DR.TECHN.OLAV OLSEN AS

Global analyses of OO-Star Wind Floater

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Outline

- Short Company Introduction
- OO Star Wind Floater
- Global Analysis
- Design Process and Structural Design

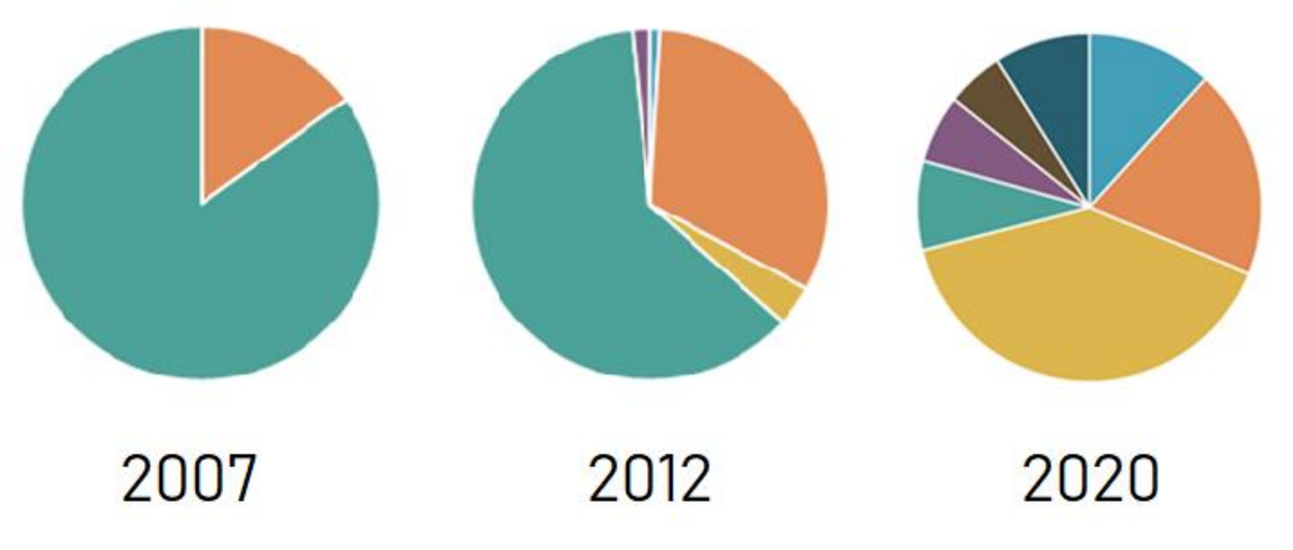
OUR HISTORY

- Founded 1962 by Dr.techn. Olav Olsen
- From October 2020 part of Artelia Group
- 110 employees (Olav Olsen)
- Artelia Group 5900 employees worldwide
- Main office at Lysaker
- Regional office in Trondheim
- Structural and marine consulting company
- Participates regularly in research and development projects

BUSINESS AREAS

- Buildings
- Infrastructure
- Offshore Oil & Gas
- Ports and Industry
- Renewable Energi
- Damsafety and Water-resources
- Geotechnical Engineering
- Futurum/CFD/Others
- Electrical Engineering
- HVAC/Water and Sanitation

Revenue distributed per business area



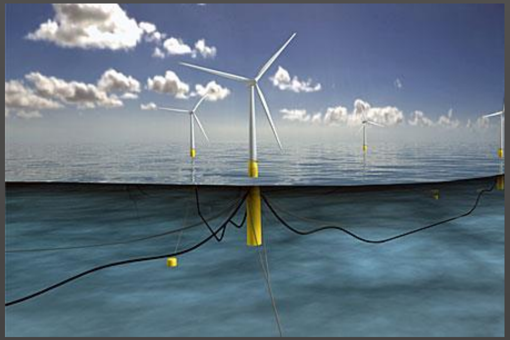
RENEWABLE ENERGY

- Coupled analyses
- Design analyses
- Concept development
- Design of foundation and towers
  - Bottom-fixed and floating
  - Concrete and steel
  - Geotechnics
- Design of mooring and anchors
- Cost and plan
- 3. party verification

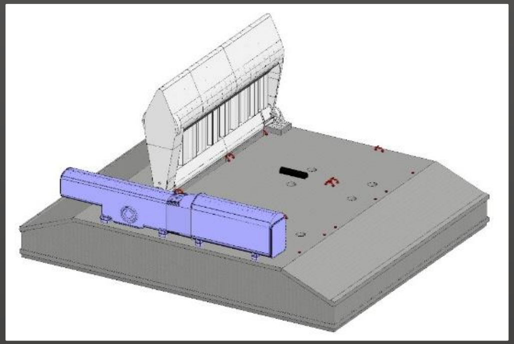
OO-Star Wind Floater

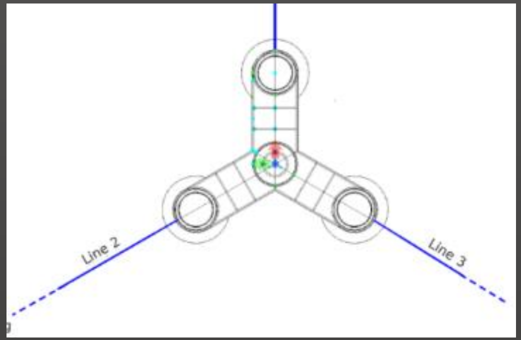
- Developed by Dr.techn. Olav Olsen
- IPR's owned by Floating Wind Solutions AS

Selected references Renewable Energy


HYWIND SCOTLAND

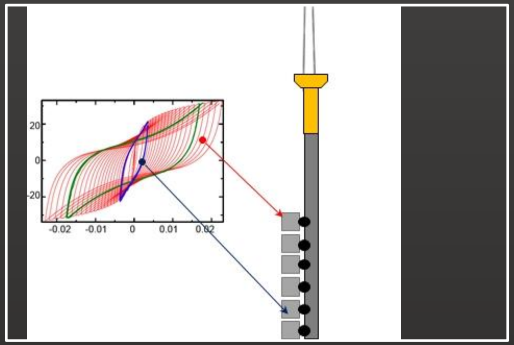

OO-STAR WF DEVELOPMENT


WAVEROLLER

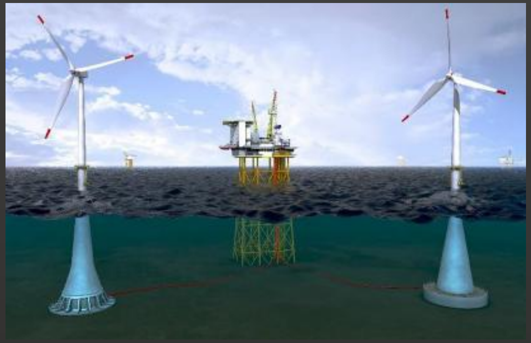


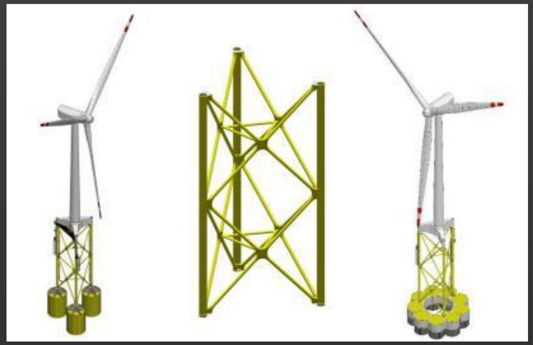
INNOVATIVE MOORING SYSTEMS

HYWIND TAMPEN



REDWIN


OFFSHORE WIND GBS


SFT JACKET

Dr.techn. Olav Olsen

Capabilities Offshore wind

> Substructures
  – Bottom fixed and floating
  – Steel and concrete
  – Concept development
  – Design and analysis (ShellDesign)
  – Geotechnics

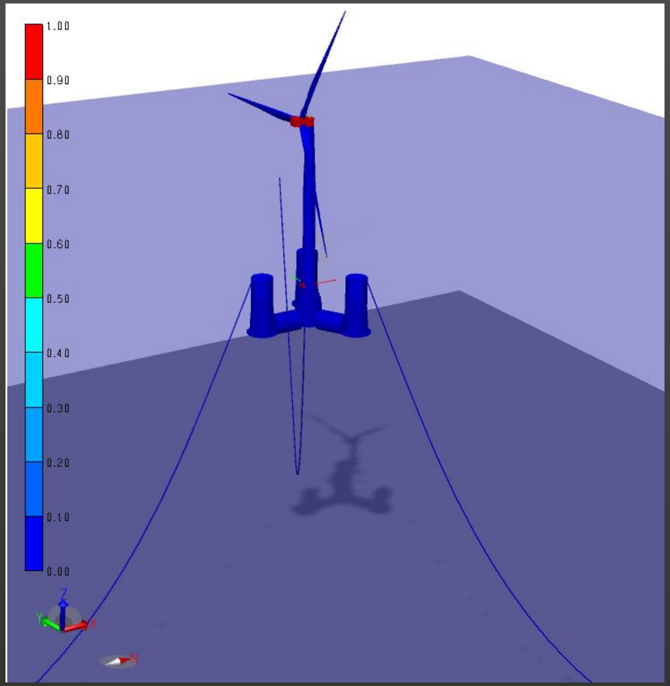
> Mooring and anchors
  – System configuration
  – System design
  – Geotechnics

> Installation
  – Method development
  – Installation concepts

> Fully coupled simulations:
  – SIMA
  – 3DFloat
  – OrcaFlex
  – (Deeplines, Ashes, Fast)

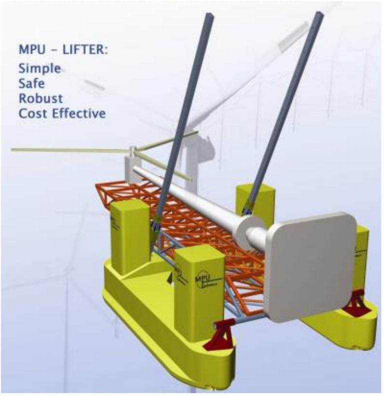
> Cost models
  – Fabrication and Installation
    • Substructure
    • Mooring
    • Anchors

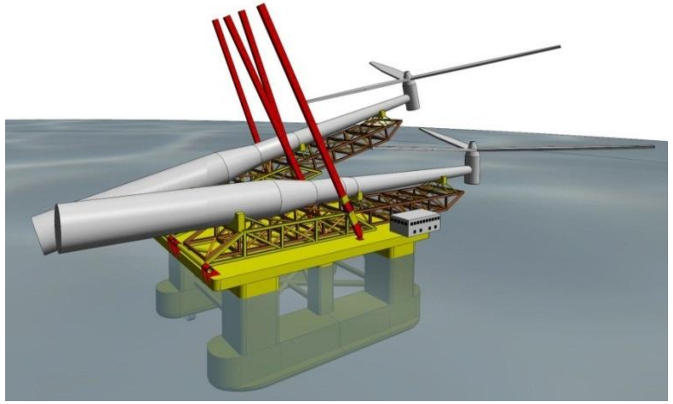
> Third party verification

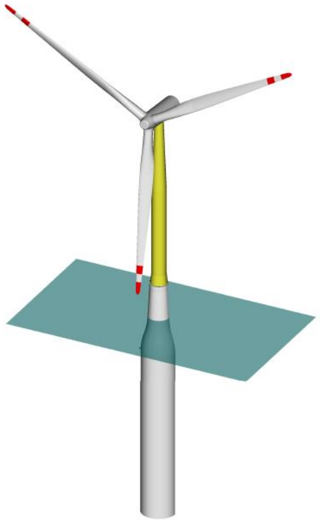


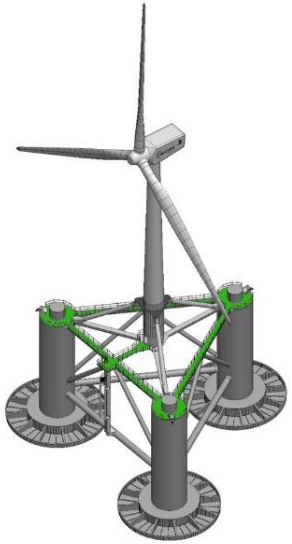
OO-STAR WIND FLOATER

OLAV OLSEN – OFFSHORE WIND





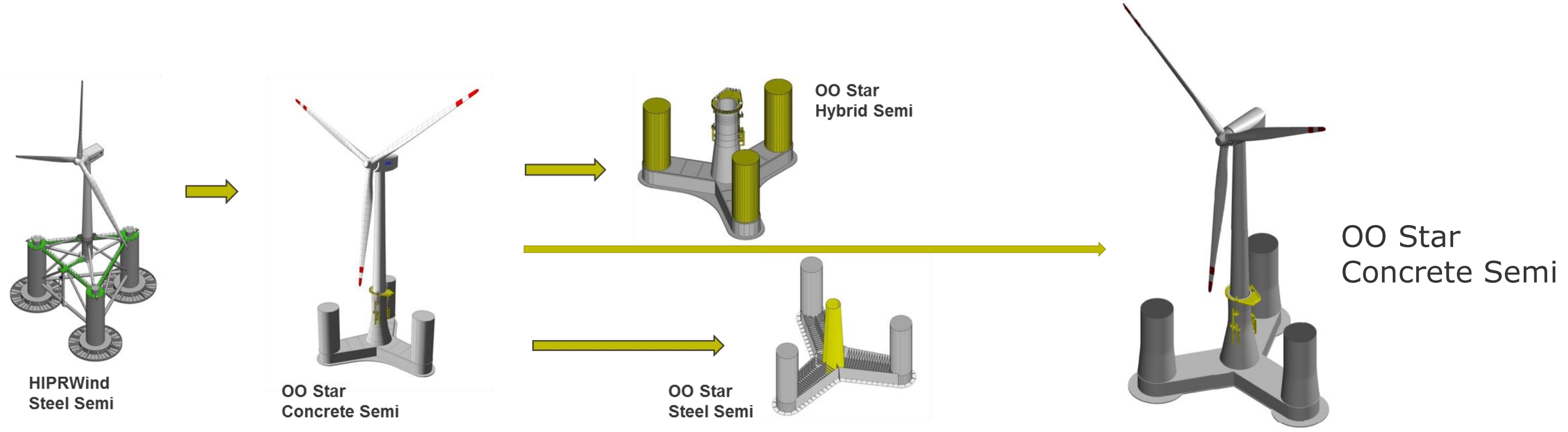




THE OO-STAR WIND FLOATER HISTORY

- Few realistic WTG floaters before 2010
- HiPRWind (2010) – questions to scalability and fatigue

- OO-Star Wind Floater developed 2010/11, presented at ONS2012
- Preferred concept (steel) for EU project Floatgen – Acciona part 3 MW WTG
- NFR project 2013-2014: Designed for 6MW, WD 100 m, North Sea
- LIFES50+ 2015-2018: Up-scaling to 10 MW, WD 70-130 m, Hs=7.0 -15.6 m
- Flagship 2020->: Full-scale demonstrator of the concept

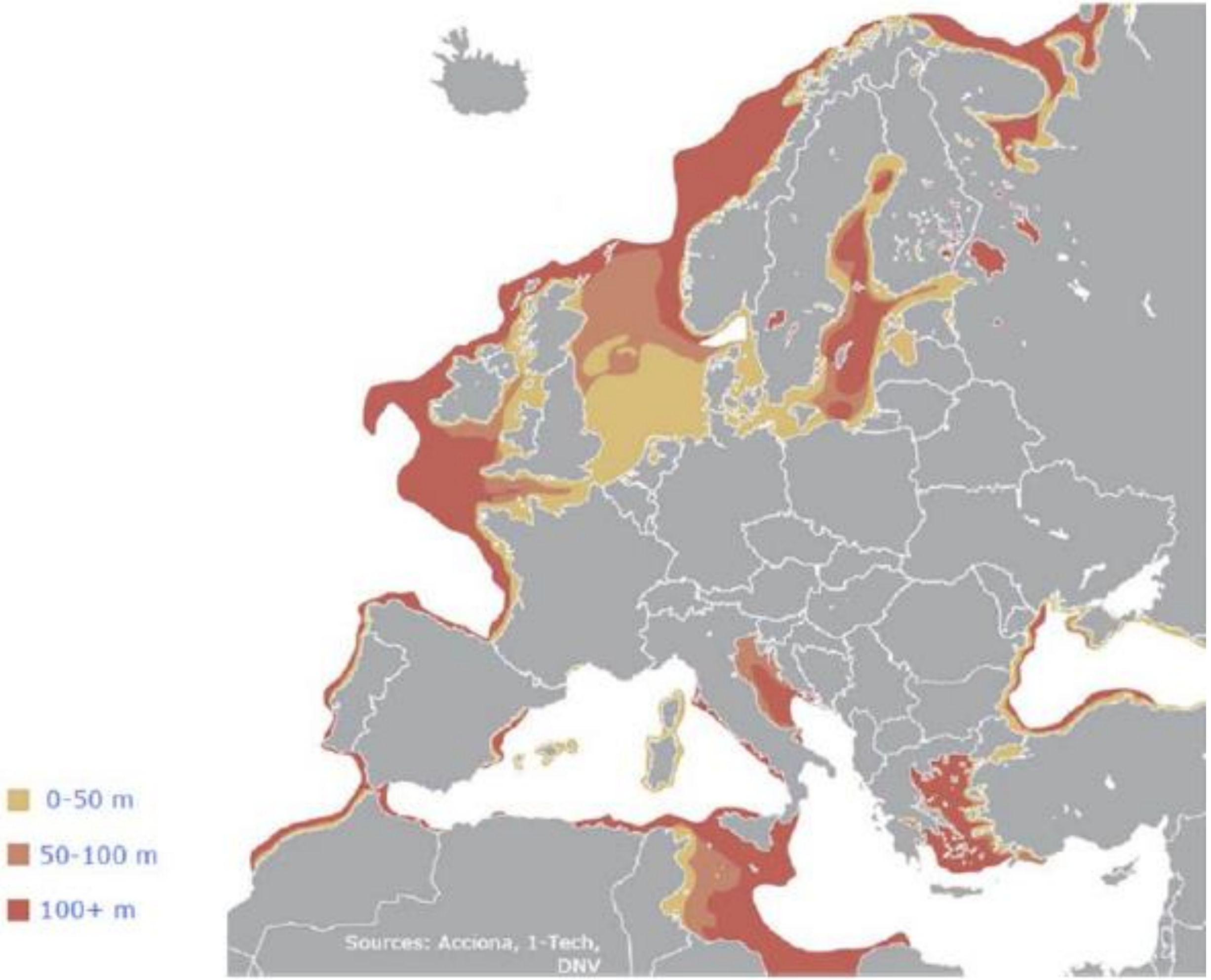


BENEFITS OF CONCRETE

- Robust
  - Fatigue properties
  - Impact loads
  - Design changes
- Good scaling with increased size and loads
- No corrosion for main load bearing structure
- Long design life
- Virtually maintenance-free

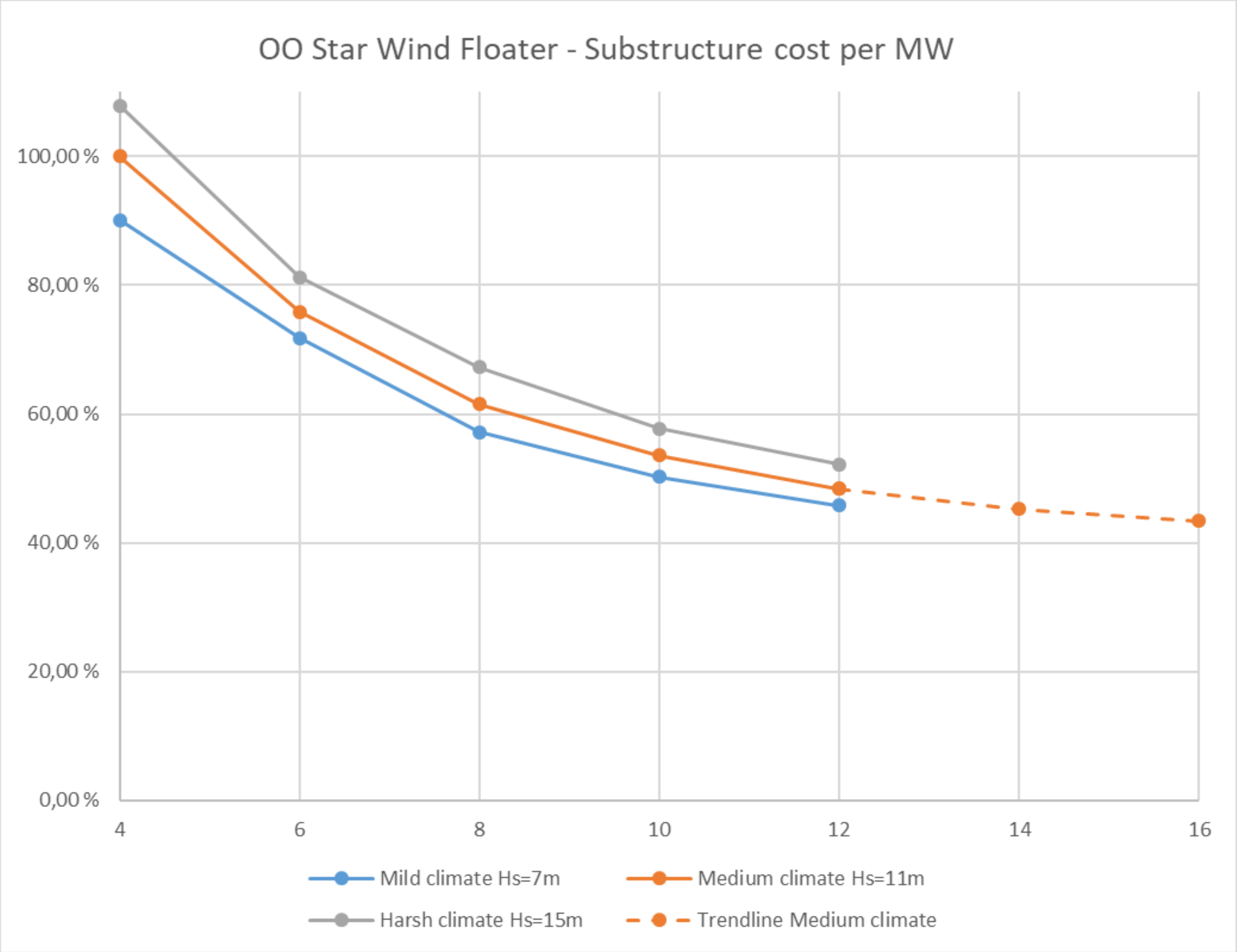
POTENTIAL AREAS AND MARKET

Figure 1.1.1.Sea depth around Europe (DNV-GL, 2014)



OO-STAR WF CAN ACCOMMODATE LARGE TURBINES

...FAVOURABLE SCALING DECREASES COST PR MW



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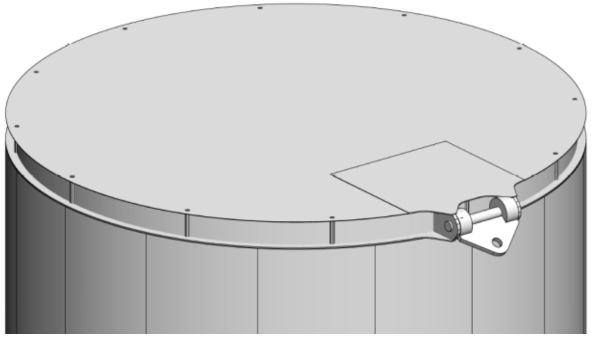
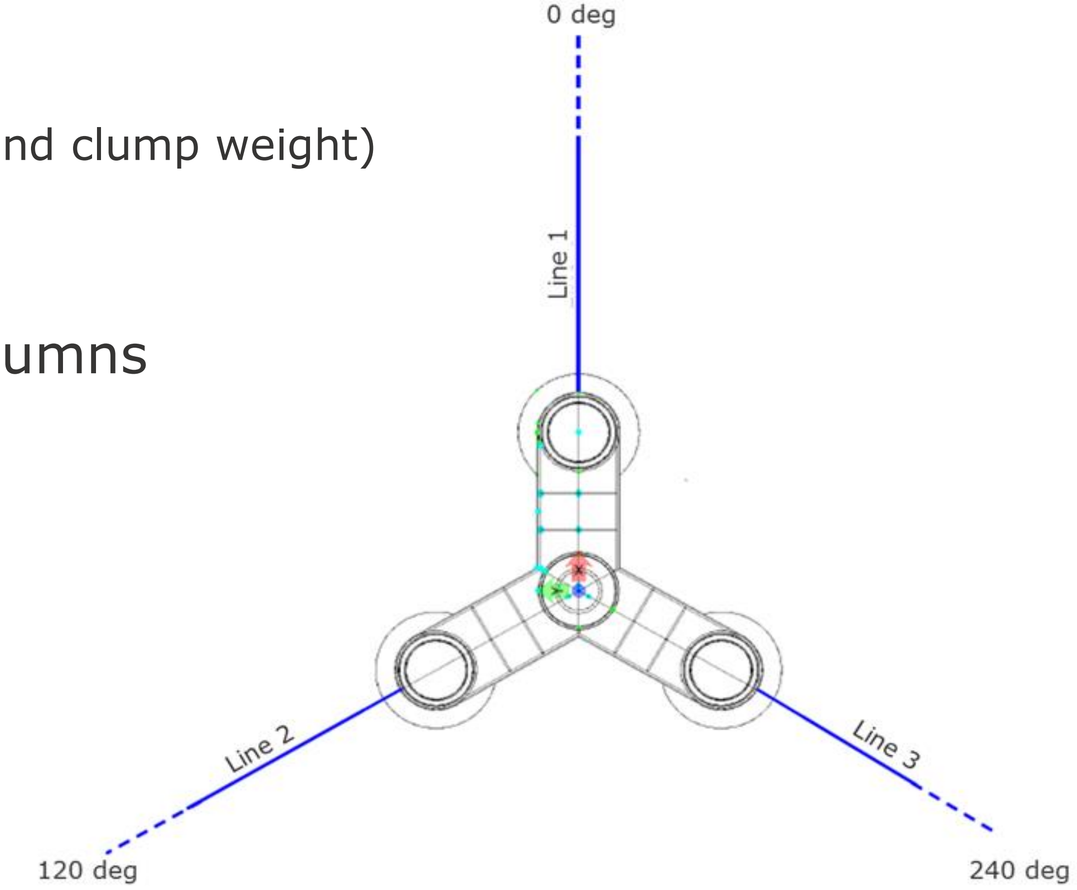
Trendline indicates 30% reduced floater cost per MW from 8 to 16 from scaling effects alone

MOORING SYSTEM

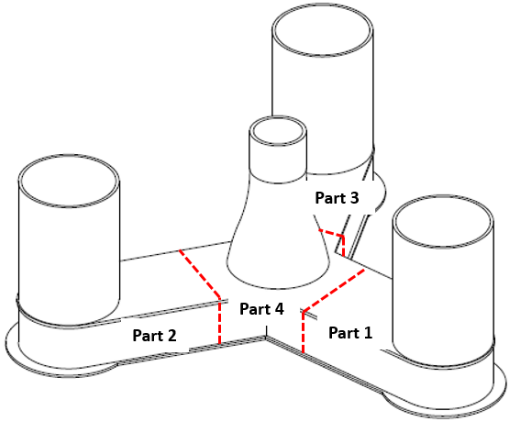
- Mooring system is site specific, but several options have been used in previous studies.
  - 3-line catenary system
  - 3-line semi taught system (Chain, polyester and clump weight)
  - 6-line system

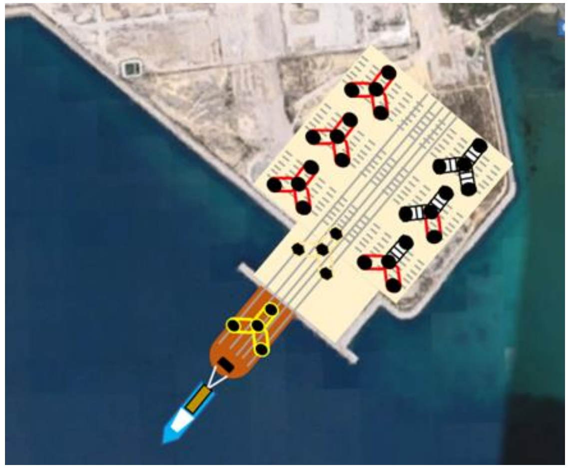
- Mooring attachment at top of corner columns
  - Passive connection – no winch

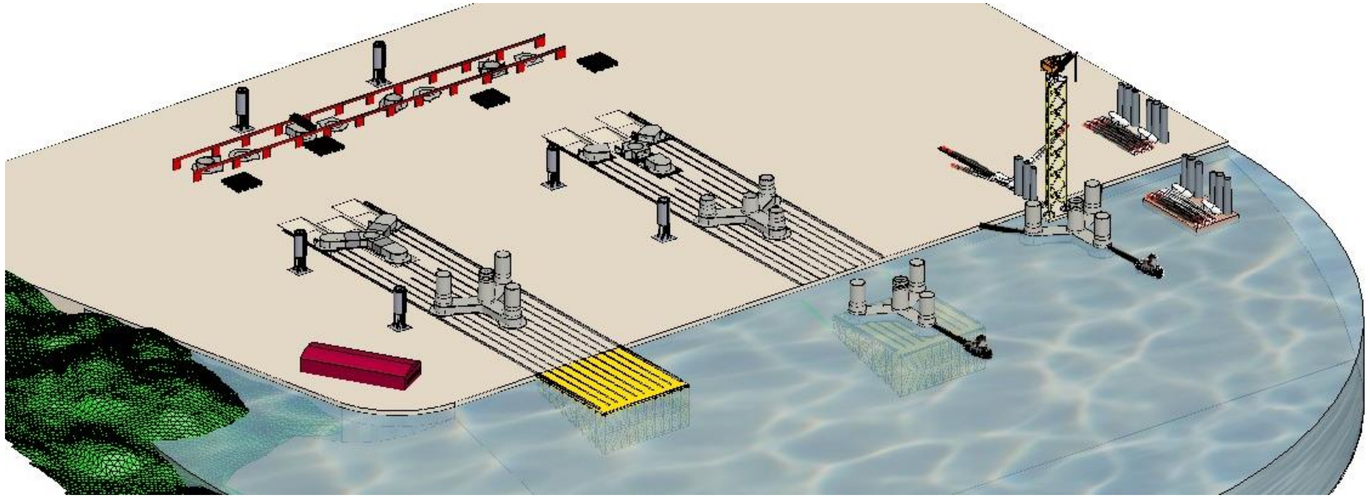


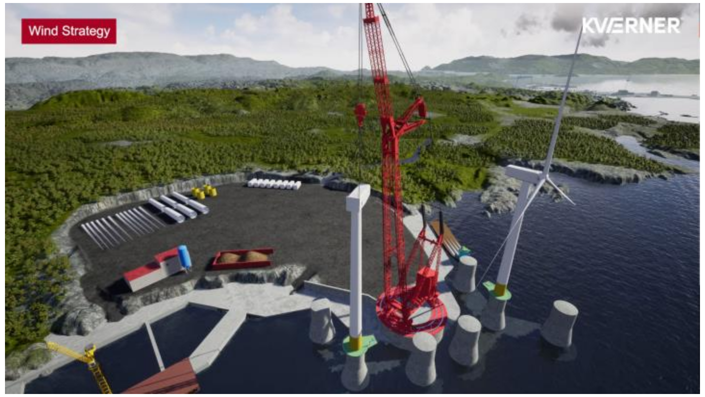


COST REDUCTION THROUGH INDUSTRIALISATION





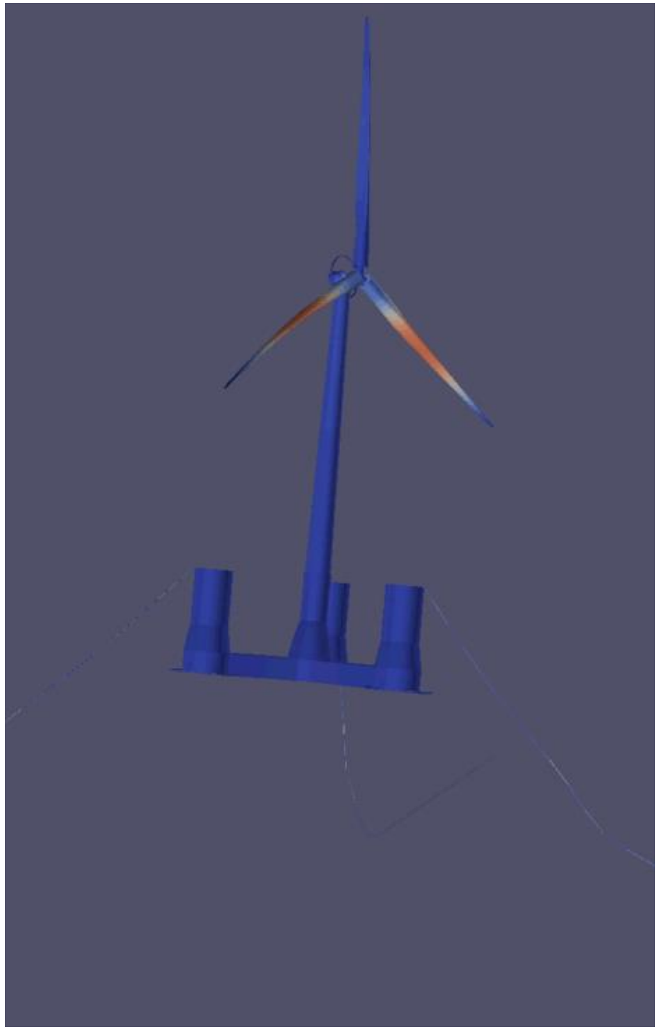




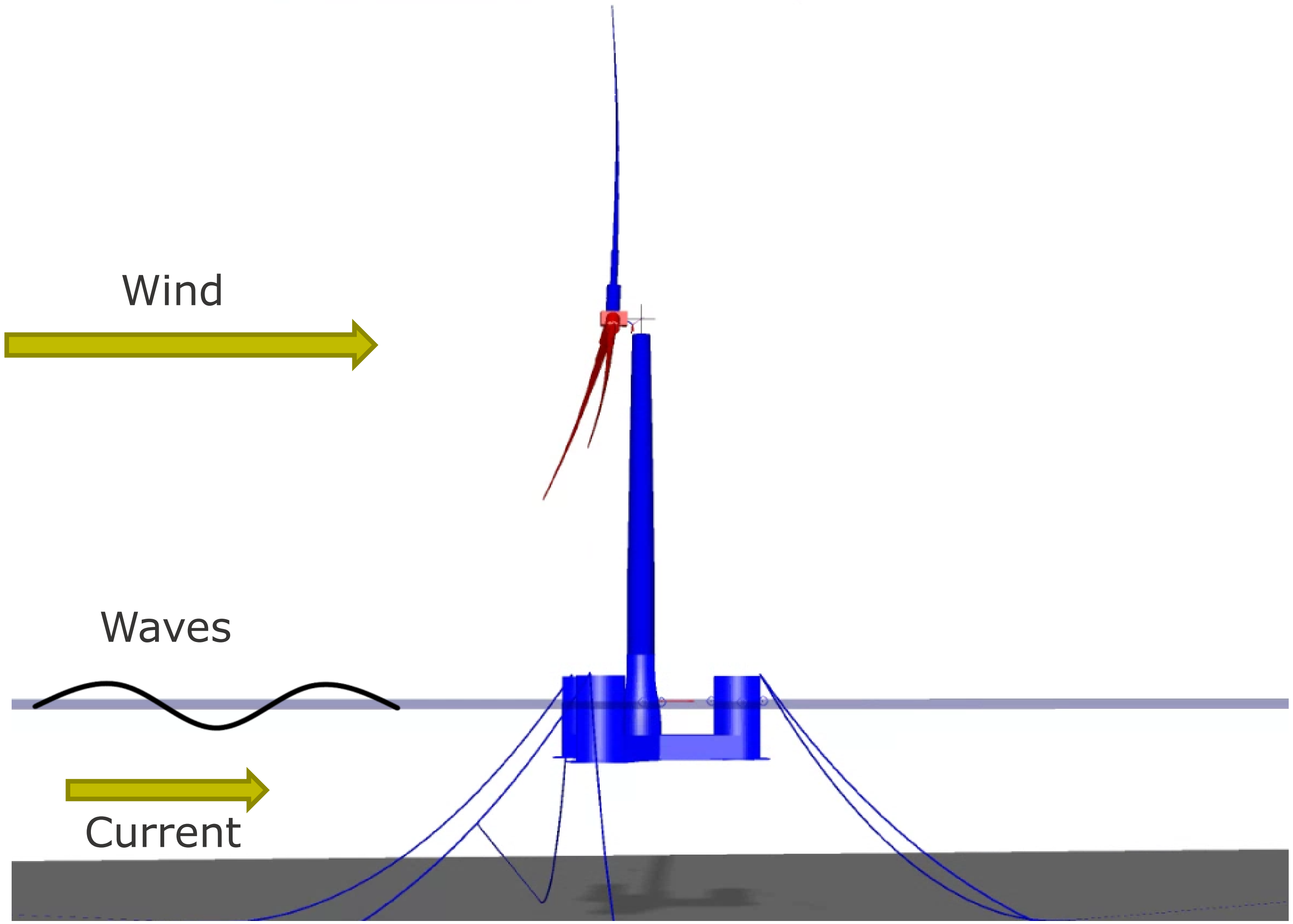
GLOBAL ANALYSIS

COUPLED ANALYSIS – SIMULATION OVERVIEW

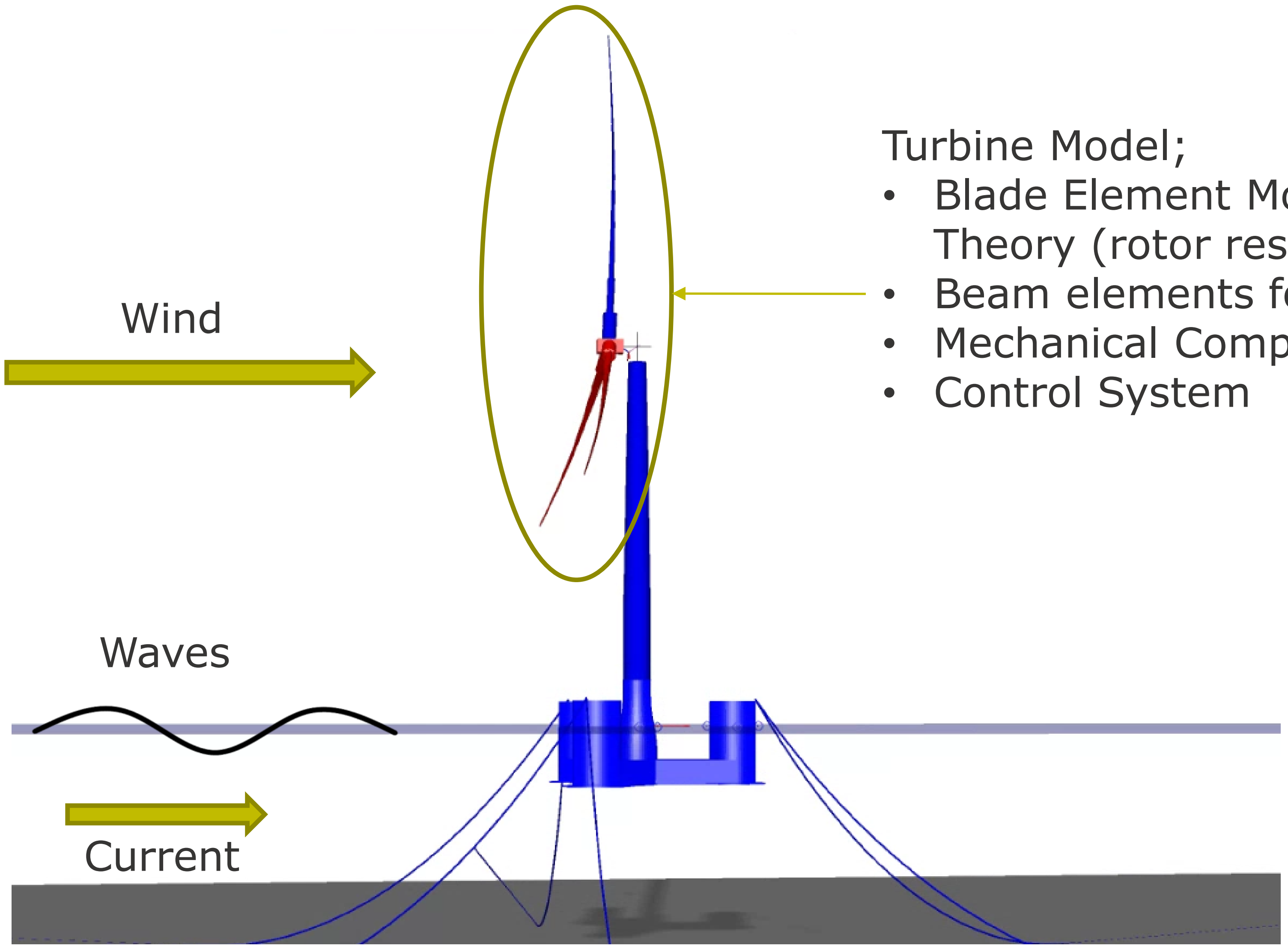
> Time domain simulations
> 1 to 3 hours simulation length
> 10+ seeds per extreme case
> Irregular sea states with linear waves
> Turbulent wind fields



COUPLED ANALYSES – EXTERNAL LOADS

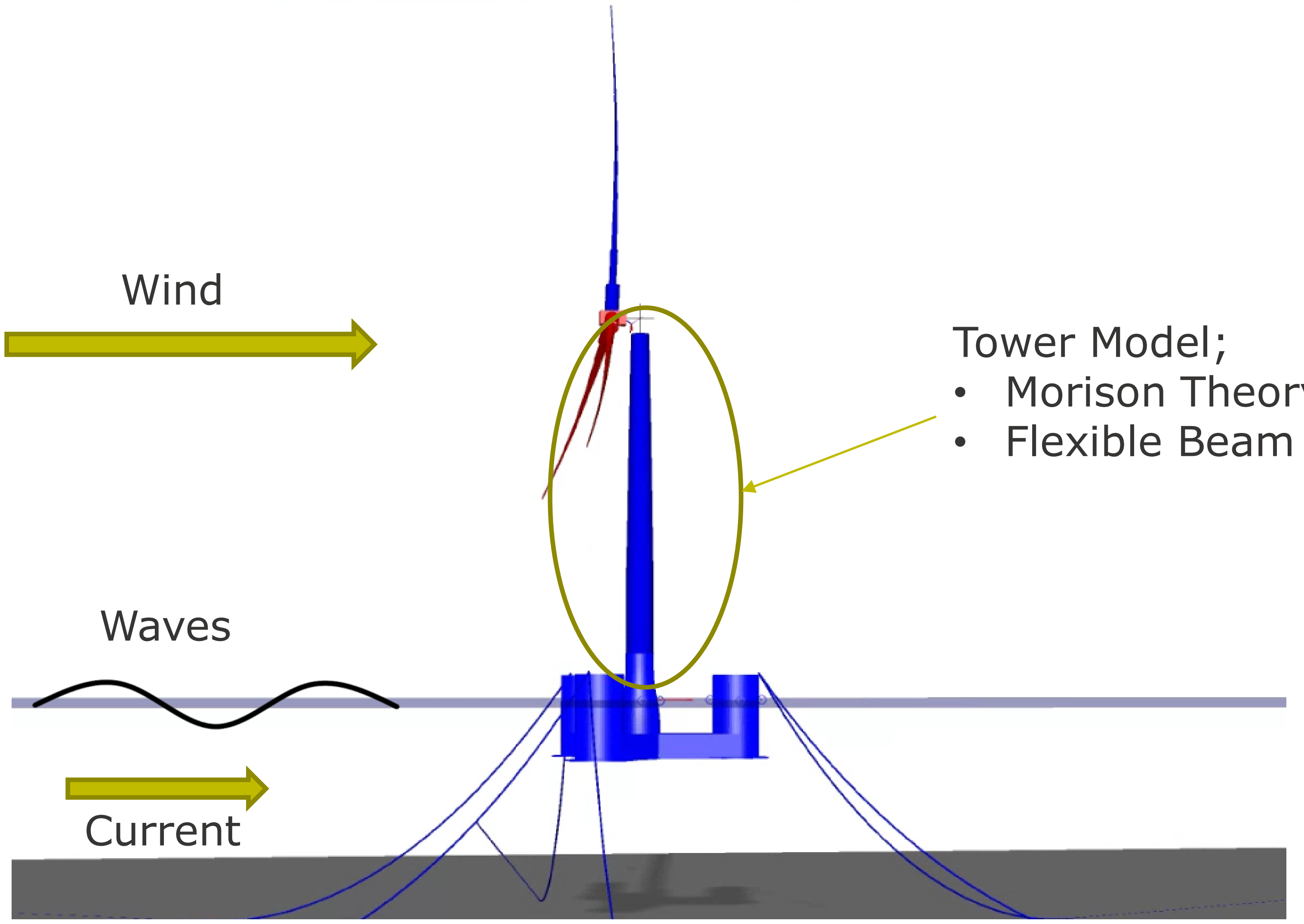


COUPLED ANALYSES - TURBINE



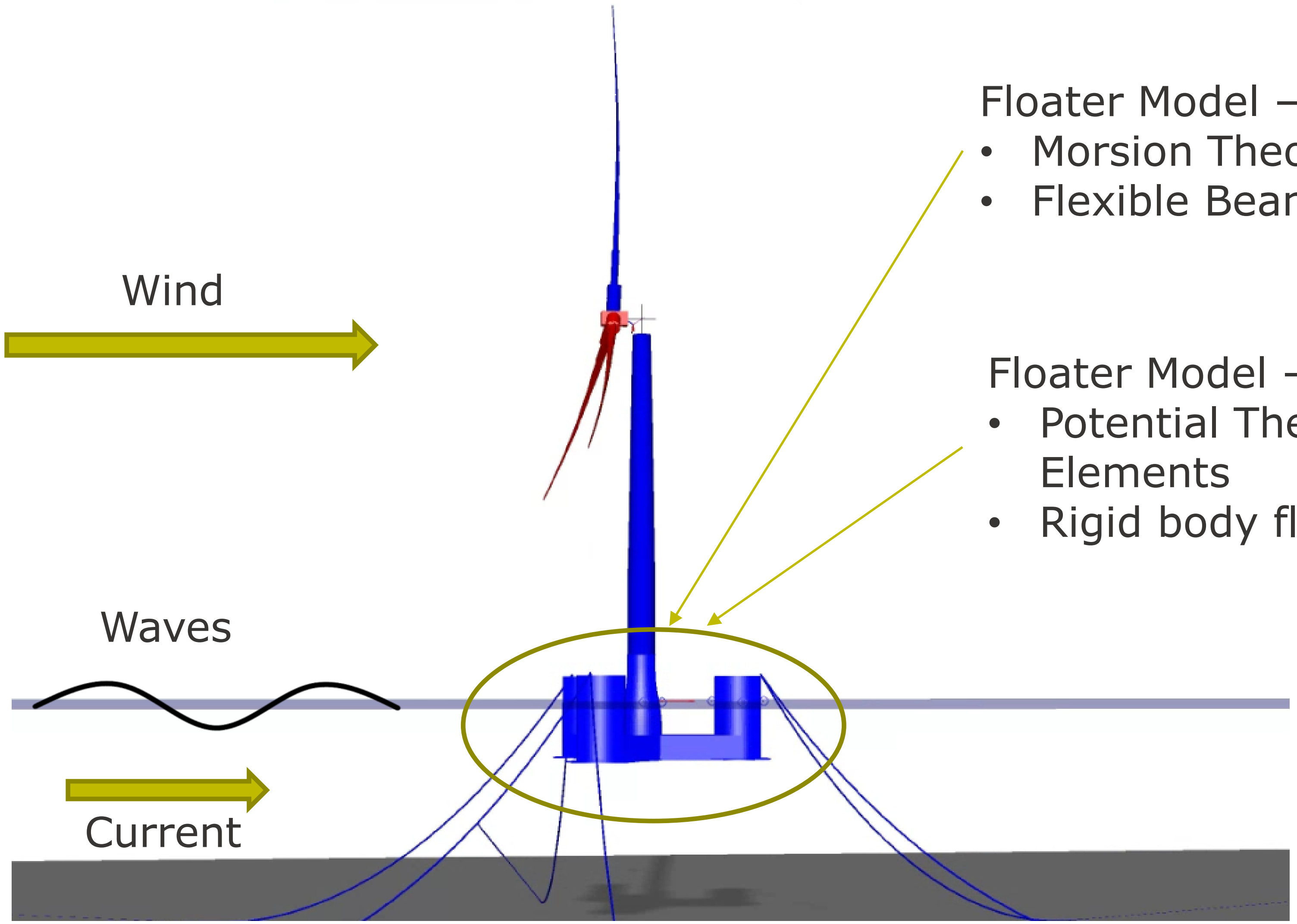
Turbine Model;
- Blade Element Momentum Theory (rotor response)
- Beam elements for compoents
- Mechanical Components
- Control System

COUPLED ANALYSES - TOWER



Tower Model;
- Morison Theory
- Flexible Beam Elements

COUPLED ANALYSES - FLOATER



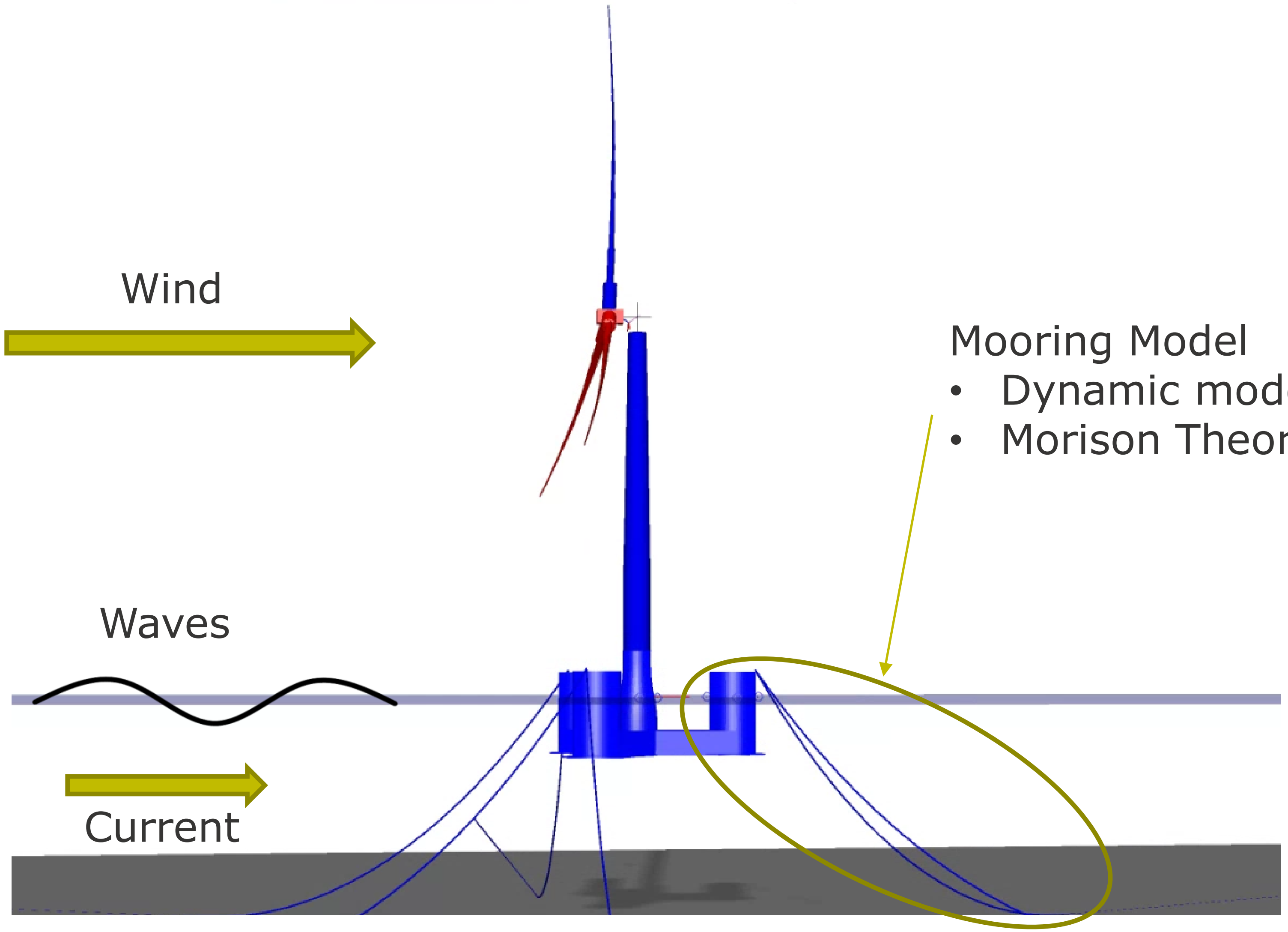
Floater Model – Alternative 1;

- Morsion Theory
- Flexible Beam Elements

Floater Model – Alternative 2;

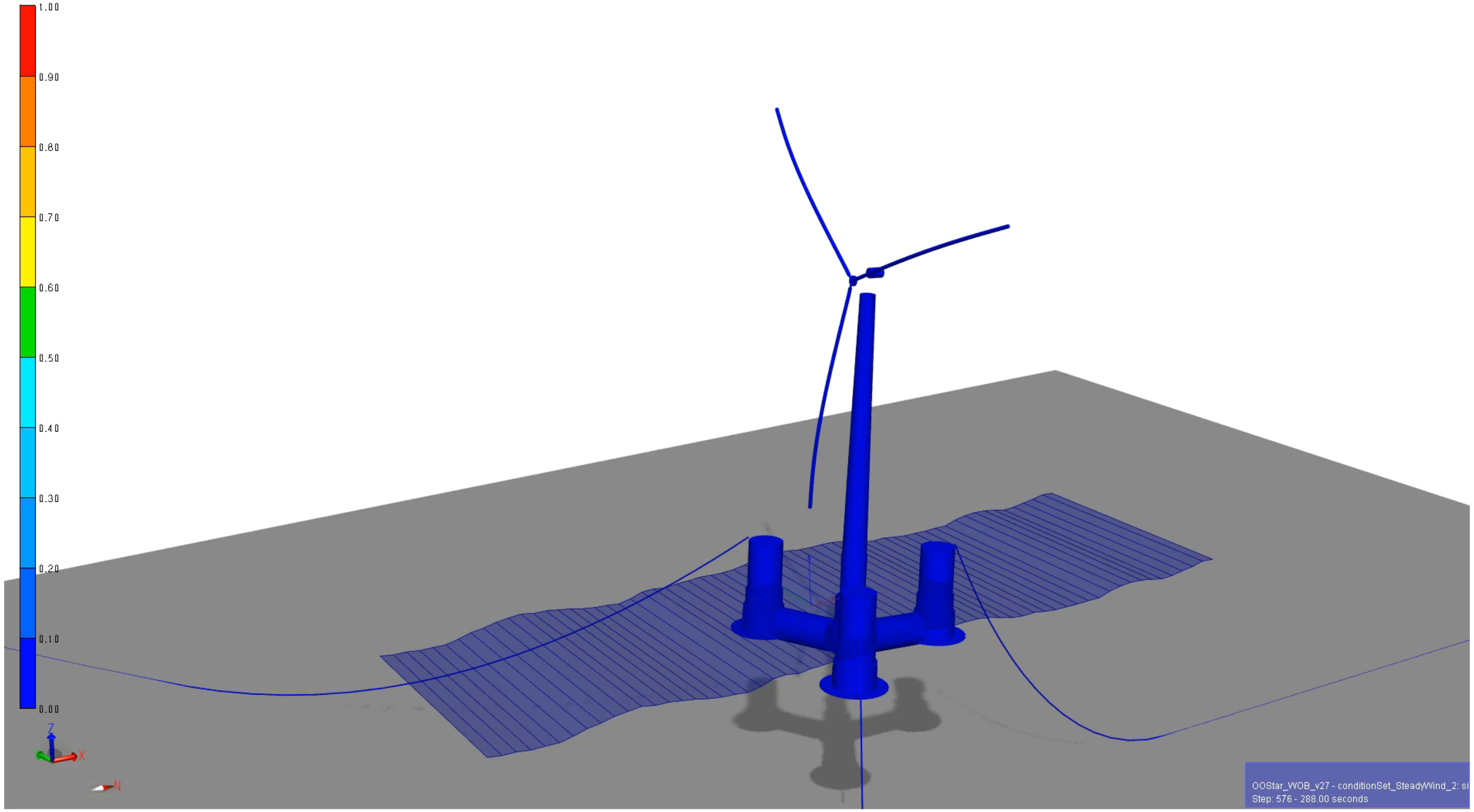
- Potential Theory and Drag Elements
- Rigid body floater

COUPLED ANALYSES - MOORING



Mooring Model
- Dynamic modelling
- Morison Theory

COUPLED ANALYSIS – TYPICAL ANALYSIS

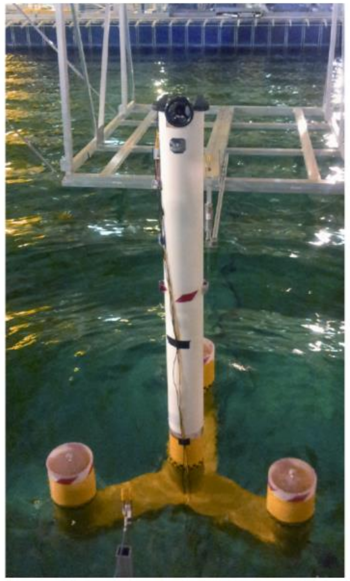


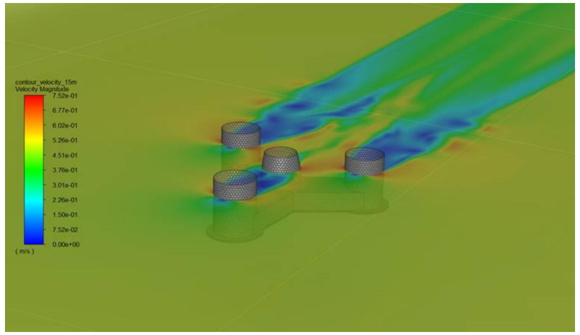
CALIBRATION

> Model Tests:
  – RCN project
  – Lifes50+

> Reference literature:
  – DNV-RP-C205 Environmental Conditions and Environmental Loads
  – DNV-OS-E301 Position Mooring

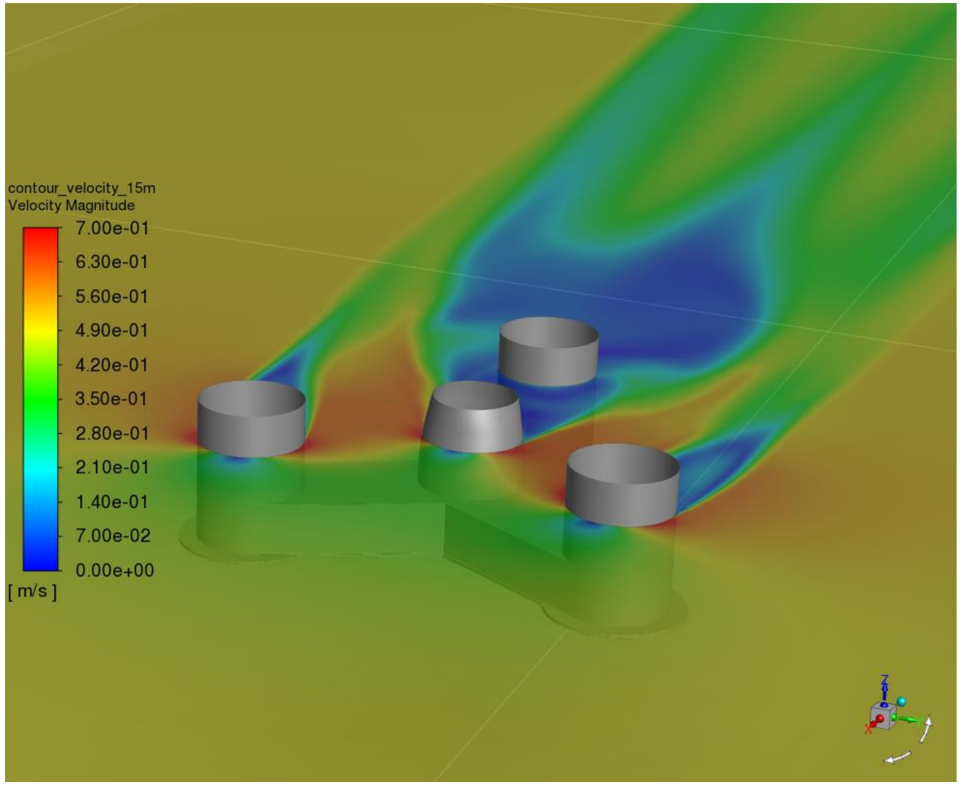
> Analyses:
  – CFD
  – Second Order Potential Theory

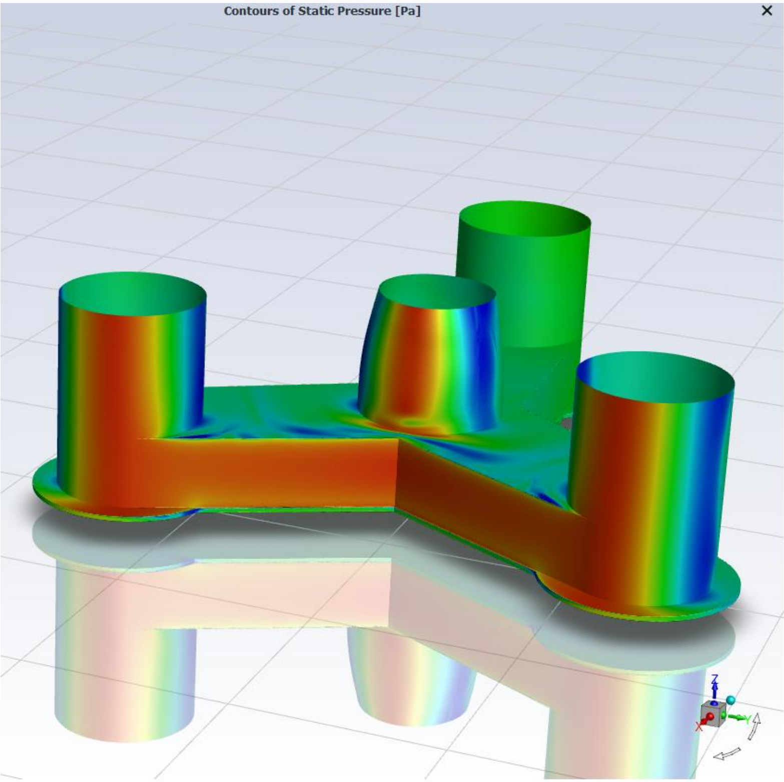




https://www.youtube.com/watch?v=l3gQeD_rVe8

CALIBRATION EXAMPLE - CFD





LOAD CASES (DNV-ST-0437)

Table 4-3 Design load cases

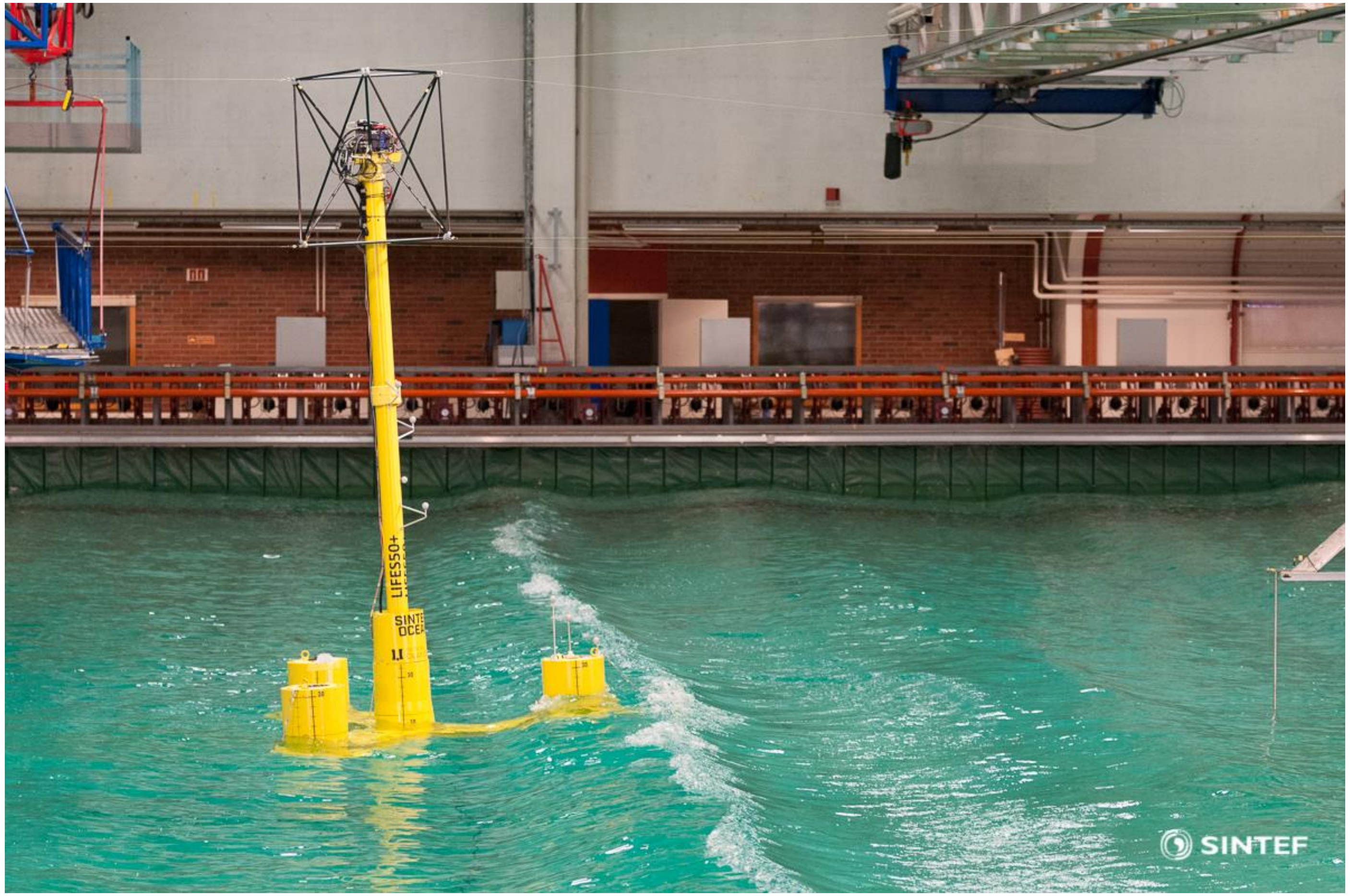
Design Situation	*DLC*	*Wind Condition*	*Marine Condition* Waves	*Marine Condition* Wind and wave directionality	*Marine Condition* Sea Currents	*Marine Condition* Water Level	*Other Conditions:*	*Type of Analysis* Onshore	*Type of Analysis* Offshore	*Partial safety factor*
1) Power Production:	1.1	NTM $V_{in} < V_{hub} < V_{out}$	NSS $H_s = E[H_s \mid V_{hub}]$	COD, UNI	NCM	MSL	For extrapolation of extreme loads (offshore – only RNA)	U	U	N (1.25)
	1.2	NTM $V_{in} < V_{hub} < V_{out}$	NSS Joint prob. distribution of H_s, T_p, V_{hub}	MIS, MUL	No Currents	NWLR or ≥ MSL		F/U	F/U	F/N
	1.3	ETM $V_{in} < V_{hub} < V_{out}$	NSS $H_s = E[H_s \mid V_{hub}]$	COD, UNI	NCM	MSL		U	U	N
	1.4	ECD $V_{hub} = V_r - 2$ m/s, V_r, $V_r + 2$ m/s	NSS $H_s = E[H_s \mid V_{hub}]$	MIS, wind direction change	NCM	MSL		U	U	N
	1.5	EWS $V_{in} < V_{hub} < V_{out}$	NSS $H_s = E[H_s \mid V_{hub}]$	COD, UNI	NCM	MSL		U	U	N
	1.6	NTM $V_{in} < V_{hub} < V_{out}$	SSS $H_s = H_{s,SSS}$	COD, UNI	NCM	NWLR		-	U	N
	1.7	NTM $V_{in} < V_{hub} < V_{out}$	NSS Joint prob. distribution of H_s, T_p, V_{hub}	MIS, MUL	No Currents	NWLR or ≥ MSL	Ice formation	F/U	F/U	F/N

Design Situation	*DLC*	*Wind Condition*	*Marine Condition* Waves	*Marine Condition* Wind and wave directionality	*Marine Condition* Sea Currents	*Marine Condition* Water Level	*Other Conditions:*	*Type of Analysis* Onshore	*Type of Analysis* Offshore	*Partial safety factor*
6) Parked (standing still or idling)	6.1	EWM $V_{hub} = V_{ref}$	ESS $H_s = H_{s,50}$	MIS, MUL	ECM $U = U_{50}$	EWLR	Yaw misalignment of ±8 deg Possible yaw slippage	U	U	N
	6.2	EWM $V_{hub} = V_{ref}$	ESS $H_s = H_{s,50}$	MIS, MUL	ECM $U = U_{50}$	EWLR	Loss of electrical network Yaw misalignment of ±180°	U	U	A
	6.3	EWM $V_{hub} = V_1$	ESS $H_s = H_{s,1}$	MIS, MUL	ECM $U = U_1$	NWLR	Extreme yaw misalignment Yaw misalignment of ±20 deg	U	U	N

IMPORTANT LOAD EFFECTS

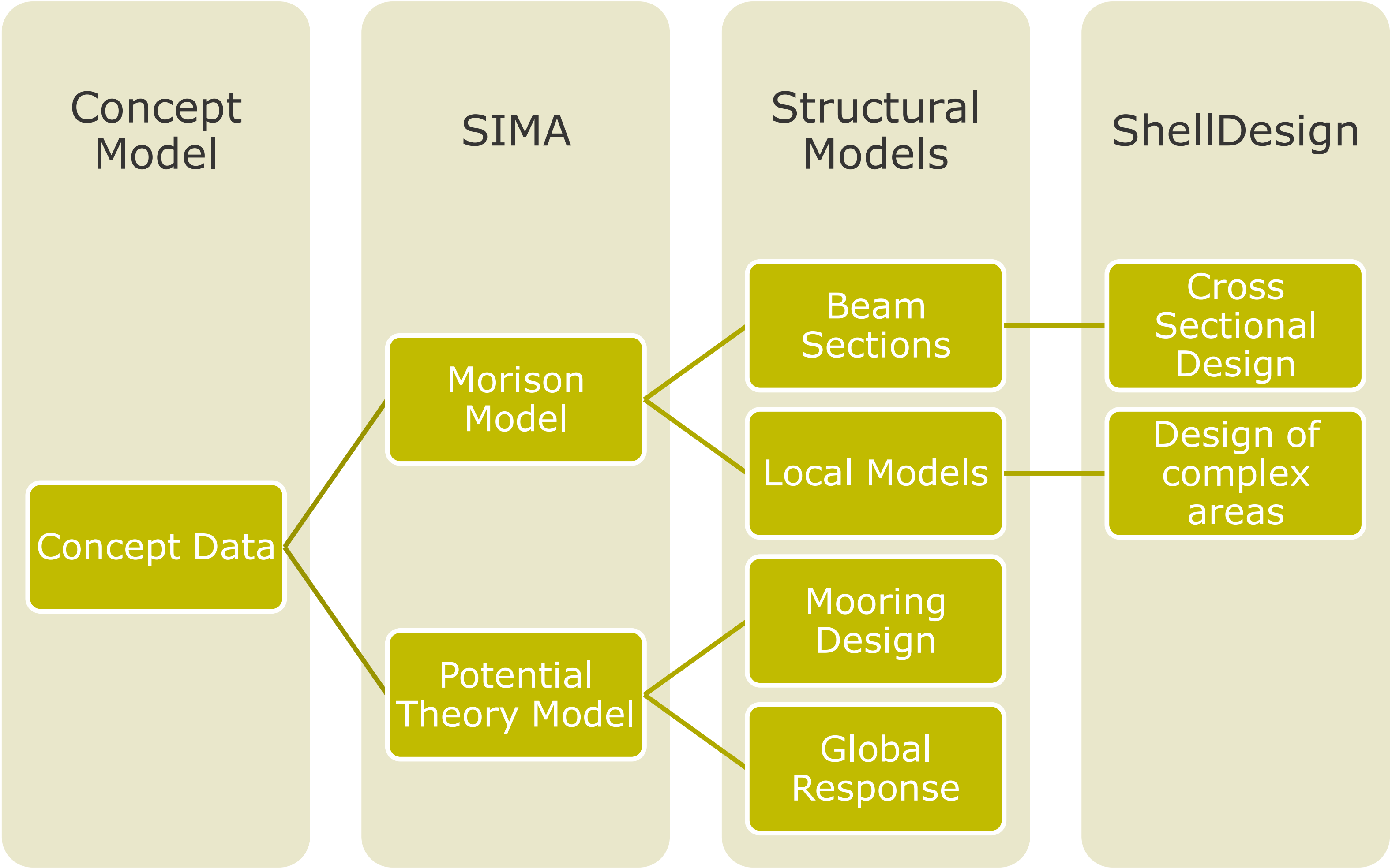
- Environmental
  - Wave loads
    - First order
    - Second order
    - Slamming
  - Current loads
  - Aerodynamic loads

- Accidental:
  - Ship Impact



DESIGN PROCESS AND STRUCTURAL DESIGN

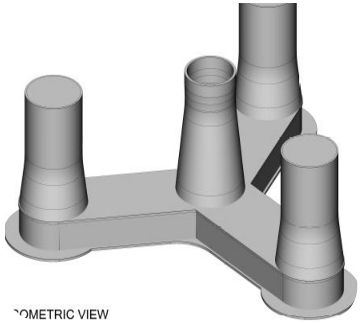
MAIN PROCESS – CONCEPTUAL STUDIES

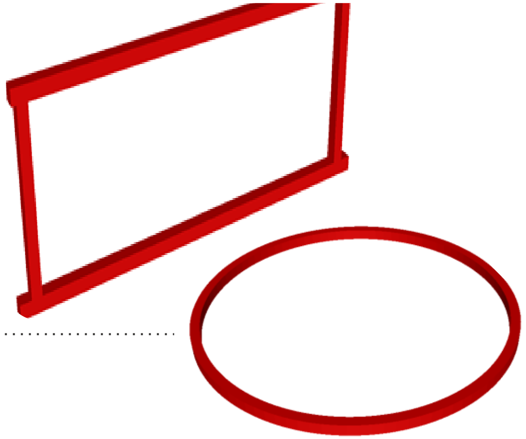


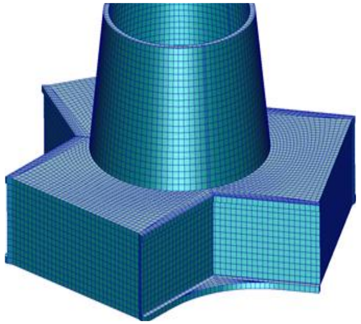
STRUCTURAL ANALYSES – OVERVIEW

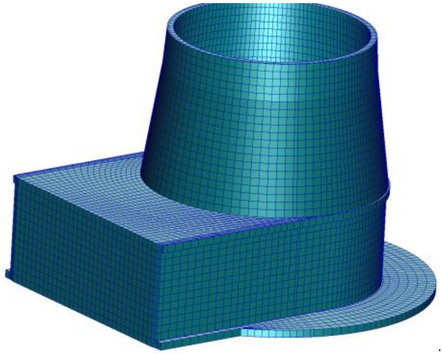
Update of mooring system (loads), geometry etc.

Initial sizing → Beam section checks → Check of local models → Final geometry and reinforcement layout

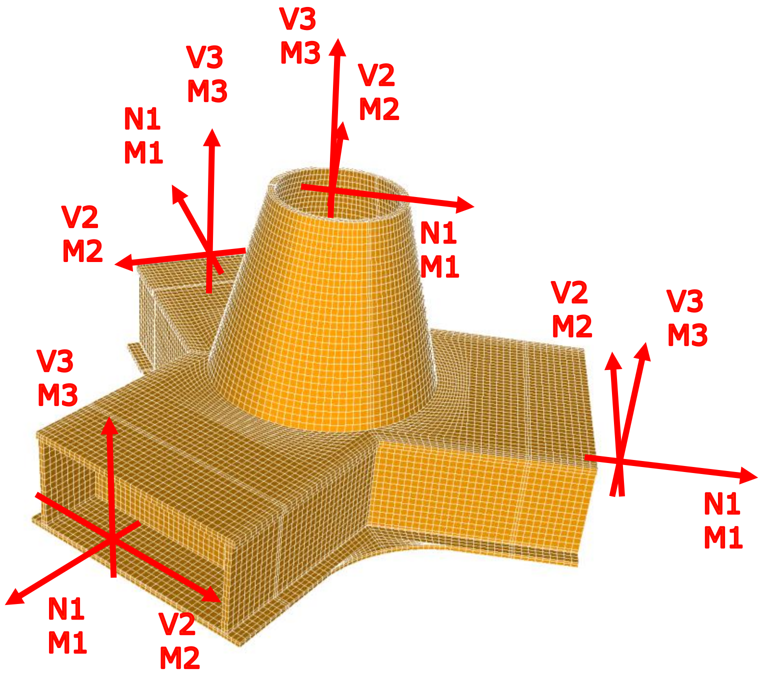




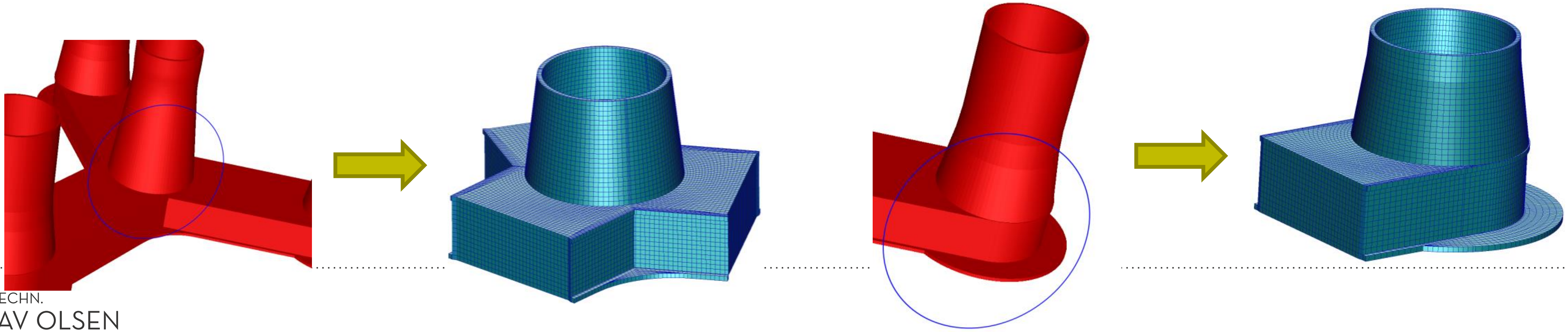




LOCAL MODELS



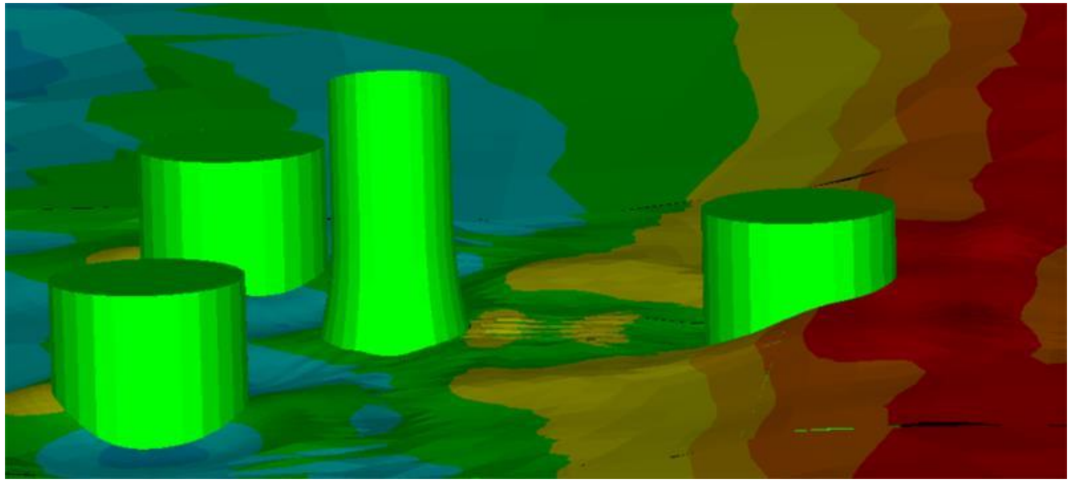
- Used to verify chosen geometry and find final reinforcement intensity in the substructure
- Loads are based on the fully coupled simulations
  - Simultaneously acting beam section forces from fully coupled analysis combined with hydrodynamic and hydrostatic pressure



OTHER MODELS

- WASIM model:
  - Used for validation of hydrodynamics
  - Air gap (idling)
  - (Validation of design forces in WADAM and SIMA)

- WADAM -> SIMA -> WASIM
  - Supported by the software
  - Currently being tested
  - Expected to be rather complicated and computationally challenging.



CHALLENGES

- A significant amount of manual work needed to calibrate models
- Defining consistent and correct design forces for complex areas
- Representative hydrodynamic pressure in design models

THANKS FOR YOUR ATTENTION

FOR FURTHER INFORMATION PLEASE VISIT OUR WEBSITE!

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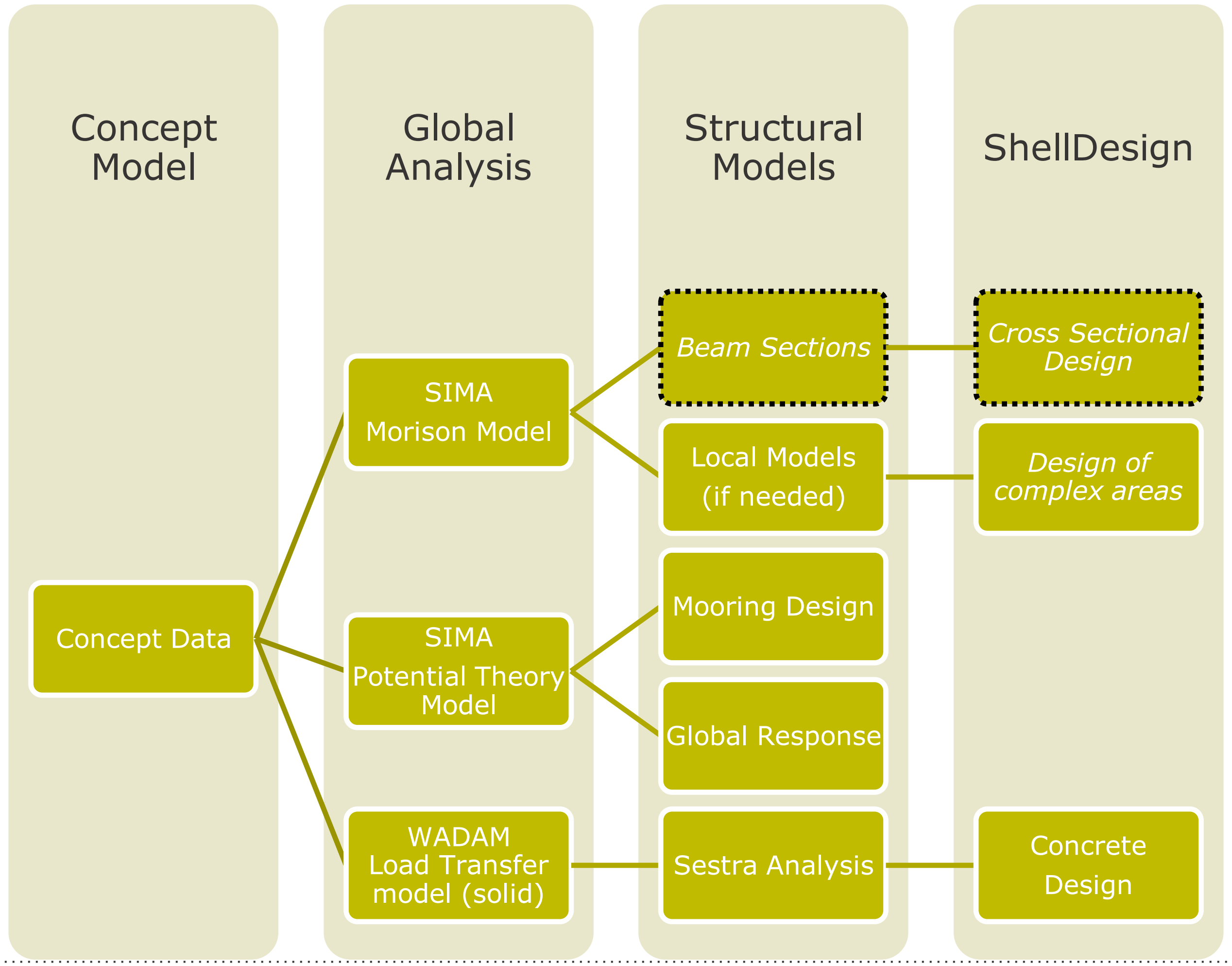
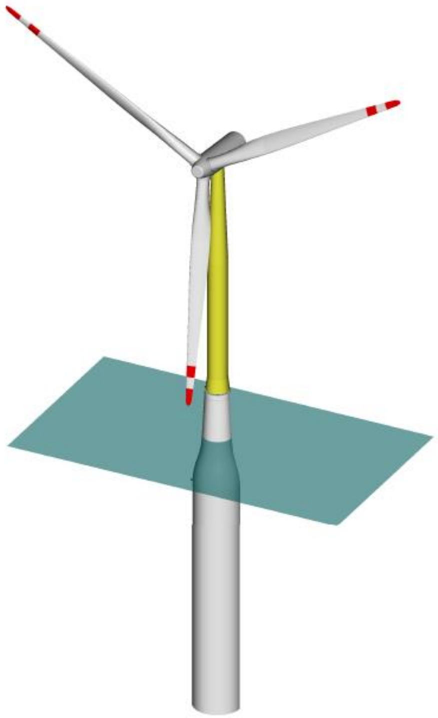
Backup Slides

PROPOSED PROCESS FOR DETAILED DESIGN

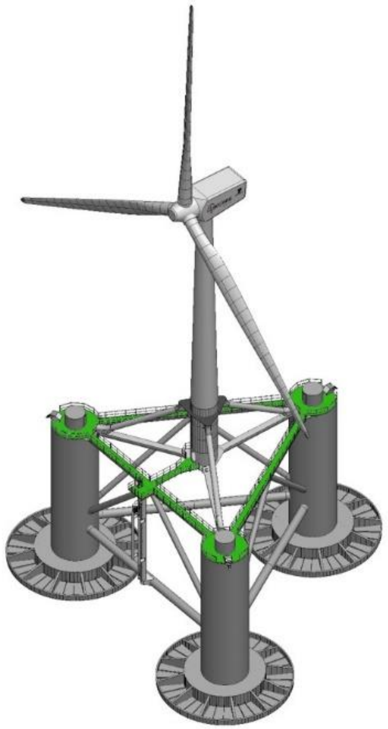


FLOATING OFFSHORE WIND – OUR EXPERIENCE



Hywind

Hydro/Equinor



HiPRWind

FP7 EU project

OO-Star Wind Floater

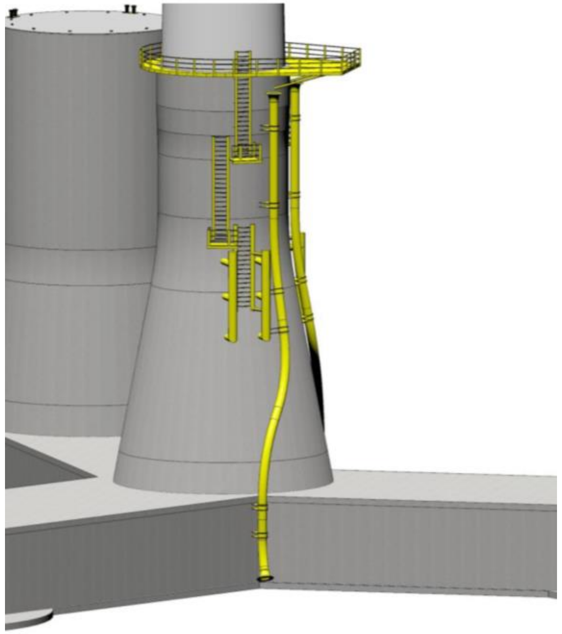
Developed by OO,
owned by FWS

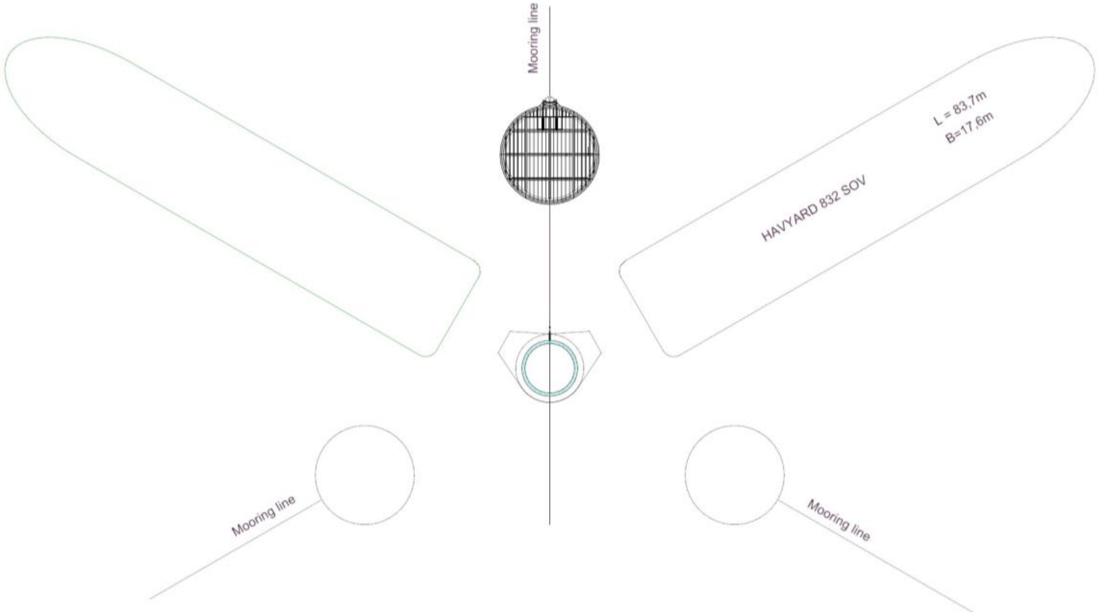
Access and Guide Tubes

ACCESS & GUIDE TUBES

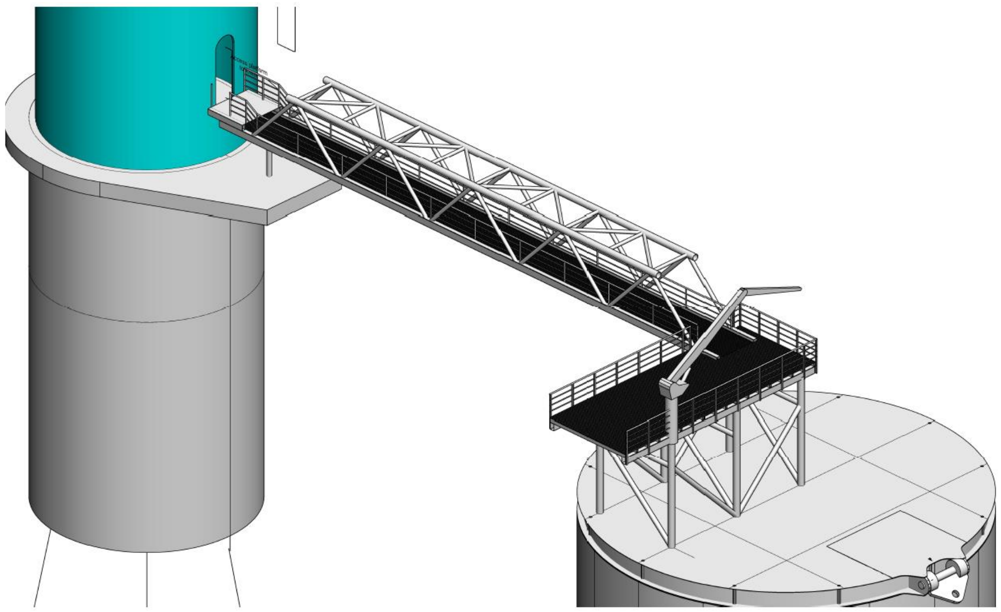
GANGWAY WORKING AREA

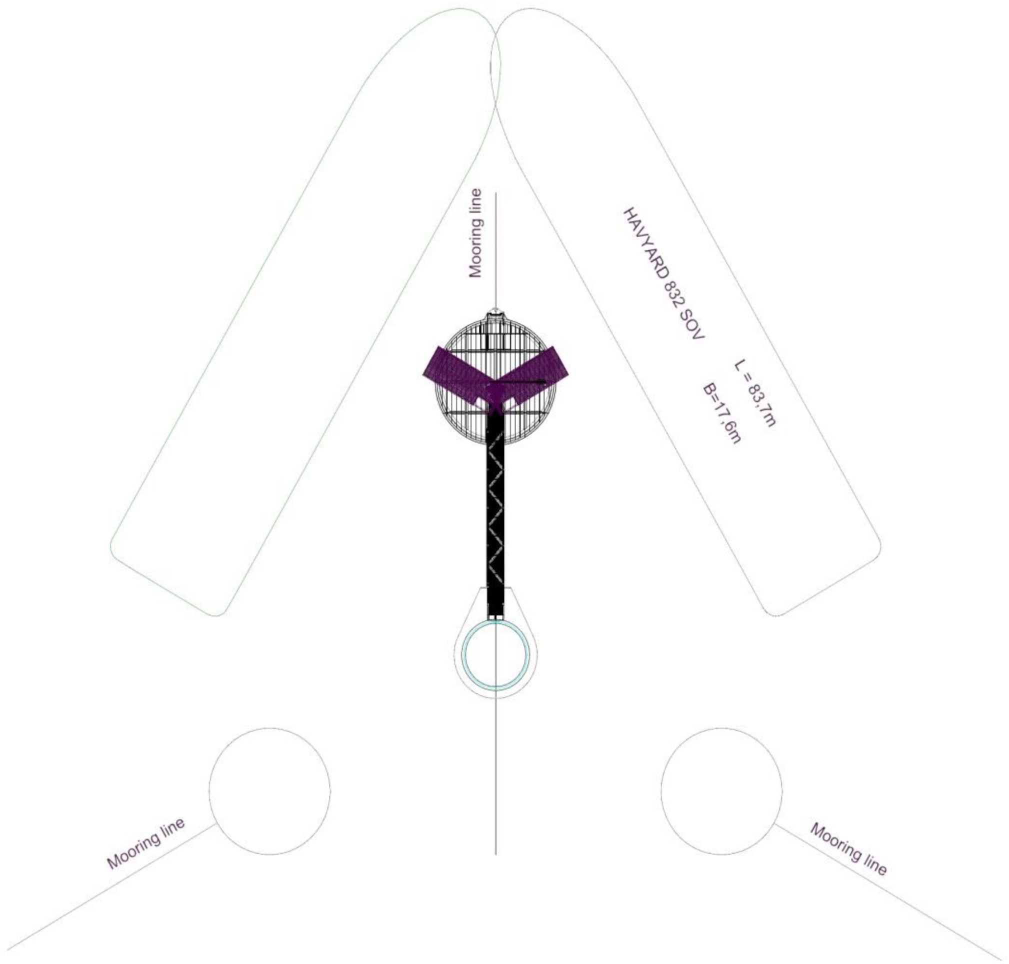
- Motion compensation in 4 degrees of freedom
    - Luffing, telescoping, slewing and heaving
- Vertically heave compensation on hinge point
    - Eliminates angle on gangway during operation
- Elevator inside tower syncs the heave compensation of the hinge point





ACCESS SYSTEM - ALTERNATIVE





FLAGSHIP Project

FLoAtinG offSHore wInd oPtimization for commercialization

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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FLAGSHIP

What is FLAGSHIP?

Main objective:
To reduce the Levelized Cost of Energy (LCOE) for floating offshore wind to the range 40-60 €/MWh by 2030.

Project is based on a Consortium created to participate in the European programme Horizon 2020, with a full-scale turbine >10 MW in site and environmental conditions comparable to the future potential projects.

Awarded with a **25 MM €** Grant from the European Commission (EC).

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Consortium

International consortium lead by **Iberdrola** and including companies and institutions from 5 different countries:

- Spain
- Norway
- Denmark
- Germany
- France

Multi-disciplinary profile of the partners to offer an appropriate balance.

Project overview

- FLAGSHIP will develop and fabricate the first 10+ MW Floating Offshore Wind Turbine (FOWT).
- Will be assembled on a floating semi-submersible concrete structure in the Norwegian North Sea.
- The starting point for large-scale 500MW+ commercial floating offshore wind farms of the future
- Project Schedule 2020-2024

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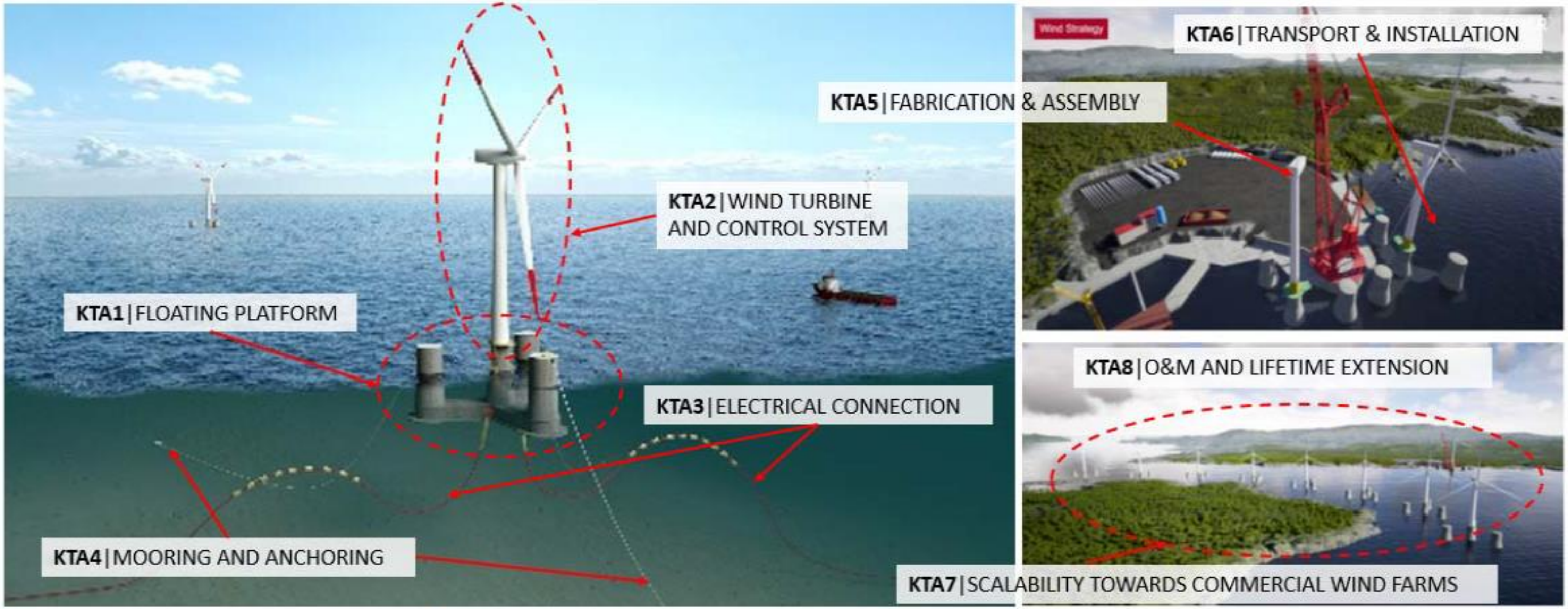
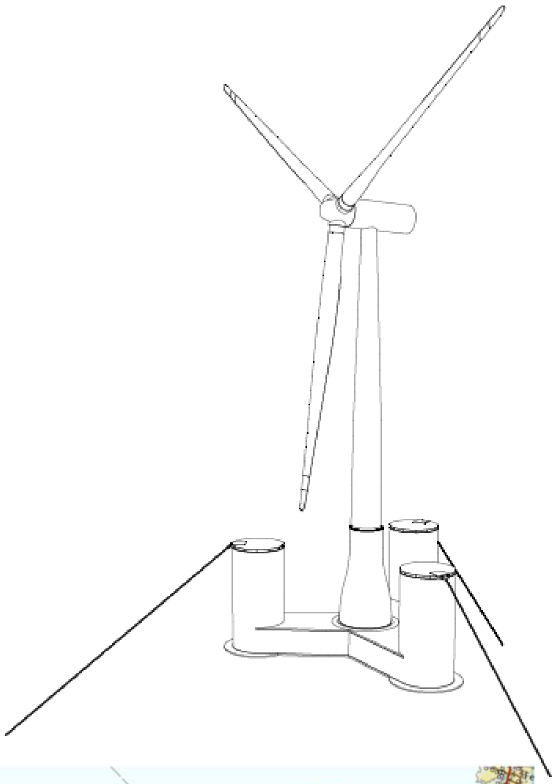
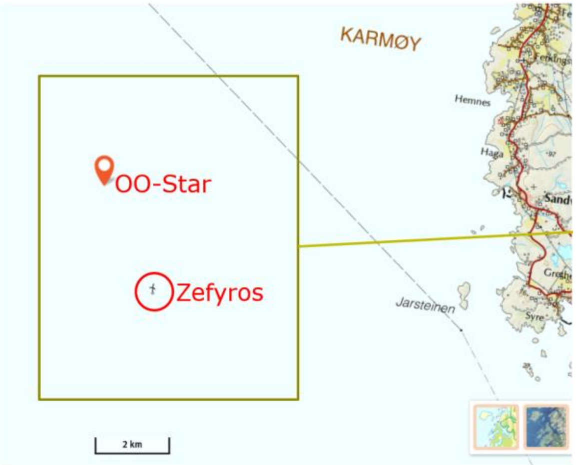
Key Technical Areas of the project



Demonstrator Unit in brief

- Floater – Concrete/Steel hull (one off)
  - Designed by Olav Olsen
  - Engineering by Olav Olsen and Aker Solutions
  - Procurement, Fabrication and Installation by Aker Solutions
  - Will be fabricated in a dry dock on the west-coast of Norway
- Mooring System – Catenary chain system (200 m WD)
  - Designed by Olav Olsen
  - Procurement and Installation by Aker Solutions
- Cable IAC – Flexible cable to Zefyros is Base Case
  - Designed and supply by Unitech
- The FLAGSHIP demonstrator will be installed at the Marine Energy Test Centre (MET) in the Norwegian North Sea.





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