corewind

COST REDUCTION OF
FLOATING WIND TECHNOLOGY

Design and costs benefits of shared anchors or mooring lines of FOWT at farm level

DeepWind conferences
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corewind.eu

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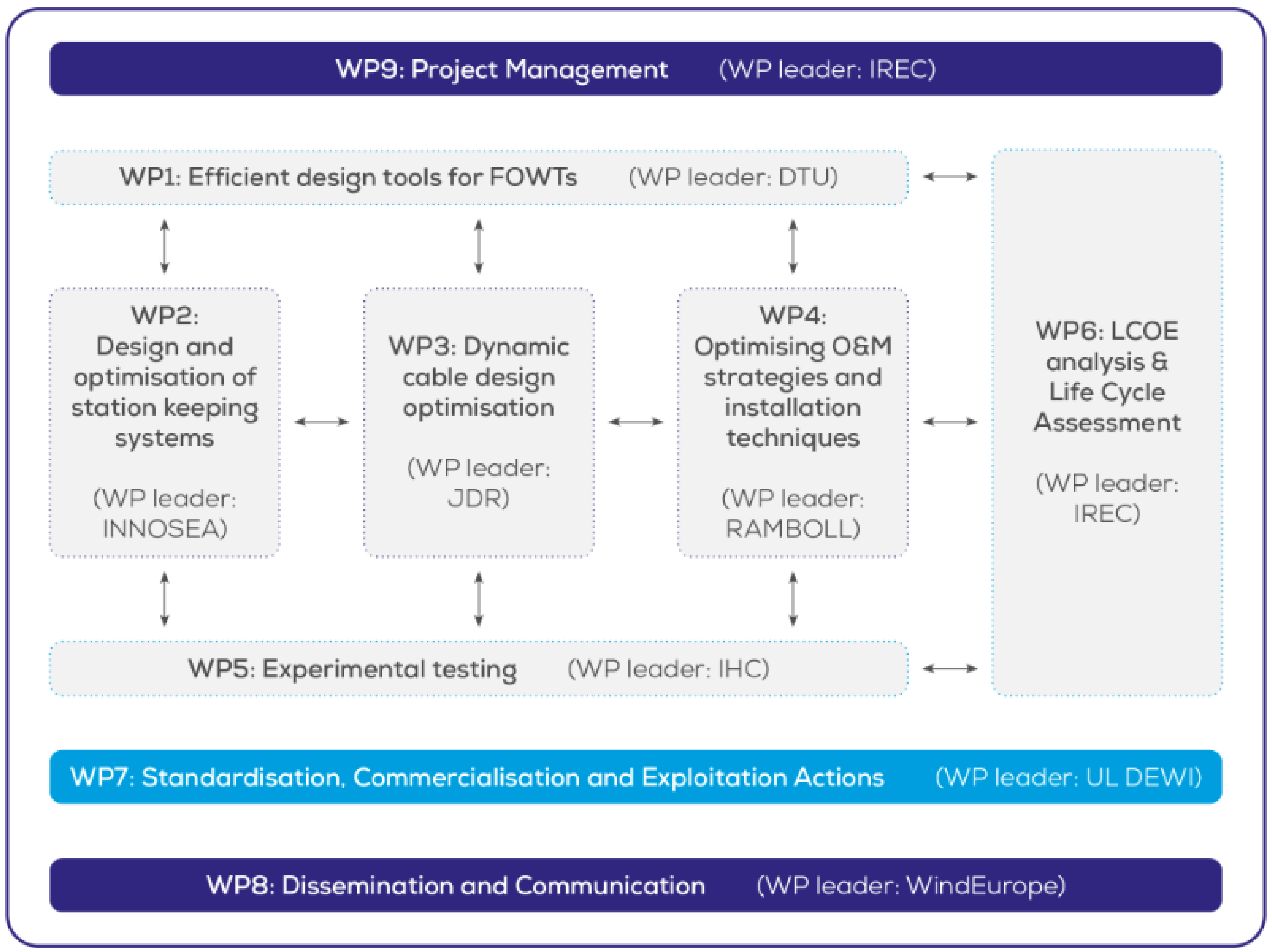
COREWIND project – Cost Reduction and increased performance of floating WIND

Project organization and partners



- Innosea was WP2 leader during the entire project.
- Website : corewind.eu

1. Introduction

COREWIND project

- 3 sites : West of Barra (Scotland), Gran Canaria (Canaria Islands) and Morro Bay (USA).
- 2 floaters : ActiveFloat (semi-submersible) and WindCrete (spar buoy).

WindCrete platform

ActiveFloat platform

1. Introduction

Scope of the study

Floater: ActiveFloat.

Sites: Gran Canaria and Morro Bay.

Conditions:

Site	Gran Canaria	Morro Bay
Location	Canaria Islands	California (USA)
Water Depth	200 meters	870 meters
Extreme wind speed at hub height for a 50-years return period	28.7 m/s	37.15 m/s
Extreme waves for a 50-years return period (Hs, Tp)	(5.11m, 9s to 11s)	(9.9m, 16s to 18s)
Extreme current at sea surface	1.06 m/s	**0 m/s**

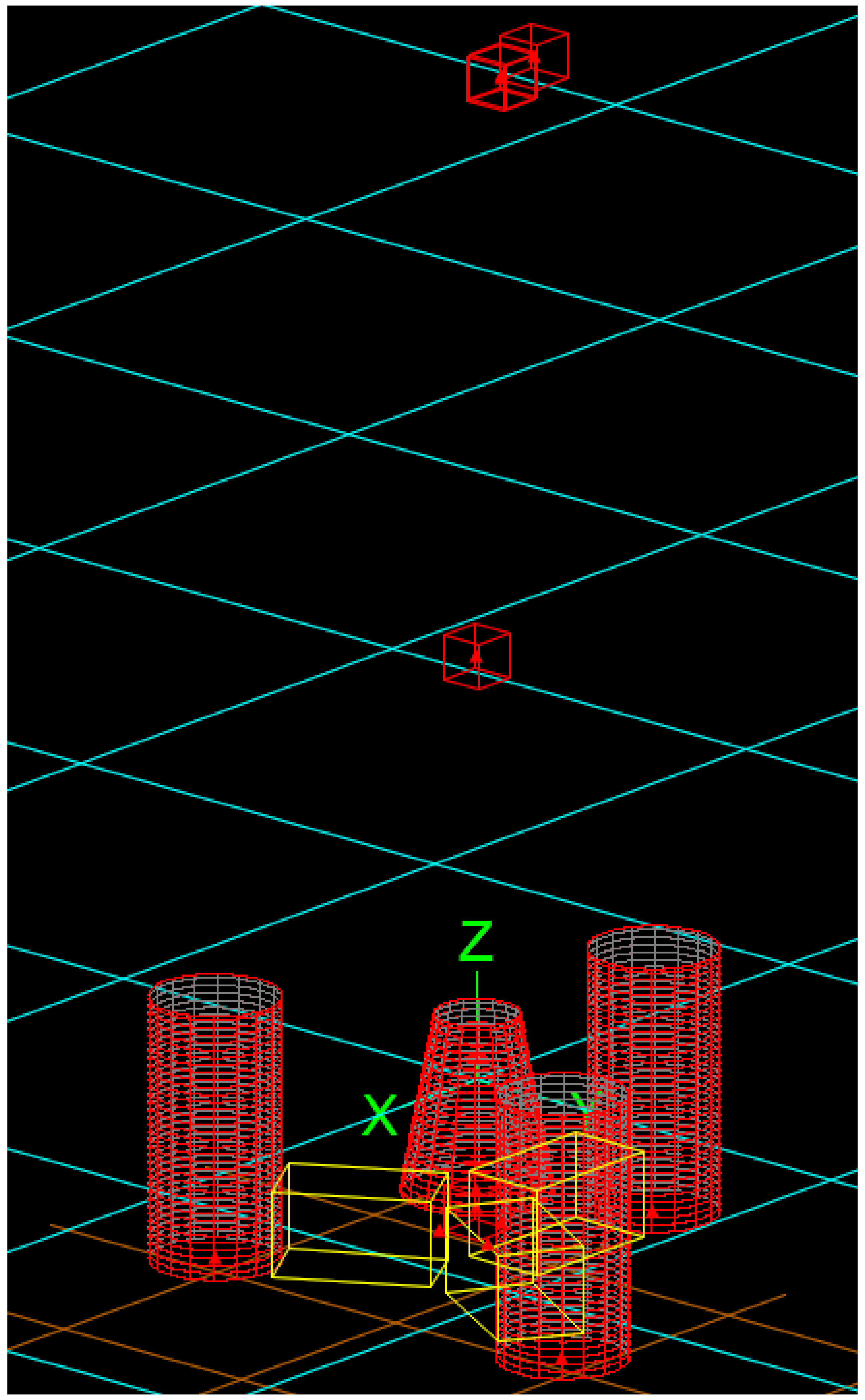
Objective:

- Investigate the feasibility and the potential benefits of sharing the anchors and sharing the mooring lines in a farm layout.
- Optimize the cost of the layouts and compare it to the cost of a conventional mooring system at farm level.

1. Introduction

OrcaFlex modelling choices

- Non-coupled models.
- Hydrodynamic Data Base attached to the platform vessel (Load RAOs, Added mass and Damping) for potential flow theory solving.
- Additional drag coefficients attached to the columns and pontoons 6D buoys.
- The tower and RNA are modelled as lumped masses (Mass and Inertia, rigid body).
- Wind loads are calculated in openFAST simulations with an initial mooring system and a turbulent wind.
- The mooring lines are modelled with the Finite Element Method. Material properties are attached to the nodes.

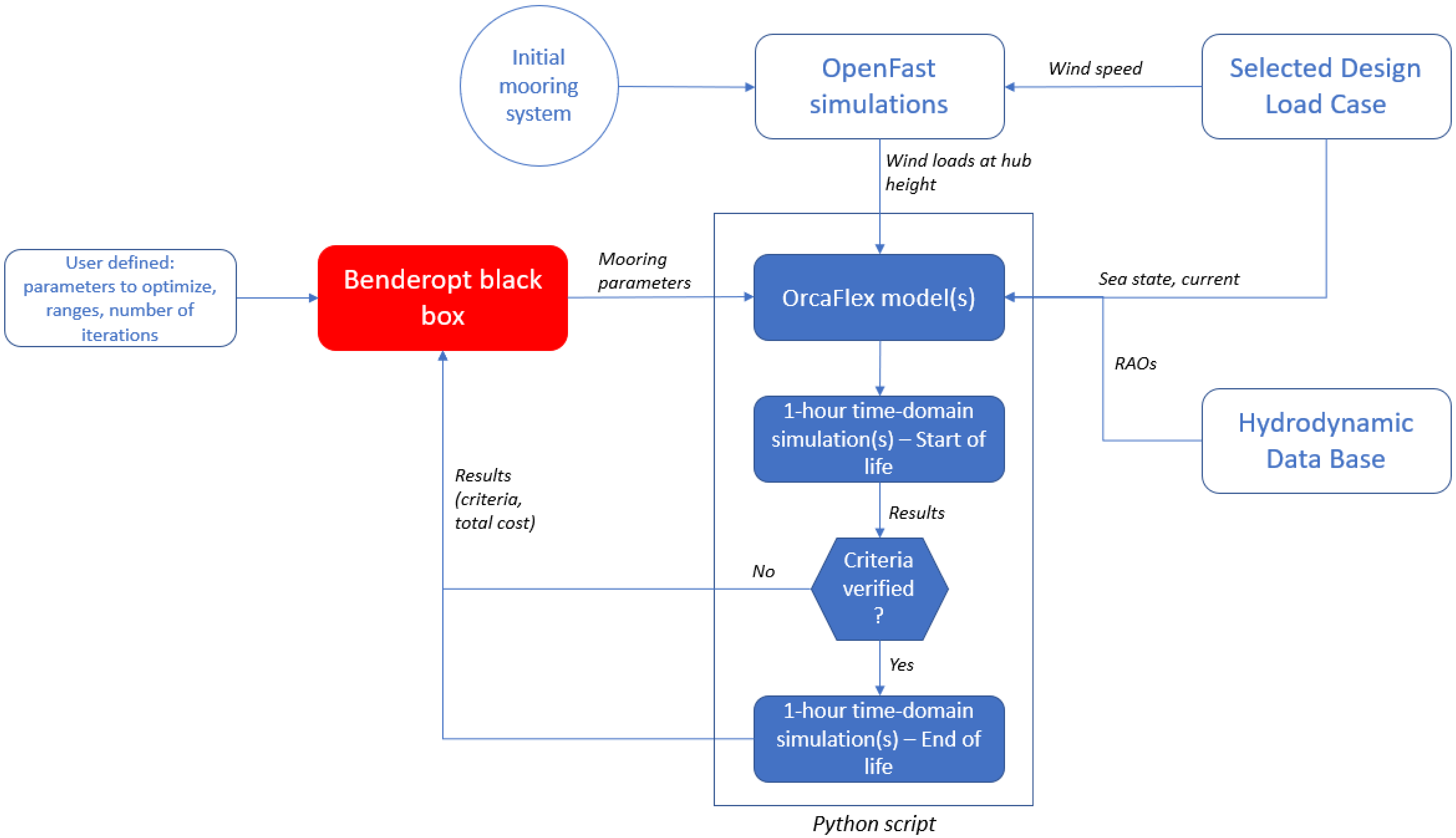


- Well suited for ULS simulations.

1. Introduction

Optimization screening tool

In-house tool developed by Innosea for Corewind:



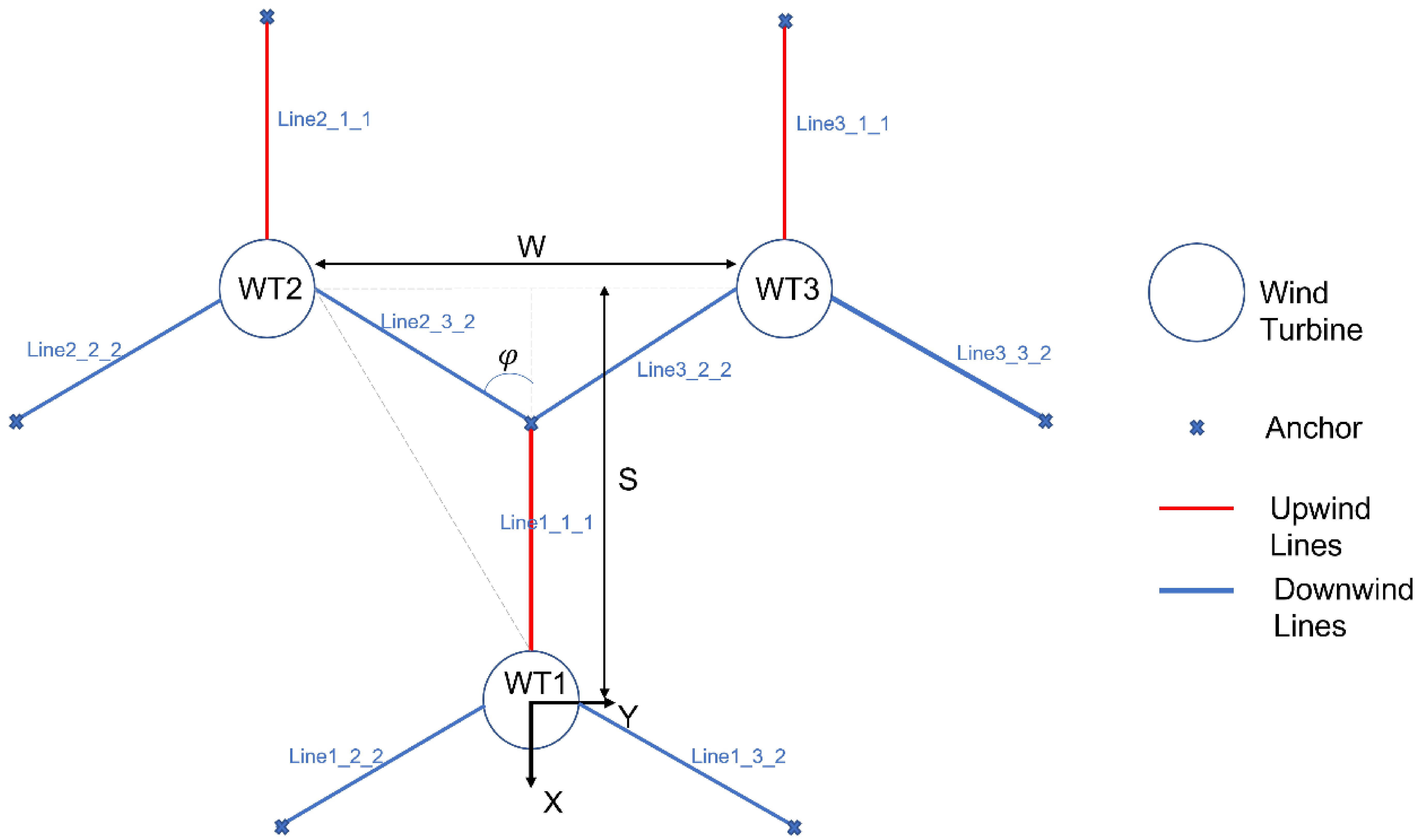
- Materials costs and anchors costs estimations based on D4.6 of Dtocean+.
- Installation costs not considered.

- Shared mooring lines layouts cannot be optimized using this tool.
- **Only adapted to conventional moorings and shared anchor moorings.**

2. Shared anchors

Global Approach

Layout:



Optimization:

Line lengths are set to their minimum, with respect to the geometrical constraints of the farm layout.

Materials costs are minimized using the optimization screening tool.

Geometrical constraints:

Turbines longitudinal spacing:

S = 7D (D = rotor diameter)

Lateral spacing:

W > 4D

Mooring lines angle:

$\varphi = 60°$

Design:

For **ULS**.

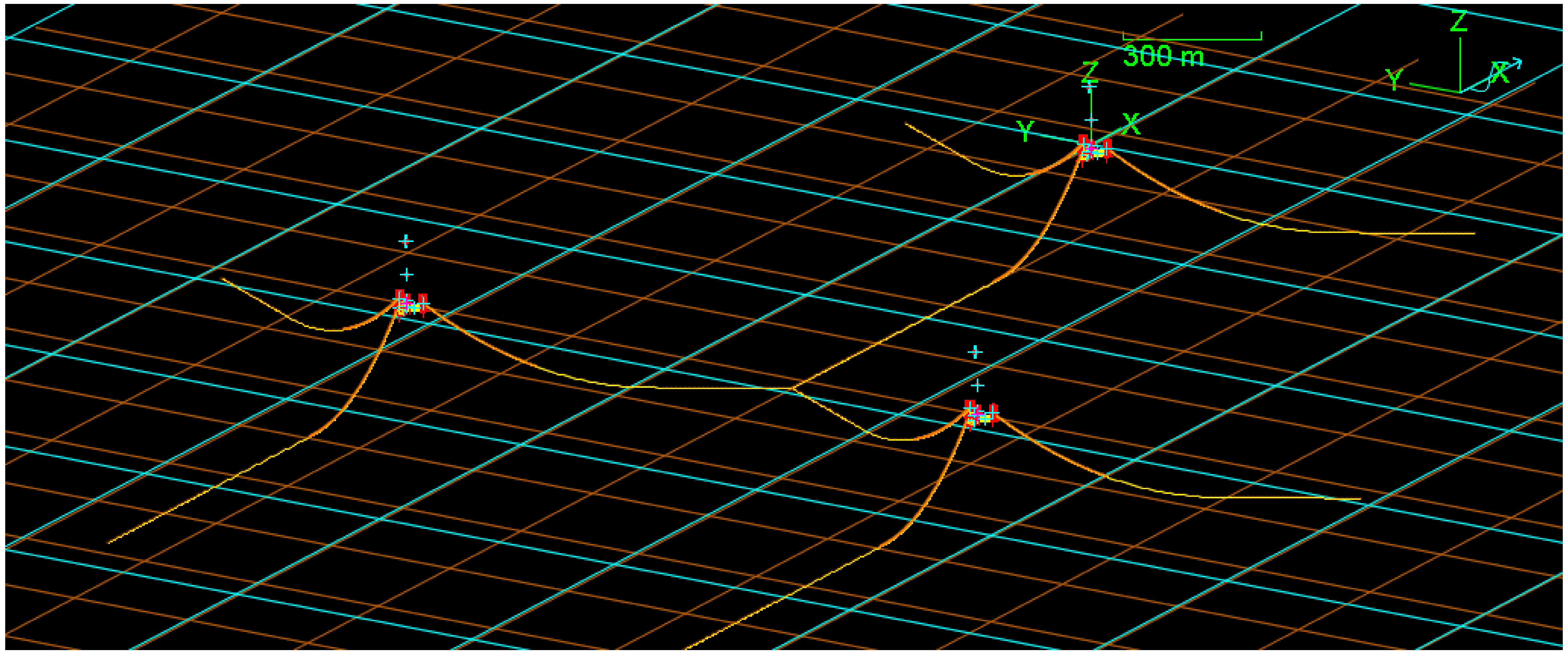
OrcaFlex simulations corresponding to **DLCs 6.1 and 6.2** have been performed, in start of life and end of life (25 years).

With respect to maximum platform offset and dynamic motions, RNA accelerations and mooring lines materials Utilization Factors.

2. Shared anchors

Results for moderate water depth:

Description of the mooring system:



- Catenary mooring made of chain.
- Uni-directional environment : upwind and downwind lines optimized independently.

-> 50mm chain of grade R4 downwind

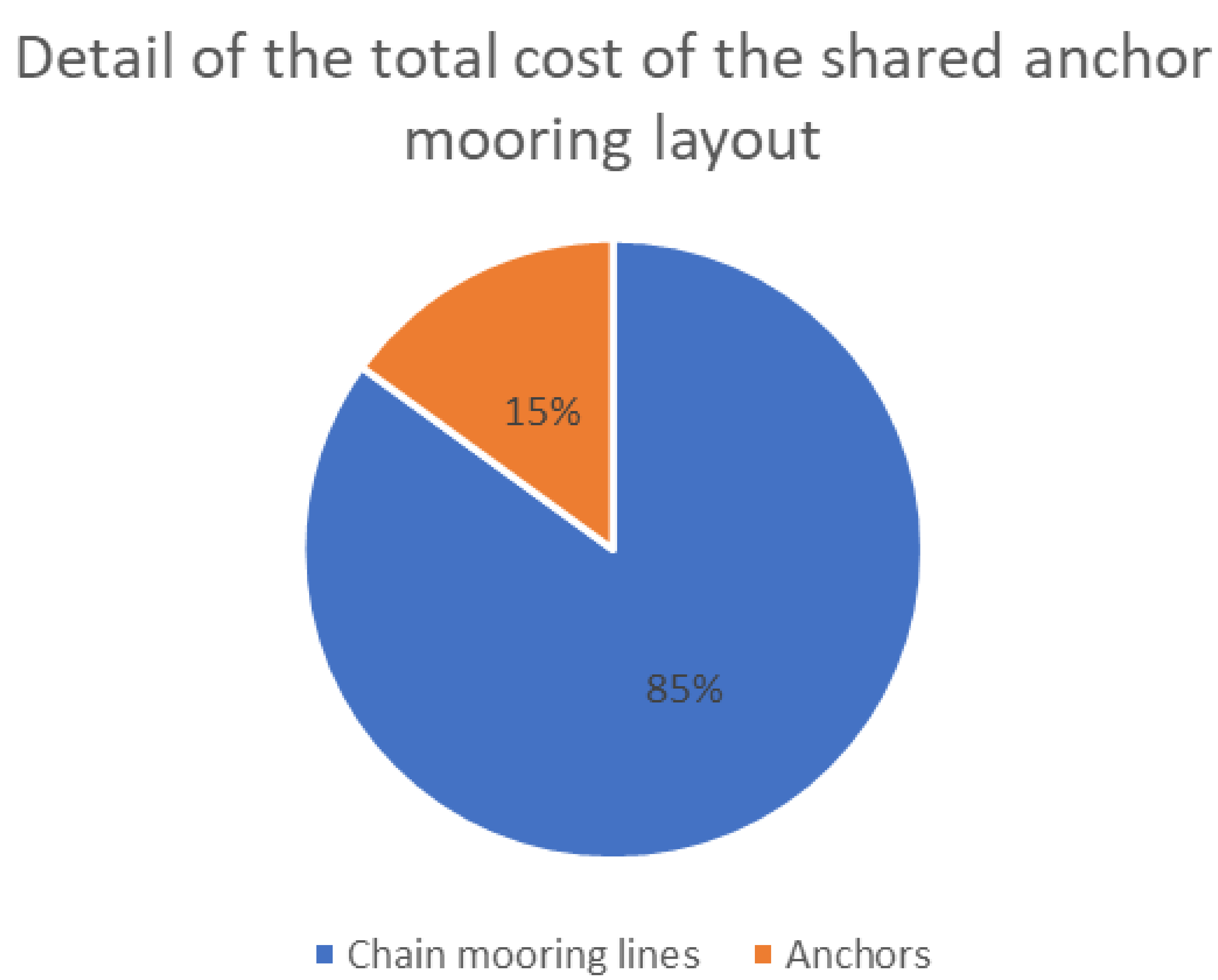
-> 110mm chain of grade R4S upwind

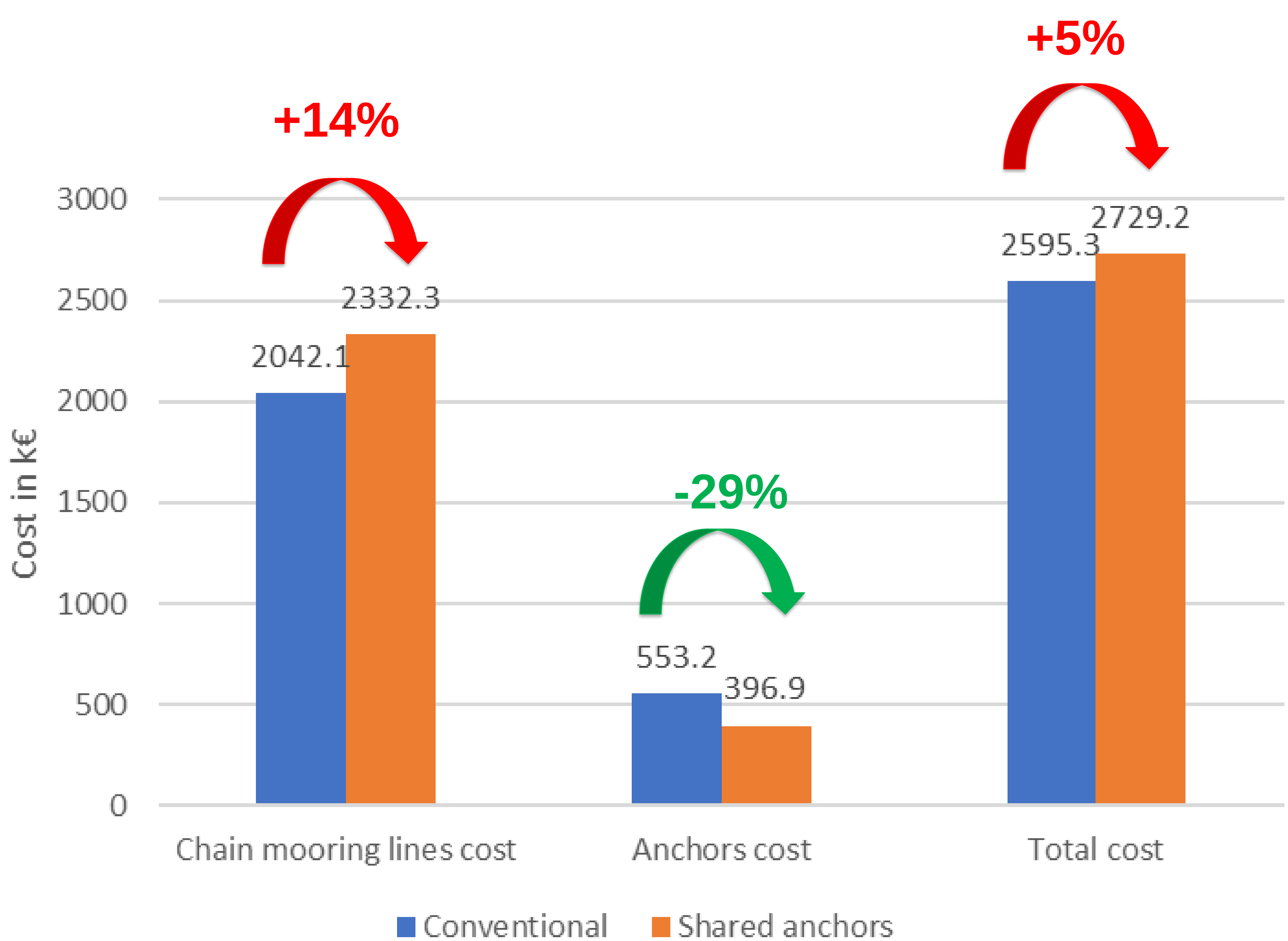
2. Shared anchors

Results for moderate water depth

Total optimized costs:

- Phase 1 : 3 times the optimized cost of the conventional mooring of 1 FOWT.
- Shared anchors : the optimized cost of the shared mooring system of the 3 FOWT layout.

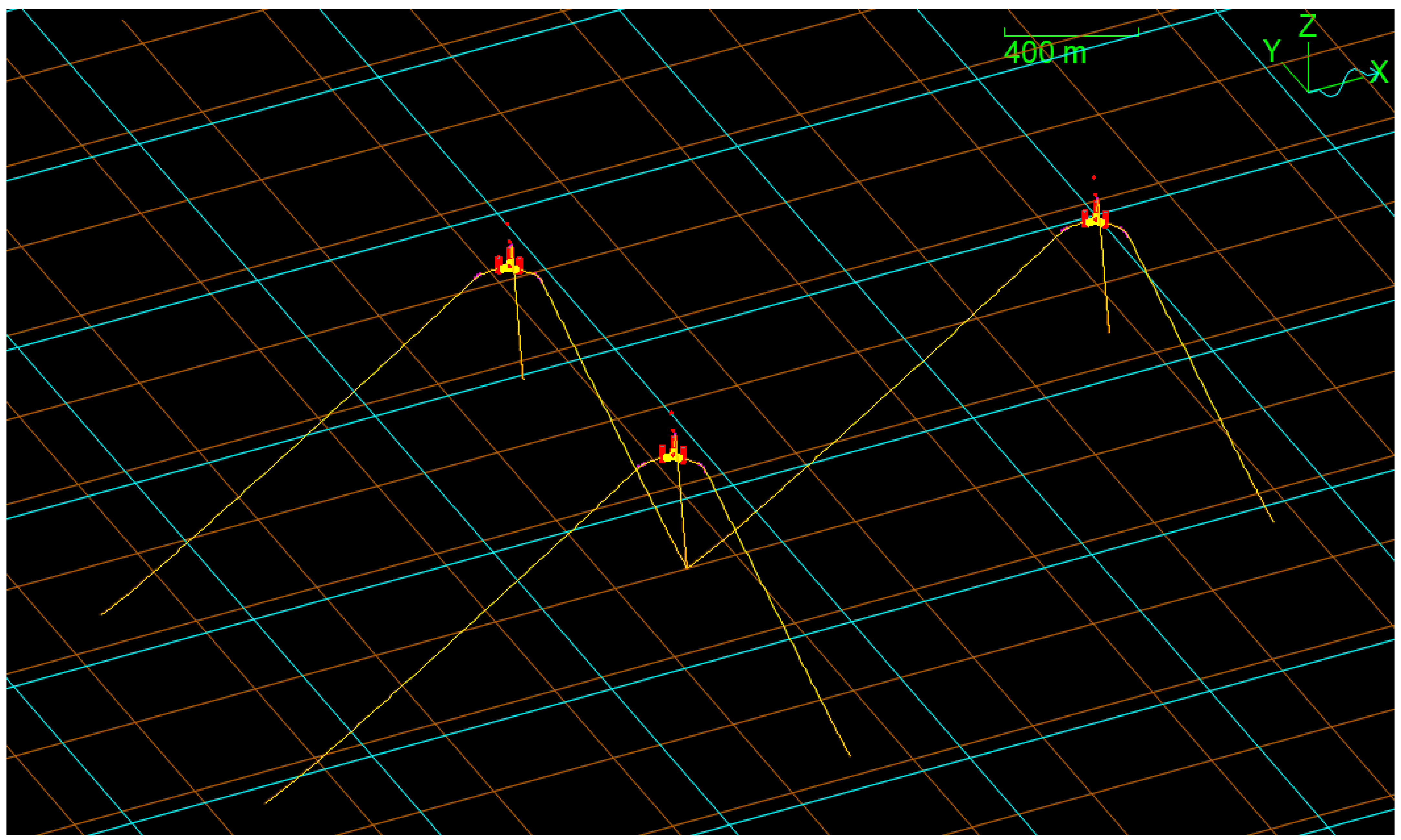




2. Shared anchors

Results for deep water depth

Description of the mooring system:



- Semi-taut mooring system.
- Chain on top and close to the anchor.
- Polyester section in-between.
- Uni-directional environment made possible to differentiate upwind and downwind lines in the optimization process.

->

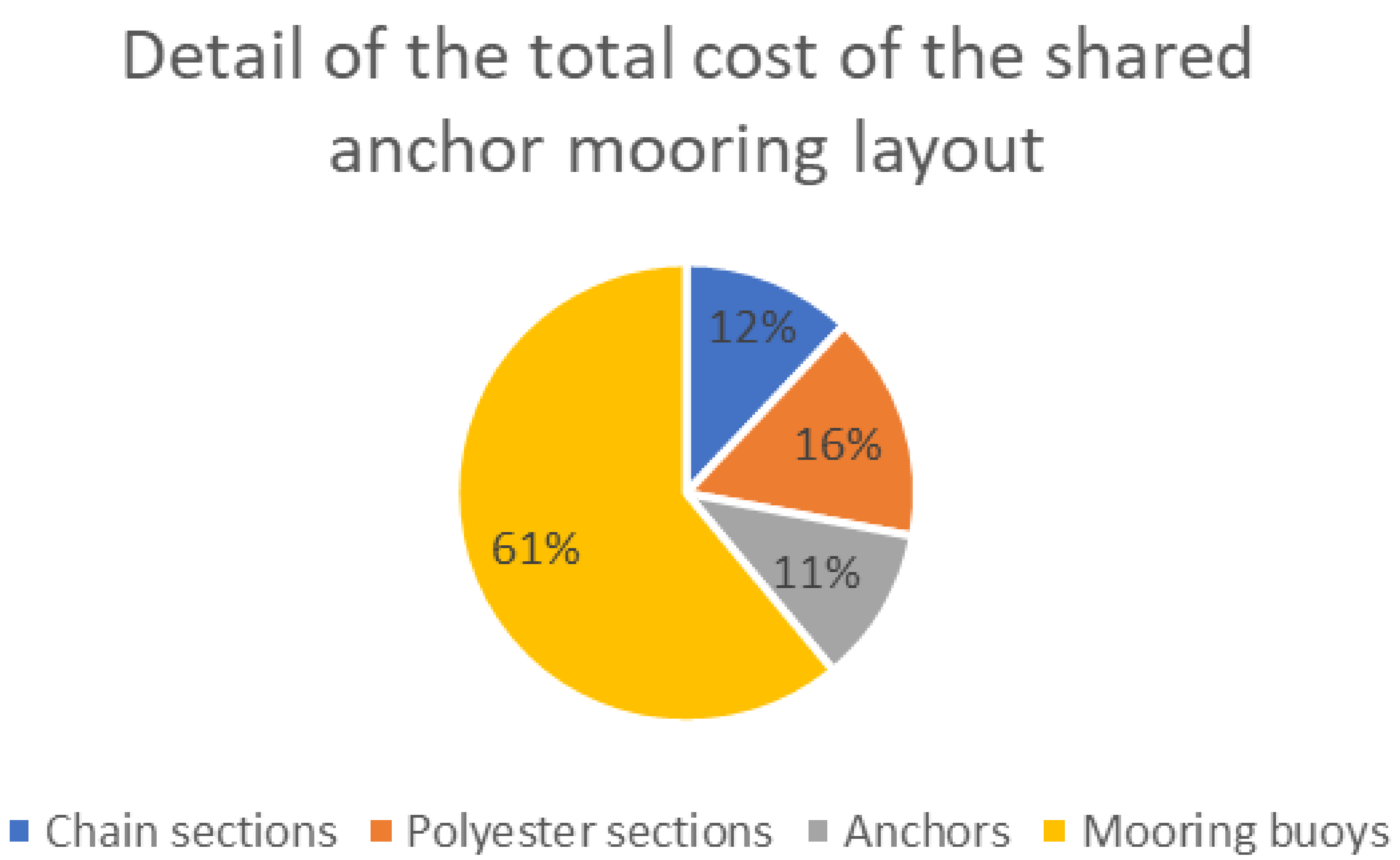
Group of lines	Material	Diameter [mm]	Steel Grade
Upwind lines	Chain	105,00	R3S
	Polyester	169,00	-
Downwind lines	Chain	90,00	R4
	Polyester	146,00	-

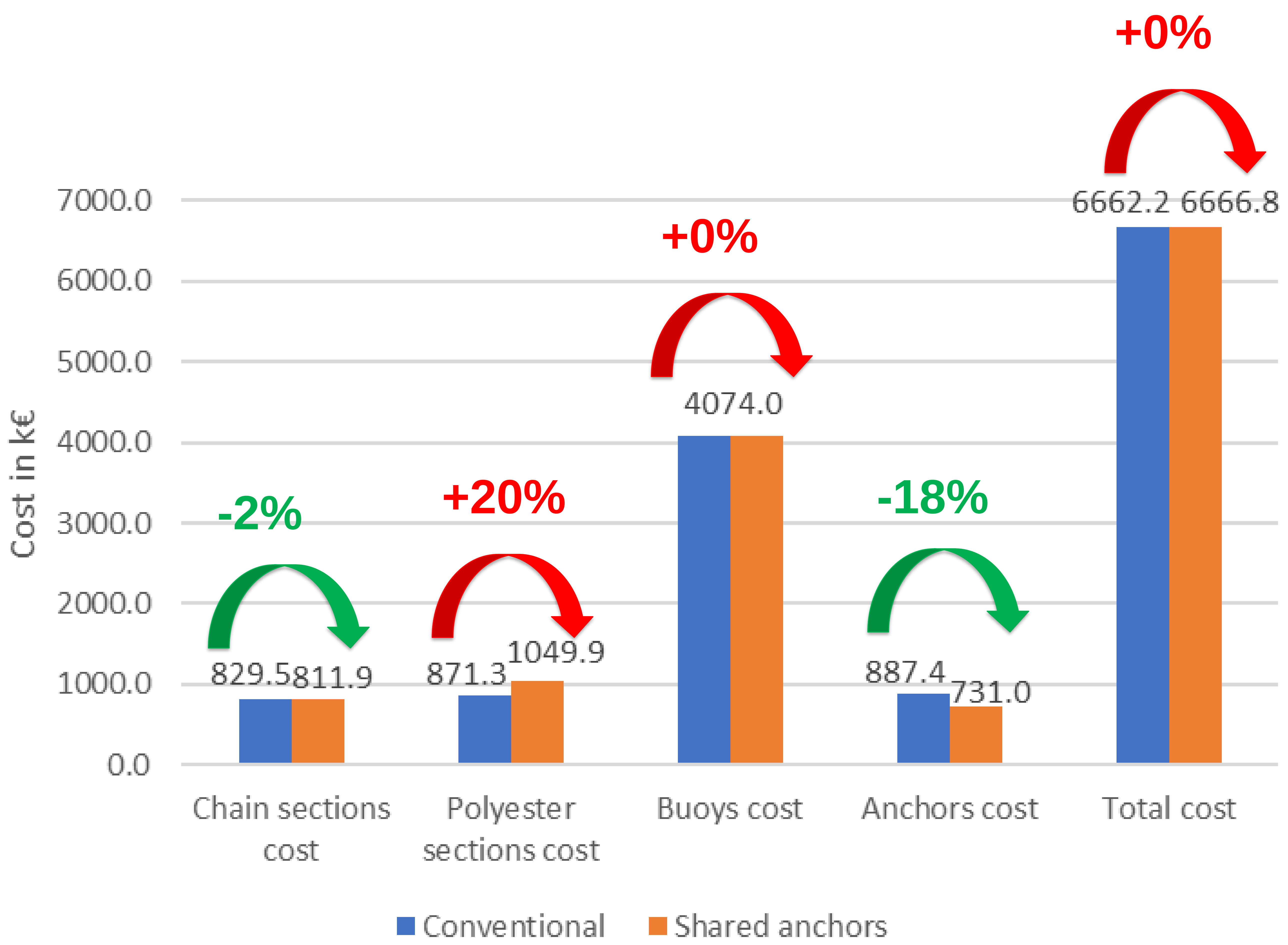
- Mooring buoys attached to the top chain sections -> increases yaw mooring stiffness.
- Costs from Balmoral catalogue.

2. Shared anchors

Results for deep water depth

Optimized costs:



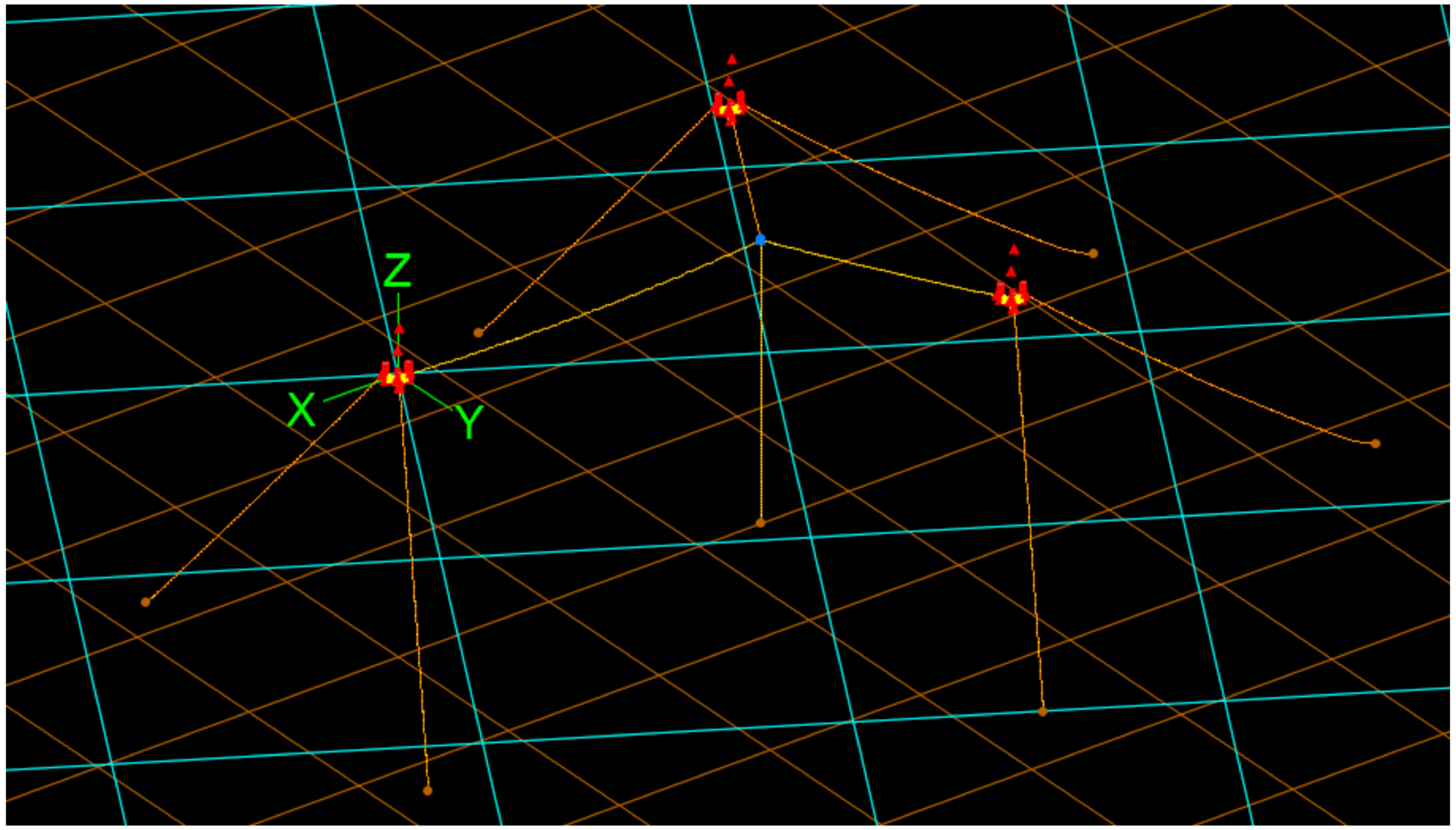


- When compared to the conventional mooring costs, **anchors cost has decreased of 18%** and chain cost of 2%.
- **Polyester cost increased of 20%** because of the line lengths.
- Resulting in **no cost reduction** when looking at the total costs.

3. Shared mooring lines

Results for deep water depth

Description of the mooring system:

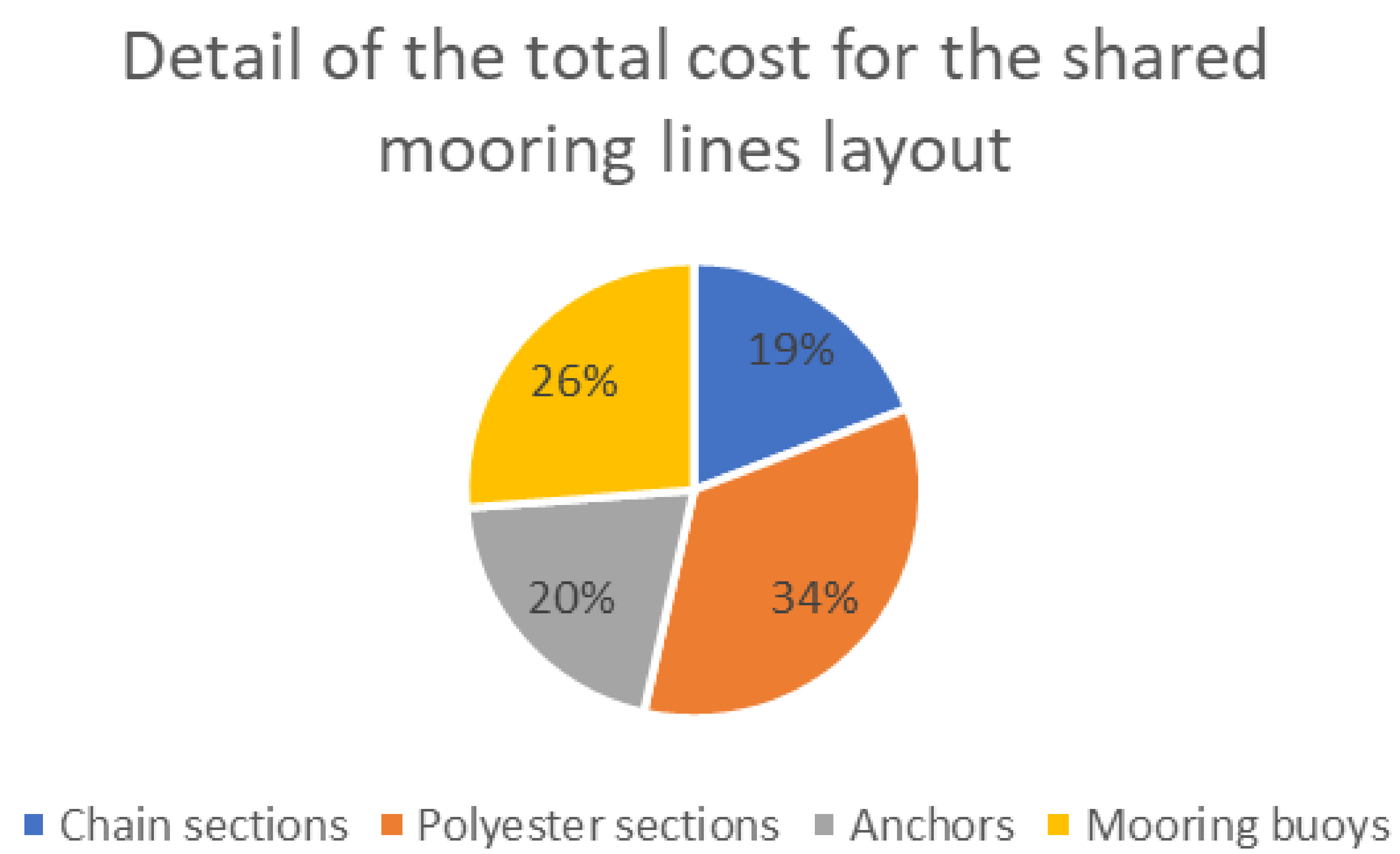


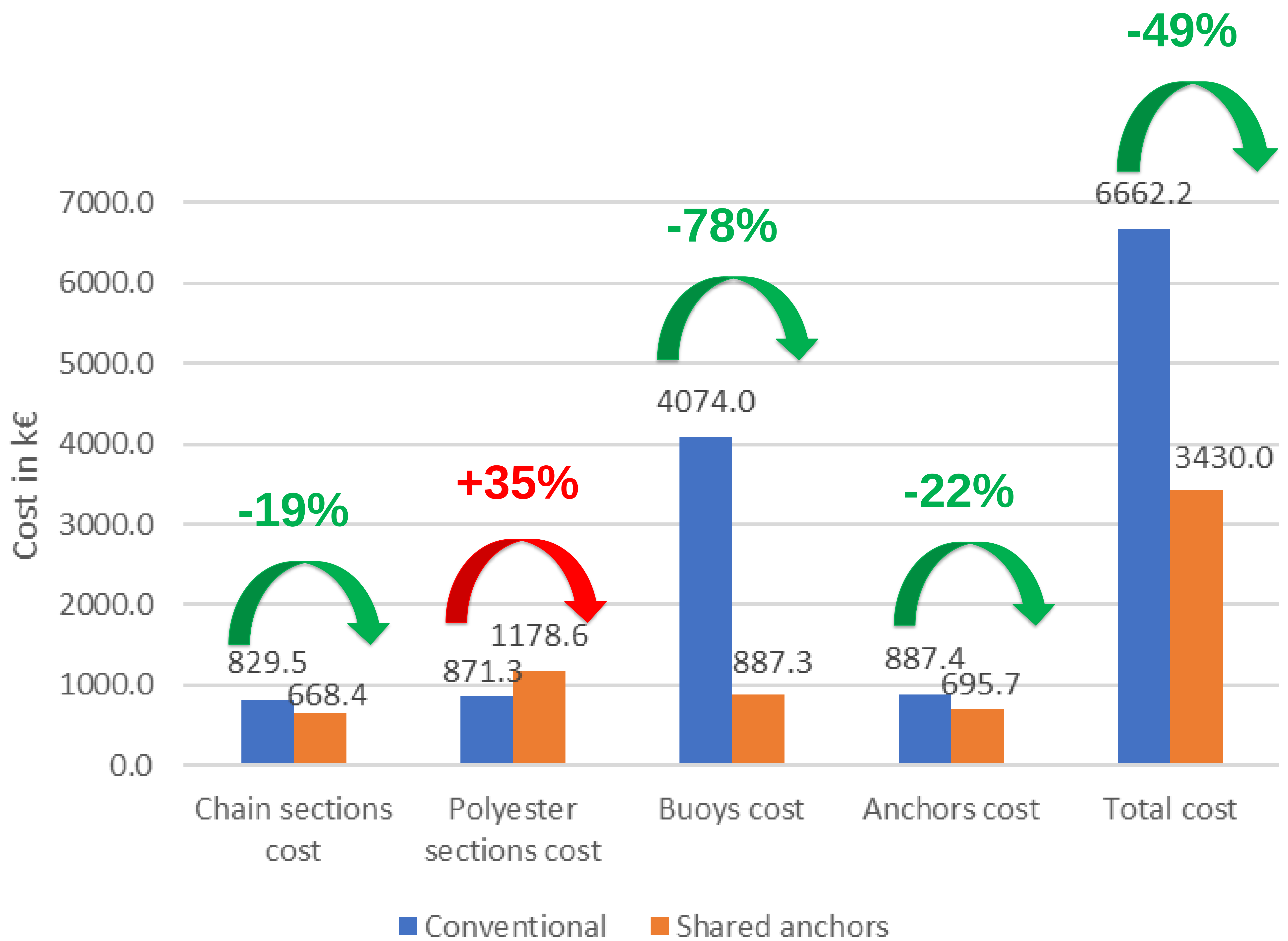
- For each FOWT, two semi-taut mooring lines anchored on the seabed.
- FOWTs are connected to each other with a mooring buoy in the center.
- Horizontal lines are made of chain.
- Vertical line in the center is made of Polyester.

3. Shared mooring lines

Results for deep water depth

Routine strategy:





- When compared to the conventional mooring costs, **buoys cost has decreased 78,2%**, anchor cost of 21,6% and chain cost of 19,4%.
- **Polyester cost increased 35%** because of the line lengths.
- Resulting in a **total cost reduction of 48,6%.**

4. Conclusions and outlook

Both anchoring possibilities are validated for **ULS at start of life and end of life**. The modal analysis did no highlight any risk of interaction with turbine frequencies.

Shared anchors:

- At farm level, the **line lengths** are increased to respect FOWT spacing.
- Decreasing the number of anchors has the effect to decrease significantly the total cost of the mooring -> not enough to get total costs benefits.

Shared mooring lines:

- **Yaw mooring stiffness is largely increased ->** allows to reduce the number of mooring buoys.
- **Decreasing the number of buoys and the number of anchors led to a 50% cost reduction** when comparing with the conventional mooring.

Perspectives:

- **Installation costs** should be considered.
- Mooring systems need to be validated for FLS.
- Sensitivity analysis on the effect of modelling farm layouts with 3 turbines.

Thank you for your attention.

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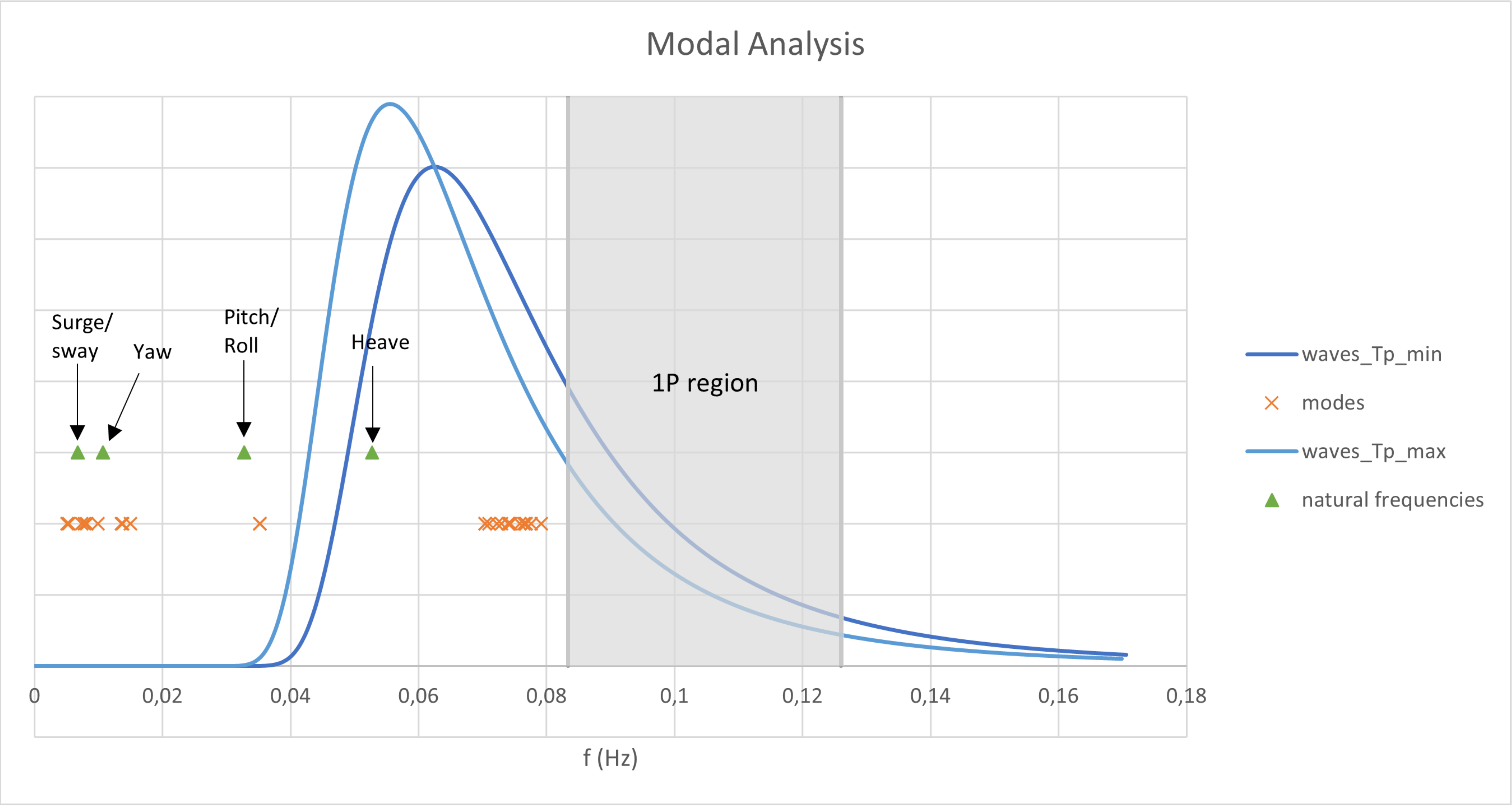
Corewind website: corewind.eu

3. Shared mooring lines

Modal Analysis

First modes of the system of three anchored FOWTs:

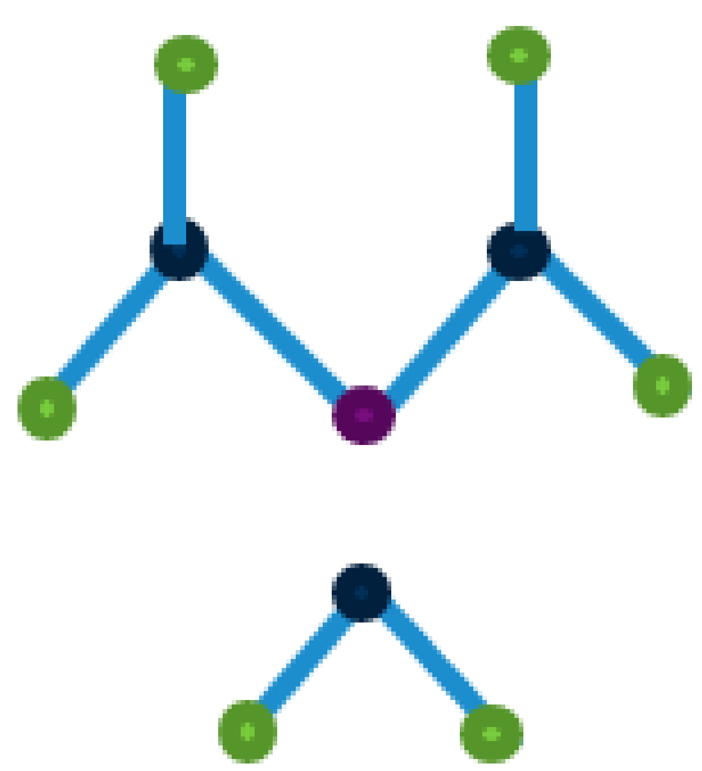


- Pitch and roll modes are specific to this system (interesting for FLS).
- All the mode frequencies found are in the wave frequencies range, far from the 1P range.

3. Shared mooring lines

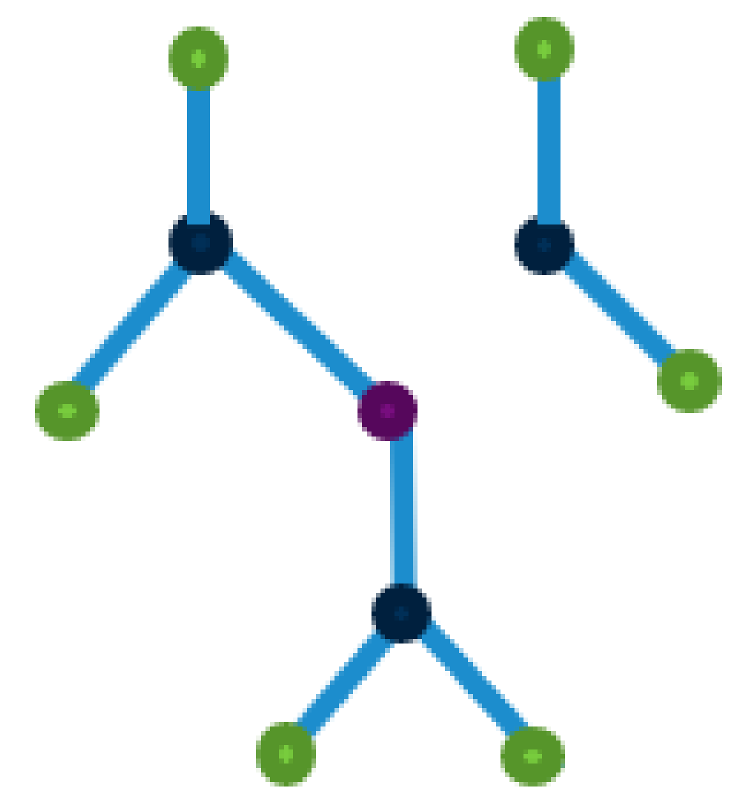
Accidental Limit State study

For DLC 7.4 from DNVGL, at start of life:



DLC7.4 (SOL) results	Upwind	Downwind
Maximum tension criterion (chain)	0,214	0,331
Maximum tension criterion (polyester)	0,132	0,382
Maximum offset (m)	321,6	
Maximum pitch (°)	4,37	
Maximum yaw (°)	47,07	
Maximum horizontal acceleration (m/s2)	2,29	
Maximum vertical acceleration (m/s2)	0,58	
Maximum pretension (kN)	405,26	

Case 1 : failure of an upwind shared line



DLC7.4 (SOL) results	Upwind	Downwind
Maximum tension criterion (chain)	0,271	0,136
Maximum tension criterion (polyester)	0,161	0,153
Maximum offset (m)	387,4	
Maximum pitch (°)	3,84	
Maximum yaw (°)	37,29	
Maximum horizontal acceleration (m/s2)	2,23	
Maximum vertical acceleration (m/s2)	0,62	
Maximum pretension (kN)	296,1	

Case 2 : failure of a downwind shared line

3. Shared mooring lines

Accidental Limit State study

For DLC 7.4 from DNVGL, at start of life:

DLC7.4 (SOL) results	Upwind	Downwind
Maximum tension criterion (chain)	0,266	0 ,399
Maximum tension criterion (polyester)	0,53	0,463
Maximum offset (m)	19 ,23	
Maximum pitch (°)	3,56	
Maximum yaw (°)	2,46	
Maximum horizontal acceleration (m/s2)	2,27	
Maximum vertical acceleration (m/s2)	0,59	
Maximum pretension (kN)	1953,9	

Case 3 : failure of the shared vertical line

1. Introduction

Costs computation

From D4.6 of Dtocean+:

$$C_{chain} = (0.0591 \times MBL - 89.69) \times L$$
$$C_{polyester} = (0.0138 \times MBL + 11.281) \times L$$

Where L is the line length

MBL is the Minimum Breaking Load of the material

For drag-embedded anchors:

$$C_{anchor} = 10.198 \times MBL$$

Where MBL is the MBL of the chain section attached to the anchor.

For pile anchors:

$$C_{anchor} = (1 + Complexity\ Factor) * M_{material} * C_{material}$$

Where $C_{material}$ is the cost of material of the anchor

$M_{material}$ is the mass of material (estimated following ABS rules)

Installation costs: Not considered because of missing data and lack of time. Will be considered further in the project.