

# FOW Mooring – Key Challenges & Opportunities and a new JIP to address Reliability in Design

Tore Hordvik, Business Lead Floating Wind

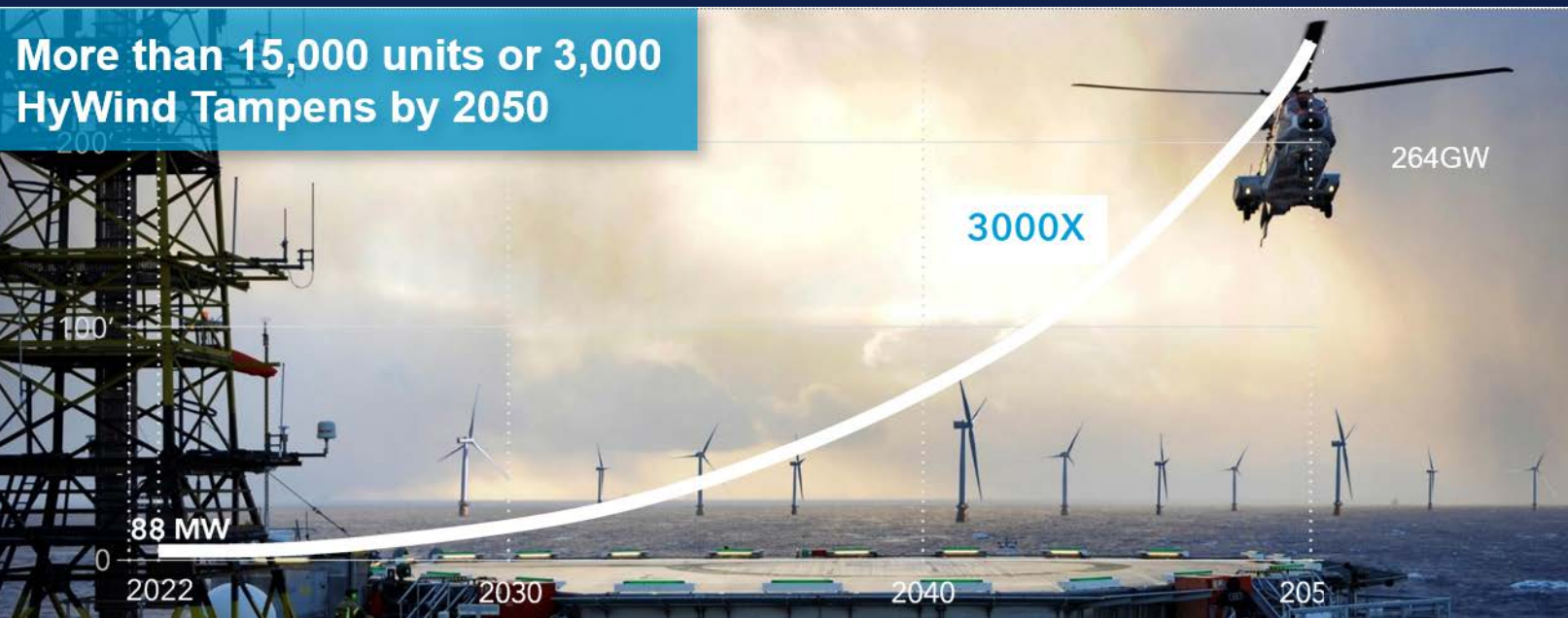
15 June 2022



# Floating Wind

**//** *In the 2020s, floating wind will progress from full-scale demonstration projects to commercial-scale developments. We predict that floating offshore wind projects will have 264 GW of installed capacity by 2050.*

*DNV Energy Transition Outlook Report 2021*



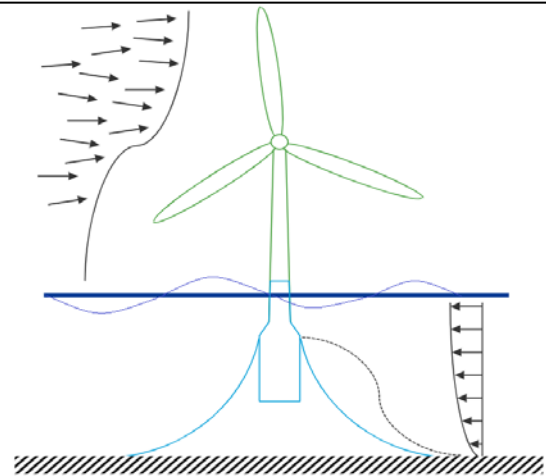
## Why floating wind:

- 4 times as much available ocean-surface as bottom-fixed
- Target areas with higher wind speeds
- Further offshore with potential for lower social and environmental impact



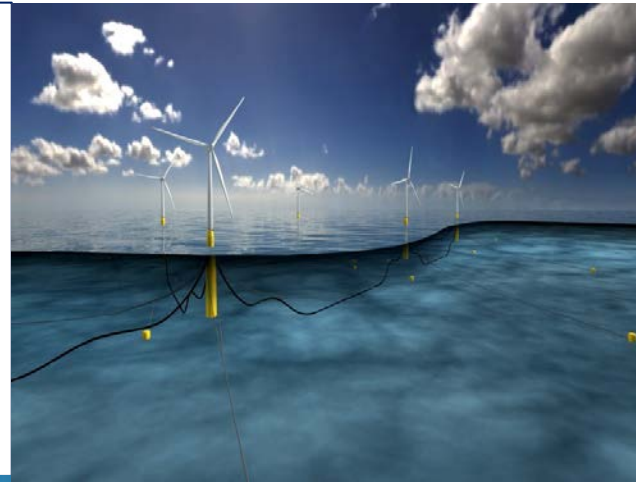
# Complex systems

- Integrating components, single turbines, farms and system of farms



## Mooring

- Limit excursions to accommodate power cable
- 3-9 lines with high mean loading
- Traditional components exposed to fatigue and peak loads
- New material, new component types
- Shared anchors and mooring (farm effects)



## Farms and system of farms

- 100++ km of mooring and cables
- Offshore substations/floating substations
- Condition monitoring, O&M
- Co-existence with community and other industries
- Power export and integration: Radials, hybrid connectors, offshore grids
- PtX: O&G integration, hydrogen

- Exposed to env. loads from wind, waves and current
- Good sites means harsh weather
- High mean loads in operational conditions due to rotor thrust
- Reduced wind loading and increased wave loading in survival conditions



## Cables

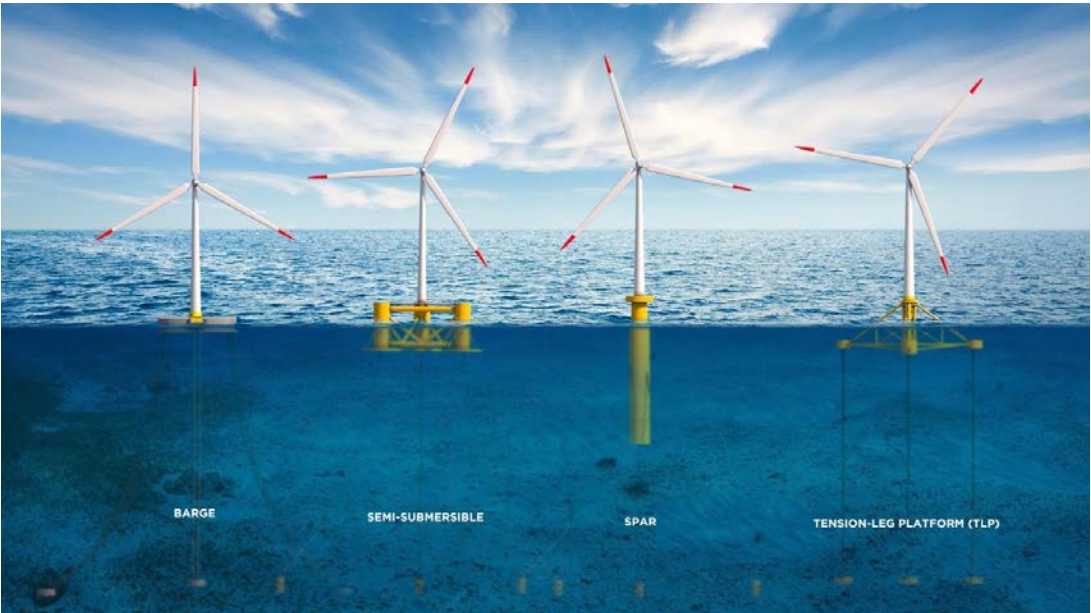
- Array cables between turbines, Base case 66kV, 3-core AC
- Compliant configurations with flexibility to absorb floater motions
- Exposed to direct wave and current loads and marine growth
- Innovation on HV, floater interface, configurations



# Current technology status

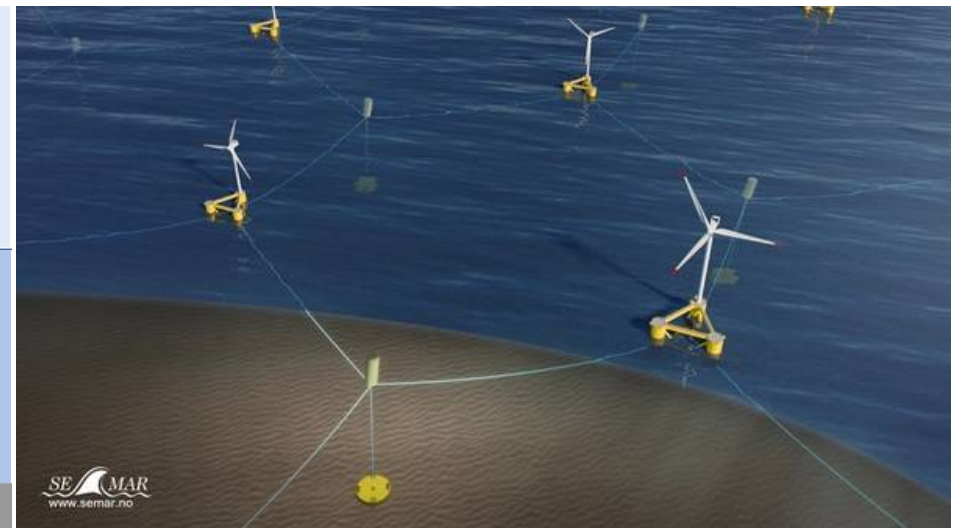
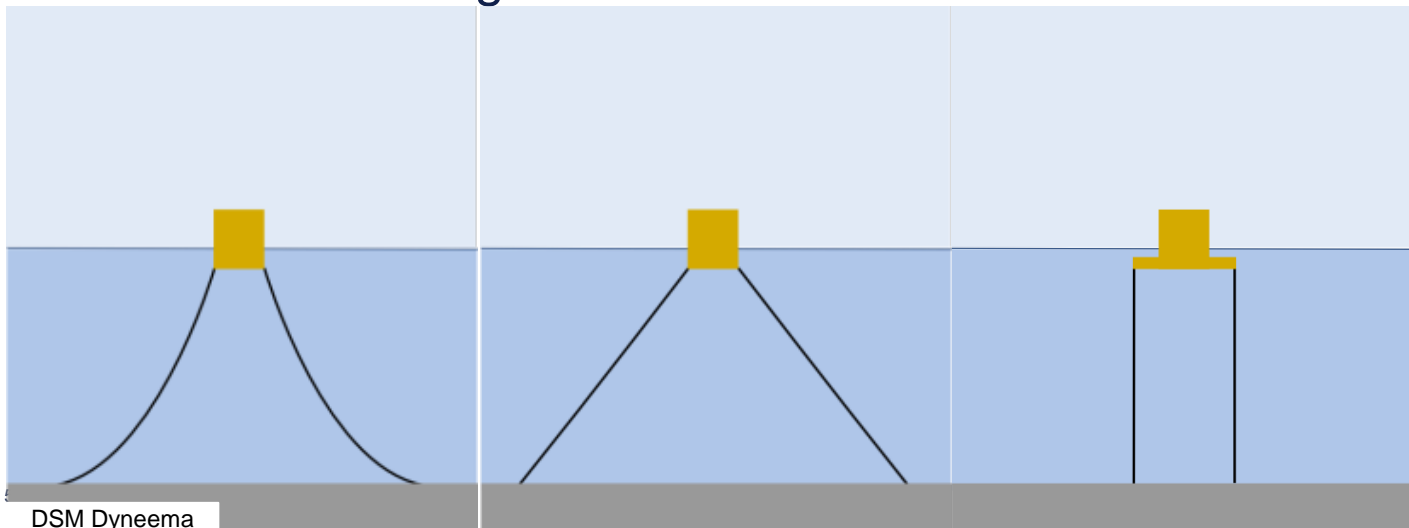
## Operating and ‘soon to be installed’ floating wind farm projects

Project name	Technology	Year	Installed capacity
Hywind Scotland	Hywind Spar	2017	5x6MW = 30MW
Windfloat Atlantic	Windfloat Semi	2020	3x8.4MW = 25MW
Kincardine	Windfloat Semi	2021	5x9.5MW + 2MW = 50MW
Hywind Tampen	Hywind Spar (concrete)	2022	11x8MW = 88MW
EFGL	Windfloat Semi	2023	3x10MW = 30MW



# Mooring of FOW

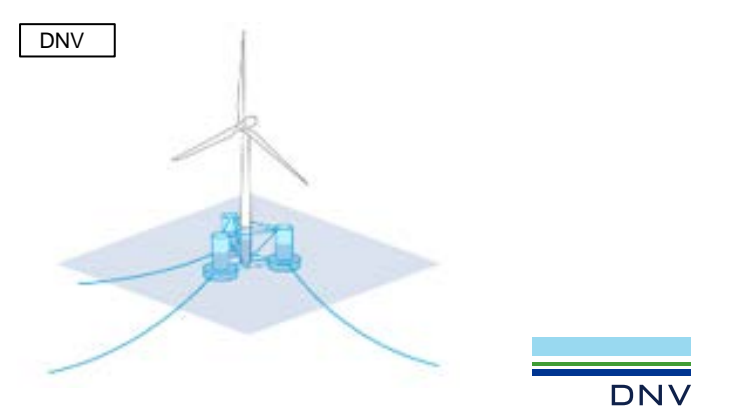
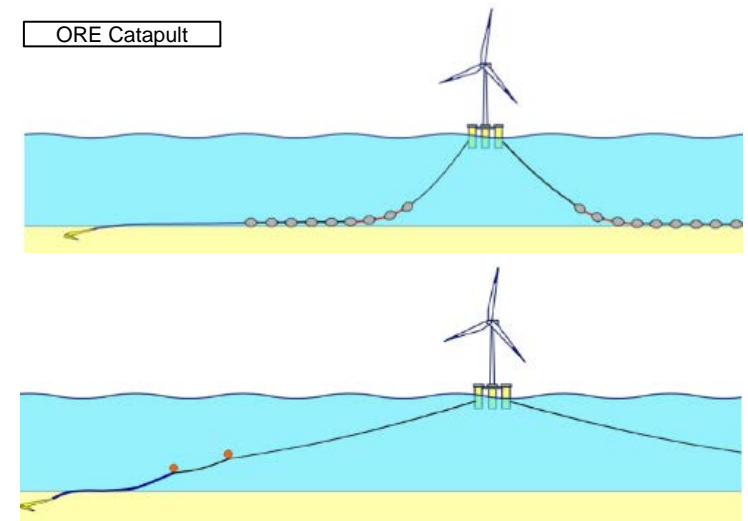
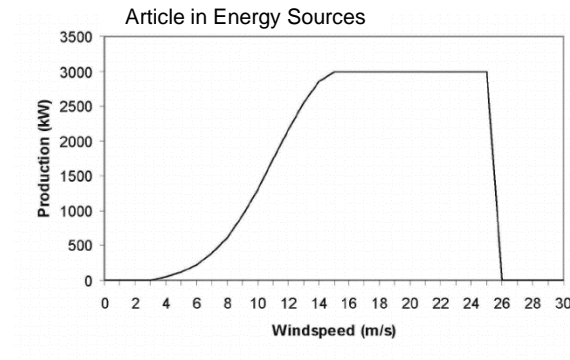
- Accounts for ~10-15% of Capex cost and ~15-20% of Opex cost
  - However, key for LCoE as failure(s) will impact the farm's availability and potentially harm power cables
- What are the performance targets?
  - Accommodate inter-array cable
  - Reliable and maintenance free operations for 20-30 years
  - Avoid collision with nearby units
  - Cost-efficient (design, manufacture, installation and operation)
- What are the configurations?





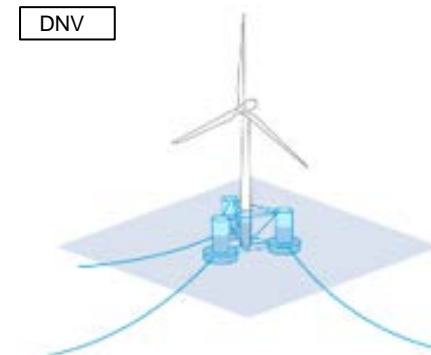
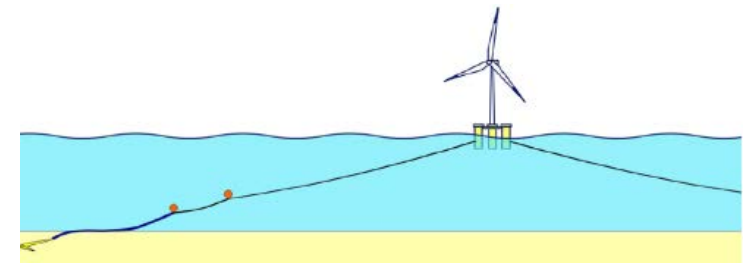
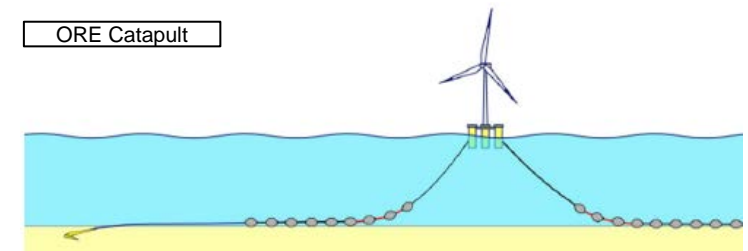
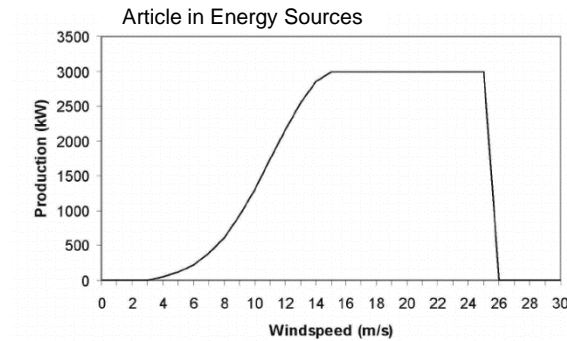
# Design – Some key aspects!

- The mooring design need to reflect requirements to e.g.:
  - Fatigue damage and extreme loads
  - Cable offset limits
  - Redundancy
  - Interference with sea bed infrastructure, sea bed contact
  - Anchor loading requirements
  - No on-site re-tensioning
  - Installation/handling requirements
  - Supply chain capabilities
  - Cost
- To navigate this using proven technology, we expect in the short-/medium term to see somewhat complicated hybrid solutions utilizing a combination of different 'proven' material and jewellery



# Design – Some key aspects!

- In the longer term, expect to see new material and new solutions to be qualified, e.g.:
  - New fibres (e.g. nylon)
  - Fibres qualified for sea bed contact and for direct hook-up at floater interface
  - Load reduction devices
  - Shared mooring
- Other complicating aspects (compared to O&G):
  - The two operational modes and complex ALS scenarios requires more load cases and more cumbersome numerical analyses than typically O&G
  - Water depth variation across project area – Require tailored mooring and cable design
  - Varying geotechnical conditions across project area, extensive surveys



# Manufacture - Summary

- Tremendous amount of mooring material and components required
- High oil price – life time extension and new FPSO projects in the short term
- Current production capacity optimized to accommodate today's needs
- Must expect long lead times for projects.
- New material to be qualified
- Upscaling production capacity required
  - Chain
  - Fibre ropes
- Need competence and equipment to ensure required quality -> systematic quality issues critical



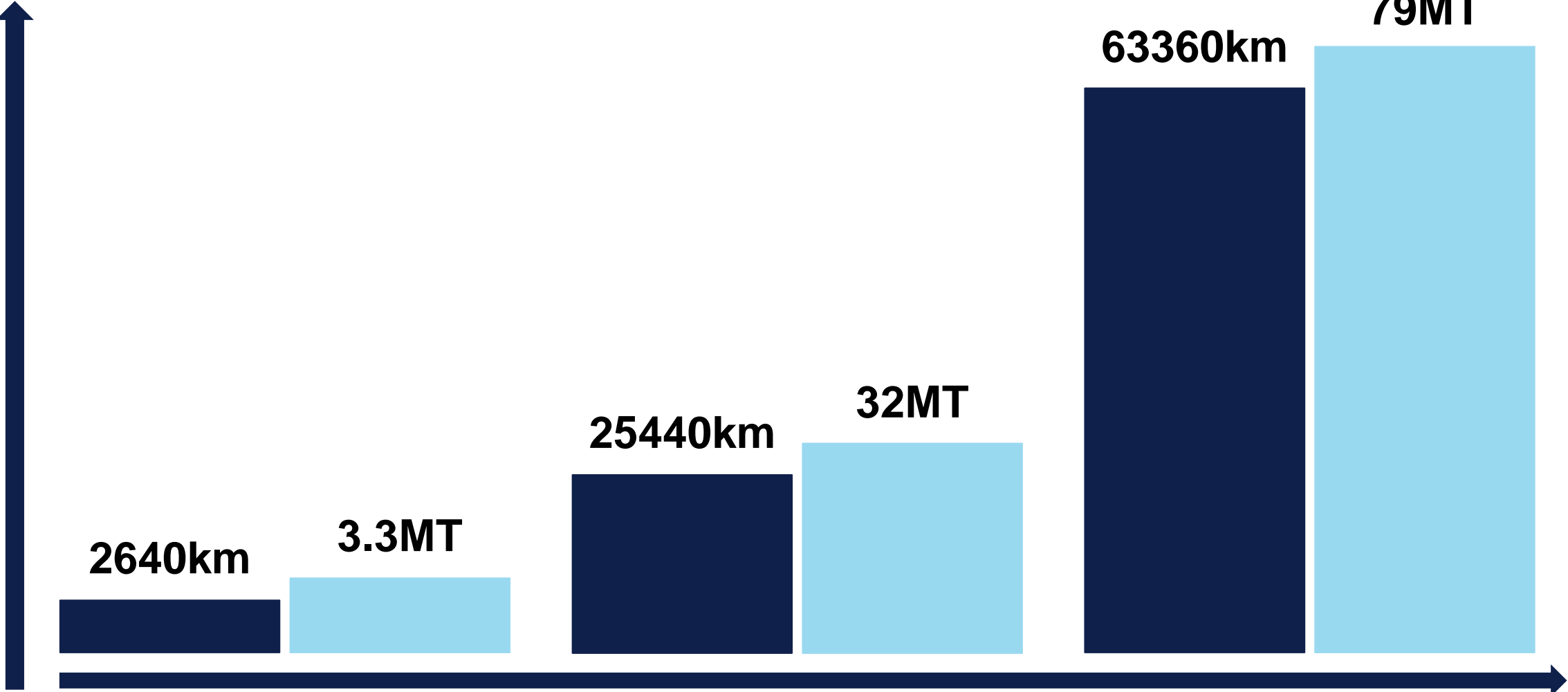




Mooring line length

Steel weight

264GW



2640km

3.3MT

25440km

32MT

63360km

79MT

2030

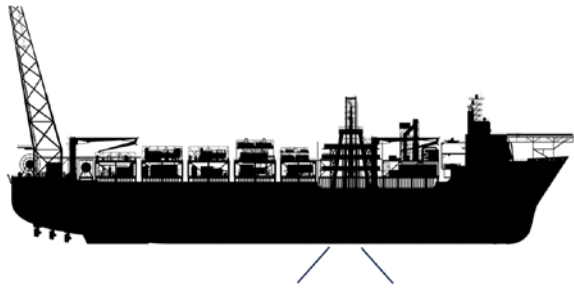
2040

2050

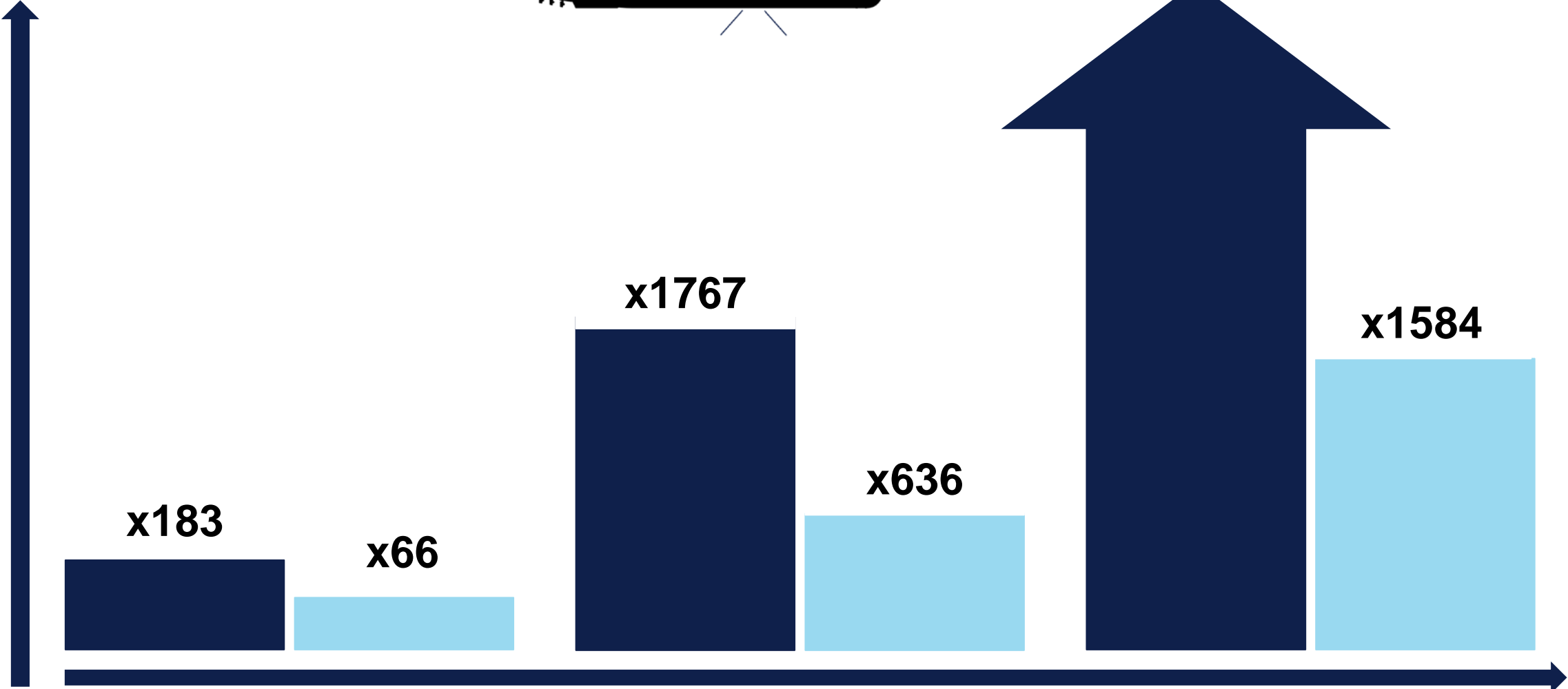


Mooring line length

Steel weight



264GW



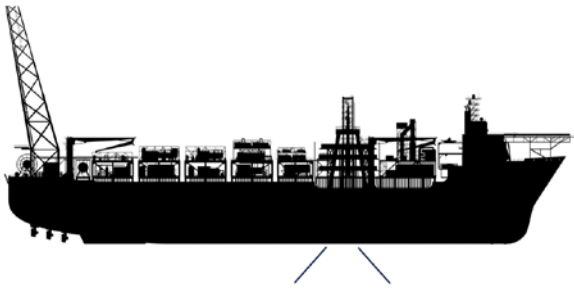
2030

2040

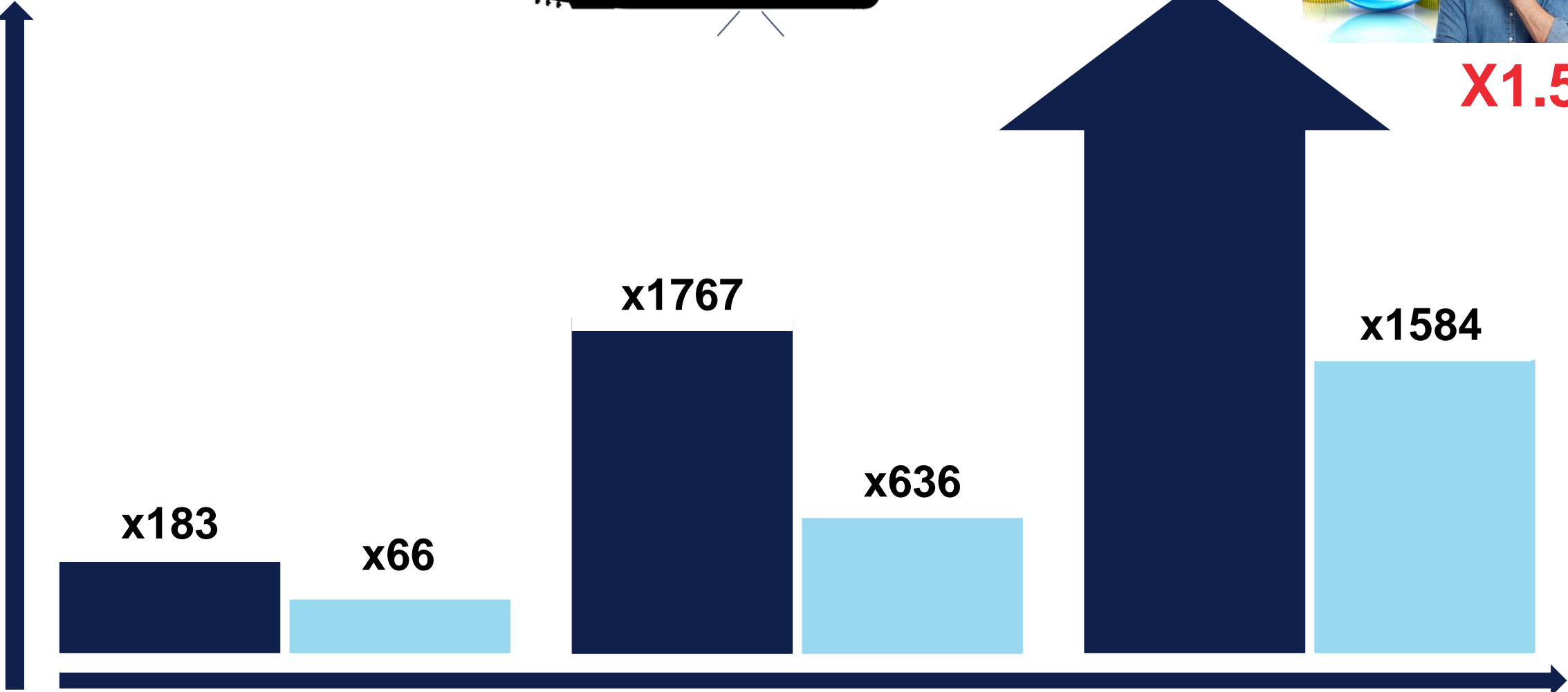
2050



Mooring line length  
Steel weight



264GW



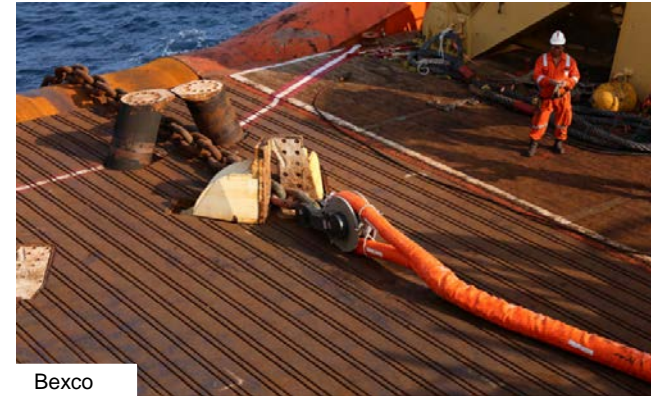
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# Storage & Installation

- Logistics, logistics, logistics
- Commercial-scale farm (50 turbines, 750MW)
  - 100-200 anchors
  - ~1000 line segments
  - 1000+ shackles, connectors, links

May be tailored for each turbine
- Availability of storage and mobilization facility close to project site
- Installation vessels
  - Drag anchors -> Bollard pull + other supporting aids
  - Suction anchors -> Deck space, crane capacity
  - Pre-stretching of fibre ropes -> Two vessels?
  - Damage of jewellery during installation?
  - Handling of large dimension chain and fibre ropes
- Careful planning of pre-lay and transport/hook-up campaigns to make it cost-efficient and to minimize risk of delays, failures and damage



# Operation

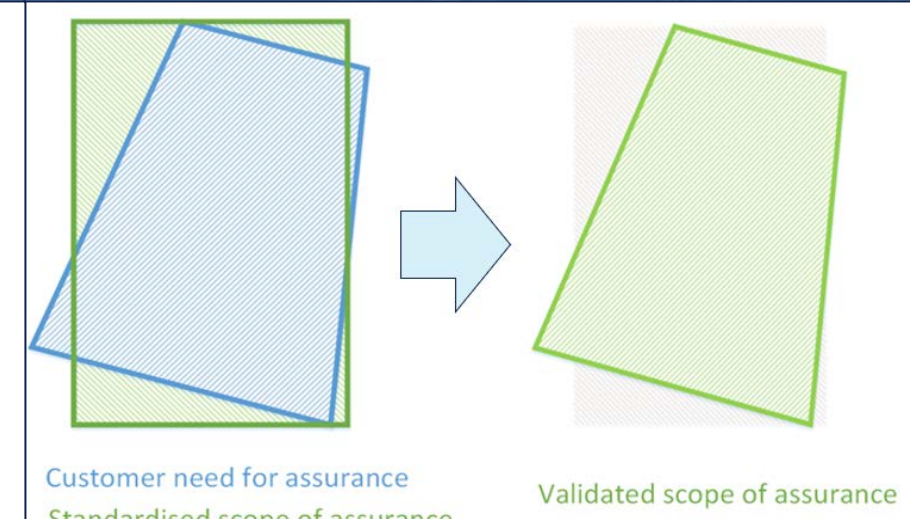
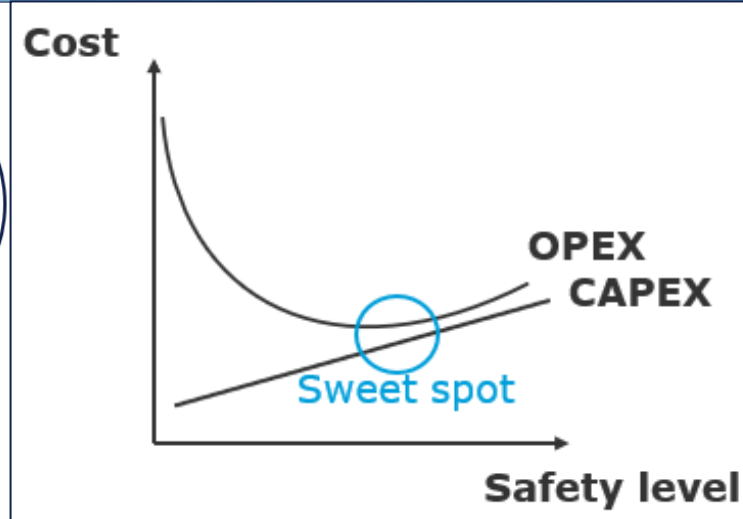
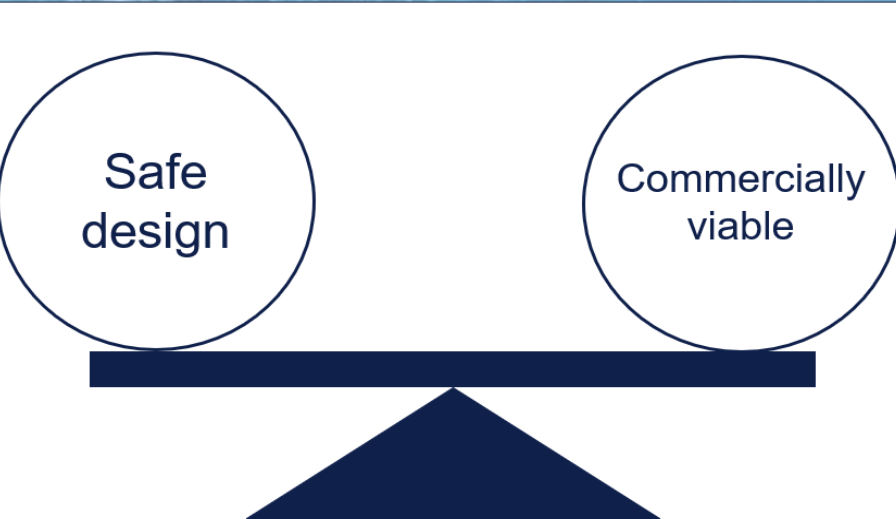
- Connect and forget?
- Less focus on O&M than design (up until now)
- Some thoughts around O&M.
  - Not practical nor cost-efficient with extensive sensor programs -> Sensor a few
  - Make use of MRU to compute loads and fatigue damage, potentially line failures. Automate what can be automated.
  - Simple designs -> E.g. Very difficult to detect loss of CW or BE in 100+ km of mooring line
  - Spot check inspections
- Key to have a robust mooring integrity management programs
  - Knowledge- and risk-based inspection: Use available information and inspection results to continuous update the MIM program
- Co-existence with other industries such as fisheries, shipping and integrated energy systems





# What about Standardization?

*Rules and regulations need to evolve to enable growth by facilitating for innovation, cost reduction and industrialization*





# FOW Reliability JIP

Current rules based on transformation of O&G requirements into a offshore wind regime (RP 50y)

Floating Offshore Wind Reliability JIP aims to lay grounds for tomorrow's rules for global design of floating turbines - Enabling Cost-efficient and Safe designs of large-scale FWT farms

The project will deliver recommendations and guidelines serving as basis for updates of DNV-ST-0119.

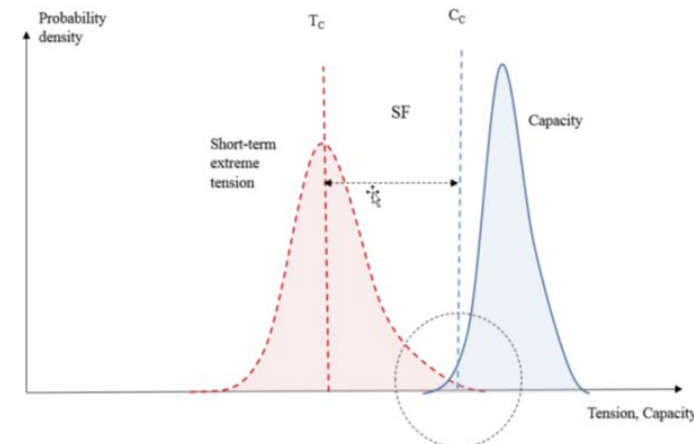
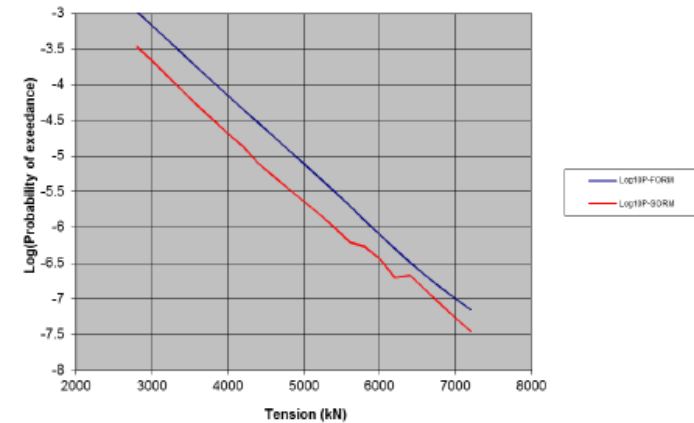
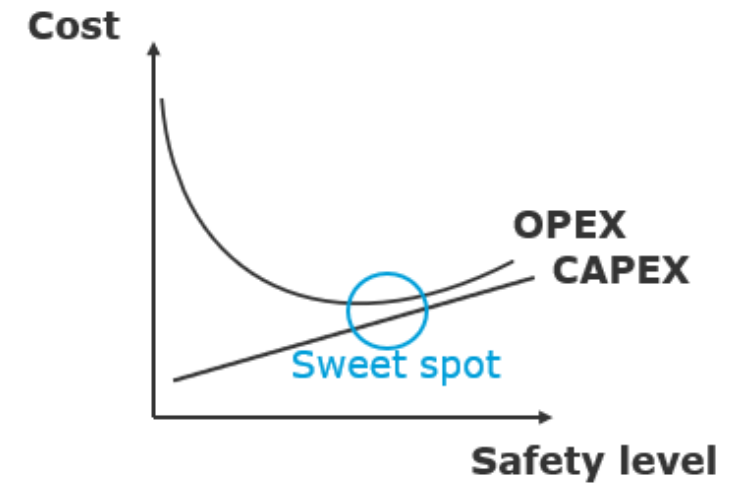


## Mooring & Cables




# How?

- **Study relationship between cost and safety level through advanced cost modelling**
  - How would the number of single units (and string layout) in a farm influence the target?
  - What is the cost/saving of increasing/reducing the reliability? (e.g. going from annual probability of failure of  $10^{-4}$  to  $10^{-3}$ ).
- **Carry out thousands of simulations to establish long-term response distributions**
  - Representative floaters -> E.g. Semi, TLP, etc.
  - Representative geographical locations -> E.g. winter storms, typhoons
  - Representative water depths -> E.g. 75m, 150m, 300m+
- **Study mooring and cable material to establish capacity distributions**
- **Requirements to future mooring and cable solutions**
  - E.g. Shared anchors, shared mooring, turret systems, load reduction devices
  - E.g. Suspended cables

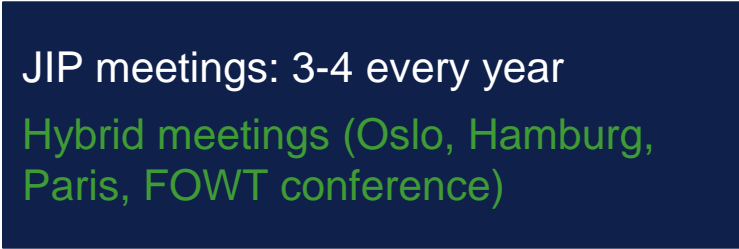


# JIP Fees & Timelines

- **Target budget:** 1.5 MEUR
- **Project developers:** 80 kEUR
- **Others:** 40 kEUR
- **Regulators, national authorities:** Free (Observer status only)



**JIP  
execution  
period**



JIP meetings: 3-4 every year  
Hybrid meetings (Oslo, Hamburg,  
Paris, FOWT conference)



**2022**

**Mid 2025**



# Why join?



- This is a great opportunity to influence and shape future FOW design requirements -> To contribute to cost-efficient requirements
- Valuable insight and data on cost models, load models, capacity models
- Valuable insight into mooring and cable integrated performance and design drivers
- Expert forum for sharing knowledge, networking and learning

# Thank you!

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