FLOATING OFFSHORE WIND
CENTRE OF EXCELLENCE

Delivered by CATAPULT Offshore Renewable Energy

Guide to a Floating Offshore Wind Farm

Scott Davie

Floating Offshore Wind 2023

Photo courtesy of Principle Power. Artist: DOCK90

Guide to a Floating Offshore Wind Farm

- The ‘Guide to a Floating Offshore Wind Farm’ is an online interactive guide to the fundamentals of floating offshore wind technology
- This guide follows on from the success of the existing ‘Guide to an Offshore Wind Farm’ created for fixed-bottom offshore wind
- Funded by ORE Catapult, the Floating Offshore Wind Centre of Excellence (FOWCoE), The Crown Estate and Crown Estate Scotland
- The FOWCoE programme aims to accelerate the commercialisation of floating offshore wind
- Produced by the FOWCoE in collaboration with BVG Associates
- Launched in June 2023

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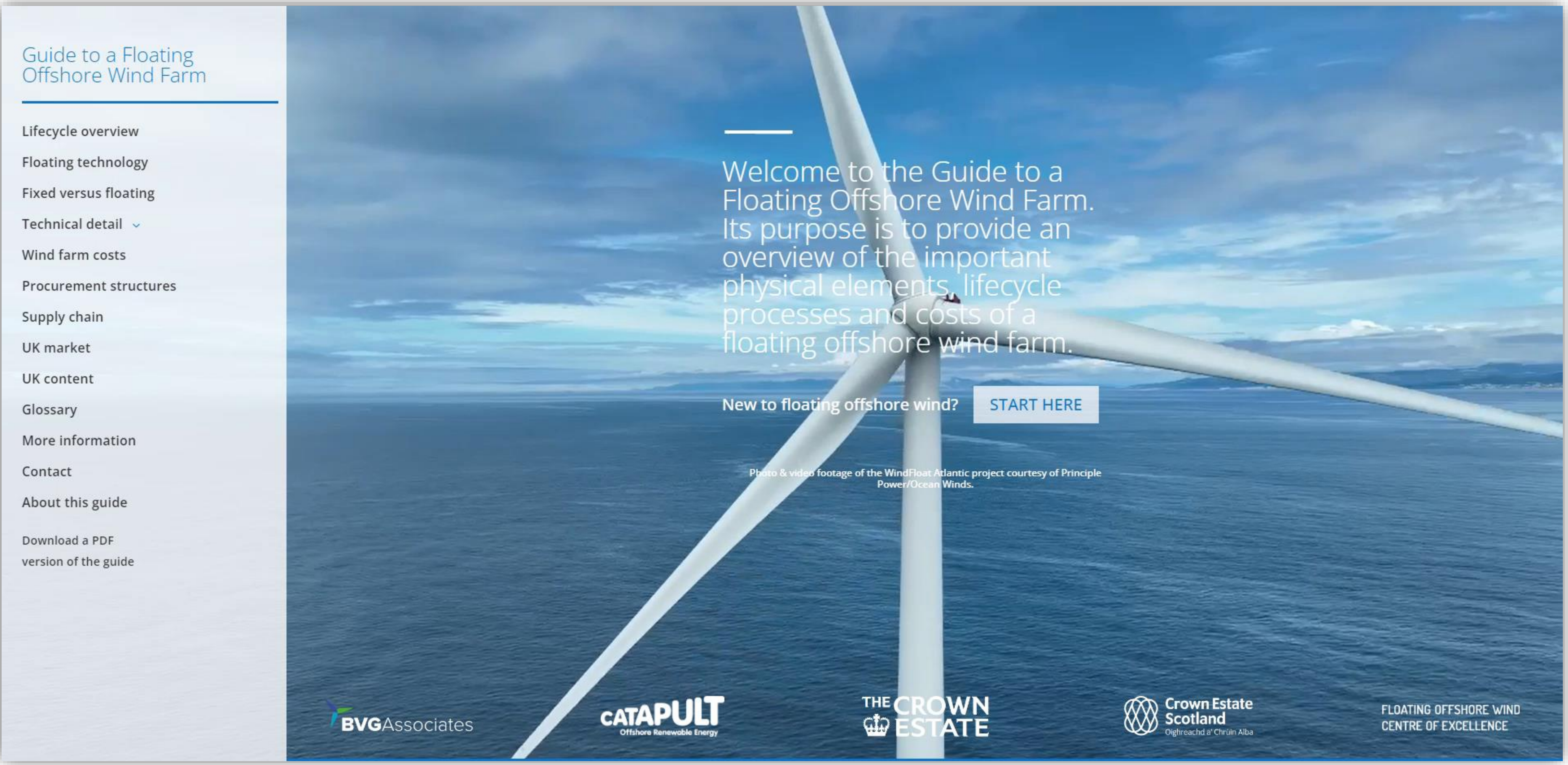

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Floating Technology

This page provides an overview of the main types of floating offshore wind substructure:

- Semi-submersible
- Barge
- Spar
- Tension-leg Platform (TLP)

The main characteristics of each substructure type are described, including their manufacture, installation and operational performance

Image Courtesy of Principle Power/ Ocean Winds

Image Courtesy of BW Ideol

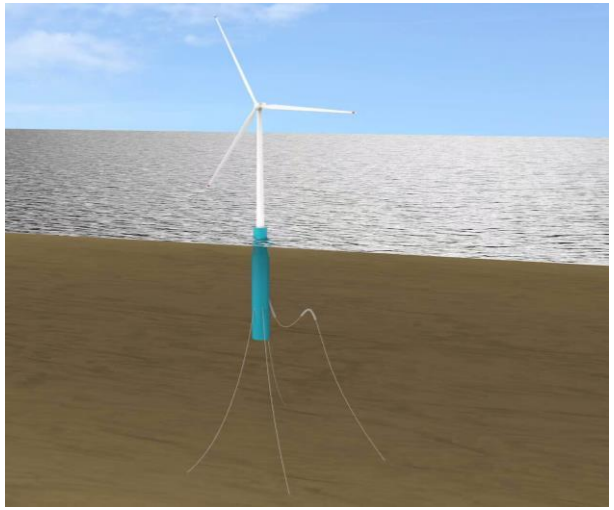


Image Courtesy of ORE Catapult

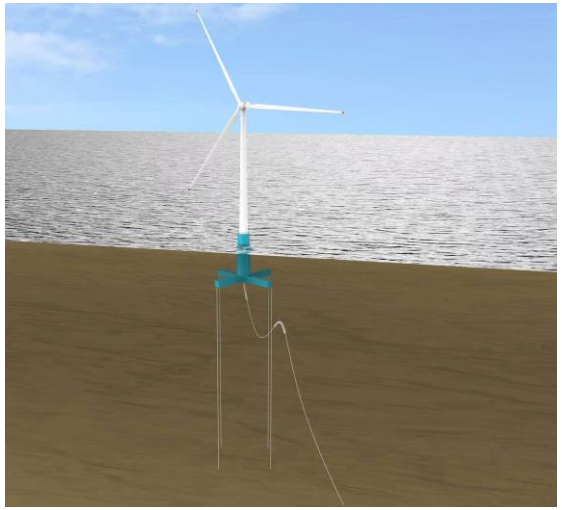
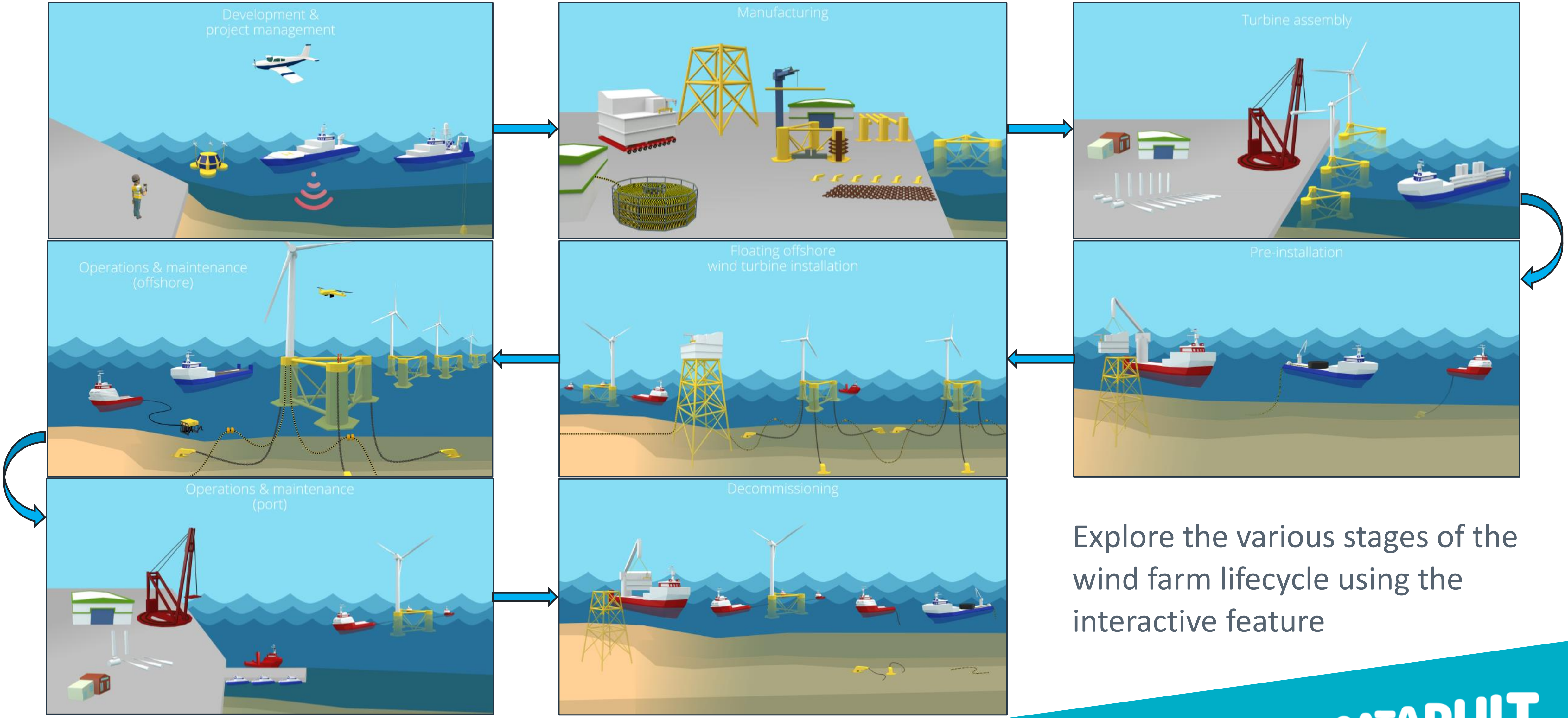


Image Courtesy of ORE Catapult

Lifecycle Overview



Explore the various stages of the wind farm lifecycle using the interactive feature

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Technical Detail – Technology and Wind Farm Definitions

- This guide uses a single reference design of floating substructure to provide a narrative that can be followed easily. This is a three-column, steel, semi-submersible substructure.
- It is selected because it has already been demonstrated at two pre-commercial floating offshore wind farms and could be used widely elsewhere. It was not selected to represent the best future solution.

This guide also assumes that:

- Each floating substructure uses a three-point mooring with drag embedment anchors
- The offshore substation is supported by a fixed jacket foundation, not a floating foundation

Site definitions used in this guide

Parameter	Data	Unit
Year of FID	2025	
First operation date	2028	
Wind farm rating	450	MW
Turbine rating	15	MW
Water depth at site	100	m
Annual mean wind speed at 100 m height	10	m/s
Distance from offshore substation to export cable landing point on the shore	60	km
Distance from to export cable landing point onshore substation	10	km
Ground conditions	Benign, allowing a piled substructure for the substation and drag embedment anchors for the floating offshore wind turbines	

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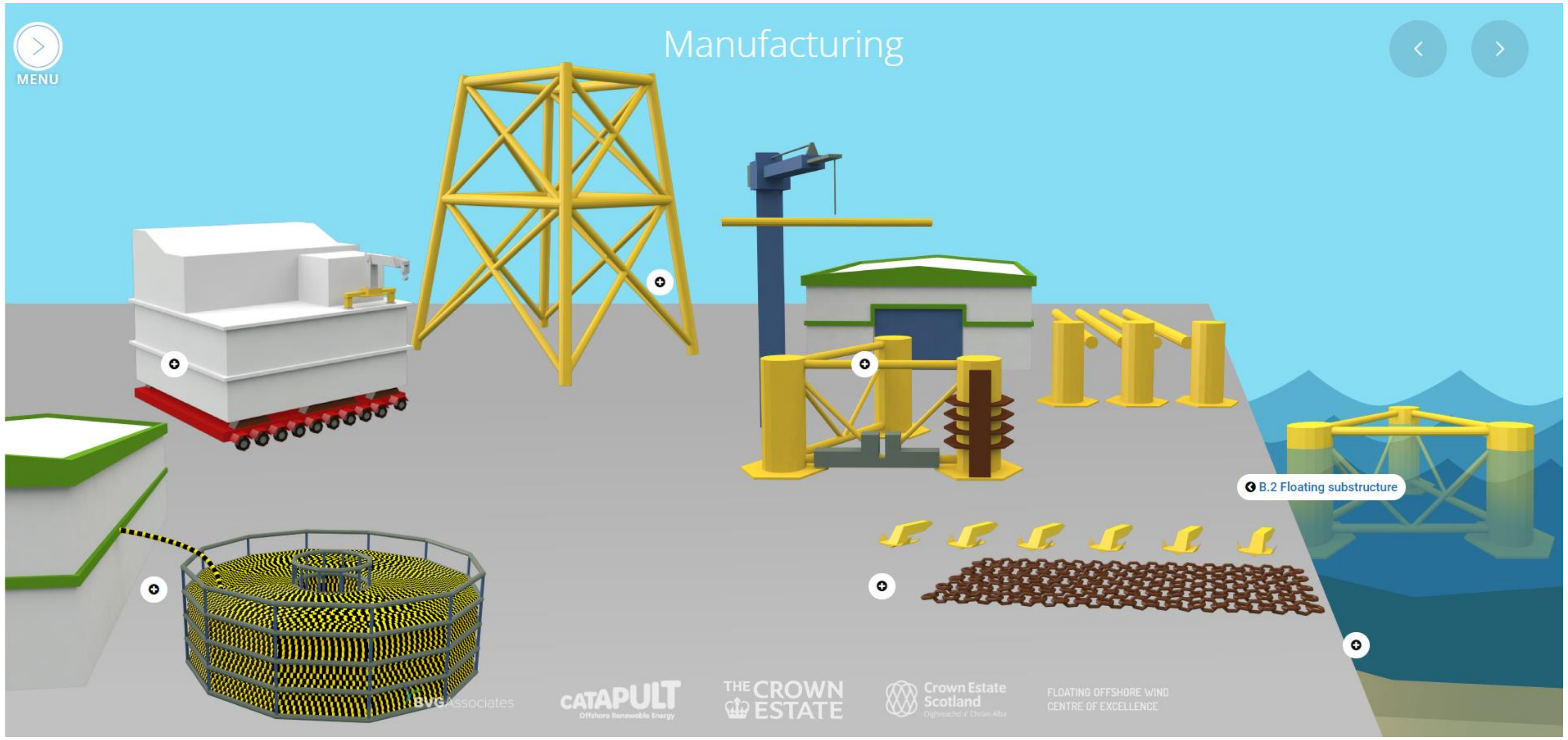
Technical Detail – How to access?

Technical detail
- Introduction
- Development and project management
- Wind turbine
- Balance of plant
- Installation and commissioning
- Operations and maintenance
- Decommissioning

Technical detail
- Introduction
- Development and project management
- Wind turbine
- Balance of plant
  - B Balance of plant
    - B.1 Cables
      - B.1.1 Array cable
        - B.1.1.1 Array cable core
        - B.1.1.2 Array cable outer
      - B.1.2 Export cable
        - B.1.2.1 Export cable core
        - B.1.2.2 Export cable outer
      - B.1.3 Cable accessories
        - B.1.3.1 Interface
        - B.1.3.2 Cable protection
        - B.1.3.3 Buoyancy
        - B.1.3.4 Connectors and joints
    - B.2 Floating substructure
      - B.2.1 Primary structure
      - B.2.2 Secondary steel
      - B.2.3 Substructure auxiliary systems
      - B.2.4 Corrosion protection
    - B.3 Mooring system



- The technical detail menu can be expanded to show all the information contained for each lifecycle stage
- The information can also be accessed via the interactive lifecycle overview

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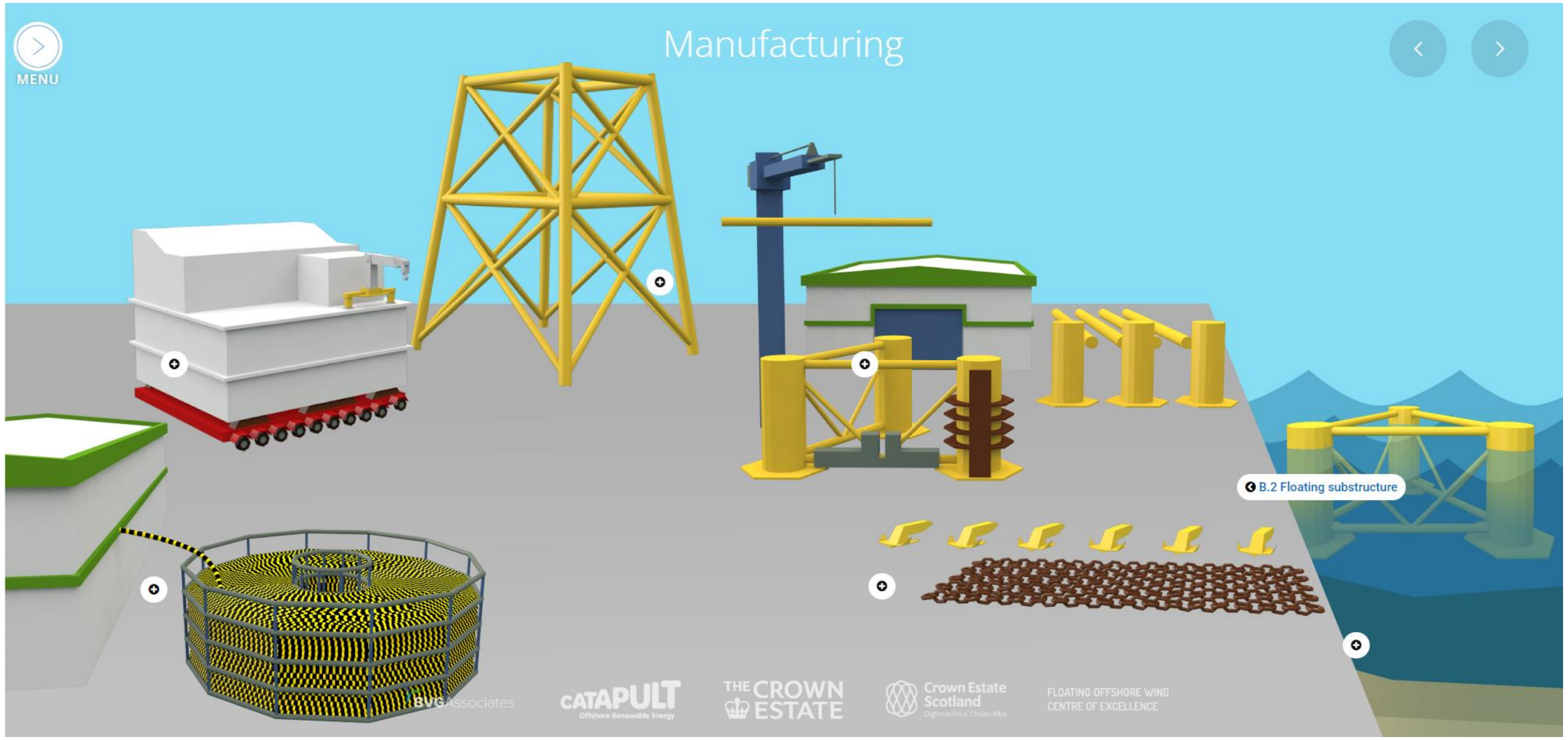

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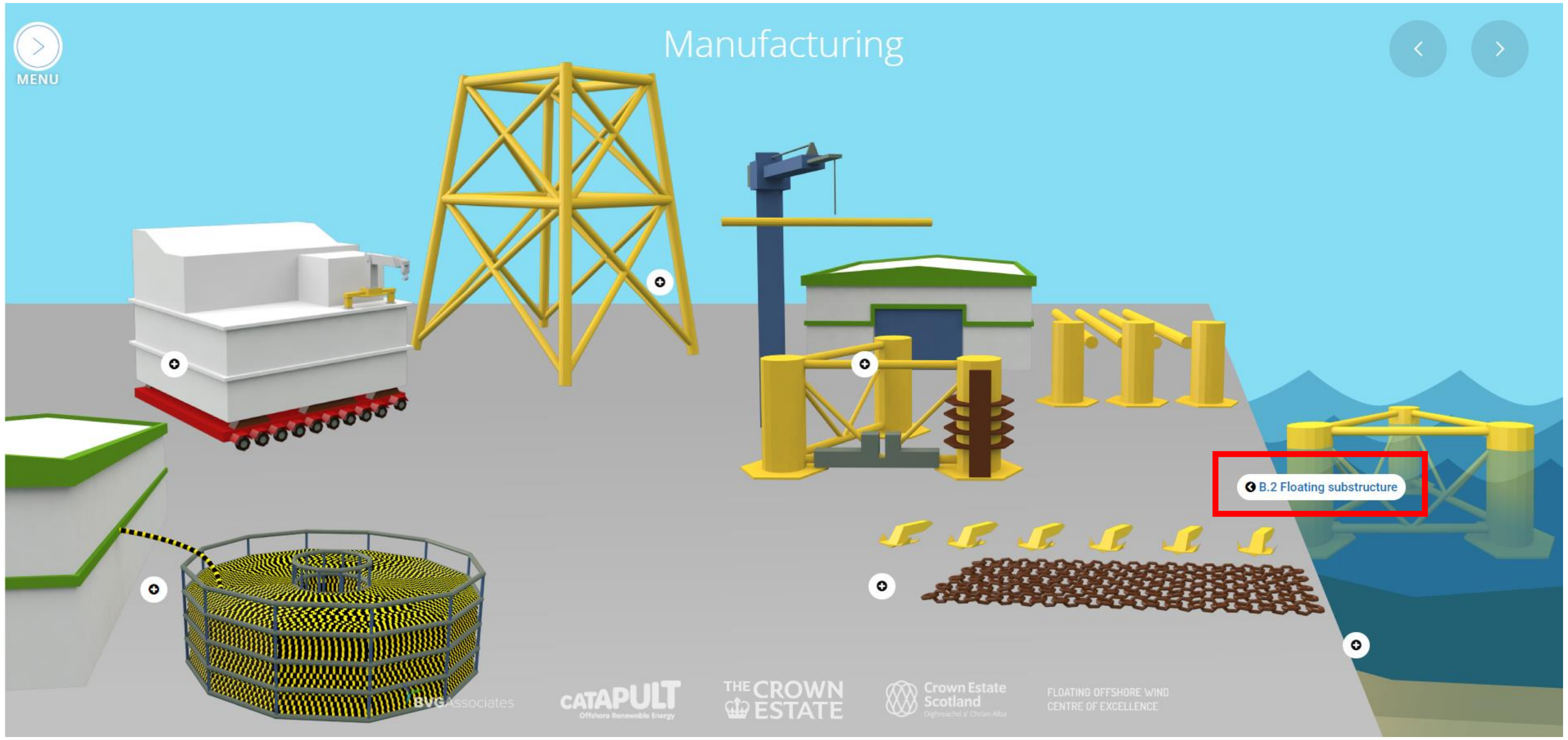

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Technical Detail – What's included?

Image Courtesy of Principle Power/ Ocean Winds

B.2 Floating substructure

← B.1.3.4 Connectors and joints

B.2.1 Primary structure →

Function

The floating substructure provides buoyancy to the turbine and, in conjunction with the mooring system, maintains the turbine's verticality and movements within acceptable limits. It also provides secondary functions of allowing access from vessels and accommodating ancillary equipment.

What it costs

About £430 million for a 450 MW floating offshore wind farm.

Who supplies them

Floating innovators: BW Ideol, Principle Power, Saitec, Stiesdal and SBM Offshore.

Engineering consultants: Kent and Ramboll.

Project developers: Equinor.

Steel fabricators: Bladt, EEW, Harland & Wolff, Lamprell, Navantia, Sif, Smulders, Welcon and Eiffage.

The contract for supply may be directly with the steel fabricator, or it can be through an EPCI contractor such as Aker Solutions, DEME, or Jan de Nul.

Key facts

There are four main types of floating substructures:

- Semi-submersible
- Barge
- Spar buoy, and
- Tension leg platform (TLP).

A typical steel semi-submersible for a 15 MW turbine has an unballasted mass of about 3,500 t and dimensions of about 80 × 90 × 35 m.

The substructure can move along three axes (heave: up/down, sway: right/left, and surge: forwards/backwards) or rotate about three axes (pitch: tilt from front to back, roll: tilt from side to side, and yaw: rotate when seen from above). Accelerations from all six degrees of freedom contribute to the loads on the wind turbine, so it is vital that the substructure (in combination with the mooring system) controls these to within acceptable limits for a range of metocean and wind turbine load cases.

What's in it

B.2.1 Primary structure | B.2.2 Secondary steel | B.2.3 Substructure auxiliary systems | B.2.4 Corrosion protection

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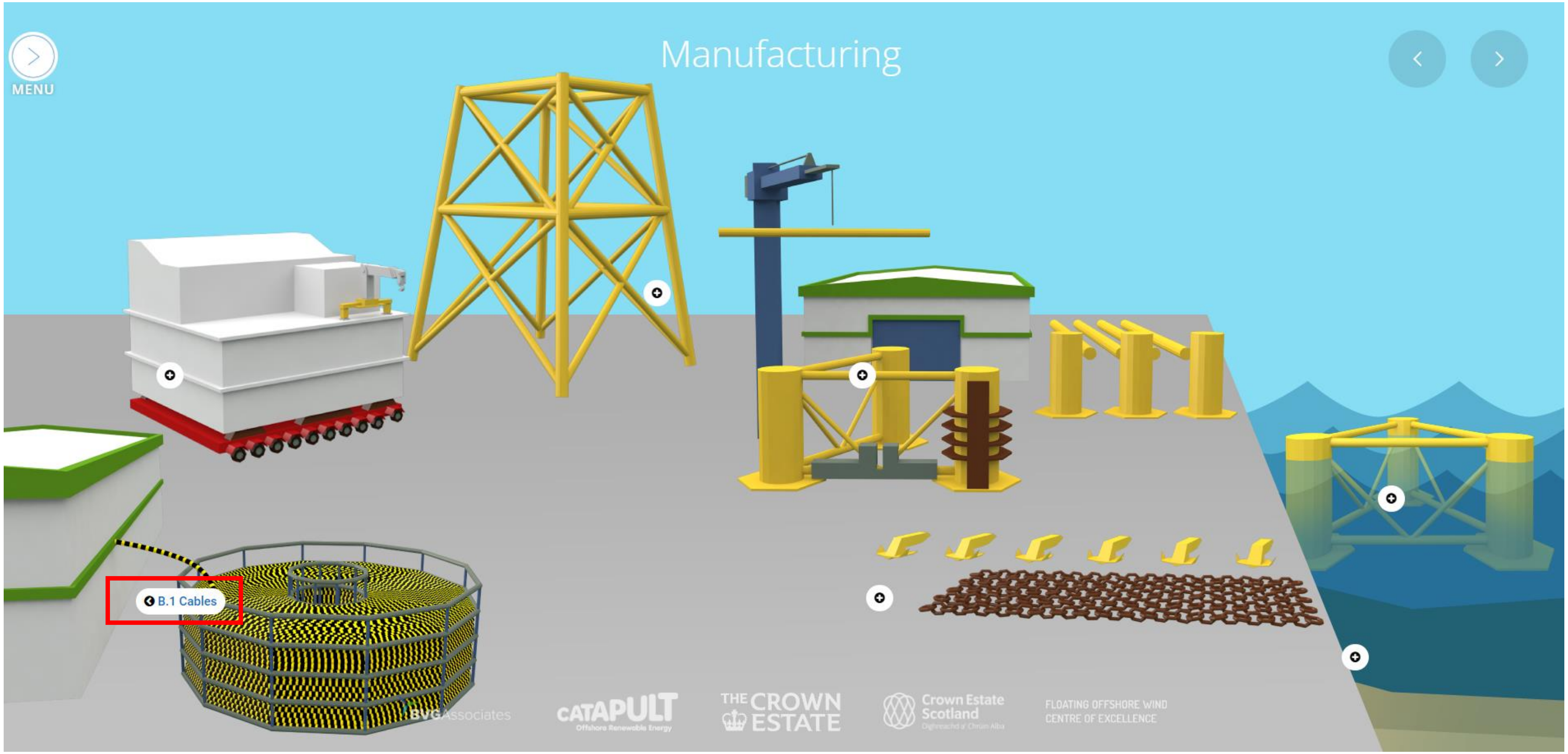
Technical Detail – What's included?



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Technical Detail – What's included?

B.1.1 Array cable

← B.1 Cables B.1.1.1 Array cable core →

Function

The network of array cables transfers power from the wind turbines to the offshore substation. It also provides auxiliary power to the turbines when they are not generating and provides fibre communications.

What it costs

About £32 million for a 450 MW floating offshore wind farm.

Who supplies them

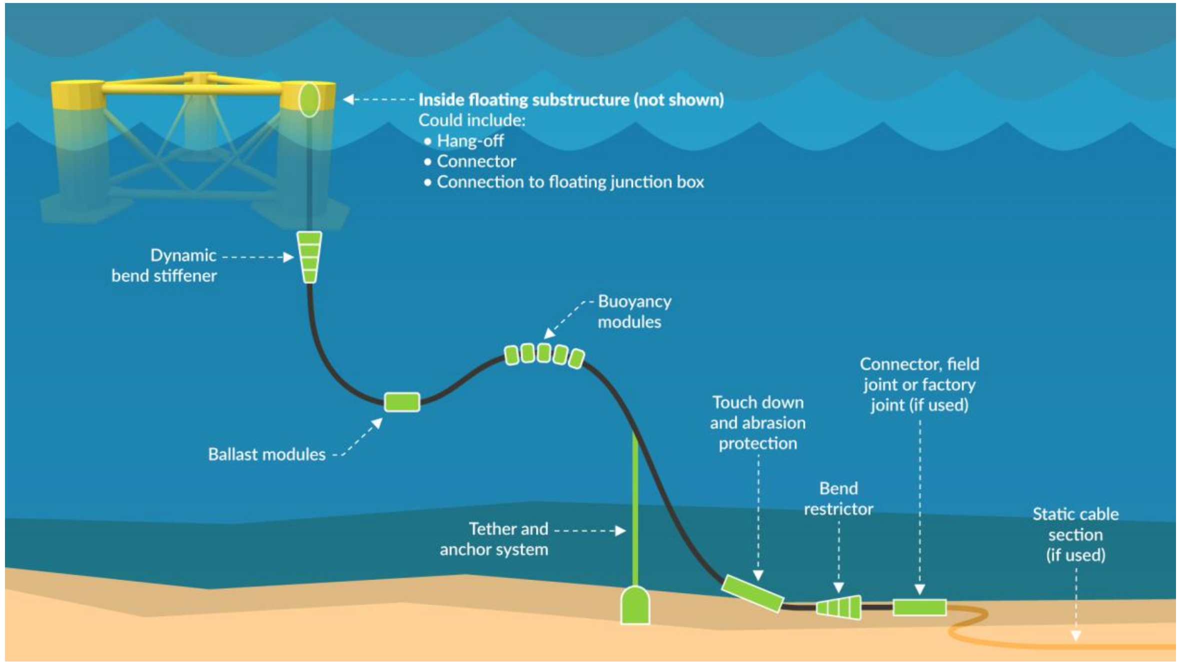
Hellenic Cables, JDR Cable Systems, LS Cable & System, Nexans, NKT, Prysmian, Sumitomo Electric and TKF.

There are other cable manufacturers based in China and Japan, but they have yet to be used widely for UK projects.

What's in it

B.1.1 Array cable B.1.2 Export cable B.1.3 Cable accessories

Dynamic array cable. Image courtesy of JDR.

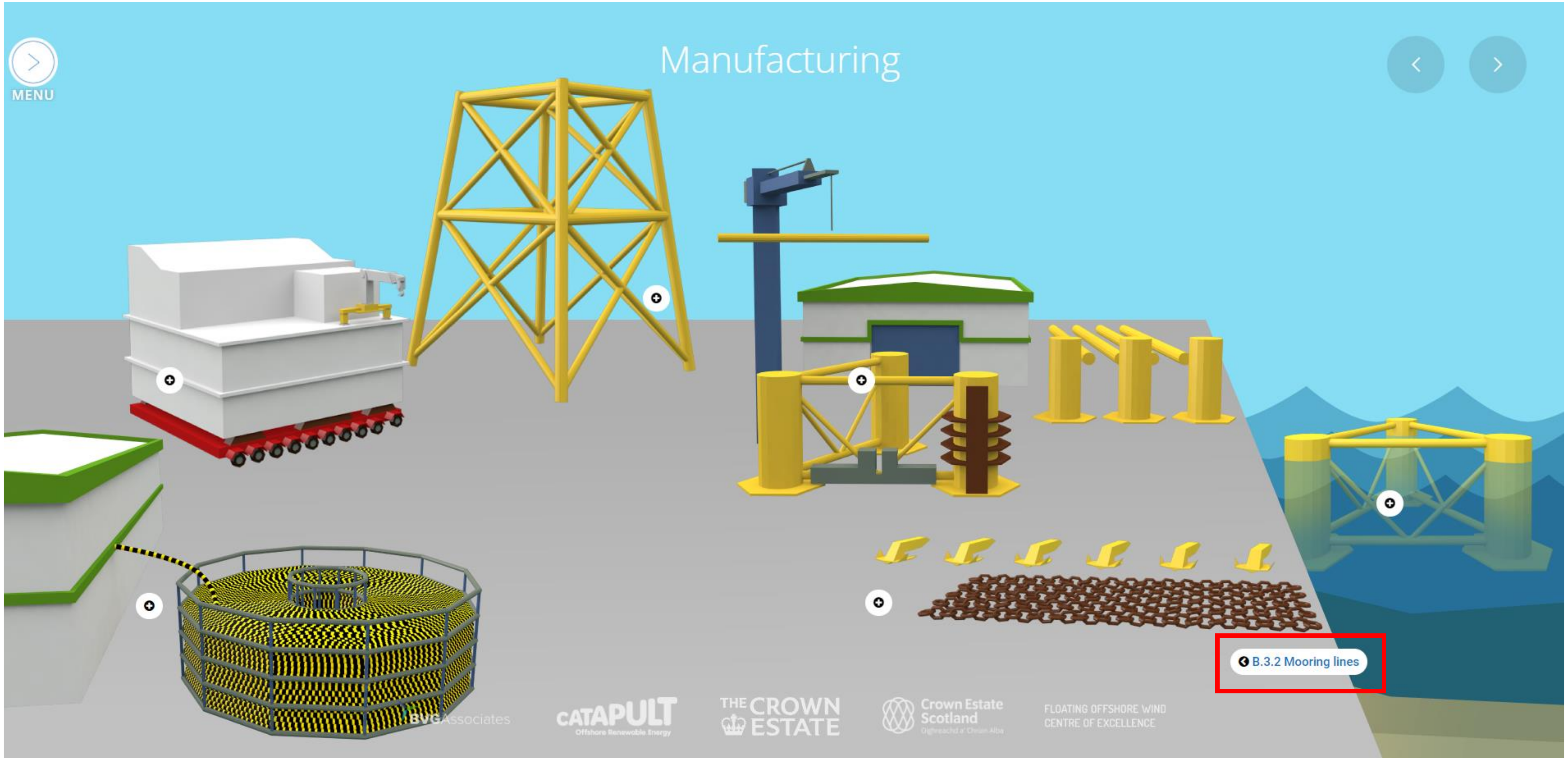


Key facts

Array networks are most often designed as "strings" which connect several turbines to the substation. They can also be designed in loops to increase redundancy.

Array cables are typically rated at 66 kV. In the next few years, array cable voltages are expected to increase to 132 kV. This is to accommodate more efficiently turbines rated at and above 16 MW and to reduce the number of array cable strings required.

Technical Detail – What's included?



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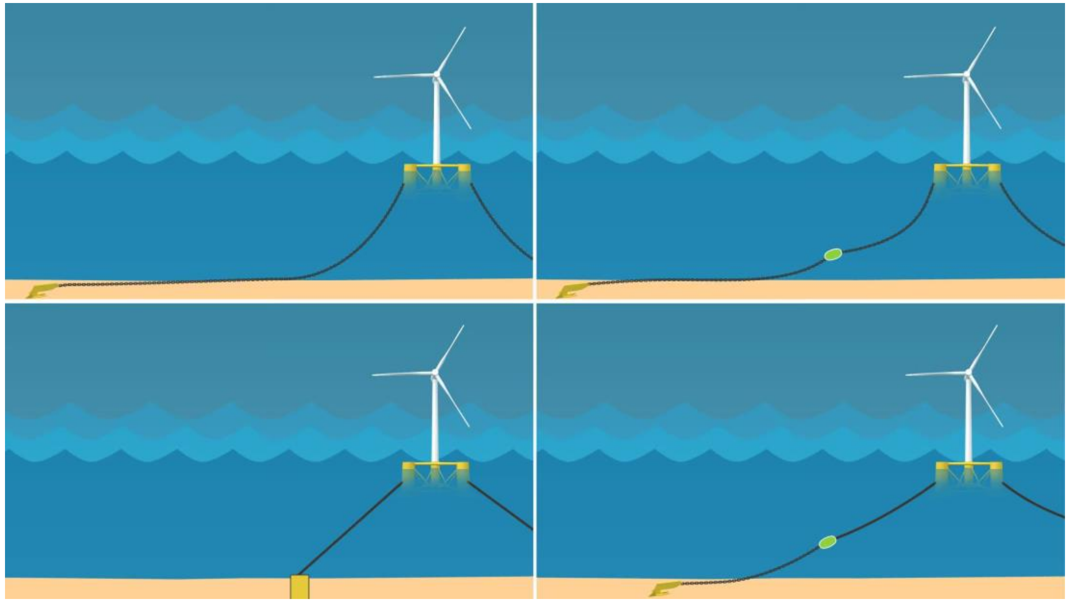
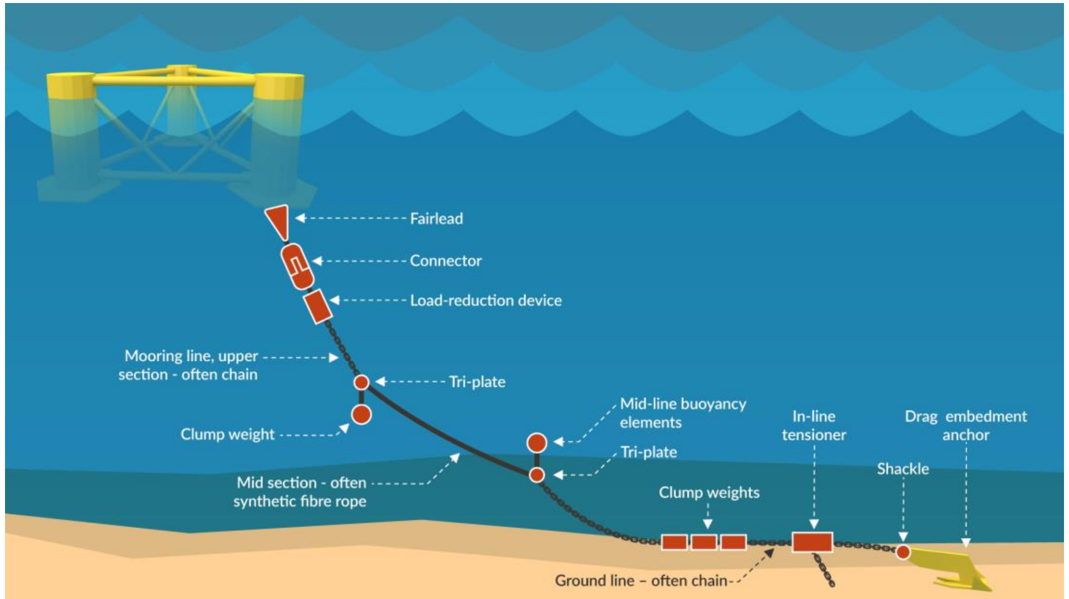
Technical Detail – What's included?





B.3 Mooring system

← B.2.4 Corrosion protection
B.3.1 Anchors →

Function

The mooring system provides the station keeping capability for the floating offshore wind turbine and contributes to the stability of the substructure and turbine.

What it costs

About £80 million for a 450 MW floating offshore wind farm.

Who supplies them

Bridon-Bekaert, Bruce Anchor, Delmar Vryhof, InterMoor, MacGregor, NOV and Vicinay.

What's in it

B.3.1 Anchors | B.3.2 Mooring lines | B.3.3 Jewellery | B.3.4 Topside connections

Key facts

There are four major mooring system options for a semi-submersible structure, shown in Figure 25 which provide compliance in different ways. The optimum design for each site is a technical and economic trade-off.

Anchors are used across many different industries and so the existing design types are well established, although new devices are coming on to the market at low technology readiness levels, providing the opportunity to anchor in a wide range of ground conditions. The anchor types expected to be used most for floating offshore wind turbines are:

- Drag embedment
- Driven pile, and
- Suction pile.

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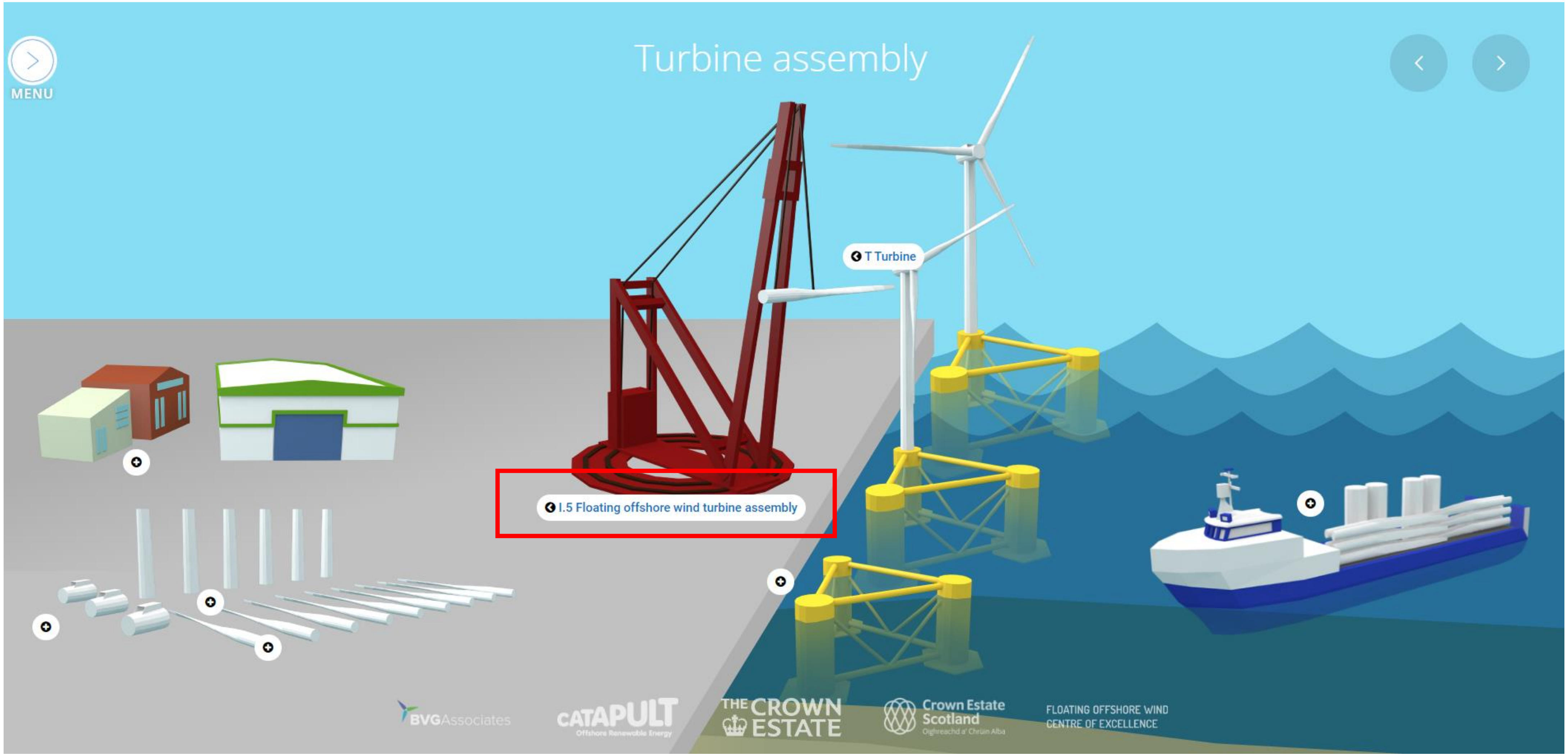
Technical Detail – What's included?



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Technical Detail – What's included?

I.5 Floating offshore wind turbine assembly

← I.4.2 Installation equipment

I.5.1 Heavy lifting and moving equipment →

Function

The assembly, pre-commissioning, and storage of floating offshore wind turbines that are ready for tow-out and installation.

What it costs

About £31 million for a 450 MW floating offshore wind farm.

Who supplies them

This work is usually contracted to either the wind turbine supplier, or to a wind turbine installation and commissioning contractor. The contractor normally provides supervisory input and subcontracts the work to a technician services company.

Key facts

Offshore wind developers have become used to assembly and installation rates of about two turbines per week for fixed wind farms, enabling the turbines for a 1 GW fixed offshore wind farm to be installed in a single season. An output rate of at least one floating offshore wind turbine per week is needed for a 450 MW wind farm with 30 turbines to be installed in one season, given typical constraints including weather.

The major turbine components are moved to the quayside, normally using SPMTs. Some pre-assembly work is expected to be performed at this stage, for example installing electrical equipment in the base of the turbine tower. Major turbine components have such high mass that they are normally stored, and pre-assembly work carried out, on specially reinforced pedestals.

The major turbine components are then assembled onto the floating substructure in a process known as final assembly or turbine integration. This activity can either be completed with a landside crane located on the quayside or by a temporary jack-up crane vessel alongside the quay. Ballasting the substructure so that it rests on a mattress laid on the sea bed improves its stability for lifting activities.

Image Courtesy of Principle Power

What's in it

- I.5.1 Heavy lifting and moving equipment
- I.5.2 Technician services
- I.8. Construction port
- Jack-up crane vessel
- Quayside crane
- Tower pedestal
- Transport and storage frames for major components including nacelles, blades, and tower sections

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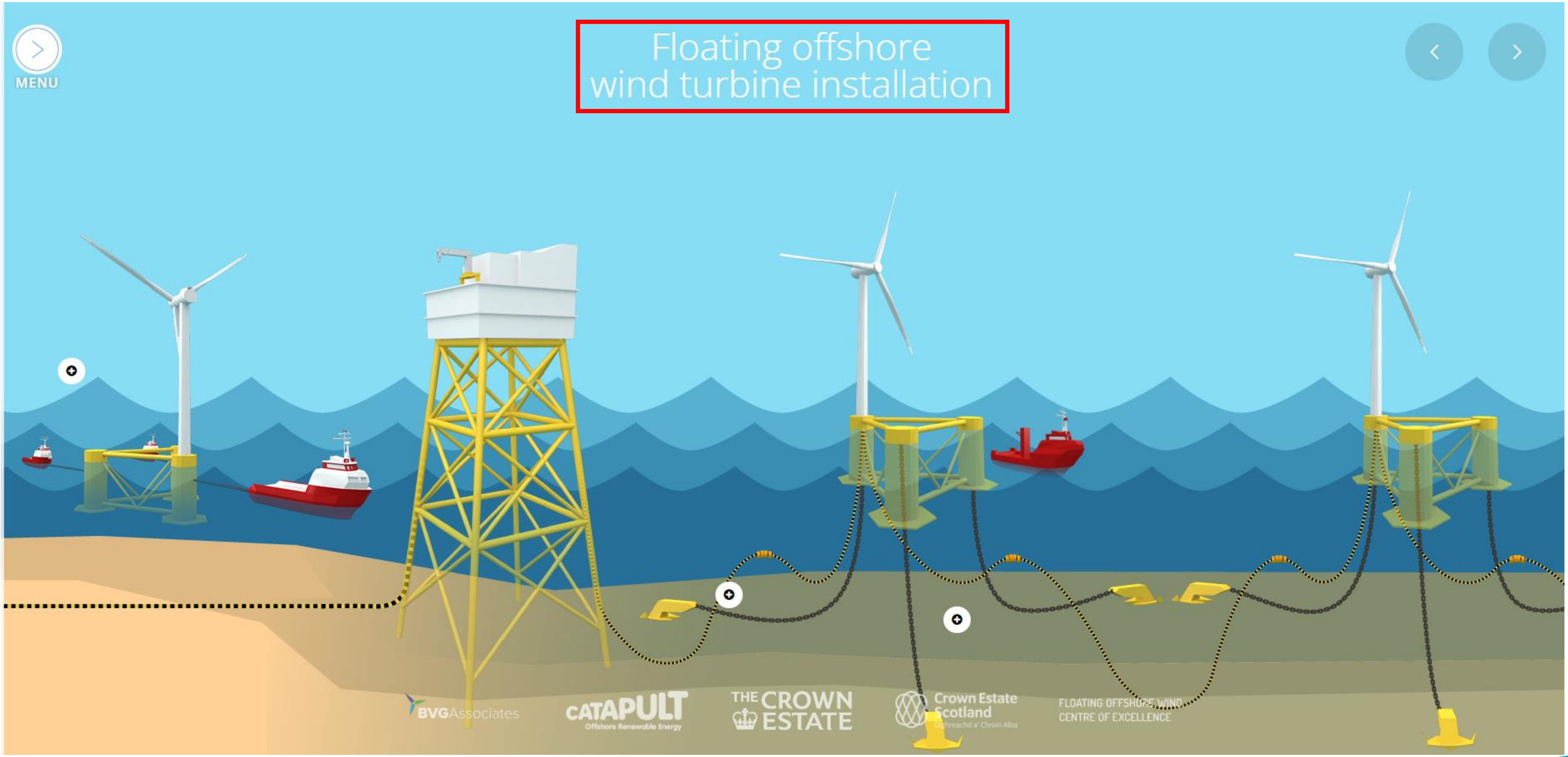
Technical Detail – What's included?



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Technical Detail – What's included?

I.6 Floating offshore wind turbine installation

← I.5.2 Technician services

I.6.1 Tow-out →

Image Courtesy of Principle Power/ Ocean Winds

Function

Tow-out of an assembled floating offshore wind turbine to site, hook-up to mooring lines and array cables, and the final commissioning of the installed floating offshore wind turbine.

What it costs

About £24 million for a 450 MW floating offshore wind farm.

Who supplies them

Boskalis, Bourbon Offshore, Maersk, Saipem and Seajacks.

Key facts

Floating offshore wind turbines are towed from the construction port to the offshore site with a primary AHV and smaller support vessels.

The floating offshore wind turbine is hooked-up to a pre-installed mooring spread once it arrives at site with the aid of the towing vessels.

The array cable is either connected to the floating offshore wind turbine once it arrives at site or later during post lay operations.

What's in it

I.6.1 Tow-out | I.6.2 Mooring line hook-up | I.6.3 Array cable hook-up | I.6.4 Final commissioning

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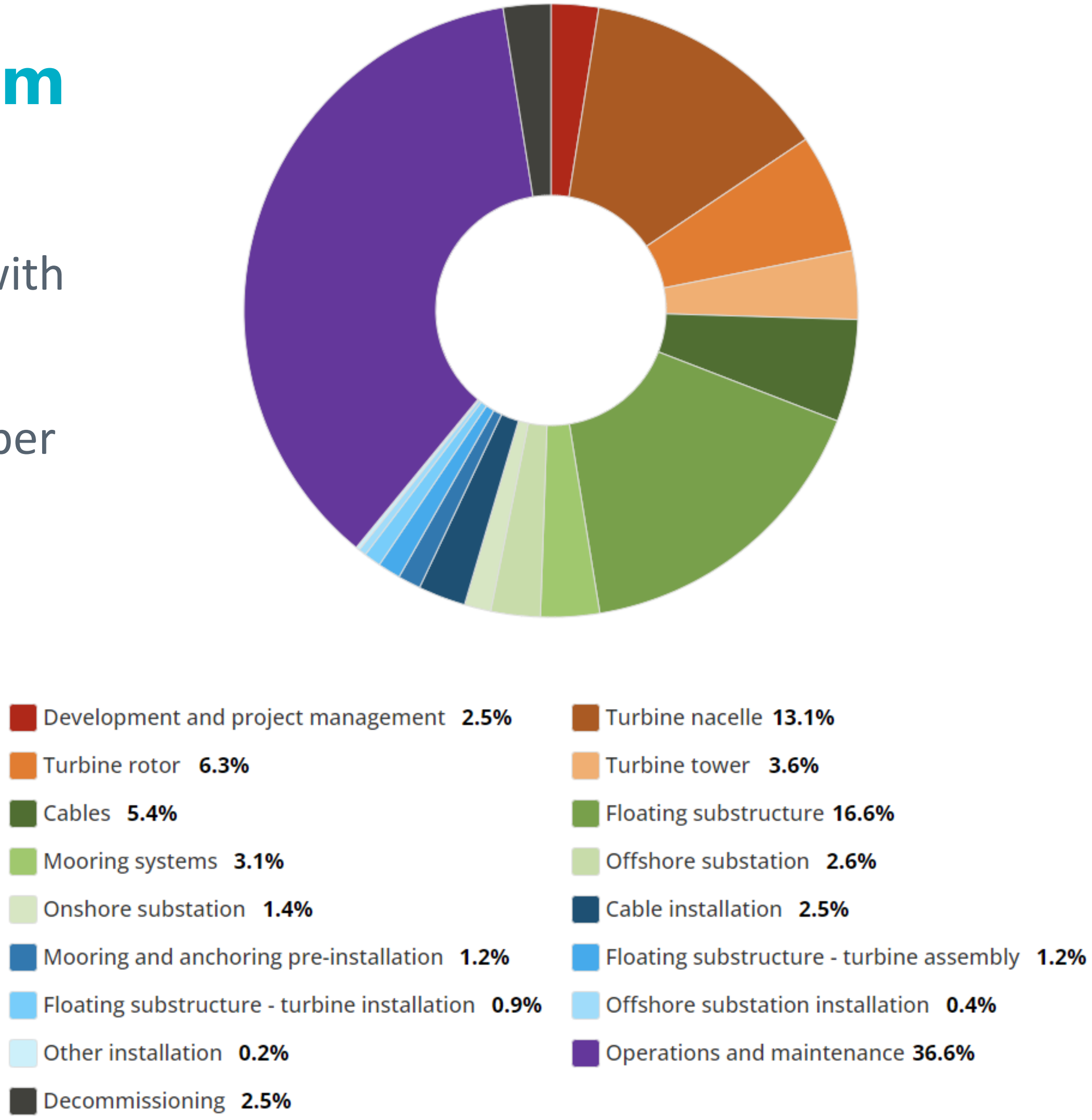
Cost of a Floating Offshore Wind Farm

- Cost calculation is based on a 450MW floating wind farm with 25 years operational life
- Costs presented have been scaled per MW for CAPEX and per MW/year for OPEX



Category	Rounded cost	Unit
Development and project management	150,000	£/MW
Wind turbine	1,300,000	£/MW
Balance of plant	1,700,000	£/MW
Installation and commissioning	370,000	£/MW
Operations and maintenance	71,000	£/MW/year
Decommissioning	150,000	£/MW
Contingency and insurance	270,000	£/MW

- Cost page of the website also includes an overview of Levelised Cost of Energy (LCoE), including its purpose, the key drivers and how it is calculated

FOW UK Market

2017

Hywind Scotland Pilot Park, first multi-turbine floating offshore wind farm

The first multi-turbine floating offshore wind farm is installed in the UK 30 km off the coast of Aberdeen. The project features five Siemens Gamesa 6 MW turbines mounted on spar floating substructures. Hywind Scotland follows on from a successful Norwegian demo project using a single 2.3 MW turbine which was installed off the coast of Norway in 2009.

2020

Erebus, first floating offshore Celtic Sea project

Simply Blue Energy and Total (now TotalEnergies) secure a lease for their 96 MW Erebus project in the Celtic Sea from The Crown Estate.

2021

Kincardine Offshore Wind Farm, second multi-turbine floating offshore wind farm

The second multi-turbine floating offshore wind farm is installed in the UK. This project features five Vestas 9.5 MW turbines mounted on Principle Power semi-submersible floating substructures and becomes the largest floating offshore wind farm in the world.

2021

Celtic Sea floating offshore projects

The Crown Estate awards three more test and demonstration licences for three 100 MW projects in the Celtic Sea. These are: Cobra Group/Flotation Energy's 100 MW Whitecross project, and Cierco's Lyr 1 and 2 projects each rated at 100 MW.

UK Market Overview includes:

- FOW demonstration project construction milestones including Hywind Scotland, Kincardine and Hywind Tampen
- FOW demonstration project award milestones including several ~100MW Celtic Sea developments
- FOW leasing round milestones including AR4, ScotWind and INTOG

FOW UK Market

2021

Wave Hub, renewable energy test site in Cornwall acquired by Hexicon

Swedish floating developer Hexicon acquires the Wave Hub renewable energy test site in Cornwall, which has permits and grid connection in place to allow the installation of up to 40 MW of capacity. The site will feature the first deployment of the TwinWind floating substructure technology.

2021

Floating projects included in CfD Allocation Round 4

The UK Energy Ministry BEIS publishes its terms for Allocation Round 4, which is open to participation from floating offshore wind projects for the first time. Floating projects for delivery in 2025-2027 compete for supports against other eligible 'less established' technologies, but BEIS ringfences budget in this technology pot for first access to floating offshore wind projects. EDF's 58.4 MW Blyth Phase 2 and Hexicon's TwinWind demonstrator are expected to participate.

2022

Scotwind lease round

In January, 17 new projects were awarded leases through Crown Estate Scotland's Scotwind process. 10 projects that will use floating technology secured 15 GW of the 24 GW total capacity awarded in the round. The sea bed leasing process raised a total of £700 million in option fee payments for the treasury.

In August an additional three floating projects totalling 2.8 GW were awarded off Shetland.

2022

Hywind Tampen takes shape

Equinor installs most of the 11 Siemens Gamesa 8 MW turbines on concrete spar buoys at its Gullfacks and Snorre oil field in Norway, marking the first time an offshore wind project has been connected to an oil and gas platform.

UK Market Overview includes:

- FOW demonstration project construction milestones including Hywind Scotland, Kincardine and Hywind Tampen
- FOW demonstration project award milestones including several ~100MW Celtic Sea developments
- FOW leasing round milestones including AR4, ScotWind and INTOG

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FOW UK Market

2022

INTOG lease round

Following the success of the Scotwind process and Equinor's progress with Hywind Tampen, Crown Estate Scotland opens its 'Innovation and Targeted Oil and Gas' (INTOG) leasing round. The round will allow developers to bring forward innovation projects less than 100 MW and projects capable of providing power to oil and gas platforms. The round may create 6.2 GW of new capacity across both its parts.

2022

FLOWMIS launch

UK Energy Ministry BEIS is expected to open the 'Floating Offshore Wind Manufacturing Investment Scheme' (FLOWMIS) which will allocate around £160 million of funding towards the essential upgrade of port infrastructure required to enable the construction and marshalling of floating offshore wind technology in Scotland and Wales.

2023

Celtic Sea lease round

The Crown Estate is expected to launch the Celtic Seas leasing round in 2023 which will award around 4 GW of new floating offshore wind farm leases.

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- FOW demonstration project award milestones including several ~100MW Celtic Sea developments
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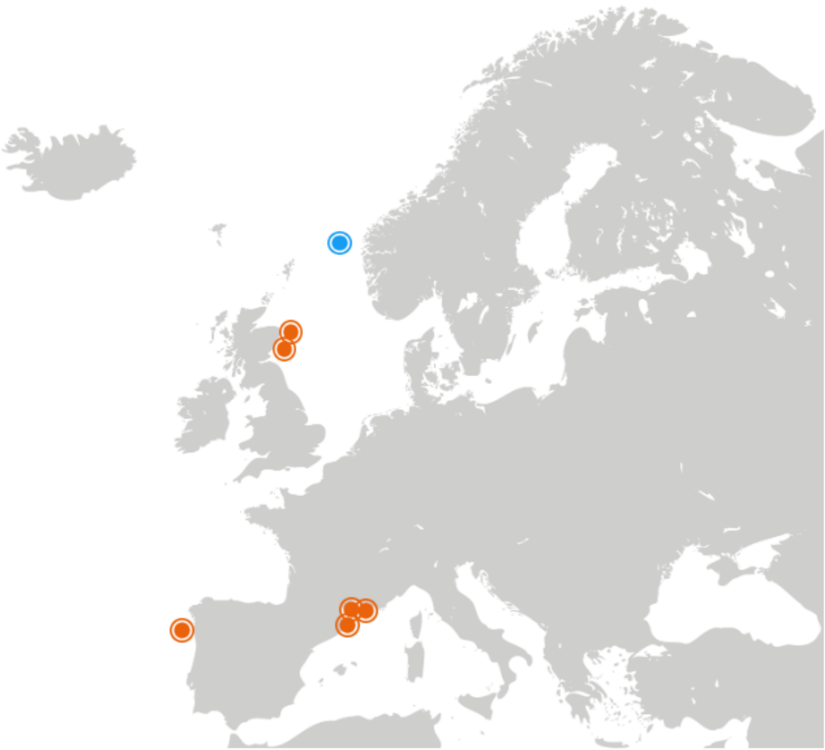
Supply Chain

Floating project suppliers

- Supply Chain page includes an interactive map of floating wind demonstration projects
- Supply chain companies involved in each project are listed
- Suppliers will also be able to sign up to our FOW Supply Chain Database linked to the Supply Chain page



Hywind Tampen

Supply chain area	Supplier
Developer	Equinor
Wind turbine supplier	SGRE
Array cable supplier	JDR Cable
Export cable supplier	JDR Cable
Floating substructure designer	Equinor
Floating substructure manufacturer	Kværner
Mooring line supplier	Bridon-Bekaert, Vicinay
Anchor supplier	Aker Solutions
Export cable installer	Seaway 7
Array cable installer	Seaway 7
Turbine and floating substructure installer	DOF Subsea
Turbine and floating substructure installer	DOF Subsea, Tronds Marine AS
Construction port	Skipavik-Gulen (NO)
O&M port	Skipavik-Gulen (NO)

Success so far

In the first 4 months since launching the Floating Guide there has been:

- Over 15,000 users
- Over 64,000 page views
- More than 4 times as many page views than the previous Guide to a (Fixed) Offshore Wind Farm

Come and check out the Guide to a Floating Offshore Wind Farm for yourself!

https://guidetofloatingoffshorewind.com/

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CONTACT US

Floating Guide Enquiries:

scott.davie@ore.catapult.org.uk

Floating Guide Website:

https://guidetofloatingoffshorewind.com/

FOWCoE Programme Enquiries:

andrew.stormonth-darling@ore.catapult.org.uk

FOWCoE Website:

https://ore.catapult.org.uk/FOWCoE/

GLASGOW

BLYTH

LEVENMOUTH

GRIMSBY

ABERDEEN

CHINA

LOWESTOFT

PEMBROKESHIRE

CORNWALL

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