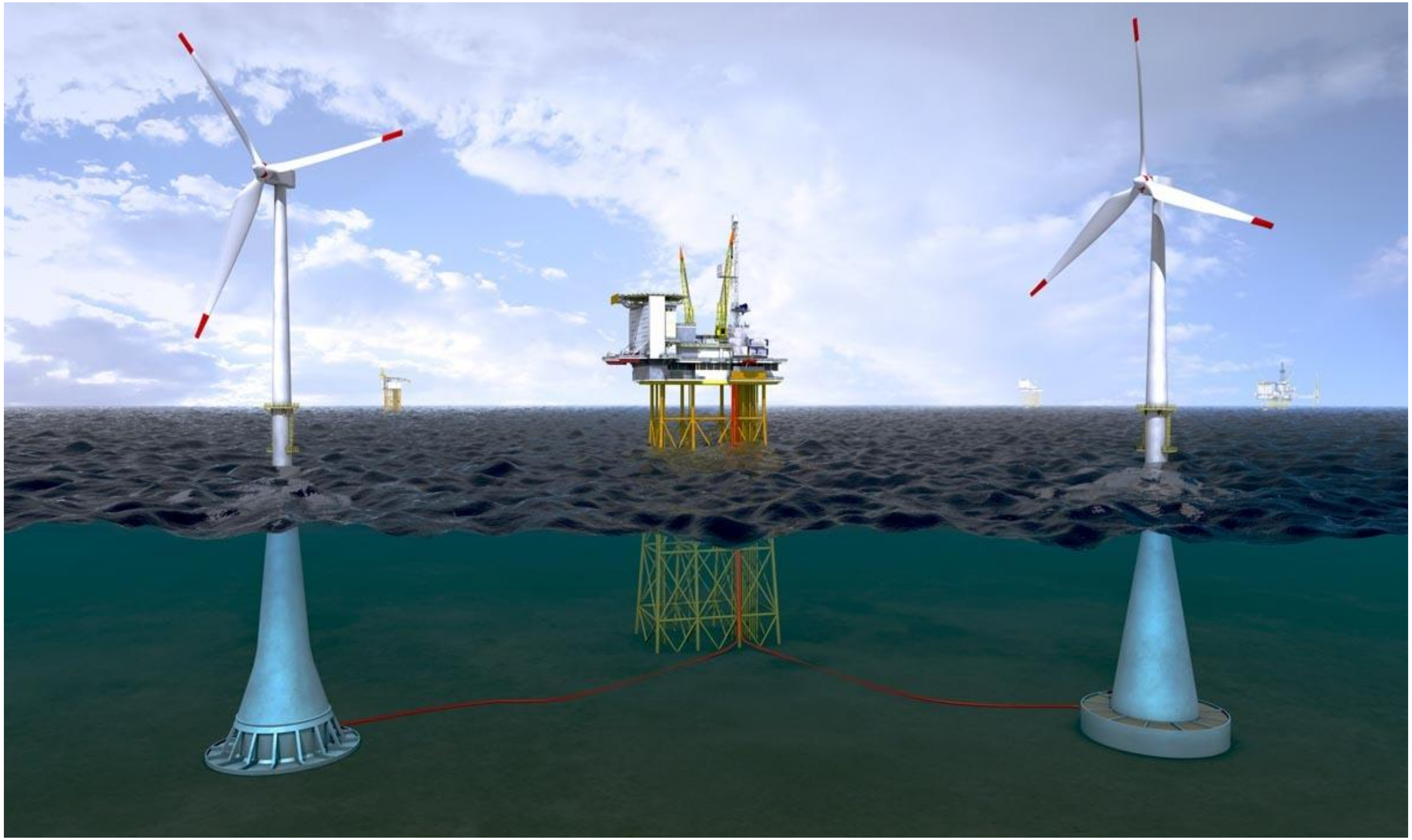
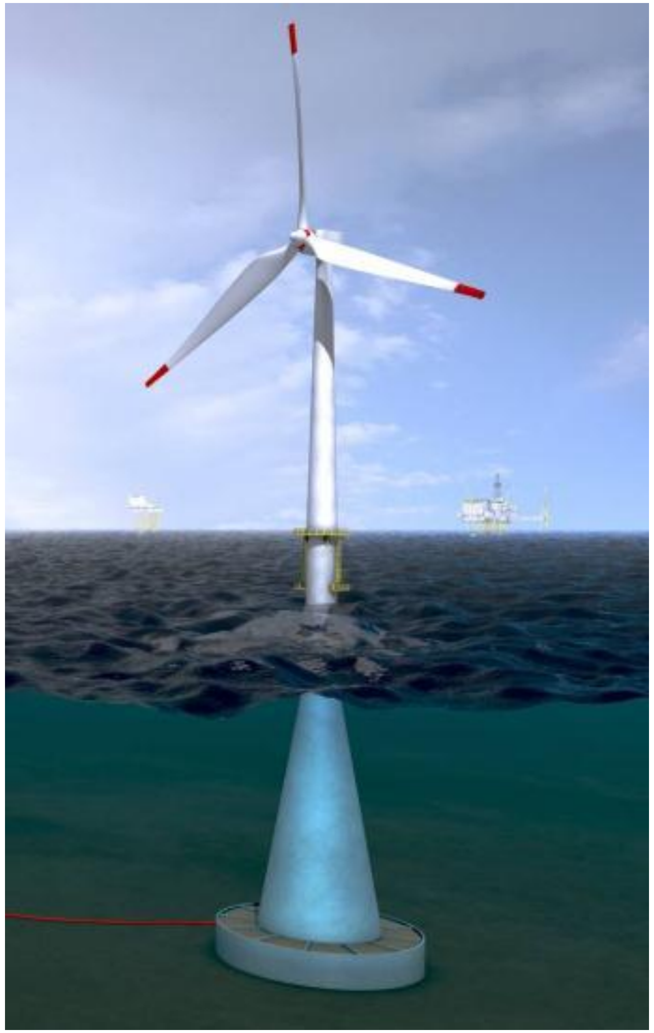


OLAV OLSEN - CONCRETE FOUNDATIONS - GBS

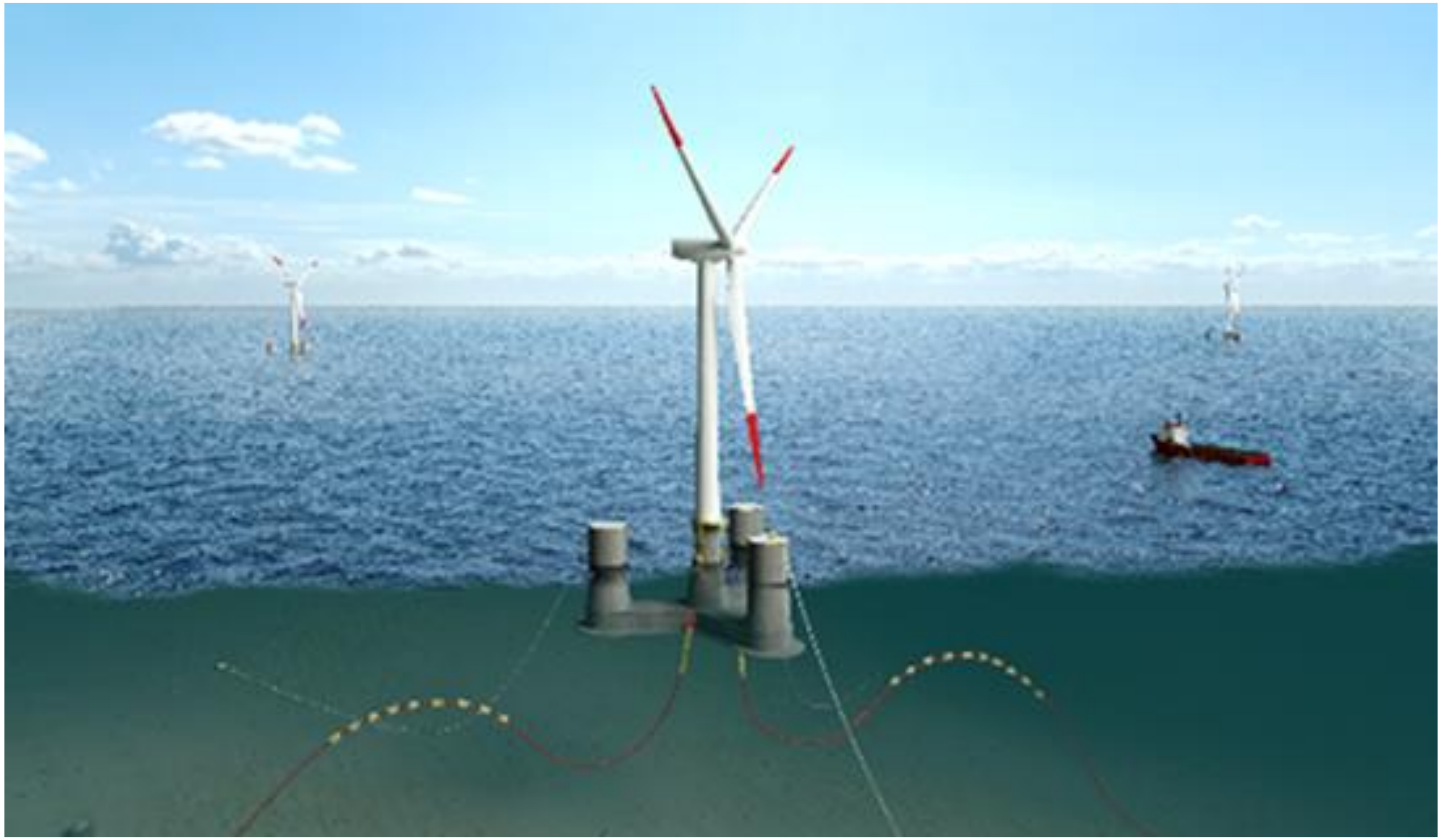


Simple and robust

- For water depths up to 100 m +
- Inshore completion and testing
- Self floating, no offshore heavy lifting
- Firm or soft soil
- Optimal stiffness and dynamic characteristics
- Not fatigue sensitive
- Maintenance free
- Long design life, 100 years +
- Can support new turbines in the future

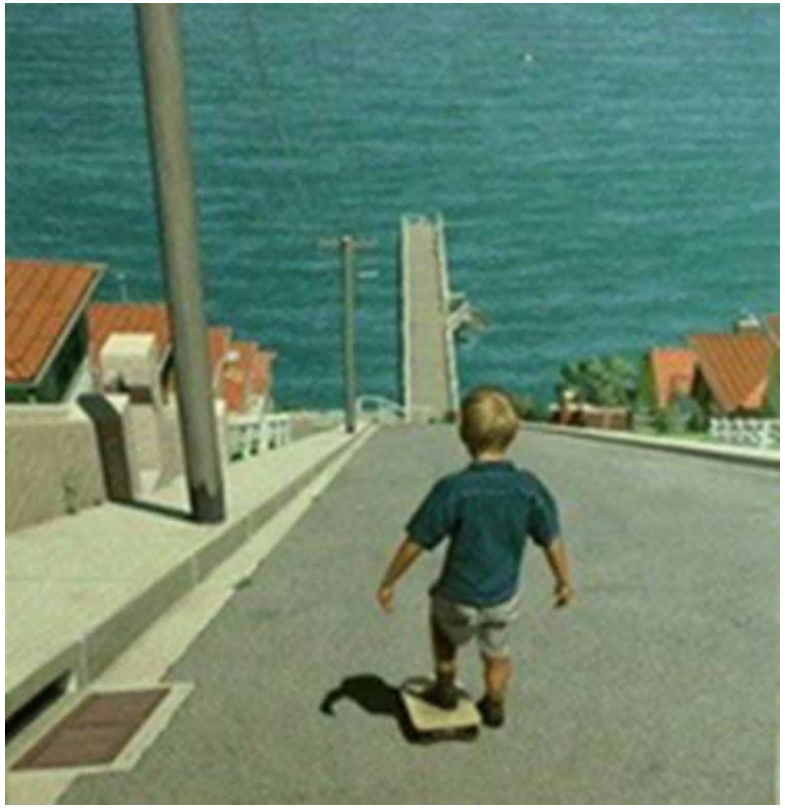
Marine environment friendly

- No piling
- No anchors
- Not sensitive to boulders below seabed




SINTEF

Design



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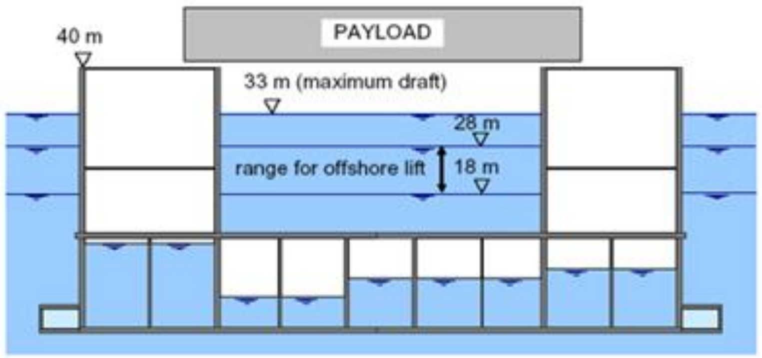

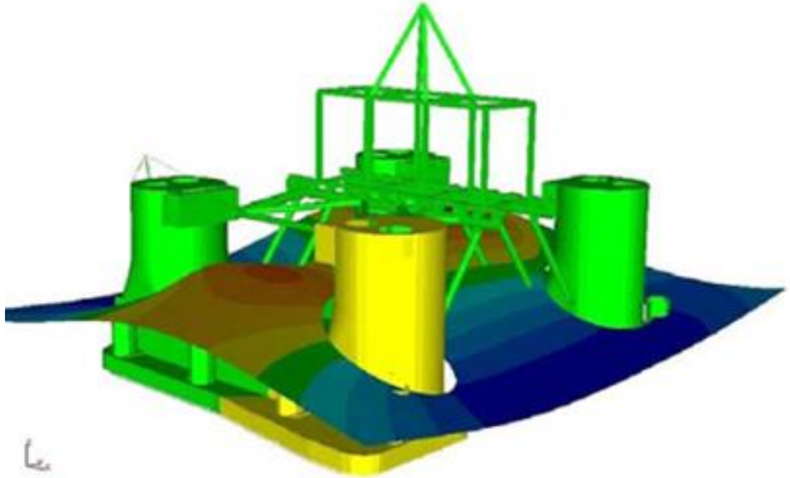

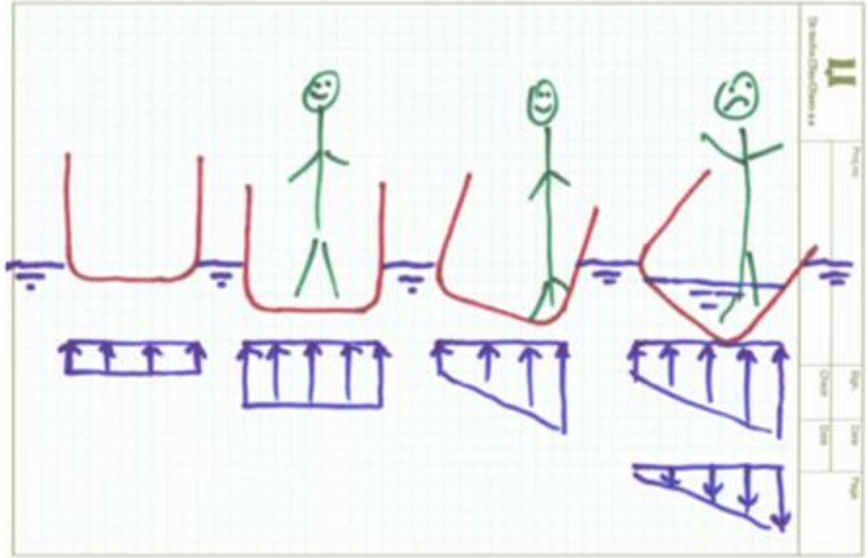

- Weights (self weight and live load)
- Hydrostatic pressures (External and internal)
- Payload (results from time-domain analysis applied as static loads),
- Post-tensioning,
- Design wave pressures
- Acceleration (inertial forces).

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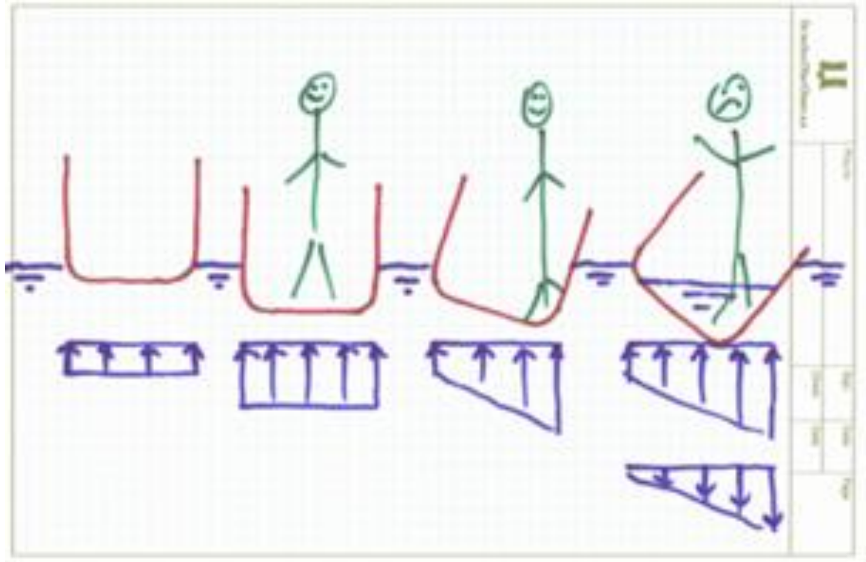

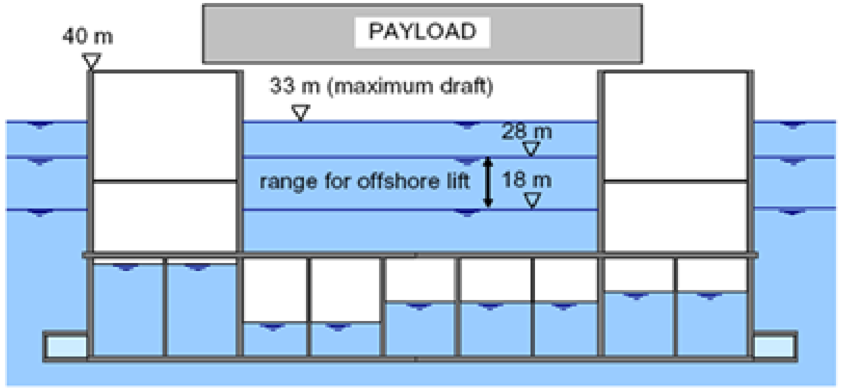

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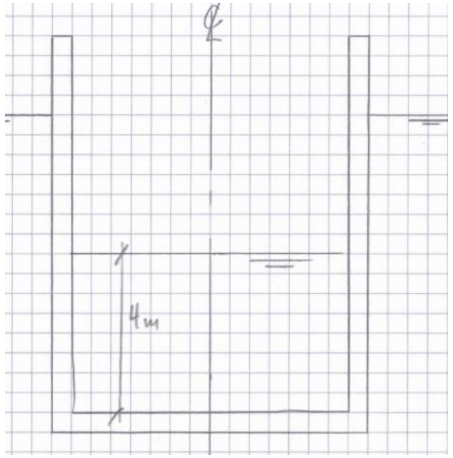
ACHIEVING BUOYANCY

Some simple basics:

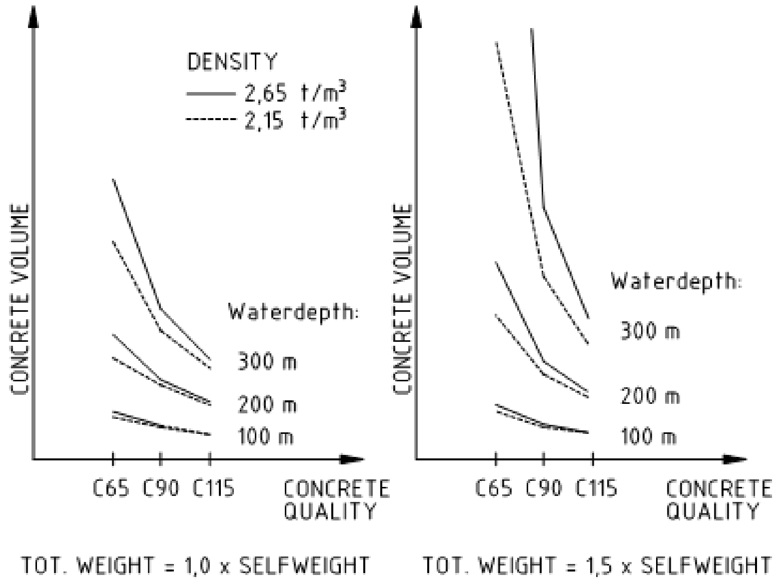
First of all, it is the structure itself that provides the buoyancy. The structure has a weight. Light structures are preferable, often achieved by shell structures, they are efficient in carrying distributed loads.

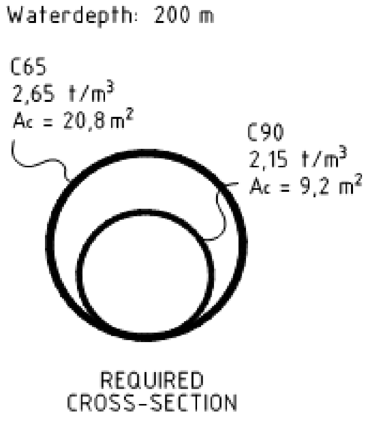
A simple model of a cylindrical bucket will illustrate the effects of concrete unit weight, concrete strength and wall thicknesses.



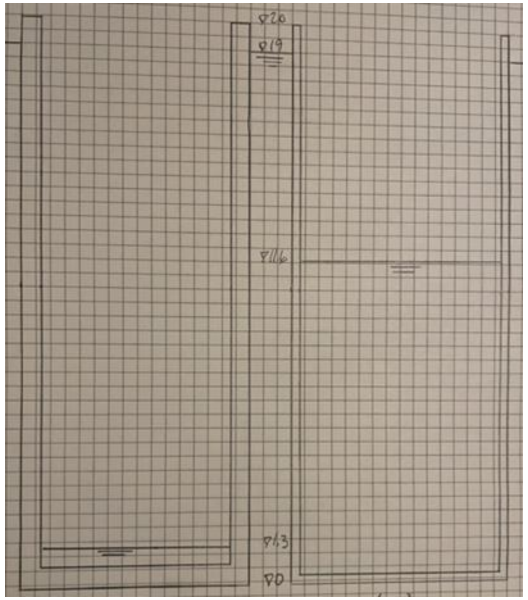
The Condeep prototype

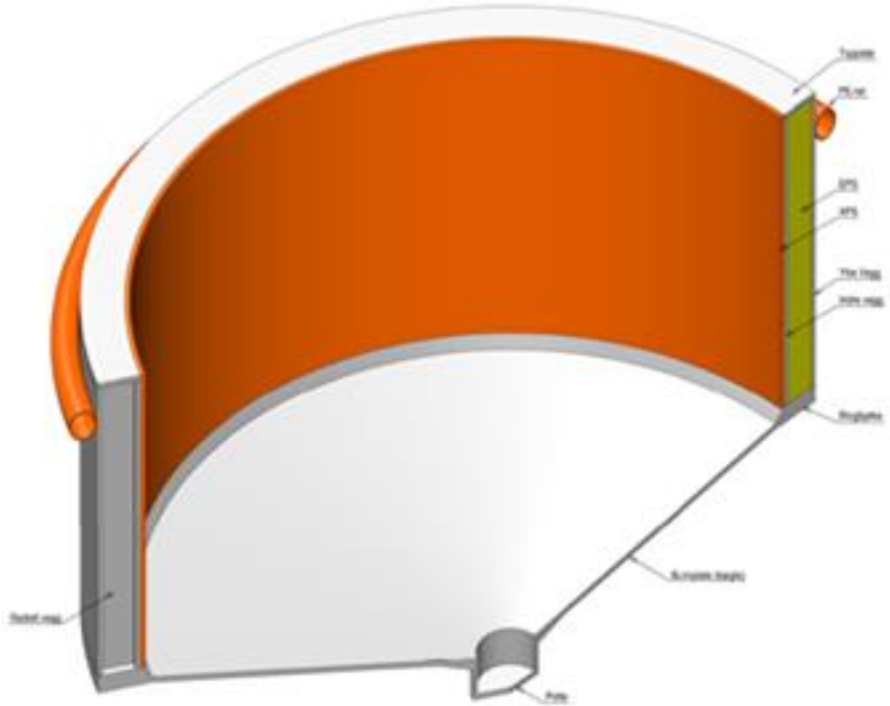
There are some additional remedies: Styrofoam or similar, empty PVC tubes, and voided concrete elements, for example Bubbledeck or similar





Another simple model is a square bucket, where the pressure is carried by bending. Although tempting to increase the wall thickness to reduce the amount of reinforcement, the heavier box has increased load and becomes more expensive.

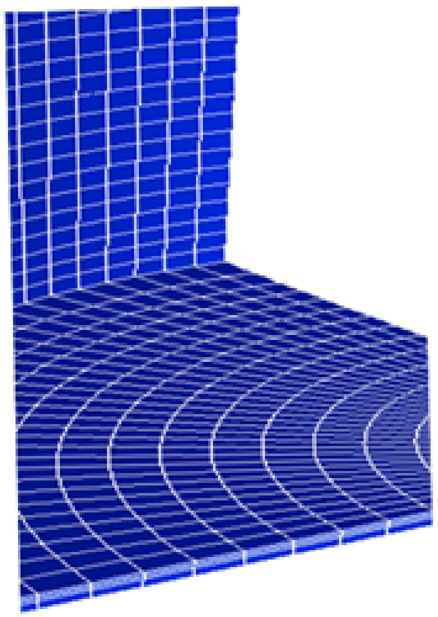




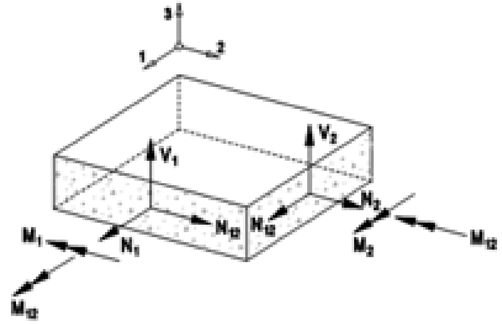
ShellDesign

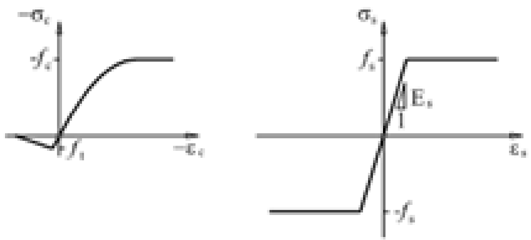
Iterative non-linear analysis and design

Global analysis → Stress resultants → Element stiffness

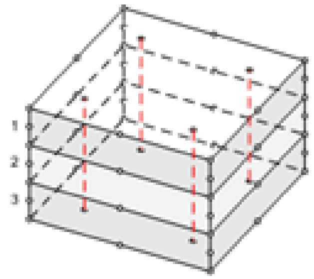


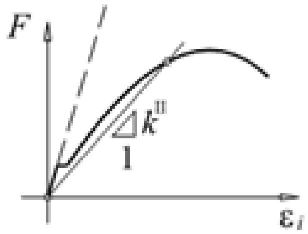
Linear FE analysis





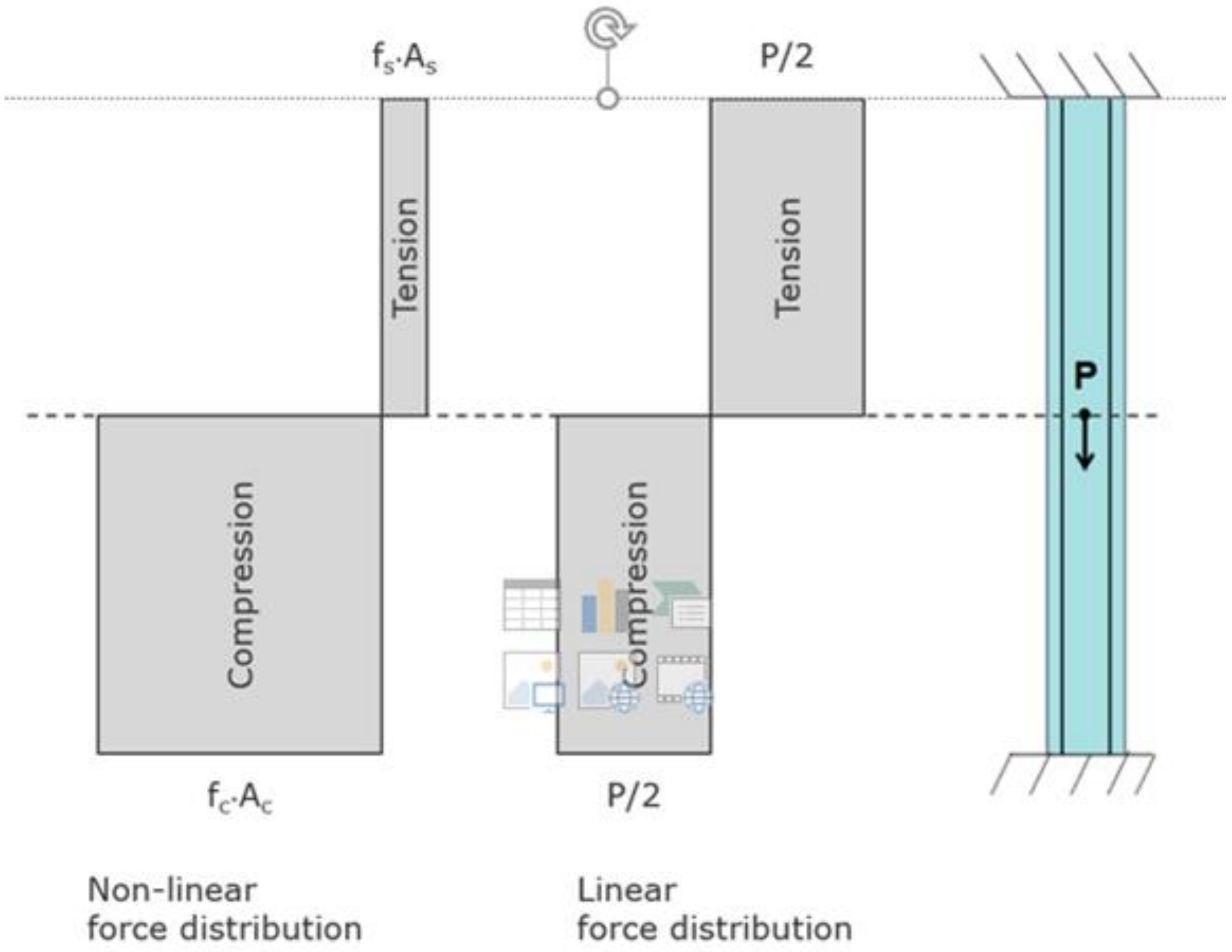
Shell section analysis





$$F = k^{II} \cdot \varepsilon$$

Stiffness formulation



fs·As
P/2
Tension
Tension
P
Compression
Compression
fc·Ac
P/2
Non-linear
force distribution
Linear
force distribution

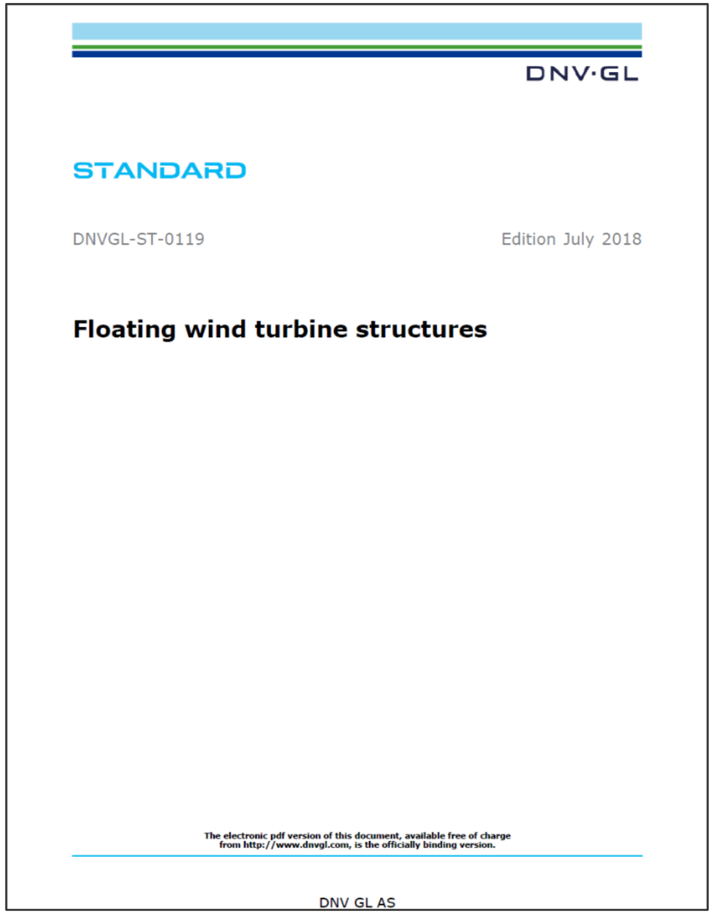
DESIGN STANDARDS

- Design standards for design of floating wind turbines

- Key to merging the practice of two major industries:
  - Traditional offshore O&G
  - Landbased and bottom-fixed offshore wind

- «Safety level» as for unmanned O&G units, although difficult to compare

- Frequent updates of the standards are needed as experience is gained



DNV·GL

STANDARD

DNVGL-ST-0119 Edition July 2018

Floating wind turbine structures

The electronic pdf version of this document, available free of charge from http://www.dnvgl.com, is the officially binding version.

DNV GL AS

IEC

IEC TS 61400-3-2

Edition 1.0 2019-04

TECHNICAL SPECIFICATION

colour inside

Wind energy generation systems –
Part 3-2: Design requirements for floating offshore wind turbines

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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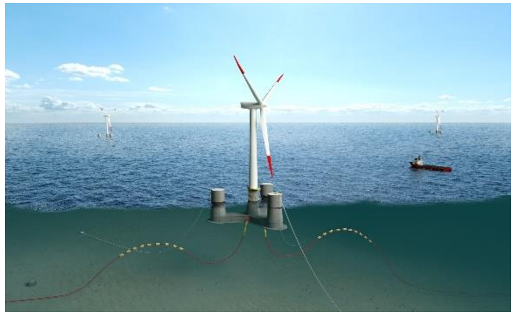
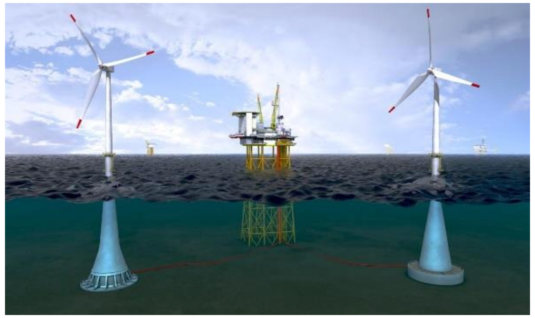
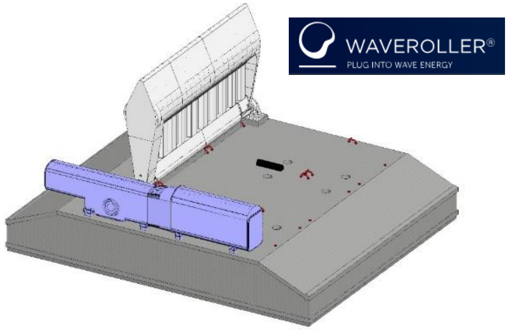
NEW FOCUS – ENVIRONMENT AND SUSTAINABILITY

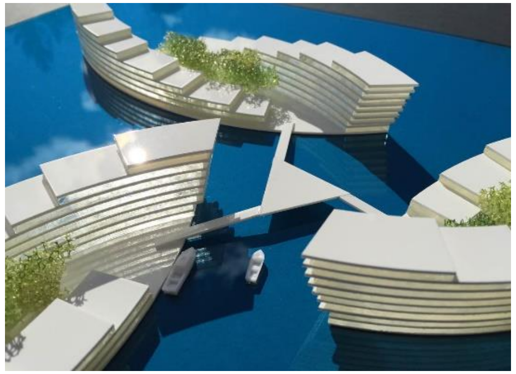











OO-STAR WIND FLOATER (Patent)

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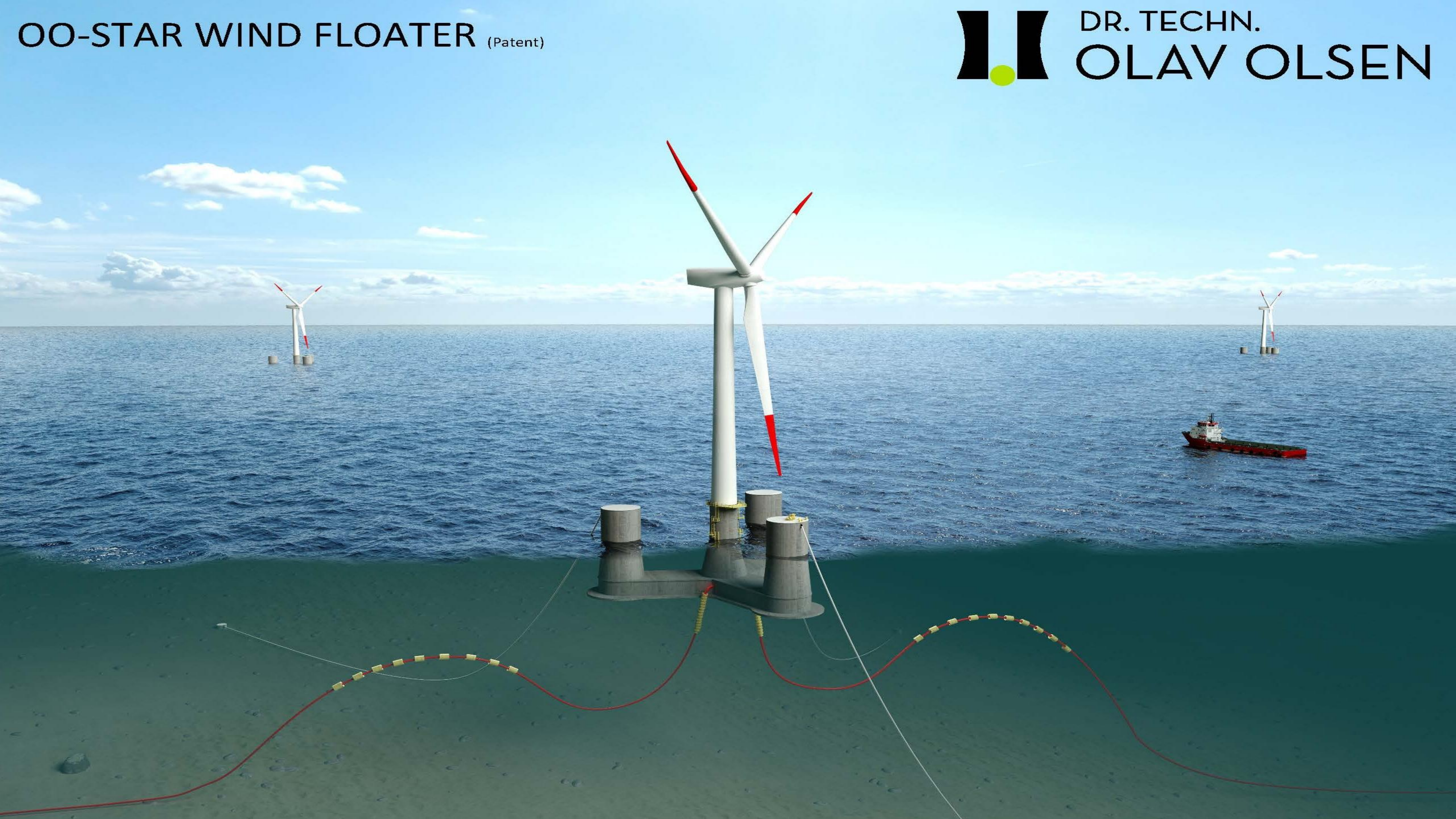
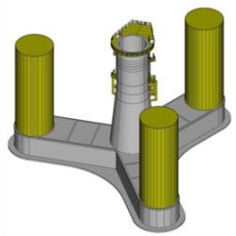


The OO-Star Wind Floater history

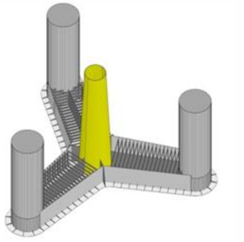
- Few realistic WTG floaters before 2010
- Hiprwind (2010) – questions to scalability and fatigue
- OO-Star developed 2010/11, presented at ONS 2012
- Floatgen 2012 - Preferred concept (steel) for EU project
  - (OO-Star part of project with Acciona, but project was terminated)
- NFR 2013-2014: Concrete Floater 6MW, North Sea
- LIFES50+ 2015-2018: Up-scaling to 10 MW
- Flagship 2020-2024: Full scale demonstrator 10+ MW

HIPRWind
Steel semi

OO-Star
Concrete Semi

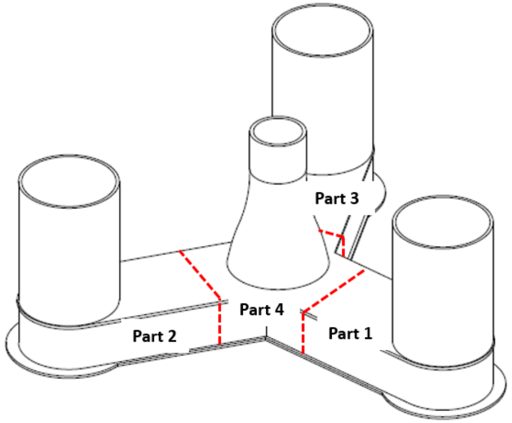


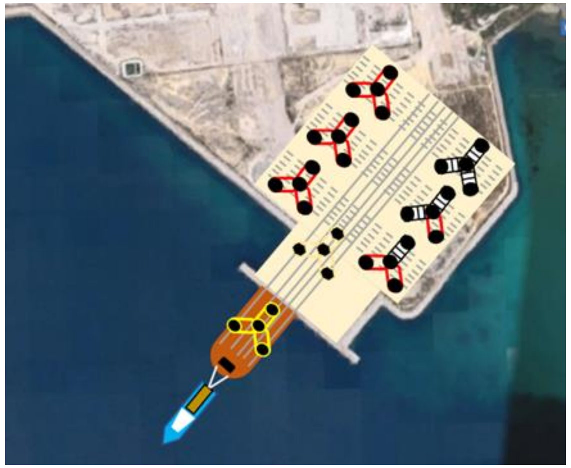
OO-Star
Hybrid Semi

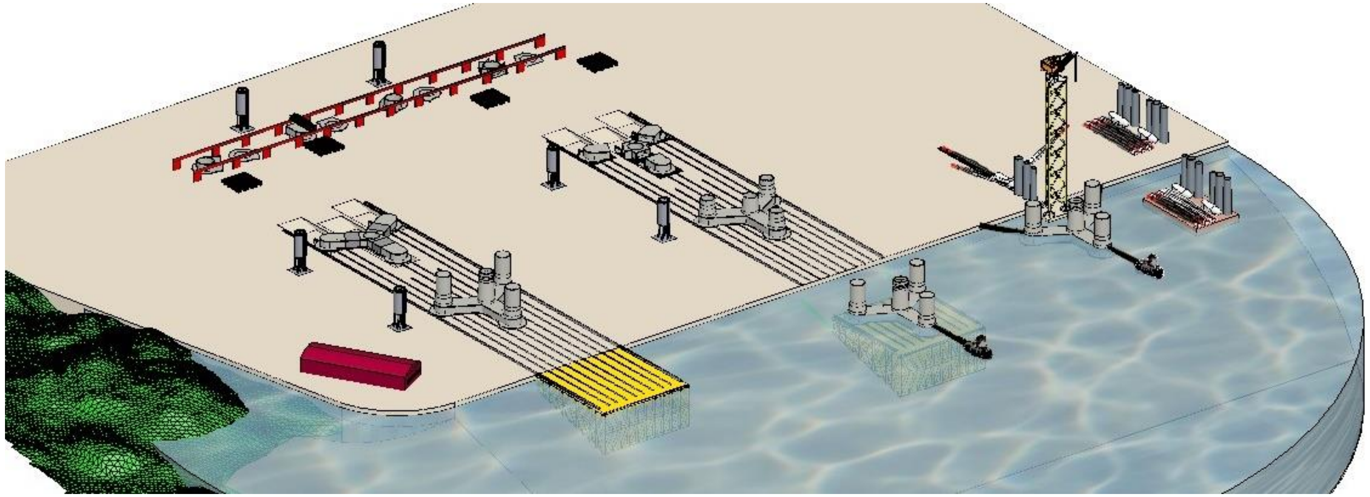


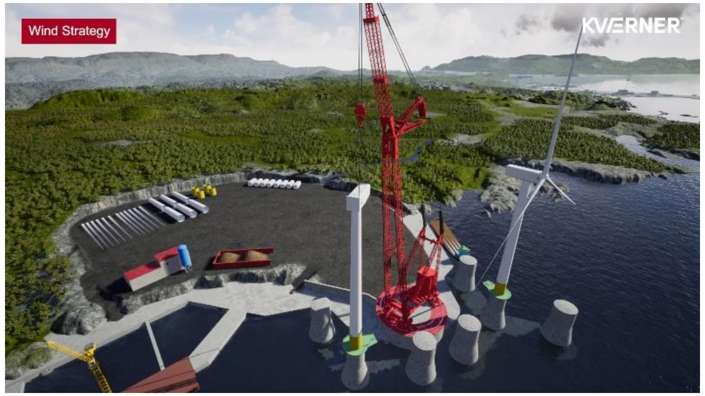
OO-Star
Steel semi

COST REDUCTION THROUGH INDUSTRIALISATION









THE NEXT STEP FOR OO-STAR WIND FLOATER:

FULL SCALE DEMONSTRATION

FLAGSHIP PROJECT OVERVIEW

Main Objective:

- Validate and demonstrate cost-effective floating wind technology, large scale
- Reduce levelized cost of energy (LCOE) to EUR 40-60 per MWh by 2030

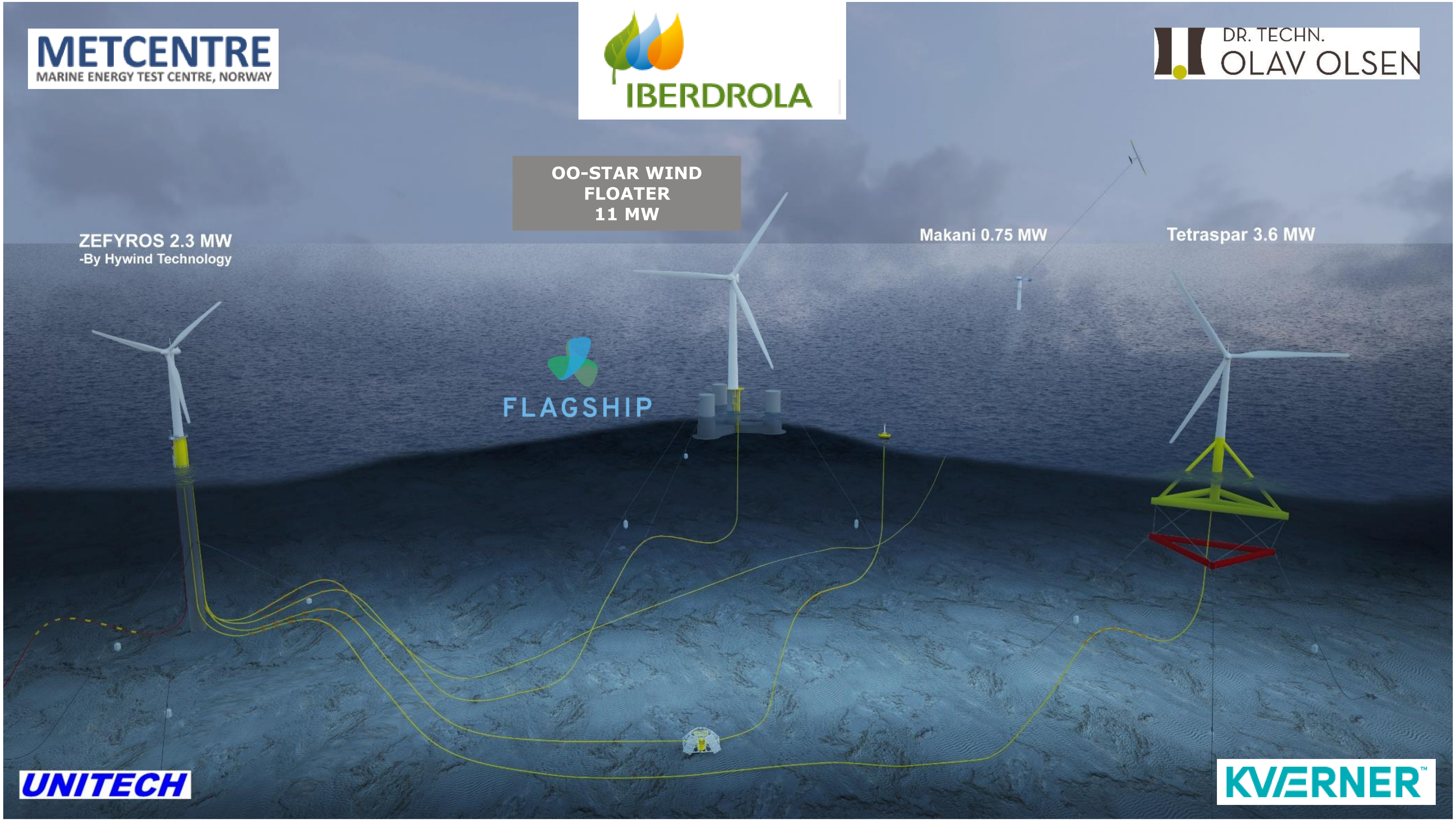
Project in brief:

- 1:1 scale floating demonstrator in the North Sea
- 11 MW turbine
- Iberdrola is the Project Coordinator
- The unit is planned to be installed in 2022, with a subsequent test period of two years

Key Innovations and R&D activities

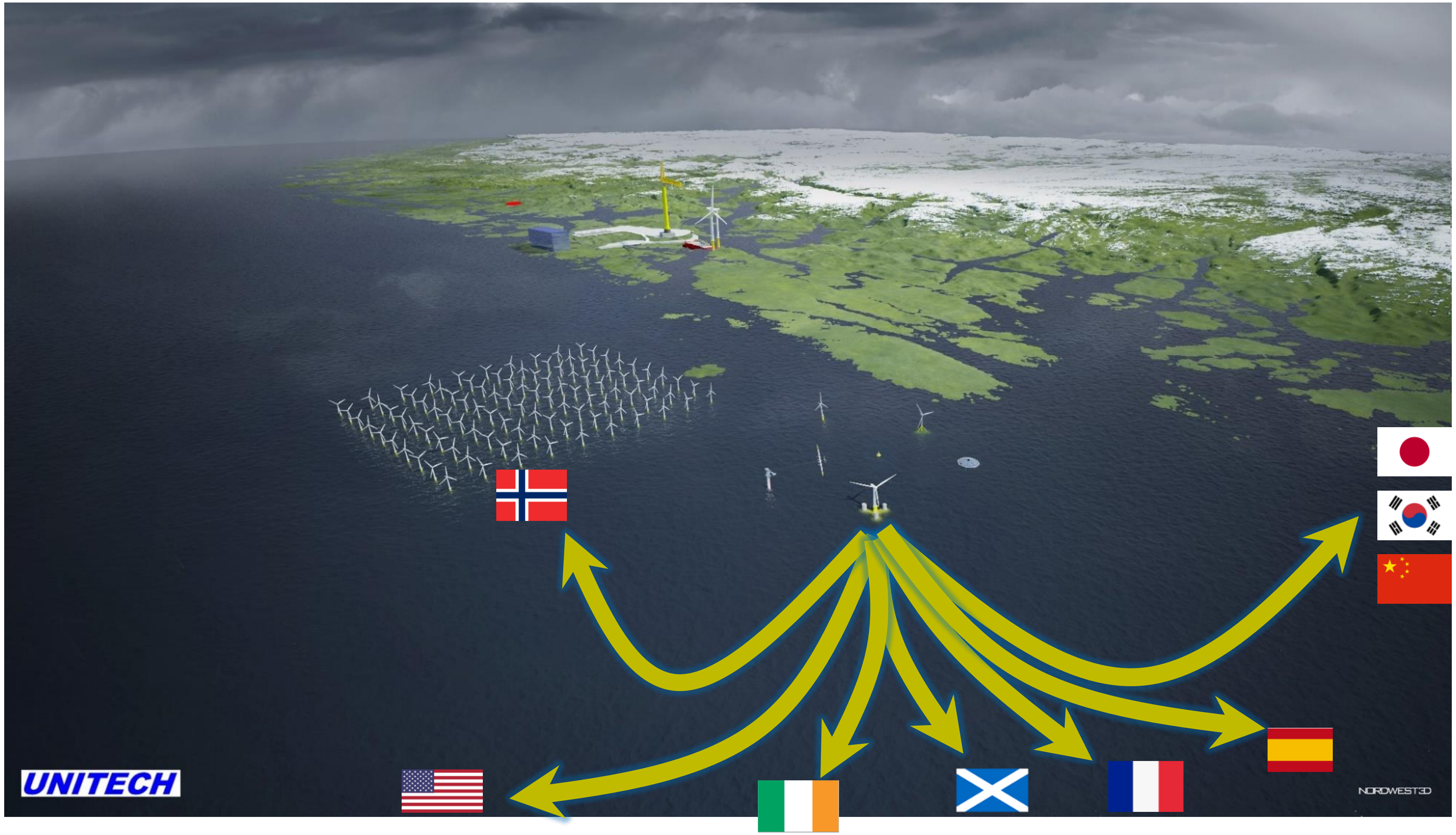
Floating Demo
- Innovative floater design in concrete
- Innovative mooring and anchor design
- Innovative cable design
- Innovative fabrication methods

R&D
- Industrialisation
- Digital Twin
- Upscaling
  - 20 MW WTGs
  - Wind farms


METCENTRE
MARINE ENERGY TEST CENTRE, NORWAY
IBERDROLA
DR. TECHN.
OLAV OLSEN
OO-STAR WIND
FLOATER
11 MW
ZEFYROS 2.3 MW
-By Hywind Technology
Makani 0.75 MW
Tetraspar 3.6 MW
FLAGSHIP
UNITECH
KVÆRNER

FLAGSHIP FULLSCALE DEMO ...AND ONWARDS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 952979



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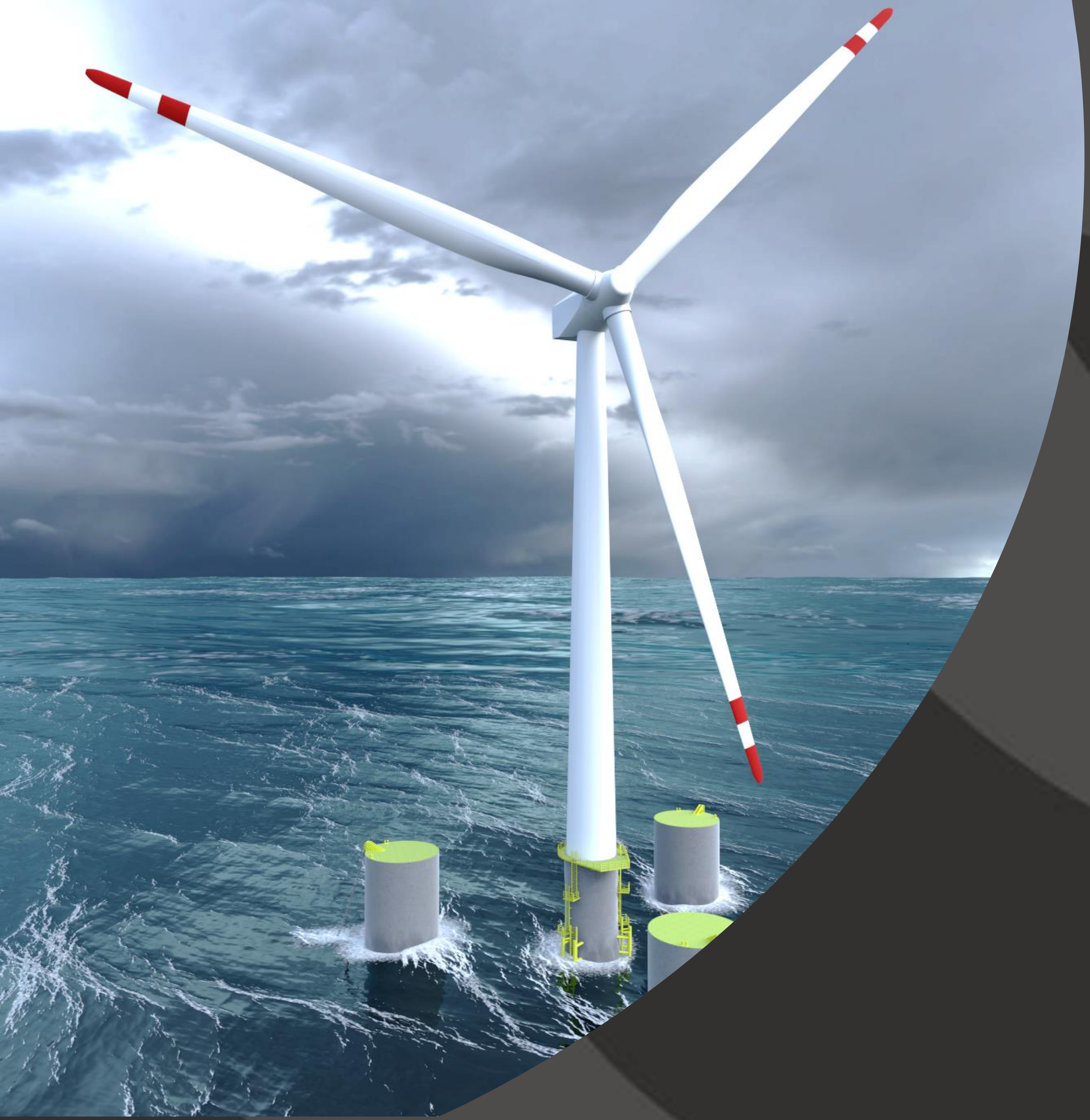

- *The technology for floating wind is available*
- *Cost reductions will come with a market*
- *Political support is required to make it happen*

Thank you for listening!

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