Introduction to Anchoring and Mooring Solutions and the Celtic Sea FOW Opportunities

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CATAPULT Offshore Renewable Energy

Agenda

- ORE Catapult
- Introduction to Anchoring and Mooring Systems
- Celtic Sea Opportunities
- FOW CoE Tender

The Catapult Network

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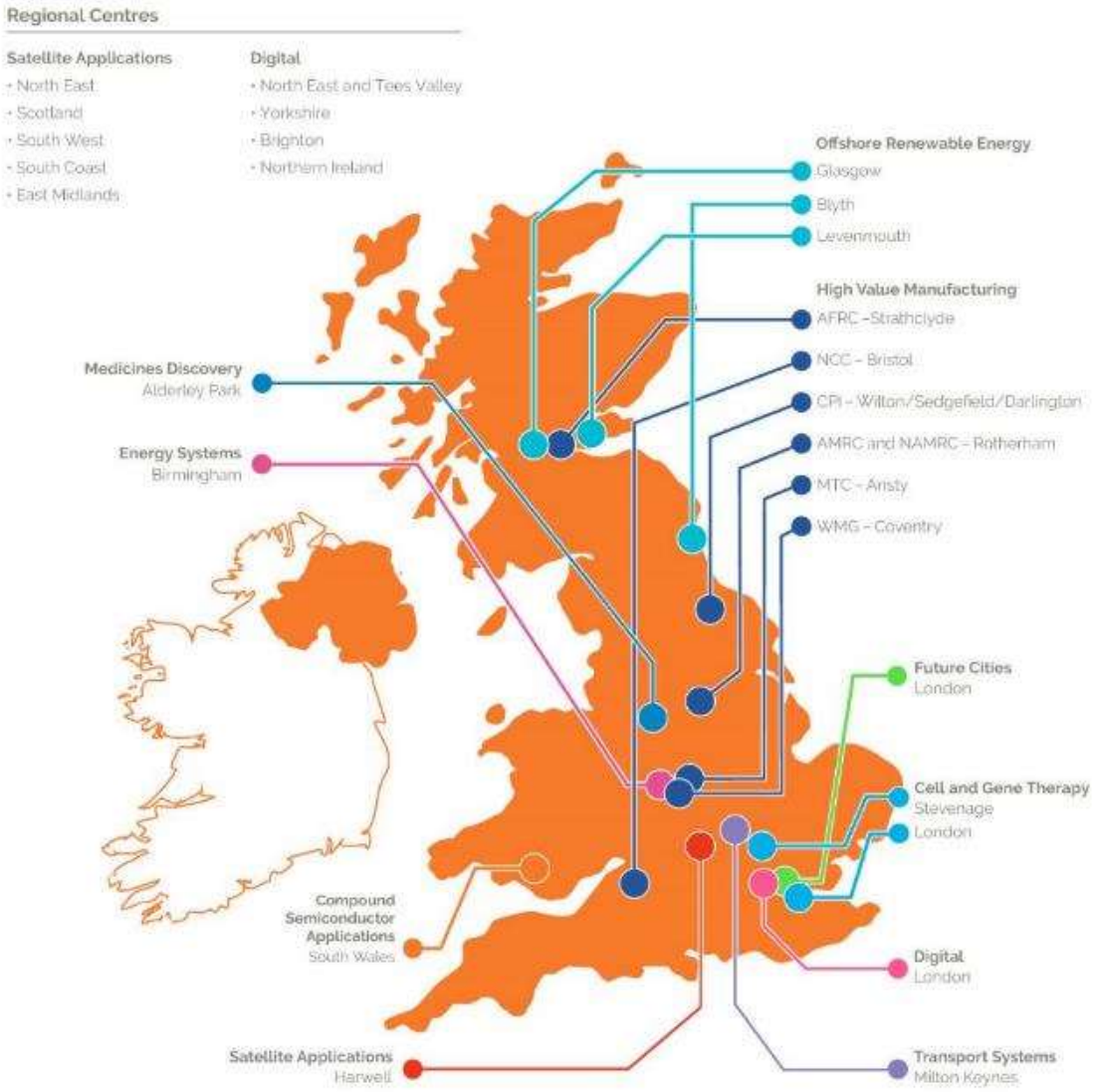
Innovate UK

- Designed to transform the UK's capability for innovation
- Core grant leveraged with industry and other public funding



Floating Offshore Wind Centre of Excellence

- Accelerating the commercialisation of Floating Offshore Wind – to deliver net zero and drive economic growth
- Collaborative programme with industry, stakeholder, academic and supply chain partnerships
- Developing and delivering a portfolio of collaborative project activity across four workstreams:
  - Technical development
  - Supply chain and operations
  - Development and consent
  - Delivering net zero
- Working with existing industry programmes, initiatives and activities to augment and accelerate

Introduction to Anchoring and Mooring

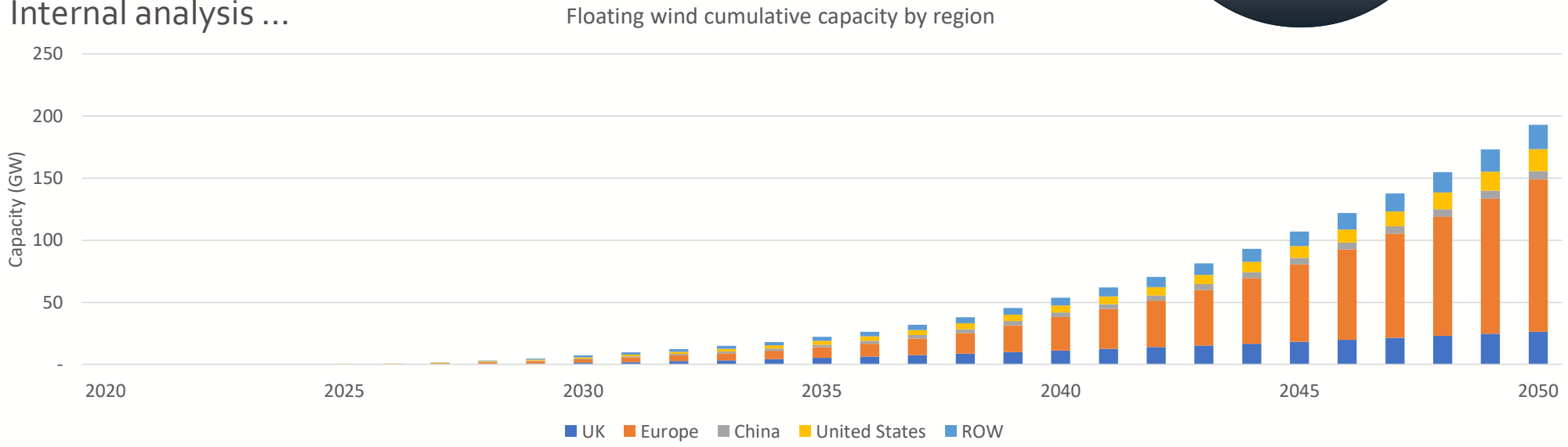
Floating Wind Potential

- ~75 MW installed globally with only one floating substation
- Over 50 substructures in development
- 4-30 GW by 2030 and 50-255 GW by 2050 depending on the source
- Critical for meeting net-zero targets
- Clear synergies with bottom-fixed wind and O&G, but also some key differences
- Internal analysis …

75 MW installed to date

Up to **30 GW** installed 2030

Up to **255 GW** installed 2050



Requirements for 1GW of Floating Offshore Wind (66 x 15 MW turbines)

2 years(???) of port leasing

Design services
Surveys
Monitoring
PM

170,000 tonnes of primary steel

8,000 tonnes of secondary steel

400+ mechanical connectors;
~130 electrical connectors

7,000 tonnes of auxiliaries

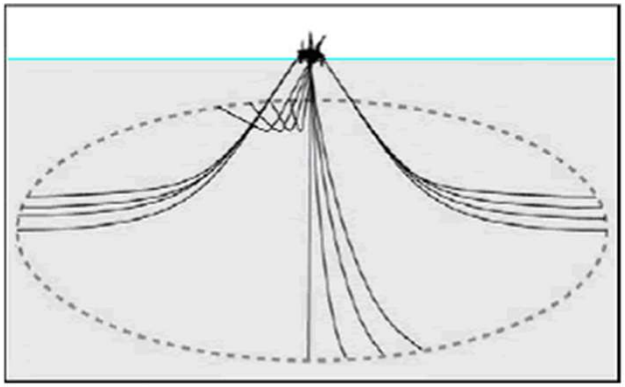
140 km of mooring lines;
200+ anchors

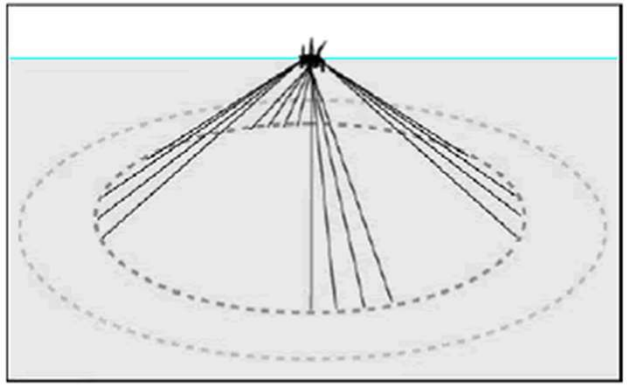
150km of array cables and associated protection and install

2,000 vessel days for anchors/moorings and platform/turbine installation

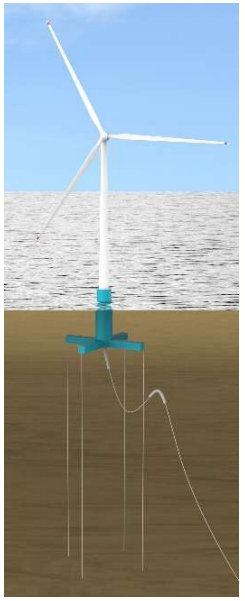
ILLUSTRATIVE ONLY

Mooring Solutions - Catenary vs Taut vs Tension





Credit: Vryhof

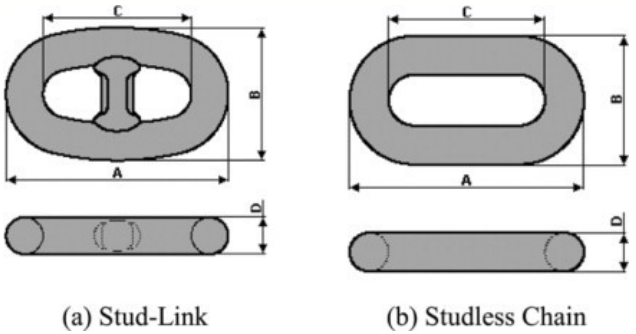


	Catenary	Taut	Tension
Stability	Buoyancy	Buoyancy / mooring	Mooring
Connection to seabed	Horizontal	Horizontal and vertical	Vertical
Loads on anchors	Reduced	Large	Large
Installation	Simple	Complex	Complex
Area required	Large	Medium	Small
Seabed disruption	High	Low to Medium	Low
Common material	Chain / wires	Synthetic fibres / wires	Synthetic fibres / wires

Mooring Solutions – Mooring Materials

Chain

- High abrasion resistance
- Large weight
- Good bending properties



(a) Stud-Link (b) Studless Chain

Steel Wire

- Lighter than chain
- Higher elasticity
- More likely to be damaged / corroded, jacketing is important

Synthetic Moorings

Polyester

- Proven in O&G and FOW
- Can exhibit nonlinear axial load elongation

Nylon

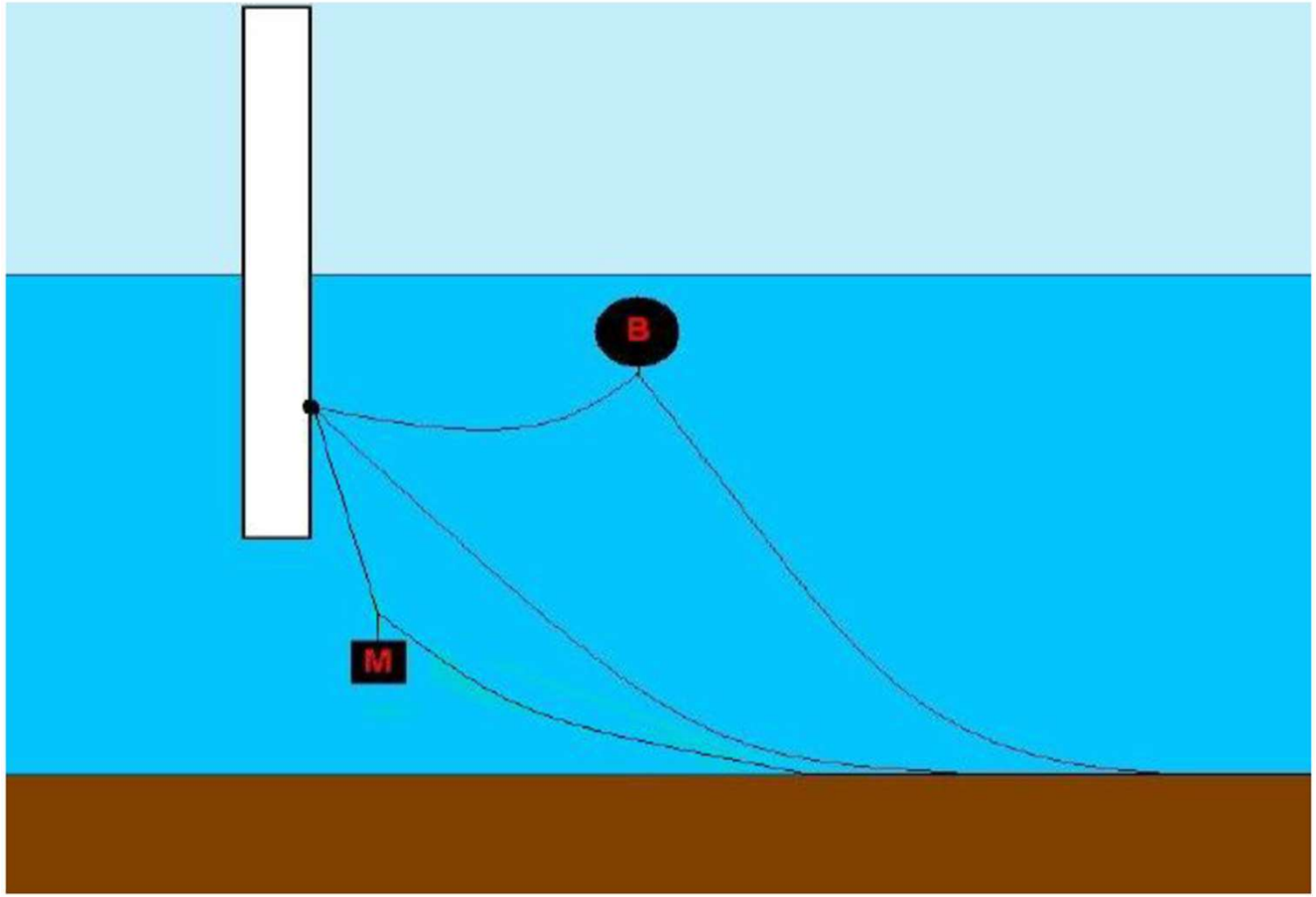
- High elasticity
- Well suited to shallow water
- Low durability

HMPE

- Higher strength
- High stiffness
- Well suited to TLP designs
- Creep may increase
- Potential or sudden rope failure

Credit: Offspring International Limited

Mooring Accessories



Credit: NTNU

Clump Weights

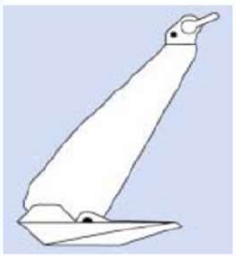
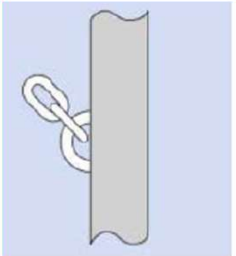
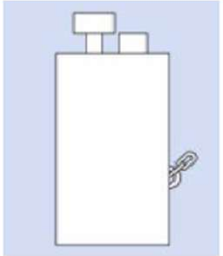
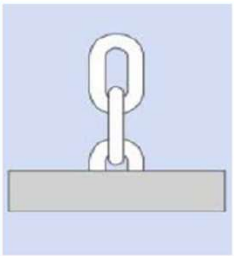
- Provide more vertical force
- Can make catenary moorings taut

Buoyancy

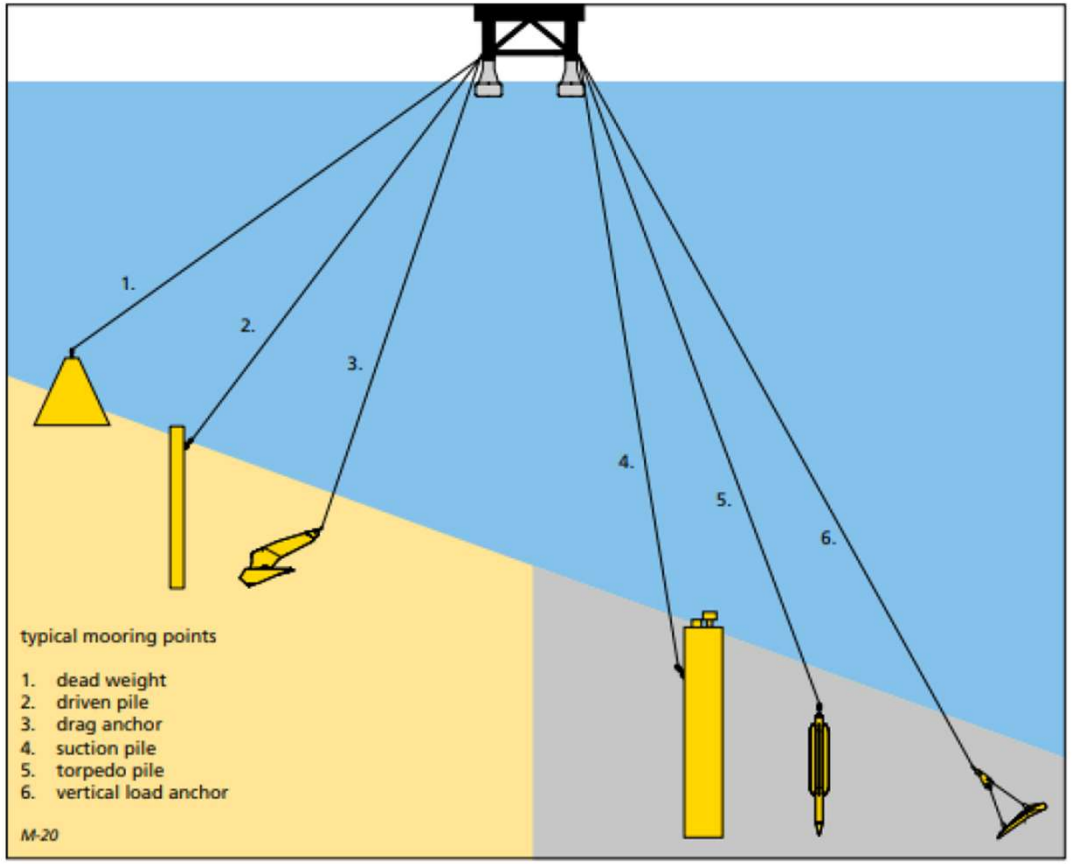
- Reduced mooring loads on platform
- Increased horizontal force

Credit: FMGC

Anchoring Solutions

Drag-embedded	Driven pile	Suction pile	Gravity anchor
			
• Best suited to cohesive sediments, though not too stiff to impede penetration	• Applicable in a wide range of seabed conditions	• Application constrained by appropriate seabed conditions - not suitable in loose sandy soils or stiff soils where penetration is difficult	• Requires medium to hard soil conditions
• Horizontal loading	• Vertical or horizontal loading	• Vertical or horizontal loading	• Usually vertical loading, but horizontal also applicable
• Simple installation process	• Noise impact during installation (requires hammer piling)	• Relatively simple installation, less invasive than other methods	• Large size and weight can increase installation costs
• Recoverable during decommissioning	• Difficult to remove upon decommissioning	• Easy removal during decommissioning	• Difficult to remove upon decommissioning

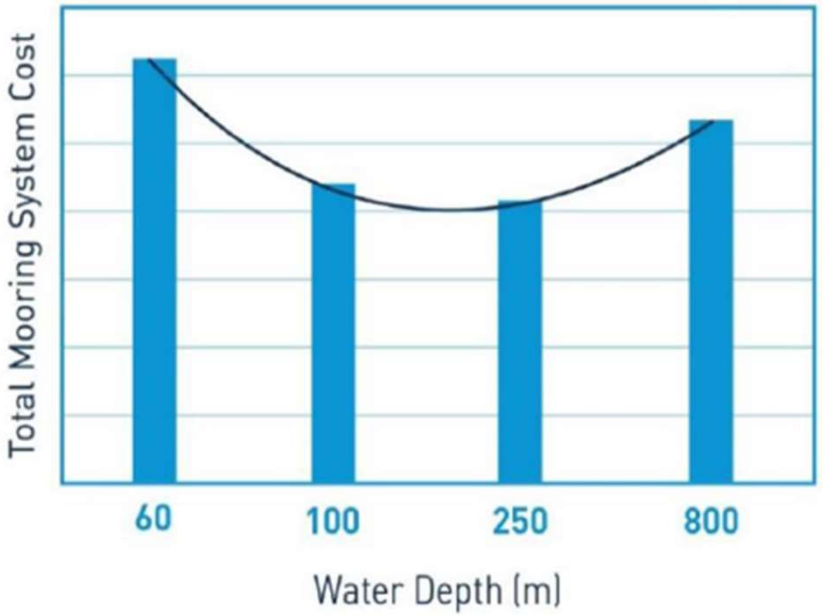
Credit: The Carbon Trust



Credit: Vryhof

Challenges for FOW Mooring Systems

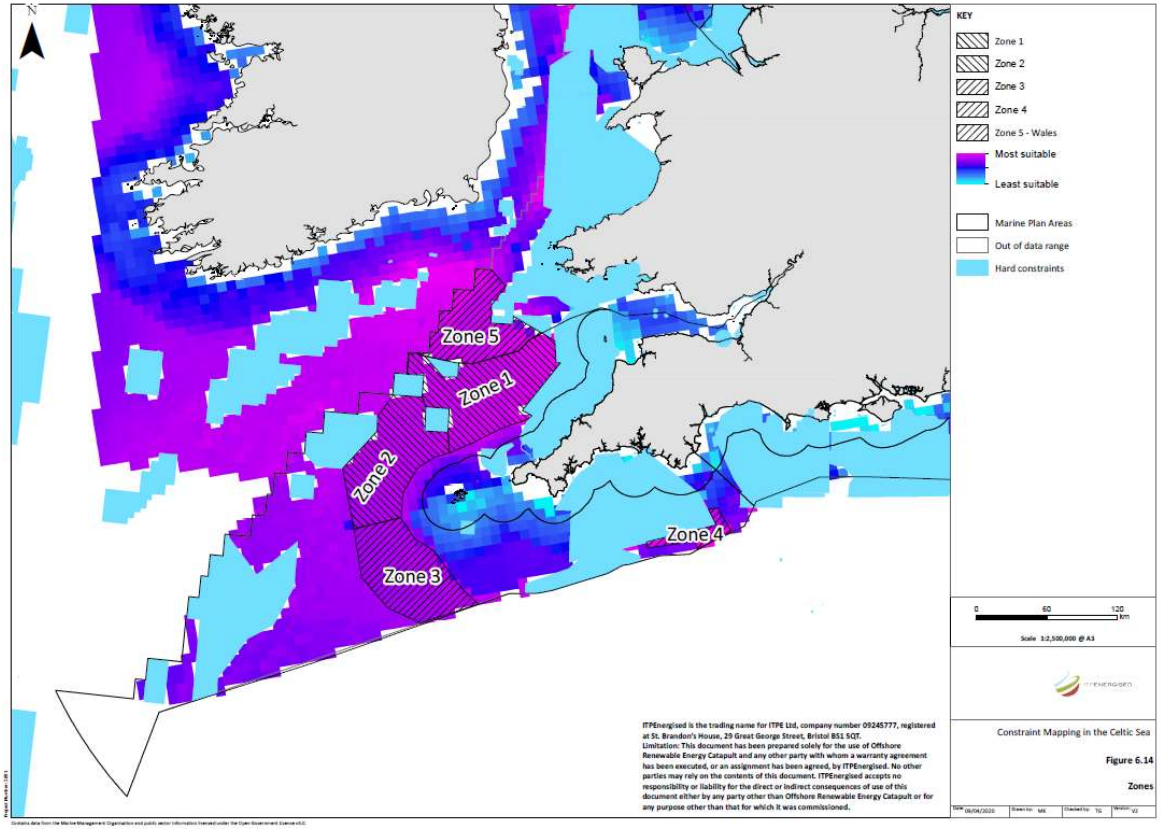
- **Shallow water moorings**
  - Relative horizontal drift increases
  - Increased fatigue damage
  - Increased cost
- **Redundancy required**
  - Possible mooring line failure based on O&G experience
  - Three mooring lines leaves room for drift in case of failure
- **Inspection and monitoring**
  - Monitoring line loads
  - Requirement for real-time monitoring of line loads
- **Quick connection / disconnection**
  - Subsequent re-tensioning of lines
- **Lack of design standards**
- **Manufacturing**



Credit: The Carbon Trust

Celtic Sea Opportunities

Identified Zones of Least Constraint



Potential Deployment Capacity:

Based on:

- High (4.8MW/km²)
- Mid (3MW/km²)
- Low (2MW/km²)

SW Zones:

Area: 18,000km²

Turbine Deployment capacity range:	36 – 86.4 GW

Welsh Zone:

Area: 3,983km²

Turbine Deployment capacity range:	7.9 – 19.1 GW

Irish Waters:

Area: 3,017km²

Turbine Deployment capacity range:	6 – 14.5 GW

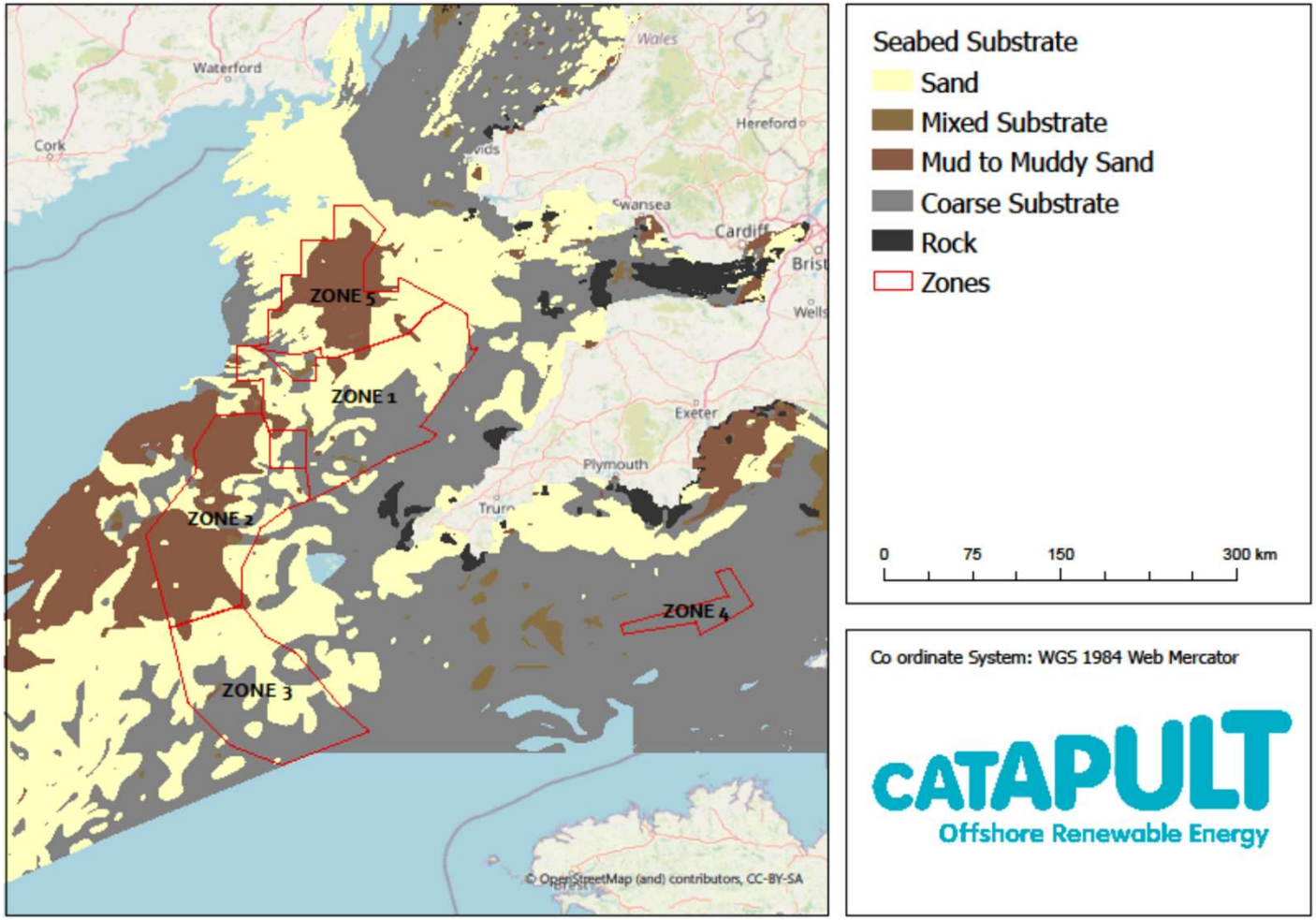
Total Celtic Sea Zones:

Area: 25,000km²

Turbine Deployment capacity range:	49.9 – 120 GW
Potential number of 15 MW WTG:	~3,000 – 7,000
Potential number of anchors (4/WTG):	~12,000 – 28,000
Potential length of moorings (140 km/GW)	~7,000 – 16,800 km

Celtic Sea – Seabed Substrate

- A number of different substrates
- Dominated by softer soils
- Limited/no rock substrate
- Site specific solutions required



FOW CoE Tender

FOW CoE – Mooring and Anchoring Systems Tender

Project Context

A key part of a floating wind turbine is the mooring and anchoring system. Alongside a diverse range of FOW substructures, there is additional complexity in designing mooring systems due to the diverse range of site conditions: ground type, water depth, current profiles, wave conditions.

This project has been developed to help the industry (primarily developers and potential supply chain companies) understand the mooring / anchoring technology requirements of FOW, and to stimulate supply of these within the UK supply chain.

The project has been designed to stimulate interest and investment in the supply of products to meet these technical needs. It will ultimately improve the FOW industry's access to suitable, reliable and cost-effective mooring and anchoring technologies for use in UK projects.

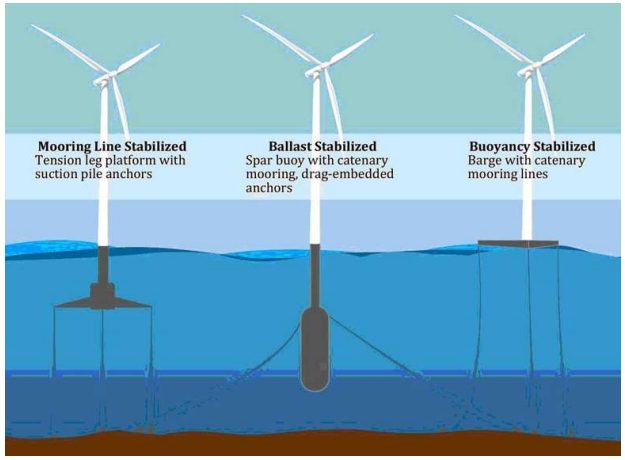
Key Project Outcomes

- Generic mooring systems design requirements for UK waters;
- Understanding of future market projections and the UK supply chain capacity / capability to deliver mooring systems to meet these;
- State-of-the-art review of mooring technologies;
- Follow-on technology design, development and /or benchmarking programme of works outlined.

Work Packages

1. Project Scope
2. Design Requirements
3. Market Projections
4. Supply Chain Capability and Capacity Assessment
5. State of the Art Review
6. Technology Development /Benchmarking Programme Design

Anticipated schedule: Dec 2020 – Aug 2021



Mooring systems for different floating substructures

Image from Google

ITT in early November on https://ore.catapult.org.uk/about/governance-2/procurement-contracts/

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