



TAILWIND

SUSTAINABLE STATION-KEEPING SYSTEMS FOR FLOATING WIND

May 28th, 2025

Bilbao

Ander Tena -Tecnalia

tecnalia

MEMBER OF BASQUE RESEARCH
& TECHNOLOGY ALLIANCE



Funded by
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PROJECT WORKFRAME

- Call: [HORIZON-CL5-2023-D3-01-05] — [Critical technologies for the offshore wind farm of the Future]
- Schedule: **48 months [2024-2027]**
- Consortium: **12 partners**

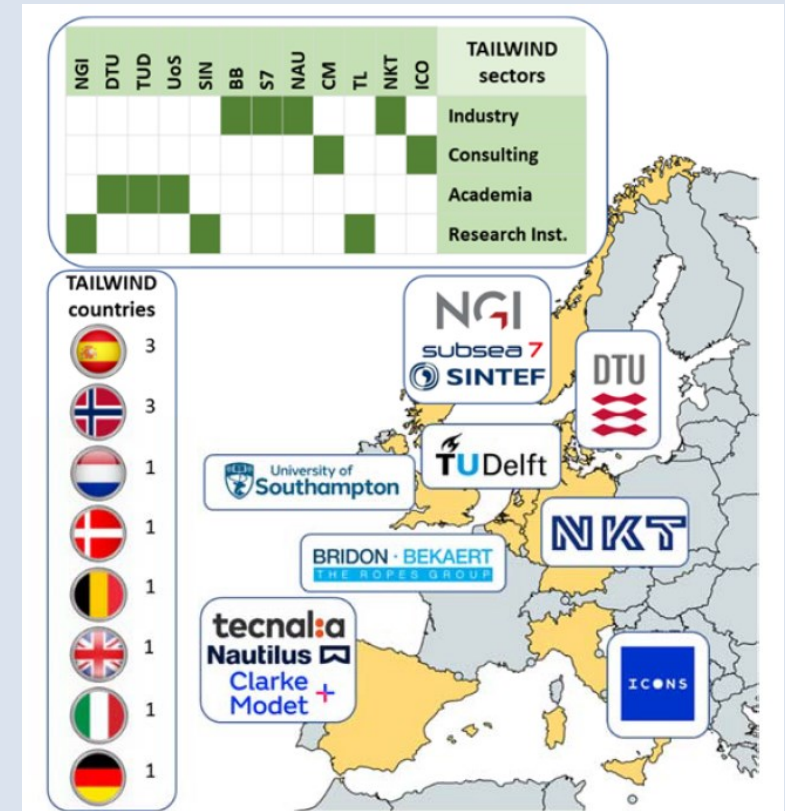


Figure 3-3: TAILWIND consortium: distribution and sectors

Why TAILWIND?

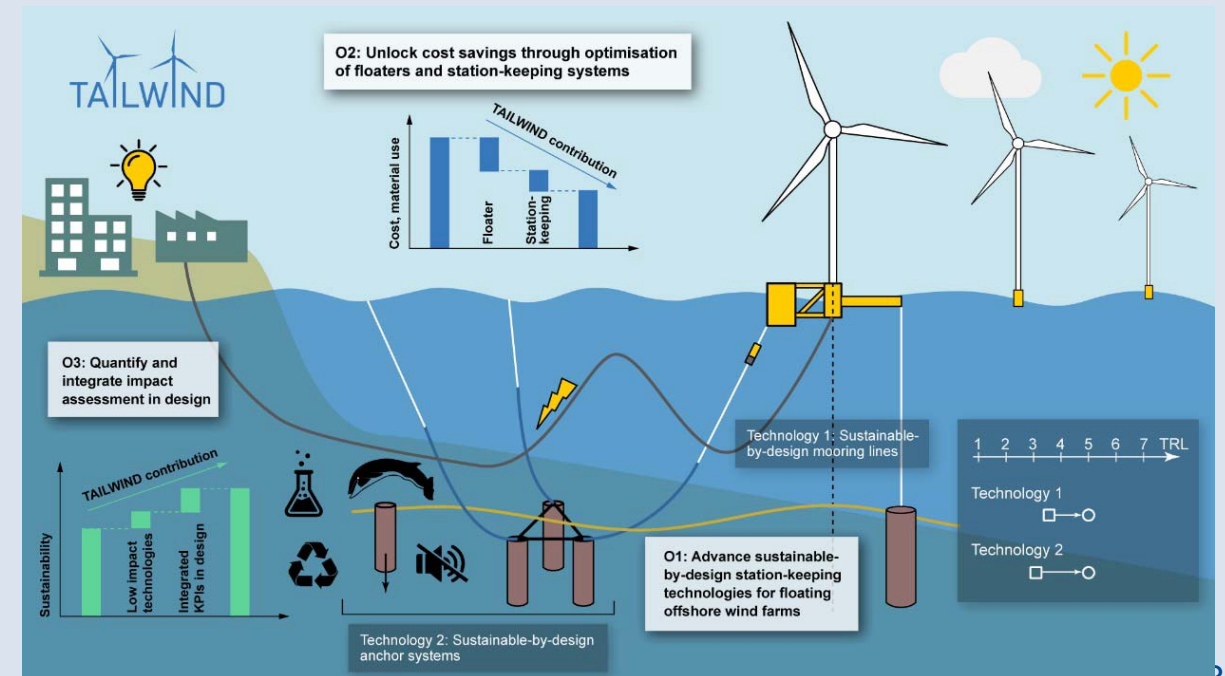
- To make floating offshore wind (FOW) farms **economically viable, scalable, and sustainable** renewable energy solutions.
- **Cost reduction focus:** Aims to **lower the costs** of floating units and mooring systems by advancing key station-keeping technologies (**up to 37.5% of CapEx** in FOW systems).
- **Potential:** Although less mature than bottom-fixed wind, FOW can achieve an **LCOE < €100/MWh by 2030** if deployed at large scale.

Key innovations in TAILWIND:

- Technology 1: **Mooring lines.**
- Technology 2: **Anchoring systems.**

Expected impact:

- Significant **reduction in materials**, reliance on primary raw resources, and costs.
- Overall **increase in the sustainability** of floating offshore wind farms



OBJECTIVES

Major objective

O1: Advance sustainable-by-design station-keeping technologies for FOW farms.

O2: Unlock cost savings through optimization of floaters and station-keeping systems.

O3: Quantify and integrate in the design process the impact of floating offshore wind parks on economy, society, and environment.

Specific objective (SO) description

SO1.1: Characterize synthetic materials for mooring lines of semi-submersibles and Tension Leg Platforms (TLPs)...[]

SO1.3: Create new geotechnical models for the long-term cyclic behavior of floating wind anchoring systems...[]

SO1.4: Conceive and develop anchor systems for semi-submersibles and TLPs that are single or in a cluster arrangement...[]

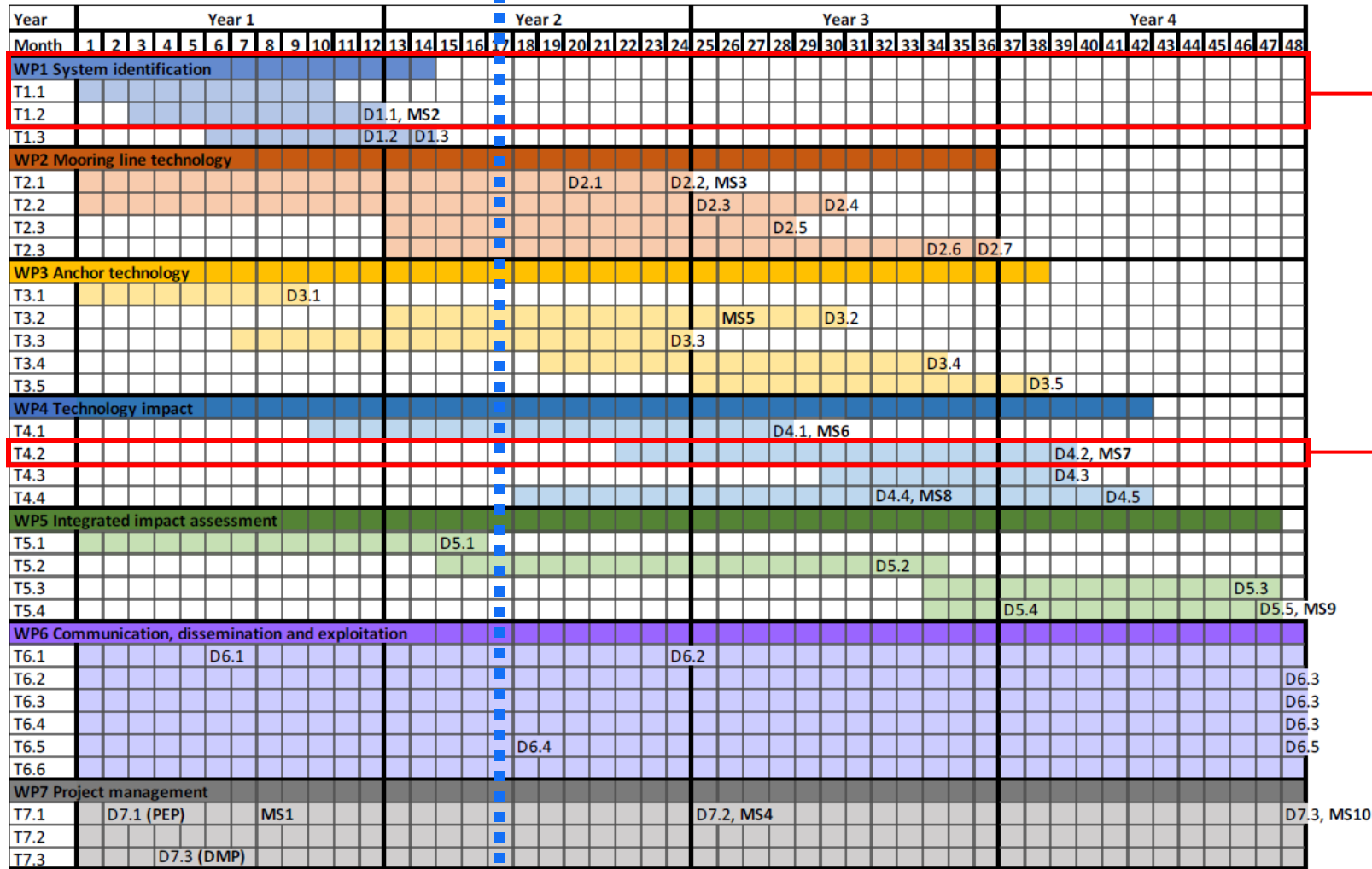
SO2.1 Design of cost optimized and sustainable single (semi-submersibles and TLP) and shared(semisubmersible) mooring lines for FOW.

SO2.2 Development of practical design methods for sustainable single (semi-submersibles and TLP) and shared (semi-submersible) anchor systems for FOW

SO2.3 Optimization of semi-submersible floater – size, ballasting, and configuration – by taking into consideration the novel station-keeping technologies.

SO3.2 Identification of sustainable KPIs and their integration into the life cycle impact assessments of the developed technologies.

May 2025



WP1 System identification

Tecnalia, NGI, Sintef, DTU, Nautilus, UoS, NKT

- T1.1 Metocean, geotechnical and deployment scenarios
- T1.2 Turbine integration and design basis

WP4 Technology impact

T4.2. Platform optimization

Figure 3-2: Gantt chart

T1.1: Metocean, geotechnical and deployment scenarios

(TEC, M1-M10)

T1.1: Metocean, geotechnical and deployment scenarios - Objectives

- Select two representative deployment **locations**.
- Collect and analyze meteorological, oceanographic, geotechnical, and environmental data.

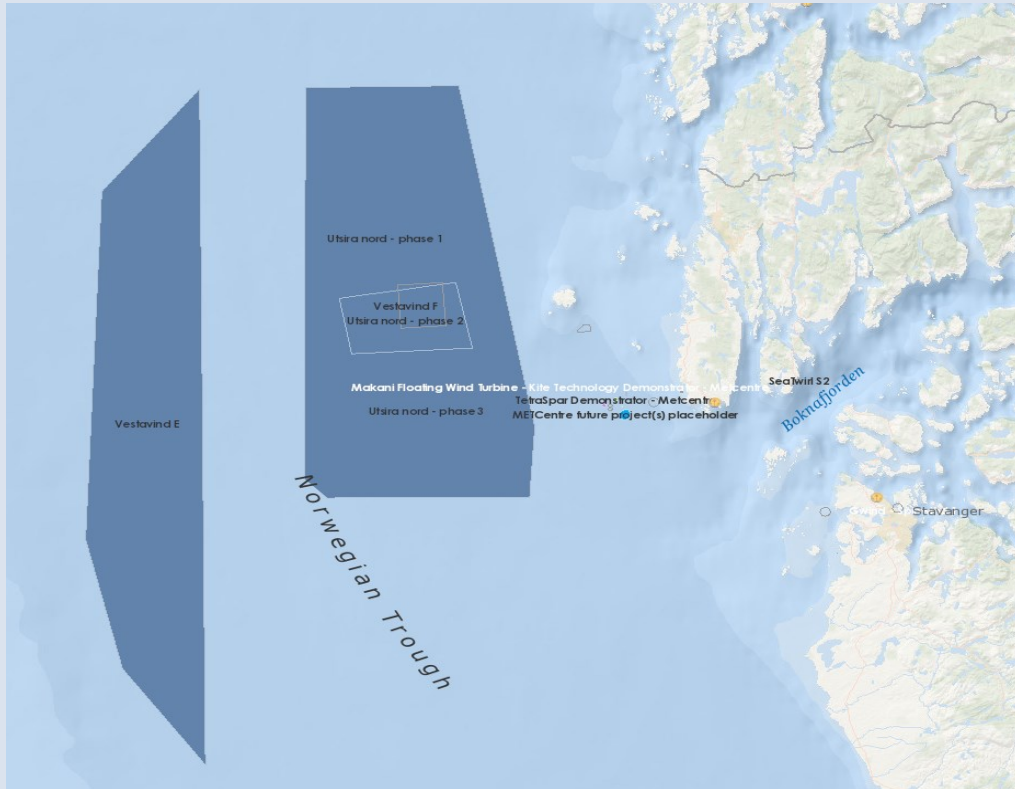
Sites selection criteria

- availability of good environmental/geotechnic **data**
- different **water depths**
- representative of different **soils/artificial soil profiles**
- **testability** of these two soil types in **WP3**
- suitable **wind** speed, **wave** height/period range values
- **market potential**

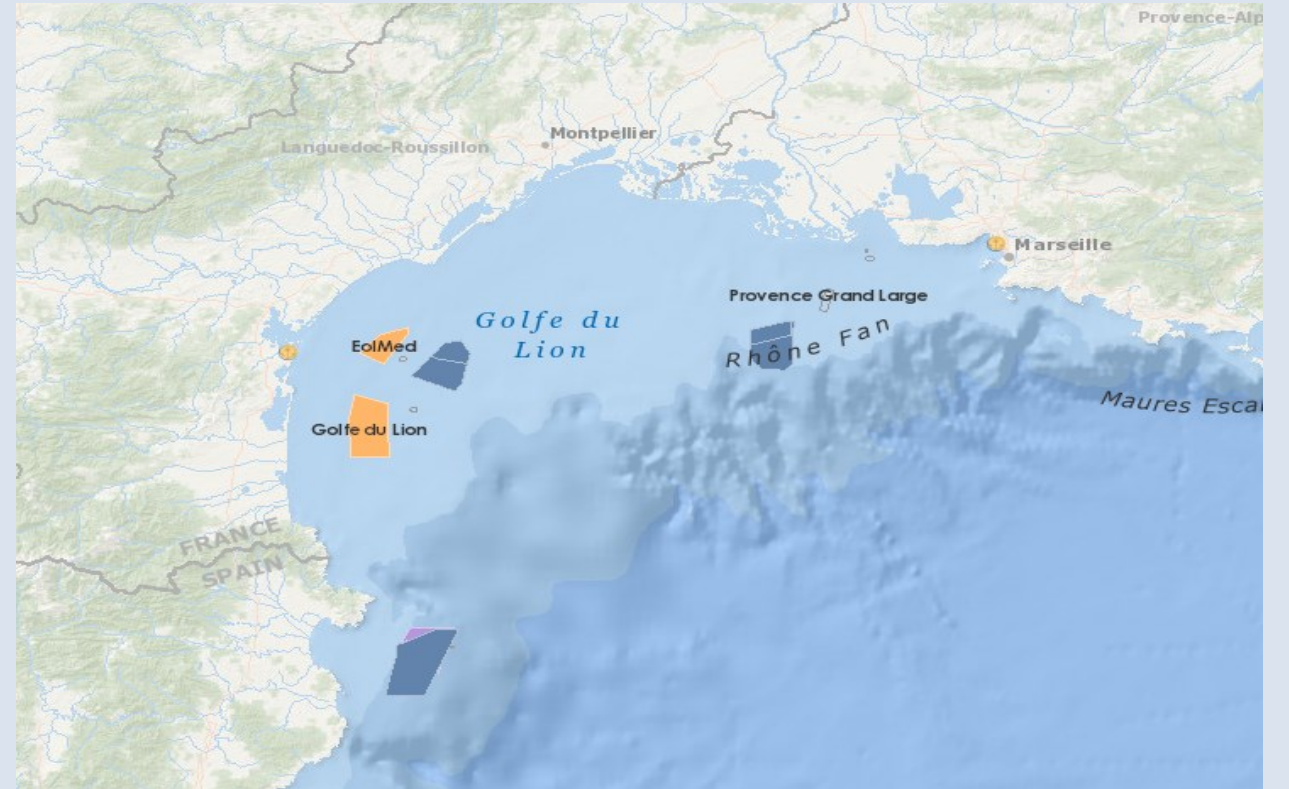
T1.1: Metocean, geotechnical and deployment scenarios - Objectives

- Two sites selected (**Utsira Nord, Provence Grand Large**):
 - Geotechnical data provided by NGI.
 - Metoceanic data collected.
- **DLCs** definition for each scenario (site/floater) according to DNVGL-ST-0437.
 - ULS cases defined (1.1, 1.6, 6.1), plus 42h storm at Utsira.
 - ALS cases to be completed (line breaking, emergency shutdown), T4.2 (Platform optimisation).
 - Sea states scatter diagram for FLS.

T1.1: Metocean, geotechnical and deployment scenarios – Water depth

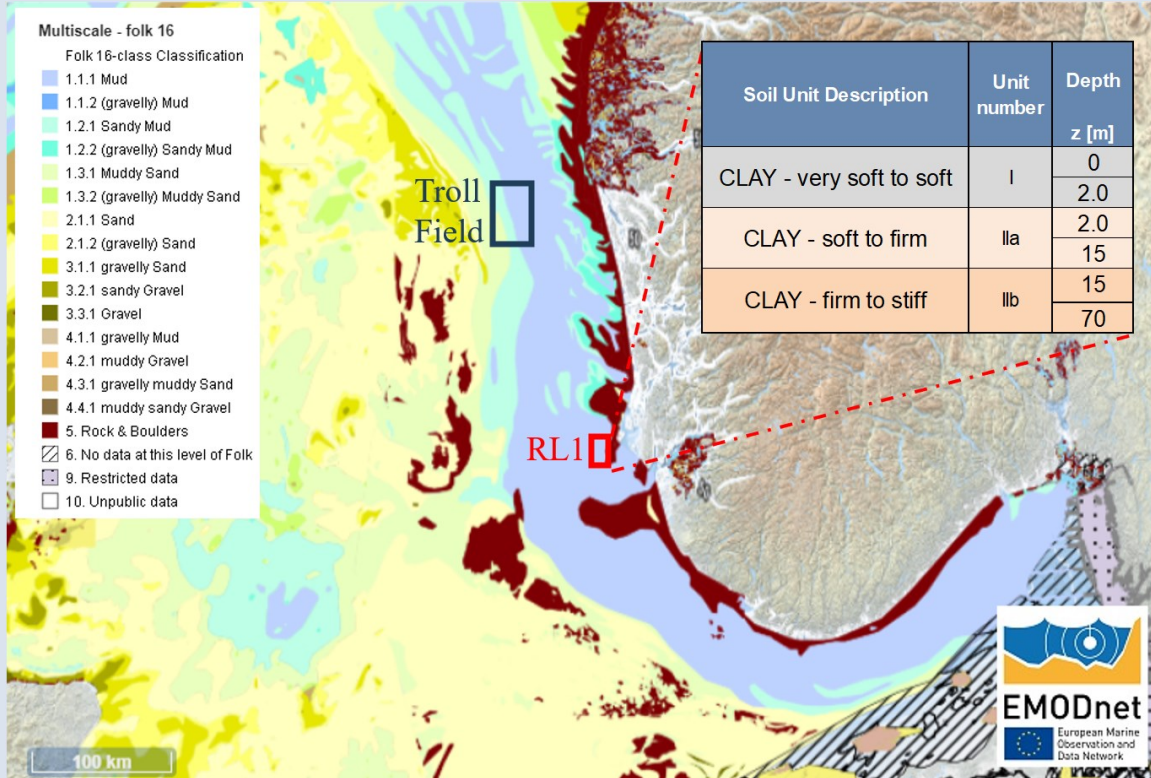


Utsira Nord (depth 260m)

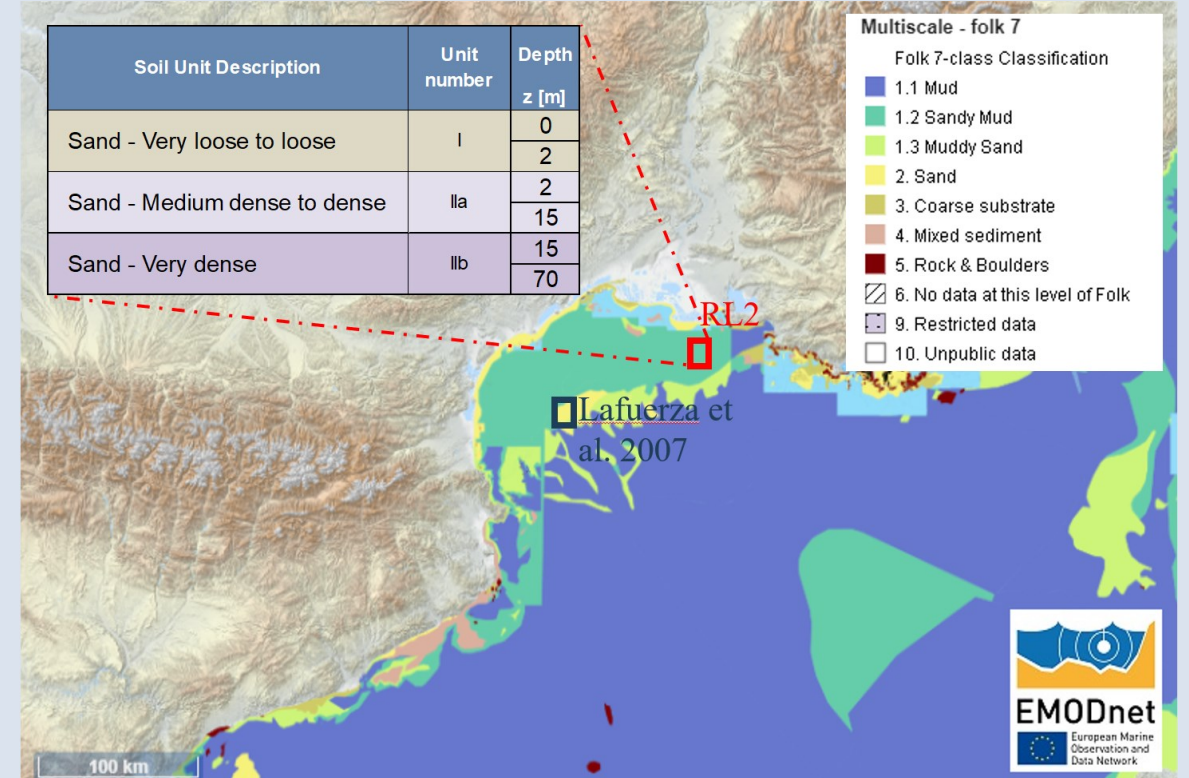


Provence Grand Large (depth 100m)

T1.1: Metocean, geotechnical and deployment scenarios – Soil type



Utsira Nord (depth 260m)



Provence Grand Large (depth 100m)

T1.1: Metocean, geotechnical and deployment scenarios – Metocean conditions

Notation: DNV-OS-J101 Sec3		Parameter	Value
Wind	EWM (B503)	$U_{10,10m,50-yr}$	40 m/s
		$U_{10,hub,50-yr}$	54.22 m/s
Waves	ESS (3.3.4.7)	$H_{s,50-yr}$; $T_{p,min}$ - $T_{p,max}$	12.9 m; 10-19 s
Current	ECS	$V_{c,50-yr}$	162 cm/s
Water level	MSL		260 m
	EWLR	$HSWL_{50-yr}$	1.5 m
		$LSWL_{50-yr}$	-0.5 m
Soil		Coarse grained soil	
Others	Water temperature (3.8.3.1)	$T_{max,50-yr}$	25 °C
		$T_{min,50-yr}$	0 °C
	Marine growth DNV-RP-C205 6.7.4.2	Thickness	100 mm
		density	1325 kg/m ³

Utsira Nord (depth 260m)

Notation: DNV-OS-J101 Sec3		Parameter	Value
Wind	EWM (B503)	$U_{10,10m,50-yr}$	28 m/s
		$U_{10,hub,50-yr}$	38 m/s
Waves	ESS (3.3.4.7)	$H_{s,50-yr}$; $T_{p,min}$ - $T_{p,max}$	7.5 m; 8-11 s
		$H_{s,1-yr}$; $T_{p,min}$ - $T_{p,max}$	4 m; 6-11 s
Current	ECS	$V_{c,50-yr}$	0.9 m/s
Water level	MSL		100 m
	EWLR	$HSWL_{50-yr}$	1.13 m
		$LSWL_{50-yr}$	-0.35 m
Soil		Coarse grained soil	
Others	Water temperature (3.8.3.1)	$T_{max,50-yr}$	30 °C
		$T_{min,50-yr}$	5 °C
	Marine growth DNV-RP-C205 6.7.4.2	Thickness	100 mm
		density	1325 kg/m ³

Provence Grand Large (depth 100m)

T1.1: Metocean, geotechnical and deployment scenarios – Design Load Cases

- 20 DLCs run for each scenario
- Some wave periods and loads incidence angle adapted to floater/mooring (full tables in D1.1)

Design Situation	DLC	Wind turbulence model	Wind speed range	Sea state type	Wind & wave directionality	Currents	Water level
1) Power Production	1.1	NTM	$V_{in} < \underline{V}_{hub} < \underline{V}_{out}$	NSS	COD, UNI	NCM	MSL
	1.6	NTM	$V_{in} < \underline{V}_{hub} < \underline{V}_{out}$	SSS	COD, MUL	NCM	NWLR
6) Parked (standing still or idling)	6.1	EWM (turbulent)	$\underline{V}_{hub} = V_{50y}$	ESS (Hs,50)	MIS, MUL	ECM (U=U ₅₀)	EWLR

T1.2: Turbine integration and design basis

(TEC, M3-M12)

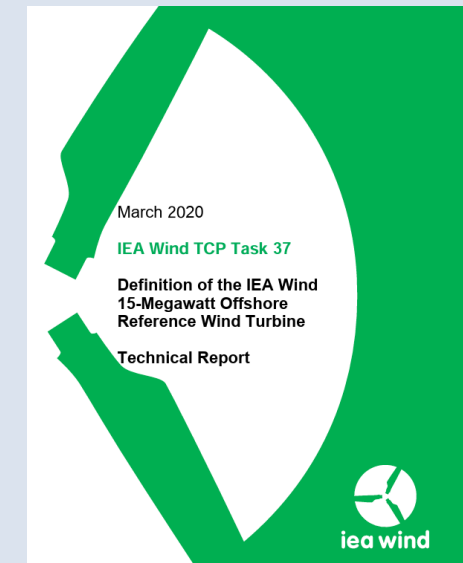
T1.2: Turbine integration and design basis - Objectives

- Preliminary **estimation of design loads** resulting for use in the development of innovative mooring lines in WP2 and innovative anchors in WP3.



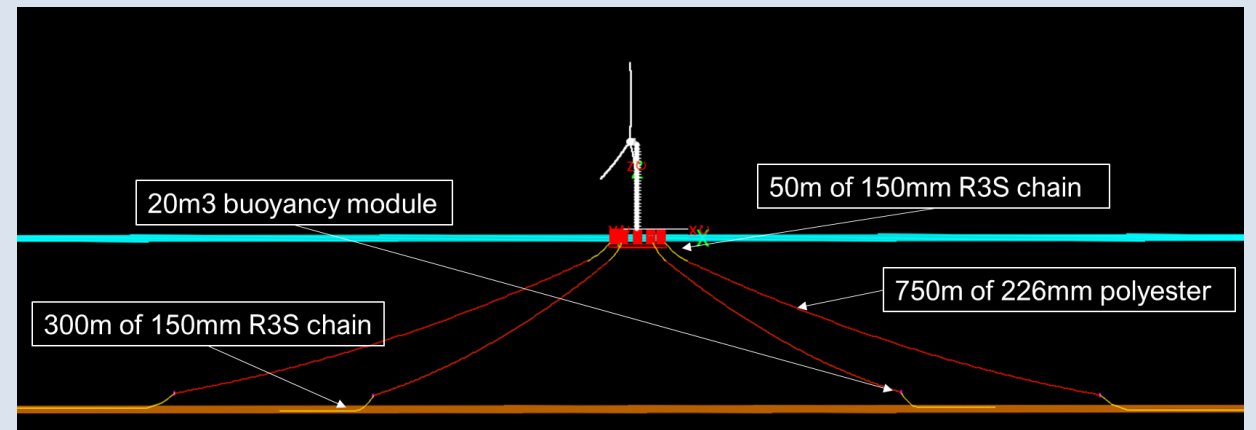
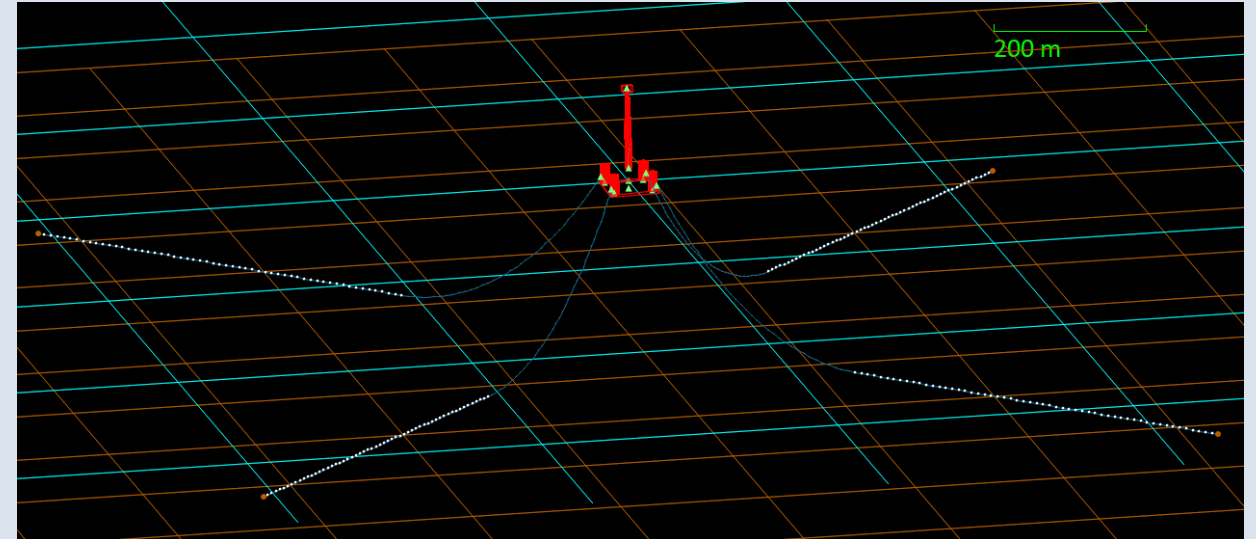
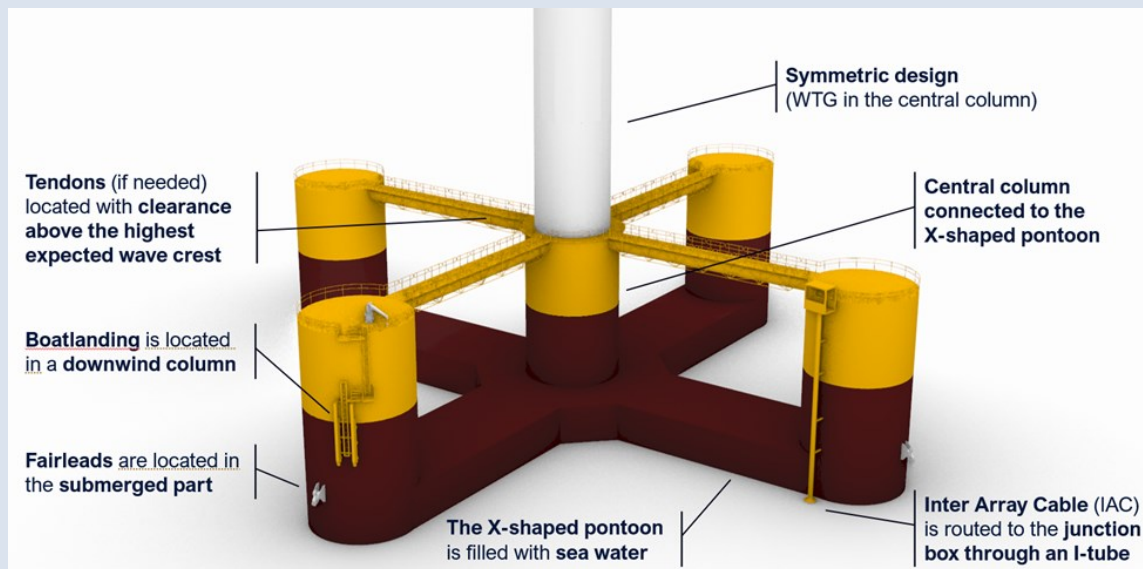
T1.2: Turbine integration and design basis – Modelling approach

- **ORCAFLEX** coupled models used for loads estimation.
- Wind Turbine (WT) used is the **IEA 15MW reference WT**
 - Rotor diameter 242 m
 - Tower reference height 129.39 m
 - Nominal wind speed 10.66 m/s
 - NREL Reference Open Source Controller (ROSCO)



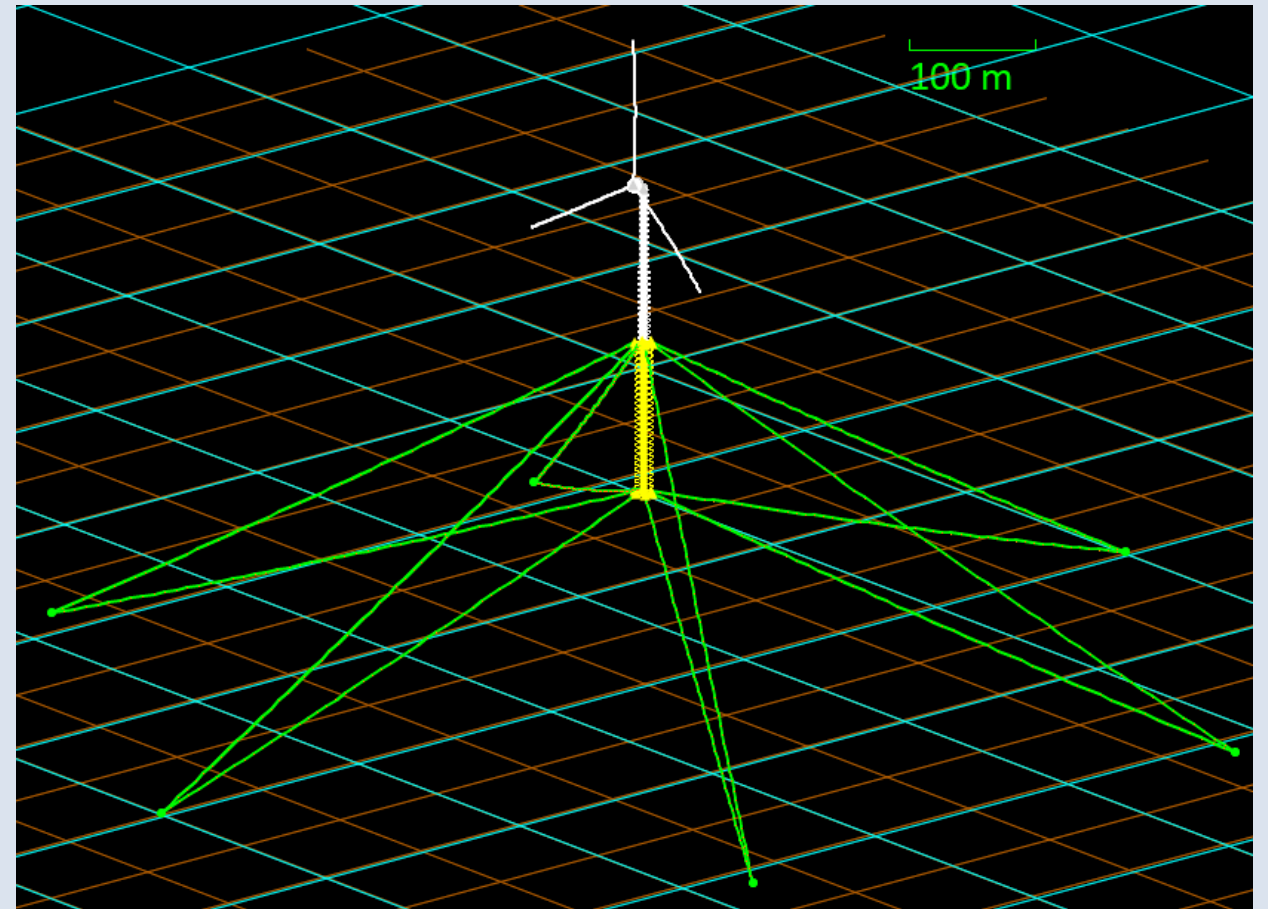
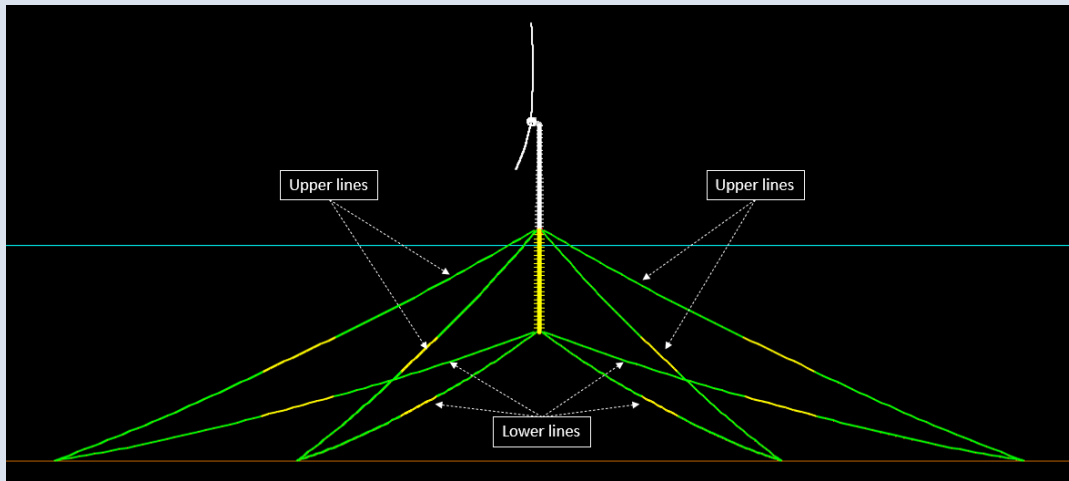
T1.2: Turbine integration and design basis - Platforms

- Semisubmersible (NAUTILUS)
 - Full chain catenary
 - Hybrid chain-polyester semi-taut configuration



T1.2: Turbine integration and design basis - Platforms

- Tension-Leg Buoy (TLB)
 - 6 pairs of lines
 - Full steel lines base case
 - Hybrid steel-dyneema taut configuration



T1.2: Turbine integration and design basis - Assumptions

- **Reference characteristics for mooring lines (hybrid %length):**
 - Steel
 - soft (nylon, polyester)
 - hard (aramid, dyneema)
- **Fixed anchors.** WP4 (T4.2) to include anchors characteristics and soil-anchor interaction in models.
- **Requirements:** floater and Mooring designed for each scenario with:
 - Tilt limit (mean 5° , max 10°)
 - RNA acceleration limit 0.3g
 - Floater maximum offset 30% water depth
- **3-hour** time domain simulations (6 seeds, 1 seed for non-critical DLCs).
- **Single FOWT** for sharing anchors scenarios.

T1.2: Turbine integration and design basis - Scenarios

Scenario: Combination of Platform/Site/Mooring concept/Line material:

- **Platform:**
 - Semisubmersible (NAUTILUS)
 - Mooring stabilised TLB-(TECNALIA)
- **Site:**
 - Utsira Nord
 - Provence Grand Large.
- **Mooring concept:**
 - Catenary
 - Semi-taut
 - Taut.
- **Line material:**
 - Steel
 - soft (nylon, polyester)
 - hard (aramid, dyneema).

Platform	Site	Mooring concept	Line material	Comments	Scenario
Semisubmersible	Utsira Nord (265m)	Catenary	Soft (Nylon, Polyester)	Too long lines for this water depth	1
			Hard (Aramid, Dyneema)		2
		Semitaut	Soft (Polyester)	Hybrid chain+polyester+chain line without drag anchor	3
			Hard (Aramid, Dyneema)	Anchor sharing configuration. Similar to Scenario 3	3b
	Provence Grand Large (100m)	Catenary	Soft (Polyester)	Semitaut with hard material too similar to chain line	4
			Hard (Aramid, Dyneema)	Hybrid chain+polyester+chain line (compatible with Drag anchor).	5
		Semitaut	Soft (Polyester)	Full chain as baseline case (compatible with Drag anchor).	6
			Hard (Aramid, Dyneema)	Hybrid chain+polyester+chain line without drag anchor	7
TLB	Utsira Nord (265m)	Taut	Soft (Nylon, Polyester)	Ignored since semitaut with hard material too similar to chain line	8
			Hard (Dyneema)	Soft material would require too high pretension	9
			Hard (Dyneema)	Hybrid Steel + Dyneema (15% line)	10
			Steel	Hybrid Steel + Dyneema (15% line). Anchor sharing configuration. Single WT	10b
	Provence Grand Large (100m)	Taut	Steel	Full steel line as baseline case	11
			Soft (Nylon, Polyester)		12
			Hard (Dyneema)	Too low water depth for TLB	13
			Steel		14
TLP	Utsira Nord (265m)	Taut	Soft (Polyester)	Hybrid Steel + Polyester. No polyester for TLP	15
			Hard (Dyneema)	Hybrid Steel + Dyneema	16
			Steel	Full steel line as baseline case	17
	Provence Grand Large (100m)	Taut	Soft (Polyester)	Hybrid Steel + Polyester. No polyester for TLP	18
			Hard (Aramid, Dyneema)	Hybrid Steel + Dyneema	19
		Steel	Full steel line as baseline case	20	

T1.2: Turbine integration and design basis - Results

- **Output results** from T1.2 for all scenarios/DLCs (*time history* and *statistics*):
 - **Mooring lines loads** at fairleads, anchors and chain-synthetic connection for all lines. Lines angles at anchors (*declination/azimuth*)
 - **Platform kinematics** (6 DOF)
 - **RNA accelerations**
 - **Hydrodynamic loads (6 DOF) on platform** (Wave 1st/2nd order, Added Mass & Damping, Current)
 - **Aerodynamic loads** on WT

WP1: Results

Mooring lines/anchors **highest design loads** (worst site/DLC/line):

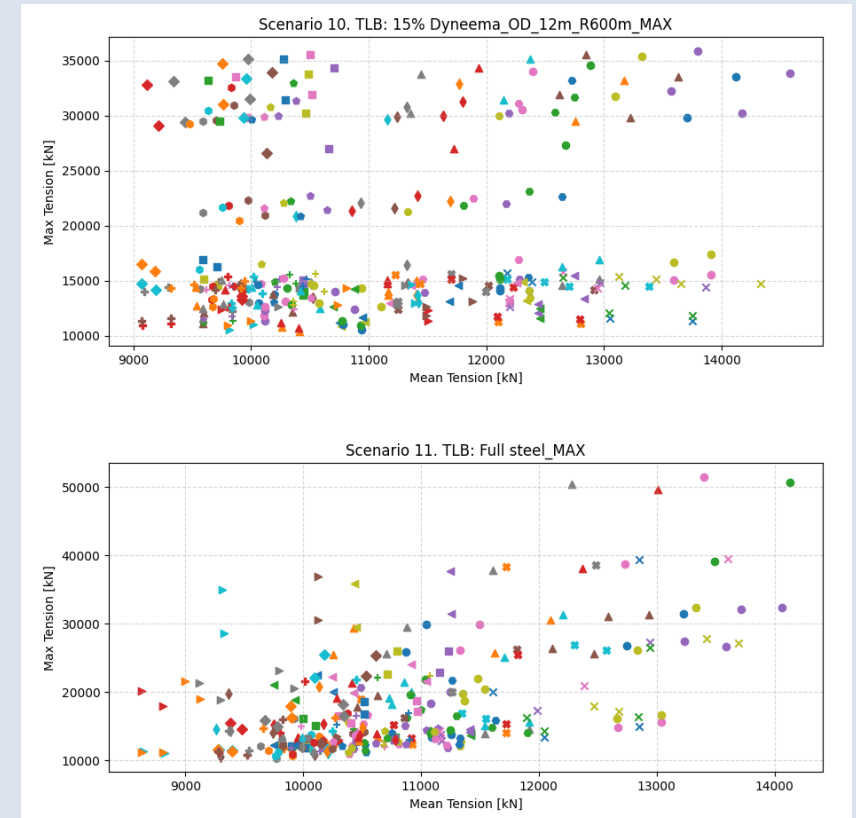
- Semisubmersible:

- 20.000 kN full chain catenary base case
- 8% reduction in hybrid chain+polyester configuration



- TLB

- 50.000 kN full steel line
- 30% reduction in hybrid steel+dyneema (15%L) configuration



T1.2: Turbine integration and design basis – Future activities

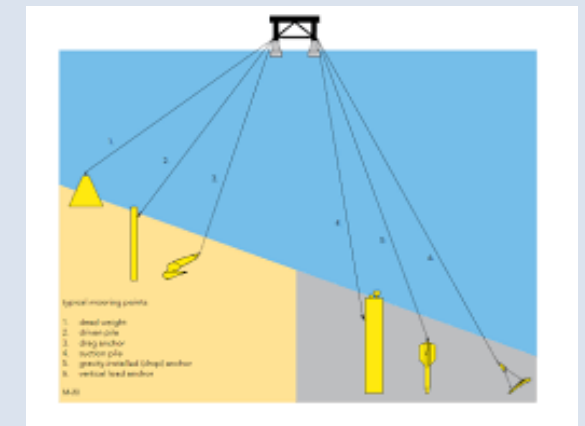
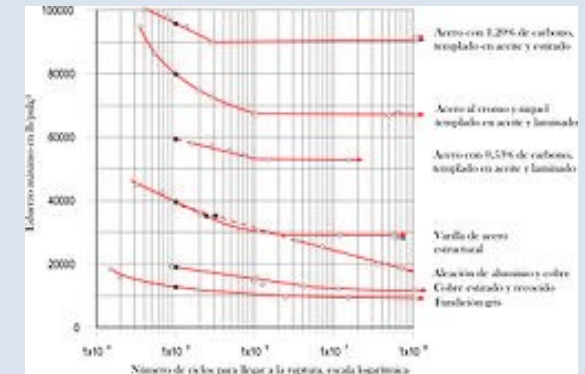
To be continued in WP4 (T4.2, M22)... for each selected Scenario:

T4.2: More realistic models with updated:

- lines material properties (input from WP2)
- anchors / soil-anchor interaction (input from WP3)

for **assessment and optimisation**.

T4.2: Optimise platform/mooring design.





THANK YOU

WP1

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