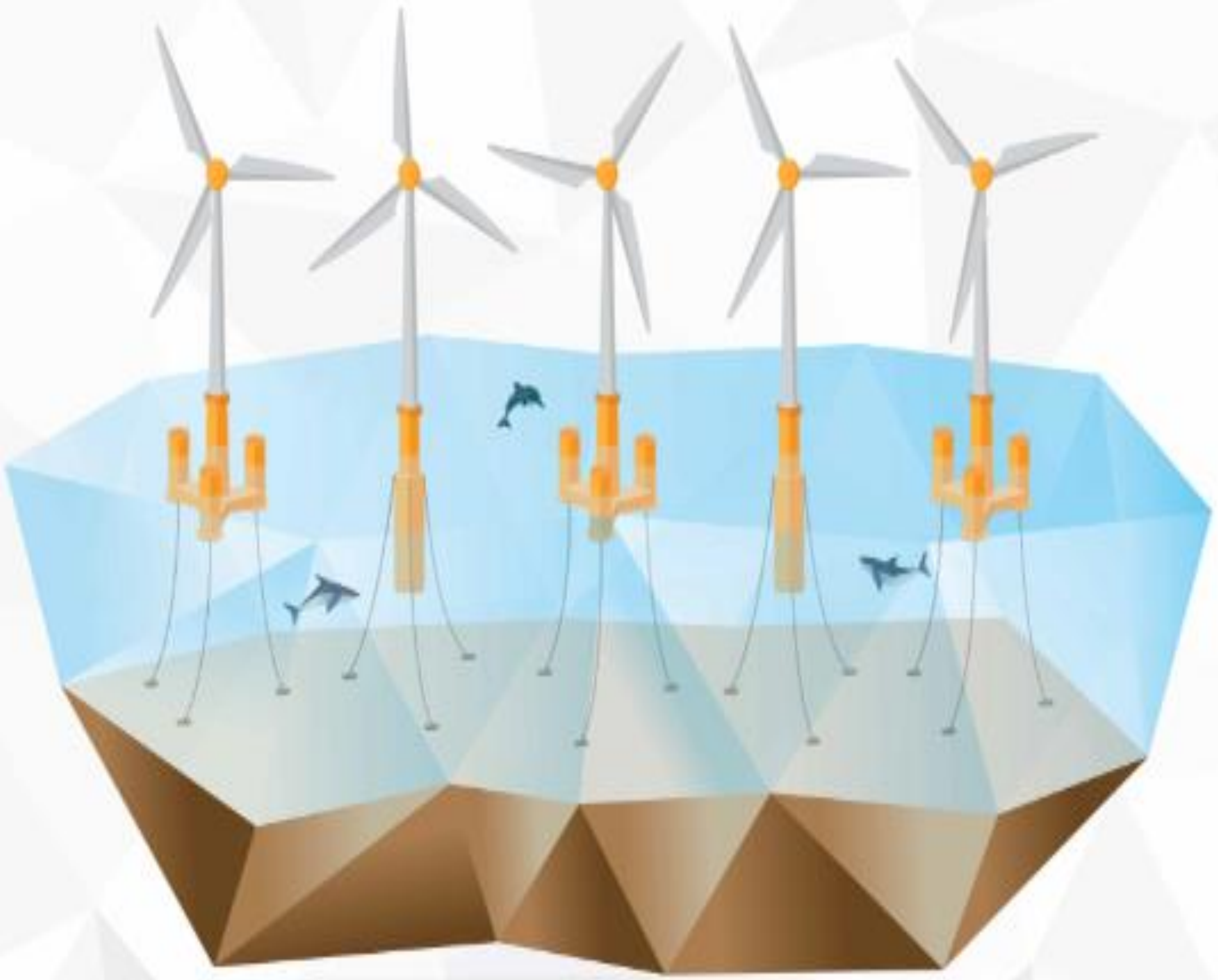
Innovations in integrated floating offshore wind systems



Agenda

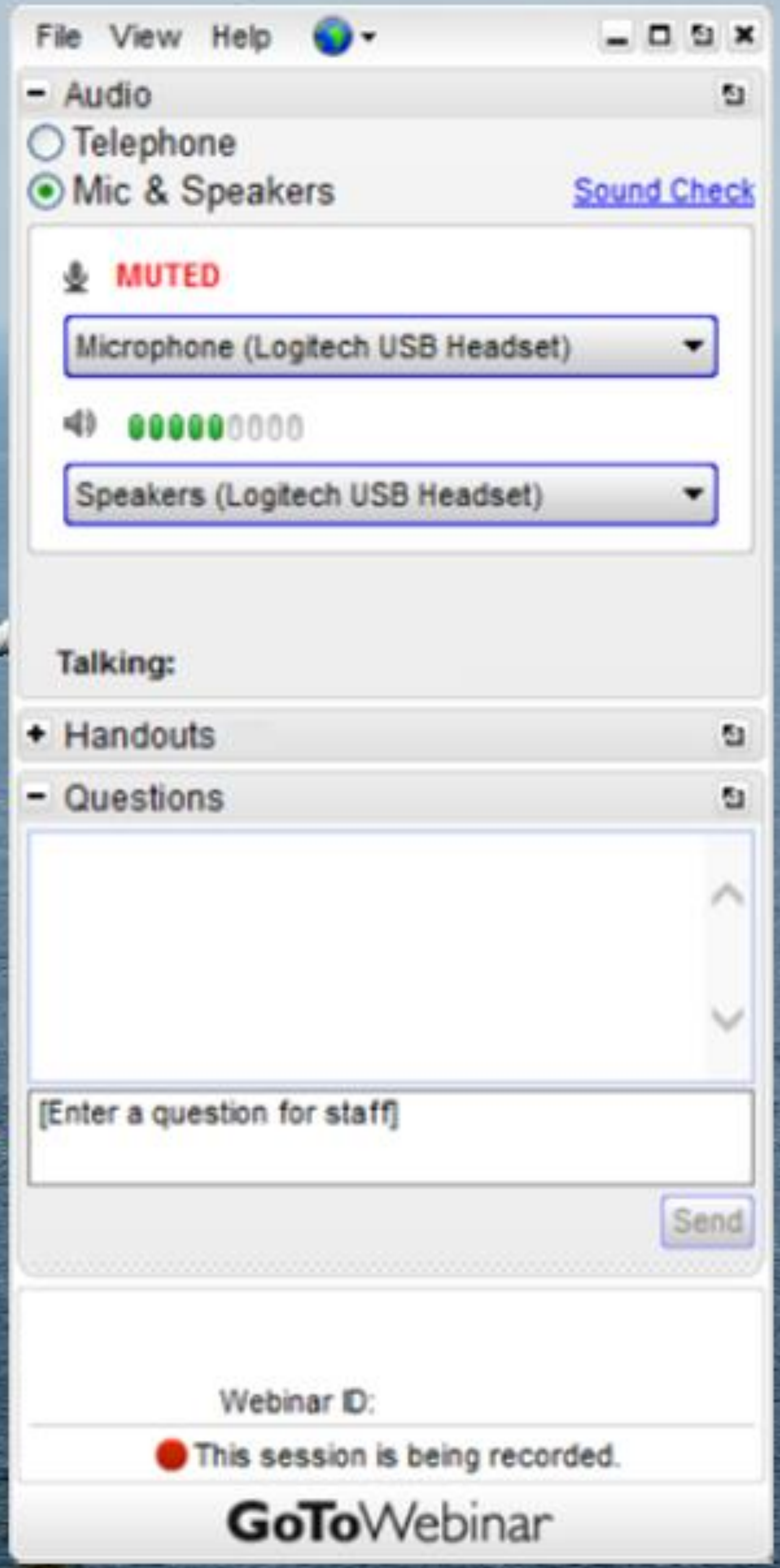
Time	Presenter	Topic
15:00-15:05	**Sabina Potestio**, WindEurope	Introduction
15:05-15:10	**Lizet Ramirez**, WindEurope	Sate of play of EU offshore policy
15:10-15:20	**Jose Luis Dominguez**, IREC	Introduction to Corewind
15:20-15:30	**Mohammad Youssef Mahfouz**, University of Stuttgart and **Climent Molins**, UPC	A FAST model of the UPC concrete spar floater and the 15 MW IEA WIND reference turbine
15:30-15:40	**Valentin Arramounet**, Innosea	Optimized mooring system for the ActiveFloat concrete semisub floater for the 15 MW IEA WIND reference wind turbine
15:40-15:50	**Marie-Antoinette Schwarzkopf**, Ramboll	O&M for commercial scale floating wind – Opportunities for maintenance strategies
15:50-16:00	**Jose I. Rapha**, IREC	Presentation on the LCOE evaluation tool FOWApp
16:00-16:10	**Pablo Necochea**, Vestas	Floating offshore wind innovations for cost reduction
16:10-16:30	**Sabina Potestio**, WindEurope	Q&A

corewind

WindEurope

Press + to expand the question box

Type your question and hit ‘**Send**’



Got a question?

corewind

COST REDUCTION OF
FLOATING WIND TECHNOLOGY

Sate of play of EU offshore policy

25 February 2021

corewind.eu

Disclaimer:

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 815083.

Project details:

Duration:
1 Sep 2019 - 28 Feb 2023
Grant agreement:
No: 815083

Lizet Ramírez
Analyst, Offshore Wind

Europe is leading the floating wind movement

Windfloat Atlantic

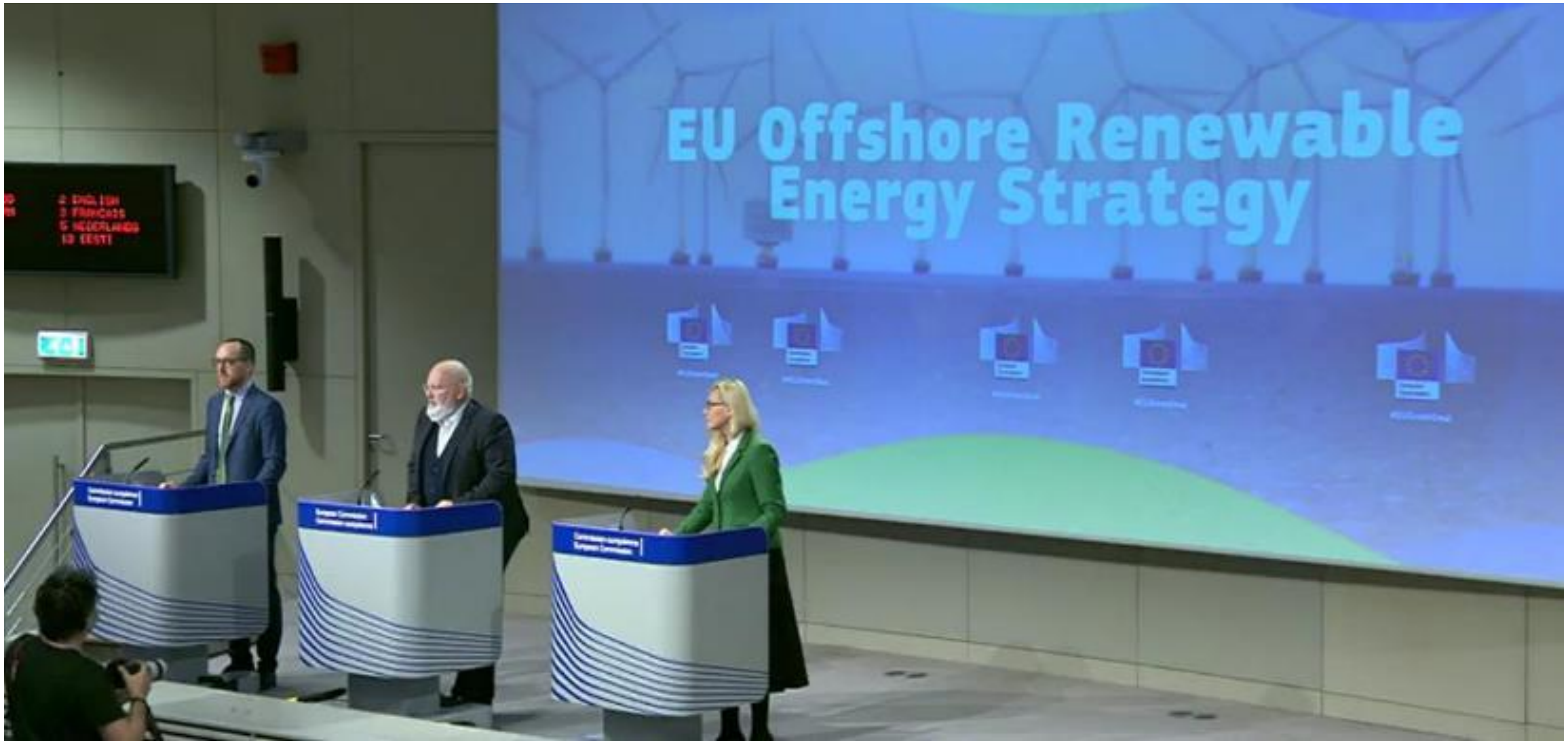
24 MW

Portugal

corewind

Photo courtesy of Principle Power. Artist name: Dock90

The Offshore Renewable Energy Strategy: Focus on scale-up



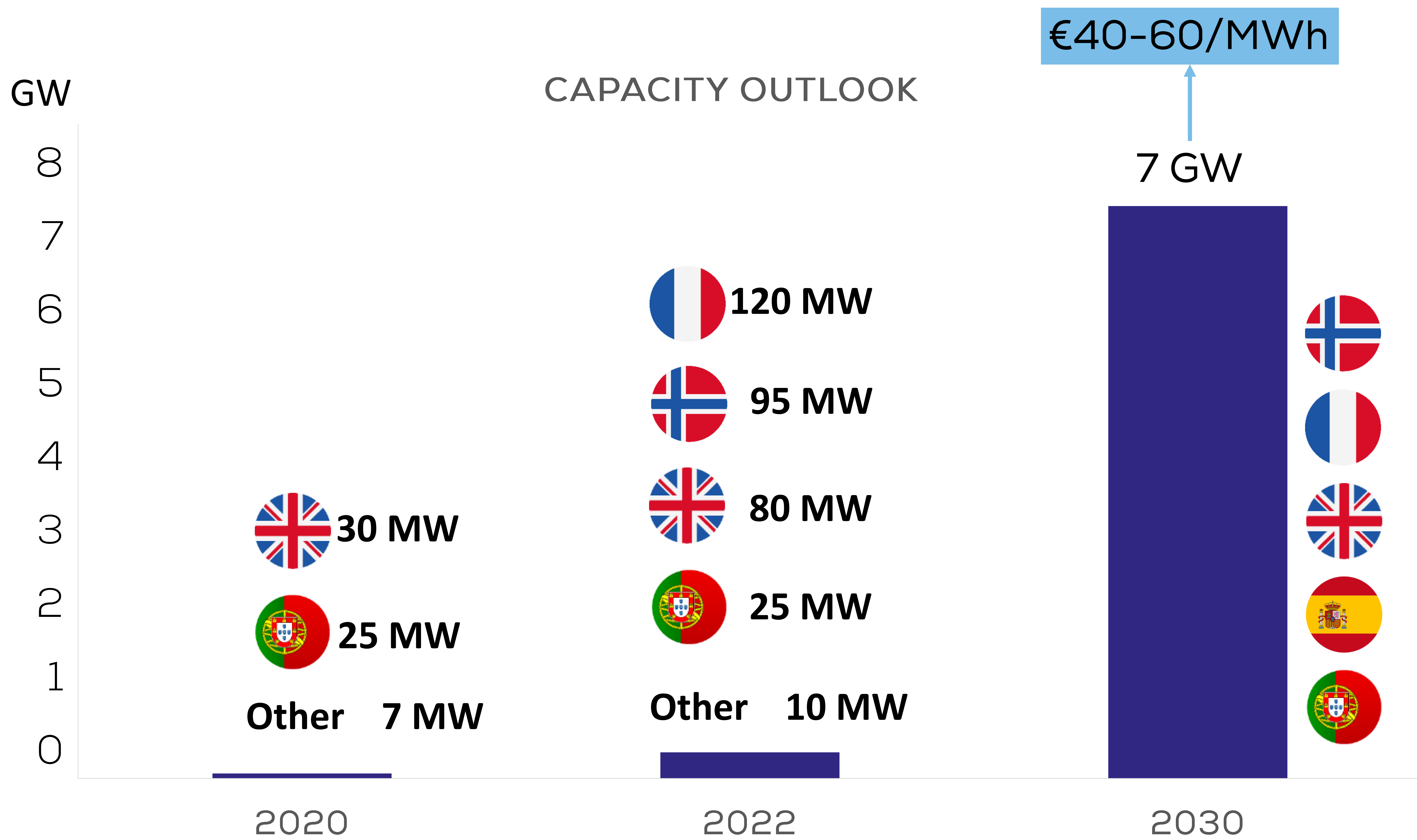
60 GW by 2030
300 GW by 2050

Released on
November 19, 2020

Europe needs both floating and fixed-bottom offshore wind

30%
Floating

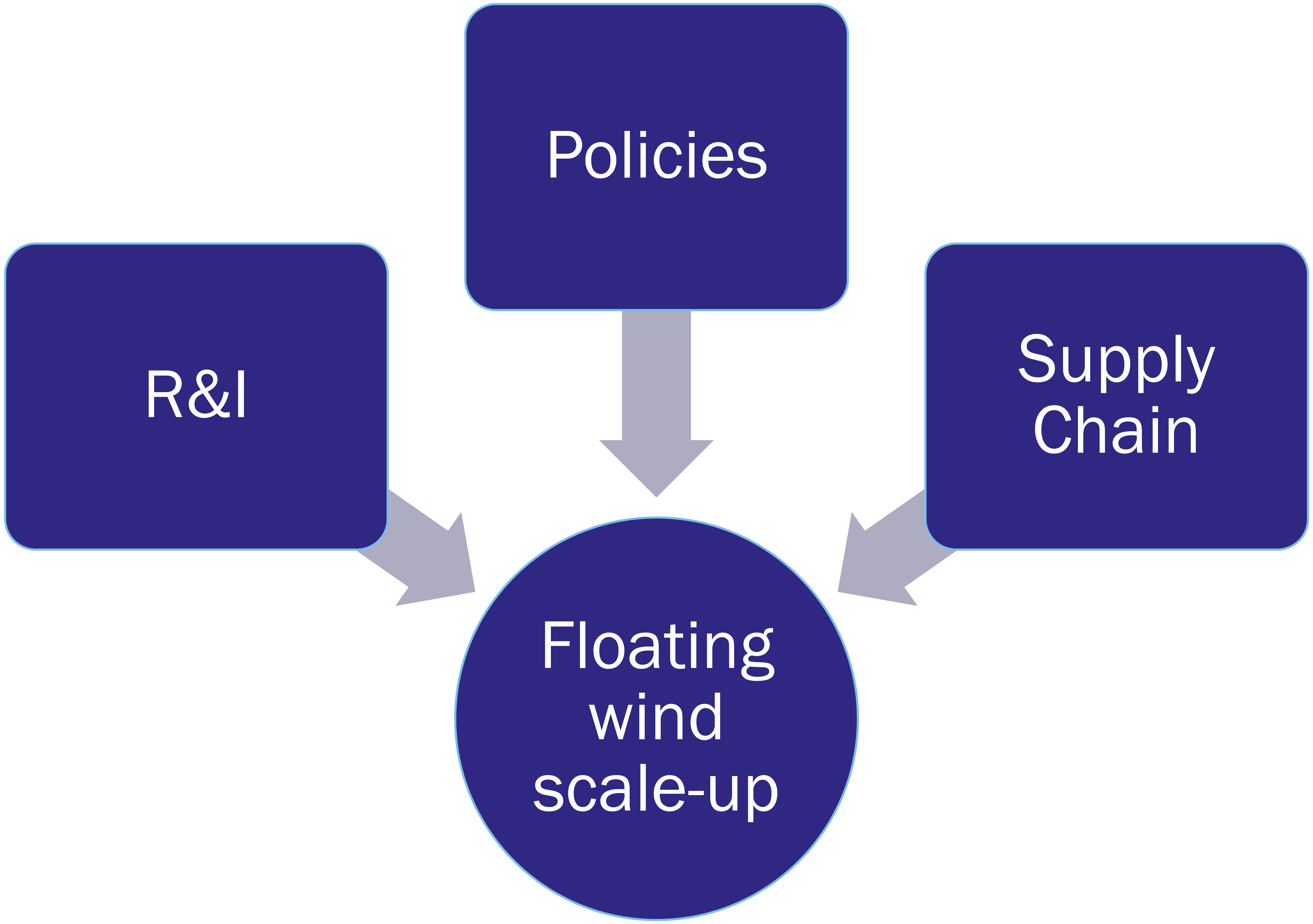
Floating Offshore Wind about to take off



Delivering the right offshore framework

1. Clear auction timetable
2. Technology-specific auctions
3. Contracts for Difference
4. One-stop shop for permitting
5. Private/Public grid development
6. Ensure happy co-existence

Delivering the right offshore framework



corewind

COST REDUCTION OF
FLOATING WIND TECHNOLOGY

Introduction to Corewind

25 February 2021

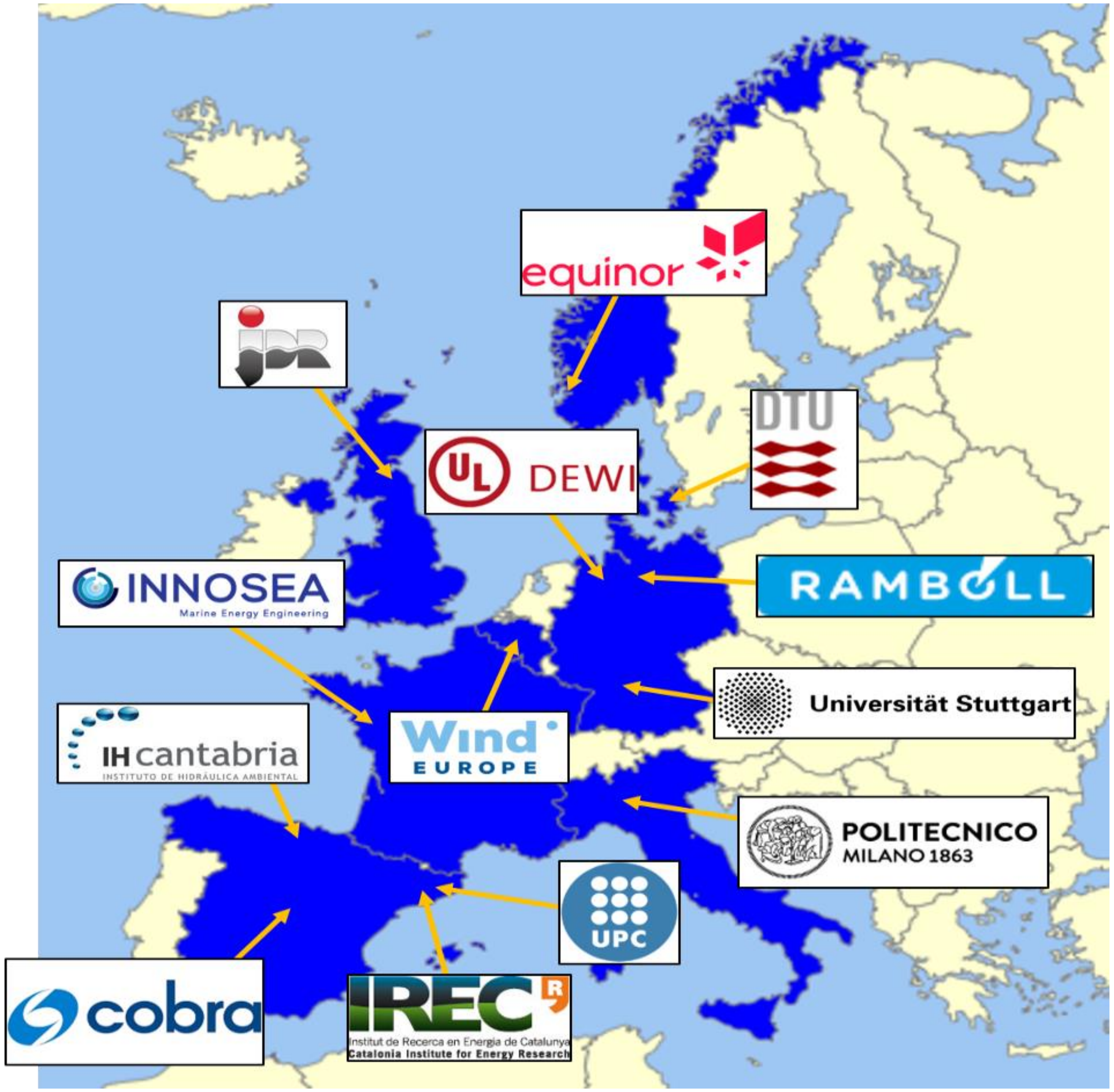
corewind.eu

Dr. Jose Luis Domínguez-García
COREWIND coordinator

Disclaimer:
This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 815083.

Project details:
Duration:
1 Sep 2019 - 28 Feb 2023
Grant agreement:
No: 815083

Project partners and advisory board



UC UNIVERSIDAD DE CANTABRIA

ESTEYCO

UL

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

DEME
Dredging, Environmental & Marine Engineering

eit | European Institute of Innovation & Technology

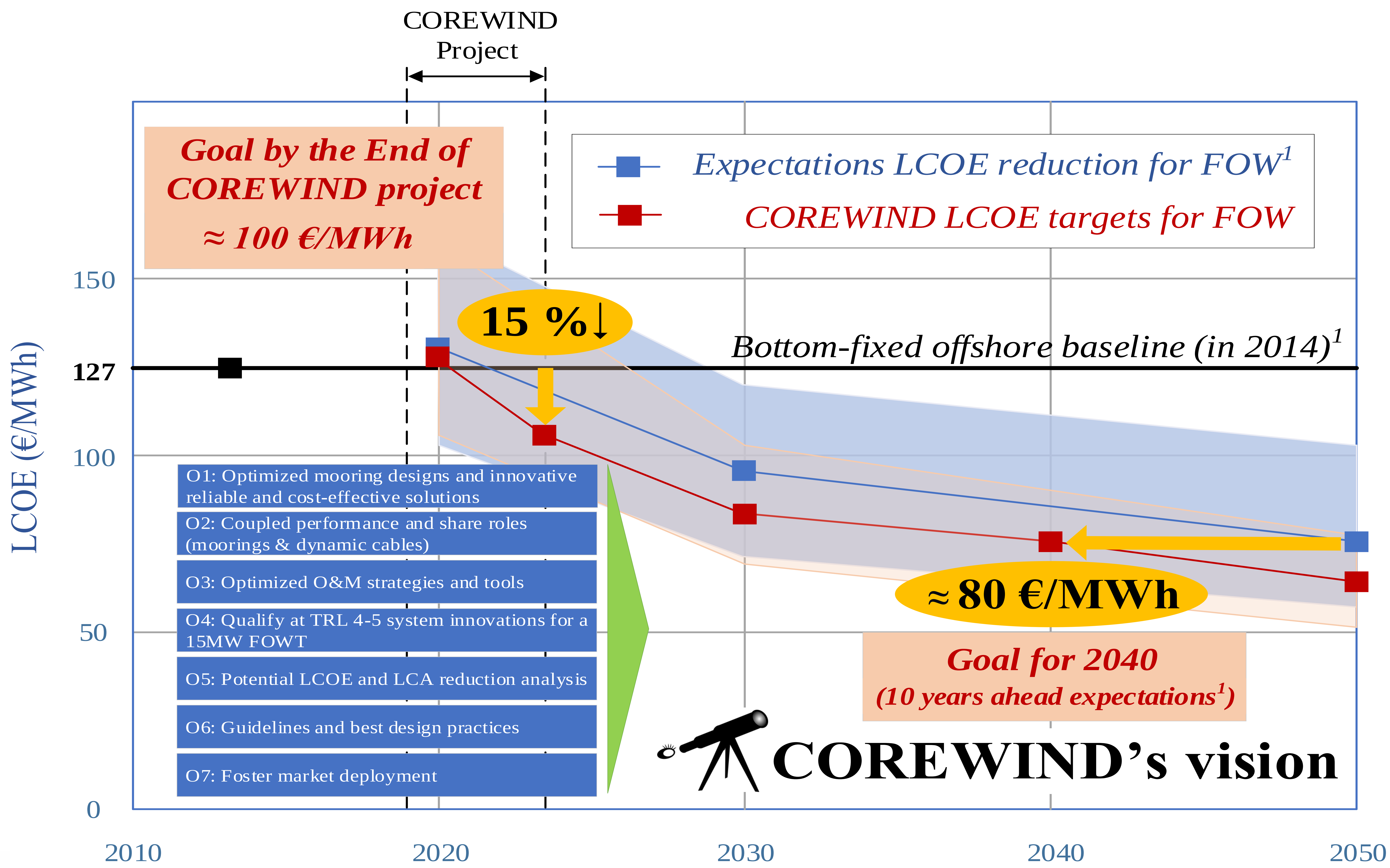
CARBON TRUST

WINDSY

corewind

Project objectives

COREWIND looks **beyond the state of the art** of the **floating technology** with the aim of accelerating the path towards its commercial deployment by **developing and validating innovative and cost-effective solutions** that allows to solve the most critical barrier of floating offshore wind technology, the cost.



Project approach

KEY FLOATING OFFSHORE WIND CHALLENGES

- **COST**
- **Reliability**
- **Lifetime**
- **Industria-lization**

COREWIND

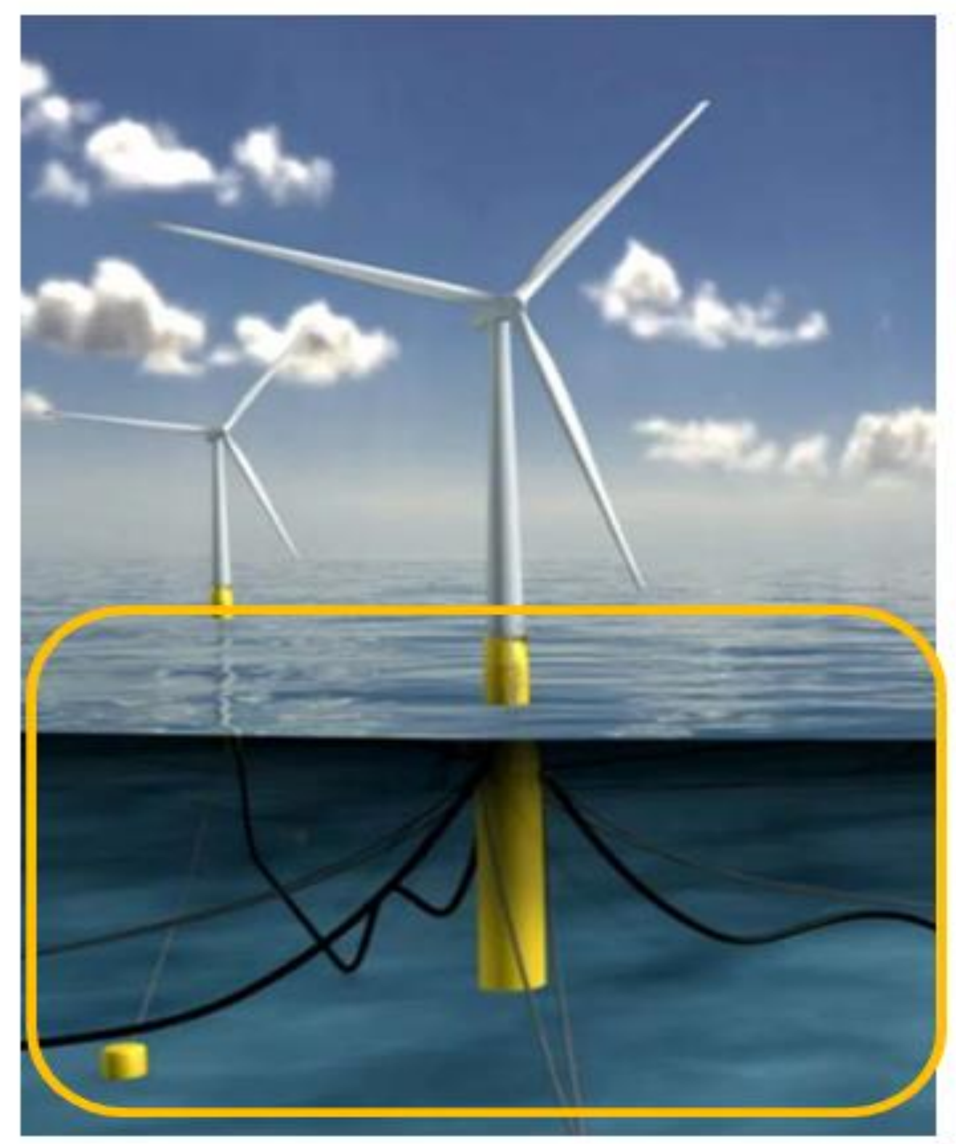
LCOE and **LCA** tools

Development of **innovative cost-effective and reliable solutions**

Multi-fidelity advanced models

Improved **condition monitoring**

Digitalization: Digital Twin + BIM toolbox



Mooring & dynamic cable design **optimization**

Standardization and certification

O&M planning & assessment tools

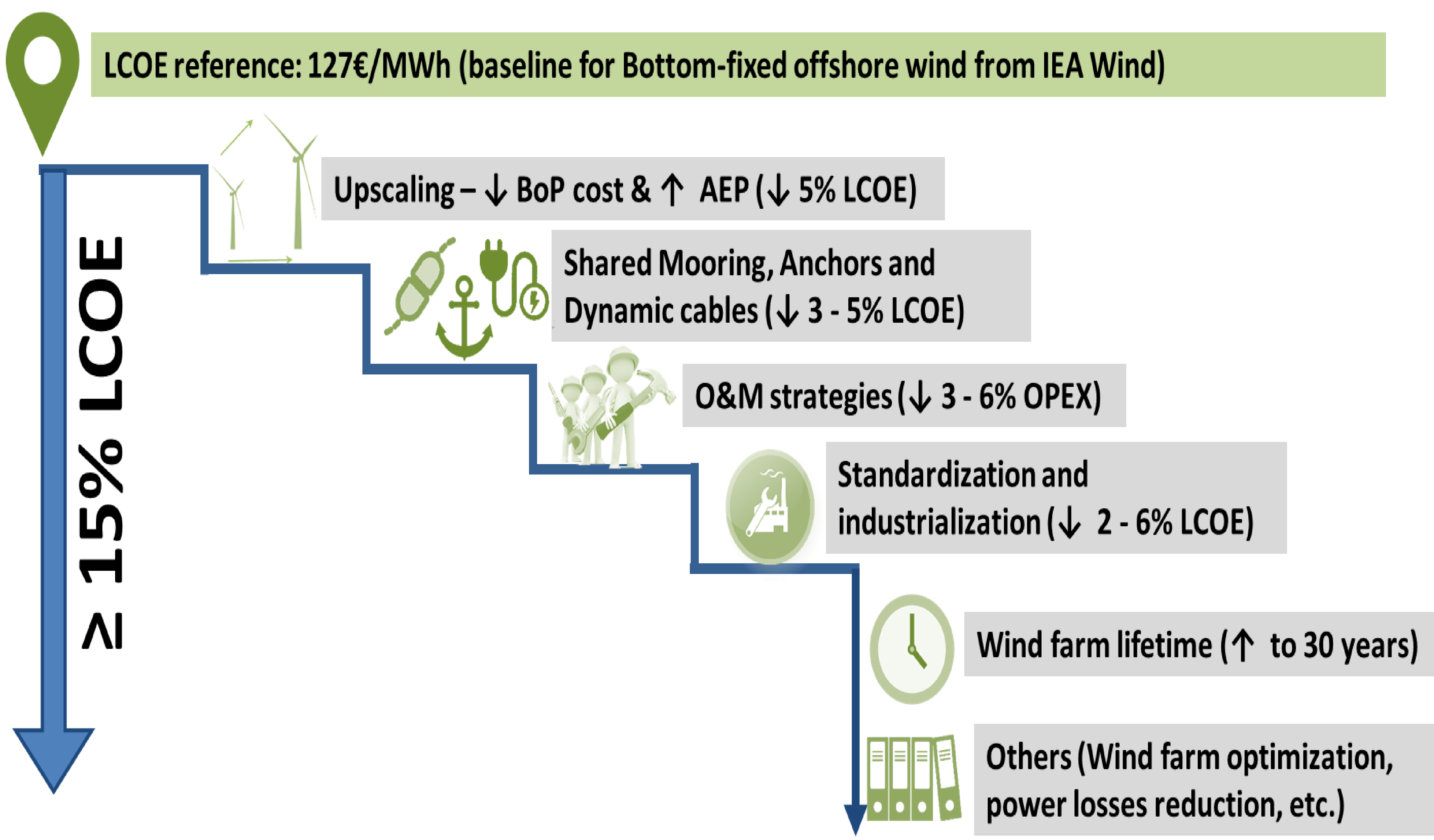
Experimental testing validation:

- Laboratory scale: Hybrid **HIL Test**: Wave Tank + Wind Tunnel
- Field testing: Synthetic lines & cable coating degradation (**biofouling, corrossion**) in marine environment

COREWIND OUTCOMES and ADVANCES

- **Open data and models available**
- **Novel mooring and anchoring designs**
- **Optimized mooring and power cable designs**
- **Concrete-based semisub & spar prototypes at TRL 5**
- **Explotation plan for innovations**
- **Guidelines and Best Practices**

Project expected impacts and outcomes



Advanced tools (DIGITALIZATION)

- **Reference models:**
  - 15 MW WT reference model
  - 2 floater (semi-sub & spar) models
- **Design and operation tools:**
  - 1 BIM toolbox for floating wind industry
  - 1 Open and agnostic Digital Twin for floating wind
  - 1 O&M planning and assessment tool
- **Economic tools:**
  - 1 LCOE and LCA calculation tool
  - Floating Wind Farm optimization modules for cost minimization

Key reference documents:

- Technologies State of the art
- Standards revision:
- Development guidelines
- Testing and design procedures recommendations.

corewind

Current outcomes and developments

M0 — M18 — M42

09/2019 — 03/2021 — 03/2023

- **Reference models:**
  - 15 MW WT reference model
  - 2 floater (semi-sub & spar) models
- **Economic tools:**
  - 1 LCOE and LCA calculation tool
- **Number of public deliverables:**
  - Several reports have been made available

Current outcomes and developments

- **Public Deliverables:**
  - They can be found at: http://corewind.eu/publications/
    - ❑ D6.1: General frame of the analysis and description of the new FOW assessment app
    - ❑ D4.1: Identification of floating-wind-specific O&M requirements and monitoring technologies
    - ❑ D2.1: Review of the state of the art of mooring and anchoring designs, technical challenges and identification of relevant DLC
    - ❑ D3.1: Review of the state of the art of dynamic cable system design
    - ❑ D1.2: Design Basis
    - ❑ D1.1: Definition of the 15MW reference wind turbine

- **Public models (available under different CC licenses):**

https://zenodo.org/communities/corewind/?page=1&size=20

- ❑ UPC-WindCRETE OpenFAST – Grand Canary Island
- ❑ COREWIND - ACTIVEFLOAT OpenFAST model 15 MW FOWT Grand Canary Island site

- ❑ Other locations to come soon

COST REDUCTION OF
FLOATING WIND TECHNOLOGY

Join the conversation
#corewind

Stay tuned and follow us for updates

https://twitter.com/corewindeu

https://www.linkedin.com/company/corewind/

Disclaimer:
This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 815083.

Project details:
Duration:
1 Sep 2019 - 28 Feb 2023
Grant agreement:
No: 815083

corewind

COST REDUCTION OF
FLOATING WIND TECHNOLOGY

Introduction to the OpenFAST model of the WindCrete spar floater

25 February 2021

corewind.eu

Supported by:

Disclaimer:
This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 815083.

Project details:
Duration:
1 Sep 2019 - 28 Feb 2023
Grant agreement:
No: 815083

Climent Molins *Professor UPC*
Mohammad Youssef Mahfouz *Researcher USTUTT*

WindCrete concept

Integrated concept of an offshore wind floating **platform plus tower** to support the wind turbine, without any joint.

Made of reinforced and post-tensioned **concrete.**

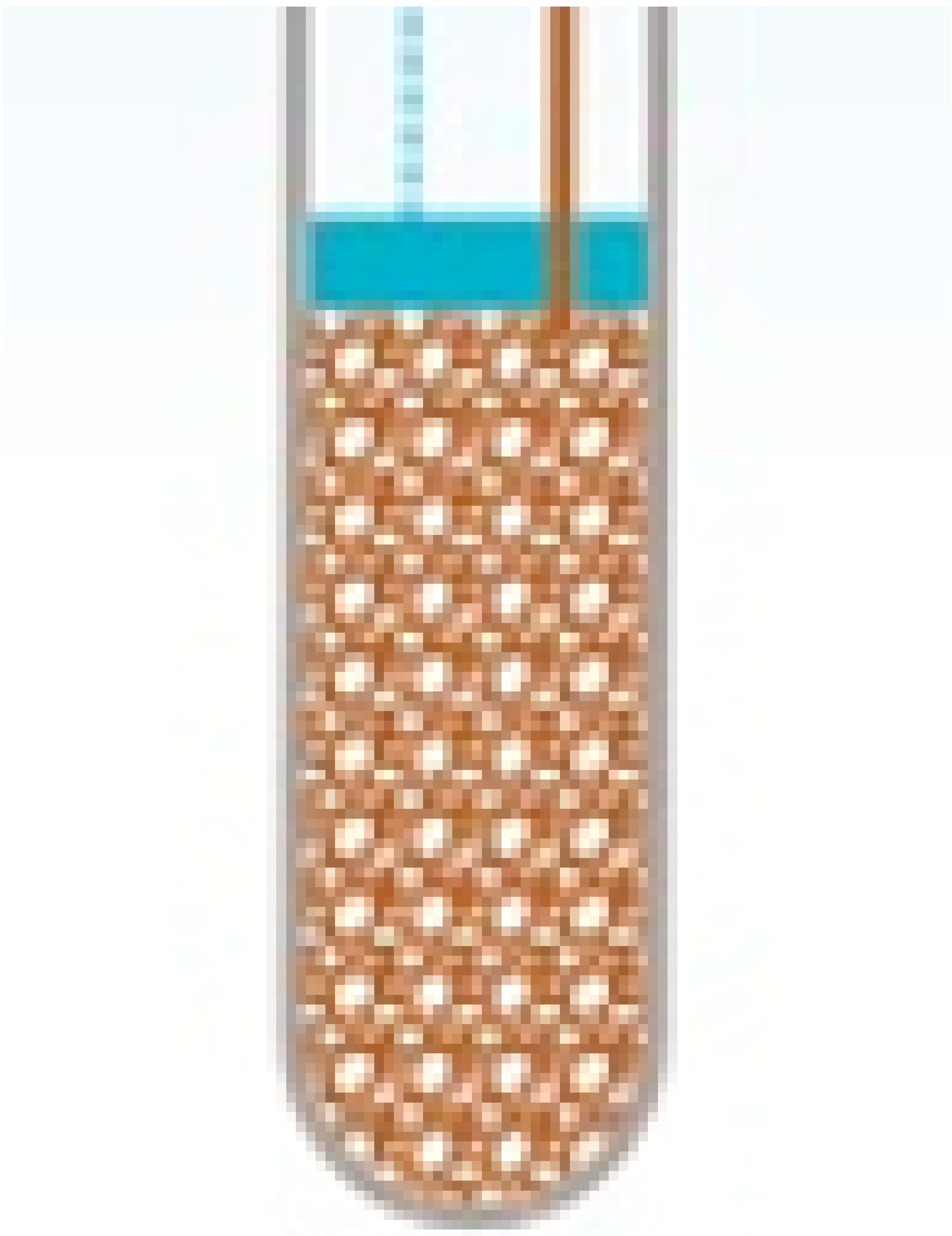
Spar type platform (ballast stabilized)

WindCrete ballast

Ballast aggregate: black slag from electrical furnace

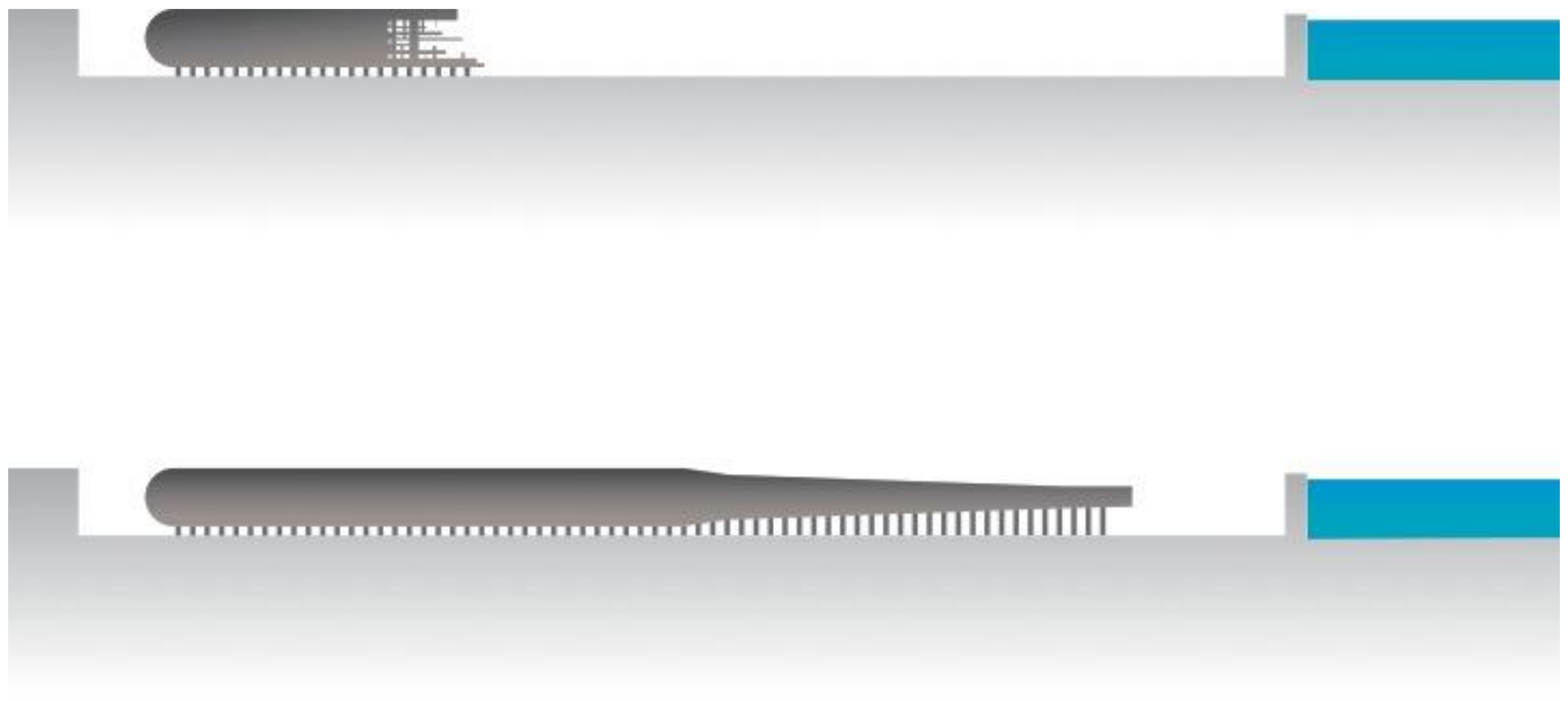
- Bulk-specific weight: 25kN/m^3

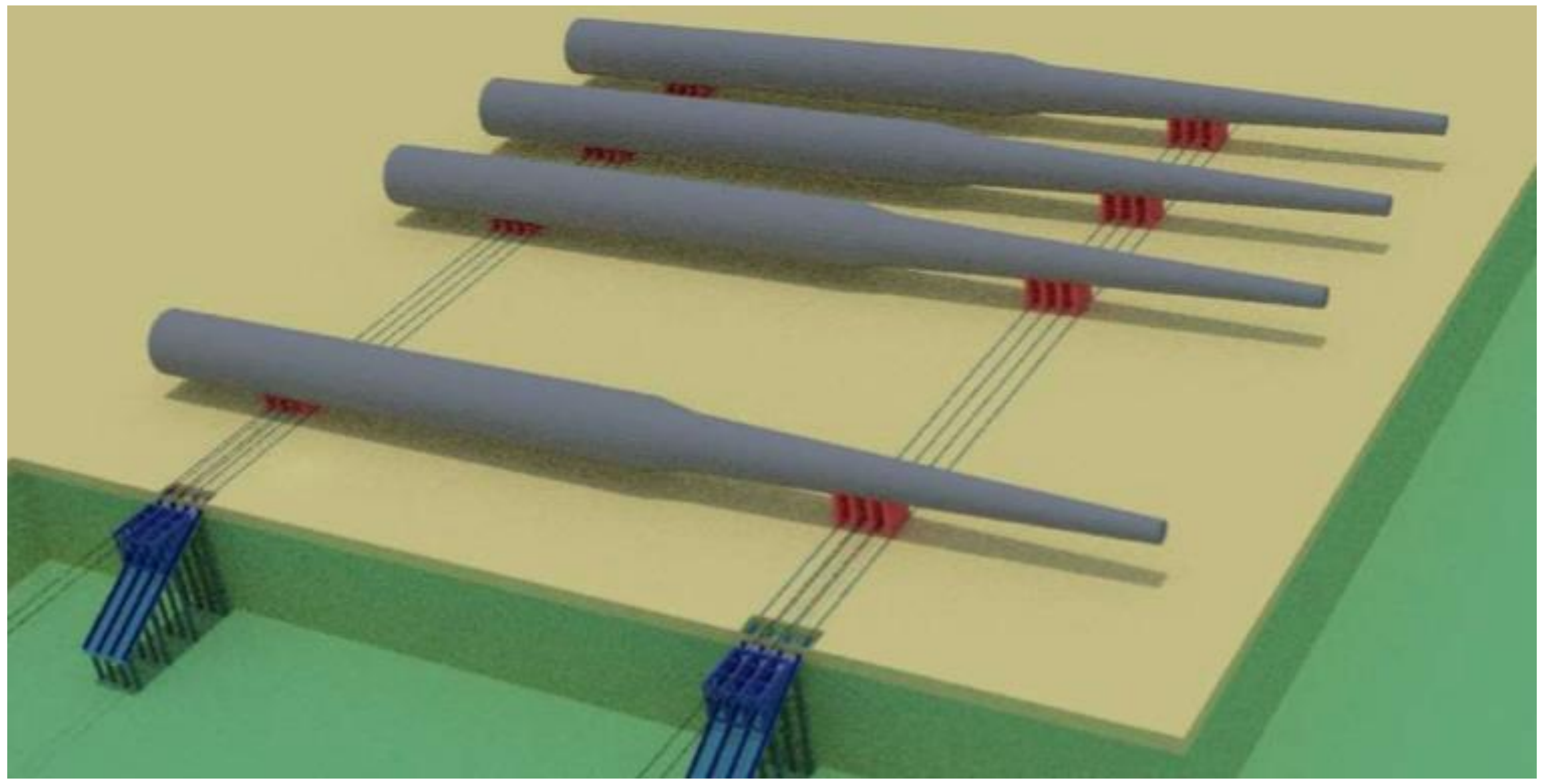
- Estimated **cost: €35/ton**



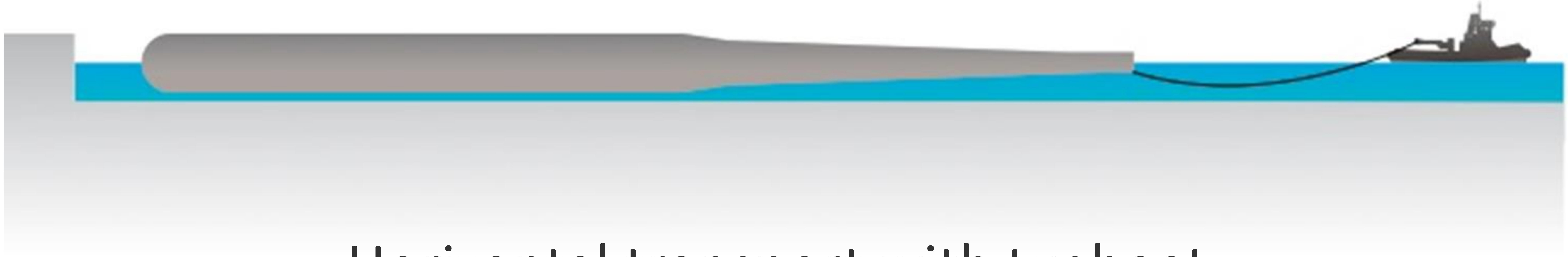
corewind

Construction in horizontal position



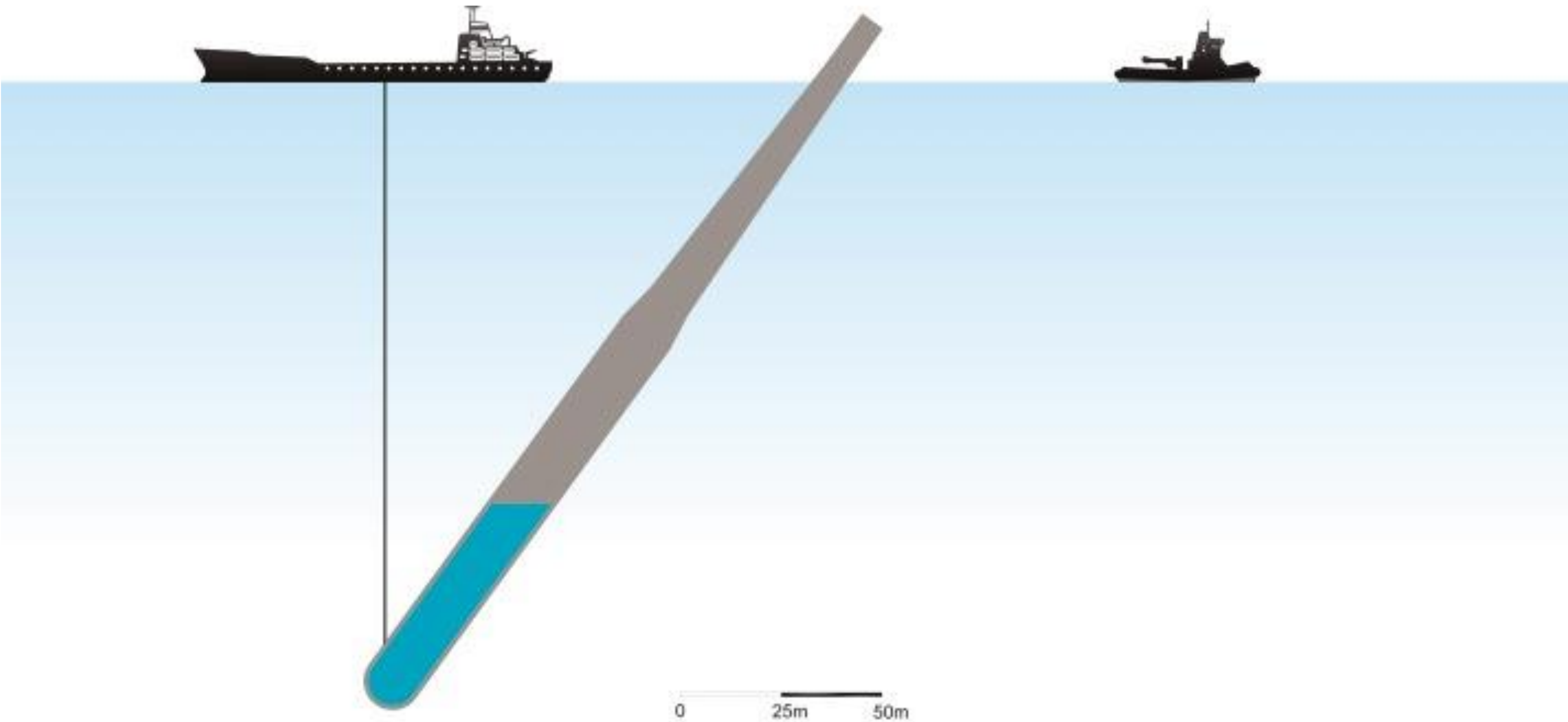


With or without drydock

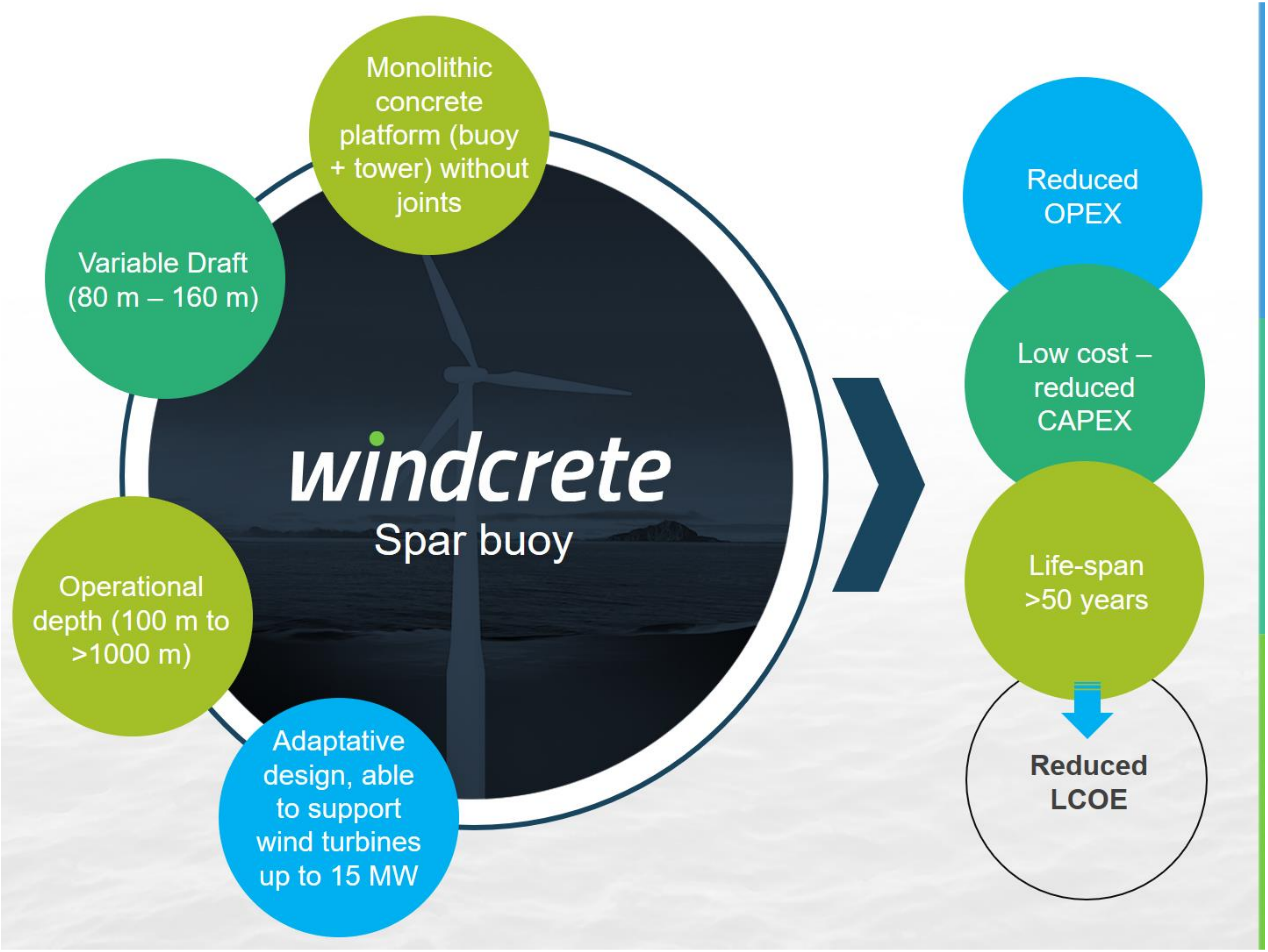


Horizontal transport with tugboat

Up ending: - Water ballasting
- Dynamic control

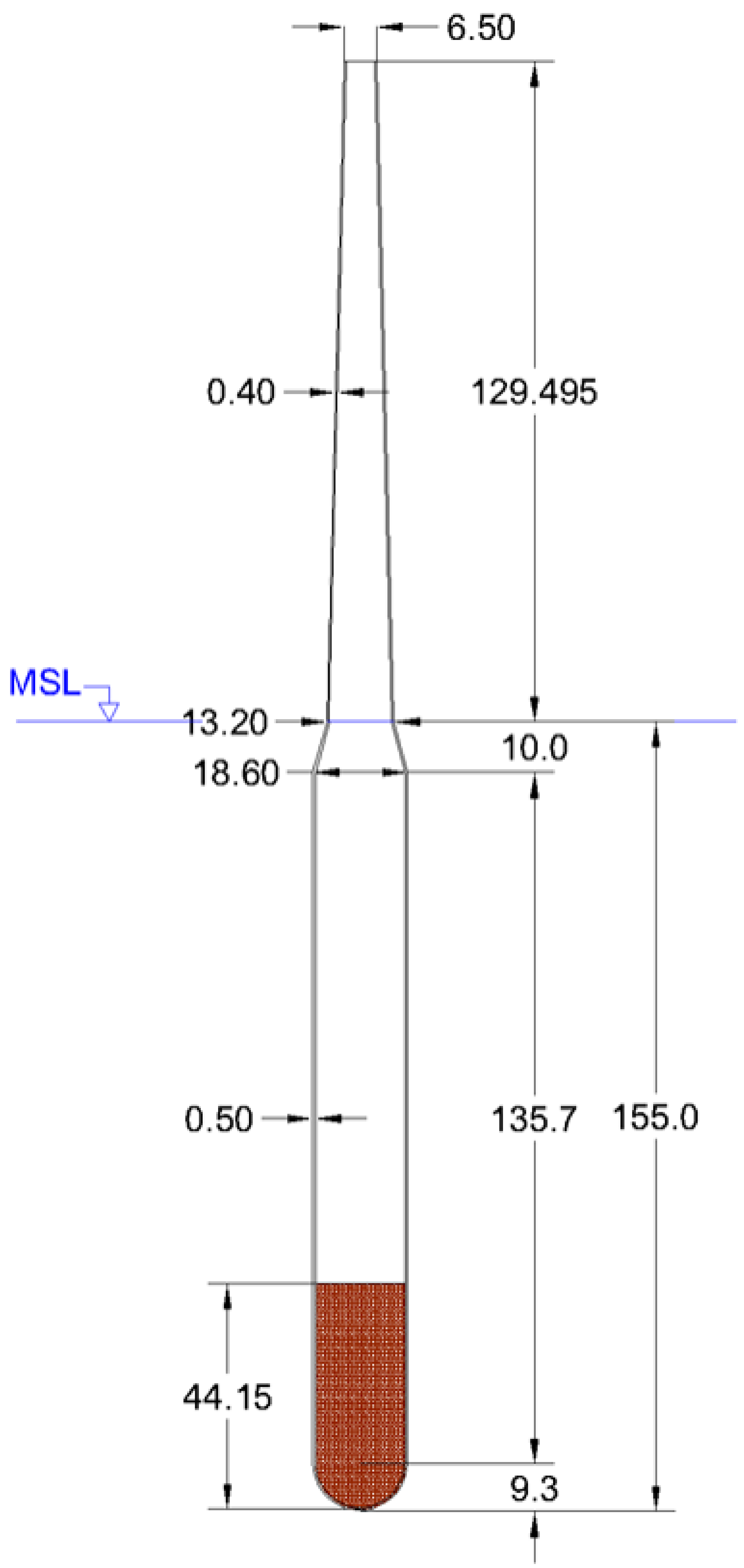


Turbine installation with a crane-less technology


Monolithic concrete platform (buoy + tower) without joints
Variable Draft (80 m – 160 m)
windcrete
Spar buoy
Operational depth (100 m to >1000 m)
Adaptative design, able to support wind turbines up to 15 MW
Reduced OPEX
Low cost – reduced CAPEX
Life-span >50 years
Reduced LCOE

WindCrete design for Gran Canaria

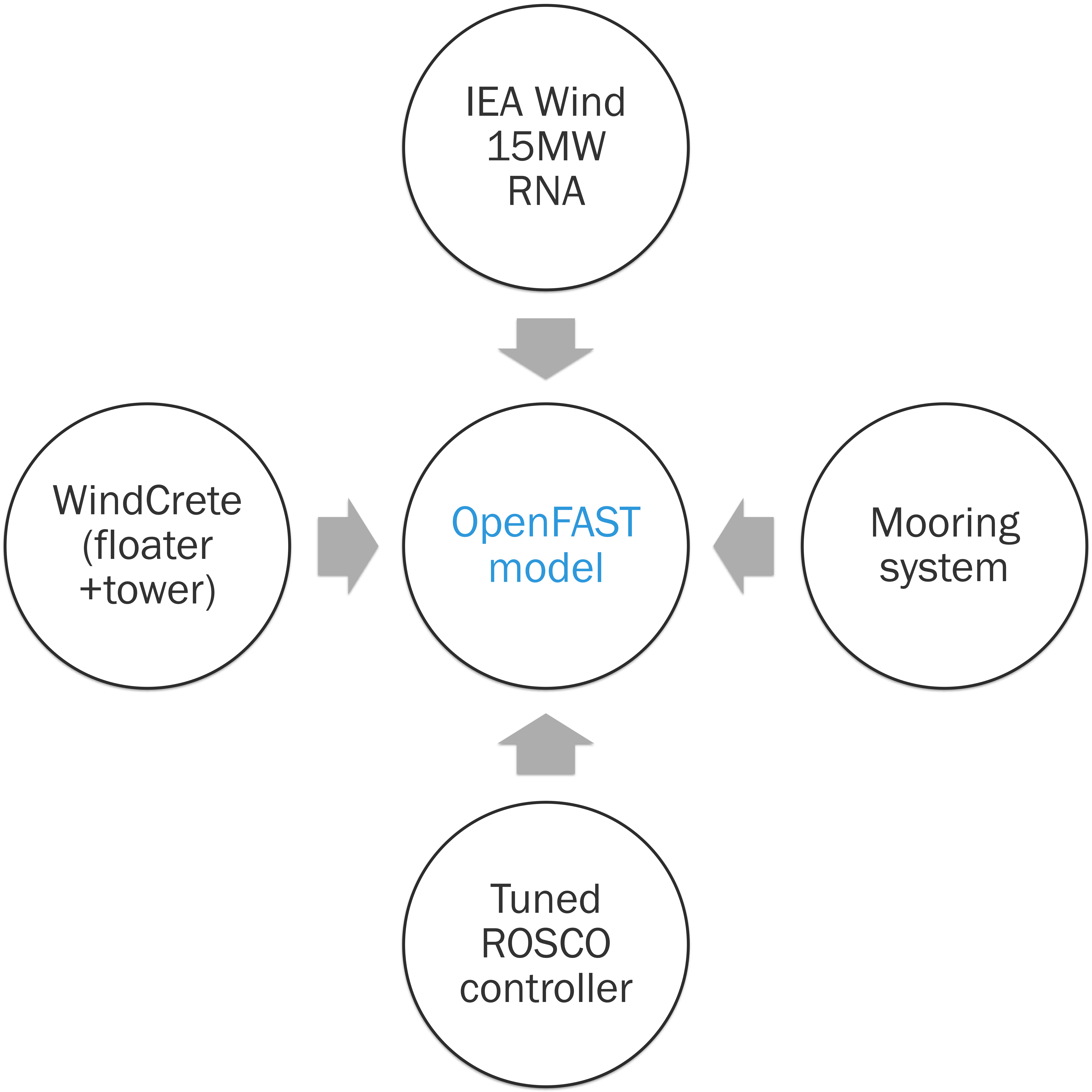
- Monolithic spar design
- Draft 155m
- Hub height 135m
- Tower:
  - Height: 129.5m
  - Radius: 6.6m->3.25m
  - Thickness: 0.4m
- Buoy
  (semi-sphere + cylinder + transition piece)
  - Draft: 155m
  - Radius: 9.3m->6.6m
  - Thickness: 0.5m



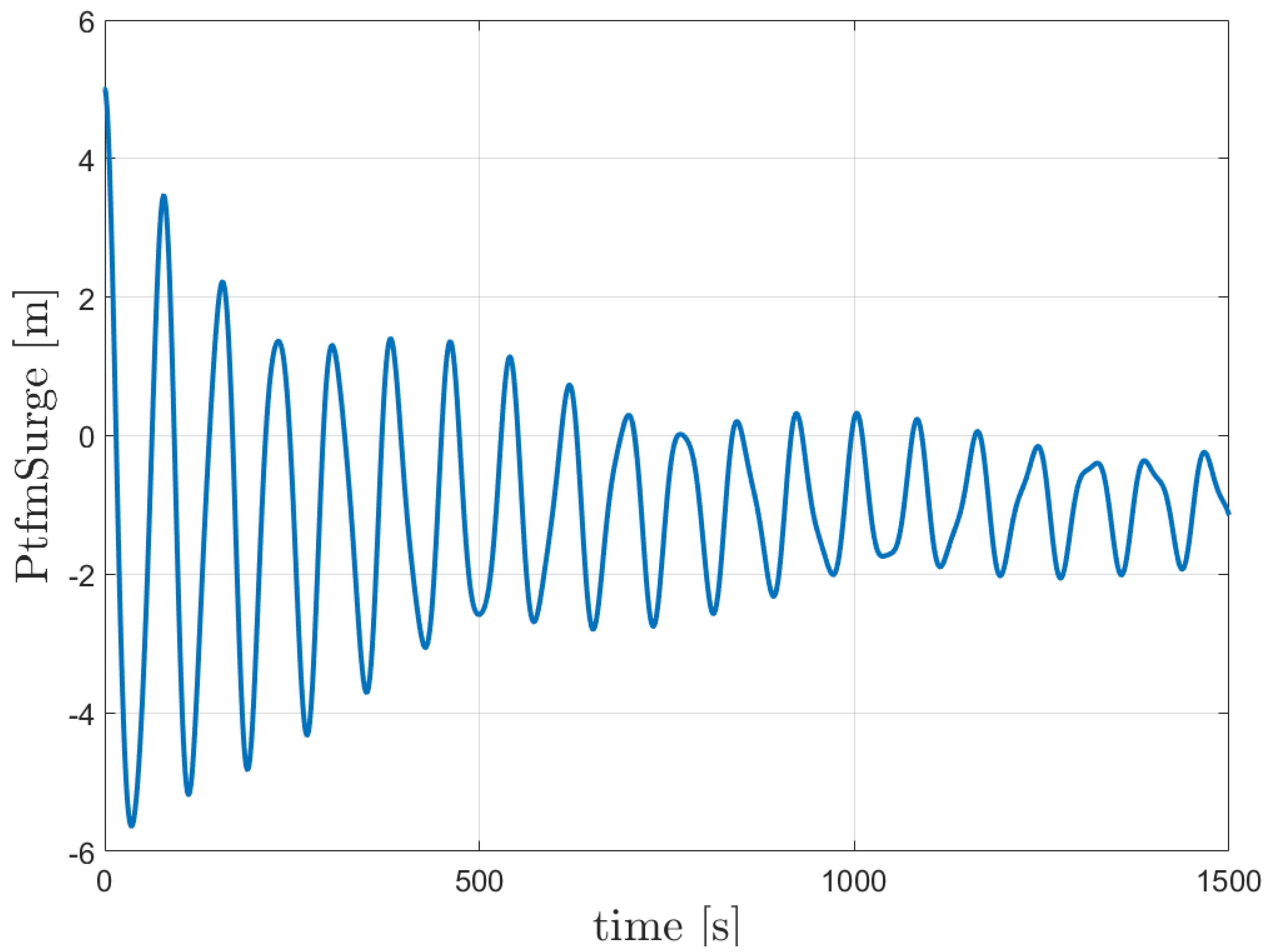
corewind

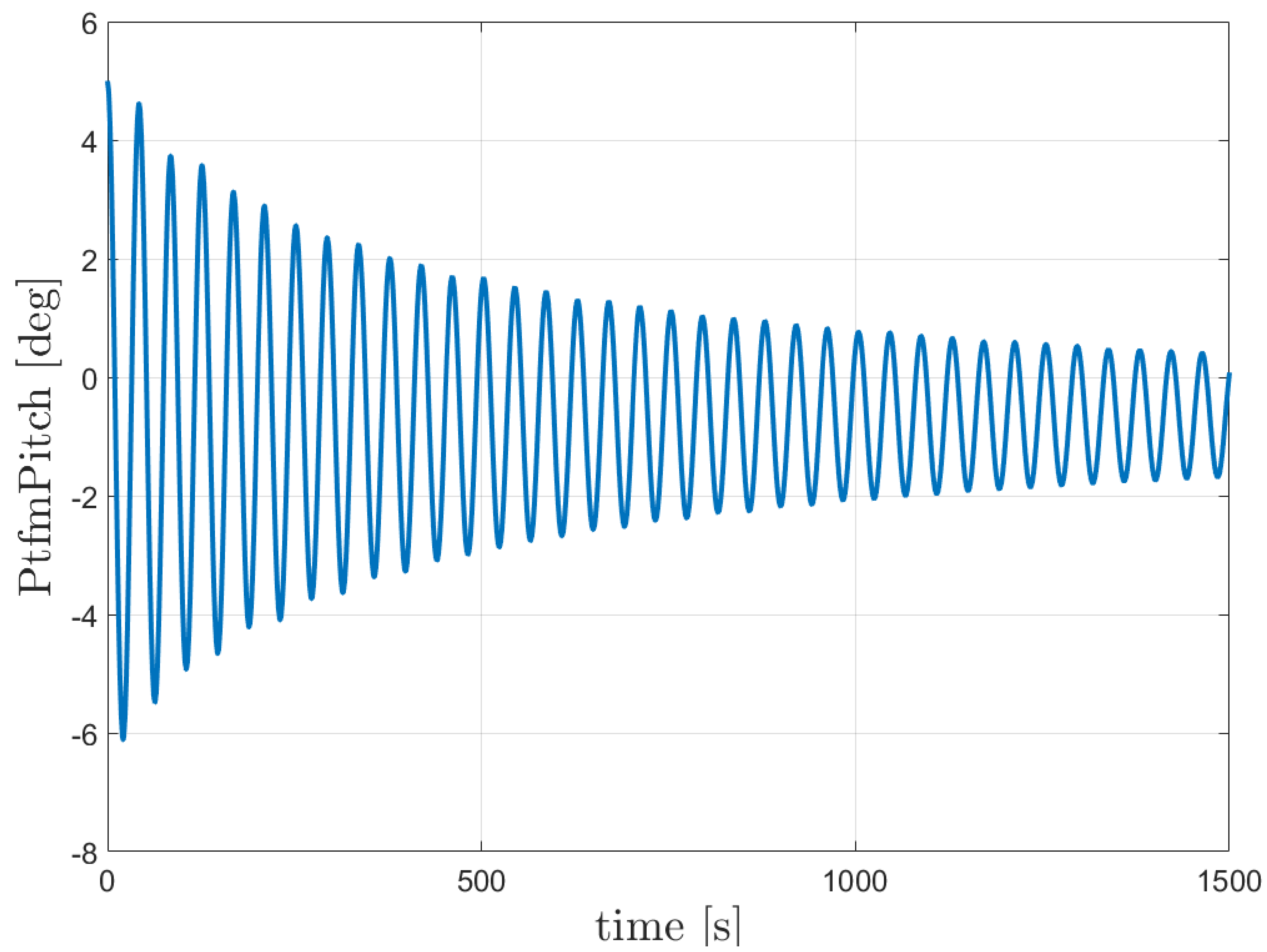
corewind.eu

OpenFAST model of WindCrete



Natural frequencies





	Surge	Heave	Pitch	Yaw
Hz	0.012	0.031	0.024	0.092
seconds	81.9	32.8	41.0	10.9

- The WindCrete model is opensource and available at: https://zenodo.org/record/4322446
- More details about the floater and its performance can be found in https://zenodo.org/record/4385727

corewind

COST REDUCTION OF
FLOATING WIND TECHNOLOGY

Optimized mooring system for the ActiveFloat concrete semisub floater for the 15 MW IEA WIND reference wind turbine

25 February 2021

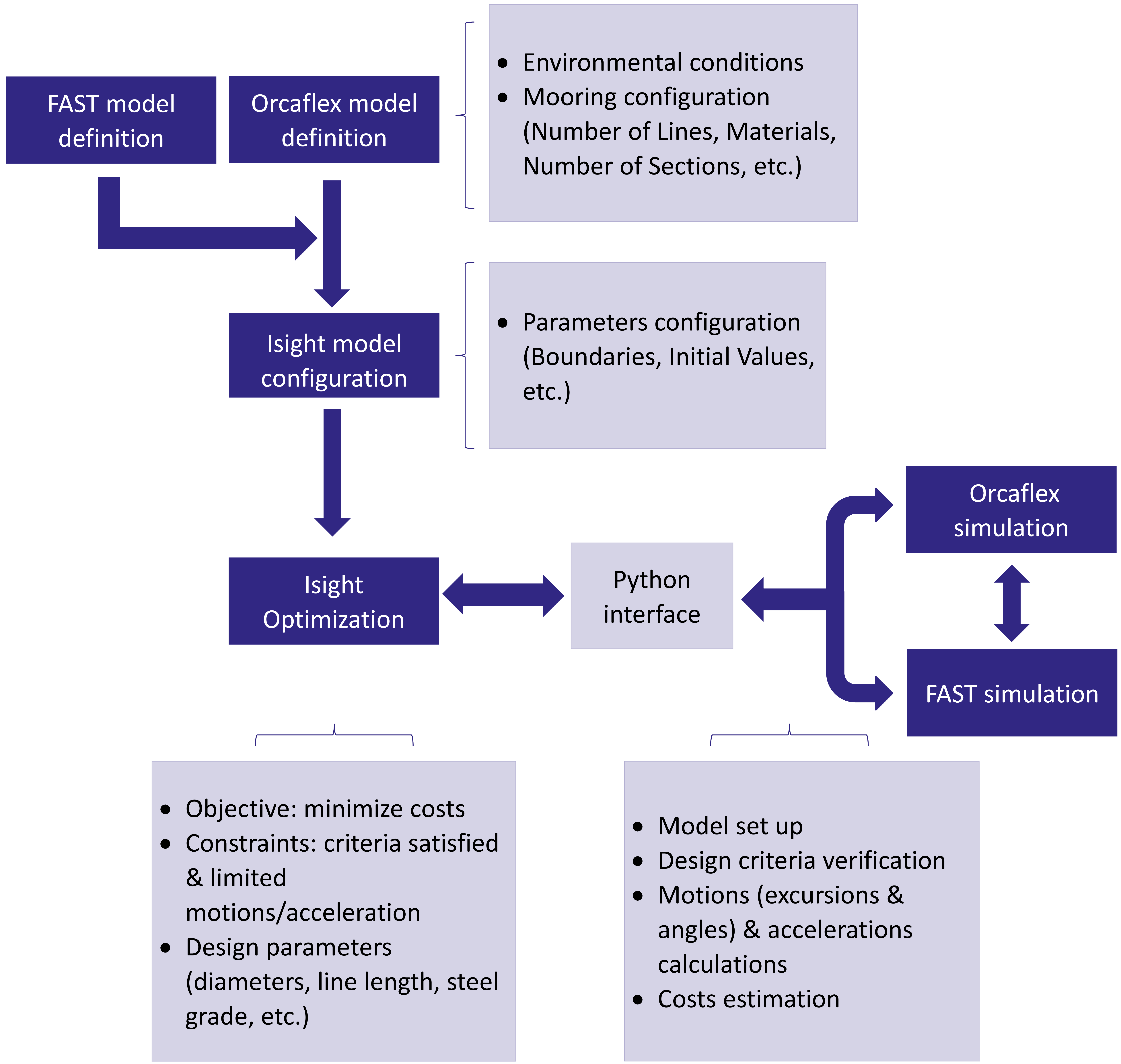
corewind.eu

Disclaimer:
This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 815083.

Project details:
Duration:
1 Sep 2019 - 28 Feb 2023
Grant agreement:
No: 815083

Valentin Arramounet
Innosea

Mooring design optimisation methodology



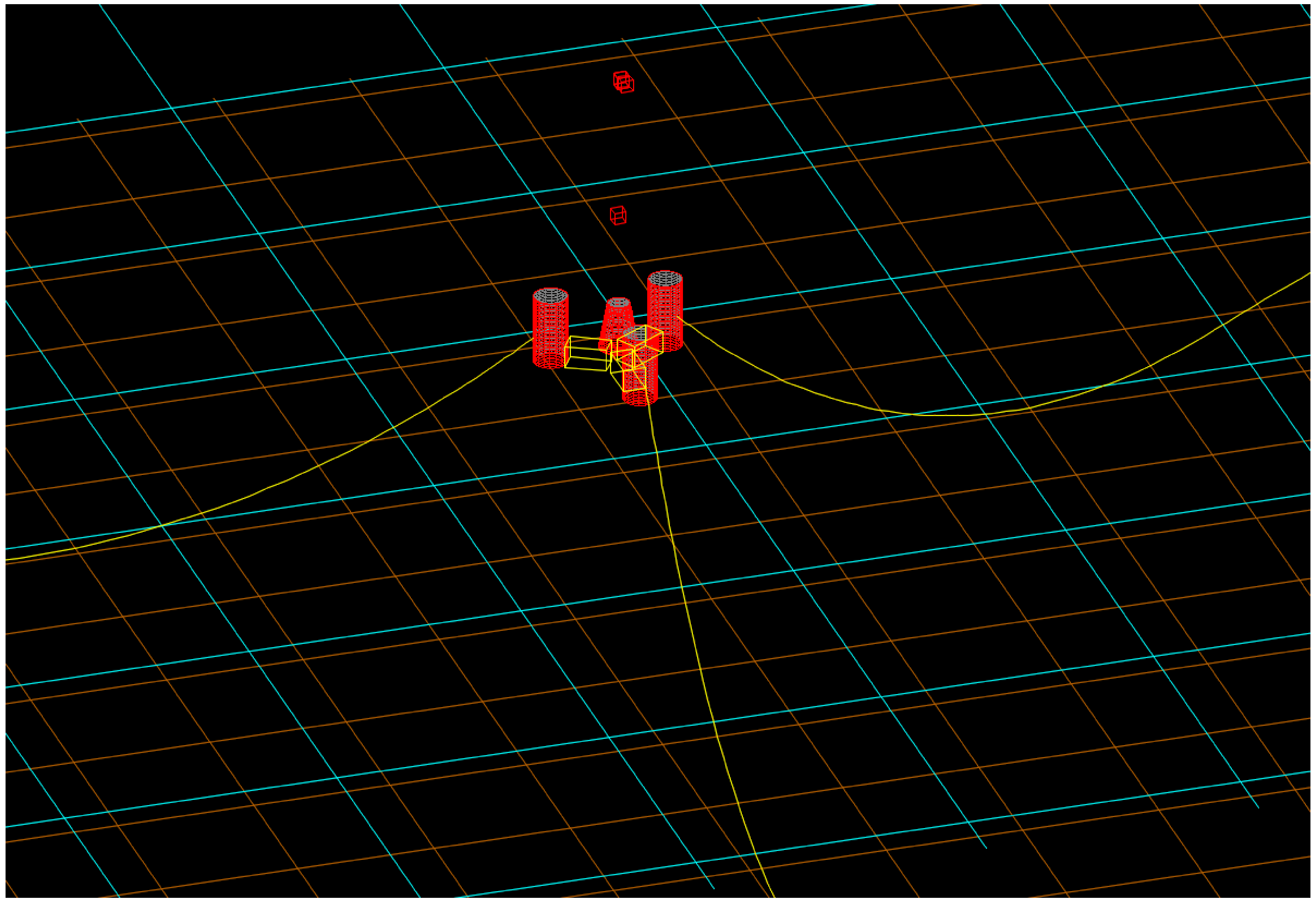
Cases studies

- DLC 6.1 and 6.2 (DNVGL-ST-0437)
- Start of Life and End of Life configuration
- Mooring systems are checked in ULS, FLS and ALS in a second step

	West of Barra	Gran Canaria	Morro Bay
Water Depth [m]	100	200	870
EWM Wind Speed at 100m 10min averaged [m/s]	47.63	27.35	35.38
Wind current speed 50 years @ surface [m/s]	1.15	0.57	0
Deep Water current speed 50 years @ surface [m/s]	0.94	0.49	0
Hs 50years [m]	15.6	5.11	9.9
Tp min 50 years [s]	12	9	16
Tp max 50 years [s]	18	11	18

Results: Gran Canaria

- 3 Lines - Catenary
- Upwind: 832m – Chain R3 - 120mm bar diameter – 286 kg/m
- Downwind: 832m - Chain R3 - 70mm bar diameter – 97 kg/m
- Estimated cost: 865 k€ (- 60% VS initial configuration)



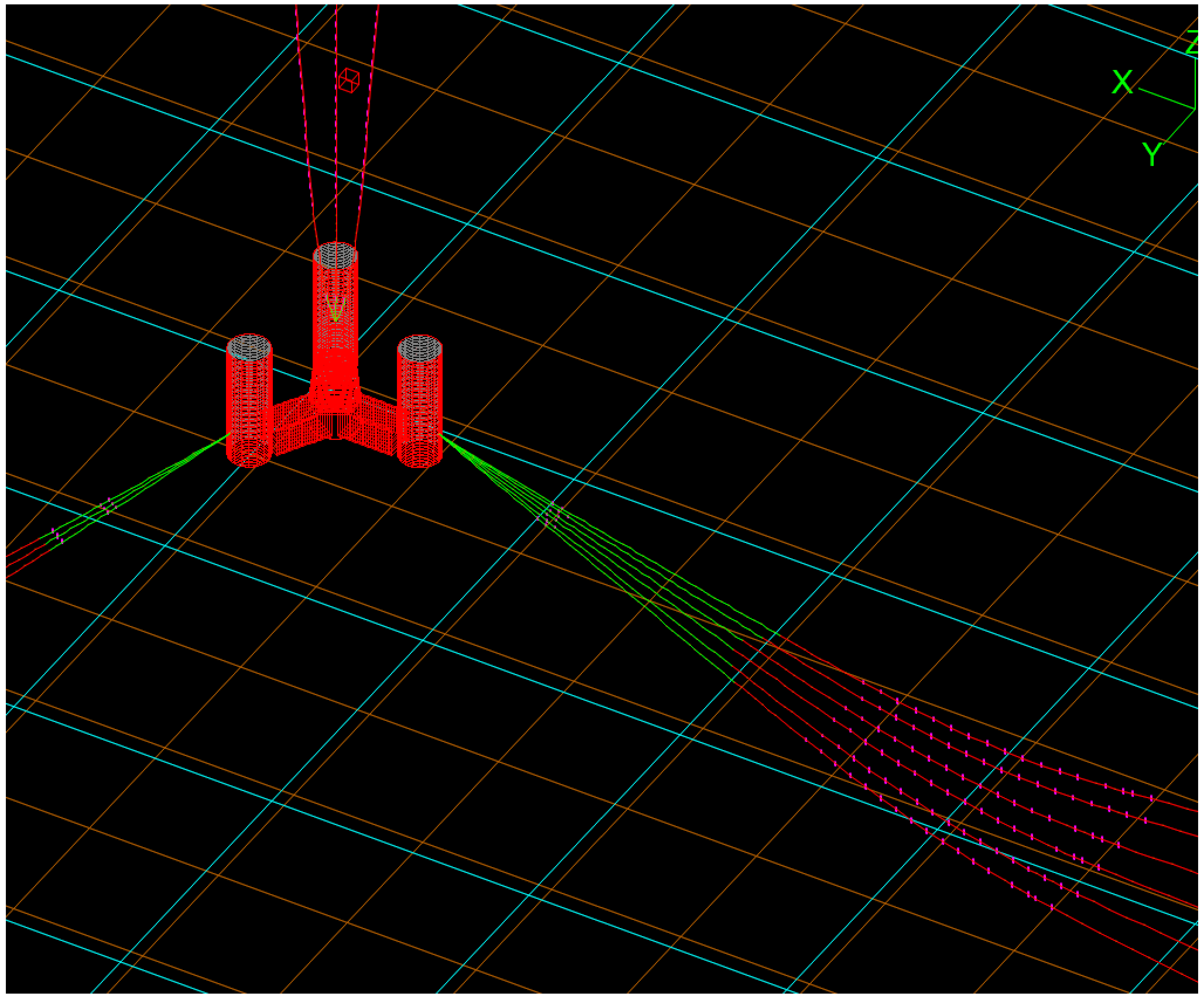
Results: West of Barra

- 12 Lines - Catenary: 6 lines upwind & 3 lines downwind

- Upwind:
  - 90m – Nylon
  - 1300m – Chain R5 – 125mm bar diameter – 310 kg/m
  - Clump weights (Harsh conditions)

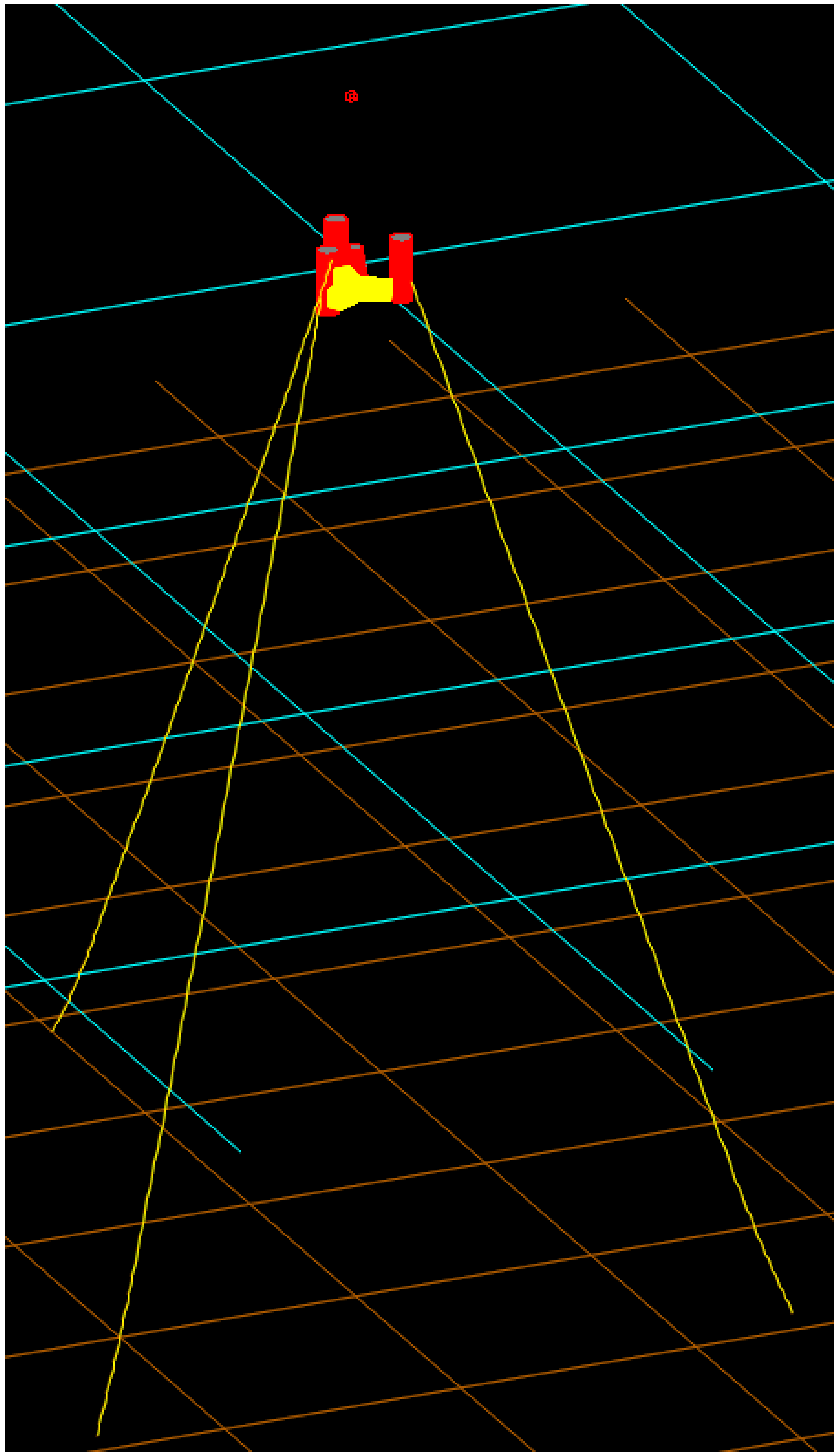
- Downwind
  - 150m – Nylon
  - 1200m – Chain R5 – 125mm bar diameter – 310 kg/m
  - Clump weights

- Estimated cost: 14800 k€



Results: Morro Bay

- 3 Lines – Semi Taut
- Upwind:
  - 50m top / 142m bottom – Chain R4S - 92mm bar diameter – 168 kg/m
  - 810 m – Polyester – 141mm
- Downwind:
  - 50m top / 130m bottom – Chain R4 - 90mm bar diameter – 161 kg/m
  - 722 m – Polyester – 126mm
- Estimated cost: 634 k€ (-55% VS initial configuration)

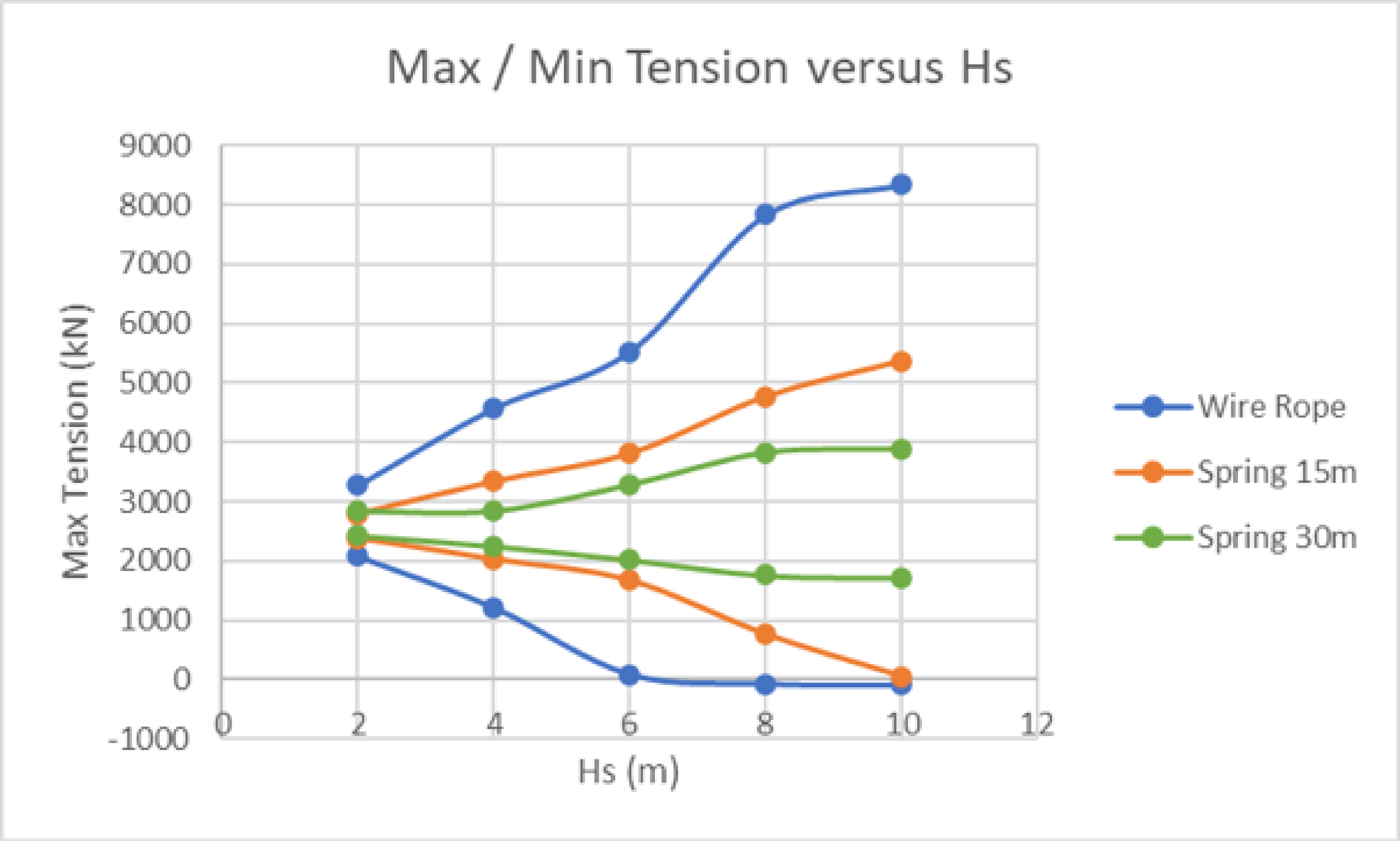


Comparisons

- Gran Canaria
  - Optimised cost: 865 k€
  - Initial cost:
    - 2156 k€ for grade R3
    - 3161 k€ for grade R5
- West of Barra: No comparison as initial mooring is not fullfilling design criteria
- Morro Bay
  - Optimised cost: 634 k€
  - Initial cost: 1399 k€

Ongoing work

- Peak load reduction systems
  - Peak loads reduction
  - Fatigue reduction

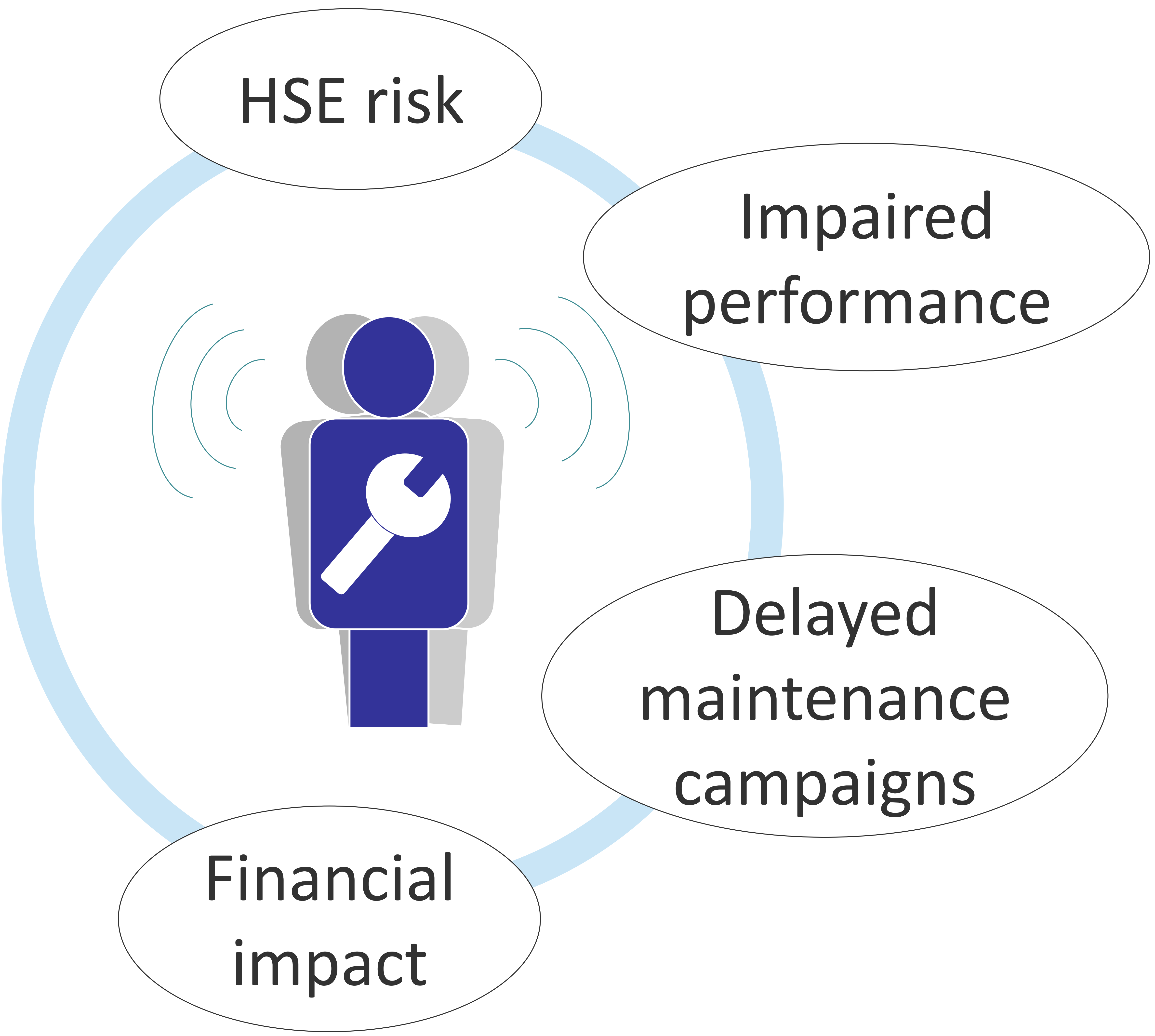


- Shared anchors and mooring lines

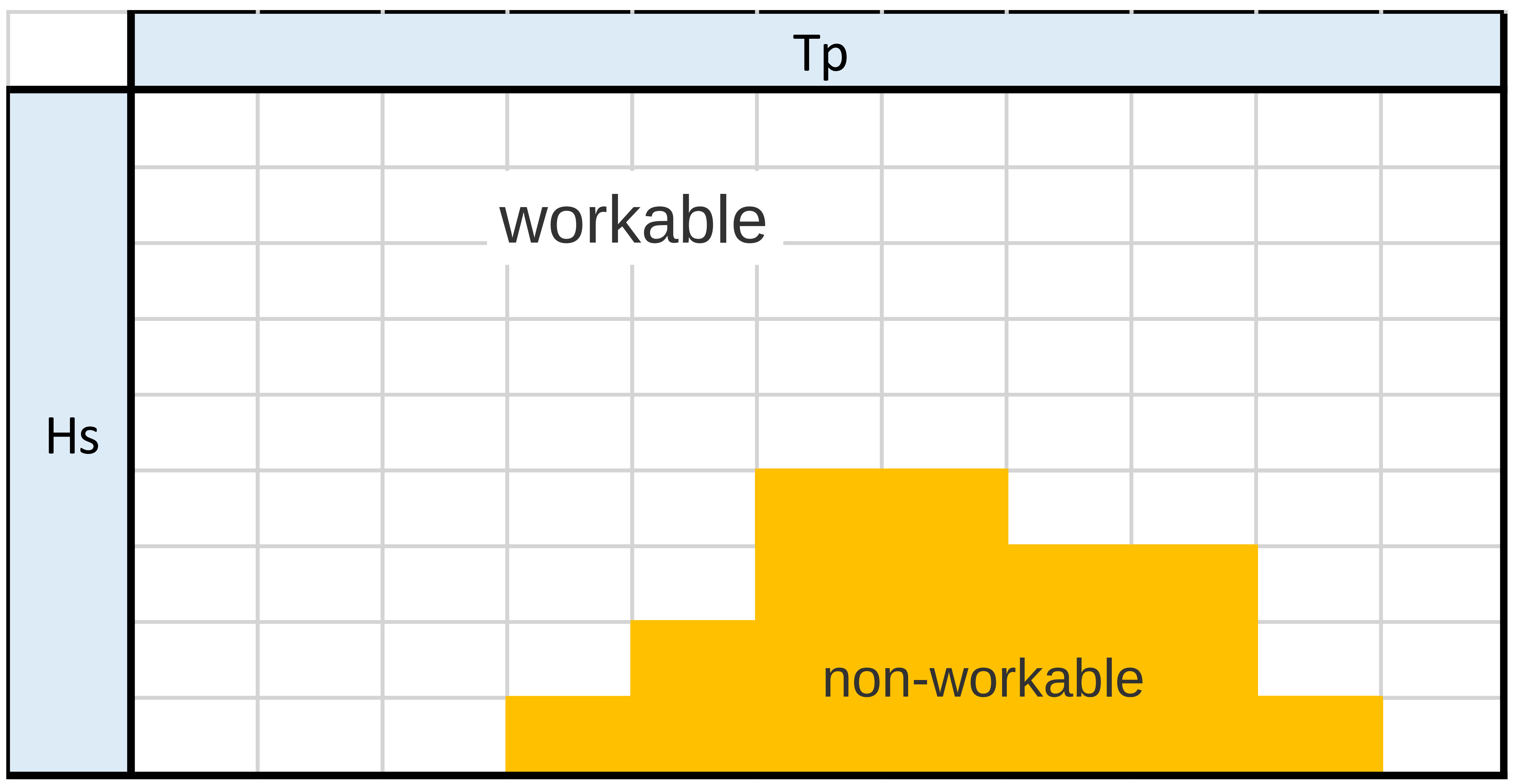
"My experience with seasickness is that at first you are afraid you will die, then after a few hours you are afraid you will not. "

G. Yancey Mebane, M.D.

Workability Assessment



Further developed methodology to determine the Workability Index[1] for the floating wind turbine in accordance with *ISO 2631-1:1997- „Evaluation of human exposure to whole-body vibration"*.



[1] Scheu et al., 2018. *Human exposure to motion during maintenance on floating offshore wind turbines.* Ocean Engineering.

Interviewed External Stakeholders

equinor

JDR Cable Group

AMPELMANN

Liftra

MARINE CONTRACTORS

DEME
Dredging, Environmental & Marine Engineering

Principle Power

windpark heliflight

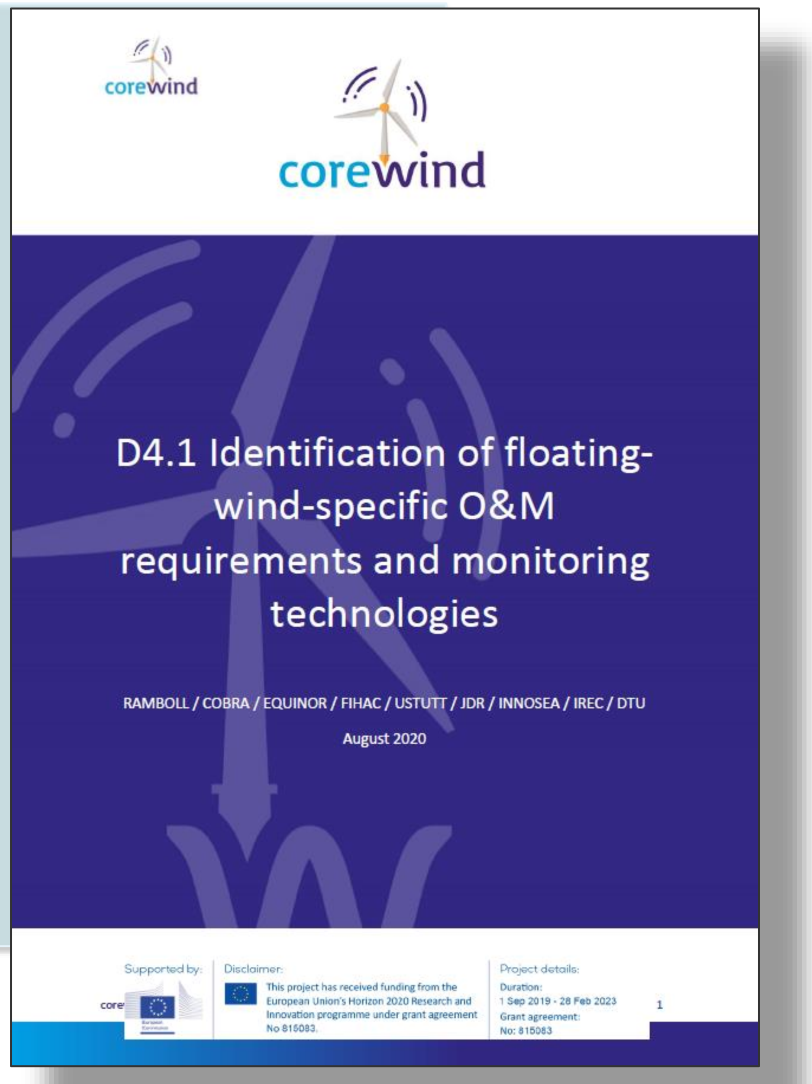
BRIDON · BEKAERT
THE ROPES GROUP

Including one **offshore wind turbine OEM** (anonymous).

All findings published in:

Deliverable D4.1
“Identification of floating-wind-specific O&M requirements and monitoring technologies”

Download link: http://corewind.eu/publications/

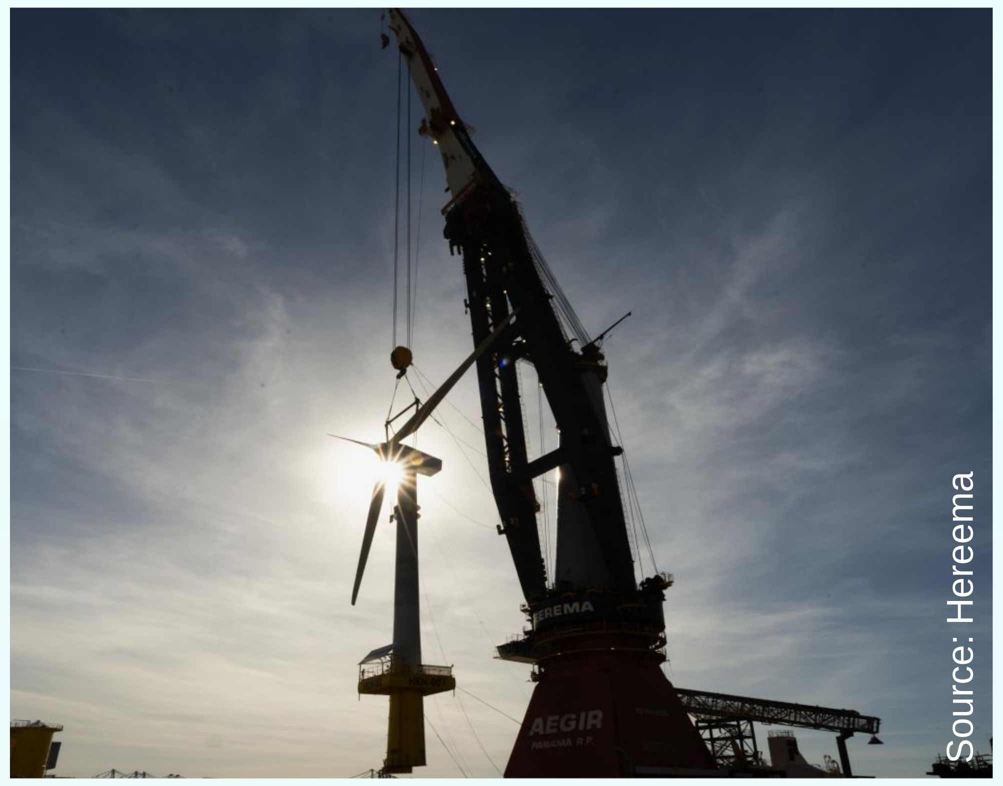

corewind

D4.1 Identification of floating-wind-specific O&M requirements and monitoring technologies

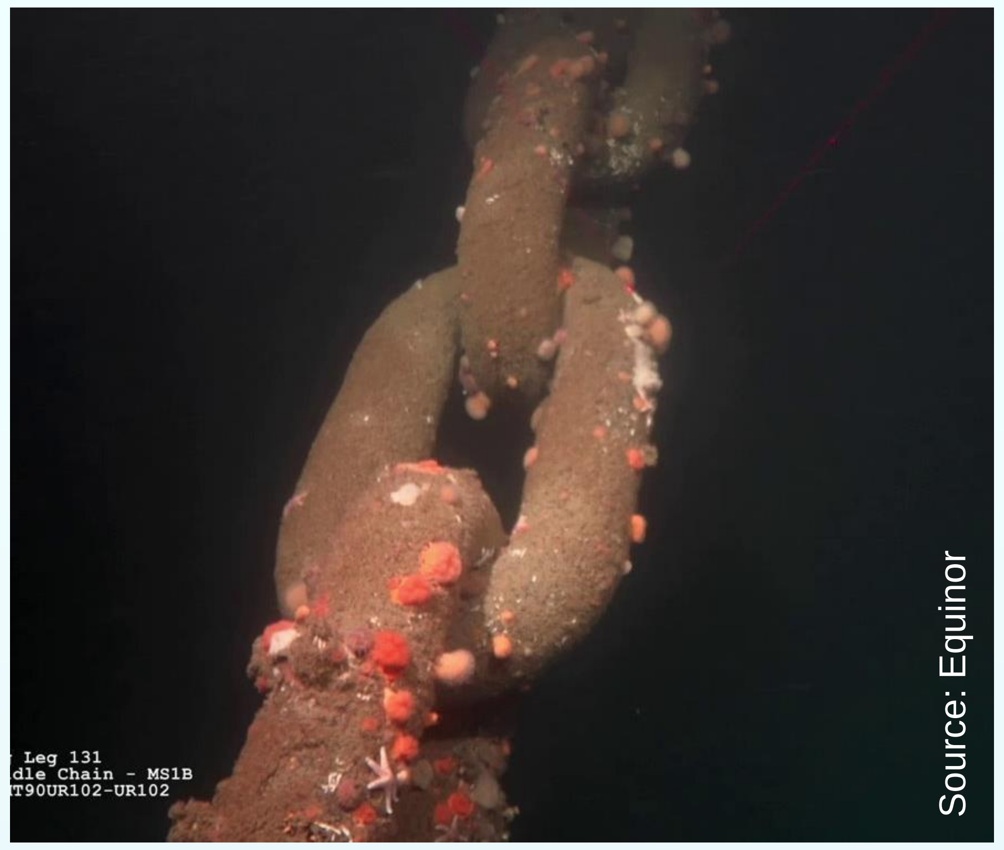
O&M Focus Areas

Workability

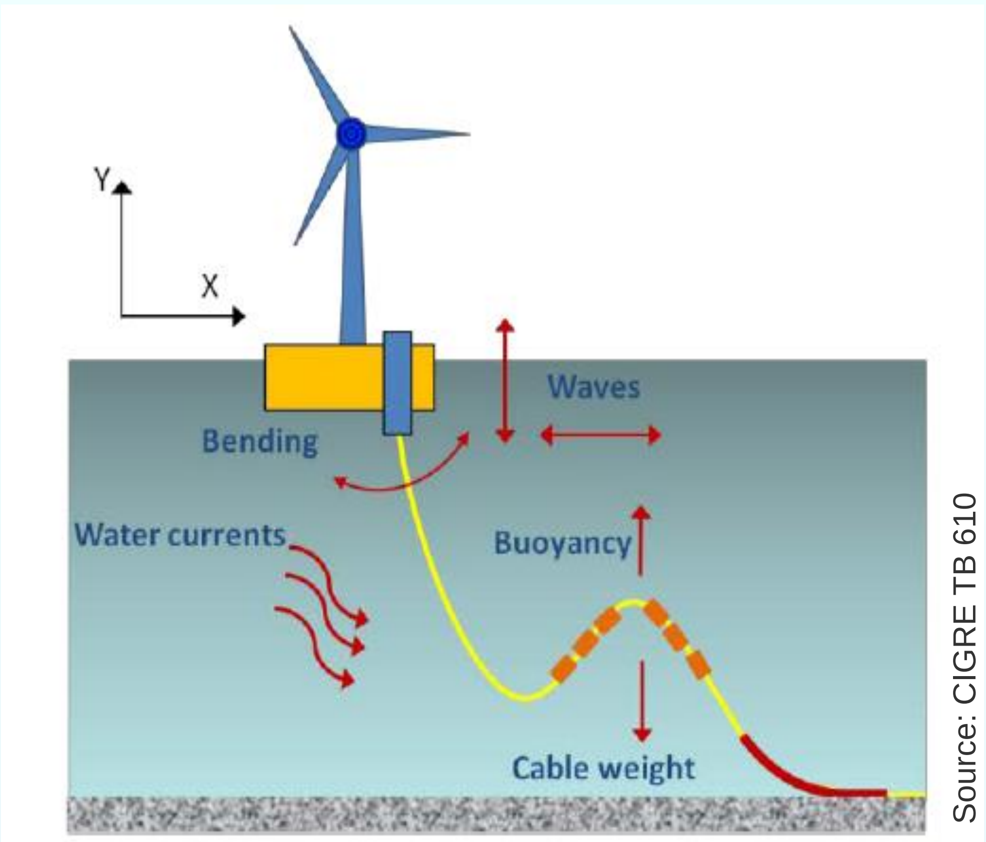
Accessibility



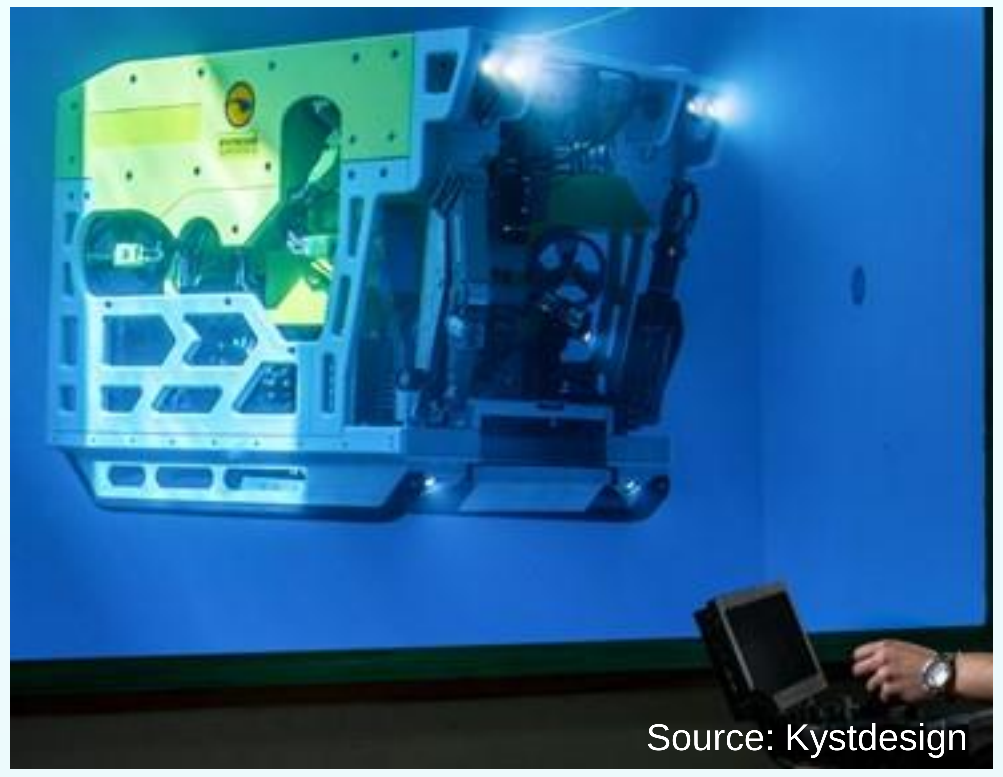
Large Component Exchange



Mooring Lines



IA & Export Cables



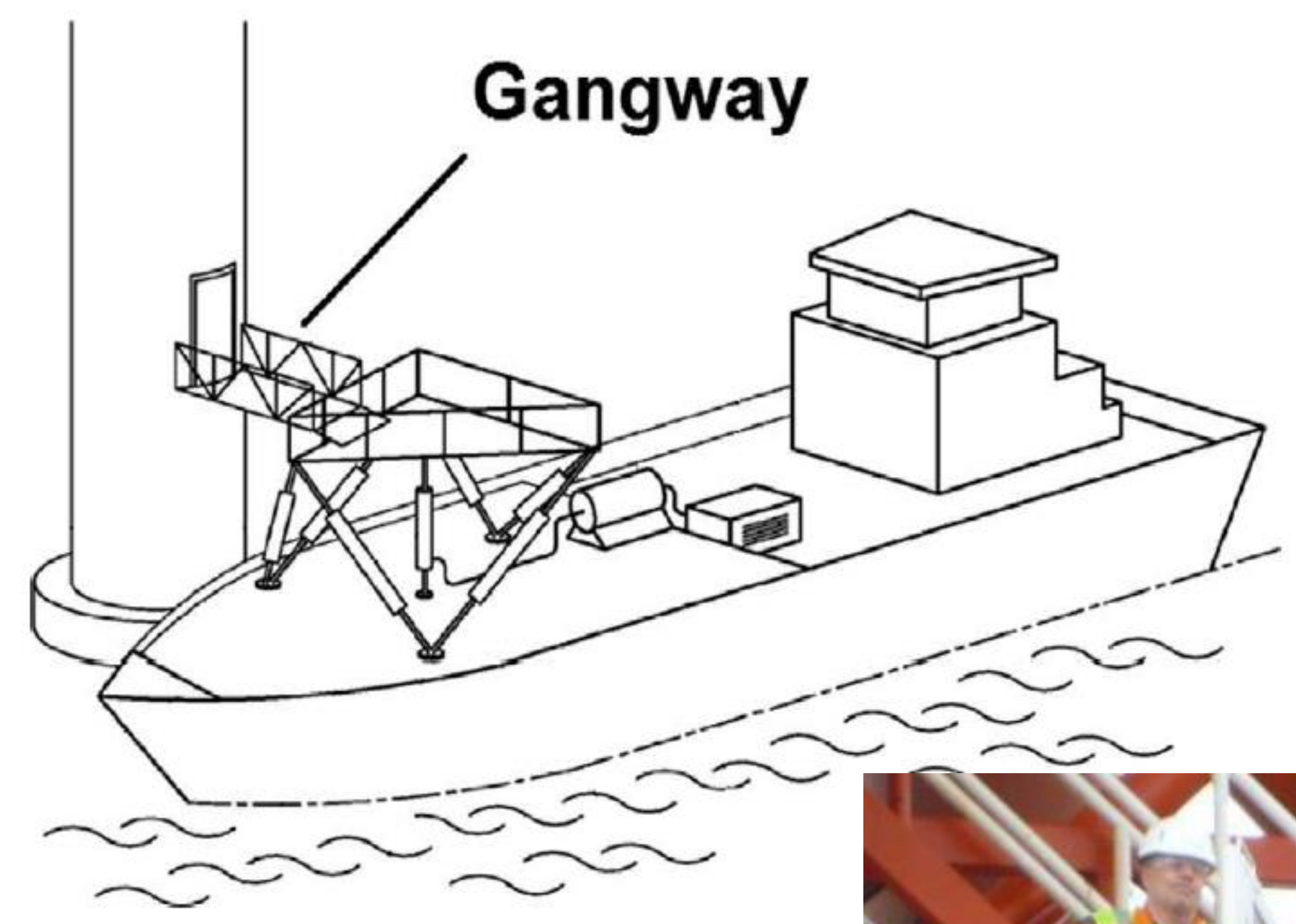
Subsea Inspections

Accessibility challenges

- Prevailing **swell waves** for sites in Atlantic Ocean challenge Hs-limits of access systems

- **Increased Relative motions** between vessel and platform

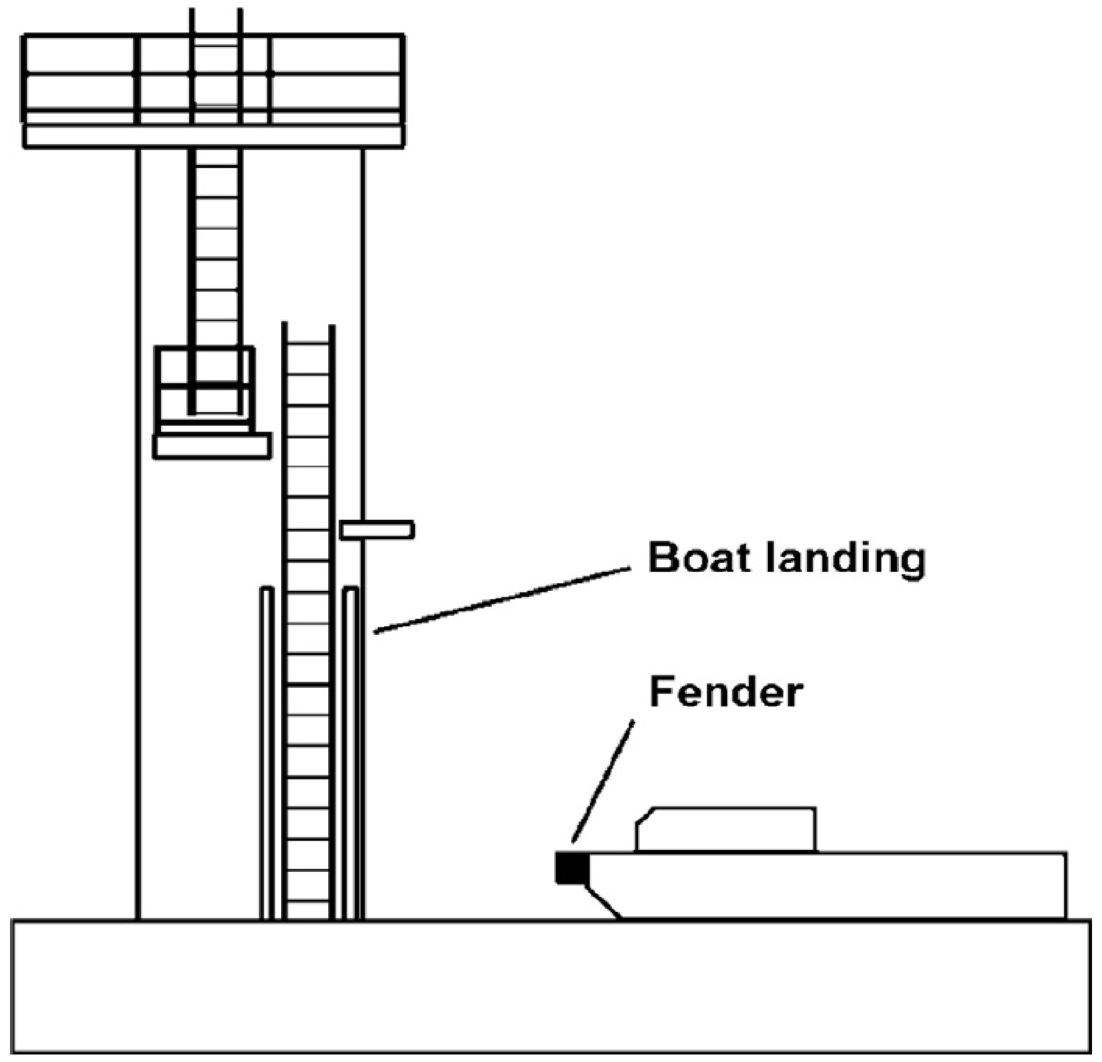
- Maintenance friendly **design**



Source: Van Der Tempel, J. et al. 2016

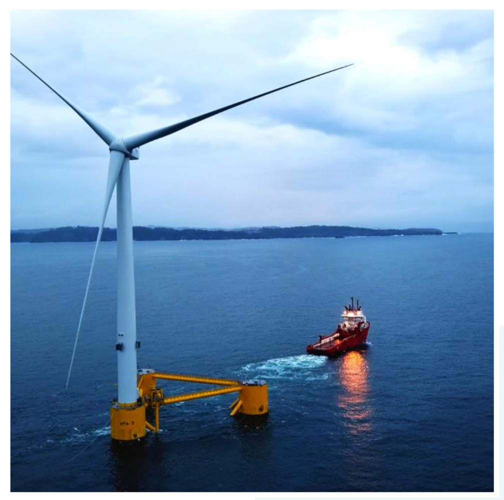
Source: Ampelmann

Source: Ørsted



Source: Van Der Tempel, J. et al. 2016

Large Component Exchange

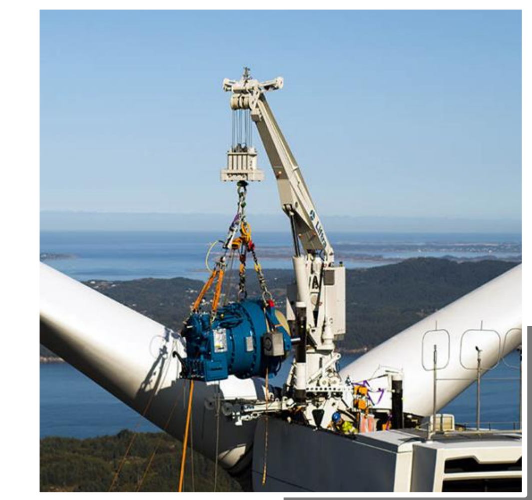


Tow-in for Repair

- Distance
- Harbor capacity
- Cable and Mooring Line de- and reconnection
- Substructure type

Floating to Floating

- Relative motions
- Two-lift operation
- Exchange performed on same reference system as crane



Self-hoisting /climbing Crane

- Onshore Wind technology
- Development for Offshore ongoing
- Crane base hosted from floater platform
- Reduced relative motions for lift

Mooring Lines

Source: Equinor

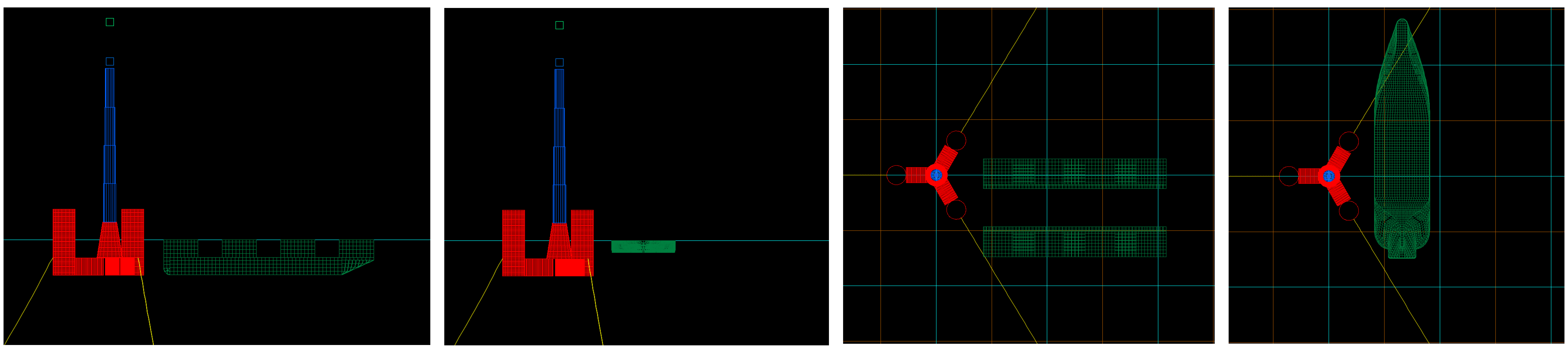
- **ROVs** used for visual damage inspection & marine growth measurement
- **External threats** : fishing nets, boats, seabed contact, ROV collision
- Difficult to justify **sample population** of mooring line inspections.
- **Wet-storage** of mooring line during floater-tow-in problematic for fibre rope:
  - Dynamic seabed contact causes abrasion
  - Retrieval operations and re-installation are expensive
- **Hybrid ropes** (steel and fibre combination) increase robustness

Outlook O&M Task 4.2

Evaluation of relative motions and compensation requirements for:

1. Two access methods simulating bow-transfer with a CTV and walk-to-work from an SOV

2. Two substructure concepts with generic semi-sub and mono-hull crane vessel



Simulation of the O&M phase with the commercial cost modelling and strategy optimisation tool Shoreline.

Optimizing **Resources, Availability and OPEX** for each reference site and floater scenario.

corewind

COST REDUCTION OF
FLOATING WIND TECHNOLOGY

Introducing FowApp

February 2021

corewind.eu

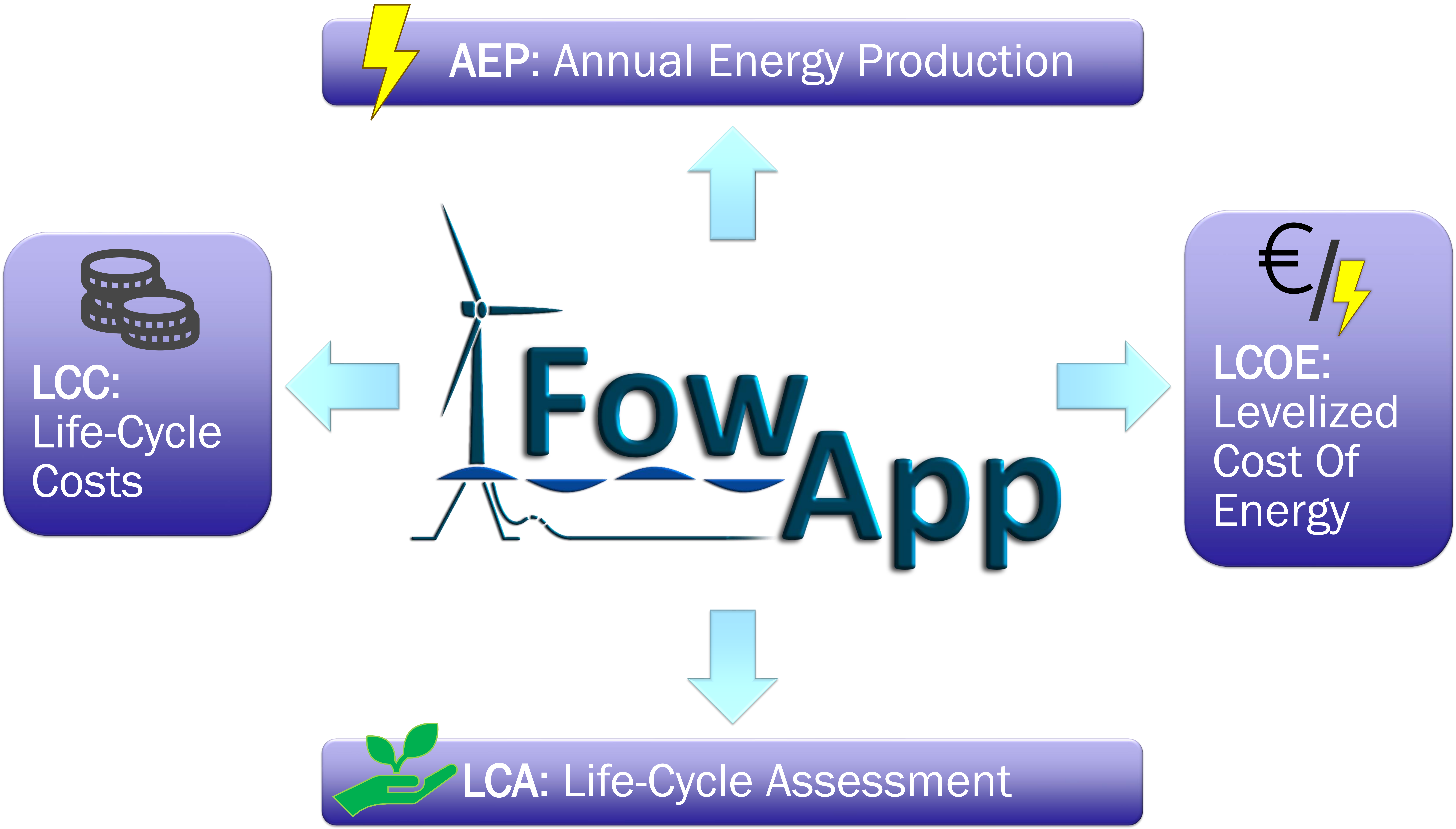
Supported by:

Disclaimer:
This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 815083.

Project details:
Duration:
1 Sep 2019 - 28 Feb 2023
Grant agreement:
No: 815083

José I. Rapha
Research Engineer at IREC

What is FowApp?



Why is it important?

New technologies + New strategies + Cost reduction = Complexity

Floating Offshore Wind Farms

FOWAT → FowApp

Other applications

Poor AEP calculation + Generic + Financial-based = Opportunity

The concept

Library

- Environments
- Components
- Auxiliary means
- Materials
- Fuels

Project

Arrangement

- Environment and components selection
- Layout definition
- Electrical connection definition

Life cycle

- Development
- Construction
- Operation and maintenance
- Decommissioning and end of life

Results

- LCC
- LCOE
- AEP
- LCA
- LCIA

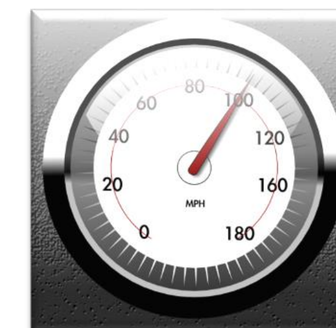
Results details

AEP

- Energy produced, delivered and loss details
- Detailed wake and subsystems efficiencies
- Capacity factor

LCC

- Detailed costs by phase
- Analysis per component and per process
- Time-based maintenance costs.



LCOE

- Summary of energy delivered
- Summary of costs
- LCOE calculation
- LCOE contribution per phase

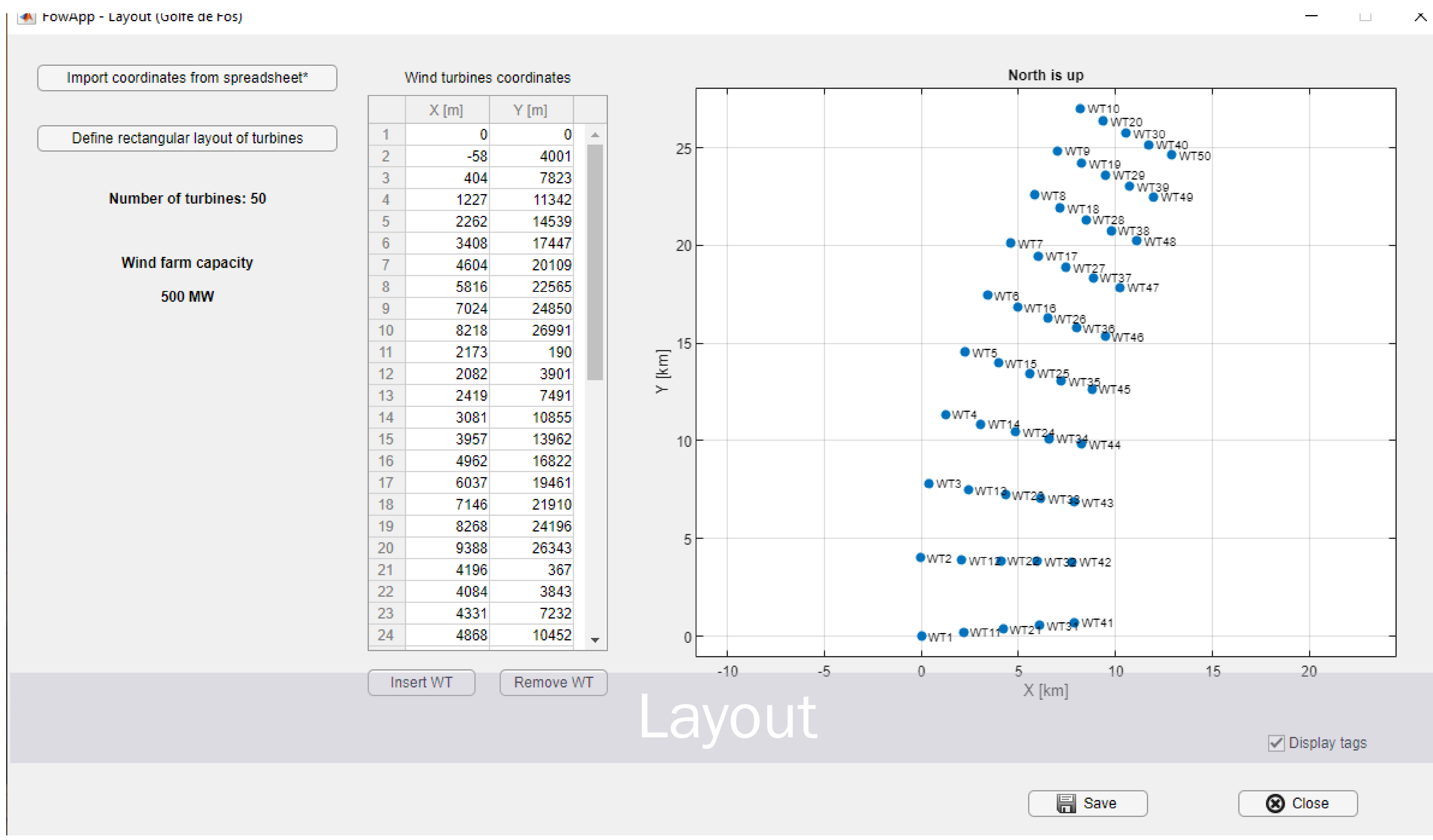
LCA

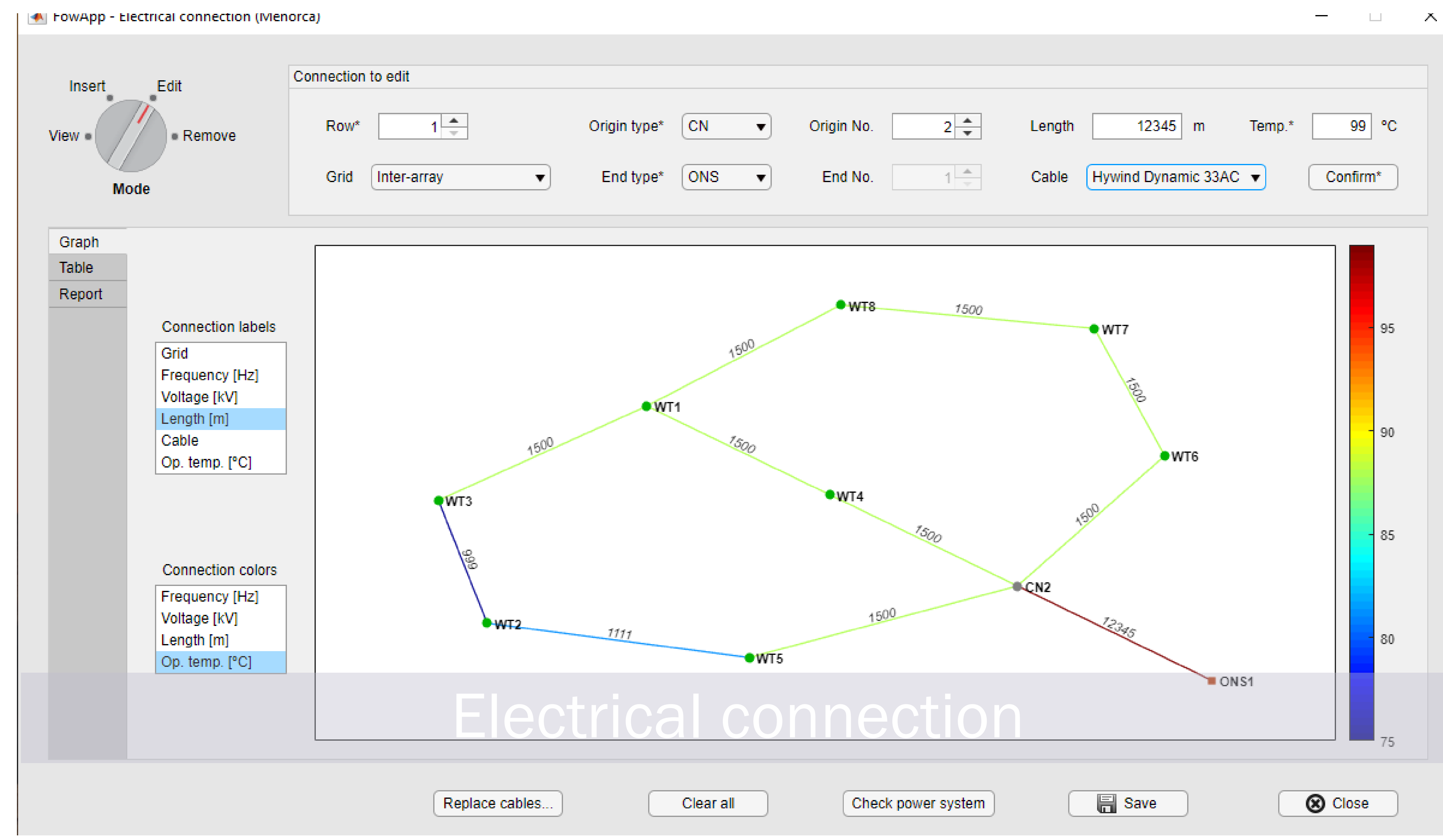
- Impact of components
- Impact of the auxiliary means
- Effect of the end of life treatment
- Summarised results

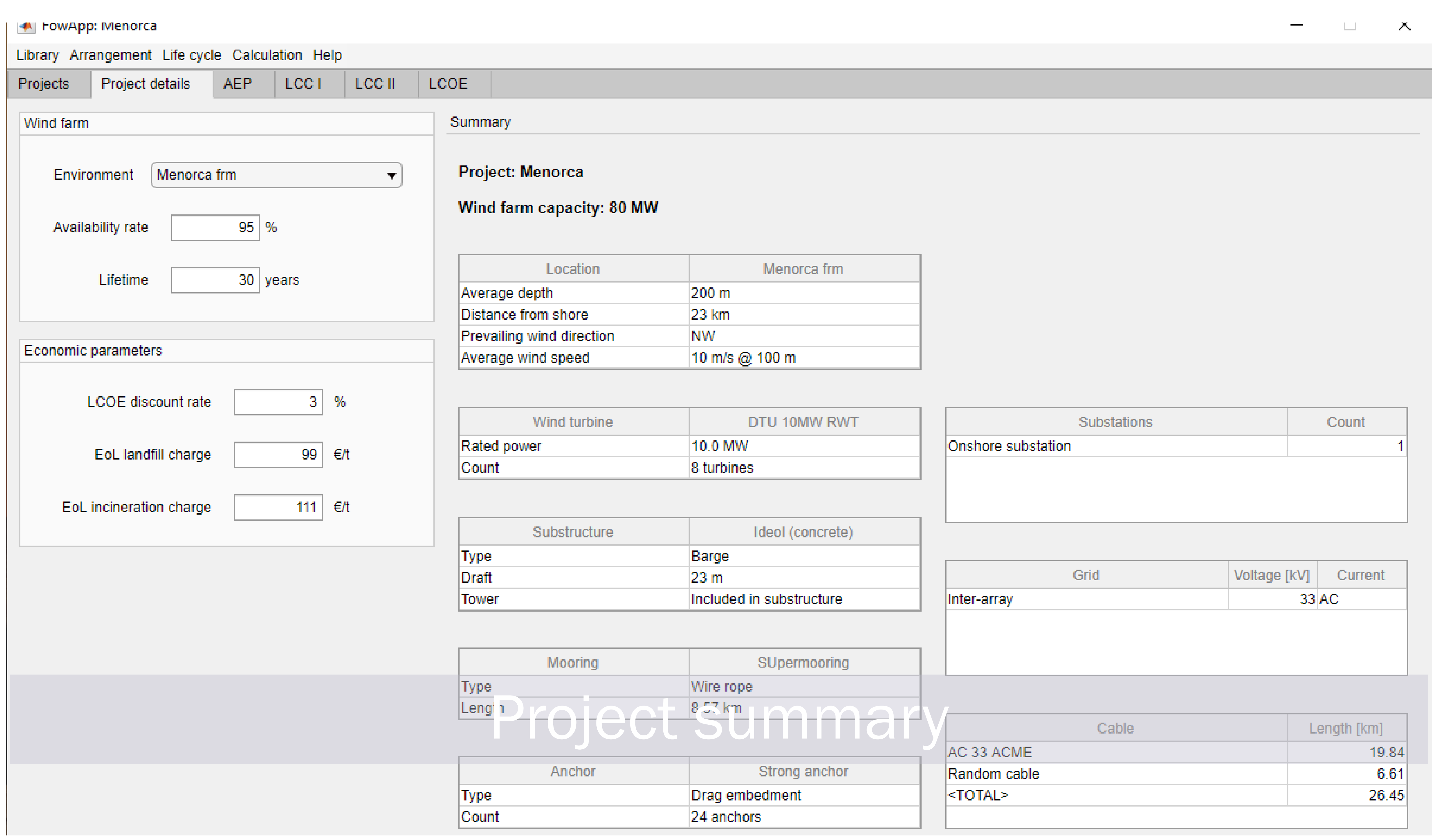
Highlights

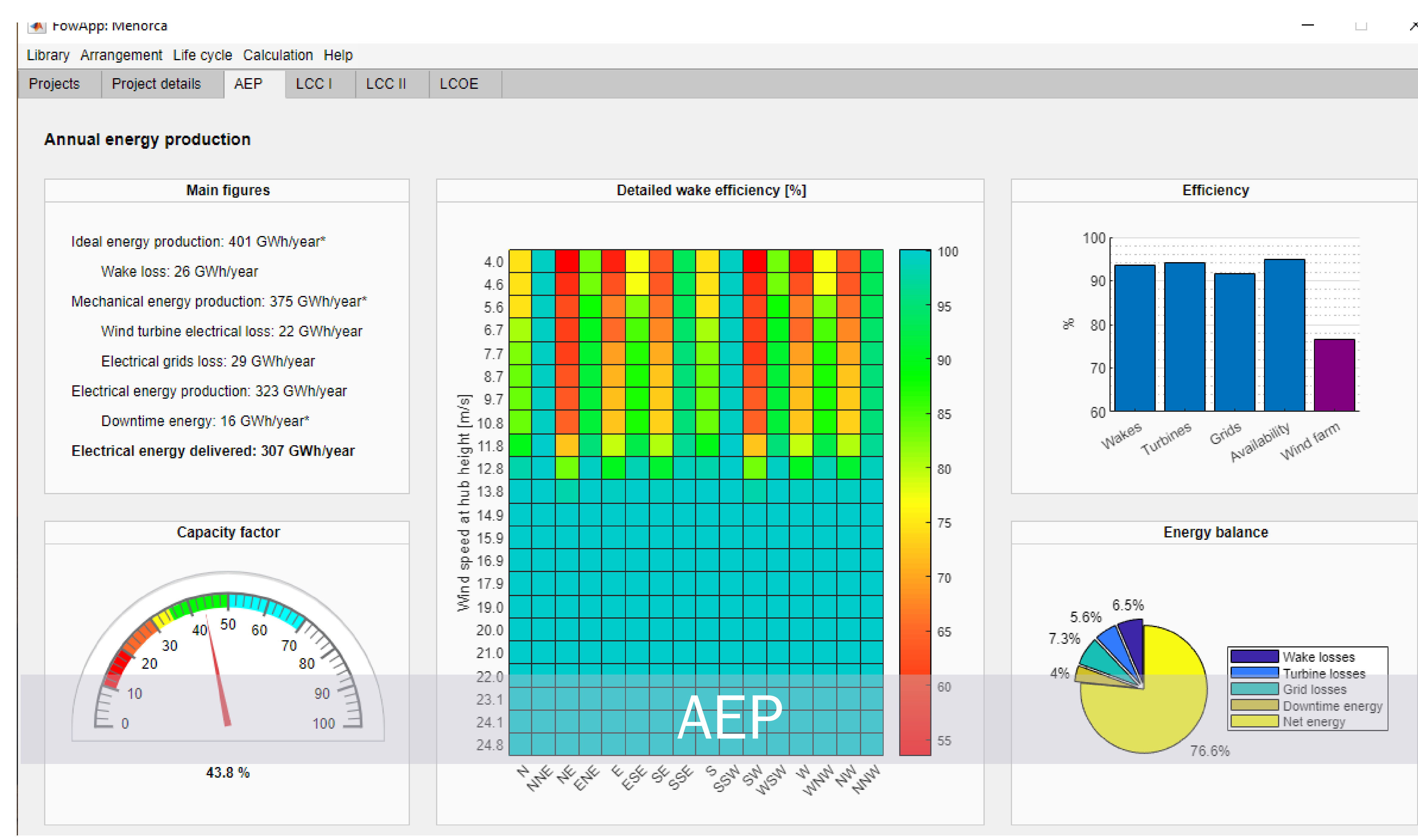
Features	Advantages	Applications
✓Built from scratch specifically for the floating wind industry ✓Possibility to import data from MS Excel ✓Data consistently stored in SQLite database ✓Integrated power flow and wake calculations ✓Full project overview	+User friendly +Variable level of input details as per user needs +Multiple substation concepts allowed +Dependable results +Combined economic and environmental analysis +Identification of aspects to improve	❖Early project development ❖Technology assessment ❖Environmental impacts evaluation ❖Performance analysis

Screenshots









Next steps

- App under registration process
- LCA module being finished
- Official testing: March 2021
- First use in the COREWIND project
- Commercial deployment: end of 2021

corewind

COST REDUCTION OF
FLOATING WIND TECHNOLOGY

Join the conversation #corewind

Stay tuned and follow us for updates

https://twitter.com/corewindeu
https://www.linkedin.com/company/corewind/

Disclaimer:

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 815083.

Project details:

Duration:
1 Sep 2019 - 28 Feb 2023
Grant agreement:
No: 815083