RWE

Awel y Môr Offshore Wind Farm

Category 6: Environmental Statement

Volume 2, Chapter 1: Offshore Project Description

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Glossary of terms

TERM	DEFINITION
The array	The area where the wind turbines will be located.
AyM	The Awel y Môr Offshore Wind Farm project.
Export Cable Corridor (ECC)	The area(s) where the export cables will be located.
Development Consent Order (DCO)	An order made under the Planning Act 2008 granting development consent for a Nationally Significant Infrastructure Project (NSIP) from the Secretary of State (SoS) .

TERM	DEFINITION
Design envelope/ Maximum Design Scenario (MDS)	The maximum design parameters of the combined project assets that result in the greatest potential for change in relation to the impacts assessed.
LiDAR	Light Detection and Ranging (remote sensing).
Marine Licence	A licence under the Marine and Coastal Access Act 2009 for marine works in Welsh waters which is administered by the Natural Resources Wales (NRW) Marine Licensing Team (MLT) on behalf of the Welsh Ministers.
PEIR	Preliminary Environmental Information Report. The PEIR was written in the style of a draft Environmental Statement (ES) and formed the basis of statutory consultation. Following that consultation, the PEIR documentation was updated into the final ES that accompanies the applications for the Development Consent Order (DCO) and Marine Licence.
Order Limits	The extent of development including all offshore and onshore works areas.

Abbreviations and acronyms

TERM	DEFINITION
AIS	Automatic Identification System
AyM	Awel y Môr Offshore Wind Farm
AyMOWFL	Awel y Môr Offshore Wind Farm Limited (the Applicant)
BEIS	Department for Business, Energy and Industrial Strategy
CAA	Civil Aviation Authority

TERM	DEFINITION
CBRA	Cable Burial Risk Assessment
CfD	Contract for Difference
CFE	Controlled Flow Excavation
CTV	Crew Transfer Vessel
DCO	Development Consent Order
DECC	Department for Energy and Climate Change (now BEIS)
DP	Dynamic Positioning
EIA	Environmental Impact Assessment
ES	Environmental Statement
GBS	Gravity Based Structure
GyM	Gwynt y Môr Offshore Wind Farm
HAT	Highest Astronomical Tide
HDD	Horizontal Directional Drill
HVAC	High Voltage Alternative Current
HVDC	High Voltage Direct Current
ID	Identification
JUV	Jack-Up Vessel
LAT	Lowest Astronomical Tide
MAP	Main Access Platform
MCA	Maritime and Coastguard Agency
MCAA	Marine and Coastal Access Act
MDS	Maximum Design Scenario

TERM	DEFINITION
MFE	Mass Flow Excavation
MHWS	Mean High Water Springs
NPS	National Policy Statement
NRW	Natural Resources Wales
O&M	Operation and Maintenance
OSP	Offshore Substation Platform
OWFIZ	Other Wind Farm Infrastructure Zone
PEIR	Preliminary Environmental Information Report
PINS	The Planning Inspectorate
PLGR	Pre-Lay Grapnel Run
PVM	Permanent Vessel Mooring
RD	Rotor Diameter
ROV	Remotely Operated Vehicle
SCADA	Supervisory Control and Data Acquisition
SLVIA	Seascape, Landscape and Visual Impact Assessment
SoS	Secretary of State
SOV	Service Operation Vessel
THLS	Trinity House Lighthouse Service
TJB	Transition Joint Bay
TP	Transition Piece
TSHD	Trailing Suction Hopper Dredger
UXO	Unexploded Ordnance

TERM	DEFINITION
WTG	Wind Turbine Generator

Units

UNIT	DEFINITION
cd	Candela
dB	Decibel
hr	Hour
km	Kilometre
kJ	Kilojoule
kV	Kilovolt
m	Metre
m^2	Square metre
m^3	Cubic metre
mm	Millimetre
MW	Megawatt
nm	Nautical mile
s	second

1 Offshore project description

1.1 Introduction

1 This chapter of the Environmental Statement (ES) describes the offshore elements of the proposed Awel y Môr Offshore Wind Farm (hereafter referred to as 'AyM'). It sets out the AyM design and components for the offshore infrastructure, as well as the main activities associated with the construction, Operation and Maintenance (O&M) and decommissioning of the offshore elements of AyM.

2 This chapter has been drafted by GoBe Consultants on behalf of Awel y Môr Offshore Wind Farm Limited (AyMOWFL) ('the Applicant'), and sets out:

- The design envelope approach;
- Consultation relating to the offshore project design undertaken to date;
- An overview of the project location and proposed offshore site boundaries;
- The design envelope of the offshore project components and the techniques used to build, operate, maintain and decommission AyM; and
- The indicative project programme.

3 This chapter details the above insofar as related to the offshore components of the proposed scheme up to and including the landfall where the offshore export cables will meet the onshore export cables. Full details of the onshore elements of the proposed development are provided in Volume 3, Chapter 1: Onshore Project Description (application ref: 6.2.1).

4 A detailed description of the site selection process that has resulted in the selection of the locations of project infrastructure and routes taken is also provided in Volume 1, Chapter 4: Site Selection and Consideration of Alternatives (application ref: 6.1.4).

1.2 Design envelope approach

1.2.1 Overview

5 At this stage in the AyM development process, decisions on exact locations of infrastructure and the precise technologies and construction methods employed cannot be made. Therefore, the project description at this stage sets out the main components and parameters of the project and the design envelope approach (often referred to as the ‘Rochdale Envelope’) has been used to provide certainty that the final project as built will not exceed these parameters, whilst providing the necessary flexibility to accommodate further project refinement during the detailed design phase post-consent.

6 This flexibility is required in terms of options for foundation types, Wind Turbine Generator (WTG) model and size, siting of infrastructure and construction methods to ensure that anticipated changes in available technologies between now and the detailed design phase can be accommodated within the DCO, whilst retaining an Environmental Impact Assessment (EIA) that considers all options, with conclusions that are robust regardless of the final design eventually built out.

7 The final project design will depend on factors including ground and environmental conditions that will be subject to detailed pre-construction surveys, project economics and the approach to procurement of resources. This chapter therefore sets out a series of options, all of which are encompassed within the overall design envelope and have been assessed.

1.2.2 Policy and legislative context

8 The design envelope approach is recognised in the Overarching National Policy Statement (NPS) for Energy (EN-1) (DECC, 2011a), the NPS for Renewable Energy Infrastructure (EN-3) (DECC, 2011b) and the NPS for Electricity Networks Infrastructure (EN-5) (DECC, 2011c). This approach has been used in the majority of offshore wind applications. The approach is also recognised in the draft NPSs which were consulted on between September and November 2021. At the time of writing being, the draft NPSs are not adopted policies, however they are considered alongside the extant NPSs in Table 1 below.

Table 1: Provisions of the NPS and draft NPS regarding the design envelope approach.

LEGISLATION/ POLICY	KEY PROVISIONS
NPS EN-3 Paragraph 2.6.42	'Owing to the complex nature of offshore wind farm development, many details of a proposed scheme may be unknown to the applicant at the time of application, possibly including: - Precise location and configuration of turbines and associated development; - Foundation type; - Exact turbine tip height; - Cable type and cable route; - Exact locations of offshore and/ or onshore substations.'
Draft NPS EN-3 Paragraph 2.23.6	'Owing to the complex nature of offshore wind farm development, many of the details of a proposed scheme may be unknown to the applicant at the time of the application to the Secretary of State, possibly including: - The precise location and configuration of turbines and associated development; - The foundation type and size; - The installation technique or hammer energy; - The exact turbine tip height and rotor swept area; - The cable type and precise cable route; - The exact locations of offshore and/or onshore substations.'

LEGISLATION/ POLICY	KEY PROVISIONS
NPS EN-3 Paragraph 2.6.42	'The Secretary of State should accept that wind farm operators are unlikely to know precisely which turbines will be procured for the site until sometime after any consent has been granted. Where some details have not been included in the application to the Secretary of State, the applicant should explain which elements of the scheme have yet to be finalised, and the reasons. Therefore, some flexibility may be required in the consent. Where this is sought and the precise details are not known, then the applicant should assess the effects the project could have to ensure that the project as it may be constructed has been properly assessed (the Rochdale [Design] Envelope)'.
Draft NPS EN-3 Paragraph 2.23.7	'The Secretary of State should accept that wind farm operators are unlikely to know precisely which turbines will be procured for the site until sometime after any consent has been granted. Where some details have not been included in the application to the Secretary of State, the applicant should explain which elements of the scheme have yet to be finalised, and the reasons. Therefore, some flexibility may be required in the consent. Where this is sought and the precise details are not known, then the applicant should assess the effects the project could have to ensure that the project as it may be constructed has been properly assessed (the Rochdale [Design] Envelope)'.
NPS EN-3 Paragraph 2.6.42	'The 'Rochdale [Design] Envelope' is a series of maximum extents of a project for which the significant effects are established. The detailed design of the project can then vary within this 'envelope' without rendering the ES [Environmental Statement] inadequate'.

LEGISLATION/ POLICY	KEY PROVISIONS
Draft NPS EN-3 Paragraph 2.23.7	'The 'Rochdale [Design] Envelope' is a series of maximum extents of a project for which the significant effects are established. The detailed design of the project can then vary within this 'envelope' without rendering the ES [Environmental Statement] inadequate'.

9 The design envelope approach is widely recognised and is consistent with the Planning Inspectorate (PINS) Advice Note Nine: Rochdale Envelope (PINS, 2018). Page 11 of that note states that:

'The 'Rochdale Envelope' is an acknowledged way of dealing with an application comprising EIA development where details of a project have not been resolved at the time when the application is submitted'.

10 Throughout the EIA, the design envelope approach has been taken to allow meaningful assessments of AyM to proceed, whilst still allowing reasonable flexibility for future project design decisions.

1.2.3 Relationship to the maximum design scenario

11 This chapter sets out the full offshore design envelope for AyM, however in4dividual impact assessments do not consider all options. Instead, for each impact, the assessment is based upon the scenario which results in the greatest potential for change, sometimes referred to as the 'worst-case' scenario. In the context of AyM, this is referred to as the Maximum Design Scenario (MDS) approach.

12 For example, for the impact of long-term benthic habitat loss the MDS is defined by the scenario resulting in the largest physical interaction with the seabed, which would result from Gravity Based Structure (GBS) foundations. However, for underwater noise impacts on fish and marine mammals, the scenario that would result in the greatest propagation of underwater noise would be from piled foundations. Adopting this approach ensures that the 'worst-case' scenario for each impact is robustly considered, and therefore any other scenario as built would not result in impacts of greater significance of effect than those assessed in the EIA. It also reduces the volume of assessment documentation required to allow a proportionate but robust EIA.

13 To avoid excessive conservatism in the EIA, the parameters assessed throughout the EIA are not necessarily a combination of the MDS for each component, hence the MDS is chosen on an impact-receptor basis, on a range of eventual build-out scenarios. The details of the MDS for each impact assessed are described in detail within the topic-specific chapters of the ES.

1.2.4 WTG scenarios

14 As described above, the Applicant requires flexibility in WTG choice to ensure that anticipated changes in available technology and project economics can be accommodated within the project design. The design envelope therefore sets a maximum and, where relevant, a minimum realistic worst-case scenario against which environmental effects have been assessed.

15 The electrical output (capacity in megawatts (MW)) of the wind farm and that of individual turbines is not considered a material factor in determining the MDS for environmental assessments. Rather, it is the physical dimensions such as tip height, rotor diameter and seabed footprint of WTGs that have meaningful implications for EIA. It is therefore not considered necessary to constrain the design envelope to a particular capacity and, as such, this is not referred to within the ES.

16 In recent years, as turbine technology has been developed, it has become clear that there is no strong correlation between electrical output and physical dimensions. Improvements in efficiency can also be made without alterations to physical dimensions. The design envelope was developed in accordance with the application requirements of The Crown Estate (TCE) extensions round and follows the conditions of the agreement for Lease (AfL). The MDS assessment parameters have been clearly defined throughout the ES and have been secured via the draft DCO (application ref: 3.1).

17 For the purposes of defining the material factors of the MDS, it is necessary to consider likely scenarios that could eventually be built out, based on realistic eventualities, in order that the MDS values can be determined. These scenarios are based on the physical dimensions of individual WTGs at either end of the design envelope, which in turn form the MDS values of the assessments presented in the ES. The electrical output of individual WTGs is not fixed against these parameters, however the final design, including the WTG model chosen, will be limited by these parameters as assessed consistently throughout the ES and as defined in the draft DCO (application ref: 3.1). For AyM, two indicative WTG scenarios are considered:

- **Larger WTG:** The largest WTGs within the design envelope. For the purposes of assessment this is assumed to be up to 34 of the largest possible WTGs with a Rotor Diameter (RD) of up to 306 m; and
- **Smaller WTG:** The greatest number of WTGs within the design envelope. For the purposes of assessment this is assumed to be up to 50 smaller WTGs with a RD of up to 250 m.

18 When WTG parameters are discussed, this chapter presents the MDS for both these scenarios, which have been chosen to represent the realistic worst-case impacts resulting from either the greatest number of smaller WTGs, or the largest WTGs spaced further apart and therefore fewer in number.

19 In line with the design envelope approach, the eventual built-out scenario may differ from these scenarios but in any event will not be permitted to exceed the MDS assessed. Therefore, confidence can be had that resulting environmental effects will not exceed the worst-case assumptions of the EIA.

1.3 Consultation

20 Consultation is a key part of the DCO and Marine Licence application processes. Consultation regarding the project description has been conducted through the Scoping Report (innogy, 2020), subsequently via the Evidence Plan process, bi-lateral stakeholder engagement, and statutory consultation. The Evidence Plan is a framework for consultation between the Applicant, its specialist advisors, statutory bodies and regulators, and covers a variety of EIA topics.

21 During statutory consultation under Sections 42 and 47 of the Planning Act 2008 (PA2008), comments were received across various technical EIA topics that related to the project design envelope. These are described within the technical ES chapters, and the Consultation Report (application ref: 5.1). However, since those comments were received in relation to technical chapters rather than the project description chapter itself, they are not repeated here. The design changes since PEIR are summarised in Section 1.3.1 *et seq*. below, however for further detail please see the Consultation Report (application ref: 5.1) and Volume 1, Chapter 4: Site Selection and Consideration of Alternatives (application ref: 6.1.4).

22 A summary of the key issues raised during consultation specific to the offshore project description is set out below in Table 2, together with a description of how those issues have been considered and addressed in this chapter.

1.3.1 Design changes adopted in response to statutory consultation

23 As described in the Consultation Report (application ref: 5.1), as a result of statutory consultation, the offshore project design was amended post-PEIR and/ or refined in a number of ways, which can be summarised as:

- The offshore array area has been further reduced in scale;
- The maximum number of WTGs has been further reduced; and
- The landfall design has been amended to avoid above-ground permanent works within the Rhyl Golf Club (see also Volume 3, Chapter 1: Onshore Project Description (application ref: 6.3.1) for further detail.

Table 2: Summary of consultation relating to the offshore project description.

DATE AND CONSULTATION PHASE/ TYPE	CONSULTATION AND KEY ISSUES RAISED	SECTION WHERE COMMENT ADDRESSED
SoS Scoping Opinion (July 2020)	Scoping Report does not provide a clear estimate of the individual or combined capacity of WTGs (MW) for the Proposed Development.	As explained in paragraph 15 *et seq.* of this document, the EIA is not linked directly to the electrical output capacity of individual WTGs or the overall capacity of AyM as it is not considered to be a material consideration in determining the MDS. Rather, it is the physical dimensions such as tip height and rotor diameter of WTGs that have meaningful implications for EIA. It is therefore not considered necessary to constrain the design envelope to a particular capacity and as such it is not referred to within the ES. Therefore, the MDS parameters assessed in the ES have been defined based on the physical parameters of the design envelope, which are consistently assessed throughout the ES and secured via the draft DCO (application ref: 3.1). In recent years, the capacity of WTGs has become more flexible and may differ depending on the conditions of the site, and
SoS Scoping Opinion (July 2020)	The Applicant should provide a clear estimate of WTG output (individual and combined) and ensure this is consistent throughout the ES and supporting documentation.	

DATE AND CONSULTATION PHASE/ TYPE	CONSULTATION AND KEY ISSUES RAISED	SECTION WHERE COMMENT ADDRESSED
		improvements in efficiency can be made without alterations to physical dimensions.
SoS Scoping Opinion (July 2020)	The Applicant should justify in the ES why scour protection has been included or excluded in the estimation of maximum footprint diameter (m^2) for all foundation types being considered for the design of the Proposed Development.	The requirements for scour protection around foundations is explained within Section 1.8.2 of this document. As the MDS for scour protection includes rock placement, this is considered a material consideration for the impact on the seabed. Values within Section 1.8 of this document provide for foundation footprints both including and excluding scour protection.
SoS Scoping Opinion (July 2020)	Scoping Report states both a met mast and floating LiDAR are being considered. However, floating LiDAR is not described in Chapter 3, Table 2 and parameters have not been provided in this Scoping Report. The Applicant should provide a description, estimate of parameters and impact assessment of floating LiDAR in the ES.	Floating LiDAR is considered as an alternative option to using a met mast. A description of the design envelope for the met mast is provided in Section 1.8.8 of this document and the parameters for floating LiDAR buoys are considered to be within the MDS for the met mast.

DATE AND CONSULTATION PHASE/ TYPE	CONSULTATION AND KEY ISSUES RAISED	SECTION WHERE COMMENT ADDRESSED
SoS Scoping Opinion (July 2020)	The Scoping Report refers to export circuits in Table 19 and Table 20 but this component has not been described in the Scoping Report. The Applicant should provide a clear description of export circuits and how this component relates to other elements of the Proposed Development in the ES.	The design envelope for export cables is described within Section 1.8.10 of this document and includes a description of how export cables are linked to other elements of the project design. For clarity, one offshore export cable is required per circuit, and therefore in terms of offshore cabling, the terms 'circuit' and 'cable' can be considered interchangeable. For the onshore export cables, each circuit may comprise more than one separate cable, as explained in Volume 3, Chapter 1: Onshore Project Description.
Statutory section 42 consultation 31st August 2021 – 11th October 2021	Several comments received during the statutory consultation requested a further reduction to the offshore array and the scale of individual WTGs, in particular to address concerns over significant effects on seascape, landscape and visual receptors.	The design evolution of the project is described in Volume 1, Chapter 4: Site Selection and Consideration of Alternatives (application ref: 6.1.4). The changes to the project design adopted in response to statutory consultation are described in detail in the Consultation Report (application ref: 5.1).

DATE AND CONSULTATION PHASE/ TYPE	CONSULTATION AND KEY ISSUES RAISED	SECTION WHERE COMMENT ADDRESSED
		The key changes to the project design since the publication of the PEIR are described above in Section 1.3.1 *et seq*.

1.4 Project overview

24 AyM is a proposed 'sister project' to the existing and operational Gwynt y Môr Offshore Wind Farm (GyM). The Order Limits of AyM, in which all project infrastructure will be located, are shown in Figure 1 below. For the offshore aspects of the project, this boundary encompasses:

- **The array area:** the area where the Wind Turbine Generators (WTGs), Offshore Substation Platforms (OSPs), associated foundations, inter-array cables, inter-platform cables, export cables (including the GyM interlink cable), a meteorological mast (met mast) (or suitable alternative such as floating LiDAR) and Permanent Vessel Moorings (PVMs) may be located;
- **The 'Other Wind Farm Infrastructure' Zone (OWFIZ):** an area to the west of the array area, which will preclude WTGs and OSPs but will allow for a met mast, inter-array cables and PVMs;
- **The offshore Export Cable Corridor (ECC):** the area where the offshore export cables will be installed, bringing power generated to the onshore cable circuits at landfall between Rhyl and Prestatyn;
- **The 'GyM interlink' zone:** an area that extends from the AyM array into the GyM array to facilitate connection from one of the AyM OSPs or a WTG to the western GyM OSP; and
- **The 'subsea infrastructure and temporary works' area:** an area that extends 500 m west of the array boundary in which cables may be located, as well as where temporary works associated with the WTG array may take place (such as jack-up operations).

25 Within these offshore areas, AyM will be comprised of WTGs and all associated infrastructure required to transmit the electricity generated to shore, where it will then be transmitted by the onshore infrastructure to the National Grid network via the grid connection at Bodelwyddan, as well as all infrastructure required to operate and maintain the wind farm.

26 The key permanent offshore components of AyM are likely to include:

- Foundations;
- WTGs;
- OSPs;

- Met mast (or suitable alternative such as floating LiDAR);
- PVMs;
- Subsea inter-array cables linking individual WTGs, inter-platform cables linking OSPs, and cables linking the met mast and PVMs to one another, to the OSPs or WTGs;
- An interlink cable linking GyM to AyM;
- Subsea export cables linking OSPs to shore;
- Scour protection around foundations;
- Cable protection where sufficient cable burial is not achievable; and
- Cable crossings.

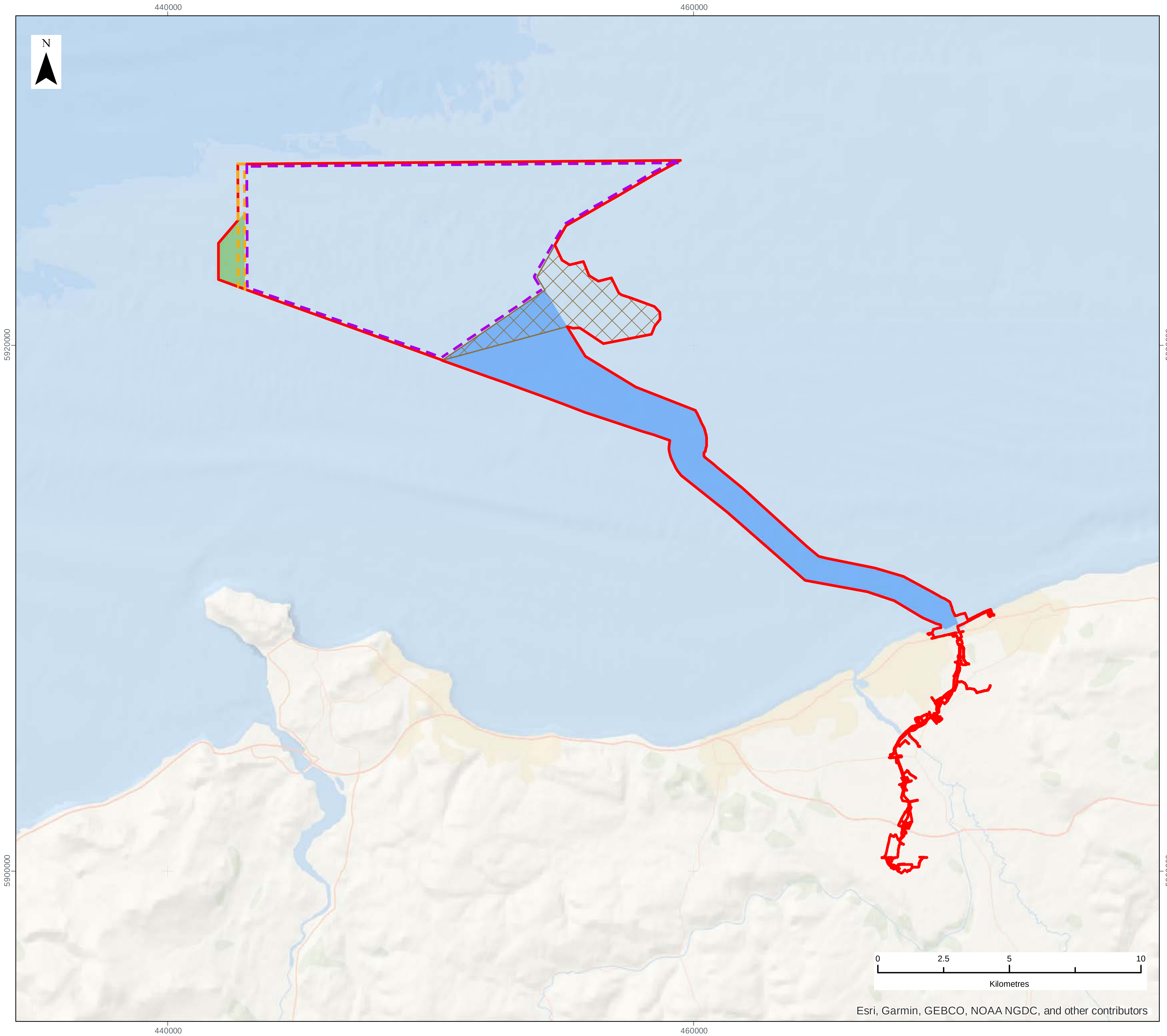
27 It is likely that the components for AyM will be fabricated at manufacturing sites across the UK, Europe and farther afield. A construction base (port facility) may be used to stockpile some components, such as foundations and WTGs, before delivery to site for installation. Other components, such as prefabricated units and cables, may be delivered directly to site when required.

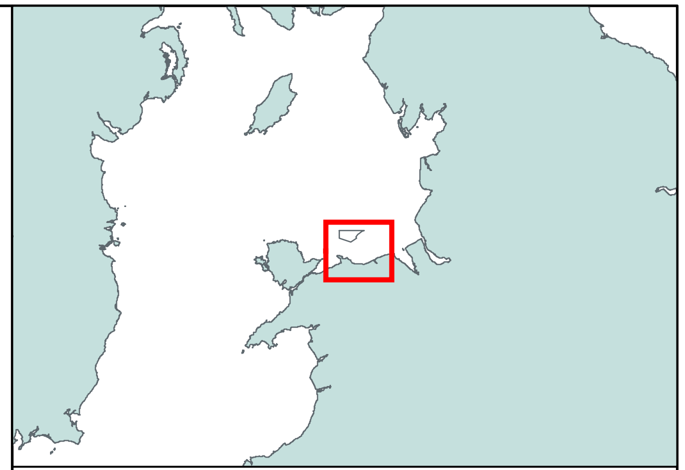
28 Table 3 below describes the general wind farm site information, with more detail on each component described in the subsequent sections.

Table 3: AyM site information.

PROJECT PARAMETER	MAXIMUM DESIGN SCENARIO
Array area (km^2)	78
Number of WTGs	50 (smaller), or 34 (larger)
Number of OSPs	2
Number of met masts	1
Number of floating LiDAR buoys	3
Number of PVMs	3

PROJECT PARAMETER	MAXIMUM DESIGN SCENARIO
Total inter-array cable length installed in the seabed (km)	116
Number of offshore export cable circuits	2
Total offshore export cable length (km)	79.4 (including 10 km for the GyM interlink cable)





LEGEND

- Order Limits
- Array Area
- Offshore Export Cable Corridor
- Other Wind Farm Infrastructure Zone
- Subsea Infrastructure and Temporary Works Area
- GyM Interlink Zone

Data Source:

PROJECT TITLE:

AWEL Y MÔR OFFSHORE WINDFARM

FIGURE TITLE:

The AyM Order Limits

VER	DATE	REMARKS	Drawn	Checked
1	15/09/2021	For Issue for PEIR	BPHB	RM
2	03/03/2022	For Issue For ES	BPHB	RM

FIGURE NUMBER:

Figure 1

SCALE:	PLOT SIZE:	DATUM:	PROJECTION:
1:150,000	A3	WGS84	UTM30N

Fferm Wynt Alltraeth AWEL Y MÔR Offshore Wind Farm

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1.5 Project programme

1.5.1 Overview

29 This ES accompanies the final applications for the DCO and Marine Licence, respectively, and the Applicant expects consent determinations from Q3 2023 onwards. Post-consent, the detailed design phase would commence with a view to beginning construction in 2026, following pre-construction surveys and works in 2024 and 2025. The Applicant's objective is for AyM to be fully operational and commissioned by 2030 in order to help meet UK and Welsh Government renewable energy targets. Further information about these energy targets is provided in Volume 1, Chapter 2: Policy and Legislation (application ref: 6.1.2).

30 The construction programme for AyM is dependent on a number of factors which may be subject to change, including:

- The timeliness and date of the works necessary to connect the project to the National Grid;
- The date that the other necessary consents, including Marine Licence(s), are granted; and
- The availability and lead-in times associated with procurement and installation of project components.

31 As stated above, offshore construction is anticipated to commence in 2026, through to final commissioning in 2030. Offshore construction works are typically carried out under relatively calm metocean conditions normally experienced during the summer, although some activities may take place throughout the year. Furthermore, 24-hour offshore working will be required, with illumination required on construction vessels during night-time and low light conditions. Figure 2 below illustrates the indicative dates and durations for each activity, and the order in which they are expected to occur in the construction campaign.

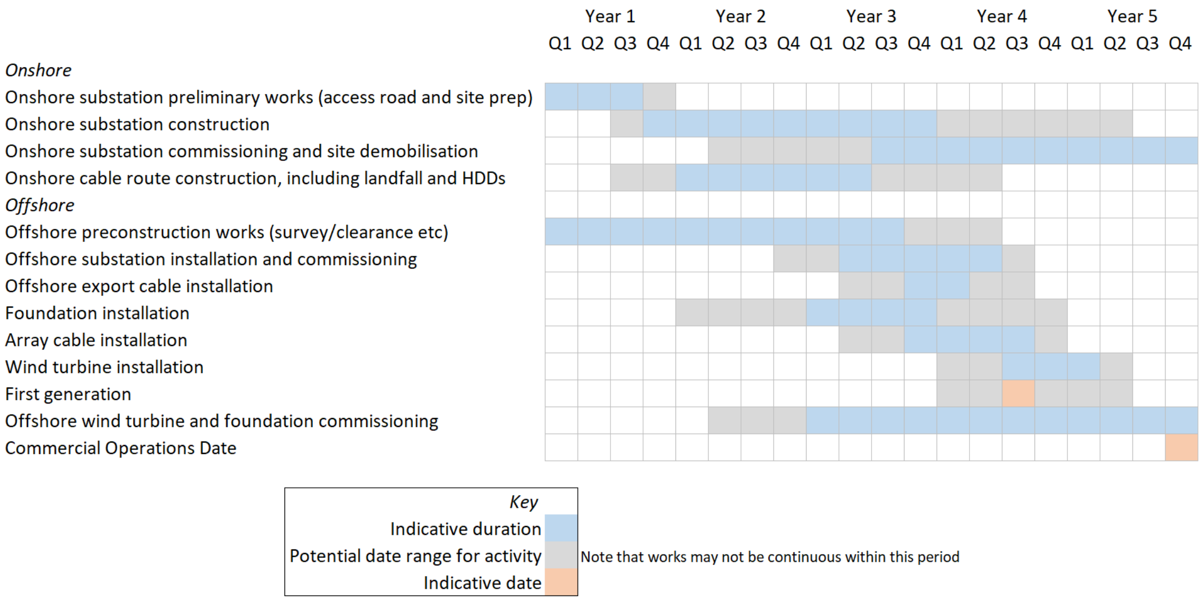

Figure 2: Indicative construction programme.

1.6 Pre-construction works

1.6.1 Pre-construction surveys

32 Geophysical and geotechnical surveys would be carried out before works commence and the information from those surveys would allow route debris, boulders, archaeological features, Unexploded Ordnance (UXO) presence, seabed features, sediment depth and the nature of the seabed to be determined. An analysis of these factors would then inform the final locations of WTGs (micrositing), the requirement for foundation drilling, installation methods for the final cable route taken, the target cable burial depth, and what (if any) additional cable protection would be required. Micrositing is intended to provide flexibility to make minor adjustments to the project layouts to accommodate unexpected on-site conditions encountered in the pre-construction surveys.

33 The surveys will include grab sampling of seabed sediment, and if necessary for pre-construction surveys, biological sampling will take place.

34 Prior to any survey, pre-construction, construction or major O&M works, it may be necessary to remove or re-locate static fishing gear (for example pots). Other users of the sea, including commercial fisheries, will be contacted in advance via Notices to Mariners (NtMs) secured through a Marine Licence condition to inform them of upcoming activities to allow time for removal or re-location of static gear to take place.

1.6.2 Seabed preparation

35 Depending on the foundation types chosen for WTGs and OSPs (see Section 1.8.8), some form of seabed preparation may be required to provide a clear and level surface for foundation installation, which may include seabed levelling and removing debris.

36 Some foundations, in particular larger GBS foundations, need to be placed on prepared areas of seabed due to their size. Seabed preparation involves levelling and/ or dredging of soft mobile sediments as required, as well as boulder and obstacle removal. It is likely that dredging would be required in the case of GBS foundations. If required, this would be carried out by dredging vessels and the spoil would be deposited on the seabed within a licensed disposal area within the array. In some cases, it may be required to place a layer of gravel on the seabed prior to the installation of GBS foundations to provide a clear, level surface.

37 Methods for seabed preparation include Mass or Controlled Flow Excavation (MFE/ CFE) or dredging (such as Trailing Suction Hopper Dredging (TSHD), backhoe dredging or water injection dredging). The design envelope for seabed preparation for the different foundation types is discussed in detail within the foundation-specific Sections 1.8.3 to 1.8.5.

1.6.3 Sandwave clearance

38 In some areas within the AyM array area and offshore ECC, existing sandwaves and similar bedforms may be required to be cleared or levelled before array and offshore export cables are installed. This is done for two reasons:

- Many of the cable installation tools require a relatively flat surface in order to achieve cable burial to the target depth. It may not be possible to successfully bury a cable on a slope above a critical gradient; and
- The cable must be buried to a depth where it is expected to stay buried throughout the lifetime of the project. Sandwaves are generally mobile features that migrate naturally. Over time, sandwave migration can cause cables to become exposed if they are not sufficiently cleared before cable installation.

39 The design envelope for sandwave clearance is described within the array cable and offshore export cable sections (Section 1.6.2). If seabed material is dredged, it will be disposed of in a licensed disposal area within the array and/or offshore ECC.

1.6.4 Unexploded ordnance clearance

40 In the offshore wind industry, it is common to encounter UXO originating from World War I and World War II prior to construction during surveys. This poses a health and safety risk where it coincides with the planned locations of infrastructure and vessel activity, and therefore it is necessary to survey for and carefully manage any items of UXO that are discovered.

41 If found, a risk assessment will be undertaken and items of UXO are either avoided, removed or detonated *in situ*. Recent advancements in the available methods for UXO clearance mean that high-order detonation may be avoided. The methods of UXO clearance considered for AyM may include:

- High-order detonation;
- Low-order detonation (deflagration);
- Removal/ relocation; and
- Other less intrusive means of neutralising the UXO.

42 As explained in Section 1.6.1, detailed pre-construction surveys will be completed post-consent to determine the precise nature of the seabed. As the detailed pre-construction surveys have not yet been completed, it is not possible at this time to determine how many items of UXO will require clearance. As a result, whilst the ES assesses the effects of UXO clearance, the activity itself is not the subject of the application. Instead, a separate Marine Licence will be applied for post-consent for the clearance (where required) of any UXO identified. In order to define the design envelope for consideration of UXO within the EIA, a review of recent information has been undertaken, in conjunction with experience from nearby offshore wind farms (including GyM).

43 It should be noted that AyM is generally in an area considered to be low risk for UXO when compared to areas of the Irish Sea closer to Liverpool and for other recent wind farm projects in the southern North Sea; indeed, the construction of GyM required the clearance of only three items of UXO. The Applicant commissioned a study to establish the potential for UXO presence at AyM. Based on the results of this study and a conservative estimate, the design envelope for UXO clearance is described in Table 4.

Table 4: Design envelope for UXO clearance.

PARAMETER	DESIGN ENVELOPE
Expected total number of potential UXO targets	373
Expected total number of potential UXO targets requiring inspection	52
Expected number of UXO requiring clearance in the pre-construction phase	10
Maximum number of clearances in one day	2

1.6.5 Boulder clearance

44 As described in Section 1.6.1 above, geophysical surveys will be undertaken post-consent to inform the seabed surface boulder clearance requirements. Where large volumes of boulders are present, micrositing of cables around these may not be possible. If left *in situ*, boulders would present the following risks to AyM:

- Exposure of cables and/ or not achieving target burial depth for cables;
- Obstruction risk to the cable installation equipment leading to damage and/or delays;
- Risk to WTG or foundation installation jack-up vessels during jacking operations; and
- Risk of damage to the cable assets themselves.

45 Boulders may be cleared using a number of methods, depending on the density of boulders encountered. Where boulders are present in high density, a boulder clearance tool or SCAR plough may be employed. In areas of low density, it may be more efficient to use a grab to target and re-locate individual boulders.

46 For the purpose of determining a design envelope for boulder clearance, it is assumed that 100% of the array cable and offshore export cable lengths will require boulder clearance, however this is expected to be greatly reduced once the results of pre-construction surveys are known. The design envelope for boulder clearance is described within the array cable and offshore export cable sections (Section 1.8.10).

1.6.6 Pre-lay grapnel run

47 Following the pre-construction route survey and boulder clearance works, a Pre-Lay Grapnel Run (PLGR) may be undertaken prior to cable installation. A vessel will be mobilised with a series of grapnels, chains, recovery winch and suitable survey spread.

48 These works will take place within the seabed preparation footprint for subsea cables described in Section 1.8.10.

1.7 Construction vessel requirements

1.7.1 Construction vessel numbers and round trips

49 The peak number of vessels on-site at any one time during the construction phase and the number of round trips between port and site (defined as a vessel movement from port to site and back to port) are summarised in Table 5. It should be noted that many parts of the construction cannot be undertaken concurrently and so the values in Table 5 which are for the total MDS are not representative throughout the majority of the construction period. It is also assumed that a total of up to 530 annual helicopter round trips by up to two helicopters may be made in the construction phase.

50 Vessels will, when necessary, undertake wet storage techniques for anchors and infrastructure across the Order Limits.

Table 5: Peak construction vessels and round trips to site.

VESSEL TYPE	PEAK VESSELS	ROUND TRIPS	
		LARGER WTG	SMALLER WTG
Foundations			
WTG foundation installation vessels (includes tugs and feeders)	16	136	133
OSP foundation installation vessels	8	16	
TP installation vessels	6	27	24
Scour protection installation vessels (including filter layer and seabed preparation)	6	87	170

VESSEL TYPE	PEAK VESSELS	ROUND TRIPS	
		LARGER WTG	SMALLER WTG
GBS ballast installation	2	371	315
WTGs and OSPs			
WTG installation vessels (includes tugs and feeders)	15	31	45
OSP topside installation vessels	4	8	
Other installation vessels			
Commissioning vessels	3	78	
Accommodation vessels	2	52	
Other (including Crew Transfer Vessels (CTVs), guard vessels and support vessels)	15	2,300	
Cable installation vessels			
Array cable installation vessels (includes support, cable protection and anchor handling vessels)	12	23 (plus 84 for cable protection vessels)	
Export cable installation vessels (including at landfall) (includes support, cable protection and anchor handling vessels)	12	23 (plus 164 for cable protection vessels)	
Total construction vessels			

VESSEL TYPE	PEAK VESSELS	ROUND TRIPS	
		LARGER WTG	SMALLER WTG
Maximum total construction vessels	101	3,399	3436
Indicative peak vessels on-site simultaneously	35	N/A	

1.7.2 Jack-up operations and anchoring

51 Jack-Up Vessels (JUVs) are installation vessels that are capable of lowering three or more legs onto the seabed and lifting themselves out of the water to provide a stable platform where craning of heavy infrastructure such as foundations, WTGs and OSP topsides can take place. The legs of the JUV have direct impacts on the seabed within the footprint of the feet, known as ‘spud cans’.

52 Alternatively, multiple anchors may be used to position and secure the vessel, which will also have direct impacts on the seabed and are considered within the overall footprint of the project. Anchor handling and deployment of anchors may be required outside of the Order Limits. In addition, vessels may be required to anchor in and around the Order Limits for the purposes of maritime navigational safety. Anchoring is not a licensable activity under the Marine and Coastal Access Act (MCAA) 2009.

53 For WTG, OSP and met masts, the methodologies available for installation include JUV operations and anchoring. Therefore, the values in the tables below are not additive as the two activities are mutually exclusive.

54 Table 6 describes the design envelope for JUV operations and Table 7 describes the anchor handling footprints in the construction phase.

Table 6: Design envelope for JUV operations.

PARAMETER	DESIGN ENVELOPE
Individual spud can footprint (m^2)	275
Maximum seabed area per vessel (m^2)	1,100 (note JUVs with greater numbers of legs have a smaller individual leg footprint)
Typical seabed penetration (m)	0 – 15
Total jack-up operations during construction	312
Maximum seabed area impacted (m^2)	343,200

Table 7: Design envelope for anchor footprints.

PARAMETER	DESIGN ENVELOPE
WTG, OSP and met mast installation (foundations and topsides)	
Number of anchors per deployment	8
Anchor footprint (deployment and recovery per anchor) (m^2)	116
Typical anchor penetration depth (m)	4
Number of deployments per location	5 (4 for foundation installation, 1 for WTG/ OSP topside installation)
Total impact area (m^2)	242,112
Total impact volume (m^3)	968,448
Array cable installation	
Number of anchors per deployment	9

PARAMETER	DESIGN ENVELOPE
Anchor footprint (deployment and recovery per anchor) (m^2)	61
Typical anchor penetration depth (m)	1.5
Number of deployments	264
Total impact area (m^2)	144,077
Total impact volume (m^3)	216,115
Export cable installation	
Number of anchors per deployment	9
Anchor footprint (deployment and recovery per anchor) (m^2)	61
Typical anchor penetration depth (m)	1.5
Number of deployments	143
Total impact area (m^2)	78,204
Total impact volume (m^3)	117,306

1.8 Offshore infrastructure

1.8.1 Foundation options

55 The WTGs, OSPs and met mast are secured to the seabed via foundation structures. There are a number of foundation types that are being considered for AyM, with the final design selection being dependent on factors including physical and environmental constraints, project economics, and supply chain strategy.

56 Table 8 below describes which foundation options are considered within the design envelope for AyM. The only foundation option considered for the met mast is a monopile, and this would be smaller than those considered for WTGs.

57 Further detail on the maximum design parameters for the different foundation options is provided in Sections 1.8.3 to 1.8.5, below.

Table 8: Foundation options considered for AyM infrastructure.

FOUNDATION OPTIONS	AYM INFRASTRUCTURE		
	WTG	OSP	MET MAST
Monopile	Yes	Yes	Yes
Alternative monopile configuration (see paragraph 65 *et seq.*)	No	Yes	No
Multi-leg pin-piled jacket	Yes	Yes	No
Mono suction caisson	Yes	No	No
Multi-leg suction caisson jacket	Yes	Yes	No
Mono GBS	Yes	Yes	No
Multi-leg GBS jacket	Yes	Yes	No

1.8.2 Scour protection

58 Scour protection is designed to prevent foundation structures from being undermined by hydrodynamic and sedimentary processes, resulting in seabed erosion and subsequent scour pit formation. The shape of a foundation structure is an important parameter in influencing the potential depth of scour pits, as well as the local hydrodynamic regime and seabed sediment conditions. Scour around foundations is usually mitigated by the use of scour protection measures, which include concrete mattresses, bagged solutions (containing rock/sand or similar), protective aprons/coverings, and flow energy dissipation devices (such as frond mats). The most common type of scour protection, however, is the placement of loose crushed rock around the base of the foundation (rock placement) (see also paragraph 123 *et seq.* on cable protection, which describes these methods in more detail).

59 A typical scour protection solution may comprise a rock armour layer resting on a filter layer of smaller graded rocks. The scour protection can either be installed before or after the foundation is installed. Alternatively, by using a heavier rock material with a larger gradation, it is possible to avoid using a filter layer and install a single layer of scour protection.

60 The amount of scour protection required will vary depending on the foundation type selected. Flexibility in scour protection choice is required to ensure that anticipated changes in available technologies and foundation design can be accommodated within the design envelope. The final choice of scour protection solution will be made post-consent in the detailed design phase, taking into account geotechnical data, meteorological and oceanographic conditions, water depth, foundation type and maintenance strategy. The design envelope for scour protection is described in the tables for each foundation type in Section 1.8.3 to 1.8.5.

1.8.3 Piled foundations

61 Piled foundations are anchored via tubular piles driven into the seabed to the required depth, usually by impact piling, but may also be vibro-piled or drilled, or a combination.

Monopile

62 Monopile foundations typically consist of a single tubular section, consisting of a number of rolled steel plates welded together, which is driven into the seabed, usually via impact or vibro-piling. A Transition Piece (TP) may be fitted over the monopile and secured via bolts or grout. The TP may feature a boat landing, ladders, a small crane and other ancillary components as well as a flange for connection to the WTG tower. The TP is typically painted yellow and marked according to the relevant regulatory guidance and may be installed at a separate time to the monopile itself. As an alternative to a TP, it may be possible to have an extended monopile. In this case, the ancillary components and regulatory markings are applied directly to the upper section of the monopile instead. An example of a monopile foundation is illustrated in Figure 3 and the design envelope for this foundation type is described in Table 9.

63 Monopiles and transition pieces will be transported to site either on the installation vessel itself or on feeder barges as described in Section 1.7. Once on site, the monopiles will typically be installed using the following process:

- The monopile is lifted into the pile gripper on the side of the installation vessel;
- The hammer (see paragraph 69 *et seq.*) is lifted onto the monopile;
- The monopile is driven into the seabed until the required embedment depth is achieved;
- In the event of pile refusal, relief drilling may be necessary to embed the pile to the required depth;
- The TP is lifted onto the monopile; and
- The TP is secured using bolts or grout.

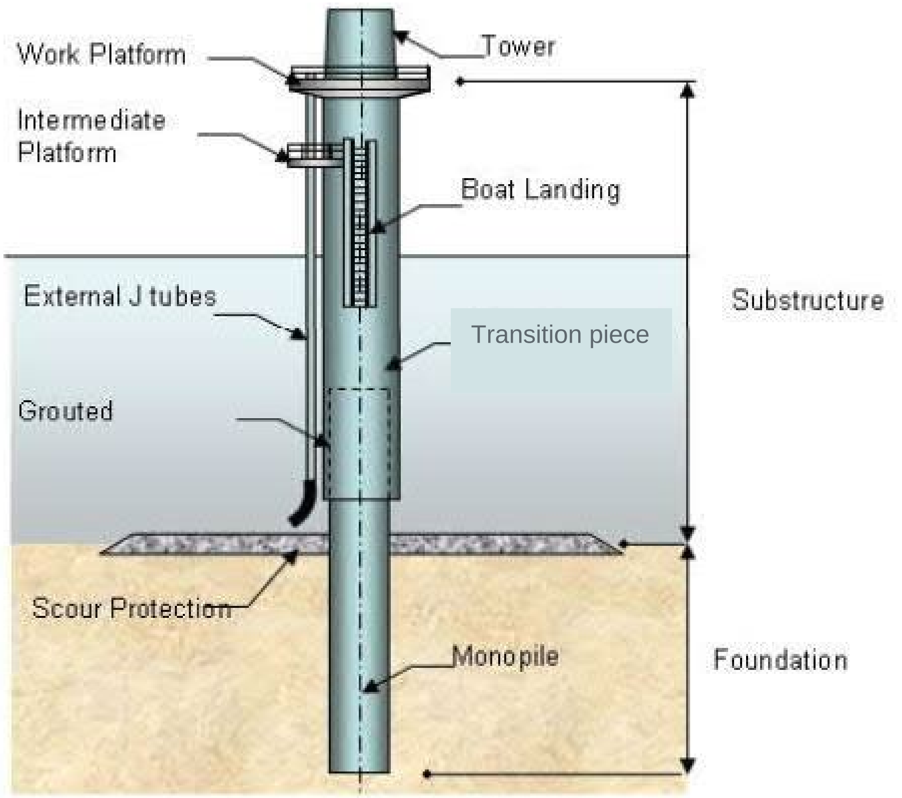

Figure 3: Monopile foundation with TP.

64 Seabed preparation for monopiles is usually minimal and may not be required at all. If pre-construction surveys show the presence of boulders or other seabed obstructions at foundation locations, these may be removed (as described in Section 1.6.5) if the foundation cannot be micrositied to avoid the obstruction.

65 For OSPs, an alternative monopile configuration is considered. OSPs may be installed either:

- **Option A:** On a single monopile (as is the case for WTGs);
- **Option B:** On up to six smaller diameter monopiles (up to 8 m) in a rectangular configuration.

Table 9: Design envelope for monopiles.

PARAMETER	DESIGN ENVELOPE			
	LARGER WTG	SMALLER WTG	OSP	MET MAST
Number of monopiles	34	50	Option A: 2 Option B: 12	1
Diameter (m)	15	13	Option A: 15 Option B: 8	5
Footprint (excluding scour protection) per foundation (m^2)	177	133	Option A: 177 Option B: 302	20
Total seabed footprint (excluding scour protection) (m^2)	6,008	6,637	Option A: 353 Option B: 603	20
Typical embedment depth (m)	65	55	60	30
Hammer energy (kJ)	5,000	5,000	5,000	3,000
Drilling				

PARAMETER	DESIGN ENVELOPE			
	LARGER WTG	SMALLER WTG	OSP	MET MAST
Foundations requiring drilling (%)	100	100	100	100
Drill diameter (m)	16	14	16	5
Typical drill penetration depth (m)	68	59	60	30
Indicative volume of drill arisings per pile (m^3)	13,572	9,005	12,064	589
Total drill arisings (m^3)	276,862	270,161	24,127	589
Seabed preparation				
Seabed preparation for monopiles is expected to be minimal and typically limited to within the footprint of clearance for boulders, UXO and sandwaves. The total extent of seabed preparation will be significantly lower than for GBS foundations (Section 1.8.5).				
Scour protection				
Typical scour protection depth (m)	2	2	2	2
Diameter of scour protection at	83	73	Option A: 98 Option B: 120 x 90 rectangle	33

PARAMETER	DESIGN ENVELOPE			
	LARGER WTG	SMALLER WTG	OSP	MET MAST
seabed level (including foundation footprint) (m)				
Area of scour protection (including foundation footprint) (m^2)	5,411	4,185	Option A: 7,543 Option B: 10,800	855
Volume of scour protection per foundation (m^3)	9,450	7,213	Option A: 13,526 Option B: 21,600	1,282
Total area of scour protection (including foundation footprint (m^2)	183,961	209,269	Option A: 15,086 Option B: 21,600	855
Total volume of scour protection required (m^3)	321,250	360,650	Option A: 27,050 Option B: 43,200	1,282

Multi-leg pin-piled jacket

66 Multi-leg pin-piled jacket foundations are formed of a steel lattice construction comprising tubular steel supports and welded joints. These are secured to the seabed by steel pin-piles that are similar in construction to monopiles (though typically smaller in diameter) attached to the jacket feet. Unlike monopiles, there is no need for a separate TP, since the TP and ancillary structure is typically fabricated as an integral part of the jacket. An example of a multi-leg pin-piled jacket foundation is illustrated in Figure 4 and the design envelope for this foundation type is described in Table 10.

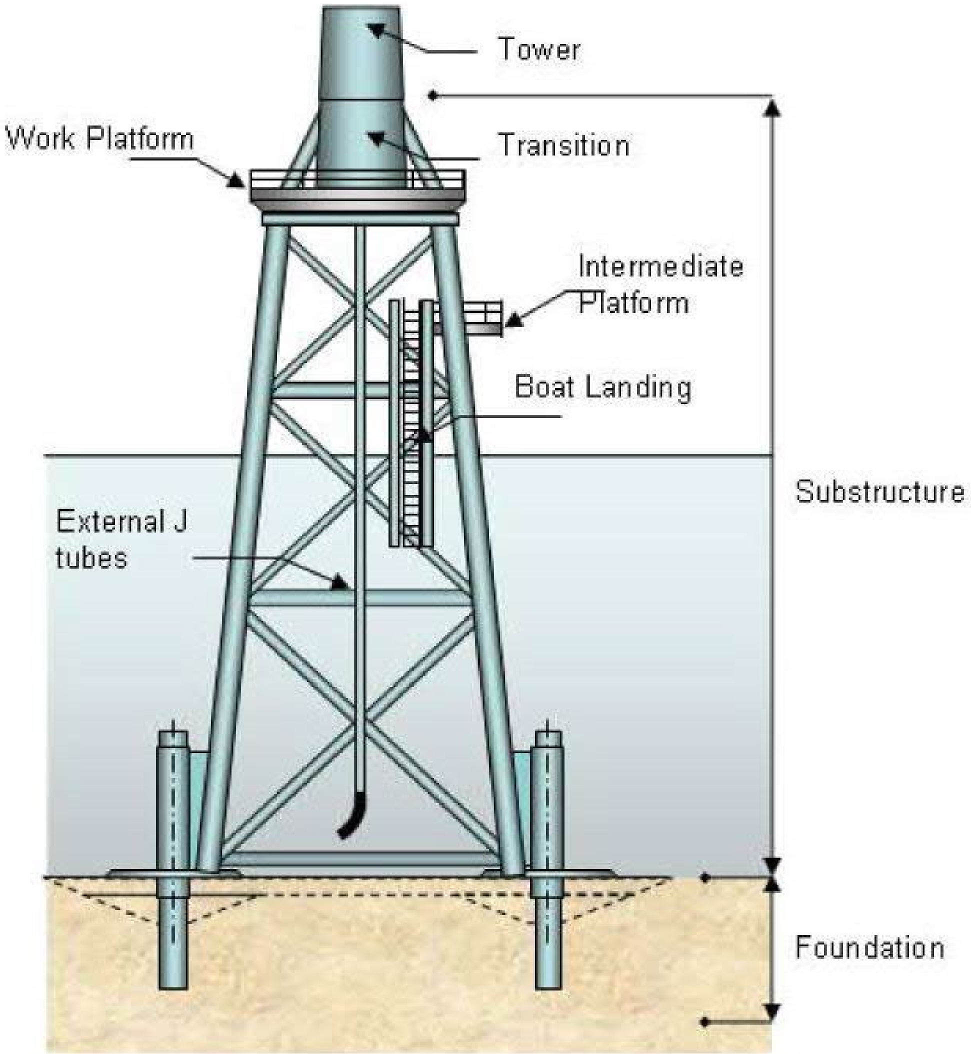

Figure 4: Wind turbines on multi-leg jacket foundations.

67 The installation sequence will be similar to that of monopiles (paragraph 62 *et seq.*), with the structures transported to site by installation vessels or feeder barges, where they will be lowered onto the seabed. The pin-piles can either be installed before or after the jacket is lowered to the seabed. If before, a piling template is typically lowered onto the seabed to guide the pin-piles to the exact required locations. The piles are then installed through the template, which itself is then recovered to the installation vessel, and subsequently the jacket is fixed atop the pin-piles by grout or other means such as welding. Alternatively, the need for a piling template can be negated by installing the pin-piles after the jacket has been placed on the seabed.

68 Because jacket foundations typically have a larger seabed footprint compared to monopiles, some degree of seabed preparation is usually necessary to clear obstacles and provide a level surface for jacket installation.

Table 10: Design envelope for multi-leg pin-piled jackets.

PARAMETER	DESIGN ENVELOPE		
	LARGER WTG	SMALLER WTG	OSP
Number of jacket foundations	34	50	2
Separation of adjacent legs at seabed level (m)	40	30	50
Separation of adjacent legs at sea level (LAT) (m)	30	25	40
Number of legs per foundation	4	4	6
Pin-piles per leg	1	1	2
Total pin-piles	136	200	24

PARAMETER	DESIGN ENVELOPE		
	LARGER WTG	SMALLER WTG	OSP
Pin-pile diameter (m)	3.5	3.5	3.5
Footprint of pin-piles (excluding scour protection) per pin-pile (m^2)	9.6	9.6	9.6
Total seabed footprint (excluding scour protection) (m^2)	1,306	1,924	231
Typical pin-pile embedment depth (m)	60	60	60
Hammer energy (kJ)	3,000	3,000	3,000
Drilling			
Foundations requiring drilling (%)	100	100	100
Drill diameter (m)	3.5	3.5	3.5
Typical drill penetration depth (m)	60	60	60
Typical drilling rate (m/hr)	0.25-2	0.25-2	0.25-2
Volume of drill arisings per pile (m^3)	577	577	577
Total drill arisings (m^3)	78,508	115,454	13,854
Seabed preparation			

PARAMETER	DESIGN ENVELOPE		
	LARGER WTG	SMALLER WTG	OSP
Seabed preparation for piled jacket foundations is expected to be minimal and typically limited to within the footprint of clearance for boulders, UXO and sandwaves. The total extent of seabed preparation will be significantly lower than for GBS foundations (Section 1.8.5).			
Scour protection			
Typical scour protection depth (m)	2	2	2
Diameter of scour protection at seabed level per foundation (including foundation footprint) (m)	22	22	Rectangular 120 x 90
Area of scour protection per foundation (including foundation footprint) (m^2)	1,521	1,521	10,800
Volume of scour protection per foundation (m^3)	1,959	1,959	21,600
Total area of scour protection (including foundation footprint (m^2)	51,698	76,027	21,600
Total volume of scour protection required (m^3)	66,550	97,900	43,200

Piling techniques, soft start and ramp up

69 The most common method of installing driven piles is to use a percussive hammer. Impact piling is presented as the basis for the design envelope, however alternative piling methods such as vibro-piling, Blue Piling or HiLo Impact may also be considered as technologies that reduce the source level of underwater noise compared to impact piling. The suitability of such technologies would be informed by pre-construction surveys post-consent.

70 For impact piling, the hammer would use a maximum energy of 5,000 kJ for monopiles and 3,000 kJ for pin-piles. Piling for both scenarios would include the use of a soft start at 15% of the maximum hammer energy, followed by a 'ramp up' to the required hammer energy (see the Schedule of Mitigation (application ref: 8.11).

71 In the case of monopiles, piling will only occur at one location at a time – there is no possibility of simultaneous or concurrent piling. In the case of pin-piled multi-leg jacket foundations, pin-piles may be installed concurrently, but only on adjacent legs of the same jacket foundation – there is no possibility of simultaneous or concurrent piling at two separate foundation locations.

72 The maximum soft start and ramp up scenarios are described in Table 11 below and have been modelled as detailed within Volume 2, Annex 6.2: Subsea Noise Technical Report (application ref: 6.4.6.2).

Table 11: Piling scenarios.

PARAMETER	SOFT START	RAMP UP				MAX
Monopile						
Hammer energy (kJ)	750	1,000	2,000	3,000	4,000	5,000
Strikes	100	100	340	680	1,020	6,528
Duration (s)	600	600	600	1,200	1,800	11,520

PARAMETER	SOFT START	RAMP UP				MAX
Strike rate (strikes per minute)	10	10	34	34	34	34
Pin-pile						
Hammer energy (kJ)	450	600	1,200	1,800	2,400	3,000
Strikes	100	100	340	680	1,020	5,100
Duration (s)	600	600	600	1,200	1,800	9,000
Strike rate (strikes per minute)	10	10	34	34	34	34

Drilling

73 If piling is not possible due to the presence of rock or hard ground conditions, the material inside the pile may be drilled out to facilitate driving the pile to its required embedment depth. This can be done either in advance of piling, or if the embedment rate slows significantly during piling (such as in the event of pile refusal).

74 Various drilling methodologies are possible, but drills are typically lifted by crane into a part-installed pile, ride inside the pile during drilling, and are removed in the event driving recommences. Drills may only bore out to a diameter equal to the internal diameter of the pile, or they may be capable of expanding their cutting disk below the tip of the pile and boring out to the pile's maximum outer diameter or greater (known as under-reaming).

75 Drilling systems are available in sizes ranging from those required for small jacket pin piles, to large diameter monopiles. Water is continuously pumped into the drill area and any drill arisings generated are flushed out and allowed to disperse at the surface, falling to the seabed in the vicinity of the pile.

76 It may be necessary to adopt a drive-drill-drive sequence depending on ground conditions. Other similar sequences of drilling and driving are also possible. The design envelope for drilling scenarios is described for the piled solutions above. In the case of piled jacket foundations, drilling may take place at the same time as piling or drilling at an adjacent jacket leg.

1.8.4 Suction caisson foundations

77 Suction caisson foundations are secured to the seabed via hollow steel cylinders, capped at the upper end. They are typically larger in diameter compared to driven piles, but do not require a hammer or drill for installation. Instead, the foundation is lowered into place to form a seal between the seabed and the suction caisson structure, after which powerful pumps remove the seawater from inside the caisson to create a vacuum which pulls the foundation down into the seabed to the required embedment depth. If necessary, the void between the caisson and the seabed may be filled with grout or a similar material.

Mono suction caisson

78 A mono suction caisson foundation is similar in construction to a monopile but consists of a single suction caisson at its base supporting a single monopile structure. An example of a mono suction caisson foundation is illustrated in Figure 5, and the design envelope for this foundation type is described in Table 12.

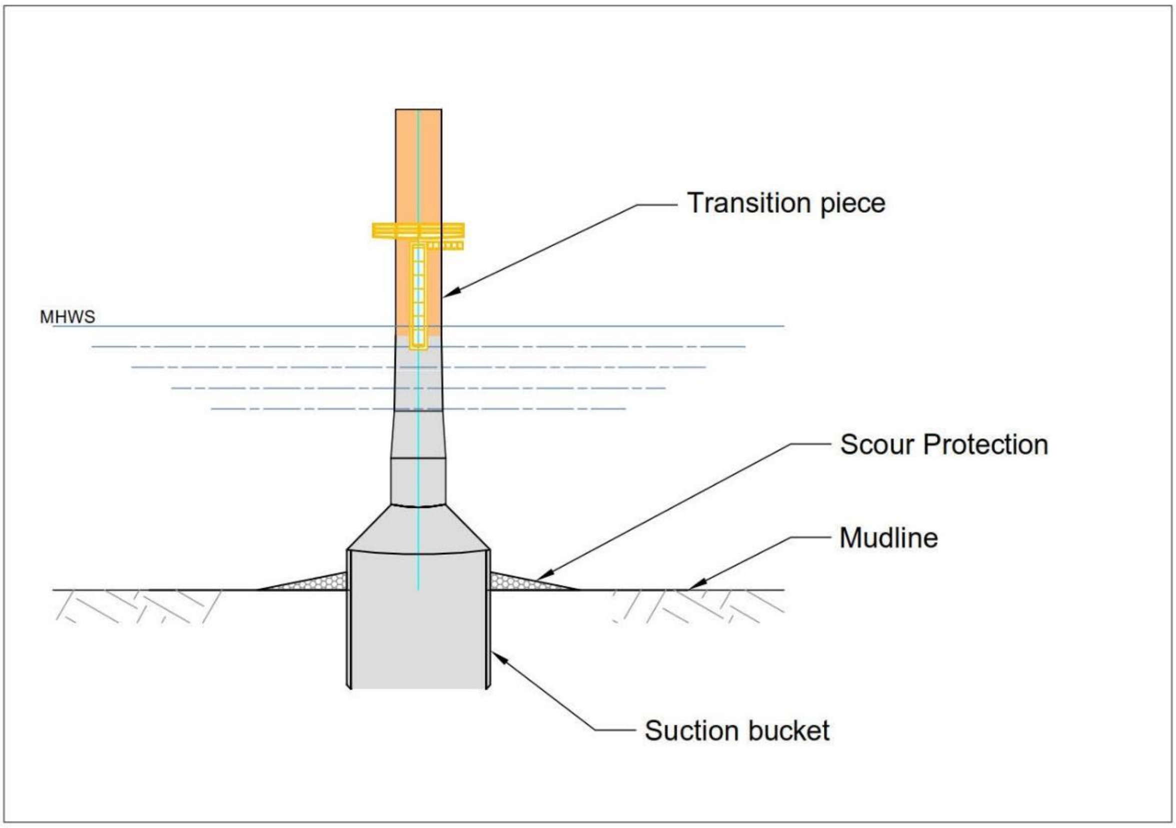

Figure 5: Mono-suction caisson foundations.

Table 12: Design envelope for mono suction caisson foundations.

PARAMETER	DESIGN ENVELOPE	
	LARGER WTG	SMALLER WTG
Number of foundations	34	50
Suction caisson diameter (m)	35	35
Monopile diameter at sea surface (LAT) (m)	15	15
Typical suction caisson penetration depth (m)	25	25
Height of suction caisson above seabed level (m)	8	8

PARAMETER	DESIGN ENVELOPE	
	LARGER WTG	SMALLER WTG
Footprint of suction caissons (excluding scour protection) per foundation (m^2)	962	962
Total seabed footprint (excluding scour protection) (m^2)	32,712	48,106
Seabed preparation		
Total area of seabed preparation required (including foundation footprint) (m^2)	32,712	48,106
Typical depth of seabed preparation required (m)	4	4
Volume of sediment disturbed by seabed preparation (m^3)	130,847	192,423
Scour protection		
It is assumed that for WTG mono suction caisson foundations, the scour protection envelope will not exceed the maximum parameters described for multileg GBS foundations in Section 1.8.5.		

Multi-leg suction caisson jacket

79 Multi-leg suction caisson jacket foundations are similar in construction to a multi-leg pin-piled jacket foundation consisting of a steel lattice structure (paragraph 66 *et seq.*) but are secured to the seabed via three or more suction caissons, rather than pin-piles. An example of a multi-leg suction caisson foundation is illustrated in Figure 6, and the design envelope for this foundation type is described in Table 13.

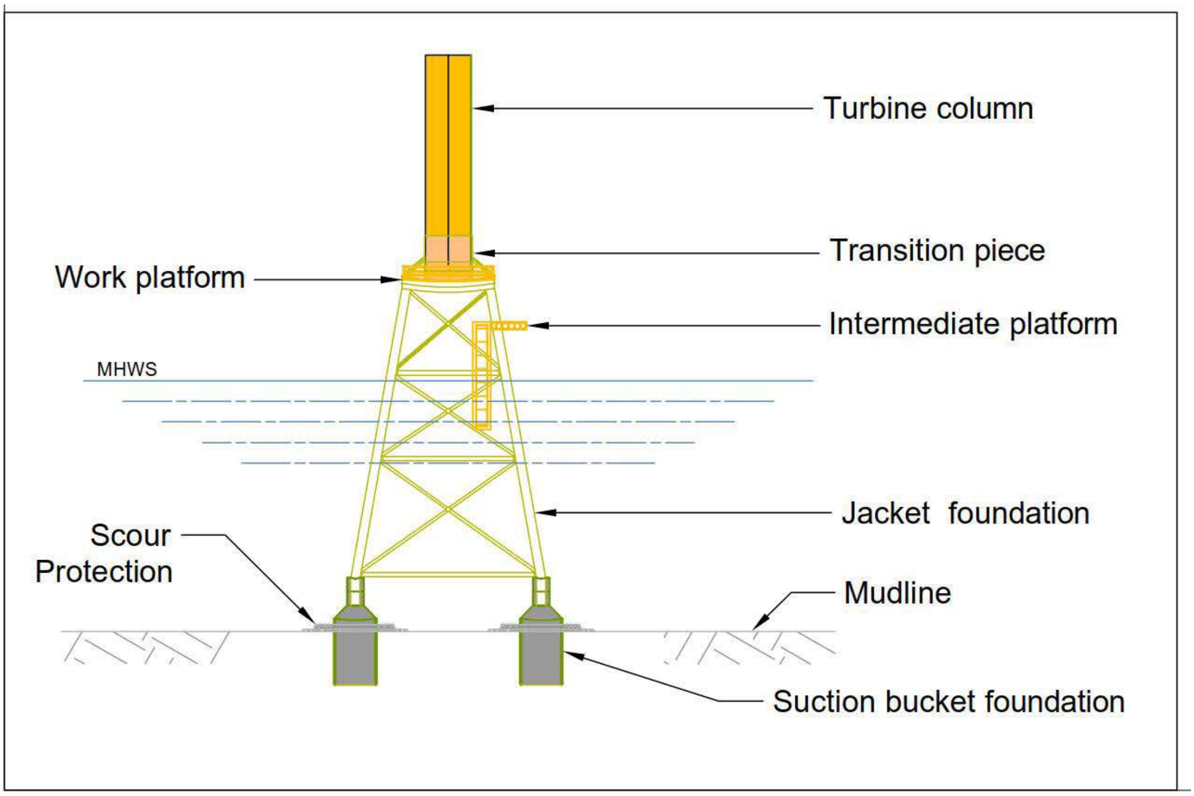

Figure 6: A multi-leg suction caisson jacket foundation.

Table 13: Design envelope for multi-leg suction caisson jacket foundations.

PARAMETER	DESIGN ENVELOPE		
	LARGER WTG	SMALLER WTG	OSP
Number of foundations	34	50	2

PARAMETER	DESIGN ENVELOPE		
	LARGER WTG	SMALLER WTG	OSP
Separation of adjacent legs at seabed level (m)	40	30	50
Separation of adjacent legs at sea level (LAT) (m)	30	25	40
Number of legs per foundation	4	4	6
Suction caisson diameter (m)	20	15	20
Typical suction caisson penetration depth (m)	25	25	25
Height of suction caisson above seabed level (m)	5	5	5
Footprint of suction caissons (excluding seabed preparation and scour protection) per suction caisson (m^2)	314	177	314
Total seabed footprint (excluding seabed preparation and scour protection) (m^2)	42,726	35,343	3,770
Seabed preparation			
Total area of seabed preparation required (including foundation footprint) (m)	66,759	62,832	8,482

PARAMETER	DESIGN ENVELOPE		
	LARGER WTG	SMALLER WTG	OSP
Typical depth of seabed preparation required (m)	4	4	4
Volume of sediment disturbed by seabed preparation (m^3)	267,035	251,327	33,929
Scour protection			
It is assumed that for multileg suction caisson foundations, the scour protection envelope will not exceed the maximum parameters described for multileg GBS foundations in Section 1.8.5.			

1.8.5 GBS foundations

80 GBS foundations are heavy steel and/or concrete structures, sometimes incorporating additional ballast material, that sit on the seabed. GBS foundations vary in shape but are normally significantly wider at the seabed level to provide support and stability to the structure. Generally, they then taper to a smaller width at the sea surface level. GBS foundations also often include skirts that embed into the seabed under the weight of the structure to improve the natural stability and scour resistance of the foundation.

81 GBS foundations do not require percussive piling and are not attached directly to the seabed. Instead, they rely on their weight to provide stability to the structure above. GBS foundations are typically hollow and can be floated to site before being filled with ballast to sink the foundation to its required position.

82 GBS foundations in particular can require significant seabed preparation in order to provide a clear and level surface for installation (Section 1.6.2). In some cases, a layer of gravel may also be laid on the seabed to provide this level surface.

Mono GBS

83 Mono GBS foundations consist of a single GBS structure supporting a monopile structure, similar in appearance to a mono suction caisson, with a significantly wider base. An example of a mono GBS foundation is illustrated in Figure 7, and the design envelope for this foundation type is described in Table 14.

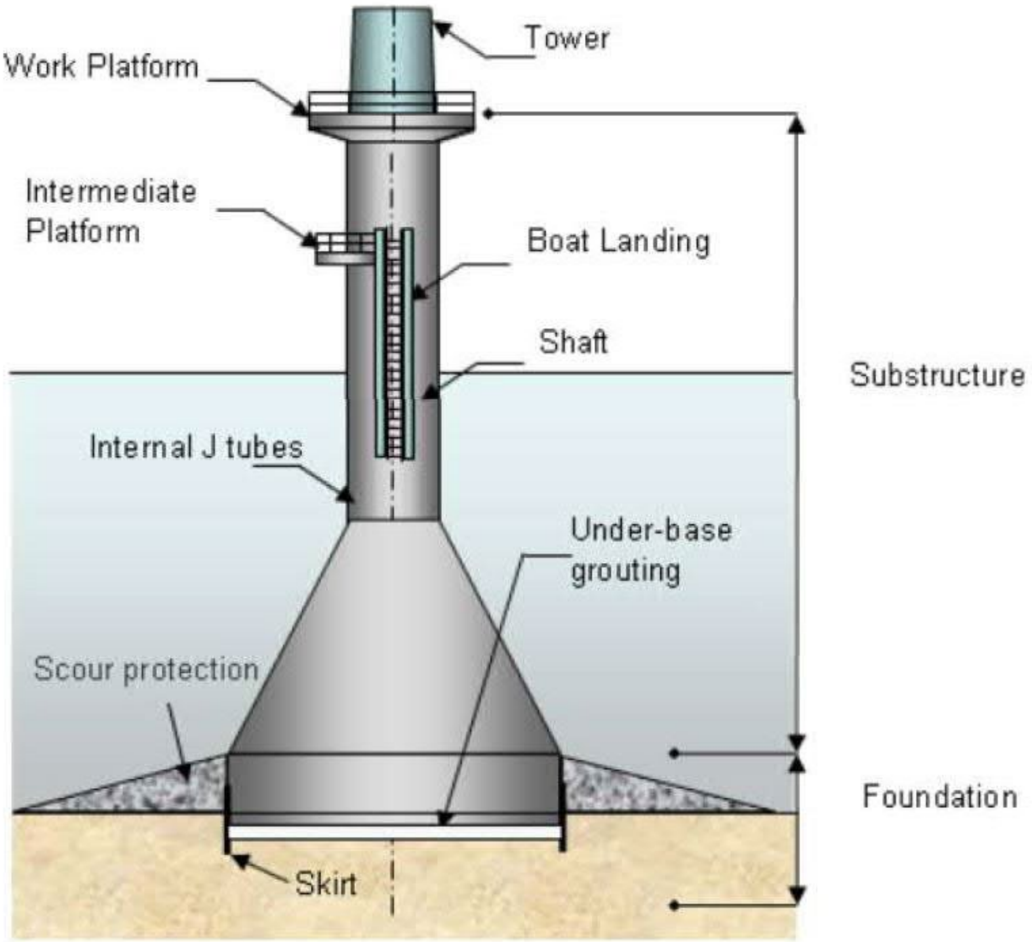

Figure 7: A mono GBS foundation.

Table 14: Design envelope for mono GBS foundations.

PARAMETER	DESIGN ENVELOPE		
	LARGER WTG	SMALLER WTG	OSP
Number of jacket foundations	34	50	2
GBS diameter (m)	55	45	55 (round base)
Shaft diameter at sea surface (LAT) (m)	15	15	15
Footprint of foundation (including seabed preparation but excluding scour protection) per foundation (m^2)	2,827	1,963	7,000 (rectangular base)
Total seabed footprint (including seabed preparation but excluding scour protection) (m^2)	96,133	98,175	14,000 (rectangular base)
Seabed preparation			
Seabed preparation diameter per foundation (m)	60	50	65 (or 100 x 70 rectangular base)
Seabed preparation area per foundation (m^2)	2,827	1,963	7,000

PARAMETER	DESIGN ENVELOPE		
	LARGER WTG	SMALLER WTG	OSP
Total area of seabed preparation required (including foundation footprint (m)	96,133	98,175	14,000
Indicative average depth of seabed preparation required (m)	2	2	4
Volume of sediment disturbed by seabed preparation (m^3)	192,265	196,350	56,000
Gravel bed requirements			
Area of gravel bed (m^2) per foundation	2,827	1,963	7,000
Thickness of gravel bed (m)	1	1	1
Volume of gravel bed per foundation (m^3)	2,827	1,963	7,000
Total area of gravel bed required (m^2)	96,133	98,175	14,000
Total volume of gravel bed required (m^3)	96,133	98,175	14,000
Surface area			

PARAMETER	DESIGN ENVELOPE		
	LARGER WTG	SMALLER WTG	OSP
Surface area of water facing structure per foundation (m^2)	4,250	3,650	4,950
Total surface area of water facing structure (m^2)	144,500	182,500	9,900
Scour protection			
Scour protection depth (m)	2	2	2
Diameter of scour protection at seabed level (including foundation footprint) (m)	146	121	120 x 90 (rectangular base)
Area of scour protection (including foundation footprint) (m)	16,627	11,404	10,800
Volume of scour protection per foundation (m^3)	26,699	18,138	13,600
Total area of scour protection (including foundation footprint (m^2)	565,321	570,209	21,600

PARAMETER	DESIGN ENVELOPE		
	LARGER WTG	SMALLER WTG	OSP
Total volume of scour protection required (m³)	907,773	906,919	27,200

Multi-leg GBS jacket

84 Multi-leg GBS foundations are similar in appearance to multi-leg suction caisson foundations, but with multiple GBS structures at the base of the legs rather than suction caissons. An example of a multi-leg GBS foundation is illustrated in Figure 8, and the design envelope for this foundation type is described in Table 15.

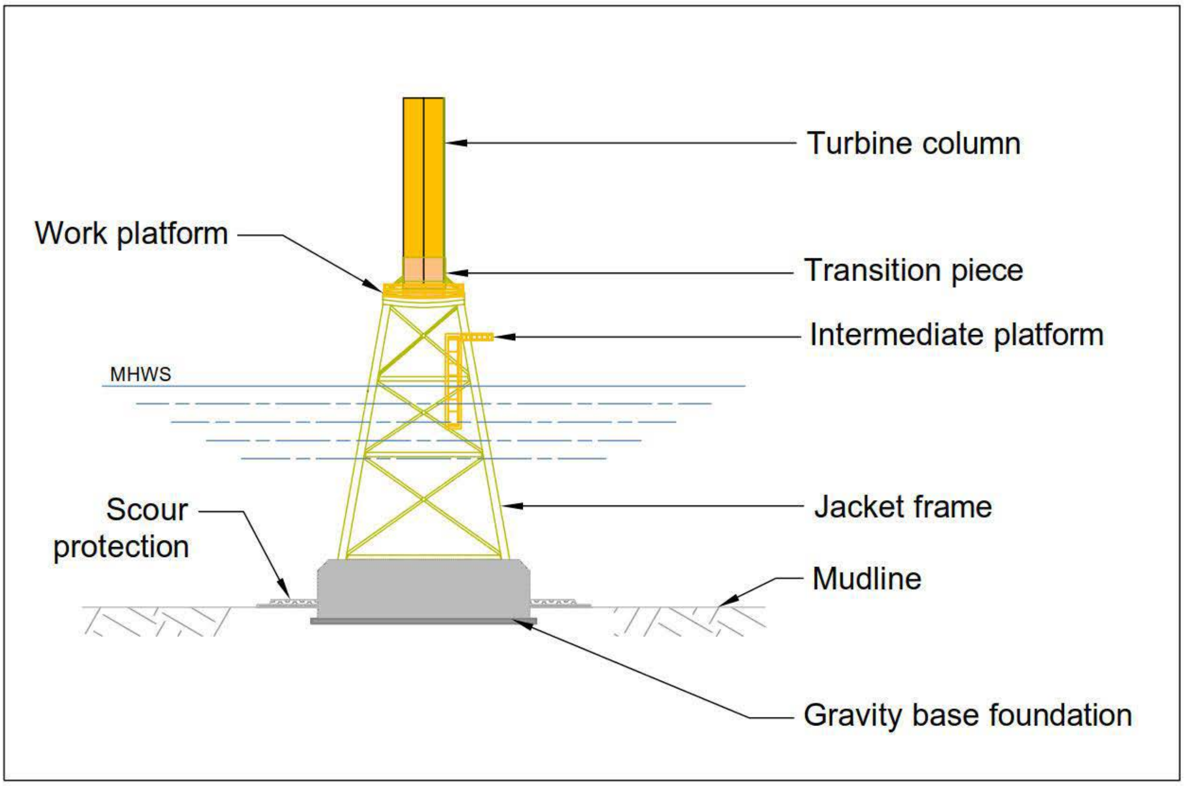

Figure 8: Multi-leg GBS jacket foundation with a single base.

Table 15: Design envelope for multi-leg GBS foundations.

PARAMETER		DESIGN ENVELOPE		
		LARGER WTG	SMALLER WTG	OSP
Number of jacket foundations		34	50	2
Separation of adjacent legs at seabed level (m)		40	30	50
Separation of adjacent legs at sea level (LAT) (m)		30	25	40
Number of bases per foundation		4	4	6
GBS diameter (m)	One base per leg	20	20	20
	Single base	50 x 50	40 x 40	65 x 95
Height of GBS above seabed level (m)		8	8	8
Footprint of foundation (including seabed preparation but excluding scour protection) per base (m^2)	One base per leg	490.9	490.9	314
	Single base	3,600	2,500	10,800

PARAMETER		DESIGN ENVELOPE		
		LARGER WTG	SMALLER WTG	OSP
Total seabed footprint (including seabed preparation but excluding scour protection) (m^2)	One base per leg	66,759	98,175	3,770
	Single base	122,400	125,000	21,600
Seabed preparation				
Seabed preparation diameter per leg (m)	One base per leg	25	25	30
	Single base	60	50	N/A (rectangular base)
Seabed preparation area per base (m^2)	One base per leg	490.9	490.9	706.9
	Single base	3,600	2,500	10,800
Total area of seabed preparation required (including foundation footprint (m^2)	One base per leg	66,759	98,175	8,482
	Single base	122,400	125,000	21,600

PARAMETER	DESIGN ENVELOPE		
	LARGER WTG	SMALLER WTG	OSP
Depth of seabed preparation required	4	4	4
Volume of sediment disturbed by seabed preparation (m3)	489,600	500,000	86,400
Gravel bed requirements			
Area of gravel bed (m^2) per foundation	3,600	2,500	10,800
Thickness of gravel bed (m)	1	1	1
Volume of gravel bed per foundation (m^3)	3,600	2,500	10,800
Total area of gravel bed required (m^2)	122,400	125,000	21,600
Total volume of gravel bed required (m^3)	122,400	125,000	21,600
Scour protection			
Scour protection depth (m)	2	2	2
Diameter of scour protection at seabed level (including foundation footprint) (m)	78	68	120 x 90
Area of scour protection per foundation (including foundation footprint) (m)	6,084	4,624	10,800

PARAMETER	DESIGN ENVELOPE		
	LARGER WTG	SMALLER WTG	OSP
Volume of scour protection per foundation (m^3)	10,952	8,192	21,600
Total area of scour protection (including foundation footprint) (m^2)	206,856	231,200	21,600
Total volume of scour protection required (m^3)	372,350	409,600	43,200

1.8.6 WTGs

85 The EIA will not be linked directly to the electrical output capacity of individual WTGs or the overall capacity of AyM as it is not considered to be a material factor in the MDS, as described in paragraph 15 *et seq*. Up to 34 large, or up to 50 smaller WTGs are planned for AyM. A range of WTG models will be considered; however, they are all likely to follow the traditional WTG design with three blades and a horizontal rotor axis.

86 The blades are connected to a central hub, forming a rotor that turns generator and in some cases a gearbox. The generator and gearbox are located within a containing structure known as the Rotor Nacelle Assembly (RNA), atop the WTG tower. The RNA is supported by the tower structure which is affixed to the foundation at its base. The RNA is able to rotate or 'yaw' in order to face the oncoming wind direction.

87 WTGs operate within a set wind speed range and have a minimum wind speed at which they start generating electricity, and a maximum wind speed at which the WTG cannot generate and operates in a standby mode. Developments in technology are increasing the range of wind speeds at which WTGs can operate, enabling a gradual ramp up and ramp down of output to support operation of the National Grid.

88 Each WTG will have a minimum clearance between sea level and the lowest position of the blade. The rotor diameter will vary depending on the chosen design. An example of a WTG is illustrated in Figure 9 and the design envelope for WTGs is described in Table 16.

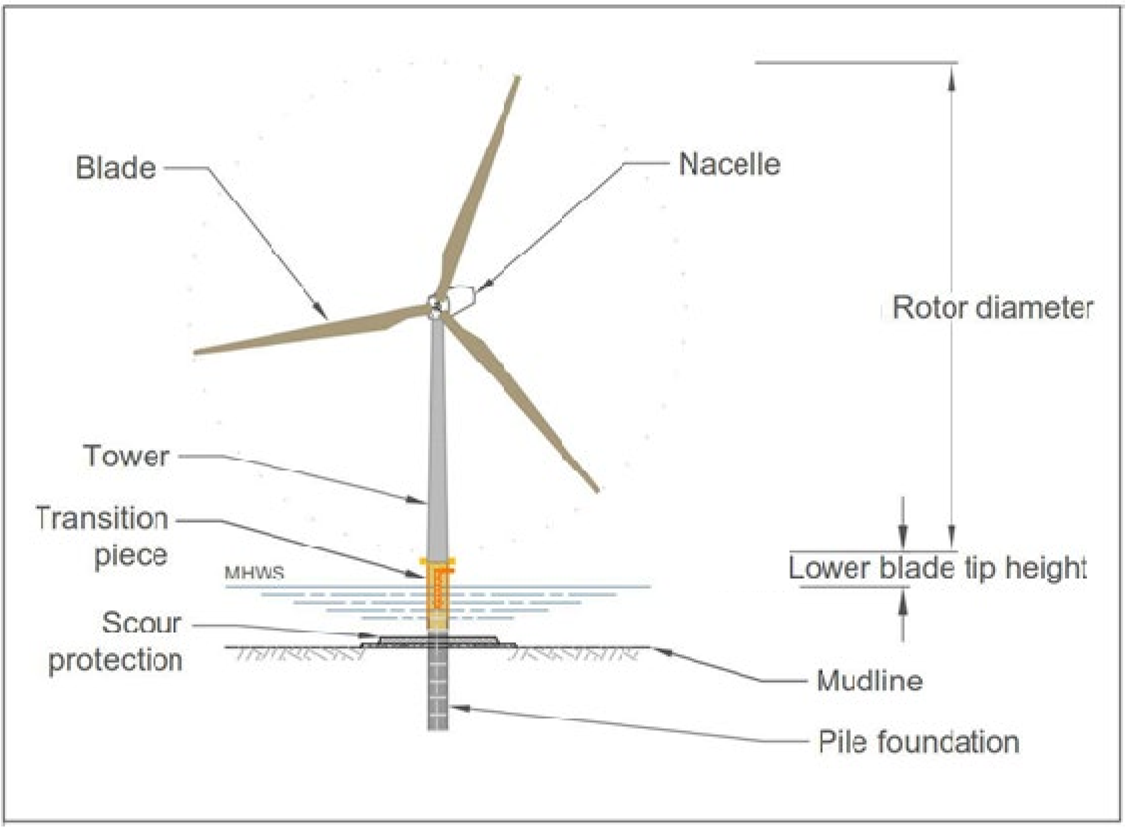

Figure 9: Diagram of an offshore WTG.

Table 16: Design envelope for WTGs.

PARAMETER	DESIGN ENVELOPE	
	LARGER WTG	SMALLER WTG
Number of WTGs	34	50
Minimum lower blade tip height above MHWS (m)	22	22
Maximum upper blade tip height above MHWS (m)	332	282

PARAMETER	DESIGN ENVELOPE	
	LARGER WTG	SMALLER WTG
Rotor diameter (m)	306	250

Access

89 The WTGs may be accessed either from a vessel via a boat landing and ladder on the foundation, via a stabilised gangway directly from a vessel, via a personnel winch system from a vessel, or from a helicopter via a heli-hoist platform on top of the nacelle. Any helicopter access would be designed in accordance with the relevant Civil Aviation Authority (CAA) guidance and standards.

Oils and fluids

90 Each WTG will contain components that require lubricating oils, hydraulic fluids and coolants for operation. Indicative maximum requirements for these fluids are described in Table 17. All oils and fluids will be contained within the WTG in case of a spill.

Table 17: Design envelope for oils and fluids.

PARAMETER	DESIGN ENVELOPE		
	LARGER WTG	SMALLER WTG	OSP
Grease (l)	1,317	838	Minimal
Hydraulic oil (l)	2,487	1,583	Minimal
Gear oil (l)	4,883	3,108	N/A
Nitrogen (l)	159,467	101,479	Minimal
Transformer silicon/ ester oil (l)	17,849	11,358	340,000
Diesel fuel (l)	1,000	1,000	20,000

PARAMETER	DESIGN ENVELOPE		
	LARGER WTG	SMALLER WTG	OSP
Sulphur hexafluoride (SF6) kg)	180	180	5,000
Glycol/ coolant (l)	34,527	21,972	Minimal
Batteries (kg)	4,000	3,000	350,000
Grey water (l)	N/A	N/A	5,000
Black water (l)	N/A	N/A	3,000

Control systems

91 Each WTG has its own control system to carry out functions like yaw control and ramp down in high wind speeds. All the WTGs are also connected to a central Supervisory Control and Data Acquisition (SCADA) system for the control of the wind farm remotely. This allows functions such as remote shut down. The SCADA system will communicate with the wind farm via fibreoptic cables (embedded within the electrical transmission cabling), radio/microwave or satellite links. Individual WTGs can also be controlled manually from control systems within the nacelle or tower base.

92 WTGs may have temporary diesel generators for commissioning and O&M activities, as well as back-up power supply for activities such as crane operation, lighting, ventilation etc.

Installation

93 In general, WTGs are installed via the following process:

- WTG components are picked up from a suitable port facility; most likely in the UK or Europe either by an installation vessel or transport barge. Installation vessels are typically JUVs or Dynamic Positioning (DP) vessels to ensure a stable platform for installation vessels when on site. A JUV would also use DP for positioning but would deploy legs during installation. Generally, blades, nacelles and towers for a number of WTGs are loaded separately onto the vessel;
- Typically, as much pre-assembly is completed as can be carried out ahead of transit to site, to ease the installation process. The components will then transit to the wind farm array area and will be lifted onto the pre-installed foundation or transition piece by the crane on the installation vessel. Each WTG will be assembled at site in this way with technicians fastening components together as they are lifted into place. The exact methodology for the assembly is dependent on WTG type and installation contractor and will be defined in the pre-construction phase post-consent;
- Alternatively, the WTG components may be loaded onto barges or dedicated transport vessels at port and installed as above by an installation vessel that remains on site throughout the installation campaign.

94 For the EIA process, assumptions are made on the maximum number of vessels, and the number of return trips to and from site required for the WTG installation campaign (see Section 1.7.1).

WTG Layouts

95 Designing and optimising the layout of WTGs and other offshore surface infrastructure is a complex, iterative process taking into account a large number of inputs and constraints, including:

- Site conditions:
  - Wind speed and direction;
  - Water depth;
  - Ground conditions;
  - Environmental constraints (anthropogenic and natural); and
  - Seabed obstructions (wrecks, UXO, existing infrastructure).
- Design considerations:

- WTG model;
- WTG wake losses;
- Regulatory requirements;
- Installation set-up;
- Foundation design;
- Electrical design; and
- O&M requirements.

96 The AyM layout will have spacing between adjacent turbines no less than 830 m. The final layout may use dense borders (perimeter weighed where more turbines are installed per km^2 than in the centre of the array area) but will not breach the minimum spacing distance. In order to inform the EIA process, the Applicant has identified MDS layouts on a topic-specific basis where required (for example for Seascape, Landscape and Visual Impact Assessment (SLVIA)). Further information on the guiding principles governing the wind farm layout is provided within Volume 4, Annex 9.1: Navigation Risk Assessment.

97 It is very important to note that these layouts are indicative for the purposes of assessment and do not represent the final layout design, which will be influenced by the bullets above. The final positions of WTGs could be located anywhere within the consented array boundary (Figure 1) and will be confirmed post-consent in the detailed design phase.

1.8.7 OSPs

98 OSPs are offshore structures housing electrical equipment to provide a range of functions, such as changing the voltage (transformer), current type (converter) or power factor (booster). In addition to the electrical equipment, the OSPs may contain ancillary items such as cranes, vessel access facilities, a helideck, energy storage, storage for water/waste/fuel/equipment, welfare facilities, and may contain vessel charging facilities. The OSPs at AyM will be the transformer type to step-up the voltage for transmission to shore.

99 The exact locations of OSPs will be determined during the detailed design phase post-consent, taking account of ground conditions and the most efficient cable routeing design. The OSPs would not be permanently manned but once functional would be subject to periodic O&M visits by staff via boat or helicopter.

100 The OSP topside unit is prefabricated in the form of a multi-level structure that is lowered and mounted on a foundation. The foundation options for OSPs are described in Sections 1.8.3, 1.8.4 and 1.8.5. Like WTGs, the OSPs may have diesel generators for commissioning and O&M activities such as crane operation, lighting and ventilation.

101 OSPs are generally installed in two phases, the first phase will be to install the foundation for the structure using an installation vessel as described in Sections 1.8.1 to 1.8.5. Secondly, an installation vessel (same or different from the one installing the foundation) will be used to lift the topside from a transport barge/ vessel onto the pre-installed foundation structure. The design envelope for the OSP is described in Table 18. The vessel requirements for this process are also described in Section 1.7.1.

102 An example of an OSP is illustrated in Figure 10 and the design envelope for OSPs is described in Table 18.

Figure 10: Example of an OSP.

Table 18: Design envelope for OSPs.

PARAMETER	DESIGN ENVELOPE
Number of OSPs	2
Topside dimension	Plan area: 4,000 m^2 Maximum length: 80 m
Topside height above LAT (excluding stowed crane, helideck and mast) (m)	65
Topside height above LAT (including stowed crane, helideck and mast)	85
Maximum unstowed crane height above LAT (m)	115

PARAMETER	DESIGN ENVELOPE
Maximum HVAC system voltage (primary) (kV)	400
Maximum HVAC system voltage (secondary) (kV)	132

1.8.8 Meteorological mast

103 Offshore meteorological masts (met masts) are used to collect data on meteorological variables such as wind speed, wind direction and air temperature. This data is then used to refine the design parameters post-consent and optimise performance during operation.

104 The met mast may be located within the ‘other offshore wind farm infrastructure’ zone (Figure 1), to the west of the array area, or within the array area itself. The met mast unit may be prefabricated in the form of a tower and will be mounted on a monopile foundation (see paragraph 62 *et seq.*).

105 The maximum height of the met mast will be aligned with the maximum hub height of the WTGs. The met mast will typically feature anemometers, wind vanes and other meteorological equipment at a minimum of three different measurement heights. Similar to WTGs and OSPs, met masts are typically installed in two phases: foundation and mast topside.

106 Alternatively, floating LiDAR buoys may be deployed, which are considered to be within the overall design envelope identified for the met mast. The maximum design parameters for floating LiDAR buoys are described within Table 19 below.

Table 19: Design envelope for floating LiDAR.

PARAMETER	DESIGN ENVELOPE
Maximum number of LiDAR buoys	3
Total seabed area affected (m^2)	18

1.8.9 Permanent vessel moorings

107 PVMs usually consist of a steel or plastic floating buoy, secured to the seabed via one of several solutions including anchor or gravity-based techniques. Driven or drilled pile solutions are not considered for PVMs. The buoy includes mooring loops, shackles or hooks to provide a suitable and secure mooring point for wind farm vessels throughout the operational lifetime of the wind farm. The PVM buoy may be connected via subsea electrical cables (included in the design envelope for array cables in paragraph 110 *et seq.*) to a WTG or OSP and may be used for electric vessel charging.

108 The design envelope for PVMs is described in Table 20.

Table 20: Design envelope for PVMs.

PARAMETER	DESIGN ENVELOPE
Number of PVMs	3
Buoy diameter (m)	6
Total area of seabed disturbed by anchor installation (m^2)	10,080

1.8.10 Subsea cables

109 Cables are required to carry the electrical current generated by the WTGs to the onshore substation and National Grid connection via export cables.

Array cables

110 Cables carrying the electrical current generated by WTGs will link WTGs, PVMs and the met mast together and to an OSP (if OSPs are required). A small number of turbines are typically grouped together on a cable ‘string’ that connects those turbines to an OSP and the wind farm array will contain several of these strings.

111 The array cables will consist of a number of conductor cores, usually made from copper or aluminium. These will be surrounded by layers of insulating material as well as material to armour the cable from external damage and to keep the cable watertight.

112 Preparatory works will be carried out prior to cable installation (see Section 1.6). The cables will be buried below the seabed wherever possible, with a target burial depth defined post-consent in a Cable Burial Risk Assessment (CBRA) taking account of the ground conditions and other factors.

113 Possible installation methods for array cables include:

- Simultaneous lay and burial via ploughing, cutting or jetting;
- Post-lay burial via cutting, jetting, ploughing, MFE or dredging (TSHD, backhoe dredging or water injection dredging); and
- Installation following pre-installation ploughing, cutting or trenching.

114 It is also possible that ducts are laid and cables subsequently installed.

115 The design envelope for array cables is described in Table 21.

Table 21: Design envelope for array cables.

PARAMETER	DESIGN ENVELOPE
Cable parameters	
Maximum system voltage (kV)	132
External cable diameter (mm)	280
Total length of array cables (km)	124 (of which 116 will be installed on the seabed)
Seabed preparation	
Indicative length of array cable route requiring sandwave clearance (%)	69 (80km)

PARAMETER	DESIGN ENVELOPE
Indicative width of sandwave clearance disturbance corridor (m)	70
Indicative depth of sandwave clearance dredging (m)	5
Total area of seabed disturbed by sandwave clearance (m^2)	5,600,000
Total volume of sediment disturbed by sandwave clearance (m^3)	28,000,000
Maximum volume of material cleared from sandwaves requiring disposal (m^3)	7,600,000
Length of array cable route requiring boulder clearance (%)	100
Width of boulder clearance tool (m)	24
Total area of seabed disturbed by boulder clearance (m^2)	2,786,000
Cable installation	
Maximum burial depth (m)	4
Minimum burial depth (m)	0 (see cable protection requirements in paragraph 123 *et seq.*)
Maximum trench width (m)	6
Maximum installation tool seabed disturbance width (jetting) (m)	18
Total area of seabed disturbed by cable installation (m^2)	2,089,854

PARAMETER	DESIGN ENVELOPE
Total volume of sediment disturbed by cable installation (assuming a V-shaped trench in which 50% of sediment is fluidized and the remaining 50% re-suspended in the water column) (m^3)	2,089,854

Offshore export cables

116 Offshore export cables will be required to transmit the electricity generated by the WTGs to shore. Cables may connect via the OSPs (if required, or be connected directly to a string of WTGs.

117 The offshore export cables are typically larger in diameter than the array cables as they contain larger cores to transmit greater power. Like the array cables, the offshore export cables will consist of a number of cores, usually made from copper or aluminium, surrounded by layers of insulation material and armour to protect the cable from external damage.

118 Preparatory works, including sandwave clearance (Section 1.6) will be carried out prior to cable installation. As with the array cables, it is the preference to bury the cables subject to a CBRA. Installation will likely take place via one or a combination of methodologies described above in paragraph 113. The design envelope for the offshore export cables is described in Table 22. It is also possible that ducts are laid and cables subsequently installed.

119 The seabed may require preparation in the areas where the export cable installation vessel is likely to rest on the seabed, for instance in shallow waters closer to shore. This would include the levelling of seabed features and the removal of boulders. Each circuit would require up to 4 laydown areas (hence 8 total) as described in Table 22 below.

GyM interlink cable

120 A single interlink cable may be installed to connect one of the AyM WTGs or an AyM OSP to the western GyM OSP, to be installed within the AyM array and the GyM interlink zone identified in Figure 1. The parameters of the cable would be within the parameters identified below in Table 22.

121 The cable will be bi-directional and will be held in open standby as a contingency measure should the AyM export cables go offline. In this event, the cable will be able to continue to export a limited proportion of power via the GyM transmission network (only if the GyM transmission network has spare capacity during times of low generation). Additionally, when the interlink is in operation, power from GyM can be exported to AyM to provide safety and integrity functions to the AyM WTGs. However, it should be noted that the existing GyM transmission network is not sufficient to allow full export from AyM and is therefore a short-term contingency measure only, hence the requirement for a new export system bespoke to AyM.

122 Where the interlink cable approaches the GyM OSP, existing rock protection will need to be manipulated to enable the cable to be safely installed. This will involve manipulating a maximum of 100 m^3 of existing rock protection around the GyM OSP using divers, Remotely Operated Vehicle (ROV) or a remote arm from a surface vessel.

Table 22: Design envelope for offshore export cables.

PARAMETER	DESIGN ENVELOPE
Cable parameters	
Maximum system voltage (kV)	400
External cable diameter (mm)	310
Number of export cable circuits	2
Total length of export cables (km)	79.4 (including up to 10 km for the GyM interlink cable)

PARAMETER	DESIGN ENVELOPE
Seabed preparation	
Indicative length of export cable route requiring sandwave clearance (km)	63
Indicative width of sandwave clearance disturbance corridor (m)	70
Indicative depth of sandwave clearance dredging (m)	5
Total area of seabed disturbed by sandwave clearance (m^2)	4,440,000
Total volume of sediment disturbed by sandwave clearance (m^3)	22,000,000
Maximum volume of material cleared from sandwaves requiring disposal (m^3)	6,281,000
Length of export cable route requiring boulder clearance (%)	100
Width of boulder clearance tool (m)	24
Total area of seabed disturbed by boulder clearance (m^2)	1,906,000
Maximum area of seabed disturbed by export cable installation vessel laydown areas (m^2)	57,600
Maximum volume of sediment disturbed by export cable installation vessel laydown areas (m^3)	57,600
Cable installation	

PARAMETER	DESIGN ENVELOPE
Indicative maximum burial depth (m)	4
Minimum burial depth (m)	0 (see cable protection requirements in Section 123 *et seq.*)
Maximum trench width (m)	6
Maximum installation tool seabed disturbance width (jetting) (m)	18
Total area of seabed disturbed by cable installation (m^2)	1,430,000
Total volume of sediment disturbed by cable installation (assuming a V-shaped trench in which 50% of sediment is fluidized and the remaining 50% re-suspended in the water column) (m^3)	1,429,560

Cable protection

123 In some cases, where burial cannot be applied, or where the minimum cable burial depth cannot be achieved, it is necessary to use alternative methods such as rock placement, concrete mattresses or other solutions such as Cable Protection Systems (CPS), flow dissipation devices, bagged solutions or protective aprons to protect the cable from external damage. It should be stressed that cable burial is the preferred method of installation, and additional cable protection will only be used as a contingency where cable burial is not appropriate or achievable.

Rock placement

124 Rocks of different grades or sizes are placed, via a fall pipe vessel, over the cable. Typically, smaller rocks are placed over the cable as a covering layer, topped with an armouring layer of larger rocks. The rock grading has a mean rock size of 90-125 mm, up to a maximum of 250 mm. Rock protection generally forms a trapezium shape over the cable, with a slope either side, designed to provide protection from both direct anchor strikes and anchor dragging.

Concrete mattresses

125 Concrete mattresses are formed by interweaving a number of small concrete blocks with rope and wire to provide a flexible protective mattress. They are lowered to the seabed on a frame and, once positioning is confirmed, released over the length of cable requiring protection. Mattresses provide protection from direct anchor strikes but rock protection provides better protection from anchor drag.

Flow dissipation devices

126 Flow dissipation devices such as frond mattresses, are suitable for use in soft, mobile sediment environments. They consist of a mattress of buoyant fronds that create a drag barrier that significantly reduces current velocity within the fronds, acting to entrain sediments to build a protective layer out of naturally occurring suspended sediments that pass over the cable. Flow dissipation devices are designed to form protective, localised sand berms and are suited to addressing cable trench stability and scour related issues. To protect cables, the flow dissipation device can be either fixed to the cable or laid over it in the form of a mattress.

Rock bags

127 Rock bags consist of various sized rocks constrained within a wire or rope net. Alternatively, geotextile bags can be used, filled with sand. They can be placed by a crane to ensure placement in the exact required location. Similar to flow dissipation devices, rock bags are more suited for addressing cable trench stability and scour related issues.

Design envelope for cable protection

128 The design envelope for cable protection is described in Table 23.

Table 23: Design envelope for cable protection.

PARAMETER	DESIGN ENVELOPE	
	ARRAY CABLES	EXPORT CABLES
Length of cable requiring cable protection (including cable ends protection) (%)	20 (32 km)	20 (16 km)
Width of cable protection on seabed (m)	6	15.2
Height of cable protection berm (m)	1	1.4
Total area of seabed covered by cable protection (m^2)	192,124	242,853
Total volume of cable protection required (m^3)	112,072	218,741

Cable crossings

129 It is necessary to cross existing cables in the area to achieve connection from the array to the landfall. Cable crossings are subject to crossing agreements post-consent with the owners of those existing assets, and are necessary to provide protection to both assets, and to ensure a minimum separation so that cables do not overheat.

130 Cable crossings usually consist of a layer of protection over the existing asset (the separation layer) over which the AyM cables would be installed. A secondary layer would then be installed over the AyM cable for protection. Cable crossings may utilise rock protection or concrete mattresses (as described in paragraphs 123 to 128) or bridging typically of steel or concrete construction.

131 The design envelope for cable crossings is described in Table 24. Cable crossings will only be required for the offshore export cables, not the array cables. One cable crossing will be required within the GyM interlink zone for the interlink cable to cross a single GyM array cable. The total number of cable crossings required is 15, however, the design envelope includes a contingency for up to 19 should future developments need to be crossed. This scenario is not anticipated to occur, but the design envelope includes sufficient contingency should this be necessary.

Table 24: Design envelope for cable crossings.

PARAMETER	DESIGN ENVELOPE
Number of offshore export cables	2 (+1 interlink cable to GyM)
Number of crossings per export cable circuit	7
Cables to be crossed	Eirgrid (1 x HVDC pair) GyM (4 x HVAC) North Hoyle (2 x HVAC) GyM array cable (in the GyM interlink zone)
Total number of crossings required	15 (up to 19 including contingency)
Indicative length of crossings (m)	Eirgrid: 300 GyM: 500 (likely managed as a single crossing) North Hoyle: 325 (managed as a single crossing) GyM array cable in GyM interlink zone: 300
Total length of cable crossings (m)	2,550
Width of crossing (m)	15.2

PARAMETER	DESIGN ENVELOPE
Height of rock berm (m)	1.4
Cross sectional area of trapezoid (m^2)	13.7
Total area of seabed covered by cable crossings (m^2)	39,500
Total volume of cable protection required (m^3)	35,700

Cable jointing

132 Cable installation vessels are limited in the length of cable they can transport and install in a single loadout. Where lengths of offshore cable must be jointed to one another, it is not possible to bury the joint using conventional cable burial tools such as ploughs. Therefore, it may be necessary to excavate a pit to accommodate the joint, which is then backfilled to ensure the joint's protection. If it is not practical to bury the joint, then it may be covered with remedial cable protection. Given the short length of the AyM offshore ECC, it may be possible to install each export cable in a single length, however, it is assumed that each cable circuit will require up to one joint each. Each export cable circuit will require up to one joint, giving a maximum requirement of two cable joints for the offshore export cables. It is assumed that the seabed footprint for cable jointing is within the design envelope for seabed preparation and cable installation described in Table 22.

1.8.11 Aids to navigation, colour, lighting and marking

133 The wind farm will be designed and constructed to satisfy the requirements of the CAA, Maritime and Coastguard Agency (MCA) and Trinity House Lighthouse Service (THLS) in respect of aids to navigation, lighting and marking. Table 25 below describes the aviation and navigation lighting requirements for AyM structures.

134 All fixed bottom structures will have low level lighting directed onto Identification (ID) marker boards.

135 Further information on aids to navigation, marking and lighting can be found in Volume 2: Chapter 9: Shipping and Navigation (application ref: 6.2.9) and Volume 2, Chapter 13: Aviation and Radar (application ref: 6.2.13). Post-consent, lighting and marking will be specifically developed within a Lighting and Marking Strategy.

136 The colour scheme for the blades, nacelles and towers is generally light grey, whilst foundation steelwork is generally traffic light yellow from Highest Astronomical Tide (HAT) up to the aids to navigation or a height as directed by THLS. Automatic Identification System (AIS) and infrared beacons may be considered if appropriate.

Table 25: Design envelope for lighting requirements.

PARAMETER	DESIGN ENVELOPE		
	WTGS	OSP	MET MAST
Aviation lighting intensity (cd)	2000 (Dimmable to 200 when visibility is >5 km at night)	N/A	2000 (Dimmable to 200 when visibility is >5 km at night)
Navigation lighting (nominal range (nm))	Significant Peripheral Structure (SPS): 5 Intermediate Peripheral Structure (IPS): 2	N/A	10
Heli-hoist lighting	Low intensity green light (200 cd) at the heli-hoist platform. Lighting will only be activated when a structure is being prepared for helicopter approach.		N/A

PARAMETER	DESIGN ENVELOPE		
	WTGS	OSP	MET MAST
ID marker board lighting	Typically low level baffled (5 – 10 cd/m^2) lighting directed towards the ID marker board. Located on the foundation body or Main Access Platform (MAP).		
Workplace lighting	Illumination levels for external areas will typically be 50 lux located at the foundation level of structures, providing illumination for the access ladder, resting platforms and MAP. Workplace lighting will only be infrequently activated during the O&M phase when a structure is manned for maintenance activities.		

1.8.12 Safety zones

137 During construction and decommissioning, it is assumed for the purposes of assessment that the Applicant will apply for 500 m safety zones around infrastructure that is under construction. Temporary safety zones of 50 m will be sought for incomplete structures such as installed monopiles without transition pieces, or where construction works are completed but commissioning has yet to be completed.

138 During the O&M phase, the applicant may apply for temporary 500 m safety zones around infrastructure that is undergoing major maintenance (for example a WTG blade replacement).

139 Outside of construction, decommissioning and major maintenance works, the applicant does not intend to apply for permanent safety zones around operational infrastructure.

1.9 Landfall

Overview

140 The landfall denotes the location where the offshore export cables are brought ashore and jointed to the onshore export cables in TJBs. There is a clear overlap in the offshore and onshore study area at the intertidal area of the landfall and therefore this Section provides a brief description of what may be considered 'onshore' works for completeness. Full details of the onshore project description are provided in Volume 3, Chapter 1: Onshore Project Description (application ref: 6.3.1).

141 The offshore export cables will make landfall east of Rhyl, north of Rhyl Golf Club (Figure 1). The works at the landfall include:

- Construction of the landfall compound;
- Horizontal Directional Drilling (HDD) works (or other suitable alternative trenchless techniques such as micro-boring) including temporary construction of HDD exit pits in the intertidal or shallow subtidal, with these exit pits potentially requiring the construction of cofferdams;
- Intertidal trenching;
- Construction of TJBs;
- Installation of offshore export cables (cable pulling);
- Installation of and jointing to onshore export cables;
- Backfilling and re-instatement works.

142 The offshore export cables are connected to the onshore export cables in TJBs, located onshore, south of the North Coast railway line. TJBs are pits in which the jointing between offshore and onshore export cables takes place, with one TJB required per cable circuit. They are constructed to ensure that the jointing can take place in a clean, dry environment, protecting the joints once completed. Once the joint is completed the TJBs are covered and the land above reinstated. The Applicant has committed to no above-ground works within Rhyl Golf Club – instead, cables will be installed underneath the club via HDD (or other trenchless technique) with no requirement for intrusive works. TJBs will not require any planned access during the O&M phase, however, smaller link boxes that do require access via manholes may be necessary.

143 The techniques used to carry out the landfall works at the intertidal area broadly fall into two categories: trenchless techniques (such as HDD, micro-tunnelling or auger boring), and open-cut installation (such as trenching). It may be possible to carry out trenchless techniques beyond the intertidal area and install the rest of the cable using an offshore installation spread. Jack-up barges may be required in the shallow subtidal, the footprints of which are within the overall footprint of disturbance within the cable corridor. The technical feasibility of this approach will require confirmation via intrusive geophysical and geotechnical survey. However, it may also be the case that this is not possible or preferred (due to ground conditions, cable design, or other factors), in which case open cut techniques would be required; or a combination of these two methodologies. It should be noted that open cut installation has been excluded for installation through the sea wall, such that the project will not interfere with either existing or planned sea defence works in the area.

144 The offshore cables will be brought ashore to connect to the onshore export cables within the TJB compound onshore south of the North Coast railway line. The design envelope for the TJB works is described in Table 26, with the trenchless and open-cut options for cable installation used to bring the offshore cables ashore described in the subsequent paragraphs.

Table 26: Design envelope for the TJB.

PARAMETER	DESIGN ENVELOPE
Number of export cable circuits	2
Number of TJBs	2
TJB dimensions (m)	20 x 5
Land take for TJBs Temporary Construction Compound (TCC) during construction (m^2)	20,000
Permanent land take for TJBs during O&M (m^2)	1,200

Trenchless techniques

145 HDD is the established solution for trenchless installation, however it should be noted that other technologies exist, such as micro-boring. HDD involves drilling a long borehole underground using a drilling rig located within a compound. This technique avoids interaction with surface features and is used to install ducts through which cables can be pulled.

146 As the drill is carried out between a start and end point, entry and exit pits must be excavated at either end of the borehole: one in the landfall compound and one on the offshore side. HDDs can vary in length depending on the ground conditions but can typically achieve up to 1,500 m in length.

147 The process uses a drilling head controlled from the rig to drill a pilot hole along a predetermined profile to the exit point. The pilot hole is then widened using larger drilling heads until the hole is wide enough to accommodate the cable ducts. Drilling fluid (typically containing bentonite) is pumped to the drilling head to stabilise the borehole, recover drill cuttings and ensure the borehole does not collapse.

148 The HDD (or other trenchless technique) exit pits may be located within the intertidal zone or the shallow subtidal. Exit pits will be excavated or dredged to the required depth, and side-cast material for backfilling will be stored adjacent to the exit pit. Depending on the final methodology and location, it may be required to install cofferdams temporarily to reduce water intrusion. Cofferdams consist of sheets of metal and may be installed by vibropiling or impact piling.

149 Once the drilling operation has taken place, the ducts are pulled through the drilled holes. The ducts are either jointed off-site, then sealed and floated to site by tugs, or will be jointed locally and pulled over the beach on rollers. The ducts are then pulled back through the boreholes either by the HDD rig itself, or by separate winches.

150 Once the ducts are in place, the exit pits will likely be temporarily backfilled until ready for cable pull-through. The ducts will then need to be re-exposed to pull in the cable. Once installation is complete, the exit pits will be backfilled using available side-cast material and the remainder left to naturally backfill.

151 Wherever possible, beach access will be maintained, however where open-cut works are necessary (for example in the case of an intertidal exit pit), parts of the beach may need to be temporarily closed to the public. The design envelope for trenchless techniques is described in Table 27.

Table 27: Design envelope for trenchless techniques.

PARAMETER	DESIGN ENVELOPE
Number of cable circuits	2
Number of cable ducts	3 (one per circuit plus one contingency)
Exit pit location	Intertidal or shallow subtidal, between MHWS and 1,000 m seaward of MHWS
Number of exit pits required	3
Exit pit dimensions (m)	10 x 75

PARAMETER	DESIGN ENVELOPE
Exit pit depth (m)	2.5
Total volume of sediment excavated from exit pit (m^3)	5,625
Hammer energy for cofferdam sheet piling (kJ)	300
Volume of drilling fluid that could be released from HDD (m^3)	18,117

Open-cut installation

152 Open-cut installation could be carried out using one or more methods described for the offshore export cables in Section 116 *et seq.* (with the exception of dredging and MFE, noting that a backhoe may also be used in the intertidal). In the event that the HDD exit pits are located in the intertidal zone, open-cut installation will be required seaward of that location. As with offshore export cable installation, cables may be installed via simultaneous lay and burial, or a trench may be opened and the cable subsequently installed within, after it has been pulled across the beach. Cable installation tools are usually pulled across the beach on skids or tracks.

153 The design envelope for open-cut installation is included within the design envelope for the offshore export cables described in Table 22. Cable protection requirements are similarly included within the envelope for the offshore export cables described within Table 23. However, if required in the intertidal, cable protection will be buried and will not consist of loose rock or gravel. In the shallow subtidal (out to 1,600 m seaward of MHWS), cable protection will similarly not consist of loose rock or gravel.

1.10 Operations and maintenance

154 The indicative project programme states that the project will be fully constructed and operational by 2030, and the operational lifetime of the project is anticipated to be approximately 25 years. The overall O&M strategy will be finalised once the technical specification is known, including WTG model and final project layout.

155 Maintenance activities fall into two categories: preventative and corrective. Preventative maintenance is carried out according to regular scheduled services, whereas corrective maintenance covers unexpected repairs, component replacement, retrofit campaigns and breakdowns. In recent years, the offshore wind industry has developed a better understanding of preventative maintenance for operational wind farms. For cables in particular, AyM will be designed to require no routine cable maintenance or re-burial as these events are disruptive and costly, however, the option is retained for flexibility in the event of unforeseen circumstances. Options for cable maintenance work include cable re-burial via jetting, or placement of cable protection. The design envelope for these O&M works is described in Table 28.

Table 28: Design envelope for O&M activities.

PARAMETER	DESIGN ENVELOPE	
	LARGER WTGS	SMALLER WTGS
O&M strategy		
Project lifetime (years)	25	25
Surface infrastructure (WTGs, OSPs and met mast)		
Number of major component replacements requiring JUVs over project lifetime	135	180
Maximum seabed disturbance from JUV footprints (m^2) per year	5,940	7,920

PARAMETER	DESIGN ENVELOPE	
	LARGER WTGS	SMALLER WTGS
Array cables		
Length of cable requiring remedial works (km)	5	5
Number of array cable repairs over project lifetime	5	5
Seabed disturbance per array cable repair event (m^2)	6,000	6,000
Total seabed disturbance for array cables over project lifetime (m^2)	30,000	30,000
Offshore export cables		
Length of cable requiring remedial works (km)	5	5
Number of offshore export cable repairs over project lifetime	4	4
Seabed disturbance per offshore export cable repair event (m^2)	6,000	6,000
Total seabed disturbance for offshore export cables over project lifetime (m^2)	24,000	24,000

156 The general operation and maintenance strategy may rely on an onshore (harbour based) operation and maintenance base, CTVs, Service Operation Vessels (SOVs), offshore accommodation vessels, supply vessels, cable and remedial protection vessels and helicopters for the operation and maintenance services that will be performed at AyM. The final operational and maintenance strategy chosen may be a combination of the above solutions.

157 The design envelope for the operation and maintenance vessels are presented in Table 29. Helicopters are also considered for crew transfer during unplanned maintenance via heli-hoist winching directly onto WTGs and landing on OSP helidecks. Up to 120 or 200 helicopter return trips per year may be required in the larger and smaller WTG scenarios, respectively.

Table 29: O&M vessel requirements.

VESSELS	DESIGN ENVELOPE	
	PEAK VESSELS	ANNUAL ROUND TRIPS
JUVs	2	6
SOVs	2	52
CTVs	6	1,095
Lift vessels	2	6
Cable maintenance	2	1
Auxiliary vessels	8	48

1.11 Decommissioning

158 For the purposes of the MDS for EIA, at the end of the operational lifetime of AyM, it is assumed that all infrastructure will be completely removed. The decommissioning sequence will generally be in the reverse of construction (reverse lay) and is expected to involve similar types and numbers of vessels and equipment and take place over a three-year period.

159 Closer to the time of decommissioning, it may be decided that removal would lead to a greater environmental impact than leaving some components *in situ*, in which case certain components may be cut off at or below seabed level (e.g. in the case of piled foundations) or left *in situ* (e.g. in the case of subsea cables and rock protection).

160 A decommissioning plan will be required to be submitted pre-construction, conditional as part of the suite of post-consent documentation for AyM. Under Section 105 of the Energy Act 2004, a decommissioning programme is required to be submitted to the SoS prior to commencement of construction.

1.12 References

Department for Energy and Climate Change (DECC) (2011a). Overarching National Policy Statement for Energy (EN-1).

Department for Energy and Climate Change (DECC) 2011b). National Policy Statement for Renewable Energy Infrastructure (EN-3).

Department for Energy and Climate Change (DECC) 2011c). National Policy Statement for Electricity Networks Infrastructure (EN-3).

The Planning Inspectorate (PINS) (2018). Advice Note Nine: Rochdale Envelope.

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