FOW Subgroup Workshop

TIC Glasgow, 22nd August

DeepWind
North of Scotland Offshore Wind Cluster

INDUSTRIAL STRATEGY CLUSTER

Image source – KOWL

Programme

12.30 - Introduction – Subgroup Co-Chairs

12.40 - Industry and project updates – floating wind projects in the pipeline

1) **Richard Wakefield – Flotation Energy**
2) **David Timmington – FWO**
3) **Takashi Harada – Toda Corporation**

13.10 – Mooring Systems Session 1

1) **Alan Duncan – Intermoor**
2) **Fredrik von der Fehr – DOF Subsea**
3) **Bill Shaw – Bauer Renewables**

13.55 – Networking coffee break

14.20 – Mooring Systems Session 2

1) **Ferdinando Samona – Maersk**
2) **Stuart Kilbourn - Fugro**
3) **Elsa Ramirez – Leask Marine**
4) **Stein Are Anderson – Bridon Bekaert**

15.20 – Co-chairs summation and next steps

15.30 – End of workshop

DeepWind
North of Scotland Offshore Wind Cluster

Green Volt Offshore Wind

23rd August 2022

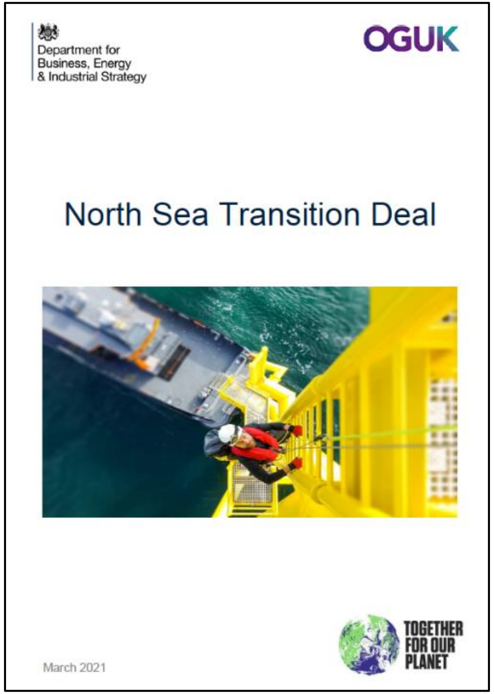
Deep Wind Update

Confidential

INTOG - the Challenge

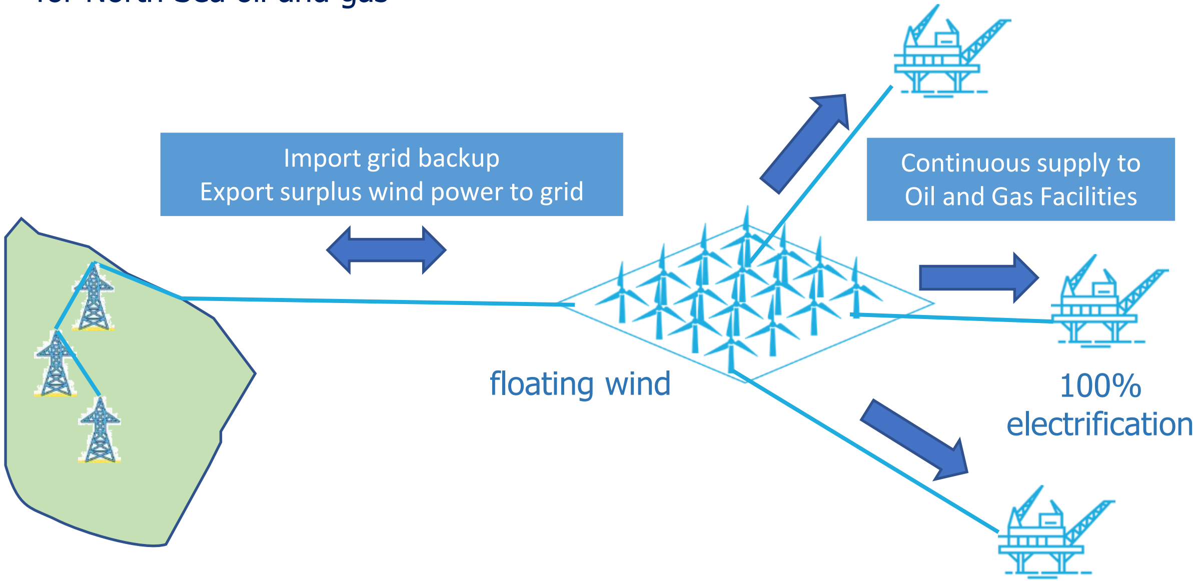
FLOTATION ENERGY

- UK oil and gas assets part of the Energy Transition
- North Sea Transition Deal goal
- 50% emission reduction by 2030
- Net Zero basin by 2050



Electrification – Our Concept

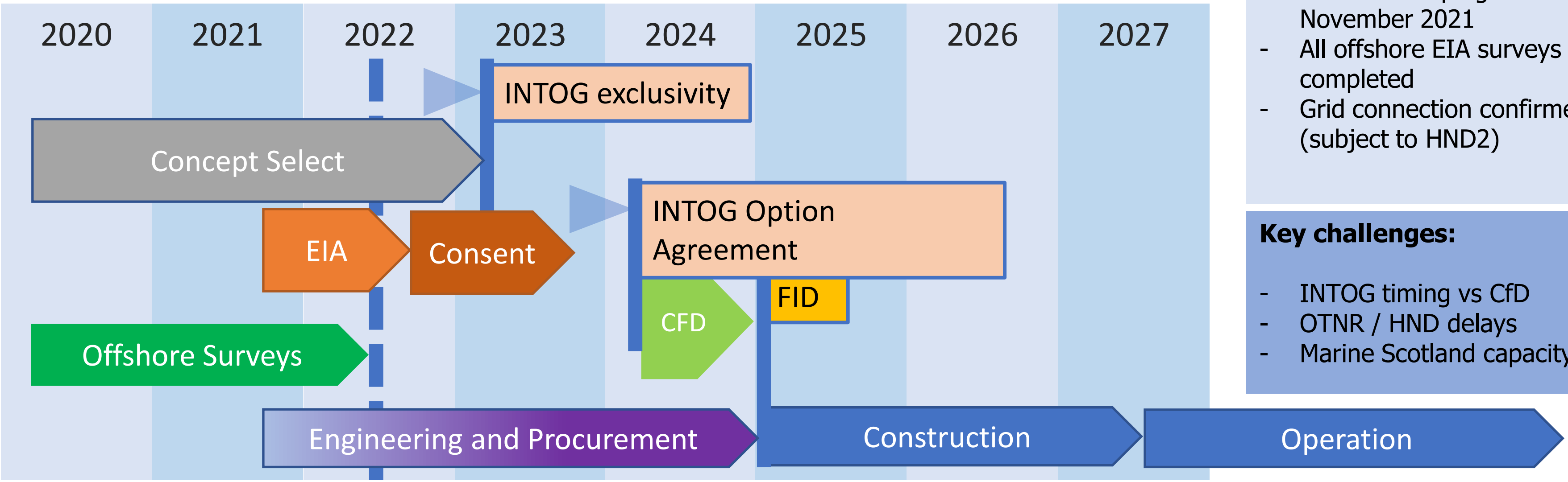
- Grid connected floating offshore wind farm to power UKCS O&G
- 100% retirement of onboard power generation
- Leverage offshore demand and CFD to provide affordable, renewable electricity for North Sea oil and gas



- ✓ 100% electrification
- ✓ Rapid deployment
- ✓ Maximum decarbonisation
- ✓ Grid reliability
- ✓ Fully eliminate GTG maintenance costs
- ✓ No late life gas buy back
- ✓ Optimal CapEx
- ✓ UK offshore wind growth targets

Green Volt Project – Project Overview

FLOTATION ENERGY



Key milestones:

- Offshore Scoping submitted November 2021
- All offshore EIA surveys completed
- Grid connection confirmed (subject to HND2)

Key challenges:

- INTOG timing vs CfD
- OTNR / HND delays
- Marine Scotland capacity

Open Discussion

Goto Pilot Farm

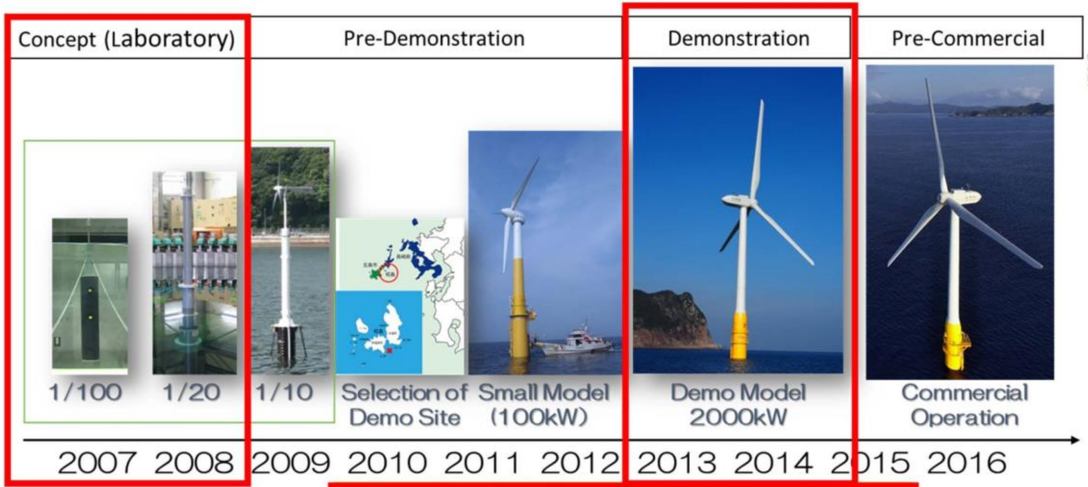
OCEAN RENEWABLE ENERGY DIV.

TODA CORPORATION

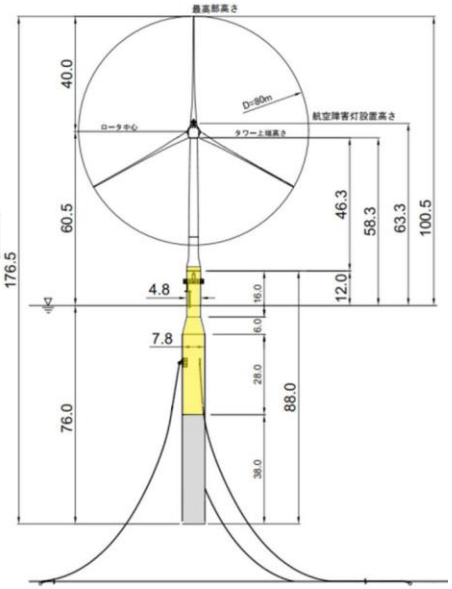
TAKASHI HARADA

Prof. Tomoaki Utsunomiya

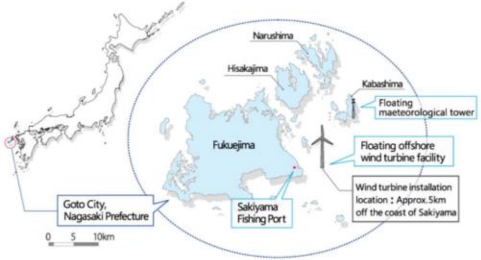
Dr. Iku Sato

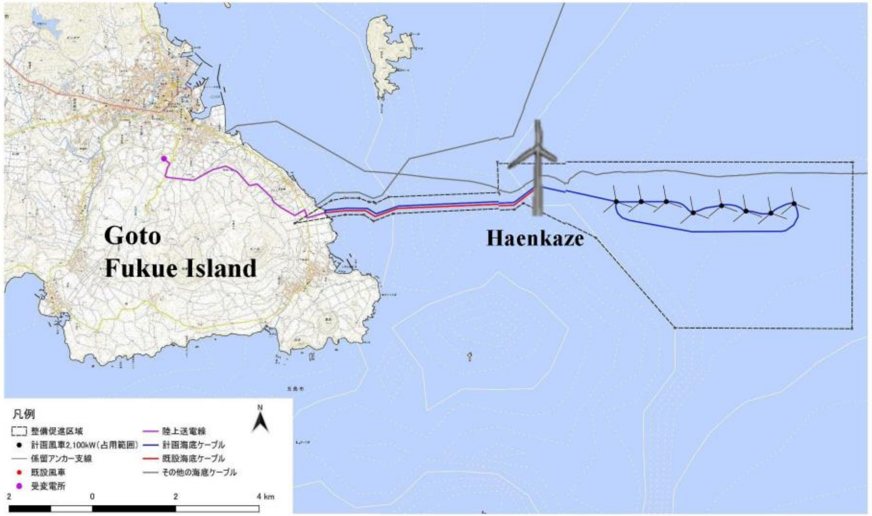


Project by the Ministry of Environment（from 2010 to 2015）

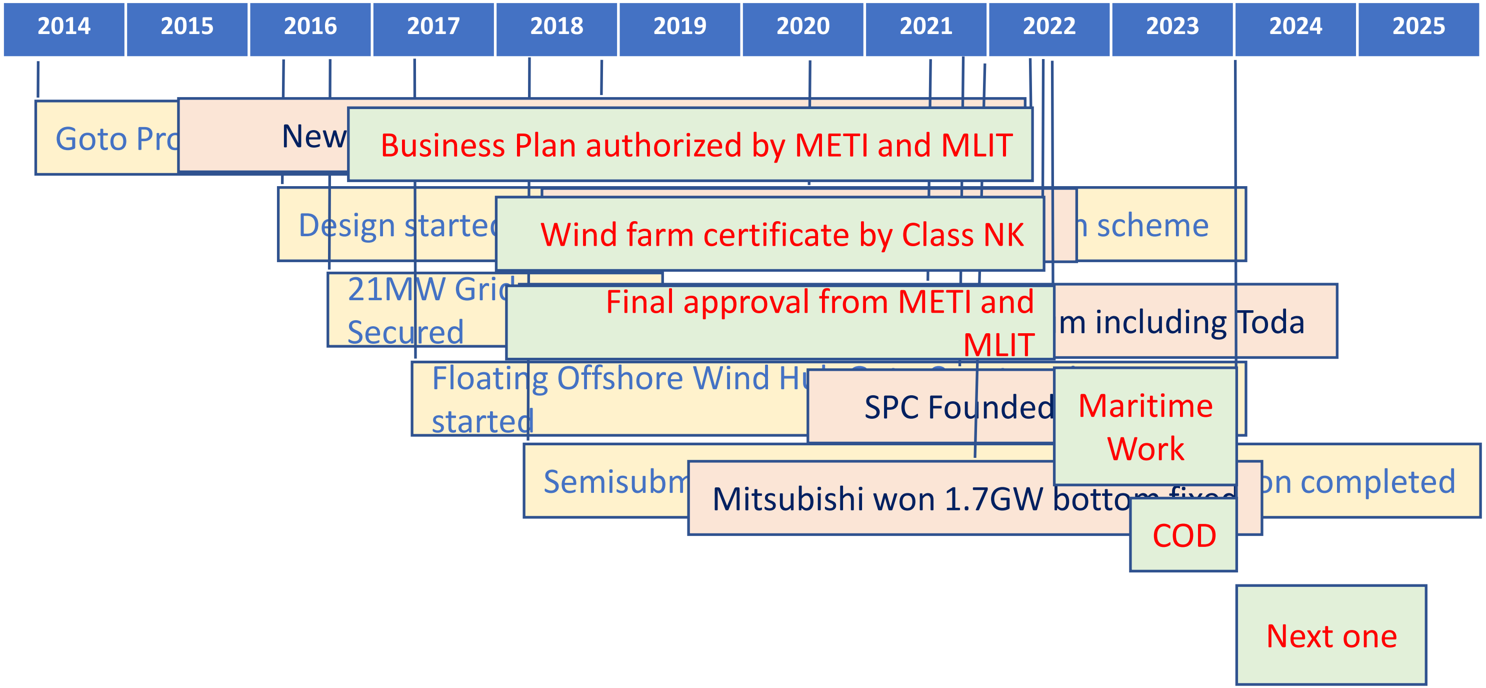


Goto Pilot Farm





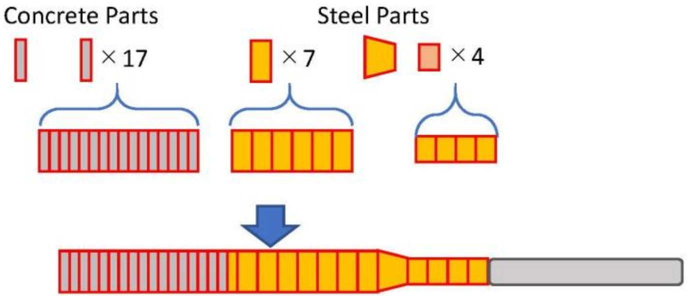
Goto Pilot Farm



Manufacturing Process

Anywhere
- Utilizing local ordinary port
- Production locally
- Horizontal process

Anyone
- Simple manufacturing process
- Assembly same size rings



Floating Offshore Wind Hub Goto

Installation Process

Cost effective process
No JUV nor Heavy crane vessel

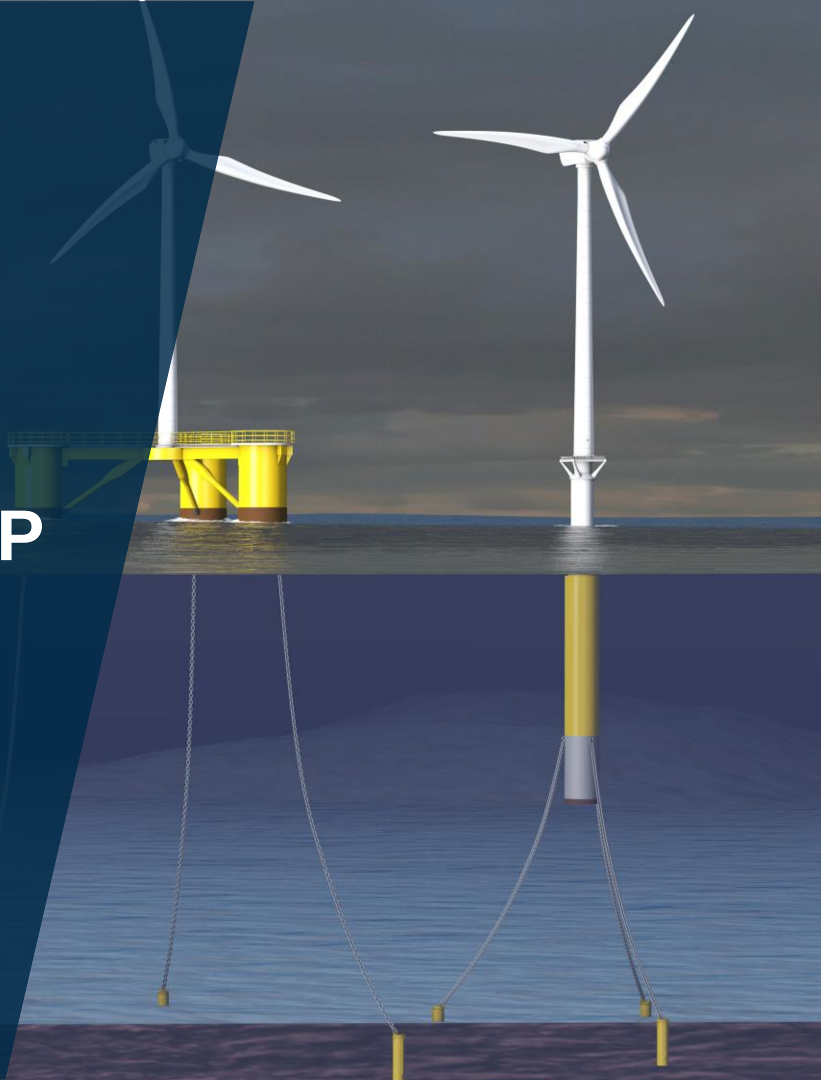
Float Raiser
< 5m draft
Semi-submersible
Sink – Drag – Raise-up

“Anyone Anywhere AS required”

- Anyone
  - Simple design
  - Simple manufacturing process
- Anywhere
  - Less than ideal condition
- As required
  - Any turbine
  - Adapting wide range of water conditions

INTERMOOR

Mooring specialist – providing mooring system design, supply storage and management of mooring equipment and marine services for installation, maintenance and decommissioning



DEEPWIND FOW SUBGROUP EVENT 23RD AUGUST

ACTEON INTERMOOR MOORINGS AND ANCHORS

AGENDA:

- Planning – Scheduling
- Supply Chain & Design Constraints
- Product standardization
- R&D – future planning

Planning ahead

When timings are known for mooring equipment and production scheduling can be considered…..

Anything is possible.

Currently, one of the largest mooring chain carousel manufacturing plants was designed, built and commissioned in less than 12 months.

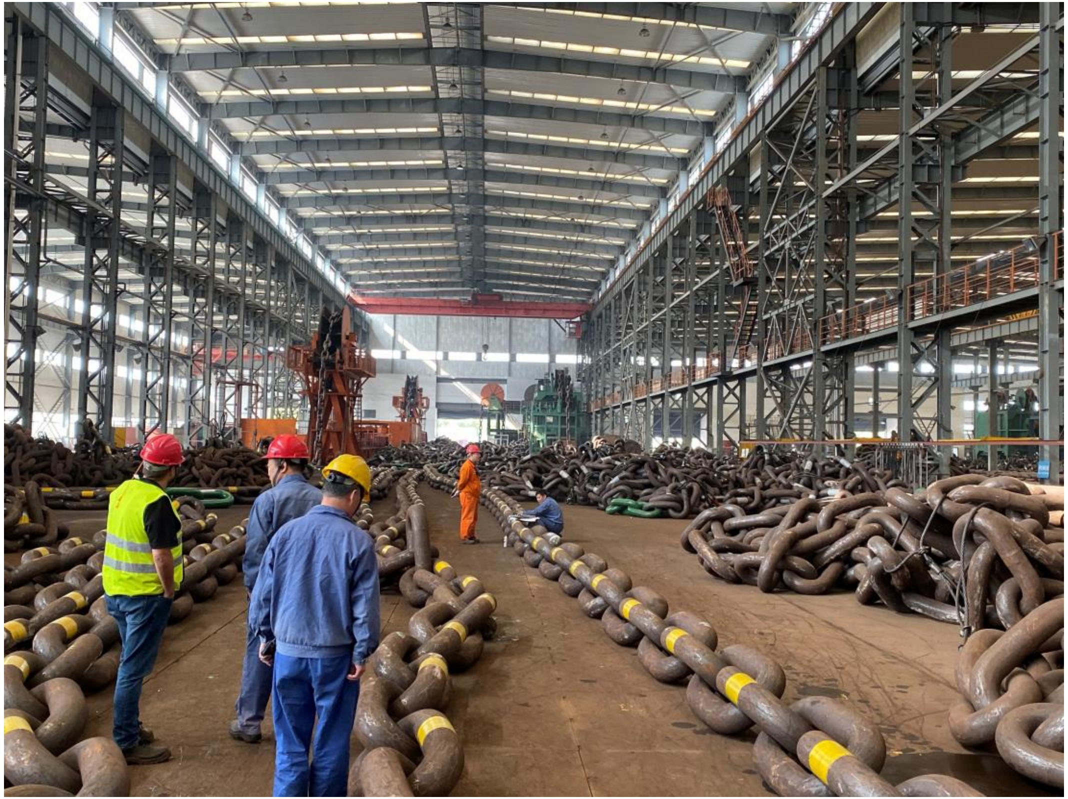
This carousel can produce chain links up to 230mm in diameter.

Planning and capacity

Currently InterMoor have the capacity to supply a total of 300,000tons of chain (annually).

However, this could only be considered if suitable forward planning and production scheduling can be looked at – well in advance.

To allow 300,000t of chain to be supplied annually, the current factories would need to increase their output to at least 500,000t to provide for the legacy O&G, shipping, fishing industries.



Capacity

ACTEON INTERMOOR MOORINGS AND ANCHORS

300,000t of chain in terms of size/length:

- 84mm studless chain (600/850t MBL) = 2,150,000m = 1336 miles
- 120mm studless chain (1100/1600t MBL) = 1,037,000m = 644 miles
- 180mm studless chain (1500/2400t MBL) = 461,000m = 287 miles

Glasgow to Munich is 1350miles (if you're a crow!)

Product Standardization

To enable the smooth transition to floating wind mooring systems, the lessons learned from O&G must be taken on board.

Petrobras had at least 4 different chain sizes on the earliest of their mooring systems offshore Brazil.

Today? A high percentage of systems offshore Brazil are 120mm studless chains manufactured in a dedicated factory in-country.

Thus, production and scheduling can be controlled in a logical manner.

Product Complexity and Risk

Product complexity, size and manufacturing lead-time MUST be considered for FOWT.

Complex systems with non-track-record items can only be grouped as “potential threats” offshore.

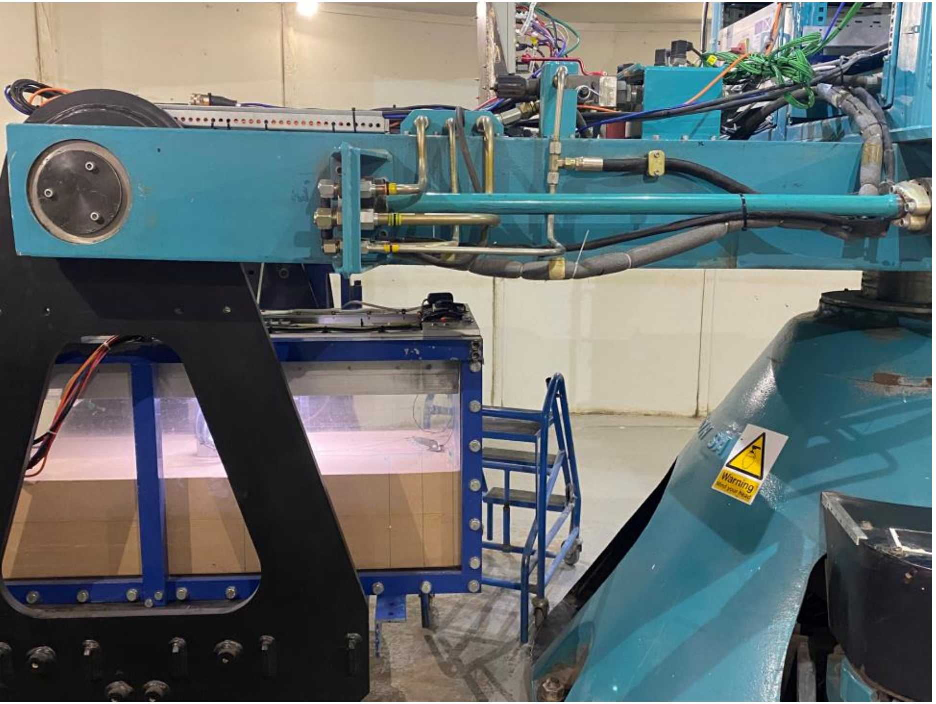
Theses “threats” could mean catastrophic failure of windfarms which could mean loss of required onshore power supply.

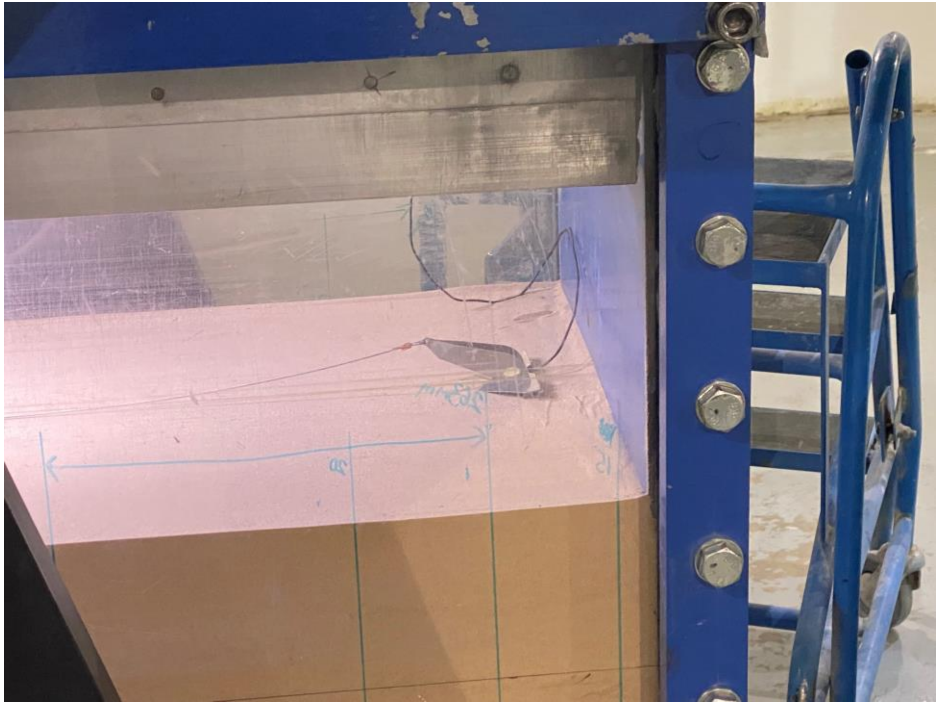
Planning of the mooring system is critical not just in terms of manufacturing lead-time but also in terms of installation and maintenance requirements in the future.

Product Complexity

Planned Production Possibilities

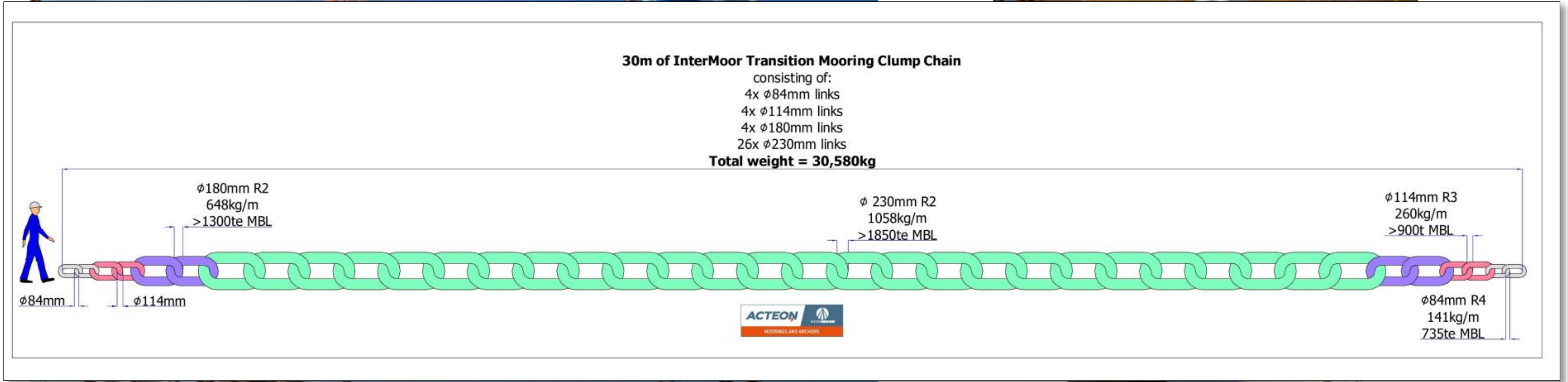
Planning ahead – R&D





Planning ahead – R&D

Planning ahead – R&D



THANK YOU

DOF Subsea

23rd of August 2022 Glasgow

Fredrik von der Fehr

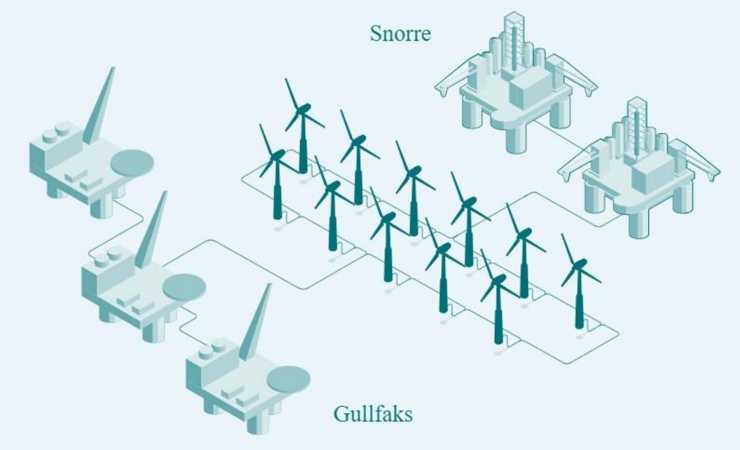
Hywind Tampen - Mooring Experiences

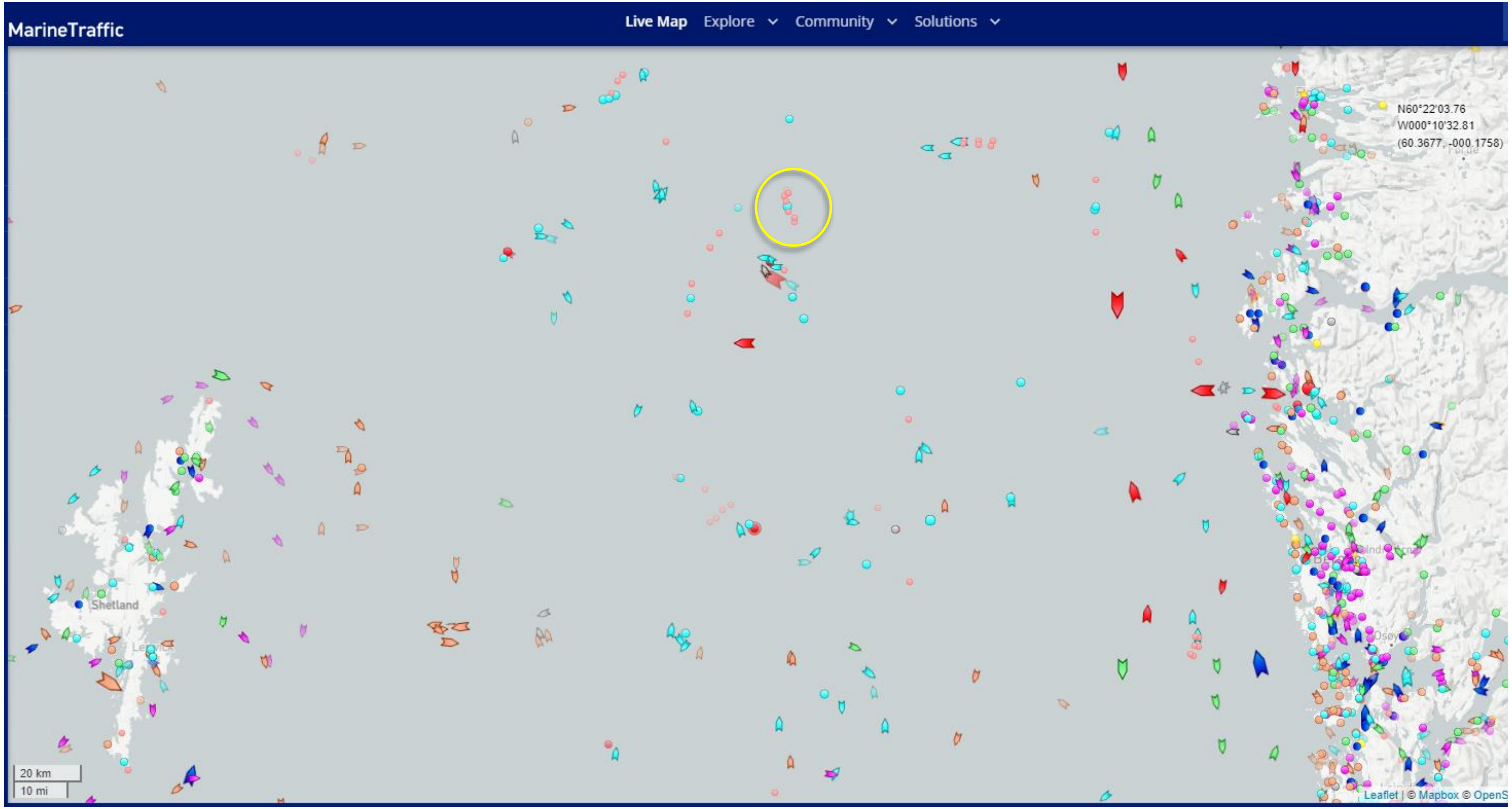
Hywind Tampen Project

equinor

DOF Subsea

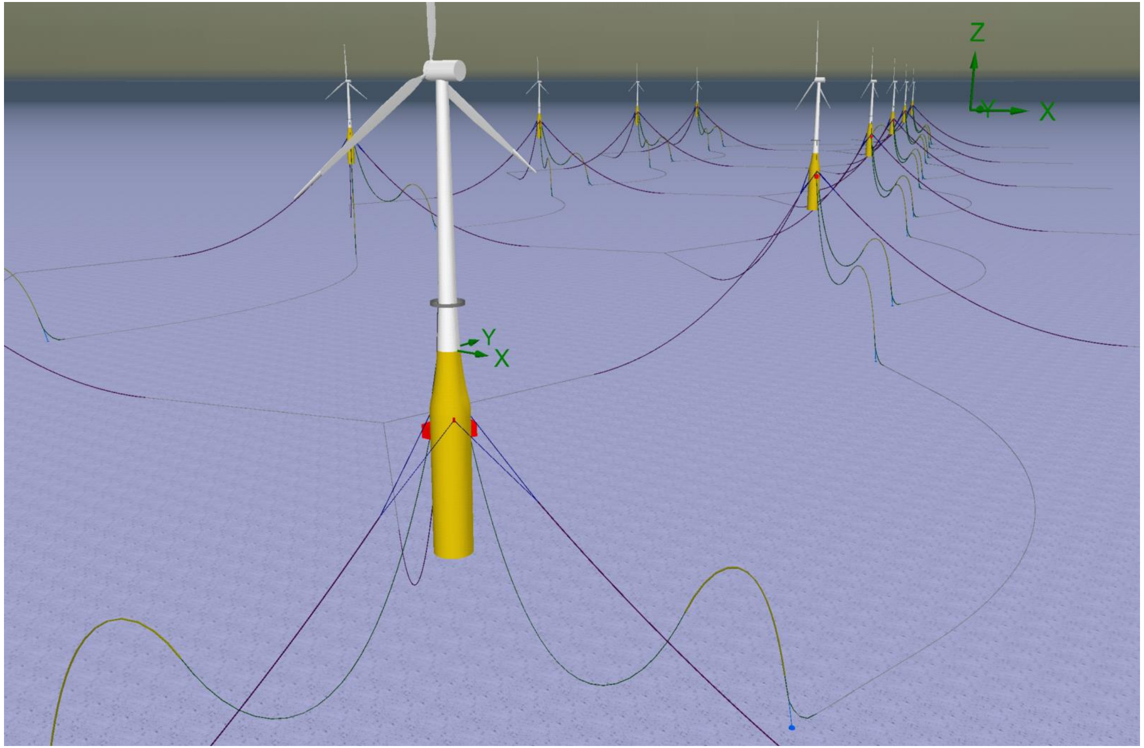
- **Hywind Tampen** at 95MW will be the world's largest floating offshore wind farm and an essential step in industrialising solutions for future floating wind farm projects





MarineTraffic
Live Map
Explore
Community
Solutions
N60°22'03.76
W000°10'32.81
(60.3677, -000.1758)
Shetland
20 km
10 mi
Leaflet | © Mapbox © OpenS

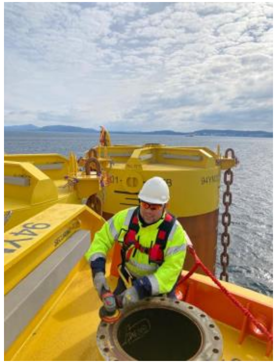
The mooring layout

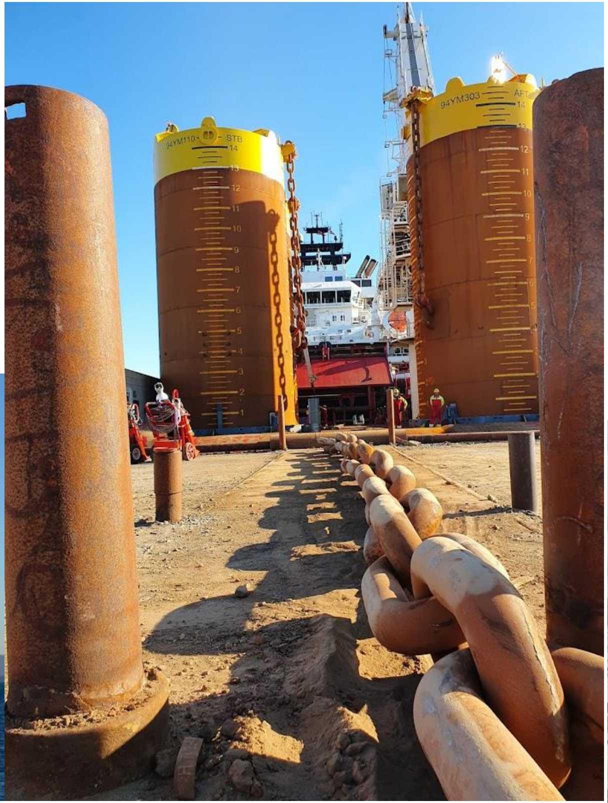


- 2 passive and 1 active line for each turbine.
- Active line with an in-line tensioner.
- Lines are SSSW and Bottom chain.
- 19 suction anchors 33 mooring lines (avg 1.7 suction anchors/ turbine).
- Anchor and chain installation (and tensioning) took 43 days incl. weather.

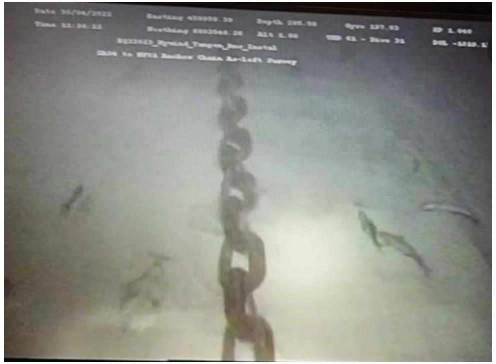
Mooring system load-out and FWT assembly site

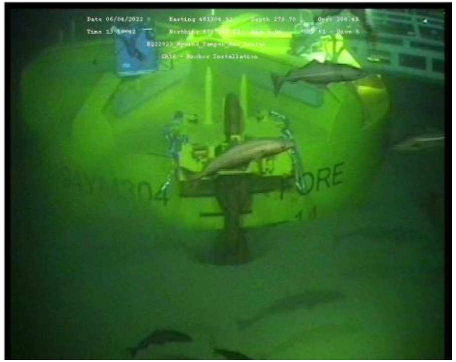
Mooring system - load out for installation



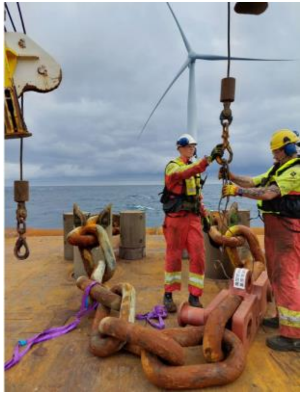


Mooring Installation

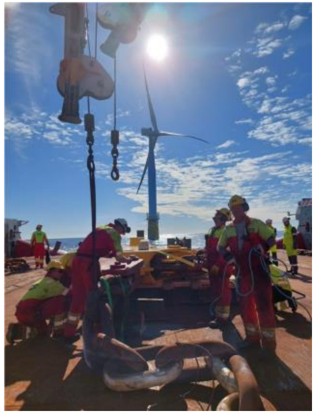


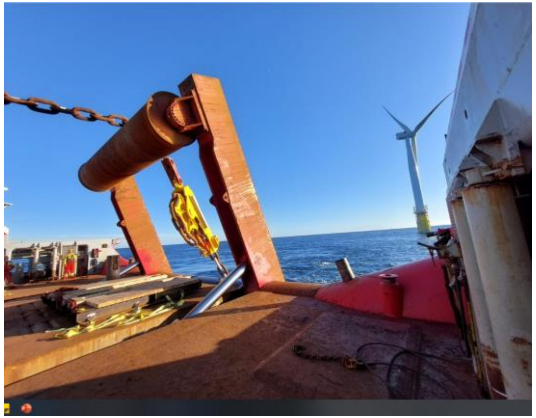


Tow out and hook-up



- Spread. 3 towing and 1 installation vessel.
- Skandi Iceman «a-frame» used for In-Line Tensioner installation. ILT launch. working well.
- Hook-up operations combining several vessels with system under tension. Not ideal, time consuming and fragile method. Fabrication (of substructure), installation, operation and maintenance should get more focus when designing the mooring system.
- Soil and water depth will vary but within some areas there should be optimalisations. Oil and gas moorings are one off, robust but expensive.
- Hook-up and installation time has to and can come down. 60 days for 7 turbines. (logistics, weather and method)





Some lessons learnt

1. To get a **good mooring design**, **more experience**, data collection and data sharing will be important.
2. The **contracts** for floating wind development must be **better adapted to the work** and **clear interfaces** must be established**. Lump sum contracts** are often used. That format is **not ideal**, as the product and interfaces are unclear and not established. Focus should be on paying for added value. With LS the focus becomes, get it done as easily as possible (and the big picture is forgotten).
3. The **installation time and weather criteria** for mooring systems **need to improve.**
4. More **specialized and cleaner vessels**, to be developed once we have sufficient experience. Long term contracts for vessels will be and advantage for all.
5. Experiences from **oil and gas is relevant and very useful**. However, the **organizing** needs to be more **flexible** and should be more **«IT driven**». **Matrix organizations with departments are not ideal** for these development projects where the way forward, roles and responsibilities are under development and constantly changing.
6. **Unforeseen changes** will come and make a major impact on projects. Examples from Hywind fuel price, tax regime, Covid, supply chain constraints etc.
7. **Offshore vessels can be unreliable**, the mooring campaigns over 4 months had vessel breakdowns three times requiring replacement vessels.

Thank you

BAUER Offshore Technologies GmbH

Marine Foundations installation

Floating Offshore Wind Subgroup

Transitioning from current areas & business

Transition opportunities

Bauer Universal Mooring Pile

Scaling up for commercial array FOW
In any combination of soil, clay & rock

Bill Shaw: Commercial Director
BAUER Renewables Ltd

In addition to our century-long drilling expertise on land, BAUER has also gained significant experience offshore since 1993

BAUER Offshore Project History

1993

Diamond deposit exploration with a BC Cutter in water depth of 160 m (South Africa, Atlantic Ocean)

2005

First MeBo Worldwide sea bed core drilling (©MARUM – Center for Marine Environmental Sc., Bremen)

2008

Barrow Offshore Windpark: Drilling inside of a monopile with a Bauer Fly Drill (Barrow / UK, East Irish Sea)

2011/12

Monopile foundation in rock for tidal turbine from Voith Hydro with BSD 3000 (Orkneys / UK, Atlantic Ocean)

2017

Relief drilling for driven pin piles with Dive Drill, commissioned by Seaway 7 (Beatrice OWF / UK, North Sea)

2021-2023

Provision of drilled & grouted pin piles with Dive Drill, (St. Brieuc OWF / France, Atlantic Ocean)

Source: BAUER AG

Bauer Offshore Project Recent History

2008 . Barrow Offshore Windpark, UK

The monopile foundations for the 90 MW windpark in the East Irish Sea were installed by the Drive-Drill-Drive technique. Bauer performed the relief drilling using the **Bauer Flydrill BFD5500**. The frictional resistance was reduced for the 4.75 m diameter foundation pieces in the hard soil layers.

2011 – EMEC Monopile – Tidal Turbine – Orkney, UK

Bauer was the principle contractor for the monopile foundation of a tidal turbine from Voith Hydro.

The drilling equipment was the **Bauer BSD3000**. Able to operate in 12 Knots current and drill hard rock – uncased

Water Depth	= 37 m
Monopile Length	= 23 m
Monopile Diameter	= 2 m
Rock Socket Depth	= 11 m

2017 – Beatrice OWF, UK

Bauer was commissioned by Seaway 7 to provide relief drilling services for driven pin piles.

The drilling equipment was **Bauer Dive Drill – DDC 40**

- 3m diameter
- 70m penetration
- 40m water depth
- Standby use based on pile hammering refusal

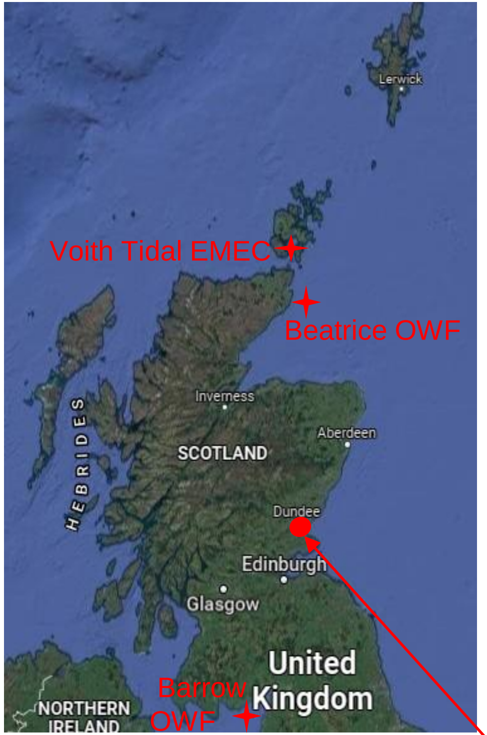
2021 to 2023 – St. Brieuc OWF, France.

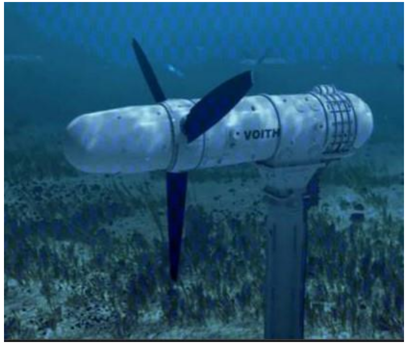
Bauer is contracted by Van Oord to provide drilled & grouted pin piles

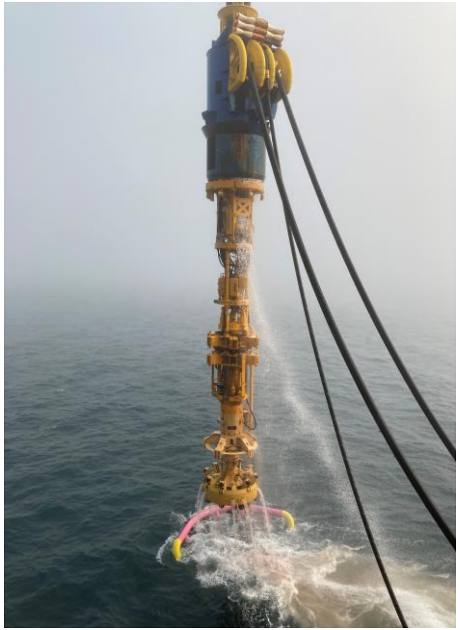
The drilling equipment is **Bauer Dive Drill – DDCU 40**

- 62 WTG / 1 OSS
- 190 Pin Piles
- 3m diameter
- Up to 47m penetration
- +40m water depth

BAUER Offshore Foundations

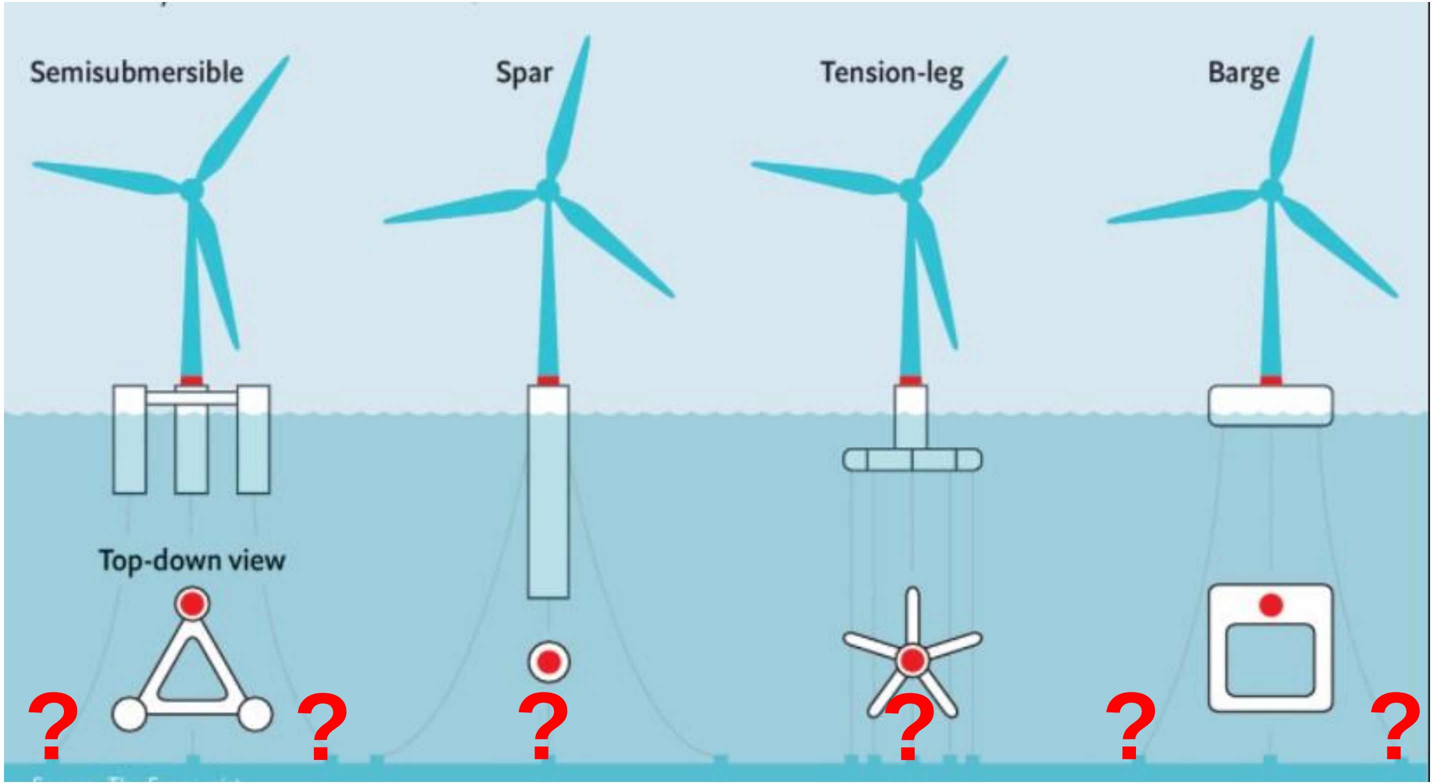






Scottish HQ - Dundee

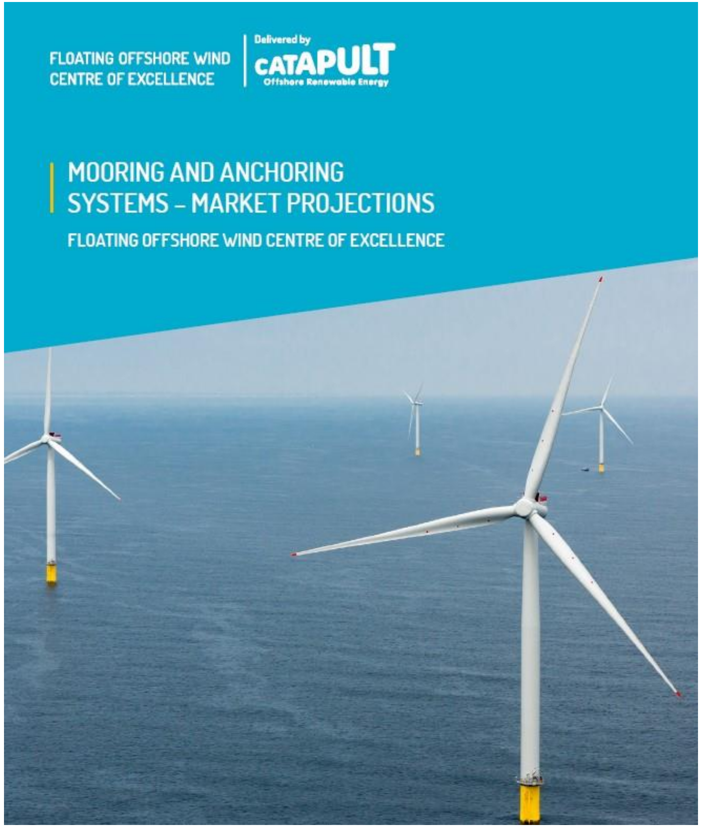
Floating Offshore Wind – Foundation fixation choices – where to start?
You start with geology – and if geotechnically it is difficult, what then?



Difficult Seabed Geology

Anchor type	Type of seabed 1. Outcrops and seabed surface rock 2. Medium & hard sub rock layers interspersed with cohesive & non cohesive soils 3. Any combination of any seabed soil/ rock
Gravity-base anchor	? Requires seabed preparation – uneconomic @ scale & often not possible
Drag-embedded anchor	X Ideal in cohesive and non-cohesive soils – some capability in hard soils but limited to fluke contact in soft limestone and coral
Driven pile anchor	X limited to <5Mpa soil strength – ideal in soft cohesive seabed
Suction anchor	X ideal in soft cohesive seabed
Driven anchor plate	X ideal in soft cohesive seabed
Torpedo embedded anchor	X ideal in soft cohesive seabed
BAUER Drilled and grouted pile anchor	1, 2 & 3 Yes - BAUER install D & G piles in any seabed material in any combination and thickness, from 1 Mpa overburden to 200 Mpa rock in any layer thickness & combination thereof. 5-50m long piles & 2 to 4m Ø

Are there disadvantages with D & G piles?



- Drilled and grouted piles
- : 4.1.4: …. *may be the only option for some seabed conditions.*
- But they can be costly? Right!

No escaping big ticket items when working at sea, however with target prices well below that for similar works in other marine sectors, then no, this is now not the case for FOW.

But how do we reduce serial costs to acceptable levels?

Floating wind needs to focus on cost and risk reduction
(IRENA – International Renewable Energy Agency)

We need to use Smaller vessels
- Lower cost
- Better Availability
- Faster more agile installation

We must Standardise wherever possible
- Utilise same equipment spread every project
- installing same pile Ø for any project - Just adjust drill depth

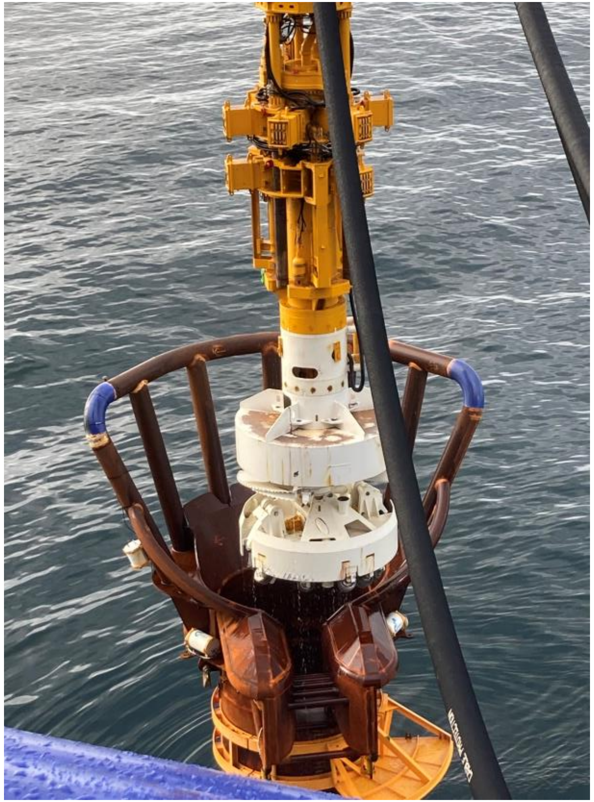
We must Optimise design & installation phase
- Pile sharing for catenary mooring – more efficient
- Bigger Turbines – using high-capacity D & G piles
- Bigger arrays – more opportunity - reduce serial cost

Higher ROI at much lower risk – yes please!

But how will we do this?

It takes experience, knowledge, resource and clever design

BAUER are now offering to all Scotwind FOW partners, fast and economic installation of high-capacity mooring piles that will de-risk projects in hard soils and rock – and make them financially attractive.



Thank you and Questions

Please contact Bill Shaw for more information:

Bill.shaw@bauer-renewables.co.uk

PASSION for PROGRESS

DeepWind FOW Subgroup Event – Mooring Systems

Ferdinando Samonà – Floating Wind Engineering Manager

Glasgow, 23/08/2022

MAERSK SUPPLY SERVICE

A Green Transition at Maersk Supply Service

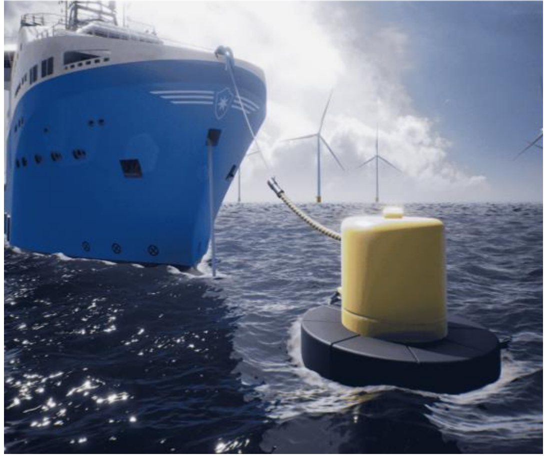
Our green technology and solutions

Floating wind

End-to-end solutions
with tailored work scopes

Stillstrom

Electric charging
power buoy technology



Vertical Installer

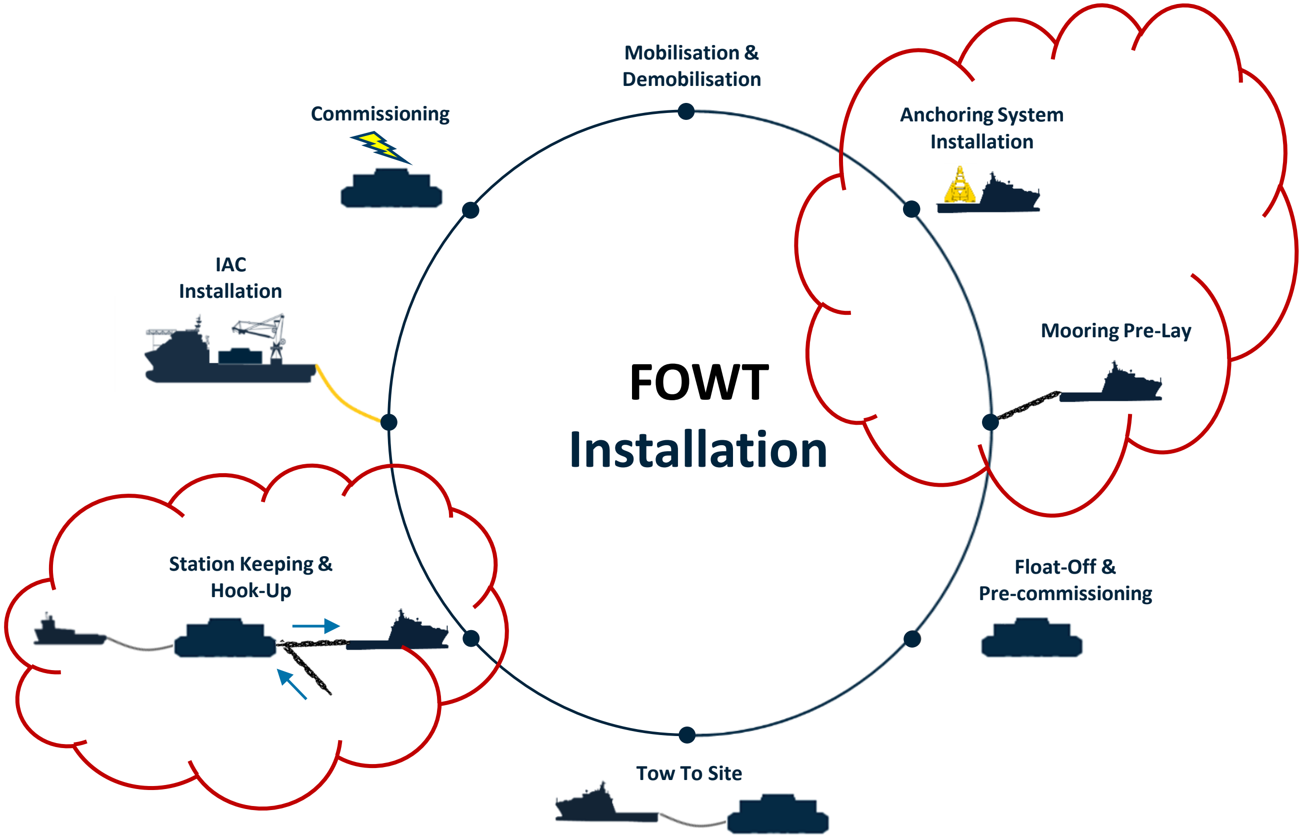
Innovative solutions for
wind turbine installation

MAERSK
SUPPLY SERVICE

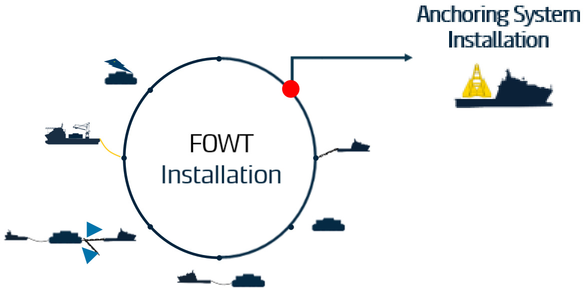
Mooring related topics of Today's Event

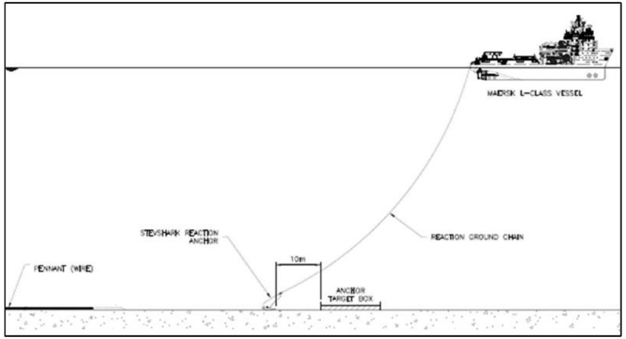
- Mooring component manufacturing
- Marshalling and load out
- Mooring Systems Installation → Some lessons learned on Mooring Tensioning Activities
- Innovations related to mooring and anchoring systems for FOW

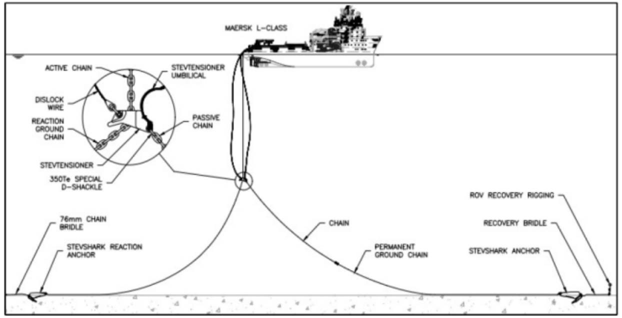
FOWT Installation - Typical Installation Sequence



Anchoring System Installation





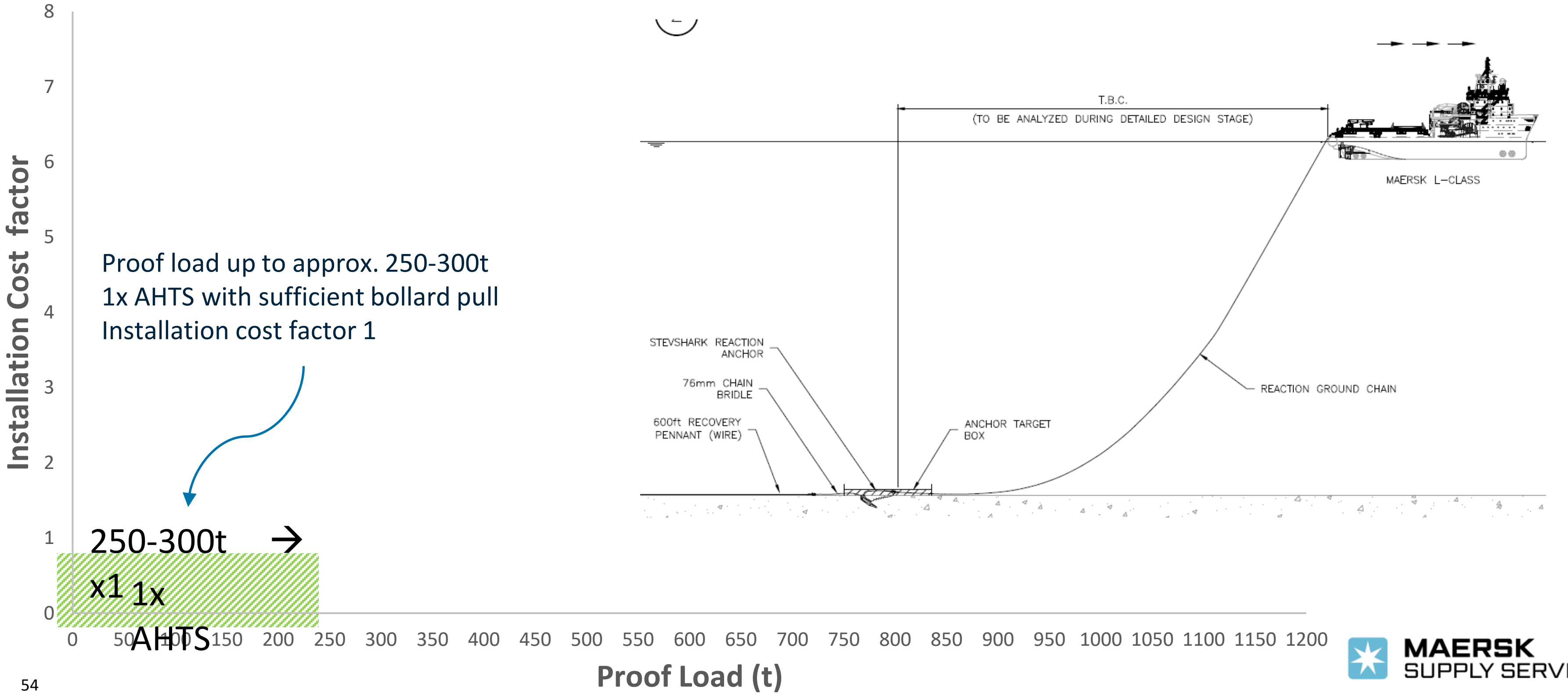


- Drag Embedment Anchors (DEA), Suction Piles, Driven Piles, Drilled-Drilled/Grouted Piles, Deadweights, etc.
- DEAs require to be proof loaded offshore.
- The proof load shall be equal to the max. line tension under extreme conditions (Ref. DNVGL-OS-E301 Ch.2 Sec. 3.6.2).
- How does the proof load influence the selection of suitable marine asset and what can be the impact on installation costs?

MAERSK SUPPLY SERVICE

DEA Installation – Proof Load VS Installation Spread

- Installation costs depend on various parameters and specific assessment is required on a case-by-case basis
- Example below refers to a FOW Demo project in a water depth of 60-80m



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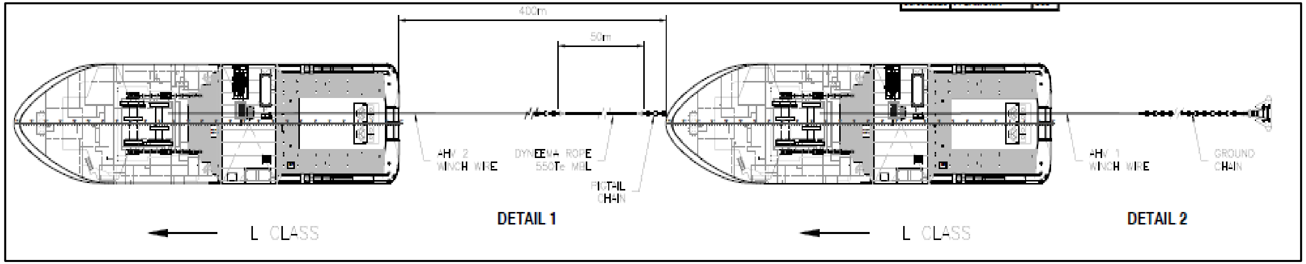
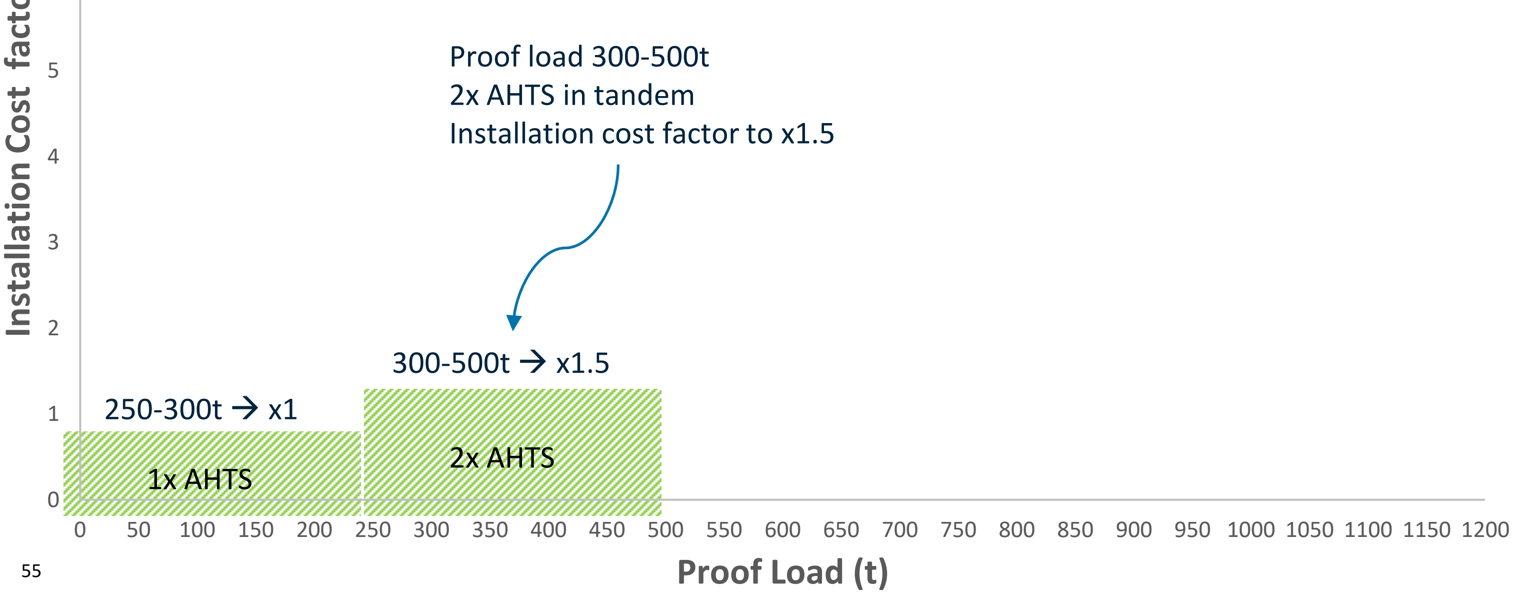
DEA Installation – Proof Load VS Installation Spread





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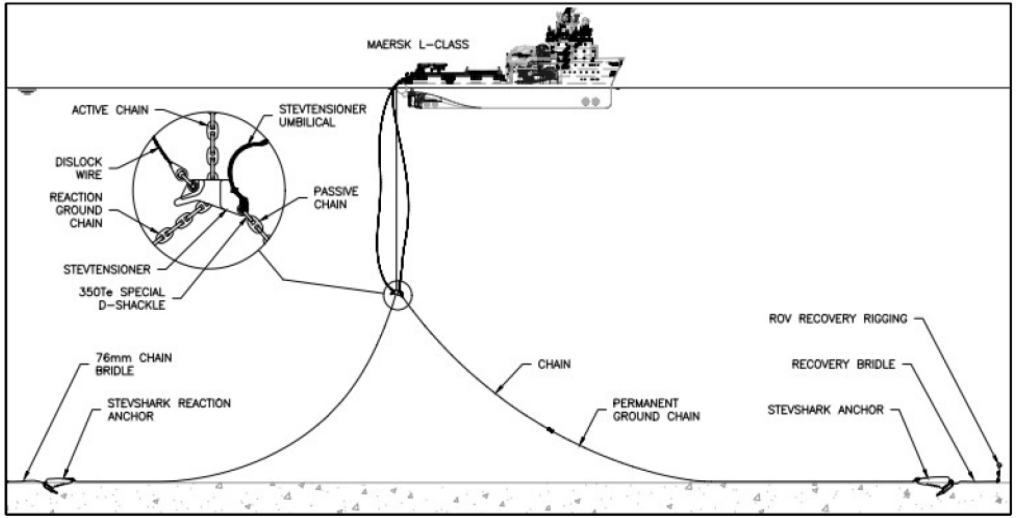
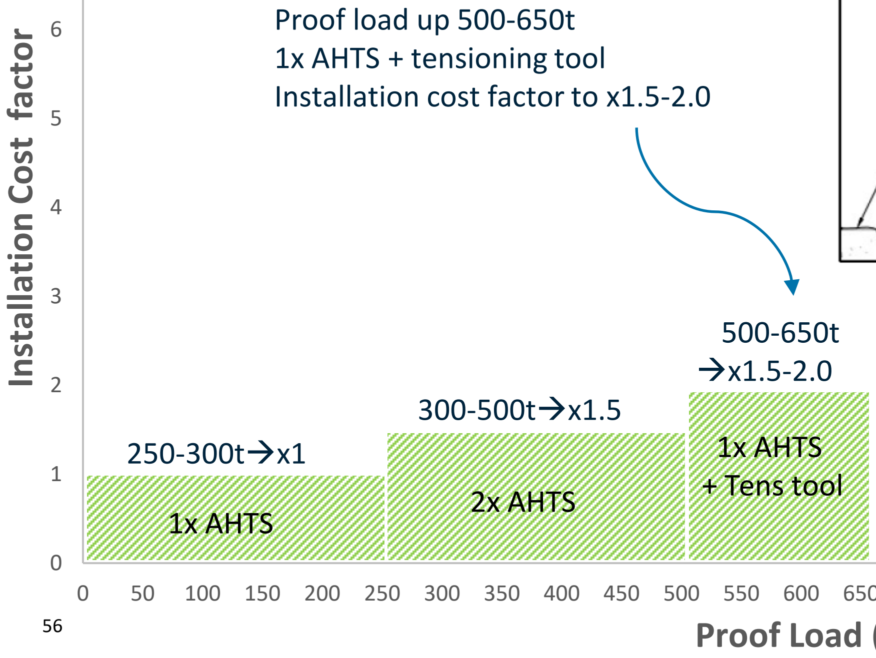
DEA Installation – Proof Load VS Installation Spread

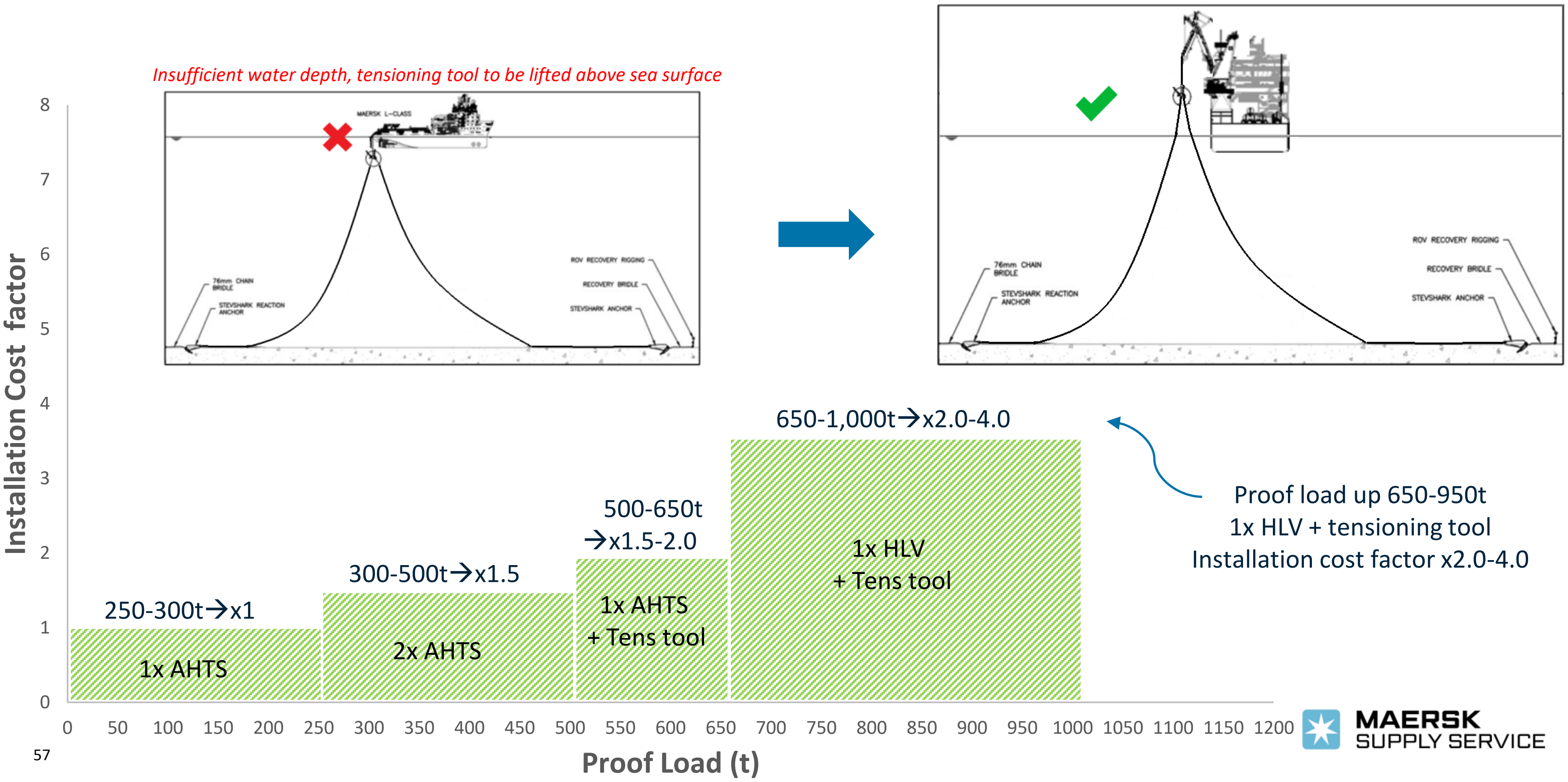




Approx. 40% of vertical pull is required to achieve the proof load – e.g. 500t vertical (applied via main AHTS winch) can achieve 1,200t horizontal.
So why only up to 650t?

MAERSK SUPPLY SERVICE

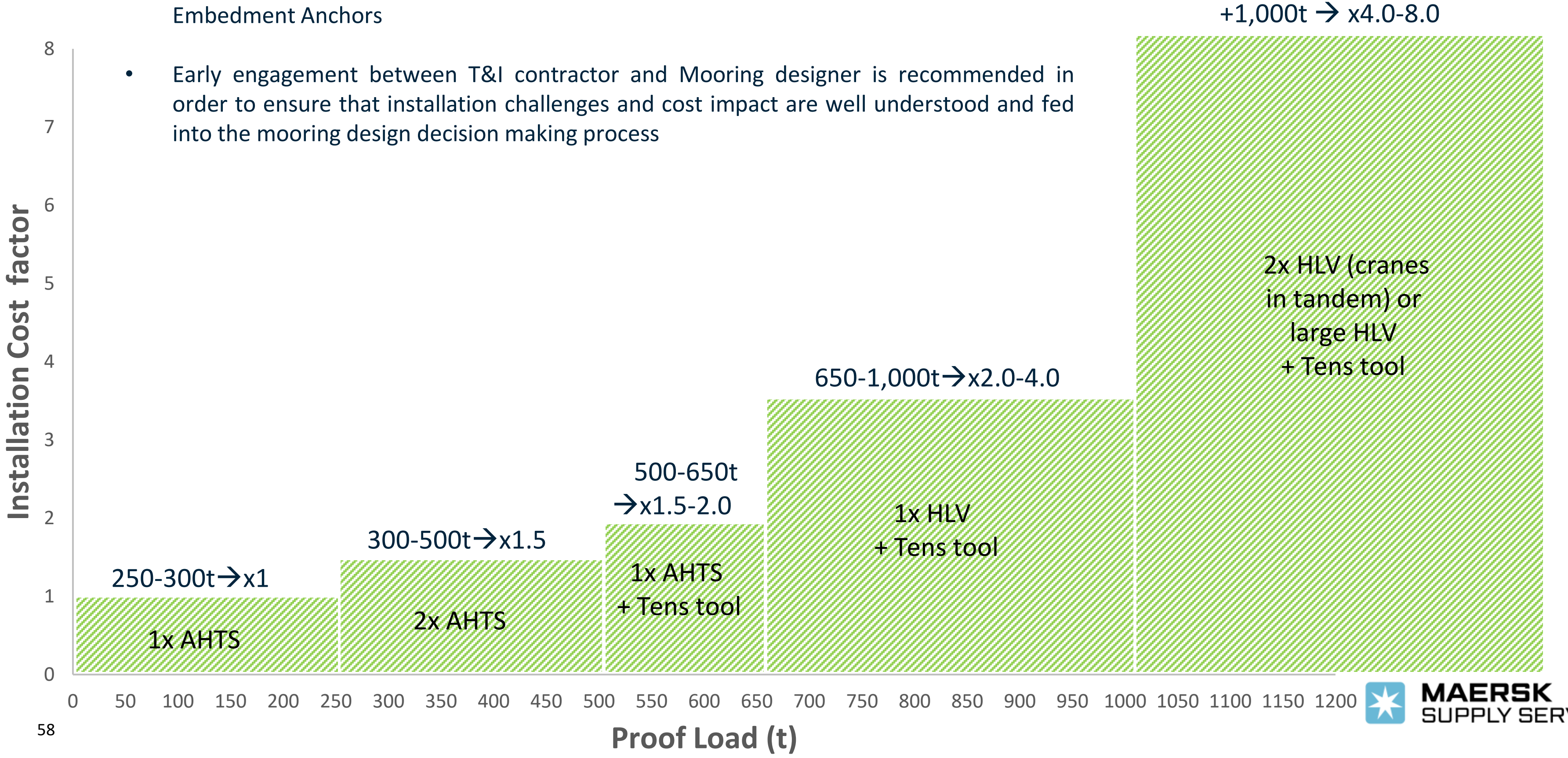
DEA Installation – Proof Load VS Installation Spread



MAERSK SUPPLY SERVICE

DEA Installation – Proof Load VS Installation Spread

- Proof load values can significantly impact the marine spread required to install Drag Embedment Anchors
- Early engagement between T&I contractor and Mooring designer is recommended in order to ensure that installation challenges and cost impact are well understood and fed into the mooring design decision making process



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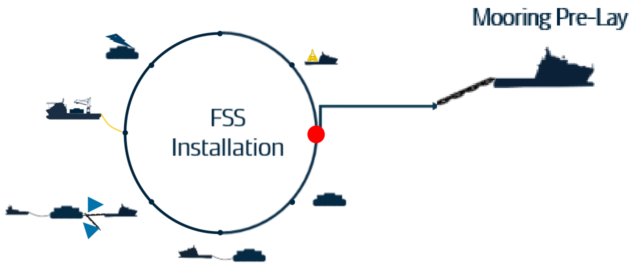
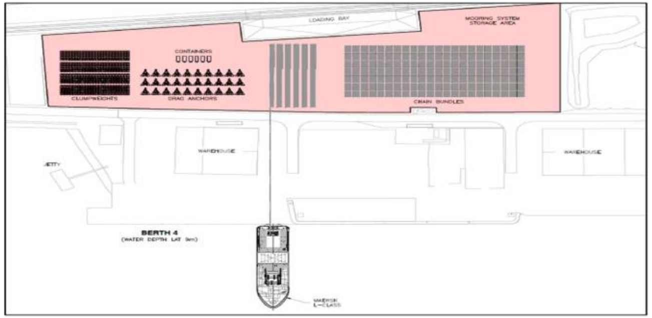
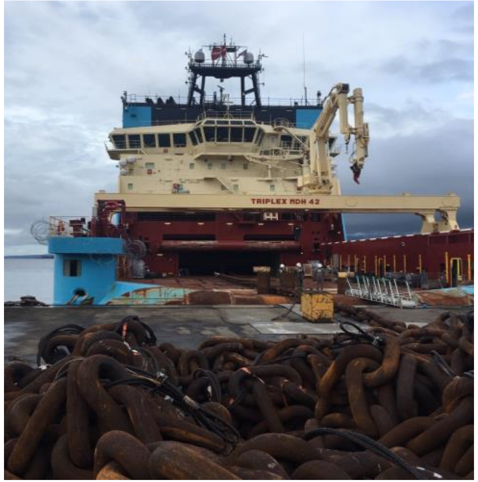
Mooring Installation – Pre-Lay





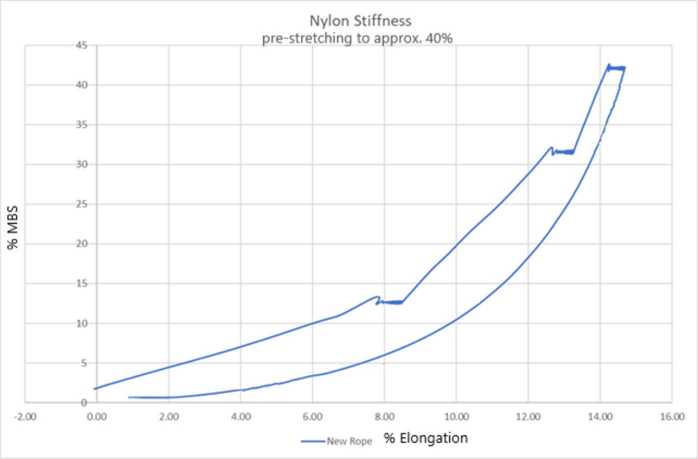


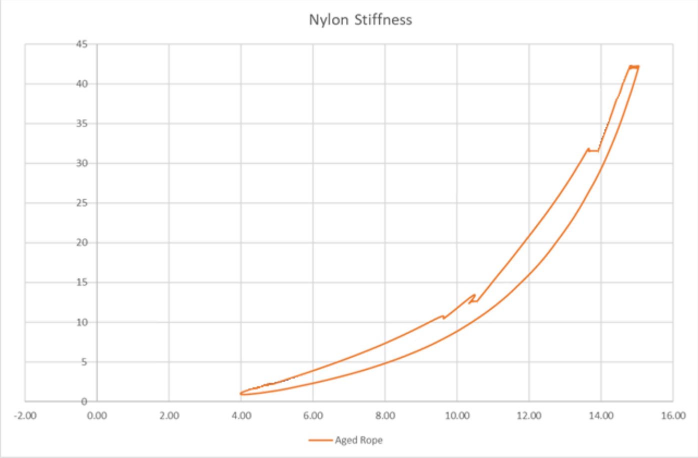
- Pre-lay of chains, ropes and connectors
- AHTS with sufficient chain locker space, deck space, bollard pull and winch capacity required
- Synthetic rope pre-stretching operation may be required to remove construction elongation
- New synthetic lines/ropes should be pre-stretched as stated by DNV-ST-N001 Sec 17.8.6.4
- But…

MAERSK SUPPLY SERVICE

Mooring Installation – Synthetic Rope Pre-Stretching

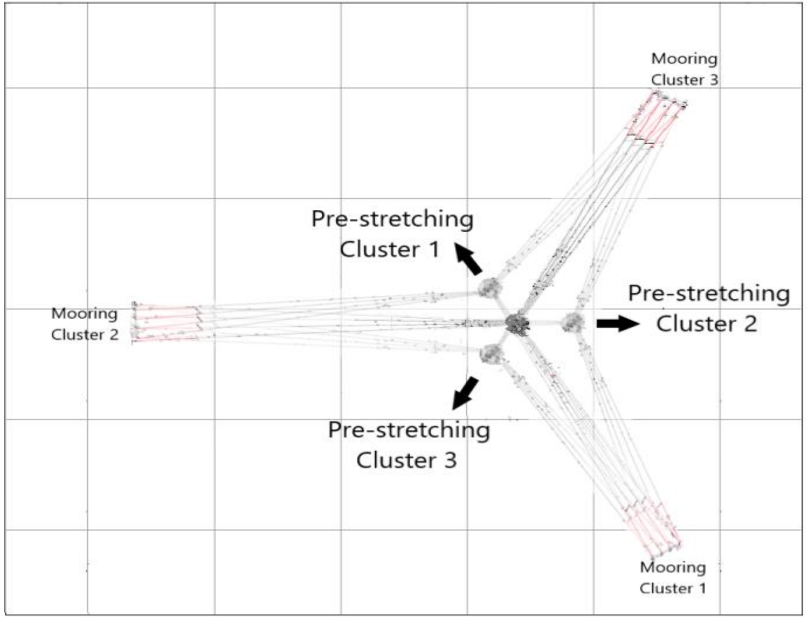
- New synthetic ropes are characterised by construction elongation and creep
- Construction elongation is a temporary elastic elongation which can be temporarily (and partially) removed by applying and holding tension. If the tension is removed, then the rope will almost fully retract back to its original length (e.g. removed construction elongation <1% on nylon rope)
- Creep is a permanent plastic elongation which will only be removed over time under long term loads
- Synthetic ropes stiffness stabilises over few years of operating life (aged rope)
- Because of these elongations, in the first few years of operating life new ropes may lead to higher Floater excursions than the capacity limits of the dynamic cable if the elongation is not carefully handled.
- For the above reasons, pre-stretching of a new rope (i.e. accelerating ageing process) may be required
- But is pre-stretching always worth it?
- E.g. is it worth pre-stretching before the hook-up and then wet-store the rope onto seabed?

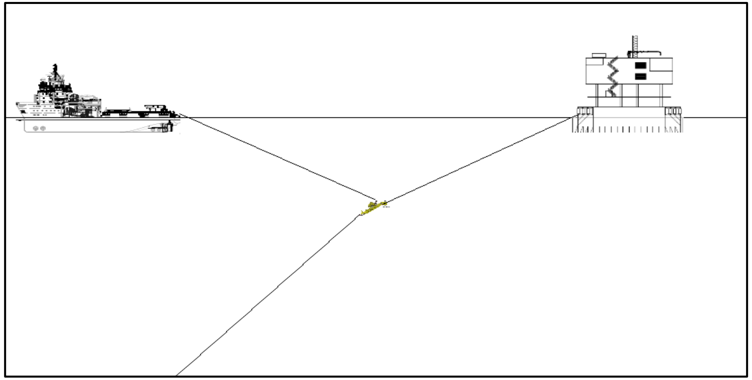




Mooring Installation – Synthetic Rope Pre-Stretching

- Unless the tension is kept high after the pre-stretching, significant construction elongation will still be expected after hook up
- Creep will only be removed over time under long term load and are unlikely to be removed during pre-stretching operations
- *Feedback from a rope supplier is that the elongation that is eliminated with a pre stretched nylon rope at 40% MBS and then removing the tension versus a non-pre stretched nylon rope can be as small as approx. 0,5%*
- In Oil & Gas industry, accelerated ageing is typically achieved by cross-tensioning the ropes after the hook-up using large tensioning equipment onboard the platforms i.e. the minimum tension seen by the rope after pre-stretching is the mooring pre-tension
- In FOW generally there are not large tensioning equipment onboard the Floater, hence this can only be done with suitable marine spread in combination with permanent subsea tensioning tools such as ILTs, chainstoppers, etc. (requiring a certain length of permanent chain)





- Due to the large ropes used in FOW applications (e.g. MBS of 2,500t), pre-stretching loads introducing significant technical and commercial challenges. The need of pre-stretching should be carefully assessed and alternatives investigated
- Careful attention to balancing the elongation effects withing the mooring and cable design is required together with an intervention which may require re-tensioning activities until the rope elongation stabilises

MAERSK SUPPLY SERVICE

Thanks

Further questions? please contact:

Ferdinando Samonà – Floating Wind Engineering Manager
Email: Ferdinando.Samona@maersksupply.com
Phone: +45 3178 1026

Structural Health Monitoring Floating Offshore Wind Turbines

DeepWind – Floating Wind Subgroup

Stuart Killbourn, 23 August 2022

Floating Wind: Fatigue Tracking

Motion and position measurements of floater are interpreted using a physics-based simulation model to infer stress cycles – hence **fatigue**.

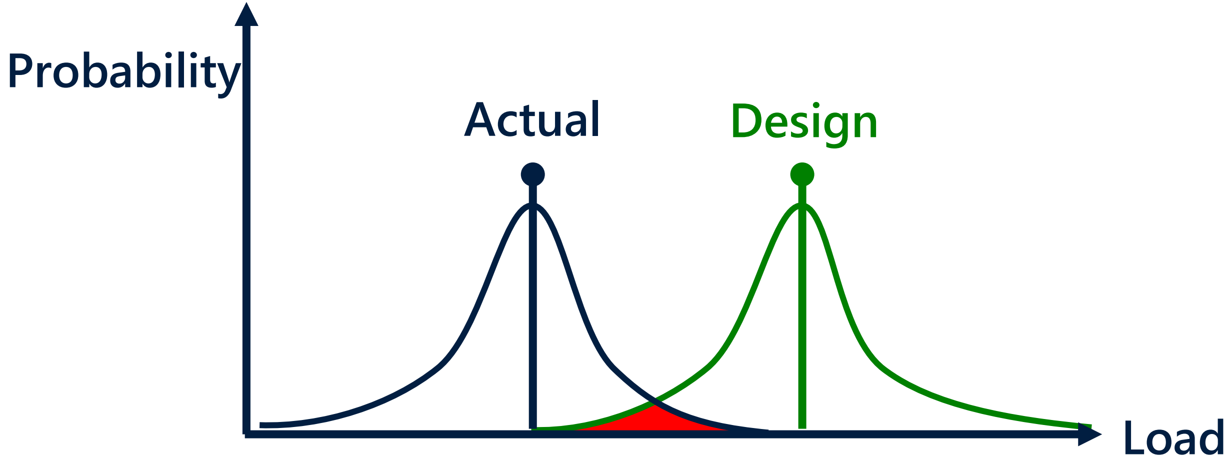
<u>Objectives</u>:

Reduce or **Eliminate Subsea Inspection**.

Utilise **Dry, Robust,** and **Maintainable** Instrumentation for low operating costs.

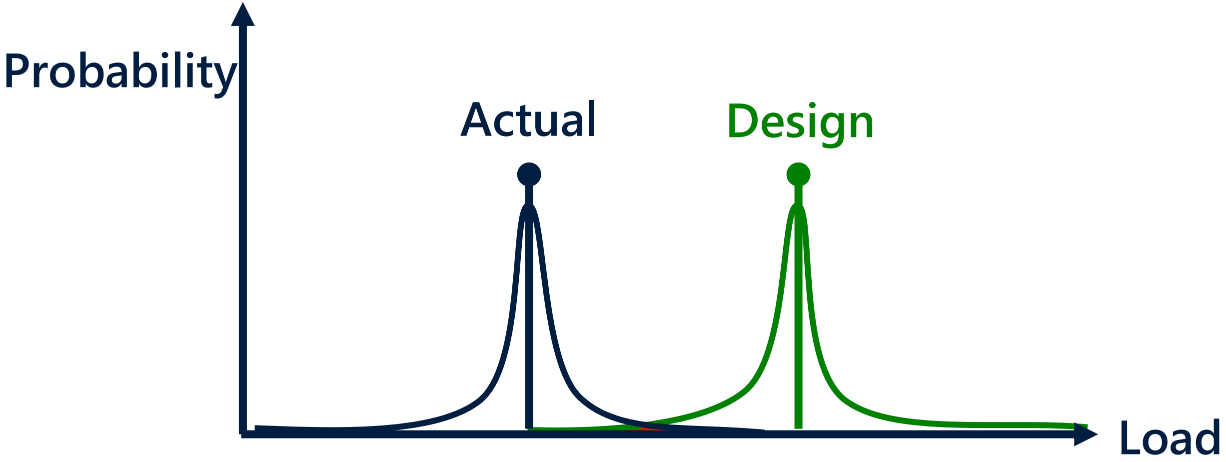
Continuous **anomaly detection** for anchor drag or similar failure scenarios.

Risk-Based Inspection



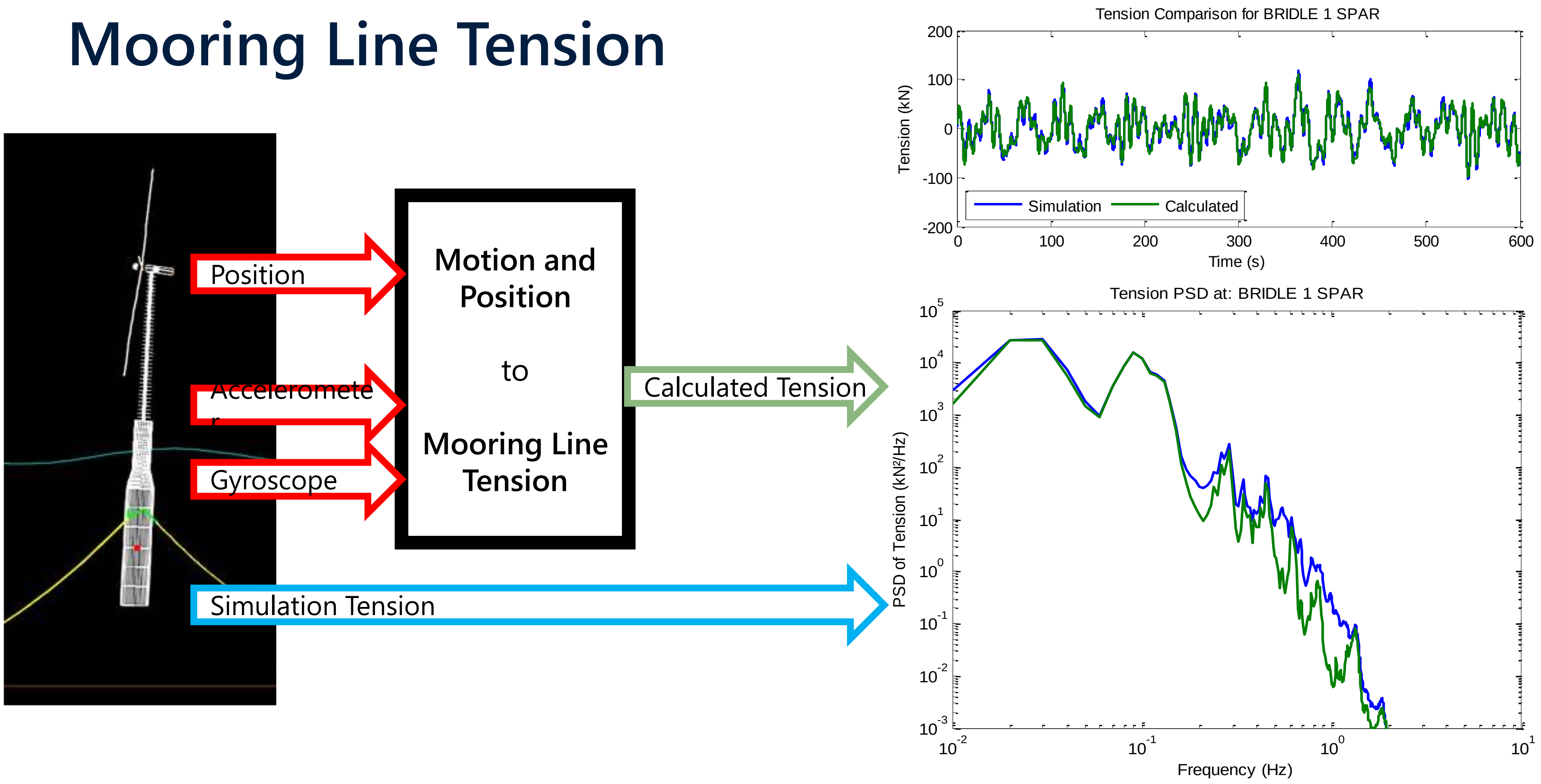
Risk-Based Inspection

Better information allows us to quantify the risks more accurately – and target inspection efforts.



FUGRO

Mooring Line Tension



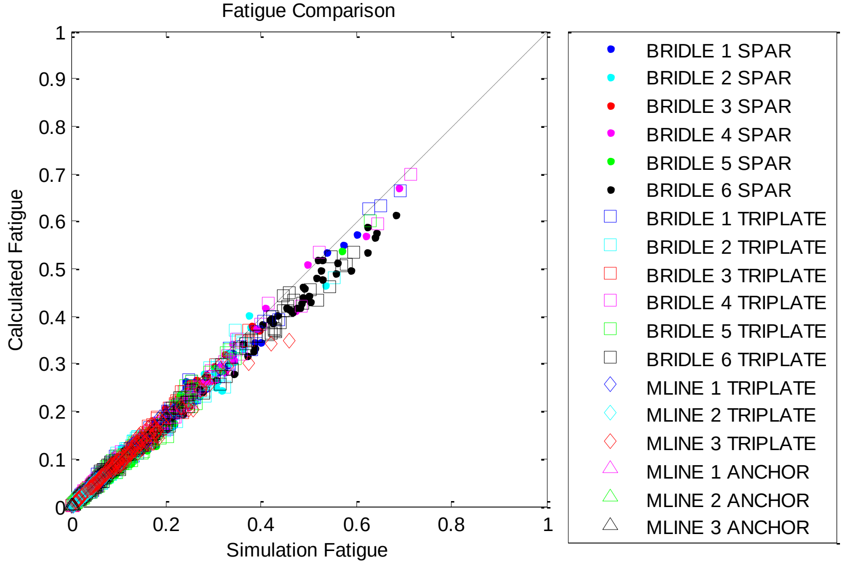
Verification: Fatigue

Verification results from Hywind Scotland simulation model show excellent correlation.

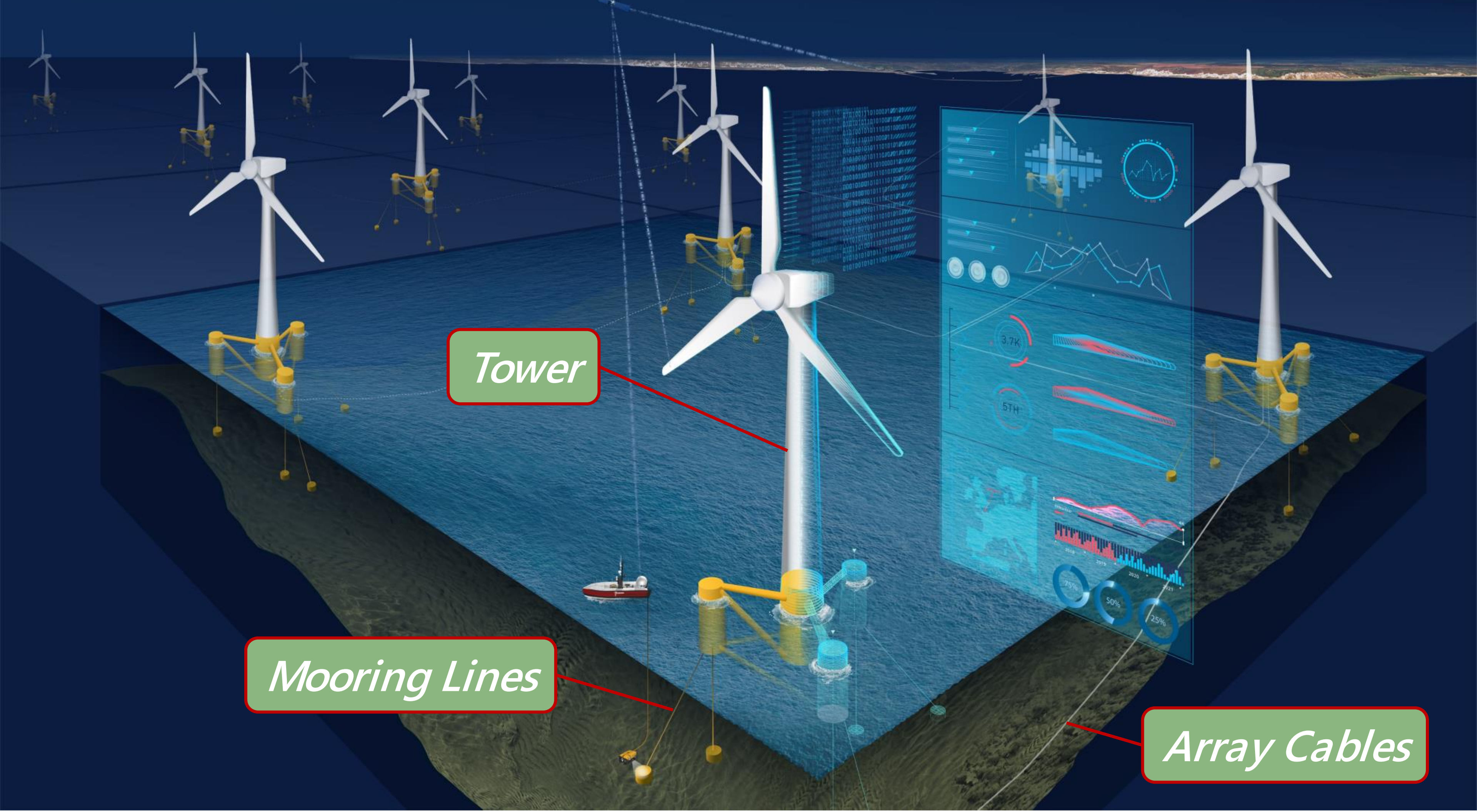
Promising results using limited Hywind Scotland published data set.

Next step: validate results in a field trial:

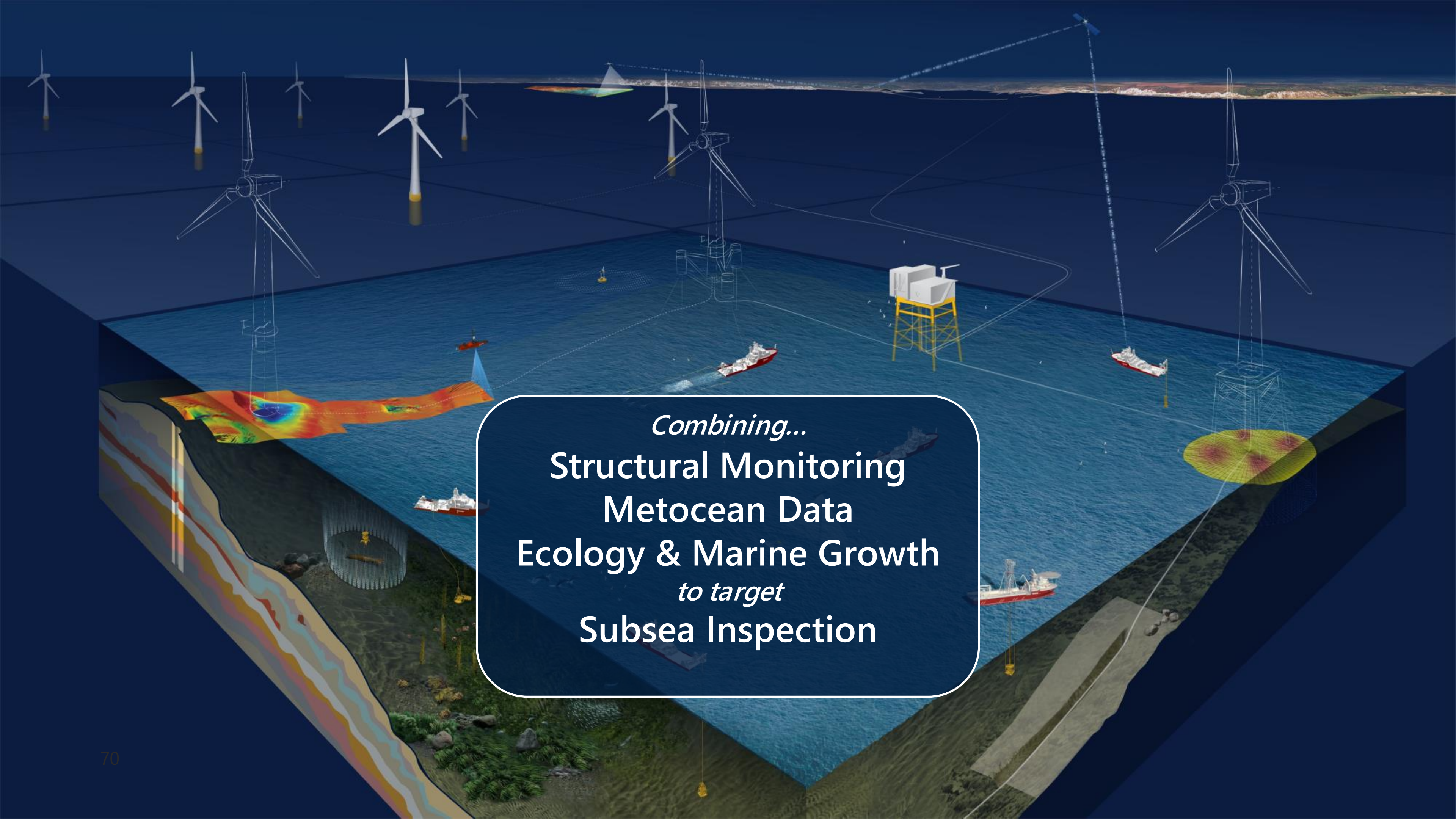
- Install monitoring system on FOWT
- Create simulation model
- Track fatigue with sensor data as input
- Ideally compare versus load cell



Typical fatigue ratio is 0.9.
10% error in fatigue
(or 4% error in stress cycle range).



Tower
Mooring Lines
Array Cables



Combining...

Structural Monitoring

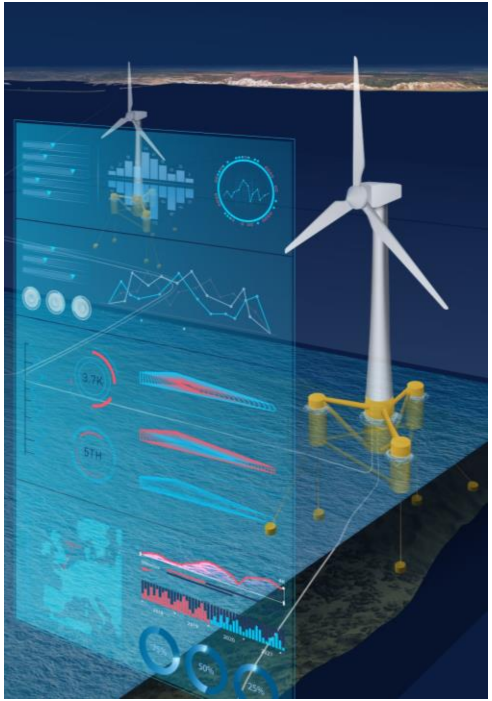
Metocean Data

Ecology & Marine Growth

to target

Subsea Inspection

Conclusion



Remote monitoring of floating wind turbines is a cost-effective, un-manned solution to asset integrity that enables:

- Life extension
- Inspection and intervention optimisation
- Identification of damage or failure scenarios

Thank you

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INTRODUCTION

LEASK MARINE
International Marine Contractors

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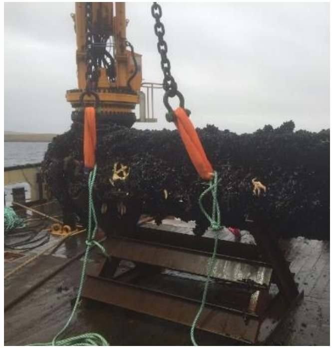
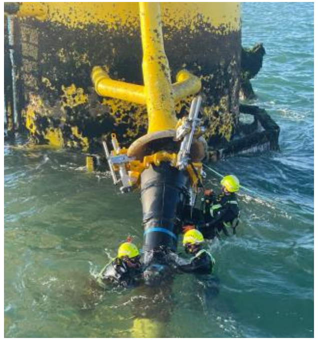
LESSONS LEARNT & CHALLENGES

Cable Operations

Preventing Maintenance
Cable Protection
Site Conditions

Bio-fouling





Subsea assets have gain close to 1t
worth of marine growth.

Mooring Operations – R&D
Mooring solutions

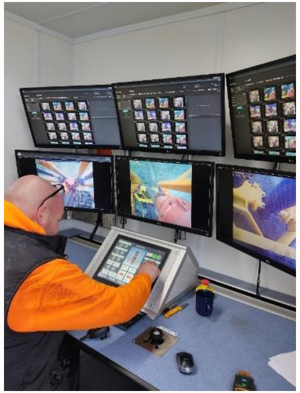
LEASK MARINE
International Marine Contractors

Gravity Bases
100T-300T

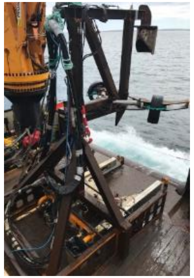
In 2019 we source and installed a total 1200t of chain to work as mooring system

The SDR project is the design, manufacture and development of cost-effective drilling option for mooring and anchoring solutions. This project augments the existing drilling rig concepts available on the market with an innovative, robust purpose-built solution that will enable low-cost drilling & piling operations.

Leask Marine
Raptor SDR



Continue Developing…



BBRG Synthetics

Preparing for Scotwind

Stein Are Andersen

23.08.2022

Bridon-Bekaert

BRIDON · BEKAERT
THE ROPES GROUP

Deep Wind Offshore Wind Cluster

Mooring Subgroup 23. August 2022

- Bridon-Bekaert
- Synthetic Mooring lines in shallow waters
- Rope solutions
- Scaling production capacity for Scotwind
- Scaling workforce
- Supply chain challenges
- Logistic challenges
- Commitment from Developers & Key stakeholders
- Partnerships & Strategic Alliances

Bridon-Bekaert

BEKAERT AT A GLANCE

Preferred partner serving customers in 130 countries

Global leader in steel wire transformation and coating technologies

Global manufacturing platform

More than 27 000 engaged employees worldwide

Corporate socially responsible company

Combined sales of € 5.9 b

WHAT SETS US APART

Unmatched products and solutions for customers across a wide range of industries

High-tech solutions leader with 1900 patents and patent rights in portfolio

Most advanced manufacturing capabilities

Experienced team with deep understanding of local customer needs

Ambitions and actions for a sustainable business

Creating value for our investors

Leading Through Innovation

BRIDON · BEKAERT
THE ROPES GROUP

Experience in Oil & Gas

- Supplied mooring lines to the first floating platform in 1983, Exxon Lena (Gulf of Mexico)
- Supplied mooring lines to first floating FLNG facility in 2013, Shell Prelude (Australia)
- Supplied first synthetic moored spar in 2004, BP Mad Dog Field (Gulf of Mexico)

Collaboration in Floating Offshore Wind

- Enerocean
- Japan's 1st nylon mooring
- Mooring sense
- Ideol
- X1Wind
- Tampen
- Honeymooring
- Provence grand large
- Firm JIP Equinor
- Umain Aquaventus
- Gazelle
- Infloat

Mooring Line Considerations

Seabed Contact

- Accelerated wear on jacket & traditional coating via abrasion
- Particle ingress leading to potential sub-rope damage

Mechanical Damage

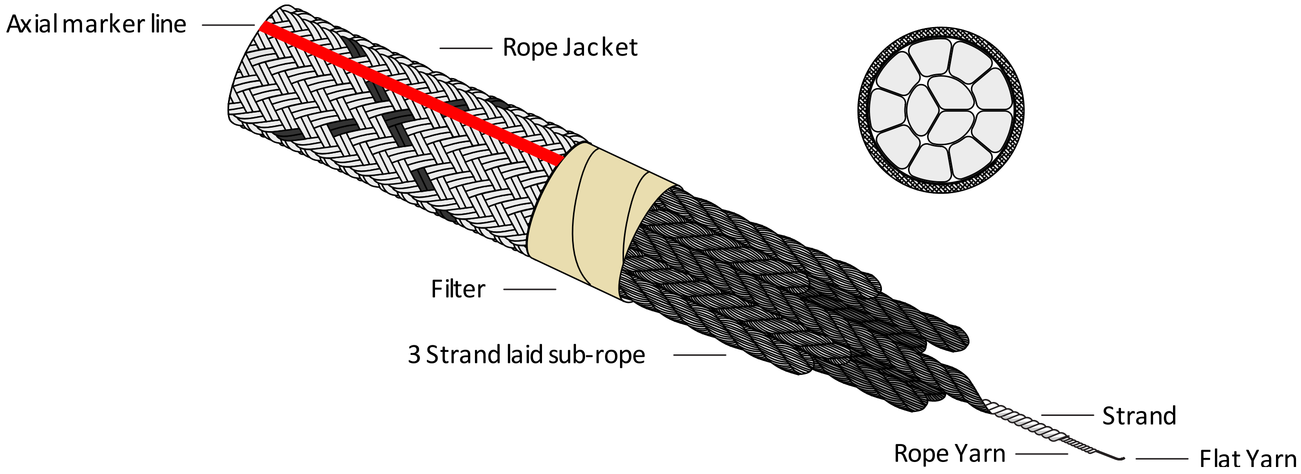
- Represents 100% of observed failures for polyester ropes (May 22)
- Threats from impact events such as over-trawling

Marine Fouling

- Localised issue that usually occurs within top 30m of water
- Additional weight and potential penetration / damage

Bridon MoorLine

- Bridon Synthetics MoorLine rope consists of:
  - Core of multiple, parallel laid sub-ropes
    - Polyester, Nylon or HMPE fibres
  - Braided jacket
    - High performance fabric filter
    - Binds structure of the rope together and protects the core and filter



“MoorLine” by Bridon-Bekaert

A Rope Specifically Developed for Offshore Mooring

Sub-Rope

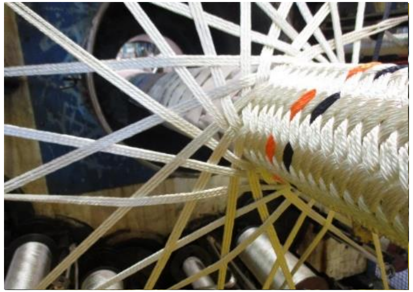
- 3-strand parallel laid sub rope, 12-strand available for TLP applications
- Low-twist ropes that retain 70-72% of yarn strength, conventional laid construction retains 45-60%

Filter System

- High performance fabric filter
- Protection from particles down to 5 microns

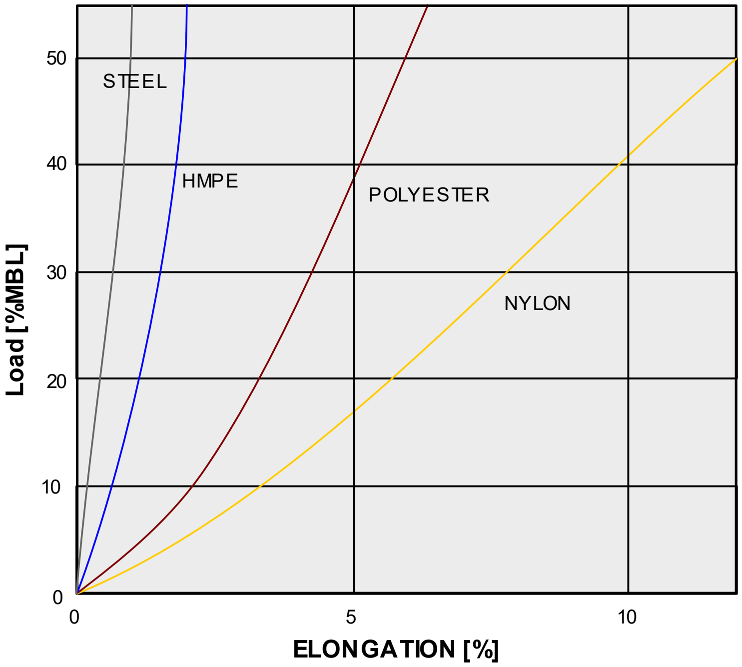
Braided Jacket

- Braided jacket binds structure of the rope while protecting the sub-ropes and filter
- Axial marker line and twist market allows identification of twists within rope



Mooring rope technology

- High tenacity Polyester
  - 20+ years of proven performance and reliability
  - Mid range stiffness characteristics
- Low creep HMPE:
  - Suitable for TLP moorings due to its high tensile strength and high stiffness
  - Lifetime can be engineered for 25 years, in accordance to predicted load scenario
  - Lower weight and easier installation when compared to steel
- High tenacity Coated Nylon
  - Next slide



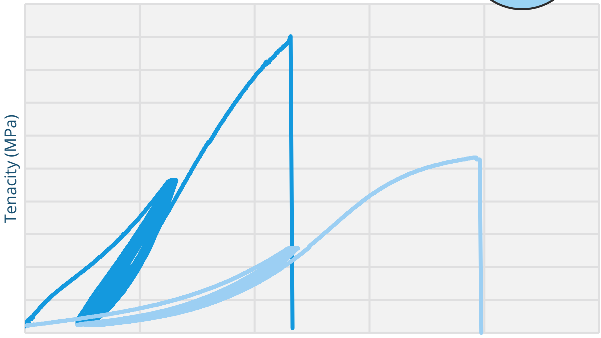
MoorLine | It takes the 'Right Materials'

BRIDON · BEKAERT
THE ROPES GROUP

	Polyester	Nylon	HMPE
Strength	★★☆	★★☆	★★★
Modulus	★★☆	★★★	★☆☆
Cost	★☆☆	★★☆	★★★

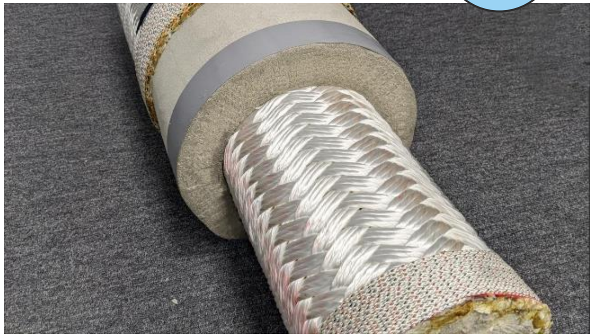
MoorLine | It takes 'Innovation'

Nylon Qualification



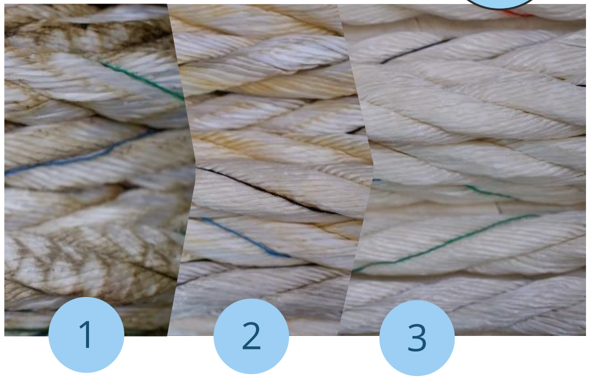
- Greater elongation compared to polyester
- Similar compliance with shorter lines*
- Ideal for shallow water sites (<100m) with harsh waves (>5m)
- DNV qualification underway

Integrated Buoyancy



- Rigid high density foam to maximise floatability & certified for sub-surface use
- Compact design fully integrated into rope & can be distributed in specific locations
- Reduces mooring line components
- Still possible to bend/spool rope

Advanced Coating



- **1. Braided Jacket:** Intrusion, staining, no significant damage to sub-rope
- **2. Jacket + Filter:** No intrusion, staining, no damage to sub-rope
- **3. Jacket + Filter + Coating:** No intrusion, no staining, sub-rope "like new"

*when compared to polyester

Seabed contact

- Sub-rope condition after strip down

Braided Jacket

- Particulate and shellfish intrusion
- Staining
- No significant damage to core

Braided Jacket + 5-micron particle filter

- Staining
- No particle ingress detected

PU overlay Braided Jacket + 5-micron particle filter

- No staining
- No particle ingress
- “like new” sub-ropes

Seabed contact / Cut resistance

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THE ROPES GROUP

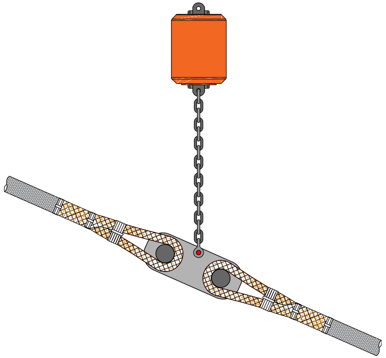
- Advanced Composite Structure

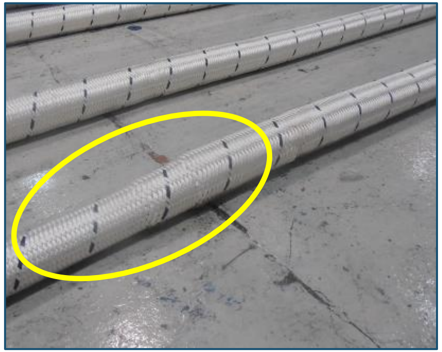
  An enhanced protection layer has been developed, that combines the know characteristics of the Polyester Braided Jacket with a polymeric matrix. This creates a composite structure that addresses the main failure mechanisms that were identified from seabed contact field trials:

  - High abrasion resistance
  - High tear resistance
  - High elongation (low/no effect axial stiffness)
  - Chemically inert
  - Long lifetime
- Cutting protection is also based on the same platform
  - Composite structure enables adding different levels of cut protection
- Testing of Jacket composite structure
  - Lab tests and field trials made to confirm the suitability of the protection layer.
  - Seabed drag testing conducted vs. base case Moorline rope.
    - Specimens were repeatedly dragged, lifted/dropped, and abandoned
    - Damage due to abrasion and particle ingress of each rope was documented..
- Currently under discussion with class societies and lead users

Integral floatation

- Why is buoyancy needed:
  - Keep rope off sea bed (e.g. Fouling weight, Leeward lines)
  - Modify mooring response
    - Inverse catenary
- Effective, economical solution developed compatible with all other line features
  - Fully integrated (protected), flexible and scalable
  - Drastic reduction in component count.





Industrial grade rope terminations

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- Human-factor
- Labor and time intensive
- Splice setting variation

APPLIED FIBER

- Industrial process
  - Higher output
  - Easier to scale (Industry 4.0)
  - Subrope condition monitoring functionality
  - Reducing human factor variation
  - Suitable hardware substrate for **monitoring**

100% Strength efficiency

100% length accurate

100% repeatable

Market Requirements & Dependencies

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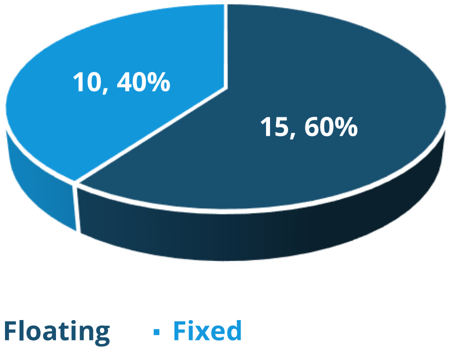
ScotWind: 25GW Offshore Wind



- Assuming 15MW turbines: 15GW floating equates to 1,000 floaters
- Each floater requires 4-6 mooring lines therefore 4,000-6,000 lines over the next 10 years

Production

- Current capacity at BBRG is 200-300 mooring lines per annum
- Therefore can satisfy the needs of 30-75 floaters per annum
- 15-30 years to meet requirement of ScotWind alone

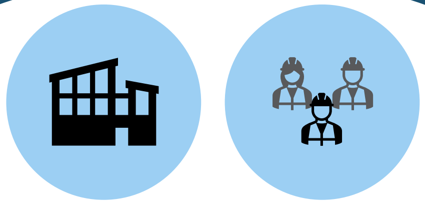
Workforce

- Current workforce employed in Scotland is approx. 40 people
- Operators, Innovation Engineers Project Teams
- Based in Coatbridge with no dedicated resource in Grangemouth

Our Commitment to Scaling-up

Local Value Creation

Horizon 1 (Today)



Horizon 2 (2-5 Years)

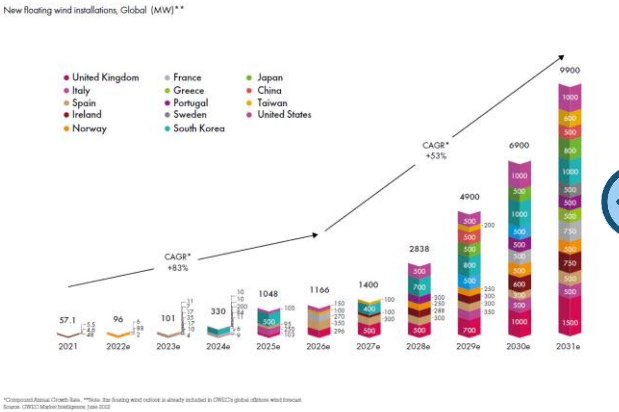
- Triple our capacity in Scotland to satisfy 200-250 floaters per year
- Invest in new factory, additional machines and equipment
- Creation of 40-60 new jobs within Scotland and increasing shifts

Horizon 3 (5+ Years)

- Further increase capacity in Scotland to 400+ floaters per year
- Additional investments such as new production sites / workforce
- Expand operations in new markets to serve requirements locally with similar capacities to Scotland

Supply Chain & Logistical Challenges

Infrastructure and supply chains need to be ready in advance of the industry scaling up



Combined with training to ensure people have the skills required in advance

Supply Chain

- Reels for mooring lines are made to measure, standardisation would result in supply chain efficiency as reels could be reused
- Typically fewer/large reels are used to reduce cost however more/small reels offer logistical benefits via shipping containers
- Scaling of mooring line capacity is relatively easy when compared to heavier mooring components such as anchors, chains and floating foundations as they are typically setup for oil and gas

Infrastructure

- Ports will need investment for floating foundation construction, mooring systems as well as storage facilities
- Access will be required to cranes for heavy lifting, which could also lead to investment in strengthening port foundations
- Vessels could become a bottleneck, potential to utilise alternative vessels or depending on reels dimensions and reel solution, container vessels.
- Predictable Freight cost internally between loading port and fabrication site

How will this be possible?

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Strategic agreements with cost frameworks for a set period

Partnerships / creation of consortiums

Government provision for training required skills

Commitment & Collaboration
Between Developers, Contractors, Supply Chain & Other Key Stakeholders

Invest in infrastructure and supply chains to enable success

Price agreements with ports to support infrastructure development

Preferred partner / exclusive supply agreement for a set period