

Project Erebus Environmental Statement Chapter 4: Proposed Development Description

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Acronyms

Term	Definition
BATNEEC	Best Available Technology Not Entailing Excessive Costs
BEIS	Business, Energy & Industrial Strategy
CAA	Civil Aviation Authority
CBRA	Cable Burial Risk Assessment
CBS	Cement Bound Sand
CEMP	Construction Environment Management Plan
CLV	Cable Lay Vessel
COMAH	Control of Major Accident Hazards
CTMP	Construction Traffic Management Plan
CTV	Crew Transfer Vessel
DoB	Depth of Burial
DoL	Depth of Lowering
DP	Dynamically Positioned
EM	electromagnetic
ES	Environmental Statement
FEED	Front-End Engineering Design
FLOW	Floating Offshore Wind
GB	Great Britain
GW	Gigawatt
GWh	Gigawatt hour
HDD	Horizontal Directional Drilling
HVAC	High Voltage Alternating Current
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
ICNIRP	International Commission on Non-ionising Radiation Protection
kJ	Kilojoule
km	Kilometre
km ²	Square kilometre
KP	Kilometer Post
kV	Kilovolt
LAT	Lowest Astronomical Tide

Term	Definition
LEMP	Landscape and Ecology Management Plan
m/s	Metres per Second
m ²	Square Metres
m ³	Cubic Metres
MCA	Maritime and Coastguard Agency
MFE	Mass Flow Excavator
MGN	Marine Guidance Note
MHWS	Mean High Water Springs
mm	Millimetre
mm ²	Square Millimetres
mT	Metric Tonne
MW	Megawatt
nm	Nautical Mile
NRW	Natural Resources Wales
O&M	Operation and Maintenance
PDE	Project Design Envelope
PEDW	Planning and Environment Decision Wales
PLGR	Pre-Lay Grapnel Run
PPI	Principle Power Inc
ROV	Remote Operated Vehicles
rpm	Rotations per Minute
SBE	Simply Blue Energy
SCADA	Supervisory Control and Data Acquisition
STATCOM	Static Synchronous Compensator
SuDS	Sustainable drainage systems
SVC	Static VAR Compensators
TSHD	Trailer Suction Hopper Dredger
UK	United Kingdom
UXO	Unexploded Ordnance
WTG	Wind Turbine Generator
XLPE	Cross-linked Polyethylene

Chapter 4 Proposed Development Description

4.1 Introduction

4.1.1.1 This chapter of the Environmental Statement (ES) presents the proposed development description for the Project. It covers both the offshore and onshore elements of the Project, further details of which are provided within Sections 4.4 to 4.7.

4.1.1.2 At this stage in the development process for the Project, the proposed description is indicative, and a Project Design Envelope (PDE) approach has been adopted. Further details of the use of a PDE or “Rochdale envelope” are provided in Chapter 2: Overview of EIA Methodology. This approach has been set out and agreed with Planning and Environment Decisions Wales (PEDW) and Natural Resources Wales (NRW) through the consultation process as detailed in the Consultation Report (Volume 3, Technical Appendix 2.3); furthermore, this approach has been adopted on all UK offshore wind farm projects to date and is widely accepted by all stakeholders.

4.2 Project Design Envelope

4.2.1.1 In accordance with NRW and PINS (2018) guidance, the EIA takes the PDE and identifies those parameters most likely to influence the magnitude of impacts arising from throughout the Project lifecycle (construction, operation and decommissioning). Design parameters with the potential for significant impacts have been tightly defined. Where parameters that are more benign, they may retain a greater flexibility in the PDE, but only to the degree that is necessary. In all cases the parameters have been set to sufficient criteria that allows the Project to be properly assessed in accordance with legislative requirements and guidelines.

4.2.1.2 Elements of the Project for which flexibility is required include:

- WTG capacity and parameters: due to the potential evolution of technology prior to offshore construction of the Project;
- Number and dimensions of the semi-submersible floating platforms proposed: direct correlation with size and capacity of WTG selected;
- Numbers and configuration of subsea mooring lines: linked to dimensions of semi-submersible floating platforms and detailed engineering studies;
- Type of mooring options, i.e. drag embedment anchors; suction piling; driven piles: linked to dimensions of semi-submersible floating platforms and site-specific ground conditions;
- Amount and exact location of cable protection along the offshore export cable: linked to site-specific ground conditions;
- Landfall methodology: installation includes Horizontal Directional Drilling (HDD) or open-cut trenching, including potential use of cofferdams, allowing for unknown ground conditions;
- Landfall location: two landfall options one north and one south of West Angle Bay
- Onshore site boundary: allowing for micro-siting of the cable route and, for example, crossings of existing utilities and other assets;
- Onshore substation maximum parameters: allowing for flexibility subject to detailed design;

- Construction timing and methodologies: only to be fully developed once project design is finalised and installation contractors are appointed; and
- Operation and maintenance activities: which will be adjusted to the final as built project requirements.

4.2.1.3 In respect of both the onshore and offshore export cables, the site boundary identifies the maximum extent corridor within which the respective cables are proposed to be routed.

4.2.1.4 In respect of the onshore export cables, this approach has been taken to ensure there is sufficient flexibility provided for the installation to be carried out around other utilities and features, whilst ensuring from the outset it is clearly known what is the maximum area that may be affected by this element of the Project.

4.2.1.5 In respect of the offshore export cables, this approach is followed to allow for the micro-routing of the cables within the identified corridor taking into account future detailed pre-installation surveys.

4.2.1.6 In certain areas, i.e. where HDD and other trenchless techniques are to be used to install the onshore export cables, or where the onshore export cables connect to the offshore export cables (Transition Joint Bay, TJB), or to accommodate temporary construction compounds, a wider site boundary is provided to ensure the full extent of the area beneath the surface where the cables may be located is identified.

4.2.1.7 This chapter, therefore, sets out a series of options and parameters for which minimum and maximum values are shown.

4.3 Overview of Project

4.3.1.1 The proposed Project is a demonstration scale Floating Offshore Wind (FLOW) development in the Celtic Sea region. The Applicant, Blue Gem Wind (BGW), is a joint venture between Simply Blue Energy (SBE) and TotalEnergies, set up to create a new low carbon offshore energy sector in the region that contributes to climate change mitigation targets, supply chain diversification and energy security.

4.3.1.2 Fixed bottom offshore wind technology can face significant challenges in deep waters and is considered to be unfeasible in water depths greater than 60 m, as a result of installation, operation and maintenance (O&M) and costs associated with foundations. This, therefore, restricts fixed bottom offshore wind to waters close to the coast. However, FLOW has the potential to circumvent these challenges and unlock deeper offshore sites. The technology is still to be tested at large-scale, but the potential contribution FLOW can play in the energy mix is being recognised by UK government, with the UK Government setting a target of up to 1 GW of FLOW to be installed by 2030 (BEIS, 2020).

4.3.1.3 FLOW demonstration projects have already been deployed in UK waters. Kincardine and Hywind, both located off the Scottish North Sea coast, have already achieved first power. Fully operational in 2021, Kincardine, at 50 MW, is the world's largest FLOW development (Pilot Renewables, 2019) followed by Hywind (30 MW).

4.3.1.4 As a test and demonstration development, the Project is the first in the Applicant's 'stepping-stone approach' for FLOW in the Celtic Sea. This stepping-stone approach is the best way to increase learning and to maximise the opportunities to the local economy for this technology, by starting with smaller demonstration projects, such as the Project, before moving incrementally to larger commercial scale projects in the 2030s. This will provide local, Welsh and UK supply chain companies with the greatest chance to grow with the sector as it expands globally; it will also maximise knowledge transfer and facilitate a sustainable transfer to a low carbon economy.

4.4 Overview of Project Components

4.4.1.1 The key project components of this Project are summarised below:

- Total generating capacity of up to 100 MW;
- Six to ten WTGs with nominal nameplate capacity ratings of between 9.5 MW to 18 MW¹;
- Six to ten semi-submersible floating platforms;
- Associated subsea catenary mooring lines, including clump weights;
- A range of potential anchoring solutions (drag embedment anchors; suction piles; drilled piles; driven piles);
- Up to ten dynamic array cables, associated protection;
- Offshore export cable (single cable laying 2 circuits “wrapped together” as a bundled solution), cable joints, associated protection;
- Onshore export cables (66 kV from landfall to onshore substation and 132 kV from onshore substation to grid connection);
- Onshore substation;
- Temporary main construction compound and up to four temporary construction compounds;
- TJB, joint bays/inspection chambers, access points and haul roads; and,
- Other associated infrastructure, such as navigational markers.

4.4.1.2 It is anticipated that the Project will be operational for a period of 25 years, with an additional 18 months for construction and up to 18 months for decommissioning the Project.

4.4.1.3 An outline Project programme is provided in Graphic 4.1.

Tasks Milestones	2021				2022				2023				2024				2025				2026				2027 -> 2052
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Submission of the ES																									
FEED																									
Detailed Design																									
Fabrication																									
Construction (onshore and Offshore)																									
Final commissioning of WTG Units																									
Start-Up of Erebus																									
Operation of Erebus																									

Graphic 4.1- Indicative development and installation programme for the Project

¹ All installed WTG will be of the of the same nominal nameplate capacity rating. The total installed export capacity will not exceed the agreed site capacity rating.

4.5 Overview of Site

4.5.1 Offshore Consent Boundary

- 4.5.1.1 The array area is located approximately 35 km southwest of the Pembrokeshire coast covering an area of 43.5 km², see Volume 2, Figure 4.1. The array area is located outside of the 12 nm limit, but all elements of the Project, array area, offshore export cable corridor (hereafter referred to as the ECC) and landfall fall within Welsh territorial waters or the Welsh Zone.
- 4.5.1.2 Water depths range from approximately 65 m to 85 m below Lowest Astronomical Tide (LAT) across the array area. An offshore export cable, up to 49 km in length, will link the array area to landfall at West Angle Bay, Pembrokeshire. The water depths along the ECC range from approximately 70 m in the offshore sections, to 0 m at the landfall location (all depths below LAT).
- 4.5.1.3 The sediment around landfall at West Angle Bay is predominantly sand and sandy gravel with outcropping bedrock, progressing to gravelly sand and sandy gravel, with some muddy fractions, along the ECC. Over the array area, the sediments vary from gravelly sand to sandy mud. Mobile bedforms also occur across the array area and along the ECC. There are also areas of boulders within the array area and along the ECC.
- 4.5.1.4 The predominant wind direction for the array area is 212°, south southwest, with a long term mean wind speed of 9.78 m/s, although extremes are known to reach up to 39 m/s (1,000 year return period) (WaveVenture, 2020).
- 4.5.1.5 The array area experiences waves predominantly from a west southwest to south-westerly direction with frequent heights of 1 m to 1.9 m (significant wave height; WaveVenture, 2020), and an extreme significant wave height of greater than 8 m (Chapter 6: Marine and Coastal Processes). The tidal currents flow from the west northwest to the east southeast on a flood, reversing on an ebb, with a range of 4.3 m to 5.6 m. Peak current speeds were found to be 0.6 to 0.8 m/s on a mean spring tide within the array area, increasing with distance along the ECC towards the adjacent coastline, up to 1.0 to 1.4 m/s nearshore, decreasing again within Milford Haven Estuary (0.4 to 0.6 m/s on a mean spring tide) (Chapter 6: Marine and Coastal Processes). Further details on the physical characteristics of the array area and ECC can be found in Chapter 6: Marine and Coastal Processes.

4.5.2 Onshore Site Boundary

- 4.5.2.1 Although the jurisdiction of onshore planning extends down to Mean Low Water Springs (MLWS), for the purpose of this assessment, the onshore export site boundary is defined as the point from Mean High Water Springs (MHWS)² to the connection point to the 400 kV grid network at Pembroke Power Station. The onshore site boundary runs for approximately 12.5 km via a 66 kV cable from the landfall at West Angle Bay, through Castlemartin peninsula to the proposed onshore substation, located approximately 0.9 km east of Wallaston Cross toward Lambeeth Farm. The onshore substation will be connected to the 400 kV grid network at Pembroke Power Station via a 132 kV cable which is approximately 2 km in length.
- 4.5.2.2 To aid design development and environmental assessment the onshore cable corridor has been divided into seven sections, as set out below. The description of the onshore cable corridor sections assumes open trenching as the method of cable installation unless otherwise stated.

² Certain works will span across the offshore and onshore consent boundaries, through the intertidal area, such as HDD and/or open cut trenching.

- 4.5.2.3 An overview of the full onshore site boundary is provided in Volume 2, Figure 4.2. The onshore site boundary has been divided in seven sections (Volume 2 Figure 4.3 to 4.9) and description of each section is provided below. Summary of main and temporary construction compounds dimension are provided in Table 4.21.

Section 1 Landfall area

- 4.5.2.4 Two potential landfall alignments have been identified as displayed in Volume 2 Figure 4.3. The preferred landfall will be selected following detailed geotechnical survey assessment of both options. The landfall behind West Angle Bay Car Park (northern option) is identified as a preferred location, with an alternate southern option, on the headland approximately 0.7 km to the south-west. The southern option is included as contingency option and will only be used in the unlikely event that geological conditions render the preferred option technically unviable.
- 4.5.2.5 For the preferred landfall, Section 1 runs eastwards from the MHWS to the agricultural field immediately adjacent to the car park at West Angle Bay. The field is the proposed location of the temporary landfall compound, HDD installation rig and the transition joint bay area. From there, it turns south to cross the B4320 and passes to the east of the West Angle Bay car park.
- 4.5.2.6 At the time of writing, the construction methodology at landfall is still to be determined but will be undertaken either by open trenching or HDD (preferred technology), within the spatial extent defined by the red line boundary shown in Volume 2, Figure 4.3. The preferred crossing methodology is via trenchless installation.
- 4.5.2.7 The southern (alternate) landfall is situated in an agricultural field between the coastal headland cliffs and a wooded area to the east. Landfall installation at this location will be via HDD and includes a temporary landfall compound and the transition joint bay.
- 4.5.2.8 The southern landfall option will then turn south passing through the agricultural fields before turning east towards the B4320 and North Studdock where it would connect to the same onshore cable corridor designed for the northern landfall option.
- 4.5.2.9 The onshore export site boundary runs predominantly through arable fields until south of North Studdock Cottage.

Section 2 North Studdock to Carters Green

- 4.5.2.10 Section 2 runs eastwards through arable fields and crosses hedgerows at three different locations (see Volume 2, Figure 4.4). Micrositing during detailed design will seek to reduce the need for hedgerows removal. Potential impacts on hedgerows at this location are provided in Chapter 20 Terrestrial and Coastal Ecology and Onshore Ornithology.
- 4.5.2.11 A satellite construction compound has been included within the onshore site boundary south of the B4320 close to Hubberton within an arable field.

Section 3 Carters Green to B4319

- 4.5.2.12 Section 3 continues running eastwards through arable fields (see Volume 2 Figure 4.5). The onshore site boundary has been positioned as close as possible to the field's boundary.
- 4.5.2.13 The onshore export cable in this section will all be installed with an open trench cut methodology including the crossing of the B4319.
- 4.5.2.14 A satellite construction compound has been included within the onshore site boundary south of the B4320 to the west of the B4319 within an agricultural field.

Section 4 B4319 to Neath Farm

- 4.5.2.15 Section 4 crosses the B4320, an agricultural field and a small, wooded area (see Volume 2 Figure 4.6); the preferred methodology to install the onshore export cable at this location is via open cut trench, however a trenchless solution may be required. A temporary construction compound will be required at both ends of this crossing to facilitate the trenchless solution.
- 4.5.2.16 The onshore export cable will then run east through arable fields crossing a small water course via open trench cut methodology. Potential impacts on water crossing at this location are provided in Chapter 19 Onshore geology, Hydrology and Hydrogeology.

Section 5 Neath Farm to Wogaston

- 4.5.2.17 South of Neath Farm Section 5 crosses a small water course and the Greenlink interconnector onshore cables (see Volume 2 Figure 4.7). The preferred methodology to install the onshore export cable at this location is via trenchless solution. A temporary construction compound will be required at both ends of this crossing to facilitate the trenchless solution.
- 4.5.2.18 The onshore export cable will then run eastwards through agricultural and arable fields towards Wogaston farm. This section will be installed by open trench cut methodology and follow field boundaries where feasible.

Section 6 Wogaston to Onshore Substation

- 4.5.2.19 Section 6 runs north to the east of Wogaston Farm through agricultural and arable fields before turning east towards Wallaston Cross (see Volume 2 Figure 4.8).
- 4.5.2.20 Wallaston Cross (unclassified road C3101) will be crossed preferably by using trenchless solution which would require temporary construction compounds at both ends.
- 4.5.2.21 The onshore export cable will then run east through agricultural fields towards the onshore substation. This section will be installed by open trench cut methodology.

Section 7 Onshore Substation and 132 kV route to grid connection

- 4.5.2.22 A 132 kV cables will exit the onshore substation running east crossing under the 400 kV overhead lines (see Volume 2 Figure 4.9).
- 4.5.2.23 The route will then run north and adjacent to the Greenlink export cable route through arable fields towards the grid connection point. This section will be installed by open trench cut methodology.

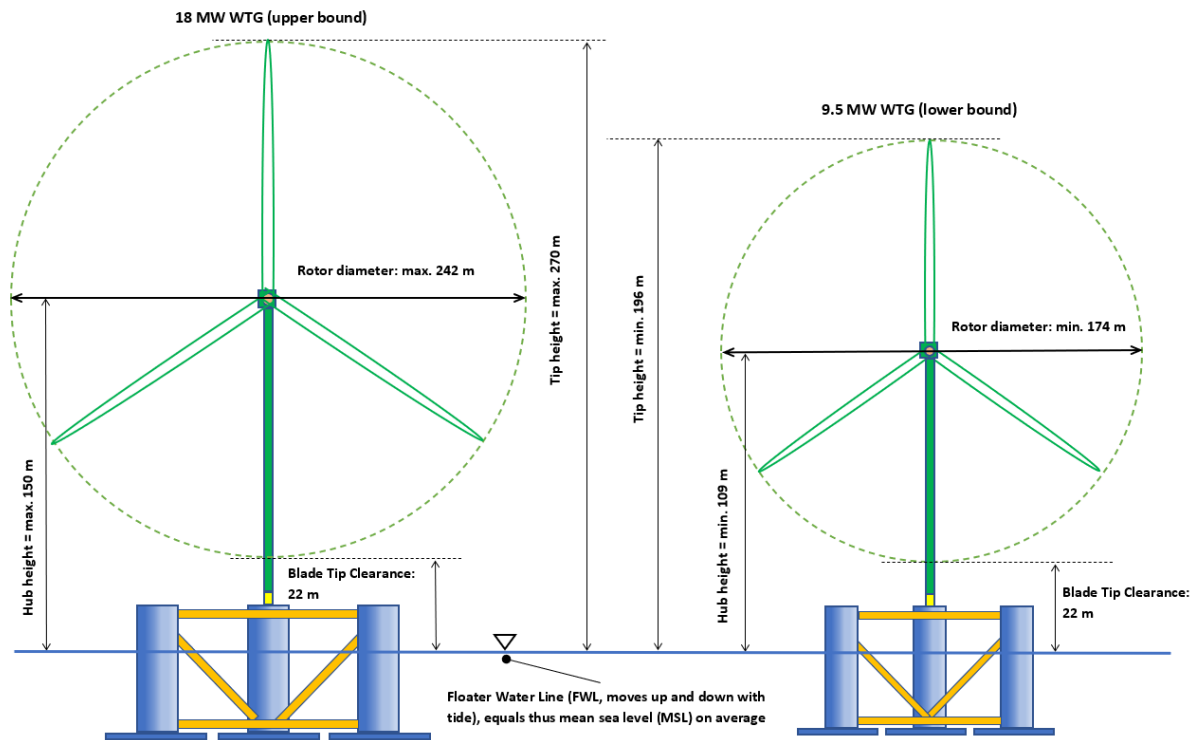
4.6 Offshore Project Infrastructure

4.6.1.0 The following sections provide more details on the key offshore project components, including specific values and parameters that provide the basis of the PDE and assessments presented in this ES. Details on the installation process for these various elements are covered separately in Section 4.8.

4.6.2 WTG Units

4.6.2.1 The WTGs proposed to be used will be between 9.5 MW and 18 MW rated capacity and will be mounted on semi-submersible floating platforms, the preferred option being the WindFloat™ platform. They will all follow the traditional offshore WTG design with three blades and a horizontal rotor axis.

4.6.2.2 The main characteristics and specification of the WTGs within the PDE are shown in Table 4.1. These parameters present the maximum and minimum dimensions and will depend on the WTG type that is ultimately selected. For example, the rotor diameter of an 18 MW WTG will be greater than that of a 9.5 MW WTG. A schematic of the maximum and minimum WTG is displayed in Graphic 4.2, although it should be noted the schematic shows a combination of worst-case or maximum parameters for the floating wind turbine generator according to the current development status of the Project.



Graphic 4.2 - Schematic of maximum and minimum WTG (Source: OWC, 2021)

Table 4.1 – Wind Turbine Generator Parameter Summary

Parameter	Minimum	Maximum
Number of WTGs	6	10
WTG Nameplate Rating	9.5 MW	18 MW*
Swept Area (per turbine)	23,779 m ²	45,996m ²

Parameter	Minimum	Maximum
Max. Blade Tip Height (from mean sea level)	196 m	270 m
Tower type and appearance	Tubular Steel painted RAL 7035 (light grey) for tower from 15 m above water line, and RAL 1023 (traffic yellow) below	
Hub Height (from mean sea level)	109 m	150 m
Rotor Diameter	174 m	242 m
Rotor Speed	8.41 rpm	9.9 rpm
Air gap / blade tip clearance (from sea level to blade tip)	22 m	22 m

* *Theoretical maximum of 18 MW WTG included to account for anticipated WTG technology development throughout Project design, noting this will be capped (devices downrated) to the agreed total export capacity of the Project of up to 100MW where necessary.*

4.6.2.3 Components within each WTG will require lubricating oils, hydraulic oils and coolants for operation. Indicative maximum requirements for these oils and fluids for a single WTG are shown in Table 4.2.

4.6.2.4 These values are based on a worst-case using a geared system, rather than a direct drive which would require less. All oils and fluids will be contained within the WTG in case of a spill.

Table 4.2 - Indicative Maximum Requirements of Lubricants within each Wind Turbine Generator

Parameter	Minimum	Maximum
Lubrication oil (gearbox, yaw drive, pumps etc.) per WTG	700 litres	1500 litres
Hydraulic oil per WTG	150 litres	700 litres
Cooling agent per WTG	100 litres with ~50% glycole to prevent freezing	600 litres with ~50% glycole to prevent freezing

4.6.2.5 Each WTG will have its own control system to carry out functions like yaw control and ramp down in high wind speeds. All the WTGs will also be connected to a central Supervisory Control and Data Acquisition (SCADA) system for the control of the wind farm remotely. The SCADA system will communicate with the wind farm via fibre optic cables, microwave, or satellite links. Individual WTGs can also be controlled manually from within the WTG nacelle or tower base in order to control the WTG for commissioning or maintenance.

4.6.2.6 All WTGs may also have diesel generators for commissioning and O&M activities. Generators are typically used for back-up power supply at the platform (crane lifting, etc.).

4.6.3 **Array Layout Description**

4.6.3.1 The Project will comprise up to ten WTGs, depending on the WTG capacity, with a maximum overall capacity of up to 100 MW.

4.6.3.2 Two indicative Project array layouts within the offshore consent boundary are shown in Volume 2, Figure 4.10. The final array layout will be determined after consideration of a number of factors, for example, the number of WTGs selected, efficiency in installation and operation, and local site conditions. The array layout will consider the requirements of Marine Guidance Note MGN654 (MCA, 2021; and any subsequent versions) and the final array layout is proposed to be confirmed in consultation with the Regulator post consent and prior to the commencement of construction.

4.6.4 **Semi-Submersible Floating Platform**

4.6.4.1 The WTG will be mounted on a semi-submersible floating platform secured to the seabed using an asymmetric mooring system designed to achieve high stability levels, such as the WindFloat™ semi-submersible floating platform. The semi-submersible floating platform will provide buoyancy to support the WTG and counteract the large wind-induced overturning momentum. An example image of a semi-submersible floating platform is provided in Graphic 4.3, with a schematic provided in Graphic 4.4. A summary of the semi-submersible floating platform dimensions within the PDE are set out in Table 4.3.

4.6.4.2 The WindFloat™ semi-submersible floating platform, designed by Principle Power Inc (PPI) is currently considered the most suitable sub-structure available for the Project. The WindFloat™ has been installed off the coast of Portugal where it was grid connected in 2011 and also at the Kincardine FLOW project off the coast of Aberdeen, Scotland.

4.6.4.3 The semi-submersible floating platform comprises three columns inter-connected with a truss structure composed of main beams, connecting columns and bracings. Secondary structures include a boat landing on one of the columns, deck space and railings (for personnel access) and associated equipment (onboard davit crane, array cable hang-off etc.).

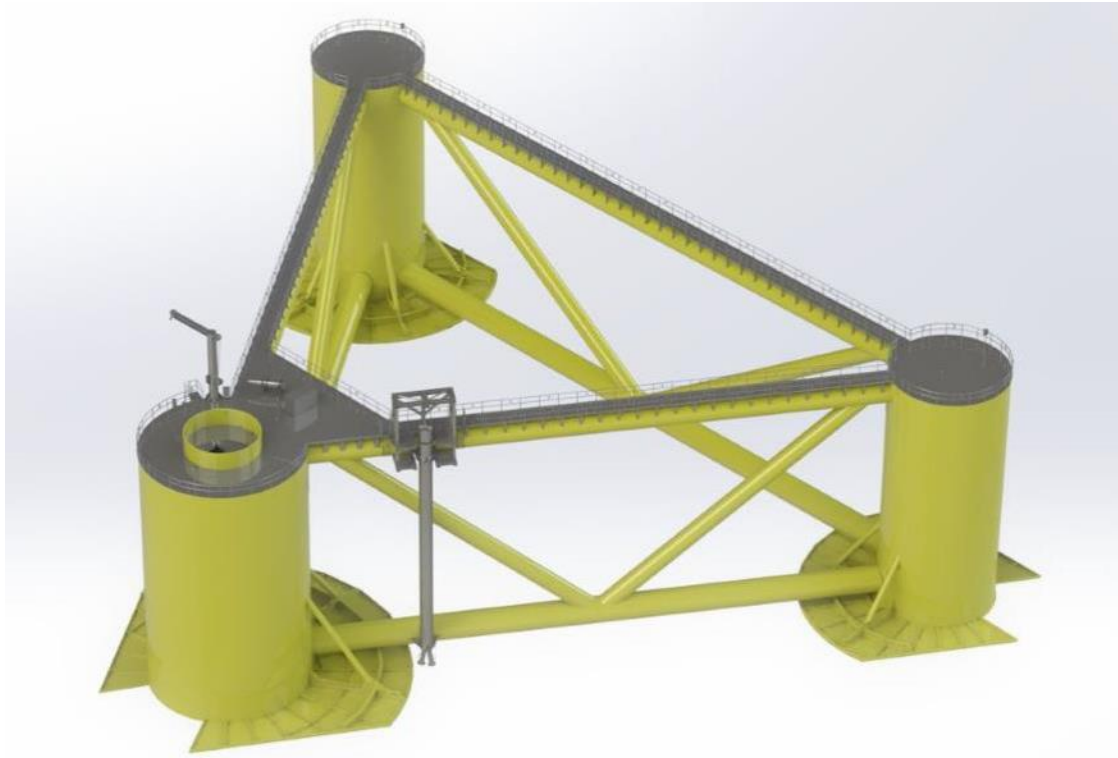
Table 4.3 – Semi-Submersible Floating Platform Parameter Summary

Parameter	Minimum	Maximum
Number of columns per platform	3	3
Column diameter	9 m	22 m
Column centre to centre distance	55 m	100 m
Column height	25 m	32 m
Operating Draft (distance from keel to sea level)	12 m	17.4 m
Maximum dimensions (x 3 sides)	89 x 96 x 77 m	112 x 123 x 96 m
Maximum footprint (per platform; base of hull assumed solid triangle)	3,478 m ²	4,264 m ²
Height above sea surface – Operating conditions	10 m (to freeboard)	14.5 m (to freeboard)
Maximum excursion of hull from slack line position/neutral	40 m	50 m

Parameter	Minimum	Maximum
Separation distance between WTGs (centre point)	1,000 m	3,500 m
Generator (back-up)	None	Diesel
Primary material and colour	RAL 7035 (light grey) for tower (15 m above water line) with the structure (floater and tower) to be painted RAL 1032 (traffic yellow) from the Floater Water Line to +15 m above Floater Water Line	
Lighting	All walkways and boat landing, access platform/davit crane. All sensor activated. An 'Aids to Navigation Management Plan' will be developed with associated navigation markers and lighting (will require approval by the MCA and Trinity House post consent and prior to construction)	



Graphic 4.3 - Example Semi-Submersible Platform, WindFloat™ Atlantic Project installed in northern Portugal. (Photo courtesy of Principle Power, Artist: DOCK90)



Graphic 4.4 - 3D Modelled Output of a Semi-submersible Floating Platform, WindFloat™ (Source: PPI, 2021)

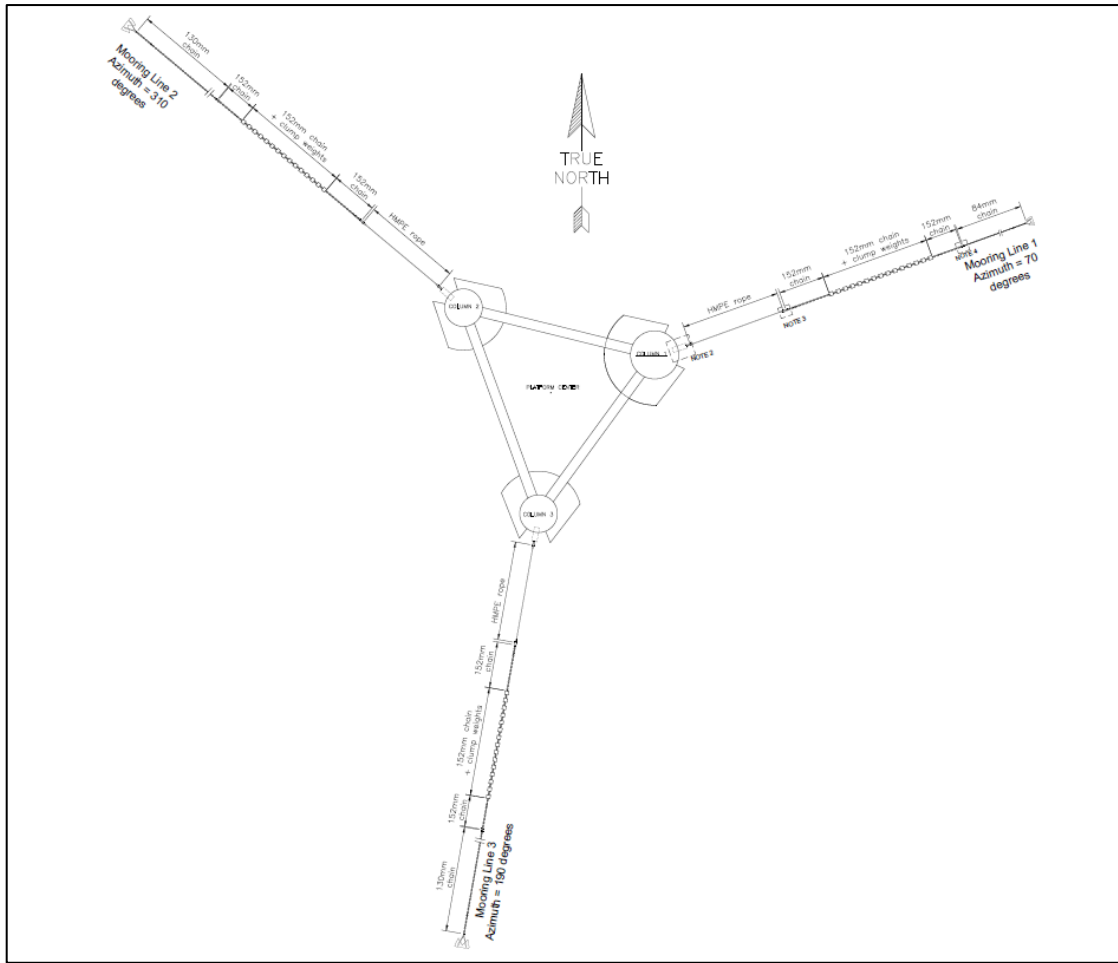
4.6.5 *Semi-Submersible Floating Platform Mooring System*

- 4.6.5.1 The semi-submersible floating platform will be attached to the seabed using a series of anchored mooring lines. The mooring system is designed to address station-keeping issues (it does not need to contribute to the platform's stability) and enables simple installation and connection-disconnection procedures that can be performed by widely available anchor handling vessels.
- 4.6.5.2 A catenary mooring system will be used, a system that is widely used in the offshore oil and gas industry. This consists of anchors, ground chains, synthetic ropes and other connectors. Clump weights, usually iron and occasionally concrete, will be used to load the line, therefore, reducing the overall length of the mooring lines.
- 4.6.5.3 Subject to verification, drag embedment anchors are the most likely and preferred option for securing the mooring lines to the seabed. However, to enable a flexible approach that encompasses all worst-case scenarios, several anchor/foundation types have been included within the PDE. These are detailed further below.
- 4.6.5.4 The parameters of the mooring system, including mooring lines and anchors, are set out in Table 4.4. An overview of the mooring configuration is presented in Graphic 4.5 and a cross sectional schematic of the mooring system is illustrated in Graphic 4.6.

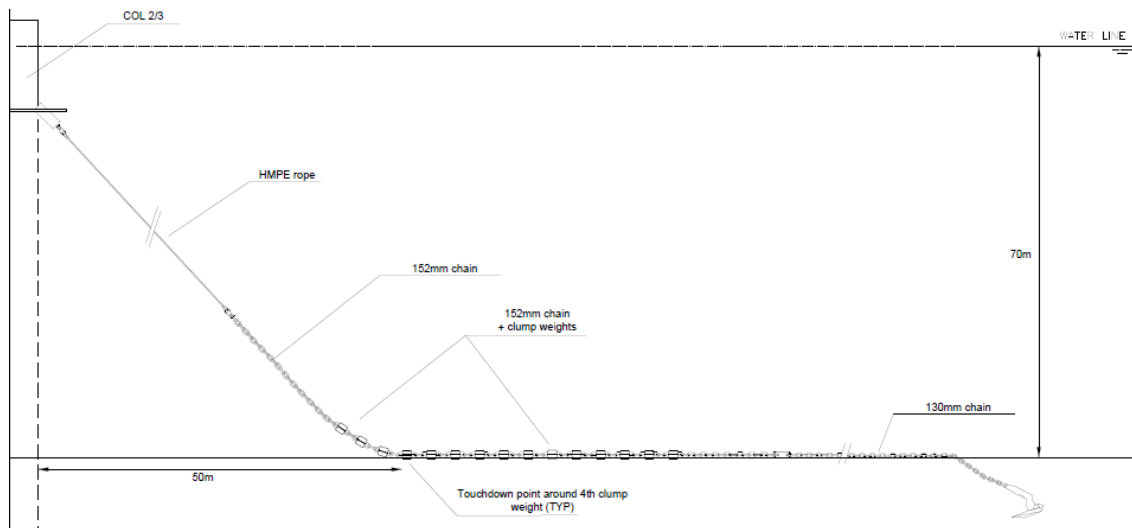
Table 4.4 – Mooring System Parameter Summary

Parameter	Minimum	Maximum
Configuration	Catenary	
Total number of mooring lines	20	35
Individual mooring line length	530 m	870 m
Radius of mooring (from platform hull to anchor)	500 m	800 m
Number of mooring clump (per line)	15	25
Number of mooring clump (total)	480	875
Mooring clump individual weight	12 tonnes	20 tonnes
Total mooring clump footprint	691 m ²	3,500 m ²
Anchors / Foundations³		
Number of Drag Embedment Anchors	20	63
Number of Suction Pile Anchors	20	35
Number of Driven / Drilled Piles	20	35

³ The installed anchor / foundation type will be dependent on ground conditions. There would not be a need to install the maximum number of each anchor type should multiple anchor types be used.



Graphic 4.5 – Indicative Schematic of an Overview of the Semi-Submersible Floating Platform and Mooring Configuration (Source: PPI, 2021a)



Graphic 4.6 – Indicative Schematic of the Mooring Line System (Source: PPI, 2021b)

- 4.6.5.5 There will be between three to five mooring lines in a triangular fashion from each semi-submersible floating platform to provide a mooring system with low pre-tension requirements. In line with the predominant wind direction (south southwest), there will always be at least two mooring lines upwind, and one downwind. For the larger WTGs the two mooring lines upwind will be doubled up resulting in 5 overall mooring lines.
- 4.6.5.6 The mooring lines are likely to be made from a combination of chain, steel and synthetic rope, using offshore grade materials. A maximum of 25 clump weights will be attached to each mooring line, each weighing up to 20 tons. Examples of clump weights likely to be used on the Project are depicted in Graphic 4.7.

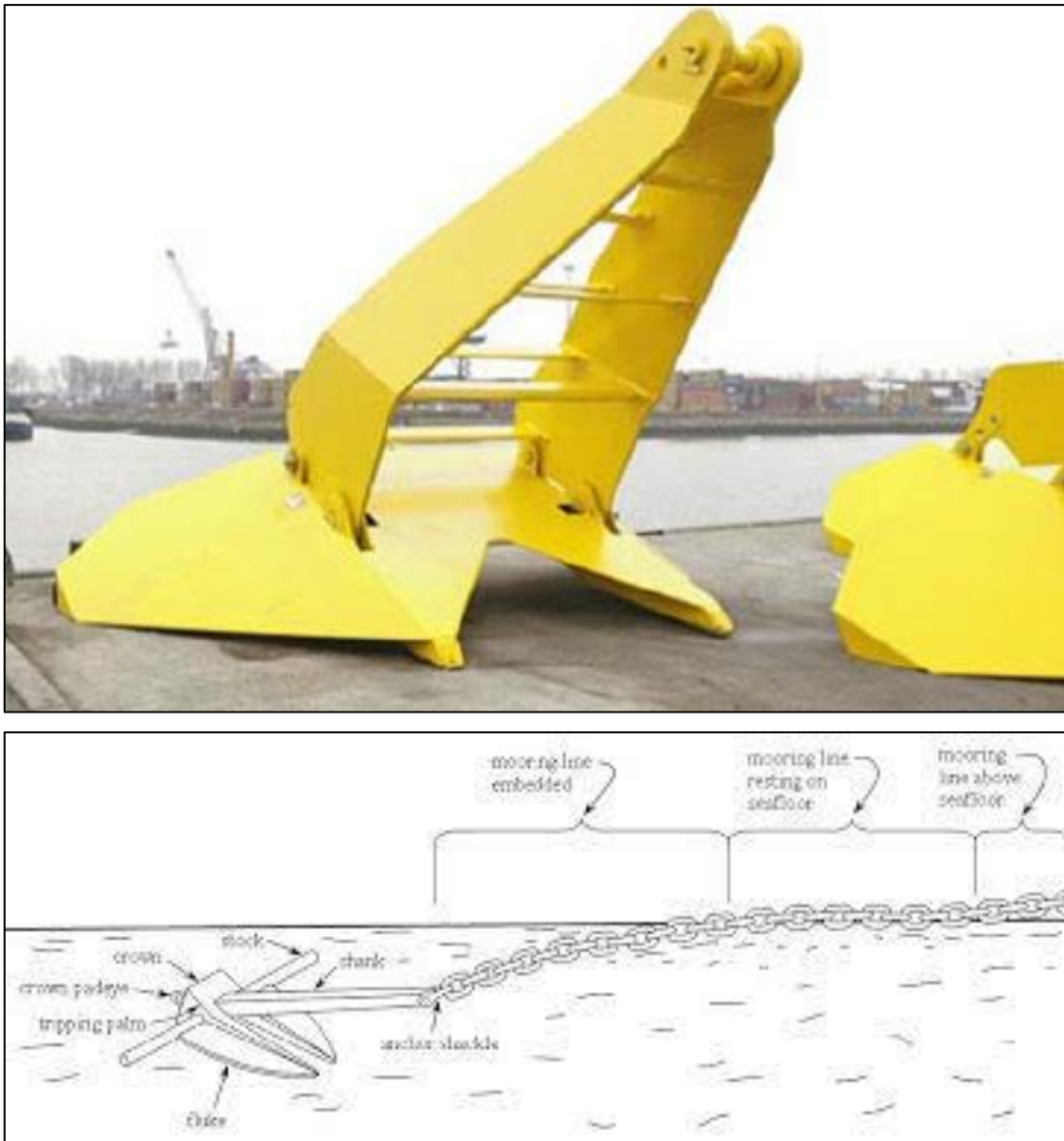


Graphic 4.7 - Image of Example Clump Weights (Source: OWC, 2021)

- 4.6.5.7 As outlined above, four anchor/foundation types may be used, depending on ground conditions on site and final design. These are (1) drag embedment anchors; (2) suction piling with gravity anchors; (3) driven piles; and (4) drilled piles. A description of each anchor type being considered is outlined in this section.

4.6.6 Drag Embedment Anchors

- 4.6.6.1 Drag embedment anchors are currently the proposed option for the mooring system for the Project. They are similar in concept to the anchors used on vessels, see Graphic 4.8. Drag embedment anchors hold in position through the resistance between the seabed substrate, the anchor and the attached platform. The drag embedment anchor will penetrate the seabed to a depth from 8 to 25 m, depending on the sediment thickness, with no part of the anchor anticipated to be proud of the seabed surface once installed.
- 4.6.6.2 Each mooring line will be attached to at least one drag embedment anchor, which will equate to between 20 to 35 drag embedment anchors in total. Where required for increased load capacity, a piggyback option consisting of two drag embedment anchors, one in front of the other along the mooring line, will be used on the upwind mooring lines only, taking the theoretical maximum number of anchors for the Project to 63.
- 4.6.6.3 A summary of the drag embedment anchor parameters is provided in Table 4.5.



Graphic 4.8 – Image of a Drag Embedment Anchor, with Schematic of an Embedded Anchor (Source: OWC, 2021)

Table 4.5 –Drag Embedment Anchor Parameter Summary

Parameter	Minimum	Maximum
Total number of drag embedment anchors	20	63 (inclusive of where 2 anchors are in series on the same mooring line)
Drag embedment anchors dimensions (LxWxH)	6.5 x 7 x 4 m	8.5 x 9 x 5 m
Total drag embedment anchor footprint	1,456 m ²	3,500 m ²
Drag embedment anchors weight	18 mT	30 mT

Drag embedment anchors penetration depth (dependent on sediment thickness)	8 m	25 m
----------------------------------------------------------------------------	-----	------

4.6.7 *Suction Piles*

4.6.7.1 Suction pile anchors/foundations are often used on deep water projects in the oil and gas industry and other floating offshore wind developments, such as Hywind Scotland (Statoil, 2015). The suction pile uses gravity to initially penetrate the seabed with seawater entering the main structure. The remaining seawater within the pile is then pumped out creating further suction and penetration into the seabed. Suction piles can then be supplemented by additional concrete weight on the top of the anchor to provide additional stability (combined gravity anchor). A summary of the suction pile parameters is provided in Table 4.6.

4.6.7.2 A precautionary approach will be undertaken and the use of suction piles will only be implemented where it can be demonstrated that there is no other Best Available Technology Not Entailing Excessive Costs (BATNEEC) solutions. Should suction piles be required, these would be located within discrete locations within the array area, however a worst case of all anchors has been used in the PDE.

Table 4.6 – Suction Pile Anchor Parameter Summary

Parameter	Minimum	Maximum
Total number of suction pile anchors	20	35
Suction pile anchor dimensions	6.5 m diameter 10 m length (incl.2-3 m concrete block on top of pile)	6.5 m diameter 20 m length (incl.2-3 m concrete block on top of pile)
Total suction pile anchor footprint	660 m ²	1,161 m ²
Suction pile anchor penetration	8 m	17 m

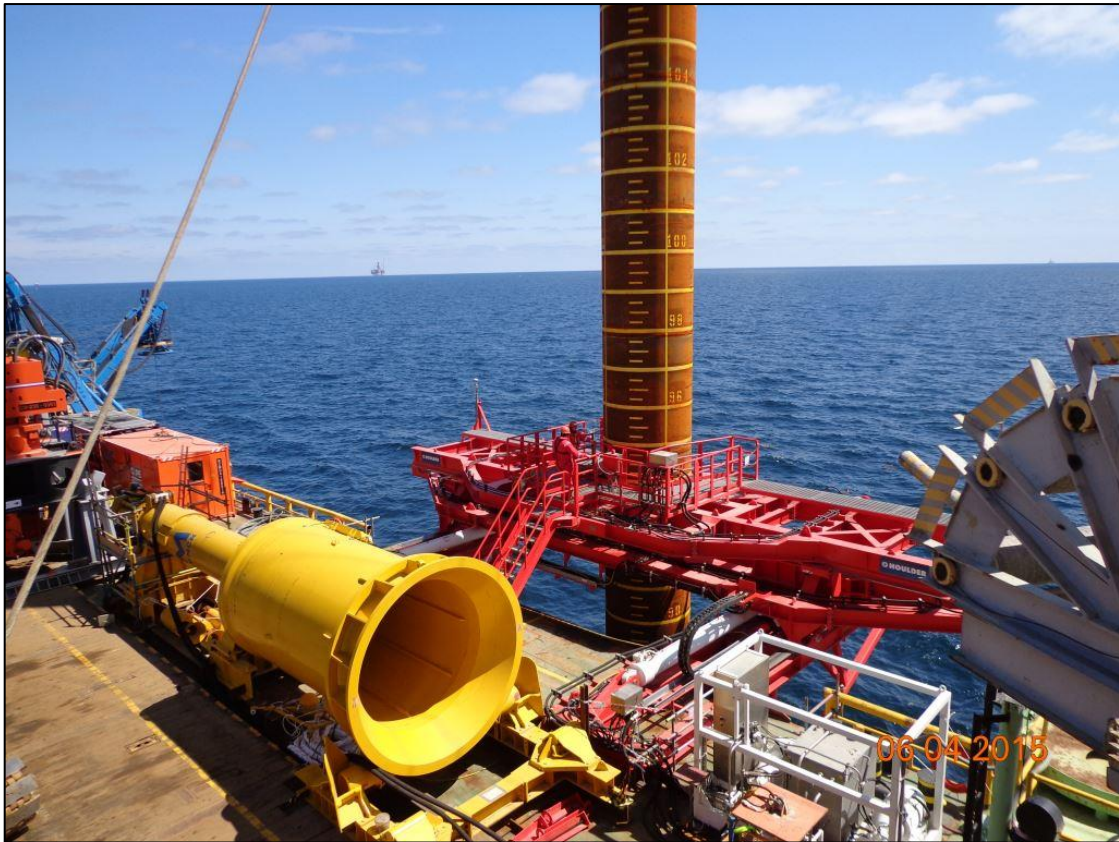
4.6.8 *Driven Piles*

4.6.8.1 Driven piles are commonly used as foundations in offshore structures. A pile is driven into the seabed using an external force, such as a hammer (impact piling) or vibration depending on the ground conditions. An example of a driven pile is provided in Graphic 4.9.

4.6.8.2 The use of driven piles may or may not be required within the array area. The need for driven piles will be confirmed through the results of detailed geotechnical survey in 2023. Driven piles will only be utilised where all other options are not viable for the seabed conditions. As the need for driven piles is uncertain at this stage in the EIA, they have been included within the PDE.

4.6.8.3 A precautionary approach will be undertaken and the use of driven piles will only be implemented where it can be demonstrated that there is no other BATNEEC solutions. Should driven piles be required, these would be located within discrete locations within the array area, however a worst case of all anchors has been used in the PDE.

- 4.6.8.4 Table 4.7. outlines the maximum and minimum parameters associated with the use of driven piles. To ensure receptor assessments use the realistic worst case scenario, which will vary across receptors, the assumption will be that driven, not drilled, piles will be used as the parameters are generally greater than drilled piles (Section 4.6.9.2).



Graphic 4.9 – Example of Driven Pile (Source: OWC, 2021)

Table 4.7 –Driven Pile Anchor Parameter Summary

Parameter	Minimum	Maximum
Total number of driven piles	20	35
Driven pile dimensions	2 m diameter 18 m length	2.5 m diameter 55 m length
Driven pile penetration	16 m	52 m
Total driven pile footprint	100 m ²	175 m ²
Hammer energy	50 kJ (soft-start)	800 kJ
Indicative piling duration (per driven pile)	90 minutes	150 minutes

4.6.9 *Drilled Piles*

- 4.6.9.1 Drilled piles are commonly used in offshore structure foundations. A pile is drilled into the seabed using an external force, the method can be dependent on the sediment type. An example of a drilled pile is provided in Graphic 4.10.

- 4.6.9.2 The use of drilled piles may or may not be required within the array area. The need for drilled piles will be confirmed through the results of detailed geotechnical survey in 2023. As the need for drilled piles is uncertain at this stage in the EIA, they have been included with the PDE.
- 4.6.9.3 A precautionary approach will be undertaken and the use of drilled piles will only be implemented where it can be demonstrated that there are no other BATNEEC solutions. Should drilled piles be required, these would likely be limited to the eastern boundary of the array area, however a worst case of all anchors to be drilled has been used in the PDE.
- 4.6.9.4 Table 4.8 outlines the maximum and minimum parameters associated with the use of drilled piles. As described in Section 4.6.8.4, should piling be required, the realistic worst case scenario, depending on the receptor assessment, will use driven pile parameters as these are generally greater than for drilled piles.



Graphic 4.10 Example of Drilled Pile (Source: OWC, 2021)

Table 4.8 – Drilled Pile Parameter Summary

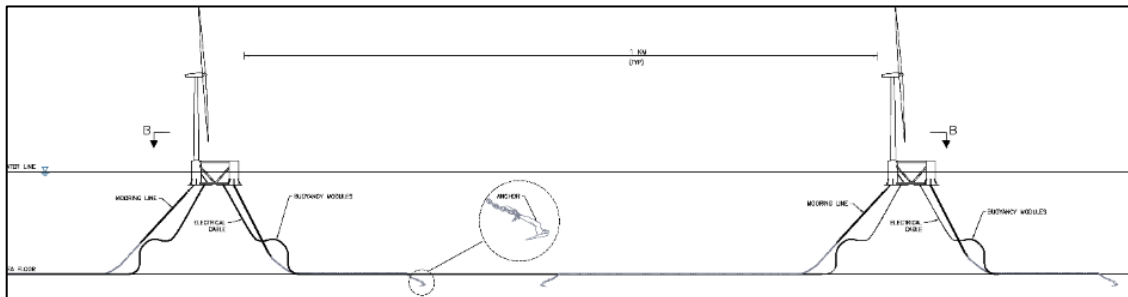
Parameter	Minimum	Maximum
Total number of drilled piles	20	35
Drilled pile dimensions	2 m diameter 18 m depth	2.5 m diameter 55 m depth
Drill penetration depth	16 m	52 m
Volume of drill arisings per pile	56.5 m ³	269.8 m ³
Total volume of drill arisings	1,824 m ³	11,340 m ³
Predicted footprint of drill arisings (m ²) (to a height of 1 m)	1,824 m ²	11,340 m ²

4.6.10 Array cables

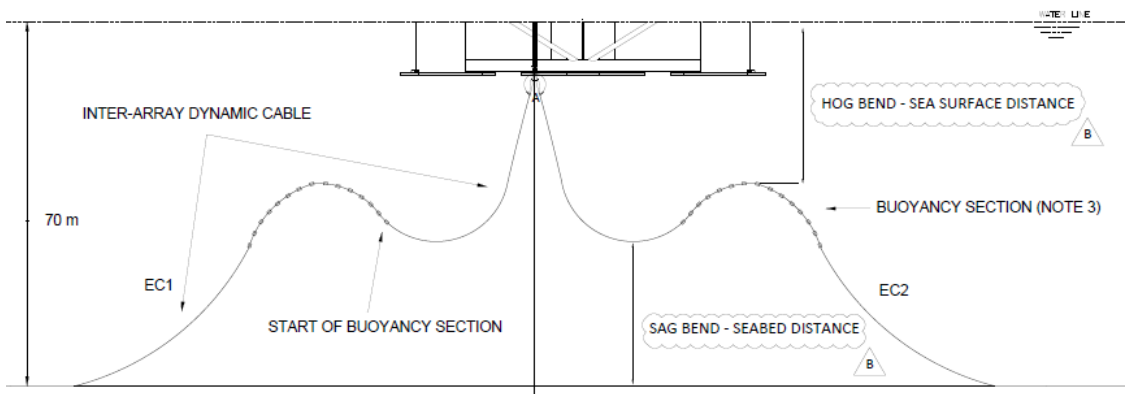
- 4.6.10.1 The WTG units will be connected through a series of array cables either through a two-way split radial array or the preferred option of a looped circuit. The key parameters of the array cables, including cable protection, are set out in Table 4.9. An example of the array cable configuration is provided in Graphic 4.11 and Volume 2 Figure 4.10 for an example of the full array layout.
- 4.6.10.2 The array cables will consist of a three-core dynamic High Voltage Alternating Current (HVAC) subsea cable rated up to 72.5 kV and fibre optic system which will be installed in a Lazy Wave configuration to decouple the floater induced motion from the catenary, achieving a mid-water arc by means of buoyancy modules. The array cables will touch down on the seabed up to 140 m from the hull of the semi-submersible floating platform.
- 4.6.10.3 The array cable system will also include the cable hang-off, bend stiffener, buoyancy modules and touchdown point protection, as part of the Lazy Wave configuration (Graphic 4.12).
- 4.6.10.4 The preferred option is for a post lay burial installation approach by means of a jet trencher (tool still to be confirmed to suit the specific seabed sediments strength across the array area). An alternative approach could be a surface laid cable with external stabilization achieved by means of grout or rock bags (see Section 4.8.4.1, Offshore Electrical Infrastructure - Array Cables,). It is anticipated that some cable protection or stabilisation will be required for the array cables where burial is not possible, or where surface laying is undertaken. Should surface laying be undertaken the cables would require a degree of external stabilisation, therefore the placement of rock bags at set distances along the static section of the array cables will be undertaken to provide the required on bottom stability. Further details on potential cable protection (array and offshore export cable) are provided in in Section 4.6.13.1.

Table 4.9 – Array Cable Parameter Summary

Parameter	Minimum	Maximum
Number of Array Cables	5	10
Length of individual Array Cables (sections)	1,042 m	6,022 m
Total length of all Array Cables (dependent on arrangement)	11.8 km	23.9 km
Diameter of individual Array Cables (include fibre optic)	130 mm	300 mm
Array Cable Rating	66 kV	72.5 kV
Number of Hang-offs	11 total (incl. 2 for export)	20 (incl. 2 for export)
Swept area per Array Cable	2,000 m ²	3,750 m ²
Total swept area for all Array Cables	24,000 m ²	82,500 m ²
Area of seabed impacted via Array Cables on the seabed and/or cable protection (also see Table 4.9)	6,405 m ² No stabilisation, surface lay, protection at touchdown only	115,200 m ² Rock protection along all array cables from touchdown, incl. 2 x cable crossing
Cable crossings	0	2



Graphic 4.11 - Array Cables Configuration (source: PPI, 2019)



Graphic 4.12 - Lazy Wave Configuration for the Array Cables (Source: PPI, 2021c)

4.6.11 Offshore Export Cable

- 4.6.11.1 Power export to shore will be provided by means of either a single or a double submarine export cable circuit connected to the lead turbine. The power will be transferred to the grid at the onshore substation. The key parameters of the offshore export cable are set out in Table 4.10. The ECC is shown in Volume 2, Figure 4.1.
- 4.6.11.2 Details of how the ECC has been developed are provided in Chapter 3: Site Selection and Alternatives.
- 4.6.11.3 The single offshore export cable assembly, comprising 1 to 2 cables will be required, consisting of a three core HVAC, 66 kV cable either as a single or bundled subsea cable circuit with a fibre optic cable.
- 4.6.11.4 The offshore export cable will be up to 49 km long. Different sections of the offshore export cable are identified by Kilometre Posts (KP) along the entirety of its route, with the starting point, KP0.0 at MHWS at West Angle Bay and up to approximately KP47.0 at the array area. The maximum offshore export cable length is measured from MHW to the nominal lead turbine location in the array area. The 49 km includes contingency for the final siting of the TJB close to MHW, and for final decision on the lead turbine.
- 4.6.11.5 Consent is being sought for an ECC that varies in width between 100 m within Row's Rocks channel to 450 m along the majority of the ECC, with widening at the array area and landfall. Having a wide consent corridor in certain sections provides the flexibility for potential re-routing and micro-siting of the final export cable once detailed site investigations have been carried out in the post-consent phase. The footprint width of export cable installation works will be approximately 10 m. Where seabed interventions, such as sandwave levelling, are required, the footprint width may increase.
- 4.6.11.6 Installation may be undertaken using a range of methods along the route, including surface laying, ploughing, Mass Flow Excavator (MFE), jetting, Trailer Suction Hopper Dredger (TSHD) and rock cutting or trenching. These methods are further discussed in Section 4.8 (Offshore Electrical Infrastructure – Offshore Export Cable) along with any associated seabed preparation works that may be required prior to cable installation.
- 4.6.11.7 Based on preliminary cable burial assessment work carried out, burial of the export cable is predicted to be achievable over approximately 41 km of the 49 km route (84%). For those areas where cable burial is currently predicted not to be completely achievable, a precautionary assumption has been made that the cable will need to be surface-laid and protected via external cable protection.
- 4.6.11.8 Further details on potential cable protection (array and offshore export cable) are provided in Section 4.6.13.1. Further details on cable repair and remediation events over the lifetime of the project are provided in Section 4.12.

Table 4.10 – Offshore Export Cable Parameter Summary

Parameter	Minimum	Maximum
Number of Export Cables (including fibre optics)	1	2 - single cable laying campaign laying 2 circuits "wrapped together" as a bundled solution, comprising on export cable route
Length of Export Cable	47 km	49 km
Diameter of individual Export Cable	130 mm	300 mm

Number of Export Cable Joints	1	2
Target Depth of Burial	0 m	3 m
Percentage of offshore export cable requiring cable protection (see <i>Scour and Cable Protection</i> , paragraphs 4.6.13.1 to 4.6.13.7)	5%	16%
Area of seabed impacted via export cable protection (also see Table 4.12)	50,000 m ²	83,380 m ²
Identified cable crossings	1	2

4.6.12 **Landfall**

- 4.6.12.1 Landfall for the offshore export cable is at West Angle Bay. Details of the process followed to select this area as the preferred landfall are provided in Chapter 3: Site Selection and Alternatives.
- 4.6.12.2 The following section provides details of the planned works in the landfall region up to Mean High Water Springs (MHWS), i.e. the extent of the Marine Licence application area. Details on associated works above MHWS (onshore) are covered later this chapter.
- 4.6.12.3 To maintain the necessary flexibility to the Project, as defined in Section 4.2, there are two HDD landfall alignments being progressed. For the northern alignment two potential installation options have been developed for landfall: HDD or open-cut trenching, including potential use of cofferdams. For the southern alignment only, HDD is being proposed (See Figure 4.1b). The preferred option for landfall is HDD as this will reduce the impact footprint on shallow sub-tidal and intertidal marine habitats. However, without information from detailed HDD feasibility studies, and further geotechnical site investigation works that will be undertaken post-submission (Q4 2022), the risk remains that HDD may not be technically feasible. Therefore, open cut trenching is also considered as a contingency option. Landfall at the southern location can only be achieved by HDD and this option will be considered ahead of the open cut trench option at the northern location.
- 4.6.12.4 Full details of the proposed installation methodologies are set out in Section 4.8 (Offshore Electrical Infrastructure – Landfall (marine) with the key parameters presented below (Table 4.11 and Table 4.12).

Table 4.11 – HDD Parameter Summary

Parameter	Minimum	Maximum
Dimensions of landfall / Transition Joint Bays (TJBs) (m ³)	NA	324 m ² (up to two 162 m ² TJB)
Intertidal cofferdam area (m ²) (if required)	0	1000 m ²
Offshore flotation pits (m ²)	140 m (l) x 38 m (w) x 5 m (d)	160 m (l) x 45 (w) x 5 m (d)
Temporary flotation pit dimensions	140 m (l) x 38 m (w) x 5 m (d)	160 m (l) x 45 m (w) x 5 m (d)
Temporary flotation pit area	5,320 m ²	7,200 m ²
HDD exit point depth	3 m LAT	5 m LAT

Volume of drilling mud to be generated (m ³)	1000 m ³	2,400 m ³
Duration of Activities (West Angle Bay N)	13 weeks	32 weeks
Duration of Activities (West Angle Bay S)	24 weeks	32 weeks

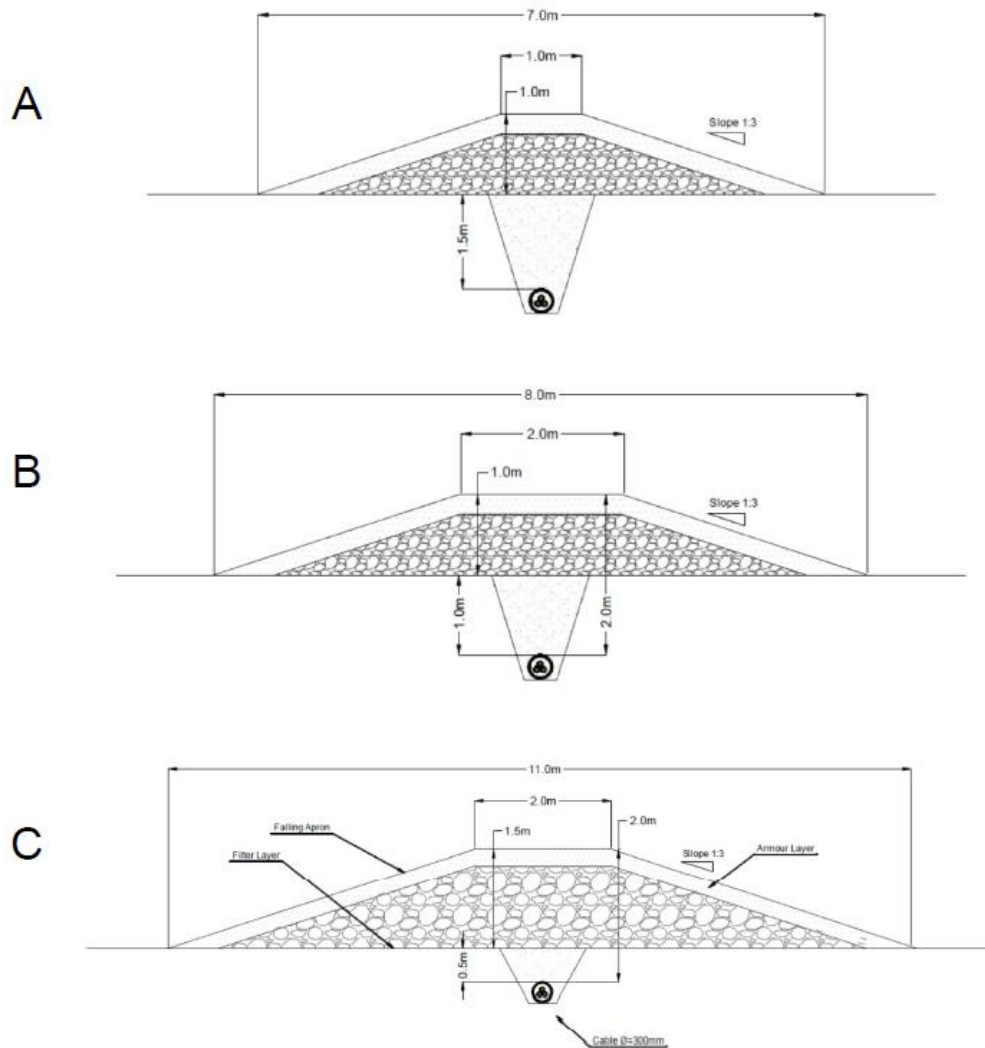
Table 4.12 – Open-Cut Trenching Parameter Summary

Parameter	Minimum	Maximum
Open-cut trench length (m)	600 m	650 m
Open-cut trench width (m)	2 m	3 m
Open-cut trench depth (m)	3 m	
Width of open-cut trench plus working area (open-cut trench plus areas where side-cast material may be stored and vehicle access needed)	3 m	10 m
Area of disturbance from open-cut trench (m ²)	TBC	1,950 m ²
Area of disturbance from open-cut trench plus working area (m ²)	NA	6,500 m ²
Temporary flotation pit dimensions	140 m (l) x 38 m (w) x 5 m (d)	160 m (l) x 45 (w) x 5 m (d)
Temporary floatation pit area	5,320 m ²	7,200 m ²
Duration of Activities	10 weeks	15 weeks

4.6.13 Scour and Cable Protection

- 4.6.13.1 The potential for external cable protection to be required in certain sections of the offshore export cable route, where burial is not possible due to unfavourable ground conditions, was assessed via preliminary studies.
- 4.6.13.2 Geophysical data from the 2020 and 2021 surveys of the ECC was used to develop a preliminary ground model of the site which has, in turn, been used to determine initial depth of burial and potential areas of shallow burial/surface laid cable.
- 4.6.13.3 The entire ECC was divided into smaller sections with a burial category assigned to each one based on ground condition information including sediment thickness, density of surface or sub-surface boulders, and presence of sandwaves.
- 4.6.13.4 Using these burial categories to inform this preliminary assessment, an initial realistic worst-case was developed that assumed a maximum of 30% of the offshore export cable may require cable protection.
- 4.6.13.5 Following further review of data collected in the 2020 surveys and more detailed assessment, this initial value of 30% of total export cable potentially requiring cable protection was reduced to the current realistic worst case of approximately 16%, on which the assessments are based.

- 4.6.13.6 The worst-case footprint of the cable protection along the offshore export cable would be in the form of a rock berm of 13 m width and 2 m height. Graphic 4.13 illustrates a schematic of the cross section. Where partial burial is possible along the ECC, it is anticipated that the rock berm required to achieve sufficient over-cable protection will be reduced, enabling utilisation of a berm with reduced footprint and elevation in comparison with the worst-case outlined above. Such instances will be location specific and only confirmed after the submission of the ES.



Graphic 4.13 –Schematic of Indicative Cross Sections of Rock Berm (Source: OWC, 2021)

- 4.6.13.7 Cable protection may also be required for some surface laid sections of the array cables located within the array area. Three potential options exist here, of which, Options 1 and 3 represent the worst-case for different ecological receptors so are both included:
- 4.6.13.8 Option 1: the entire length of array cables in contact with the seabed are covered with a continuous rock berm (worst-case for habitat loss);
- 4.6.13.9 Option 2: no continuous rock berm but rock bags placed along array cable at defined intervals (approximately every 30 m) to provide stability and protection; and
- 4.6.13.10 Option 3: No continuous rock berm or stabilisation, only rock protection (100 m) required at touchdown locations (worst-case for EMF effects)

Table 4.13 – Cable (Export and Array) Protection Summary

Parameter	Minimum	Maximum
Total Array Cable Protection (rock berm)	Only at touchdown point locations (no cable crossings): Length of cables requiring protection – 100 m Width of protection – 5 m Area – 5,500 m ²	Entire array cable in contact with the seabed protected (includes 2 cable crossings): Length of cables requiring protection – 22,500 m (crossings = 300 m) Width of protection – 5 m, except at cable crossings (14 m) Area – 115,200 m ²
Rock protection at HDD exit point (landfall)	Length of rock berm – 21 m Width of rock berm – 5 m Height of rock berm – 1.2 m Area = 105 m ²	Length of rock berm – 21 m Width of rock berm – 5 m Height of rock berm – 1.2 m Area = 105 m ²
Total Export Cable Protection Area (m ²) (rock berm)	65,000 m ²	83,380 m ² (including 1 cable crossing) ⁴
Sub-Total	70,500 m²	198,685 m²

4.6.14 Cable Crossings

4.6.14.1 Within the ECC, it has been identified that there will be the need for one cable crossing of the Greenlink Interconnector. Within the array area, dependant on the array layout required, there is potential for the array cables to require two crossings of the existing SOLAS cable.

4.6.14.2 The design and methodology of these crossings will be confirmed in agreements with the asset owners; however, it is likely that a small layer of rock and/or concrete mattresses will be placed over the existing asset for protection (pre-lay/separation layer). The export (and possibly array) cable(s) will then be laid perpendicularly across this and covered by a second post-lay layer of rock/mattresses to ensure that the export (array) cable(s) remain protected and in place. Artificial frond mats may also be used at crossings. The estimated footprint of external cable protection at the Greenlink crossing is 559.7 m² (0.00059 km²).

4.6.15 Sandwave levelling

4.6.15.1 The ECC and the array area includes areas of sandwaves, some of which have crest heights up to 11.5 m above average seabed level. Where the slope angles of such features are too steep it becomes difficult to use certain cable installation tools, and to ensure proper installation of infrastructure, resulting in areas of exposed and/or shallow buried cable. Therefore, levelling of certain sandwave features may be undertaken to facilitate the installation of the export and/or array cables, anchors and mooring lines.

⁴ Inclusive of an estimated 559.7 m² (0.00059 km²) of rock protection across the Greenlink Interconnector cable crossing point

- 4.6.15.2 The need for sandwave levelling will be confirmed through ongoing design refinement, the results of the detailed geotechnical survey, and further Front-End Engineering Design (FEED) studies. As the need for sandwave levelling is uncertain at this stage in the EIA, a conservative approach has been included with the PDE. A summary of the parameters is provided in Table 4.14 and Table 4.15.
- 4.6.15.3 The primary method of sandwave levelling would be via use of a MFE or jetting to ensure that any sediment remains in the system close to the area of removal. However, potential dredging of sandwave material via a TSHD is also included in the PDE to ensure flexibility of method is retained.
- 4.6.15.4 TSHD have been used for sandwave levelling on other offshore wind and interconnector projects. TSHD's operate by deploying a dredging arm to the seabed, where the trailing drag head is in contact with the seabed as the vessel is in motion. High pressure water pumps flush water into the seabed loosening the sediment which is sucked up into the hopper onboard the vessel. Sediment is then redeposited in the marine environment so as to avoid permanent loss of sediment from the system / maintain the local sediment 'budget', where required (e.g. by direct release from the hopper to the seabed or fluidising the sediment and pumping it to the disposal location). More details on this element of the offshore works, including the location of the disposal sites, are provided in Section 4.8 with a summary of a conservative estimate of the predicted sandwave levelling works provided in Table 4.14; further refinement will be undertaken as the Proposed Development progresses.
- 4.6.15.5 Once the cable(s) are installed, the sandwave features will be left to reform via natural processes. Recovery is assessed within the ES and further mobility studies are planned to provide greater insight into the recovery during FEED stages of the project.

Table 4.14 –Summary of Predicted Sandwave Levelling Works for the Offshore Export Cable

Section of Export Cable (KP Interval)	Sandwave Crests (crest height above mean undisturbed seabed level)	Length (m)	Width (m)	Volume (m ³)
8.0 – 8.5	4	200	50	20000
12.5 – 13.0	2	300	50	15000
13.5 – 14.0	2	400	50	20000
15.0 – 15.5	4	400	50	40000
15.5 – 16.5	5	600	50	75000
29.0 – 30.0	6	600	50	90000
45.3 – 46.3	4	500	50	50000
Sub-Total		3,000	-	310,000
<i>30% contingency added due to allow for potential changes in future</i>				
TOTAL		3,900 m		403,000 m³

Table 4.15 – Summary of Predicted Sandwave Levelling Works for the Array Area

Mooring Lines	
Length of mooring line requiring clearance (on average) per mooring	60 m
Width of potential sandwave levelling per mooring	40 m
Number of mooring lines requiring levelling	Up to 2
Area of potential sandwave levelling	4,800 m ²
Volume of sandwave material to be levelled	6,000 m ³
Anchor locations (drag embedment only)	
Number of anchor locations requiring clearance	Up to 5
Length per anchor (for installation)	50 m
Area of potential sandwave levelling	4,500 m ²
Volume of sandwave material to be levelled	15,000 m ³
Array Cable	
Length of potential sandwave levelling	550 m
Width of potential sandwave levelling	20 m
Crest height	3-4 m
Area if potential sandwave material to be levelled	11,000 m ²
Volume of sandwave material to be levelled	160,660 m ³
TOTAL volume of sandwave material to be levelled (+10% contingency)	181,600 m³

4.6.16 Navigational Markers and Lighting

- 4.6.16.1 Appropriate navigational markers, lighting and signage will be installed within the array area to mitigate potential risks and provide warning to marine operations, other sea users and the aviation industry as far as possible. Examples of typical aids to navigation are shown in Graphic 4.14. An 'Aids to Navigation Management Plan' will be developed for approval from Trinity House (TH) and the Maritime and Coastguard Agency (MCA) post-consent and prior to construction once the Project layout has been finalised. Further consideration on the use of navigational markers and lighting is provided in the Navigational Risk Assessment (Volume 3, Technical Appendix 16.1: Navigational Risk Assessment)
- 4.6.16.2 The semi-submersible floating platforms will be painted yellow (RAL 1032 (traffic yellow) from the Floater Water Line to +15 m above Floater Water Line) and be marked by marine lanterns with flashing yellow lights. Fog signals may also be installed at the array area which will take into account the prevailing visibility, topography and vessel traffic conditions, with a range of at least 2 nautical miles (nm).

- 4.6.16.3 All navigational aids will be in accordance with relevant guidance such as guidance note MGN654 (MCA, 2021), and IALA guidance (Recommendation O-139 on The Marking of Man-Made Offshore Structures, Edition 2, December 2013). Consideration will be given to use of virtual aids to navigation as well as buoyage. The site will be marked on the UK hydrographic charts and through Kingfisher Information Service – Offshore Renewable & Cable Awareness (KIS-ORCA) to manage fisheries awareness.
- 4.6.16.4 The WTG units will be marked in accordance with relevant aviation requirement, such as the Civil Aviation Authority (CAA) Guidelines on Wind Turbines CAP 764, and in consultation with other key organisation such as the Maritime and Coastguard Agency (MCA).

**(a) Special mark****(b) Cardinal buoy****Graphic 4.14 – Typical Marine Aids to Navigation (Source: OWC, 2021)**

4.7 Onshore Project Infrastructure

- 4.7.1.1 The following sections provide details on the key onshore Project components, including specific values and parameters that provide the basis of the PDE and assessments presented in this ES. In respect to the onshore cable corridor, the PDE specifies the extent of the limits within which the onshore export cable may be installed.
- 4.7.1.2 This approach has been taken to ensure there is sufficient flexibility provided for the installation to be carried out around other utilities and features, whilst ensuring from the outset that the maximum area that may be affected by this element of the Project is defined.
- 4.7.1.3 In certain areas, i.e. where HDD and other trenchless techniques are to be used to install the onshore export cable, or where the onshore export cable connects to the offshore export cable, or to accommodate temporary construction compounds, a wider onshore cable corridor is provided to ensure the full extent of the area beneath the surface where the cables may be located is identified.
- 4.7.1.4 In addition, the final burial depth of the respective cables will be confirmed when the final design is produced by the chosen contractor. Noting this, the EIA has been carried out on the basis of worst case assumptions regarding the proposed cable burial along the Project.
- 4.7.1.5 Details on the installation process for these various elements are covered separately below.

4.7.2 Landfall and Transition Joint Bay

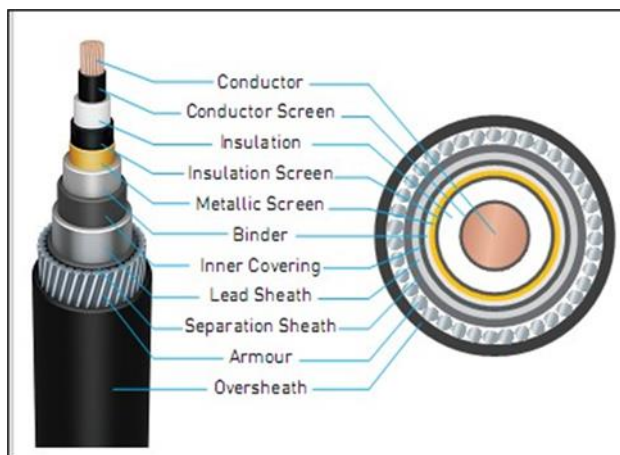
- 4.7.2.1 Landfall works above MHWS (onshore) will depend on the installation methodology selected.
- 4.7.2.2 To maintain the necessary flexibility to the Project, as defined in Section 4.2 for the northern option two potential installation options have been developed for landfall: HDD or open-cut trenching, including potential use of cofferdams. The preferred option for landfall is HDD as this will reduce the footprint of impact on shallow sub-tidal and intertidal marine habitats. However, without information from detailed HDD feasibility studies, and further geotechnical site investigation works that will be undertaken post-submission, risk remains that HDD may not be technically feasible. Therefore, open cut trenching is also considered as a contingency option. Landfall at the southern location can only be achieved by HDD and this option will be considered ahead of the open cut trench option at the northern location.
- 4.7.2.3 Full details of the proposed installation methodologies are set out in Section 4.8 (Offshore Electrical Infrastructure – Landfall (marine) with the key parameters presented in Table 4.11 and Table 4.12.
- 4.7.2.4 The TJB is located near landfall and contains the joints between the onshore export cable and the offshore export cable.
- 4.7.2.5 The TJB comprises a below-ground concrete plinth, where cables and joints are anchored. Additional reinforcements made from steel, are added if necessary.
- 4.7.2.6 The TJB is backfilled with a layer of stabilised material, typically Cement Bound Sand (CBS), for about 600 mm around the plane of the cables and native material for the remaining layers. If required, lids made of concrete/steel would be installed above the CBS, this to protect the TJB in case that heavy traffic is expected to cross over the area. The original surface is then reinstated on the top layer.
- 4.7.2.7 Indicative dimensions for the TJB are provide in Table 4.16.

Table 4.16 – Transition joint bay parameters

Maximum Number of bays at landfall	Bay length	Bay width	Bay depth
2	12 m	6 m	2.25 m

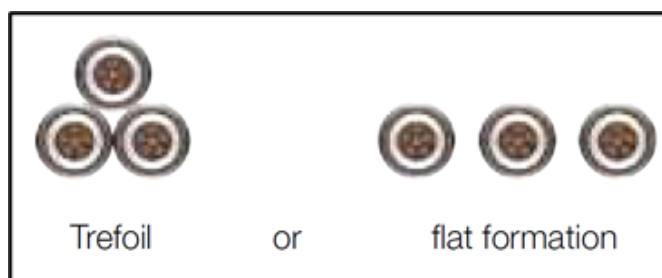
4.7.3 Onshore Export Cables

- 4.7.3.1 The onshore export cables include a 66 kV section from landfall to the onshore substation and a 132 kV section from the onshore substation to the National Grid interface point at Pembroke 132 kV.
- 4.7.3.2 Single-core cables only contain one copper (or aluminium) conductor (Graphic 4.15). Aluminium cables are typically lighter and cheaper than copper cables but offer reduced capacity for a given conductor size. Aluminium cables represent the standard technology used for recent underground export cable systems. The cables are normally insulated with cross-linked polyethylene (XLPE). The outer protective layer will be a metallic sheath consisting of aluminium tape and copper wires. A steel armouring layer provides further mechanical protection, but the installation of armoured cables is limited to specific cases, where external loading is anticipated.



Graphic 4.15 – Cross-section of single-core XLPE cable (source: Nexans, 2020)

- 4.7.3.3 The Project will comprise of up to two circuits which will each feature three onshore cables (up to six total), one for each electrical power phase, and are typically installed in “trefoil formation”, which minimises the external magnetic field by minimising the distance between conductors axis. For more difficult crossings, such as bridges or culvert crossings, where the space available is reduced, the cables can be laid in a flat formation. These formations are shown in Graphic 4.16. The Project has assumed a flat formation whilst developing onshore export cable site boundary widths to allow for worst-case dimensions.



Graphic 4.16 – Trefoil and laid flat cable formation (source: Nexans, 2020)

- 4.7.3.4 The cable specification used for the onshore export cable is subject to detailed investigation. The Project has provided an initial estimate for the cable size that could be used given as 1200 mm² Aluminium at 66 kV and 300 mm² Aluminium at 132 kV. However, the final design will take into account all the specific burial conditions which will be assessed at detailed design stage.
- 4.7.3.5 Joint bays will be required at points along the route, to connect one cable section to another. The number of joint bays along the length of the cable route is dictated by the length of cable that can fit on a cable drum (the drum-shaped reel on which the cable is stored prior to installation) and limits to the pulling tension required to pull the cable through the ducts. The distance between joint bays will depend on the technique employed by the Contractor and therefore flexibility as to the number and location of joint bays is sought in the application.

- 4.7.3.6 Excluding specific soil conditions, the joint bays are simply enlarged sections of the cable trench. The bays will be of a light construction, with a temporary timber shoring and a concrete base. Some joint bays will also allow for sheath cross-bonding (earthing link boxes shown in Graphic 4.17), visual inspection and testing. These link boxes may be underground, with a manhole access, or could be housed in above ground pill boxes. Each joint bay at each joint bay location will have a visible manhole cover.

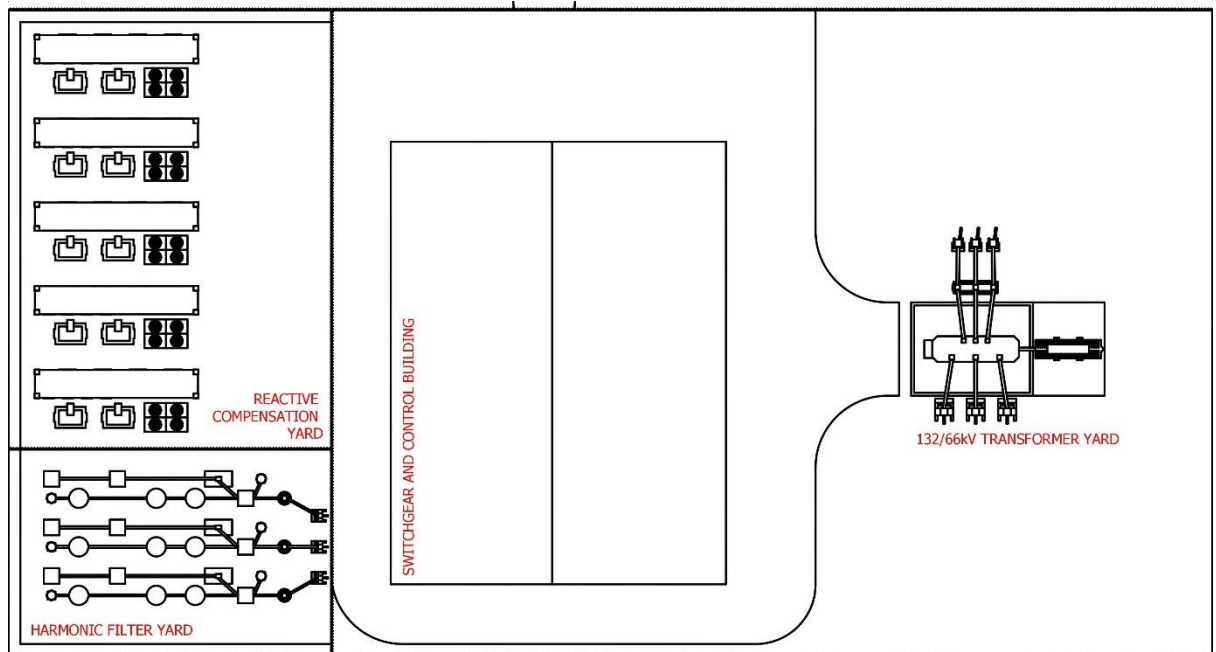


Graphic 4.17 – Earth link boxes surface and above ground

- 4.7.3.7 Link boxes are typically located alongside a joint bay and are accessed via a manhole cover, installed flush to the surrounding ground. The dimensions of a link box are approximately 0.8 m x 0.8 m x 0.6 m. Link pillars are frequently used on arable land (instead of link boxes) and they are normally located adjacent to hedgerows. They are accessed via doors at the front of the link pillar and the dimensions are approximately 1.0 m x 1.0 m x 0.6 m. The link boxes (or pillars) are connected to the metal casing of the joint via underground bonding leads.
- 4.7.3.8 The magnetic fields and electric fields associated with onshore export cables are related to the time-varying current carried by the cable. The magnitude of the current depends upon the power captured by the wind farm at any given time. The power capture of the wind farm can be understood by wind statistical analysis, which determines the wind speed distribution and availability. The magnitude of electromagnetic (EM) fields around the cables will fluctuate according to the wind farm output and based on the average wind speed, the EM fields around the export cables will be less than any expected worst-case value. Following acquisition of site-specific wind data, an estimate of the power output distribution can be derived providing further accuracy of the expected EM field around the export cable.
- 4.7.3.9 EM fields will be present around underground HVAC export cables while they are energised. Laying cables in trefoil formation is a method of reducing the magnetic field as the symmetry of the phases results in a substantially reduced external magnetic field compared to cables laid in flat formation. A minimum 900 mm depth of soil covering will also assist in reduction of EM fields at surface.
- 4.7.3.10 UK policy is to comply with 2010 International Commission on Non-ionising Radiation Protection (ICNIRP) guidelines for public exposure limits of time-varying fields. The ICNIRP revised the 1998 guidelines in which effectively doubled the advisable public exposure magnetic flux density and magnetic field strength limits. In 2016 the Control of Electromagnetic Fields at Work Regulations 2016 came into force in the UK to reflect the 2010 guidelines. The 2010 ICNIRP and 2016 UK regulations will be adhered to throughout the Project.

4.7.4 Onshore Substation

- 4.7.4.1 The onshore substation for the Project houses key electrical plant to ensure a safe and secure connection to the GB National Electricity Transmission System. It is a conventional AC substation design allowing for the project export voltage (66 kV) to be transformed to the National Grid Electricity Transmission (NGET) interface voltage (132 kV) to be operated at 132/66 kV.
- 4.7.4.2 The onshore substation will be within a footprint up to 128 m by 88.5 m featuring a concrete pad which will house the electrical plant and buildings. The maximum height would vary, it would be a maximum of 8 m if an Air Insulated Switchgear is selected or 15 m if a Gas Insulated Switchgear. Hard standing will be in the form of hard core or tarmac surfaces on the access roads within the substation and the perimeter access road. The compound will be orientated to allow the HVAC cables to enter the site from the offshore infrastructure to the west and exit the site to the NGET interface point to the north.
- 4.7.4.3 A small building is located within the substation compound which includes rooms for control and protection, telecoms, auxiliary and backup power, and personnel.
- 4.7.4.4 The defining feature is the AC switchyard, which would contain bays comprising disconnectors, circuit breakers, metering devices and ancillary services as shown in Graphic 4.18.



Graphic 4.18 Example of onshore substation infrastructure

- 4.7.4.5 A single 132/66kV transformer is required to transform the Project export voltage to the NGET interface voltage. The transformer will be placed on a transformer oil catch pit for additional health and safety and environmental protections.
- 4.7.4.6 Dedicated spaces would be allowed for reactive power compensation equipment, large Static VAR Compensators (SVC) or Static Synchronous Compensator (STATCOM) for providing fast-acting reactive power. The SVCs are made out of a combination of controlled capacitors and reactors.

- 4.7.4.7 Further space may be allocated for harmonic filter switchyards, if needed to comply with the Grid Code, which would contain a combination of power resistors, reactors, and capacitors. Harmonic filters may be operated at 66 kV, or directly connected at 132 kV.
- 4.7.4.8 An earthing system consisting of a mesh or grid of metal conductors which are installed on the substation site after earth works are completed and prior to installation of equipment or buildings to ensure suitable earthing for electrical plant.
- 4.7.4.9 The site will be constructed with all appropriate and legal measures taken to ensure security and public safety. The substation perimeter is most likely to be protected by 2.4 m tall palisade fencing. This is a common type of enclosure used on substations in Great Britain.
- 4.7.4.10 The onshore substation will include the use of SuDS to mitigate flood risk and treat run-off to an appropriate level prior to discharge. Further details are included in Chapter 19: Onshore Geology Hydrology and Hydrogeology.
- 4.7.4.11 Landscape mitigation principles have been developed for the onshore substation to further mitigate landscape and visual effects for those areas where visibility is found. Further details are included in Chapter 21: Landscape and Visual Impact.
- 4.7.4.12 Table 4.17 shows the anticipated worst-case onshore substation dimensions for the wind farm connection. A maximum building height of 15 m has so far been estimated and supported by early transformer supplier engagement. Exact dimensions will be provided by the selected Contractor. The dimension provided will allow, if required, to have a full enclosed substation to protect the transformer from weather conditions. Buildings will likely be made of painted galvanised steel sheets or masonry brick, any other buildings required such as equipment storage sheds, will be made of galvanised steel or masonry brick.
- 4.7.4.13 Adequate lighting must be provided throughout the substation in the form of compound floodlighting to facilitate any inspection or maintenance of electrical equipment at night. This would normally be 10 lux along access paths and around major items of electrical plant. A minimum of 110 lux lighting should be provided around the entry to the substation and a level of 2.2 lux around the perimeter fencing. This may require columns to fix lighting to although electrical clearances should be followed to eliminate the possibility of a column falling across electrical equipment.

Table 4.17 – Maximum dimensions for the building within the substation

Onshore Substation	
Onshore substation maximum footprint	11, 328 m ²
Number of buildings within substation footprint	1
Building dimensions	30 m (l) x 25 m (w) x 15 m (h)

4.8 Offshore Construction

- 4.8.1.1 In contrast to fixed foundation offshore wind projects, where the majority of installation works happen on-site (offshore), for FLOW projects a considerable amount of the offshore installation activity can take place onshore or in the relatively sheltered environment of a port/harbour. This not only substantially reduces the extent of marine operations associated with the project construction but also the requirement for specialist construction vessels during installation operations.

4.8.1.2 There are uncertainties remaining in the current knowledge of the construction methodology for the Project. However, an overview of the anticipated construction methodology has been summarised below for the various elements of the Project.

4.8.2 WTG Units and Semi-Submersible Floating Platform – at Port

4.8.2.1 It is proposed that the WTGs will be installed and commissioned on the semi-submersible floating platform at a port facility and/or nearby sheltered waters, in the Celtic Sea region where possible. It is also anticipated that the final stages of the semi-submersible floating platform assembly, prior to WTG integration, are also undertaken at the same local port(s), if facilities are determined sufficient to support this work. However, this will be confirmed following submission of the consent application.

4.8.2.2 The following activities are anticipated, based on installations in Europe, to be undertaken when integrating the WTG to the semi-submersible floating platform and transfer to the array area (for example see Graphic 4.19):

1. Mobilisation and erection of high-capacity land-based crane.
2. Unloading in-bound WTG components from supply vessel.
3. Laying down of WTG components.
4. Unload semi-submersible floating platforms from supply vessel (or barge), and wet store/moor semi-submersible floating platform at quayside.
5. A spacer barge or fenders may be used to separate the semi-submersible floating platform unit from the side of the quay. Mooring and spring lines would keep the unit in a stable position at quayside.
6. Preparation of WTG components for assembly (tower sections, nacelles, hubs, rotor blades).
7. Sequentially, the WTG components will be lifted and secured to the unit. The semi-submersible floating platform unit should remain even keel during the whole operation by adding or removing ballast water to / from the different compartments, or grounding at the quayside as the weight of each WTG component is being transferred from the crane onto the unit.
8. Pre-commissioning of fully assembled semi-submersible floating platform and WTG unit at quayside.



Graphic 4.19 – Example of Assembly of Wind Turbine Generator onto a WindFloat™ Platform at Quayside and Towing Out (Source: Photo courtesy of Principle Power. Artist: DOCK90)

4.8.3 WTG Units and Semi-Submersible Floating Platform – Offshore

- 4.8.3.1 The proposed installation works at the array area would involve the following sequence.
- 4.8.3.2 Pre-installation survey of area where mooring lines and anchors will be deployed.
- 4.8.3.3 Mooring System Pre-Lay: using Anchor Handling and Tug Supply vessels and specialist Remote Operated Vehicles (ROVs), the anchors and mooring lines will be laid one after another for each unit. Due to water depths on site, all vessels will be Dynamically Positioned (DP Class) with no vessel anchor deployment required. Final anchor/foundation types will be confirmed during the Front-End Engineering Design FEED stage following inputs from site surveys and design refinement. After their deployment, the anchors will be proof load tested to a level of tension specified during the engineering phase. Except for the anchor and anchor chain, no other part of the permanent mooring system will be connected during proof load testing. In order to verify the correct positioning of the anchors after the test, the mooring lines may be equipped with transponders, or similar systems.
- 4.8.3.4 Each structure will be subject to a full mooring analysis and the pre-tensioned mooring system will be completed for each structure in accordance with the outcome of these studies. Following deployment, the pre-installed/tensioned mooring system, cable ends will be buoyed off temporarily, for later recovery and attachment to the WTG/substructure assembly following its arrival on site.
- 4.8.3.5 All regulatory and required marine navigation notifications, such as Notice to Mariners and Kingfisher notices, will be issued in advance of the works or installation.
- 4.8.3.6 Offshore Tow and Mooring Hook-Up: the tow would be timed when weather forecasts indicate a suitable weather window for the planned hook-up works as well as the tow. The mooring hook-up requires the use of the tow vessel onboard winch to pull in the mooring line itself. Thus, an offshore team will be working from the unit to operate the winch.

4.8.3.7 In terms of duration of works, it is predicted that inclusive of 50% weather contingency and transit times to/from local ports to site, the installation of all the moorings/anchors will take up to 44 days.

4.8.3.8 The hook-up of the maximum number (10) semi-submersible floating platforms, also inclusive of transit to/from ports to site and 50% weather downtime, is predicted to take an additional 46 days. Therefore, it is anticipated the main works in the array area will take up to 90 days.

4.8.4 Offshore Electrical Infrastructure – Array Cables

4.8.4.1 The dynamic array cables can be installed in several different configurations depending on whether the WTG platform is being deployed to its final location.

4.8.4.0 It is anticipated that the array cables (dynamic and static sections) will be installed following the semi-submersible floating platform's deployment through a so called "dry storage" installation methodology. This method involves the dynamic cable sections being pulled into the semi-submersible floating platform through the I-Tube (part of the floating platform), while the rest of the array cable remains on the Cable Lay Vessel's (CLV) carousel. Once the array cable is fully connected to the floating platform, the lazy wave dynamic catenary shape fully developed and the touch down point location established, the CLV will start laying the static part of the cable on the seabed towards the next WTG.

4.8.4.1 The final decision on the installation of the array cables will be made at the detailed design phase which will occur after the consent application submission.

4.8.4.2 After the array cable is laid-up the pull-in operation will take place. This involves pulling the array cable up the I-Tube to facilitate electrical connection works within the floating platform.

4.8.4.3 It is anticipated that the array cables will be manufactured in a single manufacturing length with no external mate-able connectors. This design and installation configuration is the preferred approach of the major cable manufacturers and is reflected in the design assumptions for the Project.

4.8.4.4 Alternatively, the static and dynamic sections can be manufactured separately, and a permanent mate-able transition joint can be installed to connect them.

4.8.4.5 Mate-able connectors can be either wet-mate or dry-mate type. While wet-mate connectors allow each array cable end to be connected and disconnected underwater by an ROV's manipulator, dry-mate connectors require assembly on board the CLV. Therefore dry-mate connectors require the static cable end to be pulled up, and after being jointed with the dynamic cable end, lowered to the seabed ready for the "first-end pull in" operations.

4.8.4.6 Once the dynamic cable's hardware, such as :-, bend stiffeners, buoyancy modules and touchdown point protection have been installed, the array cables will likely be stabilised with rock bags (see Scour and Cable Protection, Section 4.6.13.1 to 4.6.13.7).

4.8.4.7 Assuming the maximum length of array cable is installed, the duration of installation is predicted to be up to 40 days, inclusive of any associated cable protection works, operational contingency and 50% weather downtime.

4.8.5 Offshore Electrical Infrastructure – Offshore Export Cable

- 4.8.5.1 A significant amount of work has been undertaken to select an ECC that avoids a number of constraints and seabed features (see Chapter 3: Site Selection and Alternatives). Due to the timescales between the initial assessment and construction of the Project, it is likely that detailed design work will be required prior to the offshore export cable installations. This could take the form of survey and desk-based assessments to update the original work undertaken.
- 4.8.5.2 The following sections outline the range of activities that will need to be undertaken to install the offshore export cable.

Pre-Construction Surveys

- 4.8.5.3 Prior to cable installation, further geophysical and geotechnical surveys would be carried out to gather information on route debris, boulders, presence of unexploded ordnance (UXO), seabed features and sediment depth. All these data would be reviewed to inform the final export cable route within the ECC, the target burial depth, the exact installation methods to deploy and what, if any, additional cable protection would be required (within maximum PDE parameters).

UXO Clearance

- 4.8.5.4 With respect to UXO the Project is seeking consent for one Unexploded Ordnance (UXO) detonation via deflagration (low-order). This is presented as the realistic worst case scenario throughout the ES and has formed the basis of the impact assessment undertaken in Chapter 10: Fish and Shellfish Ecology and Chapter 12: Marine Mammals.
- 4.8.5.5 Deflagration (low-order) is the Project's preferred method for UXO clearance and based on current industry knowledge and precedent set by other offshore wind farms, eg. Sofia Offshore Wind Farm (Sofia Offshore Wind Farm UXO Clearance Marine License Application (GoBe, 2021) MLA/2020/00489), is considered the realistic worst-case scenario. High order UXO detonation, as an absolute worst case, has been modelled and reported in Volume 3, Technical Appendix 12.2: Underwater Noise and Vibration Technical Report. However, this has been considered for completeness and is not deemed realistic as the Project intends to employ deflagration (low-order) as the clearance method.
- 4.8.5.6 This approach is informed by the UXO Threat and Risk Assessment (6-Alpha Associates, 2020) completed to inform Project specific geotechnical surveys, which provides an assessment of potential threat sources and the likelihood of contamination across the Project array area and ECC. The Project is also cognisant of the recently consented Marine Licence for the Greenlink Interconnector and the UXO approach adopted for the cable route in Welsh waters, i.e. the same as proposed for the Project.
- 4.8.5.7 Furthermore, a pre-installation (post-consent) geophysical survey will also be carried out and include a magnetometer survey, designed to identify any potential UXO targets in the vicinity of the planned offshore export cable corridor. If a UXO target is identified the intention would be to route around the UXO and avoid interacting with it. The offshore export cable corridor has sufficient width built in to allow this occur. However, if it is not possible to route around the UXO a more detailed assessment of the specific target would be undertaken (potentially via ROV) to determine UXO risk, and only if no alternative existed would the Project undertake UXO clearance via deflagration (low-order). This is considered the realistic worst case.
- 4.8.5.8 If the survey identified more than one UXO target requiring clearance the Project would engage with the regulators and apply for a variation to allow additional UXO clearance via deflagration (low-order).

Boulder Clearance

4.8.5.9 Prior to the Pre-Lay Grapnel Run (PLGR, see section 4.8.9 below), there may be a requirement to undertake boulder clearance, depending on the density of boulders identified via the pre-installation geophysical survey. Boulder clearance would be undertaken by one of, or a combination of, the following two methods:

- SCAR plough (15 m footprint, 0.5 m penetration); and
- Sub-sea grab.

4.8.5.10 The estimated total footprint from the use of a SCAR plough is 15 m (7.5 m either side of centre line) covering an estimated 12 km length of the offshore export cable, covering 180,000 m².

4.8.5.11 Based on current knowledge of the extent of boulders within the ECC and inclusive of operational contingency and 50% weather downtime, the boulder clearance operation is expected to take up to 30 days.

4.8.5.12 Boulder clearance should be undertaken prior to PLGR, approximately 3 to 6 months before cable installation.

Pre-Lay Grapnel Run

4.8.5.13 Following the surveys, preparatory boulder clearance and UXO clearance, additional works would be undertaken including a PLGR. The purpose of the PLGR is to clear the offshore export cable route, within the ECC, of debris prior to installation. This would involve a series of grapnels and chains (approx. 1 m width) being pulled along the cable route affecting an area of approximately 15 m width (where multiple passes are required), and penetrating the seabed to about 0.5 m.

4.8.5.14 Based on the current understanding of the route and inclusive of operational contingency and 50% weather downtime, the PLGR operation is expected to take up to ten days.

Sandwave Levelling

4.8.5.15 Where mobile bedforms are not able to be avoided seabed levelling will take place, preferably using MFE or jetting, however TSHD is an option currently included to ensure the worst-case scenario is reviewed (see Section 4.6.15.1).

4.8.5.16 Disposal sites have been allocated within the offshore consent boundary to ensure that where TSHD is required the sediment removed is retained within the local system. These sites have been summarised in Table 4.18. For the ECC, they have been identified by using defined categories associated with the preliminary cable burial assessment (OWC, 2021) and extending 500 m offshore and 200 m inshore along the ECC all within the offshore consent boundary. The array area covers the sandwave field plus a simplified 500 m buffer.

Table 4.18 –Summary of Predicted Sandwave Levelling Disposal Sites

Disposal site ID	Location of disposal site (KP Interval)	Approx. Length (m)
SLD_01	7.8-8.9	900
SLD_02	12.6-14.6	1,900
SLD_03	14.7-17.7	2,900
SLD_04	28.8-30.9	2,000
SLD_05	Northern Array Area	5,600

- 4.8.5.17 Sandwave levelling is predicted to occur at a rate of 500 m/day. With a current estimate of approximately 3,900 m of sandwave levelling required for the ECC, inclusive of contingency for operational issues and up to 50% weather downtime, this activity is expected to take up to 15 days. The array area has the potential for levelling to occur for the array cable (for 3 sections totalling 550 m), mooring lines (up to 2 totalling 120 m) and anchor locations (up to 5, totalling 250 m). Although the rate is still 500 m/day (which would mean 2 days of levelling), the contingency for transit, operational issues and weather may lead to 1 location per 2 days, therefore the activity may occur over 20 days (not necessarily levelling for the entire time).
- 4.8.5.18 Sandwaves are generally mobile in nature, therefore the cable should be buried beneath the non-mobile seabed level in order to avoid the detrimental effect of natural sand wave migration. This is usually achieved by removing the mobile layer of sediment before installation takes place, typically undertaken either via TSHD or MFE.
- 4.8.5.19 TSHD is used in aggregate extraction, navigational dredging and marine construction to remove sediment and allow access to more stable seabed sediment. MFE is widely used in the industry for sand wave or mega-ripple pre-sweeping, and for a post lay burial application with an approximate typical footprint of ranging between 7 and 10m width operating with a maximum working pressure of 350 Bar and flow rates of up to 4 m³/sec. MFE can be used in a combination of modes to either fluidise the seabed beneath the cable and allow it to sink further into the trench beneath or used to jet the seabed soils at a specific angle, pushing sediment across and into the cable trench to increase the depth of cover in loose sandy seabed.

4.8.6 Offshore Export Cable Installation Process

- 4.8.6.1 The offshore export cable will be installed using specialist cable installation vessels. Cable burial in sedimentary seabed can be completed using a number of different methods such as submarine ploughing (Graphic 4.20). A summary of the offshore export cable installation stages is provided below.

Pre-Lay Trenching / Multiple Pass

- 4.8.6.2 Pre-lay trenching or multiple passes will take place prior to cable lay in required sections of the route. A pre-trench plough will be used, creating a trench of up to 3 m depth, and the plough will run on skids extending 2 m either side of the trench with a combined width/footprint at seabed of 7m overall. Multiple passes to reach the required depth may be needed.
- 4.8.6.3 Based on current knowledge of the offshore export cable route within the ECC multiple passes, to ensure suitable trench depth is achieved, are predicted to be required over approximately 13.5 km of the route. It is anticipated that up to 3 passes of this section will be required to achieve the target depth and can be done at an average speed of 500 m an hour.
- 4.8.6.4 Based on this predicted length of operations and inclusive of operational contingency and 50% weather downtime, the multiple pass/trenching works are expected to take up to eight days.

Cable Plough

- 4.8.6.5 Installation via a conventional cable plough is proposed where possible to minimise seabed disturbance. The plough itself runs on skids with a contact width less than 5 m. The trench itself would be less than 5 m in width (typically less than 1 m) and less than or equal to 3 m in depth.
- 4.8.6.6 The exact depth of any cable trench will be linked to the target Depth of Burial (DoB) defined by the Project. This will be defined post-consent via a Cable Burial Risk Assessment (CBRA) taking into account ground conditions as well as external aggressors to the cable such as trawling and vessel anchors.
- 4.8.6.7 Typical rate of combined installation/burial via a cable plough is up to 2 km/day, inclusive of operational downtime. With 50% weather downtime applied, the offshore export cable installation is expected to take up to 49 days.

Post-Lay Burial

- 4.8.6.8 Post lay burial is currently understood to only be required at joint locations along the offshore export cable, see Section 4.8.8. MFE will be used to bury the joint once completed.
- 4.8.6.9 Each joint (approx. 150 m) and the cable either side (approx. 250 m) will take approximately 3 days to complete, including weather, operational contingency and inspection post burial. Burial will take place as close to installation of the joints as possible.

4.8.7 Cable Protection

- 4.8.7.1 Where cable burial is not possible due to hard substrates or minimal sediment cover, it is proposed the offshore export cable will be partially buried or surface laid and then protected to the required depth using various solutions such as concrete mattresses, rock bags or rock dumping. The proposed quantities are set out in Table 4.3.
- 4.8.7.2 These artificial cable protection solutions would require either a vessel with a crane in order to lift the cable stabilising product and to lower it onto the offshore export cable at the required locations, or a Flexible Fall Pipe Vessel to install the rock on the seabed (to be determined during the engineering cable stability assessment). The locations are determined to both stabilise and protect the cables (see Scour and Cable Protection, Sections 4.6.13.1 to 4.6.13.7).
- 4.8.7.3 Based on the predicted amount of cable protection needed along the offshore export cable this activity is predicted to take up to 15 days, inclusive of operational contingency and 50% weather downtime.



Graphic 4.20 Example of a plough and vessel (Source: OWC, 2021)

4.8.8 Offshore Electrical Infrastructure Installation – Offshore Export Cable Joints

4.8.8.1 Two cable joints are currently proposed to be installed along the offshore export cable, at approximately KP15.0 and KP32.0. The jointing of subsea cables offshore requires a window of good weather duration as the cables would be hanging down from the vessel posing a risk to the crew should the vessel be moving excessively. Typically, jointing will take between one and ten days after both cable ends are secured on-board the jointing vessel. Additional time will be needed to recover the cables pre-jointing and to re-bury the cable post-jointing.

4.8.8.2 The predicted length of operations to install the two planned offshore export cable joints, inclusive of operational contingency and 50% weather downtime, is 24 days.

4.8.9 Offshore Electrical Infrastructure Installation – Landfall (marine)

HDD (marine operations)

4.8.9.1 HDD is a trenchless technology widely used in cable landing applications offering several benefits compared to the traditional open-cut method. The main advantage of selecting an HDD methodology for the Project offshore export cable landing at West Angle Bay will be the minimisation of disturbance and impacts on the beach, intertidal and nearshore subtidal environments when compared to open cut trench excavation.

- A shallow draft Cable Lay Vessel (CLV) with a flat keel will be deployed to install the export cable nearest the shore from the HDD exit point in the sub-tidal area. Some flat-bottomed barges can ground out, therefore an adequate survey will be undertaken, for assessment of local conditions. They can be either self-propelled or rely on support vessels to provide towage and assistance. They also tend to operate with an anchor spread, requiring working space which is dependent on water depth but can be in the range of 200-300 m either side of the cable route.

- HDD boreholes will be required at West Angle Bay landfall to install the HDPE conduits through which the offshore export cable will be pulled in. The depth and the length of each individual HDD borehole will be determined as part of the HDD feasibility study.
- The offshore and onshore cable circuits will be jointed at landfall in a TJB. When landing a cable via HDD, the jointing of the onshore and offshore sections of the export circuit typically takes place in proximity of the HDD entry point onshore, therefore driving the final location of the TJB.
- Following the cable pull-in operations and the completion of the jointing activities, the transition joint bay will be backfilled and then the ground re-instated.
- The HDD bore path design and alignment require thorough considerations to account for any information on cable mechanical properties, local geology, nearshore physical processes, bathymetry and tides, and electrical constraints such as cable separation requirements.

Open-cut trenching

4.8.9.2 If open-cut trenching is required at landfall, the following methodology would be adopted:

- The trench will likely be partitioned into two sections; the nearshore intertidal section, which can be excavated by land-based equipment, and the offshore sub-tidal section which will require excavation by marine plant/vessels;
- For the nearshore intertidal section, a conventional, track-based excavator will be used to open up a trench from the TJB towards the subtidal region. This will be approximately 500 m – 650 m length and 3 m wide;
- Material removed from the intertidal section of the trench will be temporarily stored in situ alongside the trench via either a continuous berm of material running parallel to the trench or in a series of discreet mounds;
- Excavation and installation activities will likely be undertaken at low tide to maximise the extent of excavation equipment across the intertidal area;
- Across the subtidal section, the trench will be excavated either via a barge mounted backhoe excavator or a “walking spider” excavator – see Graphic 4.21 and Graphic 4.22.
- The latter will likely be the preferred option to undertake excavation works in proximity of MLW, as it is capable to work in water depths of up to 2 metres, featuring greater manoeuvrability compared to a traditional barge mounted excavator;
- Material removed from the subtidal section of the trench will be stored within a hopper on a small, nearshore barge;
- For whatever excavation method adopted, the CLV will likely be anchored at approximately 700 m from the MHWS line and will be assisted by rigid inflatable boats (RIBs) which will assist in maintaining the cable alignment position during the shore pull operations;
- Across the intertidal zone, the cable will either be contained within a HDPE duct in the trench or laid directly onto the base of the trench⁵;

⁵ If the open cut trench is prepared in winter with pull in the following summer, the cable will be installed in a HDPE duct, i.e. it will not be surface-laid at the base of the trench.

- A temporary trench support system, such as sheet piling or cofferdams, may be required to provide the necessary trench support and stability while minimising the extent of the excavation works on the seaward side of the beach and preventing trench flooding during the cable pull in works;



Graphic 4.21– Barge-Mounted Backhoe Excavator (Source: Courtesy of Seatools, 2021)



Graphic 4.22 – Menzi Muck Spider Excavator (Source: Nexans, 2021)

- Temporary cofferdams are steel u-shaped metal structures which will surround the open cut trench working area. They are installed individually using vibro-piling techniques in the intertidal area. The cofferdam will consist of a double wall – outer and inner;
- A service crane and ancillary lifting/loading vehicles to install and remove the cofferdam required across the intertidal area at West Angle Bay;

- Upon installation of the cable duct within the open-cut trench, the excavated material will be re-instated to the trench and the original beach profile restored via mechanical re-profiling;
- As part of the preparation for the subsea cables pull in works, the area will be marked off with a tape or a buoy line to protect the site from unauthorised public access;
- When the cable is ready to be pulled in, a Cable roller pathway will be installed across the open cut trench at landfall to facilitate the cable pull in avoiding any detrimental effect on the cable outer sheath resulting from the contact with the seabed during the shore pull;
- The rollers will be positioned with high accuracy along the designated straight pull-in pathway in order to be optimally aligned with the chute;
- An onshore constant tension winch will be installed behind the transition joint bay location and positioned in straight alignment with the rollers;
- The CLV will move into position once high tide is about to approach;
- A messenger line connected to the constant tension winch wire will be connected to the first end's cable grip;
- The cable will be paid out from the vessel chute to the shore via a messenger line, this may involve small support vessels such as RIBs, divers and equipment such as floaters to be installed across the intertidal area along with pull-in line; and,
- In case of a bundled cables pull in configuration, the bundle will need to be floated through the intertidal area, running through the chute, and ending in the roller train. The cable heads will be pulled from the land constant tension winch and assisted by workboats or RIBs.

4.8.9.3 More detailed information on all aspects of cable installation (arrays; export cable); cable joints; cable protection; landfall works would be included in a Cable Burial Management Plan that would be produced pre-installation. It is assumed that the requirement to produce such a plan will be a condition of any Marine Licence issued for the Project.

4.8.10 Outline Offshore Construction Programme

4.8.10.1 The current indicative construction programme for the development outlines the key construction activities and when these activities are planned to take place and not the actual time on-site (see Graphic 4.1). This construction programme indicates a final installation and a full generation date in 2026.

4.8.10.2 Table 4.19 provides a summary of the predicted durations of the key offshore installation activities detailed above. All the durations stated cover the maximum number of key Project components, i.e. ten semi-submersible floating platforms and WTGs, and are inclusive of transit times to site from ports, operational contingency and 50% weather downtime.

4.8.10.3 The table also contains information on the predicted maximum number of vessels that will be on-site during the various installation activities. The number, type and frequency of vessel movements offshore during the installation phase have been defined in order to provide the basis of impact assessments for a number of receptors, i.e. marine ornithology (potential displacement of birds), commercial fisheries (collision risk) and shipping and navigation (collision risk).

Table 4.19 – Predicted Duration of Offshore Installation Activities

Installation Activity	Predicted (Maximum) duration of work (days)	Predicted (Maximum) number of vessels on site	Types of vessels
Export Cable Corridor			
Pre-Construction Survey	10	1	Survey vessel
UXO clearance	5	2	Survey vessel Dive support vessel
Boulder clearance	30	1	Vessel TBC
PLGR	24	1	PLGR vessel
Multipass/pre-trenching	8	1	Vessel TBC
Sandwave levelling	15	2	THSD Support vessel
Export cable installation	49	3	CLV Guard vessel 1 Guard Vessel 2
Export cable protection / cable crossings	20	2	Rock Dumping Vessel/Multipurpose Vessel Support vessel
Landfall			
Option 1 - HDD works (marine ops)	147	6	CLV Guard Vessel AHT (x 2) 2 RIBS
Option 2 - Open-cut trenching	105	13	Shallow draught barge with backhoe excavator CLV Guard Vessel AHT (x 2) 8 RIBS
Offshore Array			
Pre-installation survey	10	1	Survey vessel
Pre-installation UXO clearance (if needed)	5	2	Survey vessel Dive support vessel
Installation of site boundary navigation aids and markers	2	1	Multi-purpose work vessel
Installation of mooring lines and anchors	44	2	Anchor Handling Vessel Feeder Barge

Installation Activity	Predicted (Maximum) duration of work (days)	Predicted (Maximum) number of vessels on site	Types of vessels
Tow-Out and hook-up of semi-submersible floating platform to mooring lines	46	4	Tow vessels (x2) Crew boat Platform Installation Vessel
Inter-Array Cable installation (inclusive of cable protection)	91	2	CLV Support vessel

4.8.11 Summary

4.8.11.1 A summary of the key parameters with respect to the offshore construction are set out in Table 4.20. All parameters are subject to further refinement from the FEED and site surveys, but the values presented below have been used as the basis for the assessments presented within this ES.

4.8.11.2 It is anticipated that the production and submission for approval of a project-specific Construction Method Statement will be a consent requirement for the Project, which will document the final construction methodology and parameters.

Table 4.20 - Offshore Installation - Summary of Key Maximum Parameters

Parameter	Maximum
Overall	
Size of array area	43.5 km ²
Overall offshore construction duration	8 months
Number of vessels offshore at any one time	6
Offshore Export Cable	
Length of offshore export cable	49 km
Width of export cable corridor	450 m (100 m through Row's Rocks channel)
Number of offshore cable joints	2
Number of cable crossings	2
Target Depth of Burial (DoB)	3 m
Overall duration of export cable works (inclusive of survey, PLGR, sandwave levelling, cable installation, post-lay burial, cable protection and boulder clearance)	Boulders clearance: 30 days; PLGR 24 days; Joints: 24 days; PLIB MFE: 6 days; SLB: 49 days; Pre lay Passes: 8 days; Sand waves levelling: 15 days; Rock dumping: 20 days.

Parameter	Maximum
	Approx. Grand total: 176 + 25% contingency = 220 days
Sandwave Levelling (Offshore Export Cable)	
Length of potential sandwave levelling (inclusive of 30% contingency)	3,900 m
Volume of sandwave material to be levelled (inclusive of 30% contingency)	403,000 m ³
Offshore Export Cable Protection	
Length of offshore export cable requiring cable protection	7,580 m
Area of cable protection along offshore export cable	83,380 m ²
Landfall (Option 1 – HDD)	
Volume of drilling mud to be released (m ³)	2,400 m ³
Duration of HDD works	32 weeks
Landfall (Option 2 – Open Cut Trenching)	
Area of open-cut trench (650 m x 3 m)	1,950 m ²
Area of temporary disturbance (650 m x 10 m)	6,500 m ²
Duration of open cut trenching works	15 weeks
Area of temporary potential flotation pits	7,200 m ²
WTGs	
Number of WTGs	10
WTG Capacity	18 MW
Maximum blade tip height	270 m
Separation distance between WTGs (centre point)	3,500 m
Rotor diameter	242 m
Air gap (from sea level to blade tip)	22 m
Semi-submersible floating platform	
Number of platforms	10
Column diameter	22 m
Footprint (per platform; base of hull assumed solid triangle)	4,264 m ²
Dimensions of each side of platform	112 x 123 x 96
Height above sea surface (to freeboard)	14.5 m
Mooring System	
Number of mooring lines	35

Parameter	Maximum
Individual mooring line length	870 m
Total number of clump weights	875
Total mooring clump footprint	3,500 m ²
Number of Drag Embedment Anchors Only	63
Number of Suction Pile Anchors Only	35
Number of Driven / Drilled Piles Only	35
Sandwave Levelling (Anchors and Mooring Lines)	
Area of potential sandwave levelling (mooring lines)	4,800 m ²
Volume of sandwave material to be levelled (mooring lines)	12,000 m ³
Area of potential sandwave levelling (anchors)	4,500 m ²
Volume of sandwave material to be levelled (anchors)	15,000 m ³
Array Cables	
Number of array cables	10
Total length of all array cables (dependent on arrangement)	22.5 km
Cable crossings	2
Sandwave Levelling (Array Cable)	
Area of potential sandwave levelling	11,000 m ²
Volume of sandwave material to be levelled (+10% contingency)	160,600 m ³
Array Cable Protection	
Length of array cable requiring cable protection	21,300 m
Area of cable protection along array cable	112,200 m ²

4.9 Onshore Construction

4.9.1.1 A significant amount of work has already been done to select an initial onshore export cable site corridor that avoids a number of constraints and sensitive receptors (see Chapter 3: Site Selection and Alternatives).

4.9.2 Construction compounds

4.9.2.1 To facilitate the construction of the onshore Project infrastructure, temporary construction compounds are to be set up. The cable laydown area required for the cable drums can be a substantial portion of the onshore export system construction compound. The laydown area footprint depends on the design option (cables dimensions and number) and the cable delivery strategy chosen. The latter is influenced by the production capability of the cable manufacturer and the number of construction compounds planned for the cable route. The Applicant is in the process of considering the location of and requirements for the construction compounds, noting the main considerations so far:

- One main compound located at the Project's onshore substation;
- One landfall construction compound at the cable landing point; and,
- Up to 4 satellite compounds along the onshore cable corridor.

4.9.2.2 Indicative locations for satellite compounds, and strategy for their use, have been proposed for the purposes of Project planning and assessment of potential maximum construction footprint parameters. However, final satellite compound locations and dimensions have not yet been confirmed; this will be considered once further design has been undertaken for both the routing and cable selection. The final requirements will be outlined by the selected Contractor and control measures will be confirmed in a Construction Environment Management Plan (CEMP) and Landscape and Ecological Management Plan (LEMP) that will need to be submitted to the competent authority ahead of any works commencing on site.

4.9.2.3 The construction compounds will need to accommodate the following elements:

- Cable drums required for the route section of pertinence to that compound (i.e. entire route for the main compound, or part of the route to a satellite compound);
- Personnel facilities and one or more lock-up(s);
- Vehicle and machinery required by the works needed for the particular section of cable route (all the machinery required by the works for the main compound); and
- Suitable construction material storage, working area and access space.

4.9.2.4 The estimated compounds' dimensions are summarised in Table 4.21.

Table 4.21 – Construction Compound's Estimated Dimensions

Compound type	Length (m)	Width (m)	Overall footprint (m ²)
Main Compound	100	50	5,000
Satellite – up to 4	50	50	10,000
Landfall	70	50	3,500
TOTAL			18,500

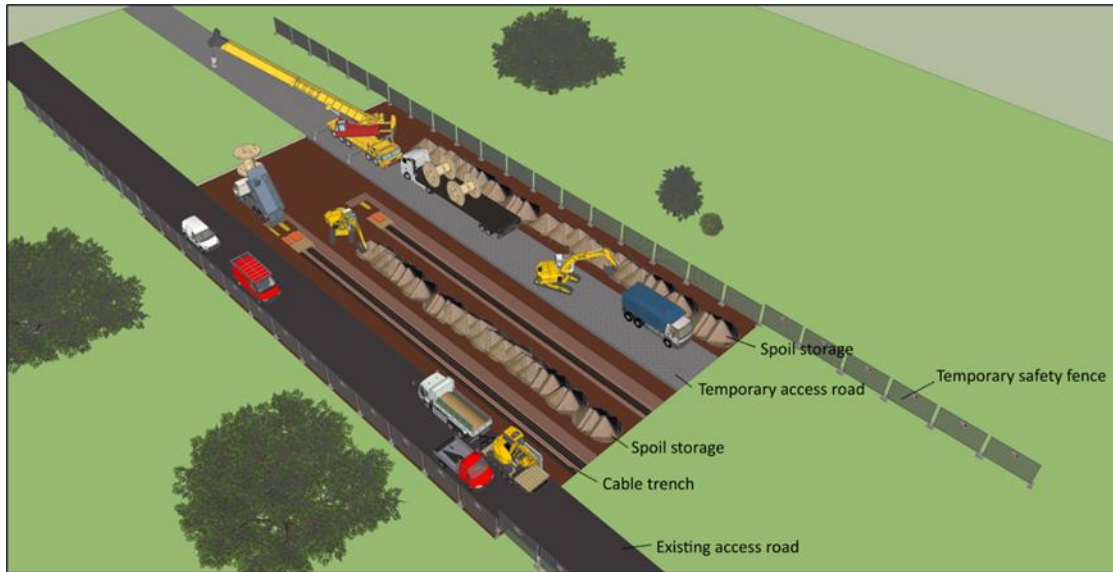
4.9.3 ***Onshore Export Cable Installation Method: Open cut trenching (arable land)***

4.9.3.1 A significant portion of the onshore export cable will be trenched, via open cut trenches. The trench will typically be made by digging up ground along the route with a large excavator. A 5 m width corridor will be required for heavy vehicle access (earth digging equipment and lifting equipment for the cable drums) along the side of the trench, and a further 5 m will be required for lay down of equipment, topsoil, and spoil from the trenching. Another 1.5 m (depending on method of trench shoring) is required from the edge of the trench on each side for safety and to prevent trench collapse under load, and a final 3 to 5 m should be provided on the far side of the trench for access, storage or working as required (Graphic 4.23).

- 4.9.3.2 After installation, the trench is backfilled with sand and/or stabilised material to approximately 300 mm above the top of the cables. The native material that was removed during construction is replaced on top of the stabilised material with any large and sharp stones removed. Finally, the trench is topped up with a minimum of 300 mm topsoil, possibly using the native topsoil, up to the surface level, and the temporary access land is to be restored as close as possible to its original conditions. Depending on the route and obstacles, various sections may use ducts and/or protective tiles may be installed in the trench above the cables.
- 4.9.3.3 Onshore export cables are typically buried at depths of 0.8 m to 1.0 m beneath the earth's surface, but through agricultural land where the risk of damage caused by agricultural machinery is high, the top of the cables must be at least 1.1 m below the surface.
- 4.9.3.4 Table 4.22 shows the trench dimensions and the overall cable route corridor for the double circuit in separate trenches in green fields. The double circuit solution could share a single trench, reducing cable installation time, cost and corridor width; however, indicative double circuit solution trench dimensions are provided to facilitate an assessment of the worst case open field open cut trenching installation footprint.

Table 4.22 – Double Trench Dimensions

Item	Width (m)
Lay down and spoil	5
Subsoil storage	3
Haul road and access way	5
Safety zone	1.5
Cable trench	1
Trench separation	2
Cable trench	1
Safety zone	1.5
Access way/storage	4
Setback	1
Total working area width (including contingency)	30



Graphic 4.23- Example illustration of typical working corridor for green fields

4.9.4 Onshore Export Cable Installation methods: Open cut trenching (in roads)

- 4.9.4.1 For a cable installation via open cut trenching in the road, the road surface is removed, and the earth underneath is dug up, a trench is made, the cables are buried/ducting laid, and the road reinstated.
- 4.9.4.2 Prior to road installation, a traffic light system is brought to site for a two-lane road, to control traffic flows so that only a single lane is closed (for the trench) when and where possible. For single-lane roads, the road must be fully closed when work is being undertaken. Signage advising detours would be erected at the road outlets. This process is gradual, necessitating the use of ducts, which are installed along each part of the route sections. Protective tiles may be installed in the trench above the cables. A guideline is that a 100 m to 300 m section of road should be closed or subject to traffic disruption at a time. Public access should be limited to that necessary for health and safety purposes, and essential services and operations, such as Control of Major Accident Hazards (COMAH) sites. Safety barriers and warning signs put in place around the working area.
- 4.9.4.3 After installation, the verge and areas used for joint bays and trench construction are fully reinstated using native topsoil removed during excavation works and left as near to its pre-construction condition as feasibly possible. The working area is demobilised of plant, with safety barriers, signage, and traffic lights removed/moved on. After the road is reinstated, traffic flow may be resumed until the onshore export cables are ready to be installed into the ducts. Once the onshore export cable is ready to be pulled, the road must be reduced to single-lane operation (for two-lane roads) or closed completely (single-lane roads) again whilst minimising duration and disruption to the highway.
- 4.9.4.4 Activities that will require road closure will be agreed in advance with the local authority and mitigation will be detailed in a Construction Traffic Management Plan (CTMP) as described further in Chapter 25: Traffic and Transport.

4.9.4.5 The cable pulling operations are typically performed at the timber-supported joint bays. At one end of the ducts, the cables are delivered on cable drums on the back of a low loader. Once on-site, the cable drums are off-loaded into position by crane and then placed onto frames and protection removed. At the opposite end of the cable ducts, a heavy-duty winch is brought to site and located within the joint bay. The pulling wire is then bonded to the end of the cable and winched through. Once in position, the bond is cut, and final cable positioning performed by hand. This is repeated for each of the cables and the fibre optic communication cables. The cables are then joined together, likely using pre-moulded joints fabricated off site. Once the pulling and jointing is complete, the joint bay is filled with the appropriate backfill material, covered and reinstated to its former condition, and after the cables are fully installed, all work areas are cleaned up and reinstated to pre-construction conditions. The road is reopened to full operation again.

4.9.5 *Crossing Methods*

4.9.5.1 The route corridor typically crosses obstacles of various nature for which special installation techniques must be considered.

4.9.5.2 Each obstacle must be addressed separately, and the most suitable crossing technique chosen. The criteria for determining the most suitable crossing technique will be based on different factors, such as the total length of the crossing, access routes, ground stability and health and safety issues.

4.9.5.3 The assessment of the overall crossing feasibility is paramount, and the site accessibility is a key factor. It must be noted that the space required by the machinery used varies significantly and it is an important factor for the definition of the most suitable crossing method. Access to the site is also important and should be carefully assessed.

4.9.5.4 The notable obstacles found along the onshore export cable site boundary are:

- Major roads;
- Watercourses;
- Trees and hedgerows;
- Existing major utilities; and
- Environmentally sensitive areas.

4.9.6 *Onshore Export Cable Installation Methods: Trenching through small watercourses*

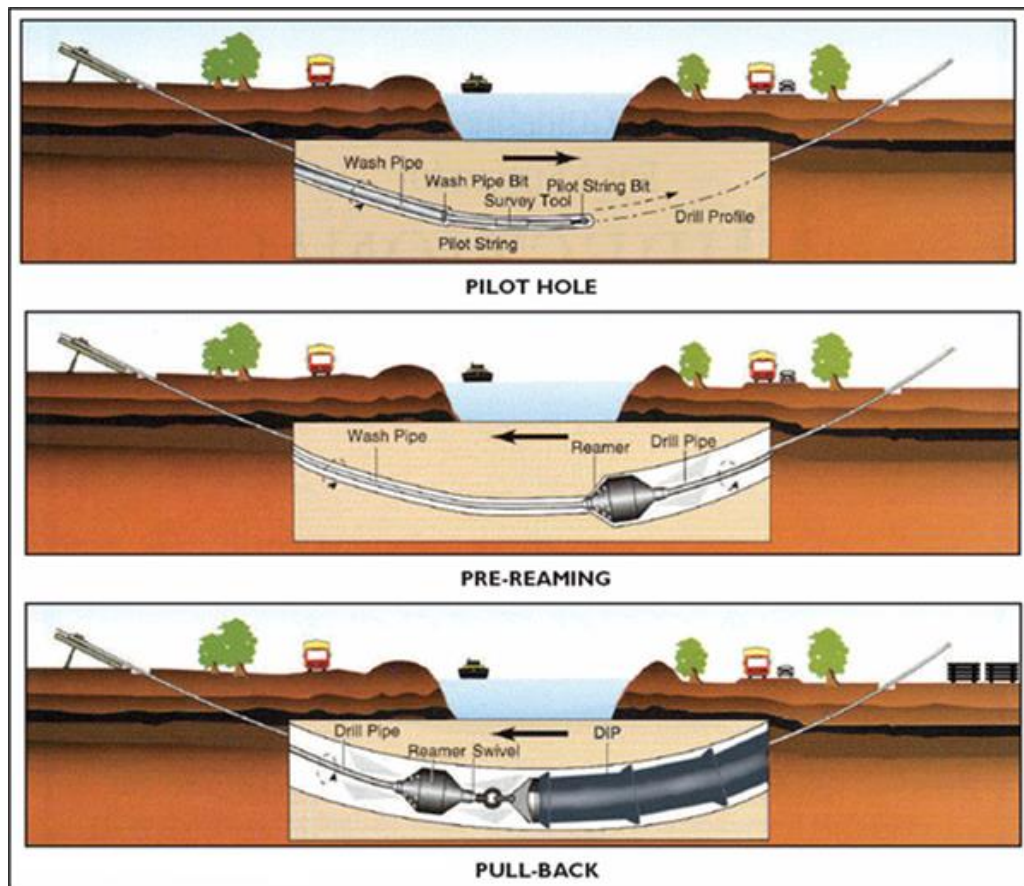
4.9.6.1 Occasional minor watercourse crossings may need to be carried out using dry open cut trench methodology. The water flow will be maintained by damming and, if necessary, over pumping or using temporary "flume" pipes installed in the bed of the watercourse. Details of these methods are outlined below.

- 4.9.6.2 For both methods, the site is first prepared by stripping the topsoil from the banks and areas adjacent to the watercourse crossing and storing it separately within the working area. When using the temporary “flume” pipes in the bed of the watercourse method a suitably sized flume pipe (usually selected by the Contractor in agreement with Natural Resources Wales (NRW)) is then installed over the point of the proposed crossing. It must be ensured that it extends on each side of the watercourse to a distance at least equivalent to the depth of the proposed excavation. The flume pipe is then bedded and packed or surrounded with soil filled sandbags to create a seal or dam across the watercourse. A flume pipe bridge will have been installed, during the preparation of the working width, adjacent to the trench-line flume in order to enable passage of plant and materials along the cable route.
- 4.9.6.3 Excavation of the riverbed then proceeds beneath the trench-line flume pipe. The excavated riverbed material will be stored within the working area separately from the bank material. De-watering and/or trench supports may be used to facilitate safe excavation.
- 4.9.6.4 If damming and over pumping methodology is adopted, then soil filled sandbags are still used to create a seal or dam across the watercourse. However, flume pumps are not installed in the riverbed but adjacent to the river instead. The discharge hose will be directed through a filtering medium to limit silt carry over before the pumped water is allowed to percolate back into the watercourse.
- 4.9.6.5 Within both methodologies the cable is then installed in the trench and checked to ensure that a minimum cover of 2 m (rivers) and 1.7 m (ditches) exists below the clean hard bed of the watercourse and the top of the cable. The cable may be protected by thick concrete protection slabs if appropriate.
- 4.9.6.6 Initial backfilling will take place using excavated subsoil free of large stones or other deleterious material. Final reinstatement will use the stored riverbed materials. The riverbanks are then reformed to their original profile to the satisfaction of both NRW and the landowner. Hard landscaping will be avoided where possible.
- 4.9.6.7 The flume pipe and packing or bags are removed once the bed materials and bank profile is reinstated. Final bank reinstatement may require further measures to stabilise the banks and prevent erosion. Geotextiles such as geojute may be used in conjunction with seeding of an appropriate grass mix. Heavier solutions such as the importation of locally sourced large stones or rocks will only be used with NRW approval.
- 4.9.6.8 Ecological and hydrogeology pre-construction surveys will be undertaken along the route to identify any sensitivities that should be avoided and as detailed in the CEMP and LEMP. All works will seek to minimise disruption to the free passage of fish and aquatic animals with appropriate actions taken dependant on sensitive species which are present. These mitigations may include screen intake, relocation of stranded wildlife, use of electro-fishing by qualified specialists as required and transplanting or watering sensitive aquatic vegetation.
- 4.9.7 *Onshore Export Cable Installation Methods: Trenching through minor roads***
- 4.9.7.1 One method of crossing minor roads is to trench through them. Generally, this is normally only permissible for roads which are two lanes or more wide in total. The amount of traffic through the road may also be a factor in determining whether a trenched crossing is allowed.

- 4.9.7.2 The working areas of trenching through a road will typically be the same as for a green field installation, especially if the road is to be completely closed off during works. It may be possible to keep one lane of the road open by installing and trenching through one lane of the road at a time while keeping the other lane open. However, this is a health and safety risk, and it would be preferable to close the road completely during a time of low traffic. This could necessitate 24 hours working to minimise the disturbance.
- 4.9.7.3 If this methodology is required, closure and diversion of minor road will be agreed with the local authority and any mitigation detailed in the CTMP.

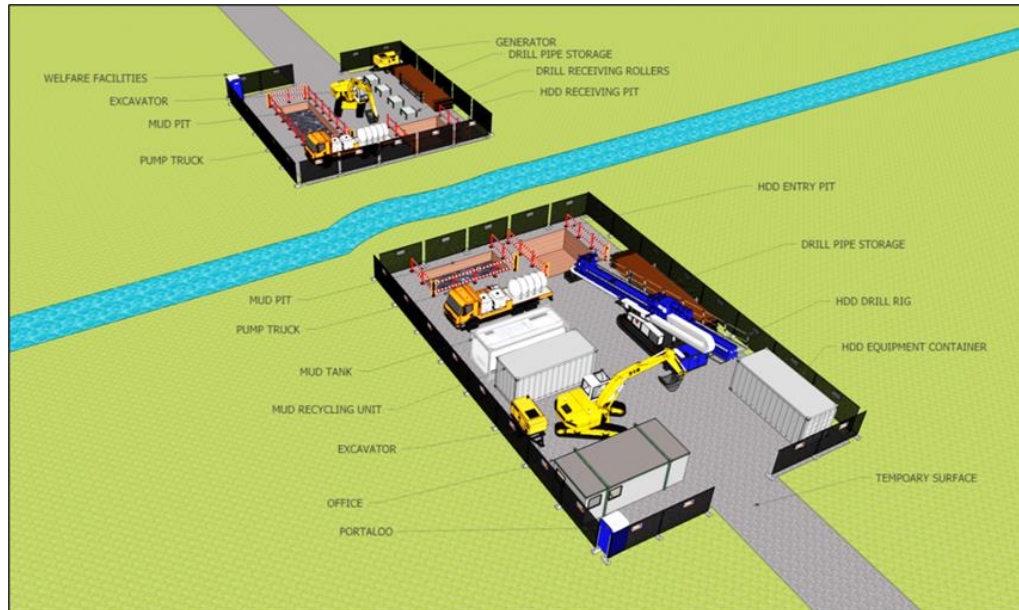
4.9.8 *Horizontal Directional Drilling (HDD)*

- 4.9.8.1 Significant obstacles may be crossed by way of a directional drilling to avoid any disturbance. An illustration showing the method of drilling is shown in Graphic 4.24.



Graphic 4.24- HDD Illustration

- 4.9.8.2 With HDD, a pipeline is bored under the crossing to emerge at a target point on the opposite side.
- 4.9.8.3 Location of the drill bit is monitored using the HDD locating system. An electronic transmitter in the drill head sends information to the locator operator's receiver.
- 4.9.8.4 Typically, each bore will accommodate a single circuit including the three power cables laid in trefoil and the fibre optic bundle. Therefore, separate drills will likely be required for each circuit crossing. Alternatively, subject to final Contractor specification, each power core of the circuit may require a separate bore and duct, likely laid in flat formation.
- 4.9.8.5 An example of a HDD working area setup is shown in Graphic 4.25. The length of the pipeline will determine the size and weight of the drill rig required.



Graphic 4.25- Typical working areas for a watercourse crossing via HDD

4.9.9 Onshore Substation Construction

- 4.9.9.1 The substation construction compound is likely to accommodate the following:
- Cable drum laydown area for the drums for part of the cable route;
 - Site offices, welfare facilities;
 - All the vehicles and heavy machinery for construction of the substation and possibly for part of the cable route installation;
 - Sustainable drainage systems (SuDS) / drainage provision;
 - A suitable construction material store and tool lock-ups for the items; and
 - Working area and access space.
- 4.9.9.2 All components, except the largest components (transformers and reactors), will be brought in on flatbed trucks. These will then be stored on-site and assembled when required.
- 4.9.9.3 The larger items may be treated as abnormal loads. Planning of the delivery of abnormal loads is essential to ensure smooth and timely delivery. All viable modes of transport must be considered such as barge, rail, and low loader. An outline CTMP (Volume 3, Technical Appendix 25.2), identifies a number of measures which could be implemented to support construction vehicle movements to ensure that they have a minimal impact on the local highway network's operation.
- 4.9.9.4 The assessment of road delivery routes will include a number of studies. An assessment of the road surface and its load bearing capacity is necessary, and weaknesses identified will have to be dealt with or alternative routes will have to be found. Bridges along the route again will be assessed for load bearing capacity. An assessment will be undertaken of the surrounding area; trees, lampposts, road signs, etc. may be removed to allow the load to pass freely without obstruction. This will happen as close to and replaced as soon after the load has passed the location, as possible.

- 4.9.9.5 There are several options for the electrical supply of the construction compound during construction of the substation. The first option is to run the entire site from portable diesel generators. The second is to connect into a permanent power supply via nearby existing 11 kV distribution overhead lines near the site.
- 4.9.9.6 The latter option will require the installation of an auxiliary transformer to adapt the 11 kV supply into a usable output, therefore a combination of the two options would be the most logical approach.
- 4.9.9.7 The main equipment access road is expected to be from the southeast direction, through local roads including the B4320 and B4319 which connect into the A4075 and A477 to the north west of Pembroke. Sections of this already provide an existing equipment access for Pembroke substation and will be used for Greenlink.
- 4.9.9.8 The substation will also require enduring rights for personnel access. This route could be the same as the equipment access route, or via an alternative.

4.10 Outline Onshore Construction Programme

4.10.1 Onshore export cable and joint bay

- 4.10.1.1 It is expected that working times of 7am to 7pm Monday through Saturday will be utilised for green field installation.
- 4.10.1.2 There are works that may require 24 hours working and this includes crossings where length of disturbance is an issue (e.g. road crossings) and HDD crossings. This may also apply to areas where commercial agreements are in place which dictate the work must be completed at certain times or within a certain window of time.
- 4.10.1.3 If 24 hour works are required prior consent will be agreed with the local authority via Section 61 consent.
- 4.10.1.4 The cable installation is likely to be sequential along the cable route starting from either landfall or the onshore substation. Concurrent installation may be undertaken if timeframes require.
- 4.10.1.5 A conservative rate for cable installation rate is 50 to 60 m per day for installation through green fields for a single AC circuit in a single trench. This includes construction of the haul road, excavation of the trench, cable installation, and reinstatement of the ground.
- 4.10.1.6 This does not include joint bays and is for agricultural fields where the typical working corridor requirements can be met. Based on the approximately 14.5 km of the onshore export cable route, the estimated time for installation is 36 weeks, without considering any sensitivity constraint.
- 4.10.1.7 Work at each joint bay takes up to ten days from delivery of the jointing tent to removal and reinstatement. This includes creation of the joint, jointing of the cables, and reinstatement.

4.10.2 Onshore Substation

- 4.10.2.1 It is expected most works will take place 7am to 7pm Monday through Saturday. The Project notes that 24 hour working may be needed for some operations such as oil filling and testing of power transformers.
- 4.10.2.2 A conservative scenario is that it will take 1.5 years of continuous work to complete construction of the onshore substation. Also, an additional three to six months may be needed at a later date, post-construction, to finalise assembly and commissioning of the substation.

4.10.3 Summary of onshore key parameters

4.10.3.1 A summary of the key parameters with respect to the onshore construction are set out in Table 4.23. All parameters are subject to further refinement from the FEED and site surveys but the values presented below have been used as the basis for the assessments presented within this ES.

4.10.3.2 It is anticipated that the production and submission for approval of a project-specific Construction Method Statement will be a consent requirement for the Project, which will document the final construction methodology and parameters.

Table 4.23 - Onshore Installation - Summary of Key Parameters

Parameter	Maximum
Overall	
Size of onshore site boundary	0.84 Km ²
Overall onshore construction duration	18 months
Export Cable	
Length of export cable	14.5 km
Width of export cable corridor	30 m
Number of onshore cable joint chambers	58
Underground utility crossings	24
Target Depth of Burial (DoB)	1.8 m
Overall duration of onshore export cable works	18 months
Substation	
Length	128 m
Width	88.5 m
Height	15 m
Overall duration of substation construction works	18 months

4.11 Commissioning

4.11.1 Onshore substation

- 4.11.1.1 The commissioning of the 132/66 kV substation will need to be based on the final design and scheduled according to the detailed circumstances which pertain at the time. However, the following provides a broad, illustrative outline of the work required to commission a substation of this sort. Please note that the description below is far from exhaustive and does not constitute any form of instruction or guidance.
- 4.11.1.2 It is broadly assumed that the commissioning will be carried out under the instructions and oversight of a commissioning engineer, who will be a different person to the construction engineer in charge of installing the equipment. This approach ensures that two suitably qualified and experienced people examine each item, to reduce the risk of something being overlooked.
- 4.11.1.3 All test equipment used during commissioning of plant should have an extant calibration certificate. All test equipment used during a particular test should be recorded on the relevant test form.
- 4.11.1.4 All commissioning will be carried out in accordance with the site safety rules (i.e. under suitable isolation and earthing certificates, permits-to-work and sanctions-to-test).

4.12 Operation & Maintenance

- 4.12.1.1 The Project lifespan is 25 years and the operation and maintenance (O&M) will be for the lifespan of the entire Project.
- 4.12.1.2 Both offshore and onshore O&M have been considered below.

4.12.2 Offshore Operations

- 4.12.2.1 Workable conditions are provided in Table 4.24. Wind speed values are given as 10-minute average values.

Table 4.24 – Summary of Typical Project Operating Modes

Parameter	Minimum	Maximum
Wind speed at which WTG will standstill (low wind)	3 m/s	5 m/s
Blade conditions when WTG Units are in standstill (due to low wind)	80°	100°
Wind speed at which WTG Units will operate	3 m/s	28 m/s
Blade conditions when WTG Units are operational	0°	30°
Wind speed at which WTG Units will shut down (due to high winds)	25 m/s	31 m/s
Blade conditions when WTG Units are shut down (due to high wind speeds)	80°	100°
Blade conditions when WTG Units are in standstill (due to maintenance)	80°	100°

4.12.3 Offshore Maintenance

- 4.12.3.1 There is anticipated to be O&M activities required throughout the Project's lifespan, an overview of these have been provided in Table 4.25. The estimations have been calculated using existing manufacturers' guidance with a realistic worst-case approach.
- 4.12.3.2 Maintenance and inspection activities will be performed after the WTG in question has been shut down. Boarding of the units will most likely be undertaken by Crew Transfer Vessel (CTV), but helicopter could potentially be an option. The CTV will dock and access will be via ladders on the substructure, while the use of helicopter will hoist personnel directly onto the nacelle.
- 4.12.3.3 The WTG Units are expected to be serviced using crew transfer vessels and standard tools. Two maintenance visits per turbine per year are expected (one major, one minor). It is assumed that the duration of servicing activities will be up to 240 hours per year (based on the worst case of 2 x 12 hour per WTG/year with 10 WTGs). Oil change will be performed at planned intervals for different systems (typical interval is two to five years). In addition, each turbine will be visited up to two additional times per annum for statutory inspections.
- 4.12.3.4 Inspections of array and offshore export cables, moorings and substructure will normally be performed at intervals of between one and four years using vessels with ROVs. To allow for adequate inspection, biofouling may also have to be removed from the substructure, cables and mooring lines.
- 4.12.3.5 In addition to scheduled service activities, it is assumed that the WTG units will require on average ten unscheduled visits per unit per year for corrective actions. The frequency of these corrective services will vary over the lifetime of the Project but in total for up to ten turbines this could range from 50 to 200 visits per year.
- 4.12.3.6 Exchange of large components could occur and equipment failures may (in extreme events) require a new nacelle, blade or rotor. The WTG units can be disconnected and towed to shore to allow more efficient working in sheltered waters if offshore lifts are hindered by waiting on weather. Offshore lifts would require a crane vessel, while the tow-in solution is foreseen to require tug boat(s), anchor handling vessel(s) and a crane vessel/barge. The remaining WTGs will continue to operate in the situation where a WTG unit has been removed.

Table 4.25 – Summary of Typical Repairs and Project Operating Modes over lifetime

Parameter	Minimum	Maximum
Vessel visits per turbine per year	2	12
Minor maintenance per turbine per year (in line with WTG manufacturer maintenance recommendations)	1	4
Major maintenance per turbine per year (asset return to port)	0	0.2
Moorings line replacement per turbine per year	0	0.1

4.12.4 Cable Repairs / Remediation

- 4.12.4.1 Table 4.25 contains information on the predicted maximum number of vessel visits to the array area during the various repair and remediation activities. The number, type and frequency of vessel movements offshore during the installation phase need to be defined in order to provide the basis of impact assessments for a number of receptors, i.e. marine ornithology (potential displacement of birds), commercial fisheries (collision risk) and shipping and navigation (collision risk).
- 4.12.4.2 An assumption has been made that a number of cable repairs and/or remediation events (cable re-burial via jetting and/or MFE) will be required over the lifetime of the Project. These activities have, therefore, been included in the PDE for the Project and form part of the relevant consent applications.
- 4.12.4.3 For a cable repair, a section of cable will be recovered either side of the fault of sufficient length to enable a repair. The repair would comprise two new joints connecting a new section of cable with the ends of the original cables.
- 4.12.4.4 Recovery of the cable will be performed by means of a suitable DP vessel or anchor barge if in the nearshore region. A suitable dive spread/platform may also be needed dependent upon operation. The exact length of cable exposed and recovered to a cable handling vessel will be proportional to 1.5 times the deepest tidal water depth at the location of the fault.
- 4.12.4.5 This ensures sufficient slack in the cable system to prevent unnecessary strain on the component parts during repair and reburial. The total length of cable exposed and replaced in any one repair event is unlikely to exceed 200 m. All recovered and redundant cable will be disposed of and recycled as appropriate onshore.
- 4.12.4.6 Cut and exposed cable ends will be sheathed and buoyed to the surface in preparation for the repair operation. The buoyed end will then be recovered onto the cable handling vessel and cable jointing will commence.
- 4.12.4.7 The new section of cable will be jointed aboard a cable-handling vessel before being re-laid back to the seabed via lowering from the repair vessel deck. Upon completion of repair works and the surface cable lowering operation from the repair vessel, the resting cable will be assessed to ensure it is in the correct position and sufficient slack is available.
- 4.12.4.8 This operation will either take place from the flat-back or cable handling vessel during recovery. The newly repaired export cable will be placed on, or as close to the original cable/trench as practicably possible.
- 4.12.4.9 If mechanical re-burial of the cable section is required, jetting with a MFE suspended approximately 1 to 2 m above the seabed will be conducted. A target burial depth of 0.8 to 2 m is sought via these operations. These techniques do not permanently add or remove any material from the seabed and take place along the existing offshore export cable route where the sediment has previously been disturbed and have been included within the PDE. This operation is expected to disturb no more than 2 m width of seabed sediment (maximum 7 m if the cable cannot be reburied in the original trench from where it was recovered initially).
- 4.12.4.10 Where jetting is not technically feasible, trenching could be undertaken with the use of a backhoe dredger as a last resort. Both jetting and trenching by these methods would occupy a similar seabed footprint. Trenching is assumed, however, to represent the worst-case scenario due to the potential for more seabed sediment to be suspended into the water column. Re-burial via ploughing methods will not be technically feasible in this instance, due to the export cables already being in-situ.

- 4.12.4.11 Exact rates of re-burial will vary depending on ground conditions and the final tool used, with a range of 100 to 250 m/hr. Re-burial of the average length of cable repair assumed in this application (1,000 m) is expected to take approximately five days.
- 4.12.4.12 Upon completion of re-burial, a post-burial survey will be carried out in order to assess whether the cable is at the correct position and required burial depth.
- 4.12.4.13 For cable remediation, any previous as-laid cable data and/or data from recent geophysical surveys will be reviewed to finalise the areas requiring remediation. Following this, a cable pre-burial survey using a Multibeam Sonar (Pipe/Cable Tracker) or similar device will be used to confirm the exact location and current cable burial depth/areas of exposure.
- 4.12.4.14 The vessel's crane wire will then be attached to the jetting equipment lift bridle and the equipment lifted overboard and down to a point approximately 2 m above the seabed. When in the correct orientation the vessel will move the jetting equipment directly over the cable and lower the equipment further to the required safe distance above the cable to conduct the burial operations.
- 4.12.4.15 The jetting equipment will be powered up and manoeuvred along the exposed cable route at a steady rate; nominally 1 m/min. A quick pass over the excavated length with the jetting equipment mounted sonar will determine the success of the operation. If necessary, another pass may be required to achieve the specified depth. A post-remediation survey will be undertaken.
- 4.12.4.16 Key parameters related to these activities are detailed in Table 4.26. As with the initial cable installation works, further details on cable repairs and/or remediation events would be included in any future Cable Burial Management Plan.

Table 4.26 – Summary of Cable Repair / Remediation included in PDE

Parameter	Minimum	Maximum
Offshore Export Cable		
No. of cable repairs over lifetime	0	5
Length of individual cable repair (length of seabed affected)	50 m	1 km
Width of individual cable repair (width of seabed affected)	50 m	50 m
Area (m ²) of seabed affected by individual cable repair	0 m ²	50,000 m ²
Area (m ²) of seabed affected by all cable repairs	0	250,000 m ²
Number of remediation events (re-burial)	6	12
Area (m ²) of seabed affected by remediation events	30 m x 1 km x 6 Area =180,000 m ²	50 m x 1 km x 12 Area = 600,000 m ²
Array Cables		
No. of array cable repair events over lifetime	0	5
Length of individual array cable repair (length of seabed affected)	1,042 m	6,022 m
Width of individual array cable repair (width of seabed affected)	30 m	50 m

Parameter	Minimum	Maximum
Area (m ²) of seabed affected by individual array cable repairs	31,260 m ²	301,100 m ²
Area (m ²) of seabed affected by all (5) array cable repairs	156,300 m ²	1,505,250 m ²

4.12.5 *Onshore O&M*

- 4.12.5.1 Cable systems are reliable and do not tend to require intrusive maintenance. At the link box/link pillar locations, electrical connections between the HVAC can be removed, enabling tests to establish the integrity of the cable overheats during commissioning, regular maintenance, and in the event of suspected damage.
- 4.12.5.2 Maintenance of the onshore export cables will be limited typically to annual visual inspections along the cable route to ensure no developments (such as heavy loads) are potentially affecting the installed cables. There is no easy access to the main onshore export cable lengths outside of the jointing bays, therefore specific onshore export cable maintenance would only be carried out on a section if a problem occurs – and only on the relevant section where the problem is located. At this point a section (e.g. tens of meters long typically) would be removed, a new section (cable spare) spliced in with field joints, and the cable reinstalled to its previous state.
- 4.12.5.3 The maintenance requirements of the onshore substation are unique based on its component makeup and the environmental conditions it exists in. Some general rules apply however, as summarised below.
- 4.12.5.4 In terms of workman usage, during repair works, there will be a minimum of two persons on site at any one time (24 hours per day, seven days per week). This is a critical health and safety measure as the substation is located in a rural area.
- 4.12.5.5 The substation is operated within its working range (specified electrical limits) and does not exceed this range on a regular basis.
- 4.12.5.6 The initial maintenance requirements of the substation within its first five to ten years of operation will be less in comparison to the work requirements of the same substation in later life; this will be accounted for in the future planning of work on the onshore substation.
- 4.12.5.7 More intensive maintenance may also be required once the substation reaches an age beyond its optimum performance age but still within its working life. This type of repair schedule is referred to as a proactive maintenance, acting upon a problem before it happens rather than a corrective maintenance program which only reacts to a problem once it has occurred, leading to in the worst-case a loss of revenue. Some of these major overhaul procedures will require the shutdown of certain items of substation equipment.

4.13 Decommissioning

4.13.1.1 *Approach to Decommissioning*

4.13.1.2 The Project will be decommissioned at the end of its operational life. The initial operational life is 25 years; however, this may be extended to longer should re-powering of the site happen. In the event of repowering, a further consenting process would be required to allow for operation beyond the initial 25 years assumed for this consent process and accompanying EIA. Any consent will likely be conditioned to require a decommissioning plan to be submitted to the consenting authority for approval in accordance with the Energy Act 2004 decommissioning requirements. Guidance from the Department of Business, Energy & Industrial Strategy (BEIS) states that the default position for decommissioning should be full removal unless there are strong reasons for any exceptions (BEIS, 2019) (see Chapter 5: Policy and Legislation).

4.13.1.3 The decommissioning process will largely be the reverse of that undertaken during the construction. It is expected that the WTG, semi-submersible floating platforms and mooring will be completely removed and returned to port for disassembly, re-use or disposal. Cable decommissioning will also be decided toward the end of the project lifetime. The preferred option is for the cable to be left in situ as far as is possible from a technical and environmental perspective. Any anchors drilled into hard rock seabed will be cut at or below surface level. Embedded material will be left *in situ* and emergent structures will be removed from site.

4.13.1.4 Onshore export cables will likely be left in-situ as is industry standard. It is noted that cable removal may result in disturbance to the local environment similar to installation. Contingency plans will be developed to ensure that appropriate actions are taken should any of the residual cables become exposed.

4.13.1.5 The operational life of the onshore substation is 40 years whereas the operational life of an offshore wind farm is typically less than 30 years. The Project is likely to only have a licence for 25 years. At the end of this period, the onshore substation may be retendered for continued use (if, for example, the Project site is repowered), or the site will likely be decommissioned.

4.13.1.6 To decommission the onshore substation, all electric plant is removed from their foundations and transported to a facility for processing for reuse, recycling, or disposal. The foundations may be pulled out and disposed of and any holes refilled with earth, if required. The control building can be demolished, and all materials disposed of.

4.14 Environmental Management

4.14.1.1 A CEMP will be produced post-consent in accordance with the Onshore Outline CEMP. The CEMP would explain how the activities of contractors and sub-contractors would be required to comply with its requirements, including where necessary the production of subsidiary plans in relation to specific construction matters. The Outline CEMP is contained Volume 3 Technical Appendix 4.1.

4.14.1.2 A LEMP will be provided post-consent which will include the detailed mitigation measures with regard to the re-establishment of hedgerows and planting of mitigation landscaping as well as detailing any mitigation measures required to safeguard ecology receptors during the construction phase.

4.14.1.3 In addition, work to install the onshore export cables in the highway will be required to comply with the Traffic Management Strategy (Chapter 25: Traffic and Transport), with individual Construction Traffic Management Plan to be produced for all locations where the onshore export cables are buried in, or impacts on, the uninterrupted use of the highway by vehicular traffic. The Outline Construction Traffic Management plan is included in Volume 3 Technical Appendix 25.2.

4.15 References

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