CHAPTER 5: PROJECT DESCRIPTION

INTRODUCTION

5.1. This chapter provides a full description of the physical components of the Seagreen Project. This includes Project Alpha, Project Bravo and the Transmission Asset Project. The chapter describes the necessary site preparation and construction stages, the operation and maintenance (O&M) and the decommissioning of the Seagreen Project.

5.2. This section introduces the elements of the Seagreen Project and provides an explanation of the flexibility required in defining the project infrastructure for assessment. Section 'Site Description and Characteristics' then provides a brief description of the Seagreen Project site and its physical characteristics.

5.3. The infrastructure options for Project Alpha and Project Bravo are described in more detail in Section 'Offshore Wind Farm Infrastructure, Meteorological Masts and Wave Buoys', whilst construction and installation are described in Section 'Offshore Wind Farm Construction'. The infrastructure options for the Transmission Asset Project are separately described in Section 'Transmission Asset Infrastructure' and their construction and installation is described in Section 'Transmission Asset Construction'. The commissioning of both offshore wind farm (OWF) projects and the Transmission Asset Project is described in Section 'Offshore Wind Farms and Transmission Asset Commissioning' and the subsequent O&M of the assets is described in Section 'Offshore Wind Farms and Transmission Asset O&M'.

5.4. The term of the site lease with The Crown Estate will be 50 years. The operational lifetime of Project Alpha and Project Bravo is expected to be 25 years. At the end of this period the OWFs could be decommissioned or repowered. If the OWFs are repowered during the period of the site lease this would be subject to a separate consent process. Repowering and decommissioning are briefly described in the later Sections of this chapter respectively.

5.5. The content of this chapter forms the basis for the assessment of impacts presented in the later technical chapters of the ES. All figures referred to in this chapter can be found in ES Volume II: Figures. All appendices referred to in this chapter can be found in ES Volume III: Appendices.

Outline of Project Components

5.6. The Seagreen Project considered in this ES will comprise the following main components, an illustration of which is given in Plate 5.1.

5.7. Two OWFs, Project Alpha and Project Bravo, which include the following:

- WTGs comprising supporting tower structures, nacelles and rotors with associated access arrangements;
- WTG foundations and substructures;
- subsea array cables linking the WTGs to the OSPs;
- scour protection and cable protection (where appropriate);
- meteorological masts; and
- wave buoys.

5.8. The Transmission Asset Project infrastructure, which includes:

- OSPs;
- HV (circa 220 kilovolts (kV) or above) subsea power cables providing inter connection between OSPs;
- HV export cables up to MHWS;
- cable landfall and connection to onshore infrastructure up to MHWS; and
- scour protection and cable protection (where appropriate).

5.9. Certain of the Transmission Asset Project infrastructure (OSPs, HV export cables, cable landfall and connection to onshore infrastructure) will ultimately be owned and operated by a separate entity under the Offshore Transmission regime. The OFTO will be appointed through tender, post construction of the Transmission Asset Project.

5.10. The general term OSP is used for the structure that houses the electrical equipment transforming the WTG electrical output from distribution (low) voltage up to transmission (high) voltage and convertor platforms that convert from HVAC power to HVDC power. An OSP may provide a combination of these functions. It should be noted that separate accommodation platforms will not be required. All accommodation requirements will be provided on the OSPs and addressed as part of the Transmission Asset Project infrastructure.

5.11. The separate Project Alpha and Project Bravo OWFs and the Transmission Asset Project will comprise the components set out in Table 5.1.

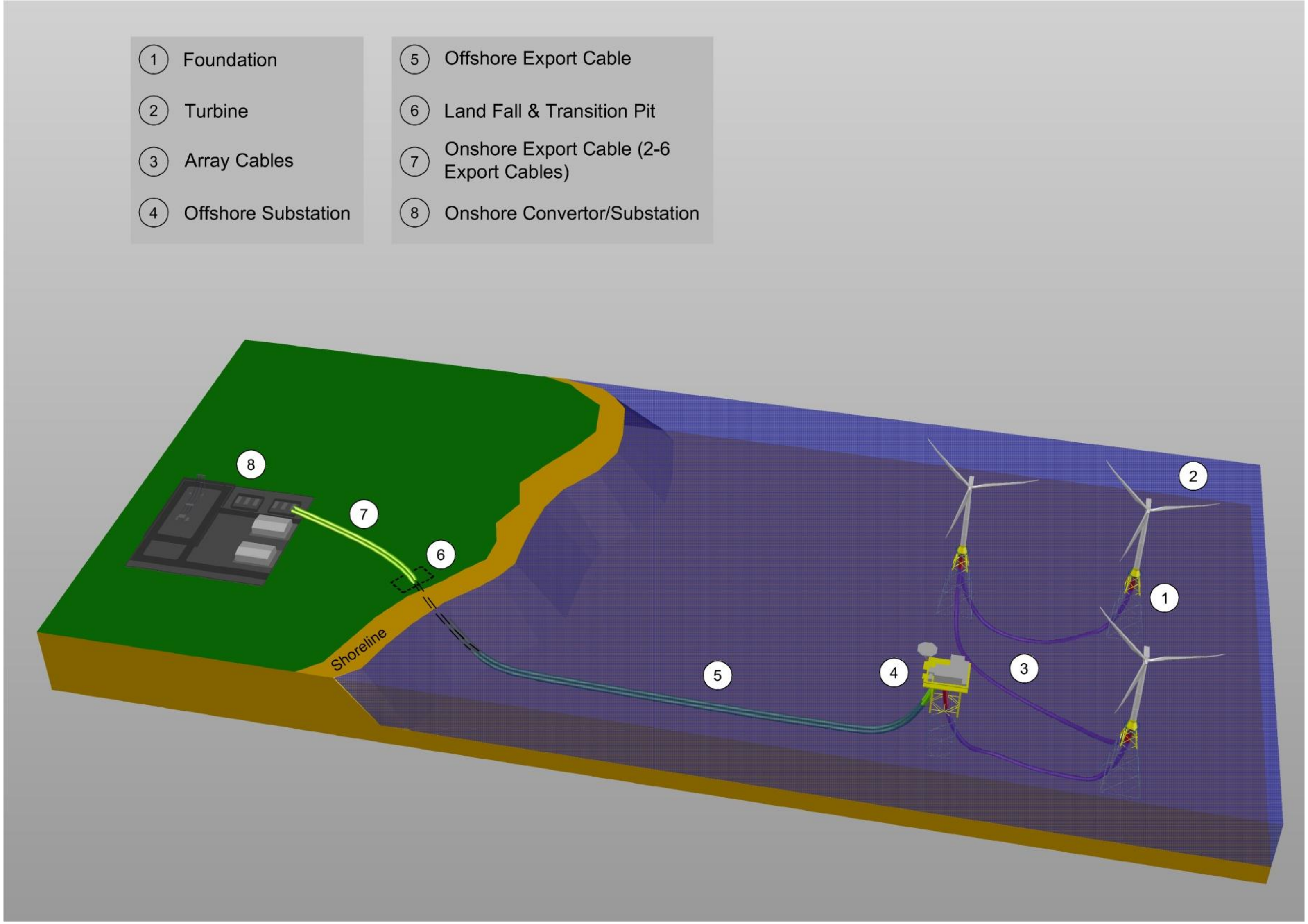
Table 5.1 Description of Project Alpha, Project Bravo and Transmission Asset components

Project Alpha	Project Bravo	Transmission Asset
Up to 75 WTGs and supporting structures with a maximum generating capacity of 525MW	Up to 75 WTGs and supporting structures with a maximum generating capacity of 525MW	Up to five OSPs and supporting structures
Array cables connecting WTG strings to OSPs	Array cables connecting WTG strings to OSPs	Transmission cables connecting OSPs and exporting power to the onshore transmission grid
Any necessary scour protection and cable protection	Any necessary scour protection and cable protection	Any necessary scour protection and cable protection
Up to three meteorological masts and up to three wave buoys	Up to three meteorological masts and up to three wave buoys	

5.12. The components of the Seagreen Project comprise the offshore elements of the full development proposed by Seagreen. The onshore elements, comprising the grid connection infrastructure from landfall, MLWS, at Carnoustie to the Tealing substation, are the subject of a separate ES and planning consent application under the Town and Country Planning (Scotland) Act 1997 (as amended). That infrastructure will be assessed separately as part of that process.

5.13. The terrestrial boundary for the Seagreen Project is delineated by the MHWS tidal limit. All the onshore works terminate at the MLWS tidal limit. This results in an overlap of study areas between the offshore and onshore assessments. This approach follows that adopted for previous Round 1 and Round 2 OWFs.

Plate 5.1 Illustration of the Seagreen Project Components



Note: Elements 6 – 8 relate to a separate planning application and are not part of the Seagreen Project in this ES. Not to Scale.

Rochdale Envelope Process

5.14. The strategy adopted by Seagreen to retain design flexibility is to adopt a 'Rochdale Envelope' approach. This is explained in Chapter 6: EIA Process of this ES, whilst the full range of likely development scenarios and construction options, comprising the Rochdale Envelope, are described in this chapter. An explanation of the process by which the parameter ranges defined in the Rochdale Envelope were determined is provided in Chapter 3: Site Selection and Alternatives in this ES. Chapter 3 also provides an explanation of the separation of the proposed development into the two OWFs, Project Alpha and Project Bravo.

5.15. For a number of the project components for both Project Alpha and Project Bravo, engineering decisions regarding preferred options and final design details have not yet been made. This includes decisions on the WTG array layouts, the WTG specification and supplier, foundation type and installation methodology, and the electrical design. Retaining flexibility in the selection of preferred design options is a vital mitigation in the management of project risks and enables significant procurement commitments to be made at a more appropriate time later in the process.

5.16. Flexibility is required in respect of the following:

- WTG location and separation within OWF arrays;
- type of WTGs and their mix, i.e. the potential to include more than one WTG type in the OWF;
- the design and location of OSPs;
- use of different foundation types within an OWF array;
- variation of detailed design for any of the identified foundation types;
- number and routing of subsea cables (except where constrained to the defined OWF sites or the ECR corridor); and
- the location of meteorological masts and wave buoys.

5.17. The parameters that affect WTG layouts, foundation choice and supporting structure design options include:

- wind resource assessment;
- water depth;
- seabed geology;
- archaeology and seabed obstructions;
- ornithological recommendations;
- stakeholder feedback; and
- proximity to the future STW OWFs.

Indicative OWF Array Layouts

5.18. Figures 5.1 and 5.2 show indicative layouts for the WTG options under consideration for achieving the maximum capacity. An indicative OSP and permanent meteorological mast locations are also shown. The minimum separation between adjacent WTGs will be five rotor diameters (5D), however future layouts developed during design optimisation may result in greater WTG separation distances. The layouts presented are purely illustrative and it should be noted that, as with other design parameters for which there is uncertainty, a realistic worst case layout has been assessed on a receptor by receptor basis within the impact assessments presented in technical chapters 7 – 21 of this ES. Complete flexibility is required to enable the WTG layout, OSP locations, meteorological mast locations and structural design to be optimised following consent and after detailed ground investigation has been undertaken. The final layout will be fixed following completion of the Preliminary Engineering Design work. This will then inform the array cable arrangement and the locations of the OSPs and transmission cables.

5.19. While flexibility is required on WTG layouts, in reality, the maximum WTG population of the OWF for any given WTG size(s) will be primarily driven by optimising the spacing and arrangement of WTGs, to gain maximum efficiency from the wind resource and by locating WTGs based on the impact of foundation feasibility studies (both engineering and commercial).

Defining the Detailed Design

5.20. Further design details will be determined during Front End Engineering Development (FEED) following further offshore geotechnical studies and detailed analysis of ground conditions to inform wind farm engineering design decisions. FEED will not proceed until the Seagreen Project has been consented.

5.21. Following consent and final detailed design, final build plans for Project Alpha, Project Bravo and the Transmission Asset Project will be provided to Marine Scotland. The purpose of this submission will be to:

- demonstrate compliance with any conditions attached to consents; and
- ensure that the final design remains within the parameters of the Rochdale Envelope considered by this ES.

5.22. The assessments presented within this ES consider all construction, operation and decommissioning activities associated with Project Alpha, Project Bravo and the Transmission Asset Project, described in this chapter.

SITE DESCRIPTION AND CHARACTERISTICS

Project Location and Capacity

5.23. The Project Alpha and Project Bravo sites are located approximately 27km and 38km offshore respectively from the nearest landfall on the Angus coastline. The location and boundary between the sites is shown in Figure 1.1. The total area within the Project Alpha site boundary is 197km^2. The total area within the Project Bravo site boundary is 194km^2. The STW OWF project Inch Cape lies approximately 9km west of Project Alpha and 12km west of Project Bravo. The STW OWF project Neart na Gaoithe lies approximately 27km south west of Project Alpha and 30km south west of Project Bravo.

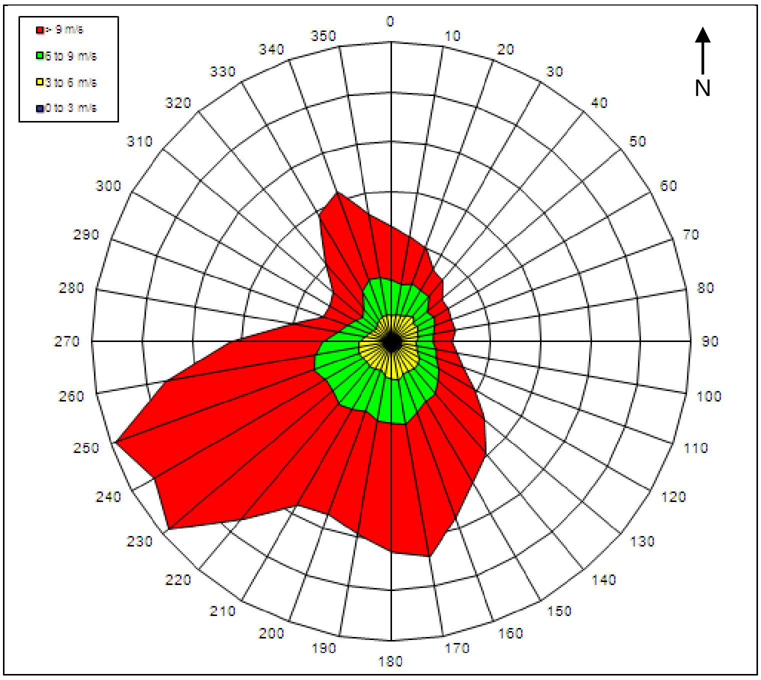
5.24. The maximum installed capacity for Project Alpha will be 525MW. The maximum installed capacity for Project Bravo will be 525MW. There will be a maximum number of 75 WTGs within each OWF.

5.25. The selected landfall for the export cable is at Carnoustie, a total distance of approximately 70km from the indicative OSP location within the Project Alpha site. The majority of the proposed ECR corridor is 1km in width (Figure 1.1). Adjacent to the western boundary of the Zone, however, it widens to approximately 4.5km to allow flexibility for the cable routing to the OSP location within the Project Alpha site, once that is determined. The total area of the ECR corridor is 97.9km^2.

Wind Resource

5.26. As there are currently no on-site wind data available, various modelled data sets have been consulted. These have been validated against meteorological mast data from other locations. It will be possible to refine this wind speed estimate once a significant period of on-site data becomes available. An approximation to the OWF sites wind rose, calculated from the modelled data is shown in Plate 5.2, which indicates a dominant wind direction from the south west quadrant.

Plate 5.2 Seagreen Project wind rose approximation based on modelled wind data (shown in degrees from north)



5.27. Seagreen has applied to Marine Scotland for consent to install a meteorological mast in late 2012 at a location 2km west of the Project Alpha site boundary and 11km west of the Project Bravo site boundary (Figure 5.1 and Figure 5.2). This will enable estimation of the wind resource available across the Seagreen Project area through direct measurement.

Metocean, Seabed and Ground Conditions

5.28. A full oceanographic survey of the Zone was undertaken over December 2010 to August 2011 (FugroGEOS, 2012; Intertek Metoc, 2012) to record wave, current and water level data with further wave data available from an extended wave buoy deployment and additional inshore wave measurements. Long term wind and wave model data for the area was also purchased from the UK Meteorological Office.

5.29. Full geophysical surveys of the Seagreen Project area were undertaken in summer 2010, for the Project Alpha and Project Bravo sites (GEMS, 2012a) and in summer 2011, for the ECR corridor (Osiris Projects, 2011). A preliminary geotechnical survey of the Seagreen Project areas was undertaken in summer 2011 (GEMS, 2012b).

5.30. The preliminary project design parameters used for assessment within this ES have utilised the data obtained in these investigations. A detailed description of the physical conditions of the Seagreen Project area is provided in Chapter 7: Physical Environment in this ES.

OFFSHORE WIND FARM INFRASTRUCTURE, METEOROLOGICAL MASTS AND WAVE BUOYS

5.31. The following sections describe the key elements of infrastructure within the OWFs, including the meteorological masts and wave buoys.

Wind Turbine Generators

5.32. This section provides a description of the WTG options considered for the Seagreen Project and included in the Rochdale Envelope for assessment, presented in Table 5.2. Conventional three bladed, horizontal axis WTGs will be used, comprising the following main components and illustrated in Plate 5.3:

- rotor – comprised of the blades, hub and spinner;
- nacelle - housing the electrical generator, the control electronics and the drive system; and
- structural support - includes the tower and rotor yaw mechanism which allows the rotor and nacelle to turn and face into the wind. Note that this does not include the foundations or supporting structure.

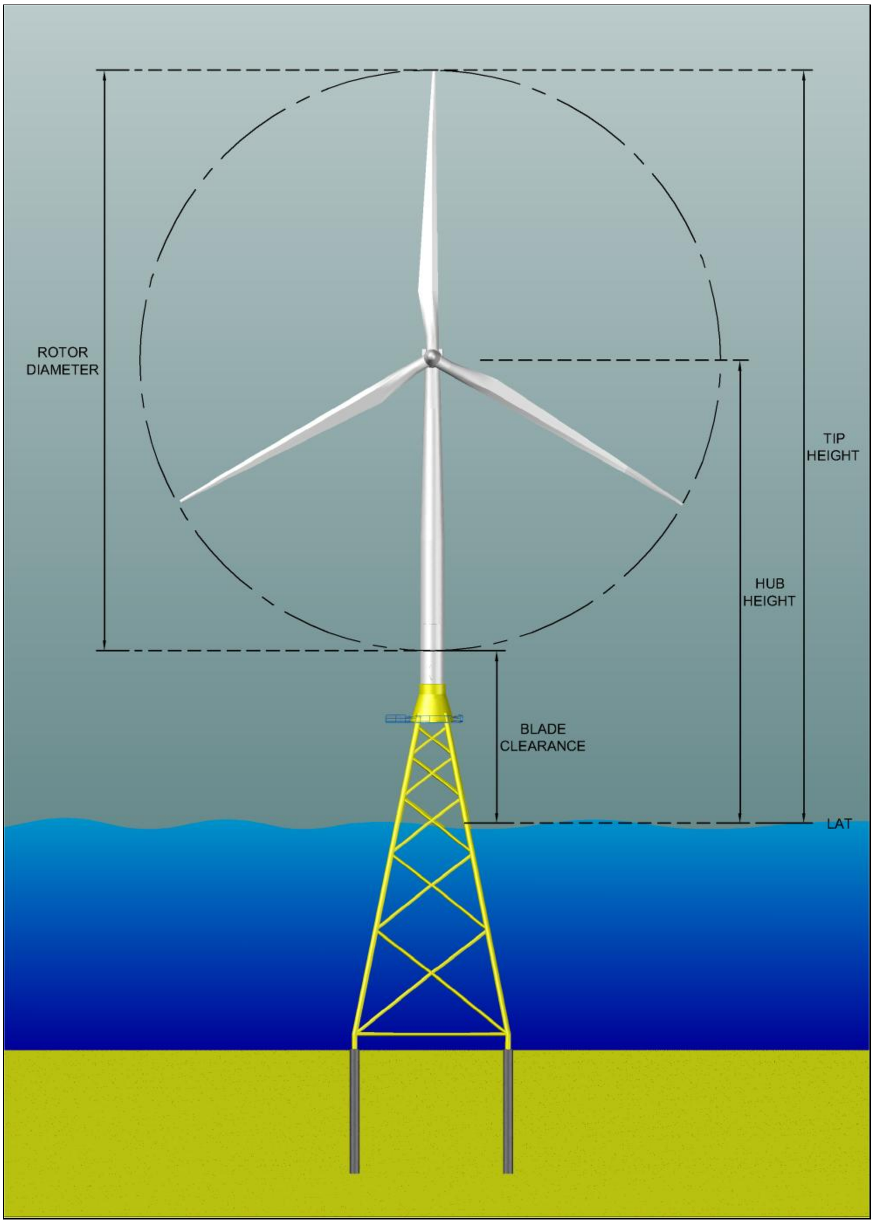
Table 5.2 WTG Parameters for Assessment

Parameter	Minimum	Maximum
Rotor diameter	122 m	167m
Blade chord	4.2m	5.4m
Blade clearance above water level (Lowest Astronomical Tide (LAT))	26.1m	42.7m
Hub height (LAT)	87.1m	126.2m
Blade tip height (LAT)	148.1m	209.7m
Nacelle Dimensions (Length x Breadth x Height)	15m x 4m x 4m	24m x 12m x 12m
Operating wind speed range (cut-in/ cut-out)	3 metres per second (m/ s)	35m/ s
Operating speed range	4 revolutions per minute (rpm)	14rpm
Rotor swept area	11,690 square metres (m^2)	21,904m^2
Minimum spacing between WTGs (5x rotor diameter)	610m	835m

5.33. WTG MW nameplate capacity is a function of the rotor swept area (determined by blade length) and internal generating components. WTGs within the parameters range will have different technical and dimensional characteristics but the Project Alpha site and the Project Bravo site will not exceed either 75 WTGs each or exceed a total output of 525MW each. The joint maximum number of WTGs will therefore be 150 and the joint maximum MW capacity will be 1,050MW.

5.34. To avoid excessive turbulent wake, no WTG will be positioned closer than 5D to any other WTG in any direction. For the WTGs within the Rochdale Envelope parameter range this corresponds to 610m to 835m separation.

Plate 5.3 Illustration of WTG dimensions



5.35. The WTG separation distance could be increased further to comply with WTG manufacturers' load calculations and consequent warranty requirements. The final array layout design will be determined through consideration of a number of factors including energy output, maintenance requirements, electrical infrastructure design requirements, and geotechnical and environmental constraints. No maximum WTG spacing is provided in Table 5.2 to allow the flexibility to optimise the final layout post consent.

5.36. In Table 5.2 the rotor diameter is based on two times the individual blade length plus the diameter of the rotor hub. The rotor hub height is determined from the blade length plus the blade clearance. The maximum and minimum rotor tip heights are based on the rotor diameter and the respective maximum or minimum blade clearance required above Lowest Astronomical Tide (LAT). These dimensions are illustrated in Plate 5.3.

5.37. The WTG operating wind speed will be in the range 3 metres per second (m/s) to 35m/s. Below the generator cut-in speed of 3m/s when the rotor turns, insufficient energy can be captured for operation. Above the cut-out speed of 35m/s the rotor is stopped to prevent damage to the WTG. The operating rotational speed between the cut-in and cut-out wind speeds is in the range 4 revolutions per minute (rpm) to 14rpm. The estimated monthly mean rotor speed, shown in Table 5.3, has been determined using available wind speed data (see Plate 5.2 Wind Resource, above) and manufacturers operational data.

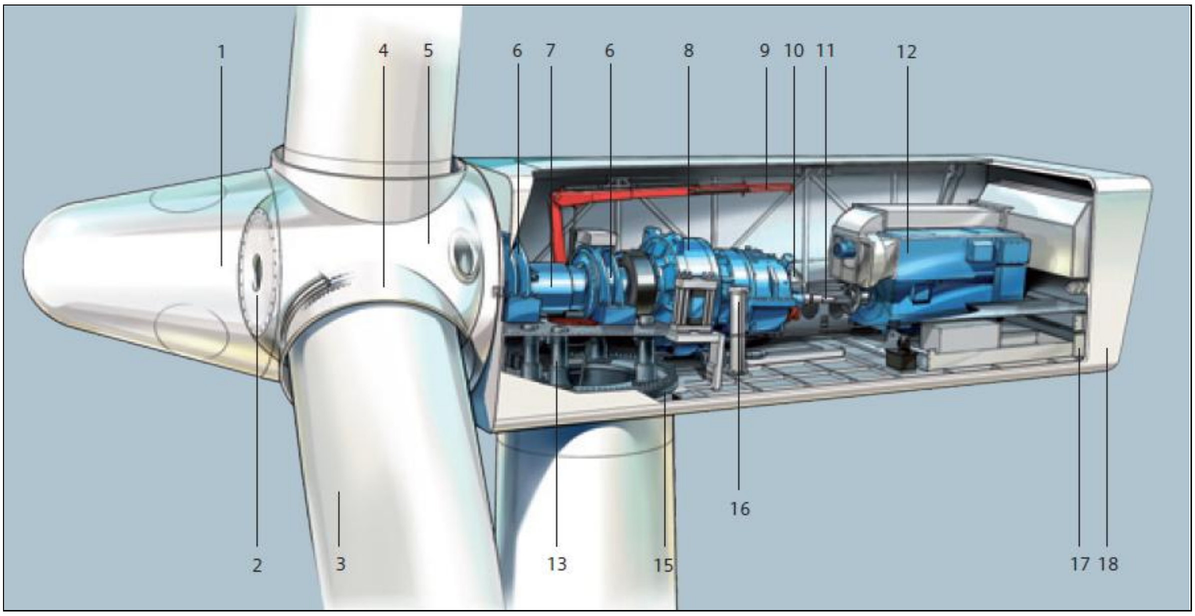
Table 5.3 Mean monthly WTG rotor speeds

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Speed (rpm)	11.2	10.9	10.8	10.5	10.2	10.3	10.1	10.0	10.7	11.0	11.1	10.9

5.38. The WTG nacelle will contain the power generation equipment, including the drive system, generator and brake. A WTG transformer converts the electrical power output generated to the desired OWF distribution voltage. The WTG monitoring and control system is also housed in the nacelle. The range of parameters in WTG nacelle dimensions within the Rochdale Envelope, are given in Table 5.2. The mass of the rotor, nacelle and blade combination is expected to be in the range of 223 - 505 tonnes. A cut away diagram of typical nacelle components is shown in Plate 5.4.

5.39. WTG and OSP access arrangements for O&M are described further in Section 'Offshore Wind Farms and Transmission Asset O&M'.

Plate 5.4 Illustration of WTG nacelle and rotor components



Source: Siemens

Notes:

1 Spinner
2 Spinner bracket
3 Blade
4 Pitch bearing
5 Rotor hub
6 Main bearing
7 Main shaft
8 Gearbox
9 Service crane
10 Brake disc
11 Coupling
12 Generator
13 Yaw gear
14 Tower
15 Yaw ring
16 Oil filter
17 Generator fan
18 Canopy

5.41. The nacelle is mounted on a yaw ring seated at the top of the WTG tower to enable the rotor to respond to changes in wind direction (Plate 5.4).

5.42. The WTG tower will be a tubular steel column. Typical tower dimensions are between 6m and 7m base diameter. The transition piece connects the WTG tower to the substructure. The transition piece can also house the WTG electrical and communication equipment. The transition piece also assists in achieving vertical alignment of the WTG structure through the adjustment possible in the grouted joint with the substructure. For jacket and Gravity Base Structure (GBS) designs (discussed later in this chapter) the transition piece is often integrated with the structure at the fabrication stage.

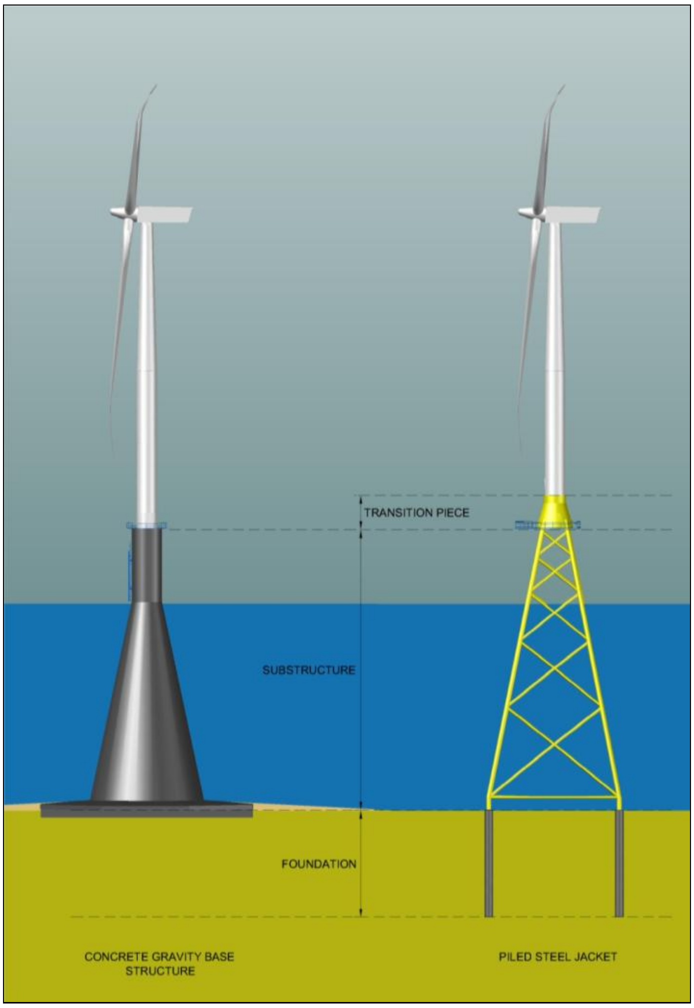
5.43. The rotor, nacelle and upper tower section will be painted the semi-matt pale grey colour RAL 7035. The lower tower section of each WTG, from 15m above Highest Astronomical Tide (HAT) to the level of HAT, will be painted the high visibility yellow colour RAL 1004. Further description of WTG marking and lighting requirements is provided in Section 'Offshore Wind Farms and Transmission Asset O&M'.

Substructures and Foundations

5.44. The substructure and foundation options described are appropriate for both Project Alpha and Project Bravo.

5.45. The WTGs, OSPs and meteorological masts (OSP and meteorological masts are discussed later in this chapter) are connected to their foundations by the substructure. The foundation secures the entire structure to the seabed (see Plate 5.5). Seagreen has undertaken preliminary assessments of the range of options available for each of these substructure and foundation components (Garrad Hassan, 2011). The installation of OWF structures is described in Section 'Offshore Wind Farm Construction'.

Plate 5.5 Illustration of substructure and foundation definitions



5.46. At this stage in the project the structures that will be installed in Project Alpha and Project Bravo can not be determined. The decision on the type of structures to be installed will be made post consent. There are three main substructure and foundation options defined within the Rochdale Envelope for supporting the WTG structures. These are:

- a four leg steel jacket with driven piles;
- a four leg steel jacket with suction piles; and
- a GBS.

5.47. Other substructure design variants may be considered, including a three leg steel jacket design and a tripod or quadropod design supporting a monopole, with driven or suction pile foundations. A GBS hybrid design consisting of a gravity base slab with a steel jacket attached may also be considered. The parameters associated with these design variants are contained within the Rochdale Envelope parameters described below for piled steel jackets and GBS.

5.48. Initial design of the substructure and foundation combinations has considered viability in respect of the WTG size to be supported; the suitability of ground conditions for the foundation; the wind and wave loading on the structure and the vibration characteristics of the WTG. Due to the variation in water depth across the Project Alpha and Project Bravo sites the substructure dimensions will be tailored to suit a specific depth range and a range of substructure heights will be installed across both OWF sites.

5.49. The foundation and associated substructure options that define the extent of the Rochdale Envelope parameters are summarised in Table 5.4. Maximum foundation dimensions for each option are given in Table 5.5, based on current understanding of the ground conditions at the sites. Further studies will be undertaken as part of the detailed design process to determine the final design selection. Installation of foundations and substructures is described in Section 'Offshore Wind Farm Construction'.

Table 5.4 Foundation Options Summary

	Foundation Type		
	Tubular piles	**Suction Piles**	**GBS**
Potential substructure	Jacket	Jacket	Integral to GBS
Potential topsides components	WTG OSP Meteorological mast	WTG OSP Meteorological mast	WTG OSP Meteorological mast
Primary materials	Steel	Steel	Concrete and steel
Brief description of foundation	Tubular steel piles on each leg of jacket driven into the seabed.	Upturned bucket style design on each leg of jacket sunk into the seabed using vacuum pumps.	Cast structure that sits on flat sea bed and relies on the weight of the structure and ballast for stability.

Table 5.5 Maximum Dimensions for Foundation Options

Foundation Type	Typical dimensions
Tubular pile	Max diameter 3m Max length 35m
Suction pile	Max diameter 14m Max penetration depth 23m
Gravity base (weak soils)	Max octagonal base plate width 72m Max cone diameter at base 35.4m Max height 78m Max ballast volume 21,890 cubic meters (m^3)
Gravity base (average soils)	Max octagonal base plate width 52m Max cone diameter at base 28.4m Max height 78m Max ballast volume 12,230m^3

Description of Jacket Substructures and Associated Foundations

Jacket Substructures

5.50. A jacket substructure is typically a lattice design comprising primary sections of steel tubes that are braced by secondary sections of smaller diameter steel tubes to form a strong, rigid frame. There are a wide range of potential geometries, including three or four leg designs and different leg angles. The jacket configuration investigated in the Seagreen engineering concept study (Garrad Hassan, 2011) was a four leg structure.

5.51. Jackets can be combined with different foundation concepts (see Table 5.4). For Project Alpha and Project Bravo, tubular piles, suction piles and GBS' are considered viable foundation options. Diagrams of these are shown in Plate 5.6. A pre-piled jacket is illustrated in more detail in Plate 5.7. This configuration offers the lowest jacket mass, where the piles are pre-installed using a piling template (see Section 'Offshore Wind Farm Construction'). Pre-piled jackets are designed with spigots at the bottom of the legs which engage with the piles and are subsequently grouted in place. The main saving is in the removal of pile sleeves from the jacket structure and simplification in the load path direct from the legs to the piles. To connect jackets to the piles the estimated volume of grout required will be approximately 45 cubic metres (m^3) per jacket. The maximum width of the jacket substructure at the water surface will be 30m.

5.52. The final design of the jacket will depend on a range of factors. These include water depth; the specific geological and seabed conditions at the location of each structure; the final WTG, OSP and meteorological mast sizes; and also supply chain implications. It may also be the case that because of these factors more than one substructure design is required across the OWF sites.

Tubular Pile Foundations

5.53. A tubular pile is a large steel tube that is driven into the seabed to the required depth by a piling hammer. For hard substrates drilling may also be required to achieve the desired depth of penetration. A jacket requires at least one tubular pile at each corner to secure it to the seabed. The size of tubular piles will depend on a number of factors, such as the loading on the structure and the ground conditions. The likely maximum WTG tubular pile diameter will be up to 3m and the likely maximum WTG tubular pile length will be up to 35m (Table 5.5). Tubular piles for OSPs and meteorological masts are likely to be smaller than those for WTGs. Installation of a tubular piled foundation is described in Section 'Offshore Wind Farm Construction'.

Plate 5.6 Tubular jacket with (a) tubular piles, (b) suction piles and (c) possible GBS hybrid

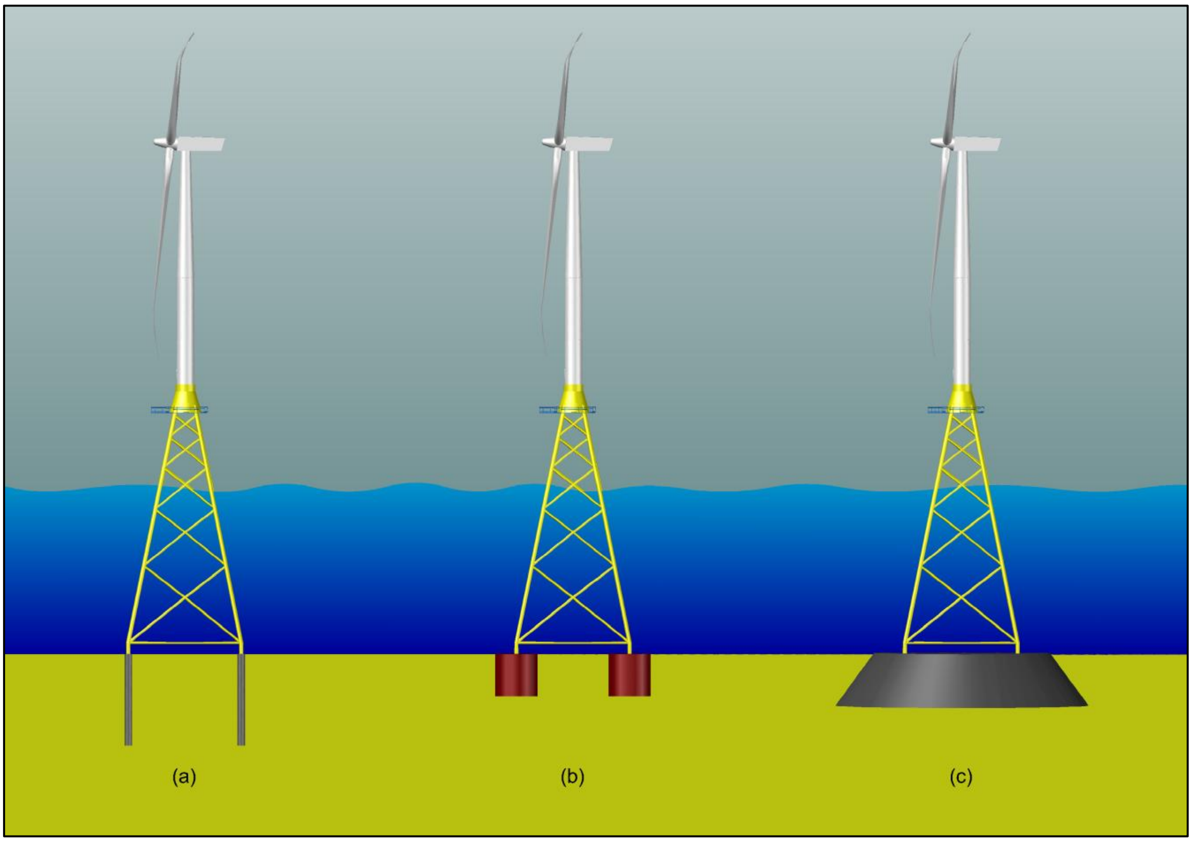
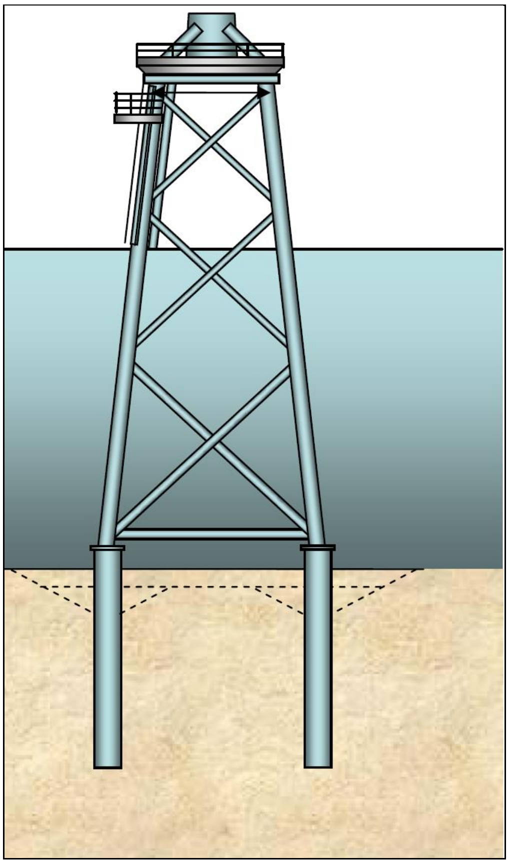


Plate 5.7 Pre-piled jacket concept



Source: Garrad Hassan, 2011

Suction Pile Foundations

5.54. A suction pile is similar to an upturned can, closed at the top and pushed into the seabed by water pressure. Water is pumped from within the foundation to create suction such that it pushes into the seabed and is secured (Plate 5.6). A jacket requires at least one suction pile at each corner to secure it to the seabed. Depending on seabed conditions and structural loading the suction pile diameters will be up to 14m and the penetration depth up to 23m (Table 5.5). A typical penetration depth for a 14m diameter suction pile is 14m. A typical penetration depth of 23m would be achieved with a pile diameter of 8m. Installation of a suction piled foundation is described in Section 'Offshore Wind Farm Construction'.

GBS Foundations and Substructures

5.55. GBS provide structural stability through their self weight and added ballast. The foundations must have a minimum base area to achieve an acceptable distribution of the load on the seabed. The design proportions of the foundation are also affected by the water depth, the wind and wave loading and the substructure design. Two GBS foundation designs have been considered at outline stage, a conical design and a cross-beam design (Garrad Hassan, 2011). Both designs require some extent of scour protection.

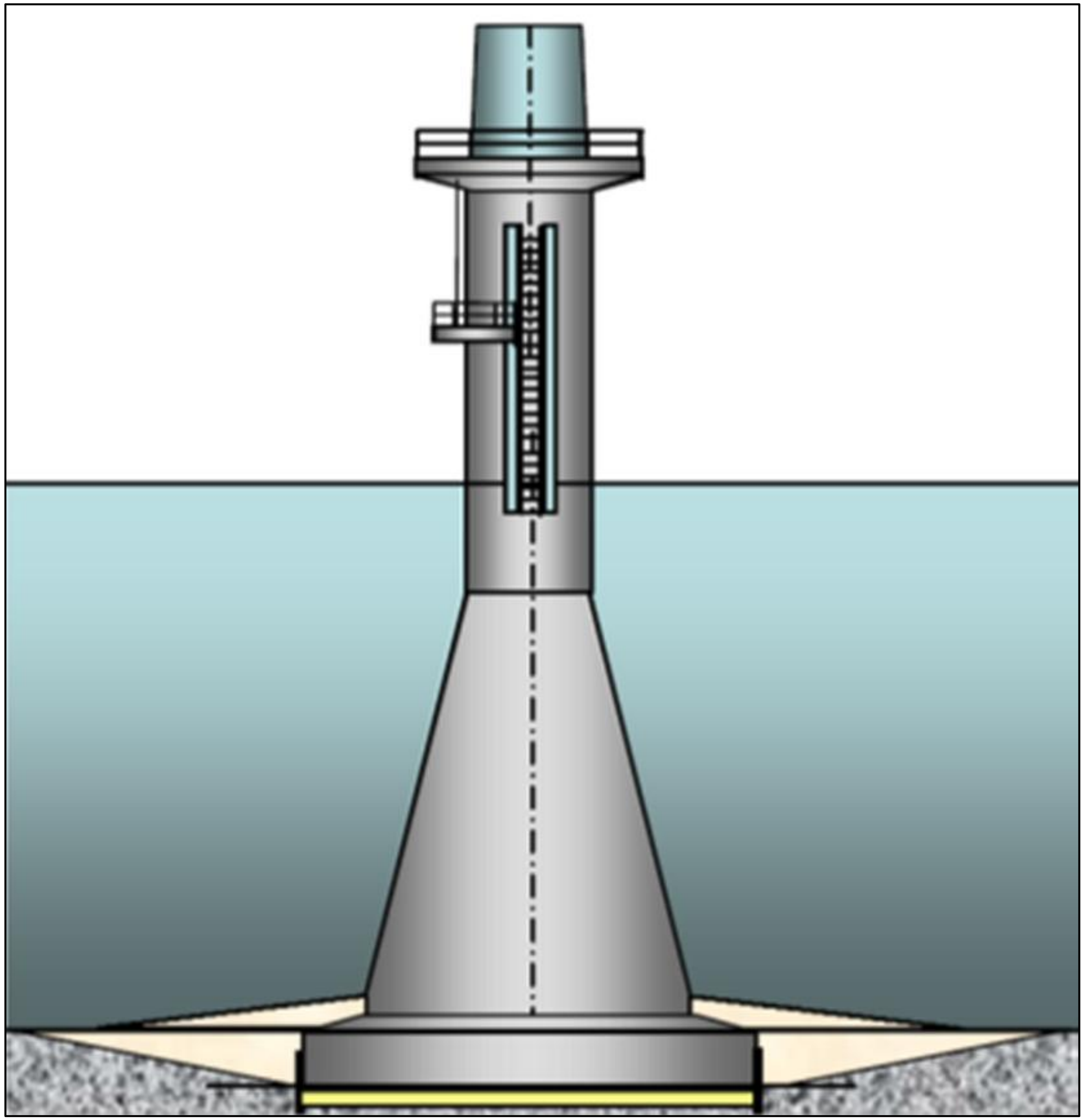
5.56. The conical design comprises a large diameter conical section that sits on a conventional solid base slab. A conical GBS is illustrated in Plate 5.8. The base may be octagonal in shape to allow easier construction compared to a circular base. The cross-beam design (illustrated in Plate 5.9) comprises a smaller conical section that sits on a deeper base.

5.57. GBS' are cast from concrete and steel and can also be combined with a jacket substructure. The likely GBS dimensions are given in Table 5.5. For weak ground conditions and up to 60m water depth the maximum GBS octagonal base plate width will be up to 72m, with a diameter of 35.4m at the base of the conical section. For average strength ground conditions the maximum octagonal GBS base plate width will be up to 52m, with a diameter of 28.4m at the base of the conical section. The GBS height will be up to 78m. Site selection for WTG foundations during detailed design will seek to maximise use of locations with good ground conditions if GBS foundations are selected.

5.58. GBS' are filled with ballast in the form of sand or water on installation. Seagreen will investigate the potential to maximise reuse of arisings from ground preparation as ballast. Additional requirements for ballast may require imported material.

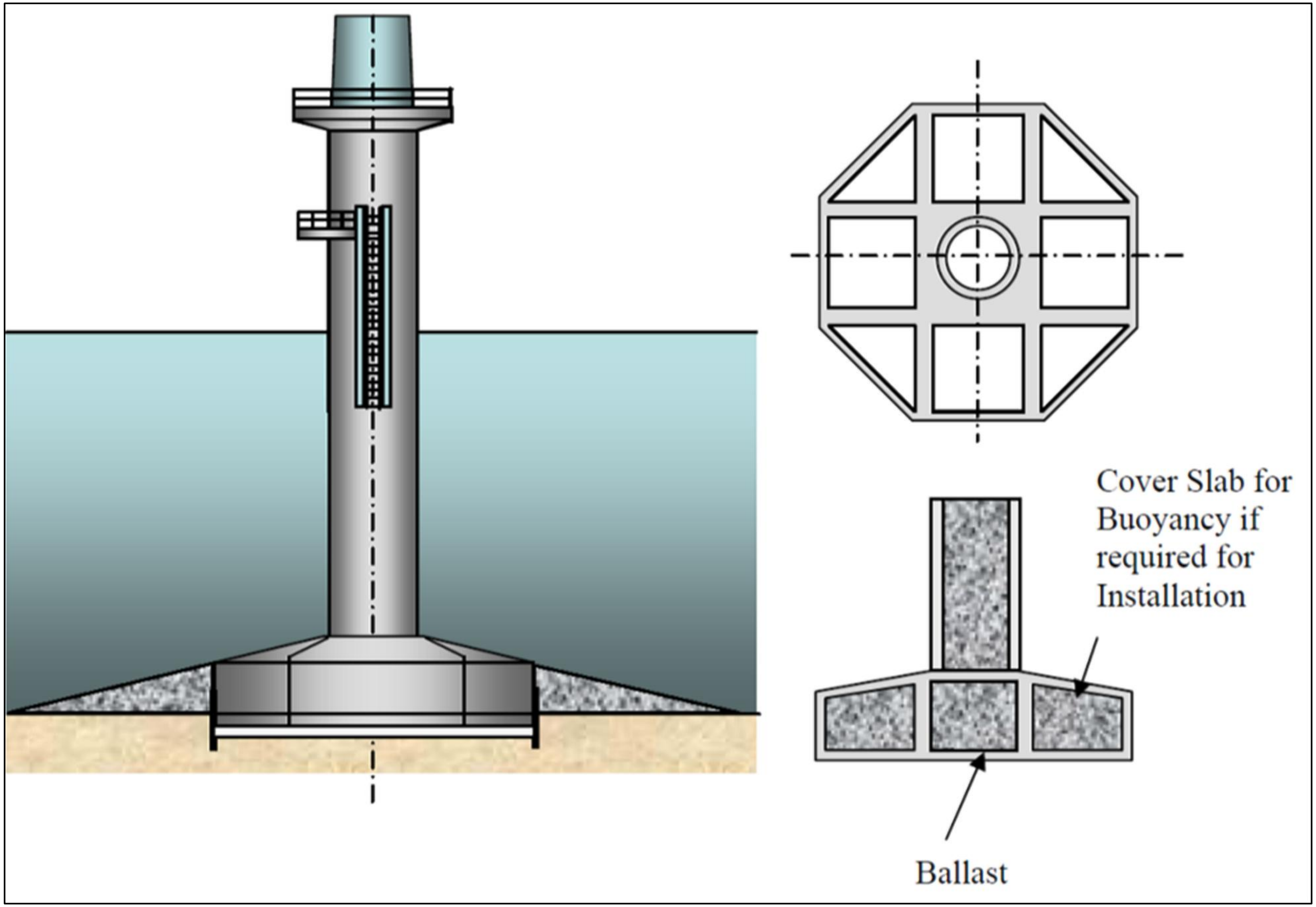
5.59. A GBS has to be placed on flat and level ground to ensure even distribution of weight and to ensure that the structure is vertical. Seabed preparation, involving some excavation to remove poor ground, may be required prior to installation. The preferred method is to place the GBS directly on the seabed although ground preparation may allow smaller structures to be used. Levelling of the foundation may require grouting or the use of a gravel layer. Approximately 0.5m thickness of grout may be used across the footprint of the foundation. Installation of a GBS foundation is described in Section 'Offshore Wind Farm Construction'.

Plate 5.8 Conical GBS foundation with monotower



Source: Garrad Hassan, 2011

Plate 5.9 Cross-beam GBS foundation with monotower



Source: Garrad Hassan, 2011

Foundation Scour Protection

5.60. Scour protection is required to ensure that erosion of the seabed around the foundation does not affect the stability or integrity of the structure. Scour protection is provided by rock placement around the foundation. The installation of scour protection is described in Section 'Offshore Wind Farm Construction'. Piled jacket foundations are assumed to require no scour protection and will be designed to accommodate local scour around the structure as well as global scour, the natural erosion of the seabed, where this occurs. Scour protection is considered likely to be required for GBS and suction piles. The final form and design of this scour protection will vary across the OWF sites and will be reviewed once detailed site data is available on the nature of the seabed.

5.61. Indicative scour protection volumes for suction piles have been determined assuming a circular scour protection footprint based on a width of 10m from the edge of the suction pile. Scour protection will be placed after the installation of the suction piles. Where the material at the seabed is more consolidated rather than an easily erodible, material scour rates may be low and total scour depths may be limited. The width of the scour protection in these cases could be significantly reduced or possibly eliminated.

5.62. GBS in particular are sensitive to scour and require scour protection to prevent the foundation being undermined. The extent of scour protection depends on the seabed conditions and the depth of erodible material present. For outline design proposes a simple approach to scour provision, with a 20m wide apron being assumed. Scour protection volumes have been determined assuming a uniform thickness of 2m. The final nature of the scour protection used will depend largely on the underlying material and its grain size.

5.63. The scour protection will be formed from a combination of a filter layer of stone (<100 millimetre (mm) diameter) and an armour layer of stone (200 - 400mm diameter). Based on 2m thickness at 20m radial extent around a 72m diameter GBS foundation, the maximum area covered per foundation will be 5,780m^2. The maximum volume of scour protection material will be 11,560m^3 with a weight of 23,120 tonnes.

Foundation and Substructure Zones of Influence

5.64. The likely area of seabed over which foundation installation and operation may have an influence has been defined by identifying various zones of influence. Different combinations of substructure and foundation type will have different zones of influence depending on ground conditions and water depth. They are described below and illustrated in Plate 5.10. Dimensions are given in Table 5.6 and relate to the installation of a single WTG. For assessment purposes the total area affected is determined through multiplying by the maximum number of WTGs and meteorological masts to achieve maximum site capacity for this design. Zones of influence for OSPs are given in Section 'Transmission Asset Infrastructure'.

- The terms used in Table 5.6 and illustrated in Plate 5.10 are explained as follows:
- *Footprint* – The area of the foundation component which is in direct contact with the seabed. The footprint is determined by calculating the cross sectional area of the foundation (tubular pile or suction pile or GBS).
- *Shadow* – The area beneath the foundation and substructure. A circular area determined using the maximum diagonal size of the foundation or substructure, plus two diameters of any pile foundations. Calculation of the shadow area has assumed that suction piles are clear of the tubular jacket and further increase the area.

- *Permanent Zone of Influence* – The area calculated by combining the shadow area with the extent of scour protection, if required, around the foundation to define total area of seabed occupied by the structure.
- *Temporary Zone of Influence* – This is determined by including an additional 5m buffer around the 'permanent' zone of influence. This allows for the extent of temporary works during installation of the structure.

Plate 5.10 Definition of terms for foundation and substructure zones of influence

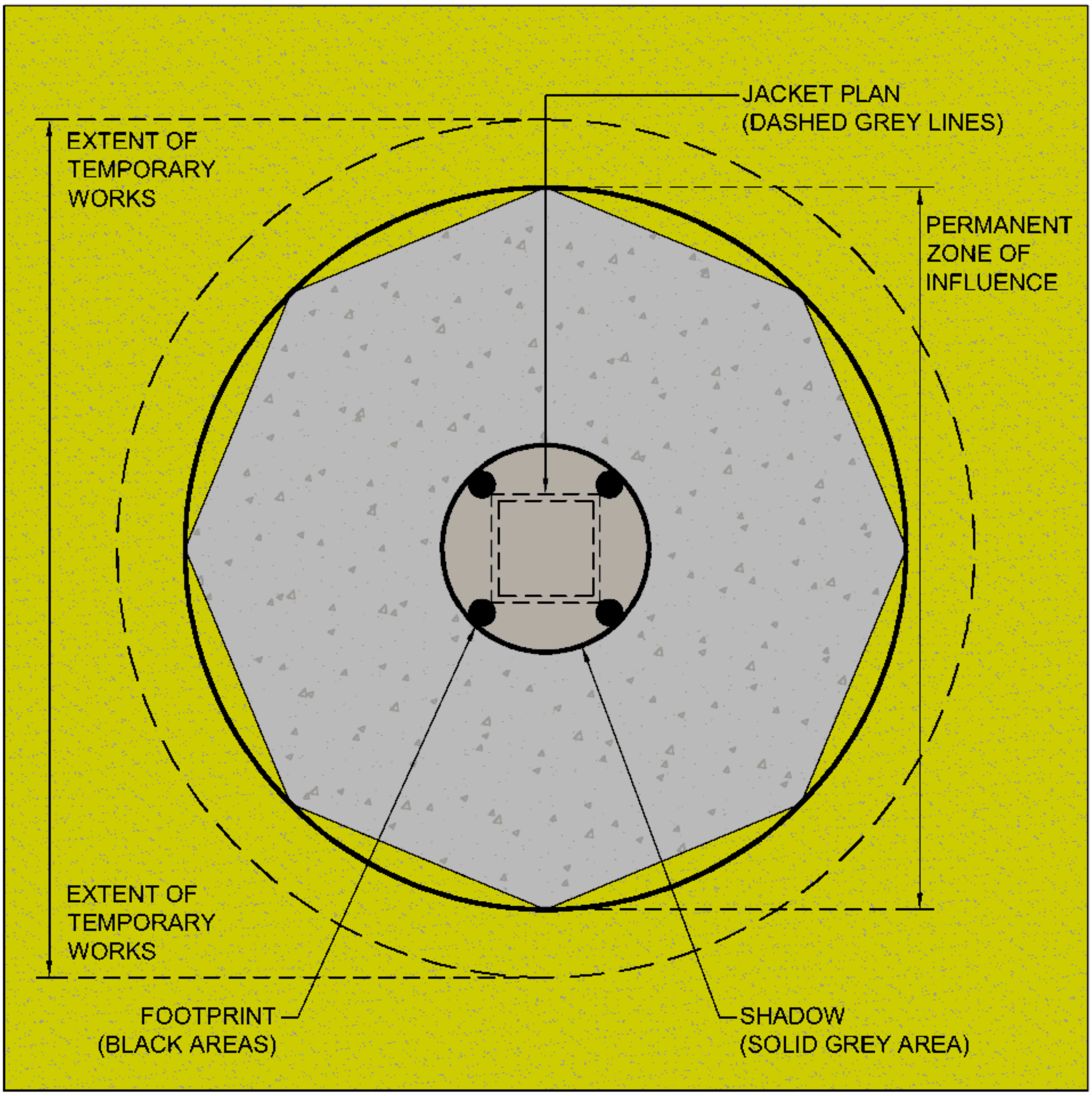


Table 5.6 Extent of WTG Foundation and Substructure Zones of Influence

Foundation	Maximum extent for single WTG			
	Footprint (m^2)	Shadow (m^2)	Temporary zone of influence (m^2)	Permanent zone of influence (m^2)
Conical GBS, 52m wide base plate (50m water depth)	2,240	2,488	8,872	7,281
Conical GBS, 72m wide base plate (60m water depth)	4,295	4,770	12,854	10,923
Tubular jacket on tubular piles (no sour protection required) (50m water depth)	20	1,921	4,822	3,670
Tubular jacket on tubular piles (no sour protection required) (60m water depth)	28	2,209	5,545	4,220
Tubular jacket on suction piles (all depths)	616	4,489	9,240	7,467

Meteorological Masts

5.65. A temporary meteorological mast will be installed within the Zone during 2012 (see Section 'Site Description and Characteristics'). This is the subject of a separate Marine Licence issued by Marine Scotland (Licence No. 04416/ 12/ 0). The temporary meteorological mast will provide site specific wind data to inform wind resource predictions and WTG array layout design.

5.66. Up to three permanent meteorological masts will be installed in both the Project Alpha and Project Bravo sites. The meteorological masts will be installed at key locations within each OWF project determined by the ultimate WTG array layouts for each site. Instrumentation mounted on the meteorological mast towers will enable measurement of wind speed and direction profiles. The meteorological mast maximum height will be governed by the WTG selected for installation at each site (Table 5.7).

Table 5.7 Meteorological mast parameters

	Alpha		Bravo	
	min	max	min	max
Number of masts	1	3	1	3
Height (m above LAT)	87.1	209.7	87.1	209.7

5.67. Wind data from the meteorological masts will be used to verify WTG performance and support ongoing OWF operations. The data will also input to wind forecasting for resource predictions. The meteorological masts will be placed on a jacket substructure, with a driven pile or suction pile foundation, or on a GBS structure as described previously in this chapter. Data logging and transmission equipment, electrical switchgear and any back-up systems will be housed on an appropriately sized deck with sufficient weather protection. Plate 5.11 shows a picture of the meteorological mast installed at the Greater Gabbard OWF, which is indicative of the proposed meteorological masts in Project Alpha and Project Bravo.

Plate 5.11 The Greater Gabbard OWF meteorological mast

Source: Greater Gabbard OWF

Wave Buoys

5.68. Wave buoys will be deployed at up to three locations in both the Project Alpha and Project Bravo sites to measure wave height, period, direction and spreading angle. The wave data will be sent via satellite telemetry to the shore and recorded internally and will provide input for the development of a forecast model for the region. On site the wave buoys will be protected by guard buoys to increase the visibility and awareness of the measuring equipment. Consultation will be undertaken with the local fishing interests prior to deployment and the standard marine notification requirements will be followed.

5.69. Seagreen will consult with the Northern Lighthouse Board (NLB) regarding lighting however it is Seagreen's understanding that each wave buoy will be marked with a flashing amber light to standard requirements and an additional radar reflector fitted to enhance radar visibility. Seagreen will seek a clearance of up to 350m at each wave buoy location. It is anticipated that the wave buoys will be deployed for a period of up to 3 years. They will be serviced at regular intervals over this period at approximately 6 month intervals. At the end of the deployment period each wave buoy and mooring will be fully recovered from the site.

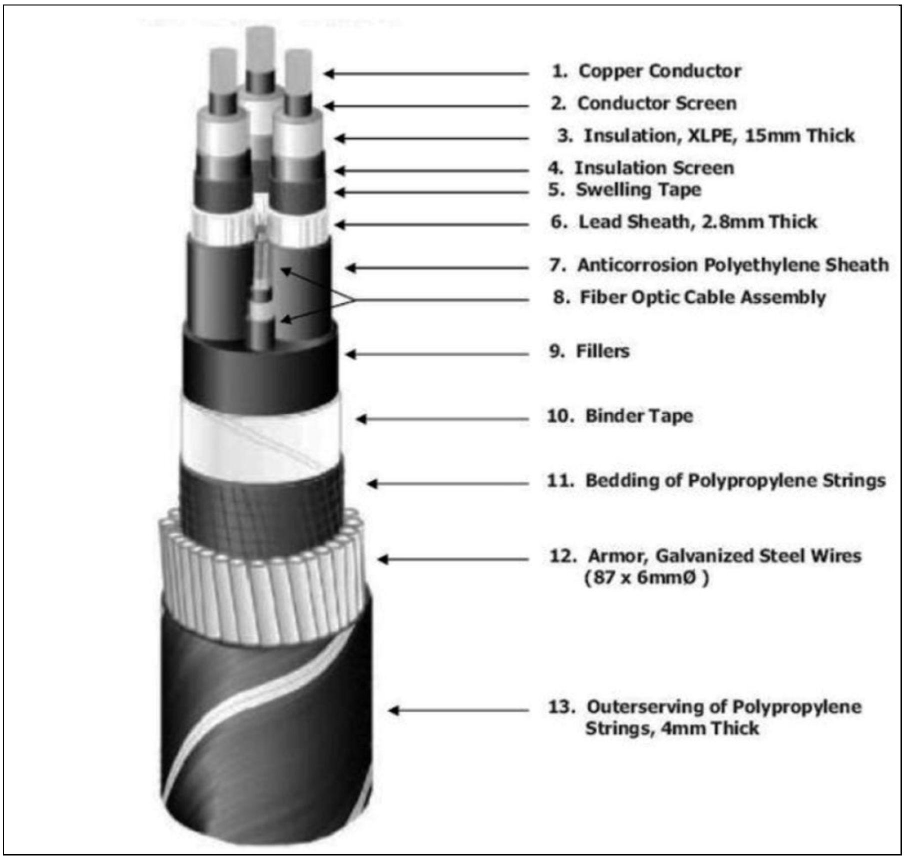
Array Cables

5.70. The array cable network of an OWF collects the electrical power generated at the WTGs and connects to an OSP where the combined generated power can be converted to a higher voltage for transmission to shore and connection to the national electricity transmission grid (hereafter referred to as 'the Grid'). The array cables are included within the consent applications for the Project Alpha and Project Bravo infrastructure, whilst the OSPs are included within the consent application for the Transmission Asset Project infrastructure.

5.71. The most commonly used OWF collection voltage in the UK is 33kV and is an established 'standard' collection voltage. Subsea cables at this voltage are available from a number of established manufacturers (Seagreen, 2011). A collection voltage of up to 66kV may be used for Project Alpha and Project Bravo.

5.72. The array cables will typically comprise three cores with copper or aluminium conductors and insulation/ conductor screening. The three cores will be bound together and protected within a layer of steel armouring. The cable bundle will also include a fibre optic communications cable for OWF monitoring and control. A diagram of a typical 132kV submarine power cable is shown in Plate 5.12, although it should be noted that insulation thicknesses for a 33kV or 66kV equivalent would be less than that shown.

Plate 5.12 Cut away illustration of a three core submarine cable (source: Nexans)



Source: Nexans

5.73. The cables will connect the WTGs together into 'strings'1. The total string length of array cables is estimated to be up to 355km for Project Alpha OWF and 355km for Project Bravo. To retain flexibility, the total array cable length is based on an estimate for standard array layouts with a range of WTG spacing with an additional factor to allow for the potential adoption of unconventional array layouts. The WTG array strings will then be connected to the OSP, possibly via a collection station. Further detail of the possible OSP arrangement is given in Section 'Transmission Asset Infrastructure'.

5.74. The precise array cable layout will be defined during FEED. It will be driven by the WTG layout configuration but it will also be influenced by ground conditions, electrical losses, installation limitations, environmental constraints and economic factors.

5.75. The array cables will be buried wherever feasible in order to provide protection against damage. Based on currently available information it is considered possible that up to 90% burial could be achieved, to a minimum burial depth of 0.5m (Table 5.8). The temporary zone of influence on the seabed during cable laying operations will be a maximum of 10m width.

5.76. Where cable burial can not be achieved protection measures will be required. A small section at either end of each length of array cable will also be unburied in order to allow connection to the WTG or OSP substructure. Cable protection will be achieved through rock armouring or placement of concrete mattresses. Cable installation is described in Section 'Offshore Wind Farm Construction'.

Table 5.8 Array Cable Parameters

Array Cables	**Alpha**		**Bravo**	
	min	**max**	**min**	**max**
Total array cable length (km)	N/A	355	N/A	355
Total trenched (plough or jet) cable length (km)	N/A	355	N/A	355
Estimated total rock or mattress protected length (km)	0	35.5	0	35.5
If trenched, estimated trench width (m)	N/A	3	N/A	3
If trenched, cable burial depth (m)	0.5	2.1	0.5	2.1
If trenched, width of temporary Zone of Influence (m)	N/A	10	N/A	10
If rock or mattress protected, max height (m)	N/A	1	N/A	1
If rock or mattress protected, max width (m)	N/A	7	N/A	7
Array cable voltage (kV)	33	66	33	66

5.77. Array cable lengths are determined by the WTG layout. An array cable options study (Seagreen, 2011) was completed using a number of potential layout configurations, including an unconventional layout that may require a greater total extent of array cabling in comparison to a standardised grid array. The maximum array cable lengths for assessment will not exceed that presented in Table 5.8. A minimum is not required for assessment and has not been defined.

1 A 'string' is a term used to describe the collection circuits / array cables that are installed in single lengths from one WTG to its neighbour, which feed into the OSPs.

TRANSMISSION ASSET INFRASTRUCTURE

5.78. The following sections describe the key elements of the Transmission Asset Project. It should be noted that for the purposes of impact assessment, OSPs are covered under the assessments of Project Alpha and Project Bravo but they will be consented separately under the Marine Licence application for the Transmission Asset Project.

5.79. As set out in Section 'Introduction', the Transmission Asset Project infrastructure will ultimately be owned and operated by a separate entity, the OFTO, from the operator(s) of Project Alpha and Project Bravo. It is anticipated that a single OFTO will provide the grid connection and transmission infrastructure for both Project Alpha and Project Bravo, meaning that the projects will share transmission infrastructure. However, it is also possible that the projects will have separate transmission infrastructure and could therefore have separate OFTOs appointed for each OWF project. The final connection design selected will enable shared or separate systems, as described below. The ECR corridor will be shared between Project Alpha and Project Bravo under both scenarios.

5.80. The Transmission Asset Project comprises the OSPs, including HVDC converter stations and/or HVAC substations and collector stations as required, and the HV power export cables providing connection to the Grid for both Project Alpha and Project Bravo. The onshore components of the Transmission Asset Project (from MLWS) are considered under a separate planning application and are therefore not described in this ES.

5.81. An OSP houses a range of electrical equipment to receive, convert, transform and transmit the incoming voltage from the array OWF cables for transmission to the shore. The equipment varies depending on the final electrical design configuration chosen and in some configurations there will be more than one OSP. The function of the OSP is to collect the incoming voltage, which will always be an alternating current (AC), from the OWF array. Should a direct current (DC) configuration be chosen the AC voltage will be converted to a DC voltage. In all cases the voltage will be transformed on the OSP to the higher voltage for transmission to the shore. The size of the OSP depends on the configuration of the various equipment, further details are explained below and in Table 5.9.

5.82. The Transmission Asset Project site is shown on Figure 1.1. The export cable landfall location will be at Carnoustie, approximately 70km from the indicative OSP location in the Project Alpha site shown in Figures 5.1 and 5.2.

5.83. Retaining the flexibility to select a HVDC or HVAC connection design is essential. HVDC is a new technology for offshore wind that may provide improved connection efficiency. HVAC is the established technology and has been used on previous offshore wind installations in the UK. The Seagreen Project is close to the limit for HVAC technical feasibility due to capacity and transmission distances. It is not possible to commit at this stage to either technology as it is not yet certain which will provide the optimum or most cost effective solution. For this reason both HVDC and HVAC technologies have been included in the assessment.

5.84. Four electrical design configurations are considered in this ES based around different transmission voltages for either HVDC or HVAC as follows:

- Scenario 1 - One 1,075MW HVDC circuit connecting both OWFs.
- Scenario 2 - Two separate 550MW HVDC circuits, one connecting each OWF
- Scenario 3 - Four 220kV HVAC circuits, two connecting each OWF
- Scenario 4 - Two 275kV HVAC circuits, one connecting each OWF.

5.85. The scenarios above are described further in the following sections. The final design selected will determine the location, number and type of OSPs and the number of transmission cables to the landfall point. The selection of a preferred transmission asset design option will be made post consent.

HVDC Connection Options

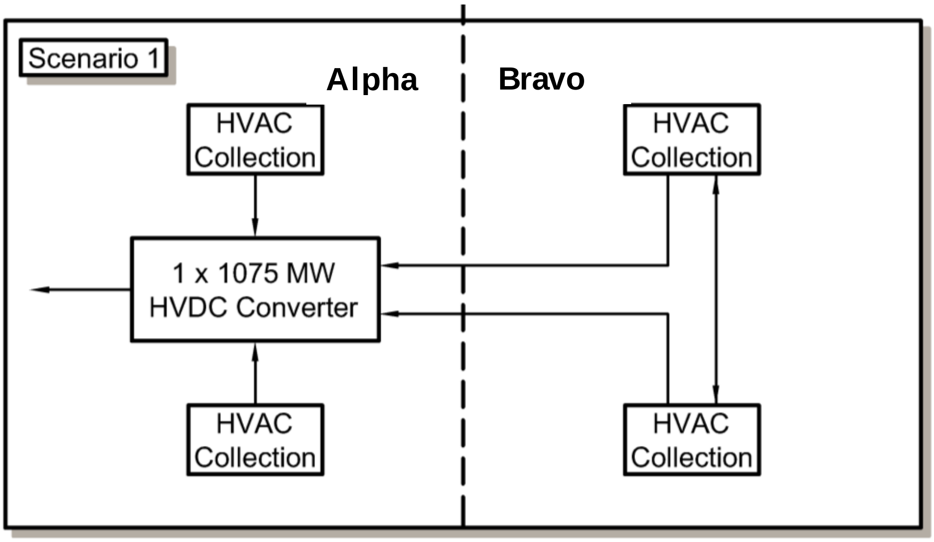
Scenario 1

5.86. Scenario 1 is the only scenario with shared offshore transmission infrastructure between Project Alpha and Project Bravo. The other scenarios have independent transmission asset infrastructure offshore. Scenario 1 consists of one 1,075MW HVDC circuit with two separate HVAC collector platforms within each OWF site connected to a single, shared 1,075MW HVDC converter platform, giving up to five OSPs in total across the two OWFs (Plate 5.13). Power will be exported from both Project Alpha and Project Bravo via a shared connection comprising two cables, positive and negative, laid in a single trench within the ECR corridor. A fibre optic control cables will also be laid in the trench.

5.87. The maximum dimensions for the OSPs are given in Table 5.9. The topside weight for a 1,050MW HVDC offshore convertor station is approximately 13,000 tonnes, based on initial design estimates. There will be up to ten HV transmission cables connecting the OSPs within the OWF sites.

5.88. The estimated total length of buried HV transmission cables for both sites is up to 250km, including HV OSP to OSP interconnections within the sites and the distance to landfall at Carnoustie. The estimated cable trench width is 3m per cable (Table 5.10).

Plate 5.13 Schematic arrangement for Transmission Asset HVDC Connection Scenario 1



Scenario 2

5.89. Scenario 2 consists of two separate 550MW HVDC circuits, with one HVAC collector platform and one combined 550MW HVDC converter and HVAC collector platform in each OWF site, giving up to four OSPs in total across the two OWFs (Plate 5.14). Power will be exported via separate connections for each OWF, each comprising a positive and negative cable. The cables will be laid in two parallel trenches within the ECR corridor. Fibre optic control cables will also be laid in the trenches.

5.90. The maximum dimensions for the OSPs are given in Table 5.9. There will be a total of four HVAC transmission cables connecting the OSPs within the OWF sites. The estimated total length of buried HV transmission cables for both sites is up to 380km, including HV OSP to OSP interconnections within the sites and the distance to landfall at Carnoustie. The estimated cable trench width is 3m per cable (Table 5.10).

Plate 5.14 Schematic Arrangement for Transmission Asset HVDC Connection Scenario 2

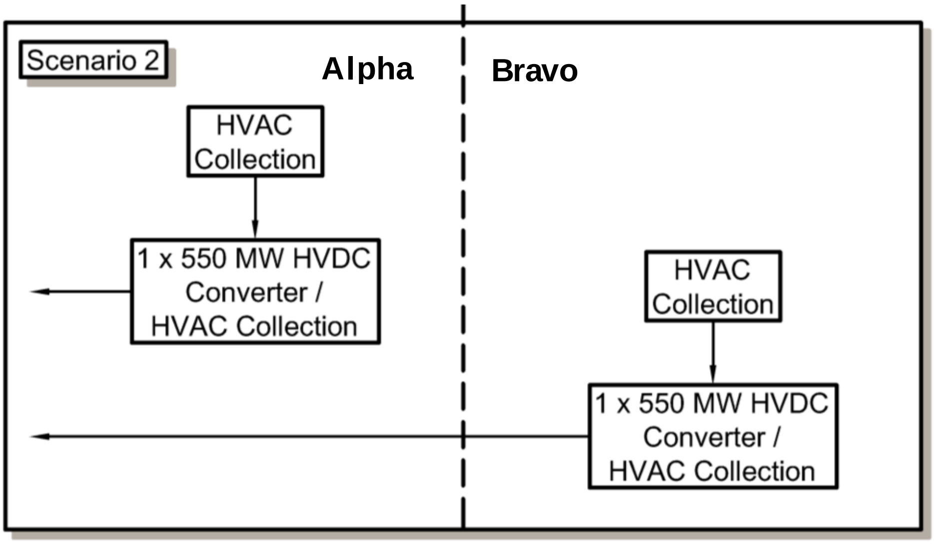


Table 5.9 OSP Parameters for Transmission Asset HVDC Connection Scenarios

Connection Scenario	**1**			**2**			
Connection design	1 x 1,075 MW HVDC circuit			2 x 550MW HVDC circuit			
No. of OSPs	5			4			
OWF Project	Alpha		Bravo	Alpha		Bravo	
OSP	HVDC converter (x 1)	HVAC collector (x 2)	HVAC Collector (x 2)	HVDC converter / HVAC collector (x 1)	HVAC collector (x 1)	HVDC converter / HVAC collector (x 1)	HVAC Collector (x 1)
Max Length (m)	100	40	40	85	40	85	40
Max Width (m)	75	40	40	55	40	55	40
Max Height (m)	60	45	45	60	45	60	45
Max Air Gap (LAT)	20	20	20	20	20	20	20

Table 5.10 Transmission Asset Export Cable Parameters for HVDC Connection Scenarios

Connection Scenario	1	2
Max number of export cables	2	4
Max number of export cable trenches	1	2
Expected cable corridor width (km)	0.6	0.6
Number of AC cables (OSP to OSP)	10	4
Number of trenches (OSP to OSP)	10	4
Estimated Transmission buried cable length (Total) (km)	250	380
Maximum rock or mattress protected length (km)	12.5	19
If trenched, estimated width per trench (m)	3	3
If trenched, cable burial depth (min – max) (m)	0.5 - 3	0.5 – 3
If trenched, width of temporary Zone of Influence (m)	15	15
If rock or mattress protected, maximum height (m)	1	1
If rock or mattress protected, maximum width (m)	7	7

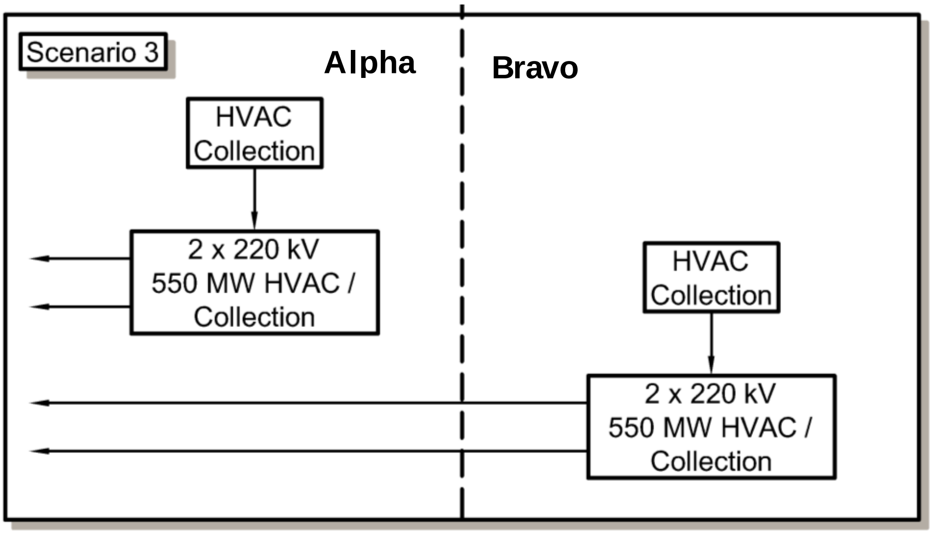
HVAC Connection Options

Scenario 3

5.91. Scenario 3 consists of two 220kV HVAC circuits connecting each OWF site separately, with two combined HVAC collector and substation platforms in each site, giving up to four OSPs in total across the two OWFs (Plate 5.15). Power will be exported via two separate connections, each comprising two three core cables including fibre optics laid in parallel trenches within the ECR corridor, giving four trenches in total (Table 5.12).

5.92. There will be a total of four HVAC transmission cables connecting the OSPs within the OWF sites. The estimated total length of buried HV transmission cables for both sites is up to 380km, including HV OSP to OSP interconnections within the sites and the distance to landfall at Carnoustie. The estimated cable trench width is 3m per cable (Table 5.12).

Plate 5.15 Schematic Arrangement for Transmission Asset HVAC Connection Scenario 3



Scenario 4

5.93. Scenario 4 consists of one 275kV HVAC circuit connecting each OWF site separately, with two collector/ substations in each site, giving up to four OSPs in total across the two OWFs (Plate 5.16). Power will be exported via two separate connections, each comprising three single core cables in separate, parallel trenches within the ECR corridor, giving six trenches in total (Table 5.11). Fibre optic control cables will also be laid in two of the trenches.

5.94. There will be a total of four HVAC transmission cables connecting the OSPs within the OWF sites. The estimated total length of HV buried transmission cables for both sites is up to 530km, including HV OSP to OSP interconnections within the sites and the distance to landfall at Carnoustie. The estimated cable trench width is 3m per cable (Table 5.12).

Plate 5.16 Schematic Arrangement for Transmission Asset HVAC Connection Scenario 4

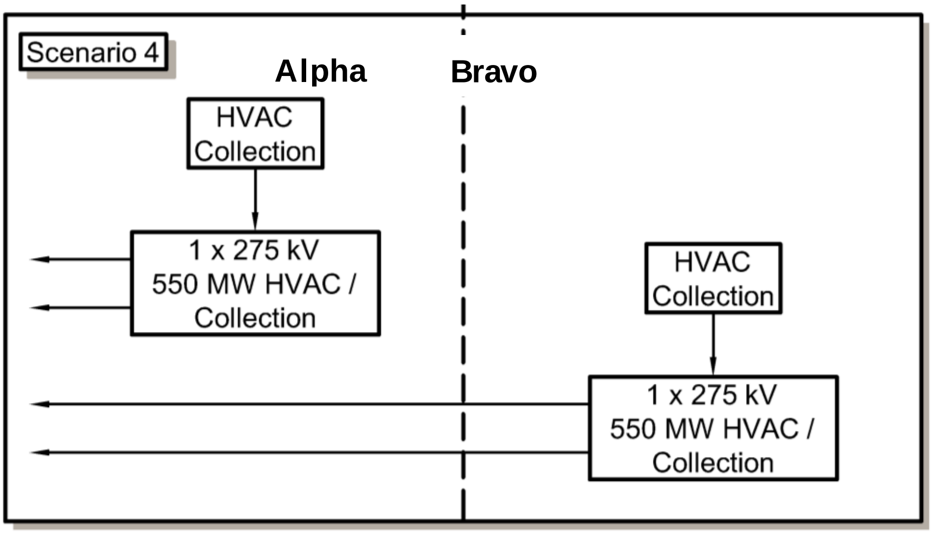


Table 5.11 OSP Parameters for Transmission Asset HVAC Connection Scenarios

Connection Scenario	**3**		**4**	
Connection design	2x 220kV HVAC		4x275kV HVAC	
No. of OSPs	4		4	
Project	Alpha	Bravo	Alpha	Bravo
OSP	HVAC collector / transmission (x2)	HVAC collector / transmission (x2)	HVAC collector / transmission (x2)	HVAC collector / transmission (x2)
Max Length (m)	40	40	40	40
Max Width (m)	40	40	40	40
Max Height (m)	45	45	45	45
Max Air Gap (m LAT)	20	20	20	20

Table 5.12 Transmission Asset Export Cable Parameters for HVAC Connection Scenarios

Connection Scenario	3	4
Max number of export cables	4	6
Max number of export cable trenches	4	6
Expected cable corridor width (km)	1	1
Number of AC cables (OSP to OSP)	4	4
Number of trenches (OSP to OSP)	4	4
Estimated Transmission buried cable length (Total) (km)	380	530
Maximum rock or mattress protected length (km)	19	26.5
If trenched, estimated width per trench (m)	3	3
If trenched, cable burial depth (min – max) (m)	0.5 – 3	0.5 – 3
If trenched, width of temporary Zone of Influence (m)	15	15
If rock or mattress protected, maximum height (m)	1	1
If rock or mattress protected, maximum width (m)	7	7

Offshore Platforms

5.95. The OSPs house the transformers and converters, if required, to increase the distribution voltage of the array cables to a higher AC or DC transmission voltage for the export cables. Illustration of an OSP in the Greater Gabbard OWF is provided in Plate 5.18, which is indicative of the proposed OSPs in Project Alpha and Project Bravo. The OSP topside may be configured in either a single or multiple deck arrangement. Decks will either be open with modular equipment housings or the structure may be fully clad. All weather sensitive equipment will be placed in environmentally controlled areas. The OSP dimensions for both HVDC and HVAC options are given in Tables 5.13 and 5.14 respectively.

Plate 5.17 OSP at the Greater Gabbard OWF

Source: Greater Gabbard OWF

5.96. OSPs will be fabricated at a quayside facility to enable the transfer of the topside structure onto a barge for transportation offshore. Whilst at the quayside the topside will be fitted out internally with all the necessary equipment. As far as possible the equipment will be made ready for operation prior to being moved offshore. Environmental mitigation measures, such as transformer bunding for spill containment, will be fully operational prior to the OSP transportation stage.

5.97. The OSP will typically accommodate the following:

- helicopter landing and refuelling facilities;
- potable water;
- black water separation;
- Medium Voltage (MV) to HV power transformers;
- MV and/ or HV switch gear;
- seawater cooling systems (HVDC convertor only);
- instrumentation, metering equipment and control systems;
- standby generator;
- auxiliary and uninterruptible power supply systems;
- marking and lighting;
- emergency shelter or temporary accommodation, including mess facilities;
- craneage; and
- control hub.

5.98. The maximum seawater cooling water volume required would be for a 1GW single circuit system (HVDC Scenario 1). At full capacity this will require a cooling water flow rate of up to 125 litres per second (l/ s) with a resultant outlet water temperature rise of approximately 20^{o}C above ambient. The flow rate and temperature rise would be proportionately reduced when operating at outputs below full capacity. Dosing of seawater cooling water with biocide may be required to prevent biofouling in the cooling water system.

5.99. The OSPs drainage system will collect waste water as well as connecting bunded areas. The drainage system will incorporate a separation unit which separates any contamination from the collected water. The collected water is re-circulated through the separator with clean water being discharged and any contaminants stored for transportation to shore and controlled processing and / or disposal.

5.100. The OSP substructure is most likely to comprise a jacket substructure analogous to that described in Section 'Offshore Wind Farm Infrastructure, Meteorological Masts and Wave Buoys' for the WTGs (Table 5.4). Typically this will have up to six legs, but on the larger structures this can be up to twelve. The OSP jacket structures will be fixed to the seabed by tubular piles, suction piles or a GBS will be used.

5.101. If a GBS is used for OSPs, the baseplate dimensions are assumed to be as for the OSP length and width given in Table 5.9 and Table 5.11. The baseplate for the largest HVDC convertor platform, in Connection Scenario 1, will be up to 100m x 75m with a thickness of up to 7.5m. For this rectangular baseplate GBS the topsides will be supported on six legs of up to

15m x 15m. The baseplate for the HVAC collector/ substation OSP, in all Connection Scenarios, will be up to 40m x 40m with a thickness of up to 7.5m. For this square baseplate GBS the topsides will be supported on four legs of up to 7.5m x 7.5m. A maximum of up to 5m depth ground preparation may be required for all OSPs with GBS.

OSP Foundation and Substructure Zones of Influence

5.102. The zone of influence on the seabed is dependent on the final OSP and substructure design and the foundation selection. Different combinations of substructure and foundation type will have different zones of influence depending on ground conditions and water depth. These are as described previously in Section 'Offshore Wind Farm Infrastructure, Meteorological Masts and Wave Buoys' and illustrated in Plate 5.10. The dimensions are given in Table 5.13 and Table 5.14 for the OSPs for each connection scenario considered.

Table 5.13 OSP foundation dimensions for HVDC connection scenarios

Connection Scenario	**1**			**2**			
Connection design	1x 1,075MW HVDC			2x 550MW HVDC			
No. OSPs	5			4			
Project	Alpha		Bravo	Alpha		Bravo	
OSP Gravity Base foundation (50m water depth)	HVDC converter (x 1)	HVAC collector (x 2)	HVAC collector (x 2)	HVDC converter / HVAC collector (x 1)	HVAC collector (x 1)	HVDC converter / HVAC collector (x 1)	HVAC collector (x 1)
Footprint (m^2)	7,500	1,600	1,600	4,675	1,600	4,675	1,600
Shadow (m^2)	13,273	2,980	2,980	8,858	2,980	8,858	2,980
Temporary zone of influence (m^2)	20,739	6,955	6,955	15,109	6,955	15,109	6,955
Permanent zone of influence (m^2)	18,265	5,555	5,555	13,009	5,555	13,009	5,555
Jacket foundation (50m water depth)							
Footprint (m^2)	40	20	20	40	20	40	20
Shadow (m^2)	13,273	2,976	2,976	8,858	2,976	8,858	2,976
Temporary zone of influence (m^2)	20,739	6,949	6,949	15,109	6,949	15,109	6,949
Permanent zone of influence (m^2)	18,265	5,550	5,550	13,009	5,550	13,009	5,550

Table 5.14 OSP foundation dimensions for HVAC connection scenarios

Connection Scenario	**3**		**4**	
Connection design	2x 220kV HVAC		4x 275kV HVAC	
No. OSPs	4		4	
Project	Alpha	Bravo	Alpha	Bravo
OSP Gravity Base foundation (50m water depth)	HVAC collector / transmission (x 2)	HVAC collector / transmission (x 2)	HVAC collector / transmission (x 2)	HVAC collector / transmission (x 2)
Footprint (m^2)	1,600	1,600	1,600	1,600
Shadow (m^2)	2,908	2,908	2,908	2,908
Temporary zone of influence (m^2)	6,955	6,955	6,955	6,955
Permanent zone of influence (m^2)	5,555	5,555	5,555	5,555
Jacket foundation (50m water depth)				
Footprint (m^2)	20	20	20	20
Shadow (m^2)	2,976	2,976	2,976	2,976
Temporary zone of influence (m^2)	6,949	6,949	6,949	6,949
Permanent zone of influence (m^2)	5,550	5,550	5,550	5,550

5.103. The zone of influence on the seabed is dependent on the final OSP and substructure design and the foundation selection. Different combinations of substructure and foundation type will have different zones of influence. The maximum total footprint for OSPs with GBS, 13,900m^2, results from Connection Scenario 1.

OFFSHORE WIND FARMS AND TRANSMISSION ASSET CONSTRUCTION

5.104. Details on the construction aspects of the Seagreen Project are sparse at this stage due to the limited current level of design detail and may be subject to modification during detailed planning of construction and commissioning. The information provided is based on best available information at the time of writing, as described in the Seagreen EIA Construction Methods Report (Seagreen, 2012a). Construction Health and Safety Plans (CHSPs) and Construction Environmental Management Plans (CEMPs) will be produced, which will manage potential environmental impacts and health and safety issues during the construction stage.

5.105. A NRA has been completed for the Seagreen Project and is presented in Appendix J which supports Chapter 15: Shipping and Navigation of this ES. The NRA provides further details on the navigational safety measures that will be applied to the construction, operation and decommissioning stages of the Seagreen Project.

5.106. The indicative construction programme provided (Table 5.15) provides a broad timescale and sequence for the required construction activities in order that Project Alpha and Project Bravo are operational and contributing to the UK 2020 targets (see Chapter 2: Need for the Project for further details). Construction of each OWF project and the Transmission Asset Project may be taken forward at the same time. Alternatively construction of each project may take place sequentially. In order to achieve the target operation date, however, all construction activities must take place within the overall timescale illustrated in Table 5.15.

Offshore Pre-Construction and Construction Sequence

5.107. Construction of the Seagreen Project will generally be completed in a number of stages as follows:

- pre-construction surveys;
- fabrication (structures constructed onshore);
- transportation (structures floated or transported offshore on vessels); and
- offshore foundation / substructure installation.

5.108. OSP installation and commissioning (including collector stations, substations and convertor stations, as required);

- export cabling;
- array cabling;
- WTG installation;
- cable landfall works; and
- commissioning.

Outline Offshore Construction Programme

5.109. The key programme elements for construction of Project Alpha, Project Bravo and the Transmission Asset Project are summarised in Table 5.15 below. The indicative programme given is based on achieving consent for the projects in 2013 and on achieving financial close in 2014. The durations given are based on the construction work for both Project Alpha, Project Bravo and the Transmission Asset taking place between April and the end of September each year of the programme and are therefore conservative. However, the assessment should allow for construction activities to take place at any time of the year as vessel utilisation is important in maintaining schedule and reducing cost.

5.110. The indicative four year programme given in Table 5.15 commences in 2015 and completes in 2019. Within this, construction of the offshore wind farm projects is phased over 2016 to 2019 to ensure that sufficient foundations are in place to allow efficient installation of substructures, which in turn enables efficient installation of WTGs. The installation of substructures and foundations is predicted to take no longer than three years in total. This is based on an assumption that offshore working takes place during April to September each year, a total construction duration of 18 months within the three year period. The overall period of construction could be reduced by extending the working period beyond the summer months, however weather sensitive activities could take longer to complete if undertaken between October and March.

5.111. A minimum period of time for the substructure and foundation installation would be six months for the purposes of the assessment. A further assumption is that installation of two substructures or foundations could be ongoing at the same time on each OWF site.

5.112. If driven pile foundations are used, a maximum of two piling operations will be ongoing at any one time. If piling operations require some drilling additional construction time may be required to install all structures. For the purposes of assessment, a maximum duration of up to two years has been assumed for the completion of all piling operations.

5.113. It is in Seagreen's interest to plan and implement an efficient and effective construction programme. Construction activities will take place within the periods below but are not expected to take the full duration shown against each activity.

5.114. Seagreen will endeavour to minimise impact or disruption to other users of the sea in planning the construction activities in more detail. For example a phased programme will be utilised to reduce safety exclusion areas while construction is in progress. As construction is completed on an area of the site the exclusion will be removed from that area and access will be restored. Array and export cables will be buried within trenches or by rock placement as soon as is practicable after being laid on the seabed to allow resumption of fishing activity, for example.

5.115. In particular it is proposed to maintain ongoing dialogue with the commercial fishing sector through a working group. This will enable direct communication to inform fishermen about planned activities and, where practicable, allow the commercial fishing sector to influence timing and sequence of activities such that any disruption is minimised.

Table 5.15 Indicative Construction Programme based on achieving consent in Q4 2013.

Programme Stage	Start	Finish
Financial close		Q4 2014
Tendering and award of contracts	Q4 2013	Q4 2015
Installation of export cables	Q4 2015	Q4 2017
Offshore foundations / substructures installation	Q3 2016	Q3 2019
Array cable installation	Q3 2016	Q3 2019
Installation of WTGs and OSP topsides	Q2 2017	Q3 2019
Commissioning of OWFs and handover to operator(s)	Q2 2017	Q3 2019
Project completion	Q4 2019	Q4 2019

Table 5.16 Construction Activity Summary

Construction Aspect	Likely vessel requirements
Pre-construction geophysical survey	Dedicated geophysical survey vessel using side scan sonar, multibeam echosounder and magnetometer. Will survey OWF sites and ECR corridor.
Pre-construction geotechnical survey	Dedicated geotechnical survey vessel will take a number boreholes, core penetration tests (CPTs) and vibrocores within the OWF sites and ECR corridor.
Cable Pre-Lay Grapnel Run (PLGR)	Dedicated vessel with PLGR device and Remotely Operated Vehicle (ROV)
Plough trails	Cable installation vessel along selected installation equipment (plough, jetting ROV and or trencher).
WTG and ancillary infrastructure substructures / foundations	Foundation installation Heavy Lift Vessel (HLV) or jack-up barge and possible foundation transportation vessel.
Scour protection	Construction barge or dedicated rock placement vessel
Cable Mattress / Rock Placement	Construction barge or dedicated rock placement vessel
WTGs	HLV or jack-up barge
Ancillary structures (OSPs, and meteorological masts)	HLV or jack-up barge, substation installation vessel
Cable lay	Cable lay barge/ vessel

5.116. Table 5.16 summarises the spread of construction vessels likely to be used for the construction programme.

5.117. A number of installation and construction options are under consideration for Project Alpha and Project Bravo. The final options selected will be determined by a range of factors. These include the type of foundations to be used; the extent of onshore assembly of infrastructure and the location of the manufacturing base(s) and the construction port base. Consideration of the onshore aspects of construction and port facilities is out with the scope of this ES (see Chapter 6: EIA Process of this ES).

5.118. The availability of construction vessels of the capacity required for the installation of large structures in the water depths found over the Project Alpha site and the Project Bravo site is also a key consideration. As the scale of the offshore wind industry develops it is likely that new innovations in large scale offshore installation methods will emerge to improve efficiency and safety of installation.

5.119. For the purpose of the assessment it has been assumed that there will be up to four construction vessels per site, each greater then 80m in length, servicing the construction stage at any given time.

5.120. The objectives in developing the construction methods will be to:

- minimise construction related health and safety risks to personnel;
- minimise construction related environmental risks;
- minimise cost risk;
- minimise schedule risk; and
- maximise production.

5.121. To meet the above objectives, the following approach will be adopted in engineering the construction methods:

- address construction issues early in the design process, specifically including safety reviews;
- minimise offshore construction;
- maximise onshore assembly and pre-commissioning;
- standardise design and components;
- minimise interdependency of offshore operations; and
- optimise timing of offshore construction.

5.122. During all marine operations a relevant safety 'exclusion' zone will be applied for. As stated in Chapter 4: Legislation, Regulation, Policy and Guidance, the safety zones will be applied for and implemented in compliance with the Energy Act 2004 and the Electricity (Offshore Generating Stations) (Safety Zones) (Applications Procedures and Control of Access) Regulations 2007. The purpose of such safety zones will be to manage the interaction between vessels associated with the OWFs and other users / developments in order to protect life, property and the environment. The fundamental principle is that vessels will be kept at a safe distance from construction and commissioning activities related to the Seagreen Project in order to avoid collisions.

5.123. Temporary safety zones will be marked with a navigation buoy at each corner of the zone. The zone will be subject to a Notice to Mariners' as a temporary construction site and off limits to third parties. The zones will be advertised using the proper channels and liaison will take place prior to implementation with the relevant local sea users and bodies, including the port authorities.

5.124. A 500m 'rolling' safety zone (the maximum permissible under international law) around wind farm infrastructure and construction vessels will be sought during construction, major maintenance and decommissioning. A principle of rolling safety zones for construction will be applied to the Seagreen Project to reduce the extent of the area from which shipping will be excluded during construction of the OWFs and export cables. Non construction related traffic will be excluded from locations where construction activity is in progress. When construction is completed at that location, and access can be safely restored, the safety zone will be lifted. A subsequent safety zone may then be placed around the next location where construction activity will commence.

5.125. It is likely that temporary navigation lights will be fitted to structures during the construction stage. The detailed requirements have not yet been determined but confirmation will be sought from the appropriate bodies during development of the CHSPs.

OFFSHORE WIND FARM CONSTRUCTION

5.126. Prior to installation of any type of foundation and substructure, a pre-installation seabed survey will be required to confirm that no obstructions are present, such as unexploded ordnance (UXO), debris or large boulders. If obstructions are identified the area will be cleared and prepared for the intended installation activity or the foundation may be microsited to avoid obstructions. In addition, there may be a need to microsite the foundations to avoid sensitive ecological or archaeological features that are identified.

5.127. Seagreen recognises the potential link which has been made between the deaths of seals and the use of certain vessel propulsion designs. This issue extends across many marine sectors. Seagreen will continue to monitor the outcome of investigations into this issue and will develop construction vessel use strategies accordingly.

Foundation and Substructure Installation

Installation of Jackets with Driven and/or Drilled Tubular Piles

5.128. Piled steel jackets have been widely deployed to support offshore oil and gas platforms and are currently being used for WTGs. Jackets are normally fully assembled at a quayside and loaded onto a large flat top transportation barge, either vertically or on their side, for transport to the OWF site. The transportation barge is towed out to the installation location and the jacket is then lifted and lowered into position by an installation vessel. The installation vessel may also be used for transportation. Under base grouting or scour protection are not envisaged during the installation of piled jackets.

5.129. Typically, the piles are brought to the OWF site on transportation vessels or barges and installed using an installation vessel. On arrival at the OWF site, piles are lifted from the transport barge using the installation vessel's crane, moved to the vertical position and then lowered to the seabed for installation to commence. Piles do not normally require any seabed preparation. The most efficient method of installing a pile is to drive it into the seabed using a hydraulic hammer.

5.130. Alternatively, the installation vessel may pick up the piles directly from a port and transport them to the OWF site. This approach is more likely if the installation vessel can carry piles for several foundation sets and there is a suitable port within a short sailing distance. The installation vessel could be a jack–up barge, a monohull crane vessel, or a semi-submersible crane vessel (SSCV) as shown in Plate 5.18.

Plate 5.18 Image of the Saipem 7000 SSCV

Source: Saipem

5.131. A jack up barge or vessel will be likely to have up to six legs. Each leg will cover a 4.5m x 4.5m area of seabed with a typical penetration of 2m.

5.132. For pre-piled jackets, the piles are installed first by driving them through a re-usable template. Once the pile has been placed in position, the pile hammer is attached to the top and the pile is driven to the required depth. Depending upon the specific ground conditions, drilling may be required to supplement the pile hammering operation to achieve the required seabed penetration. Once the template has been removed, the jacket is then lowered into place and the legs stabbed into the piles.

5.133. Using pre-piled jackets has the advantage of breaking the installation schedule dependency between the supply of piles and substructures, which improves the efficiency of pile and substructure installation. It is also a less weather sensitive method and can be carried out throughout the year with a suitable vessel, although there would be more weather down-time in the winter months compared to the summer.

5.134. In the oil and gas industry, where one-off structures are the norm, piling is usually done once the substructure is in position. In this case the piles are driven into the seabed through sleeves on the substructure using a pile hammer. This post driven piling method is likely to be adopted for piling of OSP substructures. A heavy lift vessel (HLV) or SSCV (Plate 5.18) is likely to be used for lifting the substructure and topsides.

5.135. The whole operation to install one pile takes approximately 13 hours, including positioning the installation vessel and the piling hammer, placing the template or substructure and aligning the pile. Within this overall period the pile driving activity takes place over approximately 1 hour, depending on ground conditions. The complete piling operation for a four leg jacket is expected to take approximately 2 days. For the purposes of assessment, a maximum duration of up to two years has been assumed for the completion of all piling operations.

5.136. Drilling is an alternative method to install a steel pile. Drilling typically takes much longer than driving and requires careful control of drilling fluids and cement grout as well as the disposal of the drilling arisings. Seagreen will seek to adopt best practice in this regard. It is anticipated that drilling may be required at some locations in Project Alpha and Project Bravo if piled foundations are selected. A combined drill and drive piling operation for a four leg jacket could require up to 6 days.

5.137. Placement of a steel jacket on pre-driven piles will typically be done from a floating vessel (HLV or SSCV). The placement operation can be completed in under a day. The connection between the pile and the substructure is usually achieved by injecting cement grout into the annulus between the pile sleeve and the pile. This is likely to be done from the installation vessel and will take around one day per structure. Jacket installation can be carried out all year with a suitable vessel but the operation requires a longer weather window than pile driving alone (to allow grout to cure). Jacket installation is therefore more likely to take place in summer than in winter.

5.138. Few jack-up vessels are capable of working in the water depths found across the Project Alpha and Project Bravo sites. Typically those that are capable will be larger vessels similar in scale to the MPI Resolution (130m in length, 38m beam), illustrated in Plate 5.19.

Plate 5.19 Jack up construction vessel MPI Resolution

Source: MPI Offshore

Noise Emissions from Driven and/or Drilled Tubular Piling Activities

5.139. It is well established that some construction noise sources, such as impact piling, generate high underwater noise levels. It is therefore important to consider and document the potential impact of the construction noise as part of the overall EIA process. If driven piles are selected for substructure installation, generated underwater noise has the potential to affect a range of sensitive receptors (such as marine mammals and some fish species), which are considered later in this ES (Chapter 12: Natural Fish and Shellfish Ecology and Chapter 13: Marine Mammals). The ground conditions and applied loadings to the substructures will determine the diameter and length of pile and hence the size of piling hammer, the energy force that must be applied to the hammer and the required duration of piling operations. In combination, these parameters will determine the extent of noise emissions during the construction period for Project Alpha and Project Bravo. Predicted noise from piling operations is described in Chapter 12: Natural Fish and Shellfish Ecology and Chapter 13: Marine Mammals.

5.140. The energy applied by the hammer directly determines the noise generated during pile installation. With other factors such as the pile diameter being equal, noise emissions will increase as the size of the hammer and energy force applied to the pile increases.

5.141. For the purposes of EIA the available geotechnical information was reviewed and the mostly likely and worst case soil profiles were derived. Preliminary pile driveability studies were carried out based on the derived soil profiles which informed the selection of piling scenarios for assessment within the EIA. A reasonable most likely and worst case scenario have been determined, at two blow force energies, approximately 1,000 kilojoules (kJ) and 1,500kJ, respectively. The lower energy force represents a drill assisted operation whereas the higher energy force represents a fully driven operation.

5.142. It is anticipated that the 1,500kJ blow force will only be required where firmer seabed materials are encountered. Each tubular pile could warrant up to 2,500 hammer strikes, at a rate of approximately 45 blows per minute, to drive it to the required depth, dependent on pile size and ground conditions.

Suction Pile Installation

5.143. Suction piles will usually be integrated with the substructure during fabrication. Installation will then require a single operation which would normally be undertaken from a floating vessel (HLV or SSCV, see Plate 5.20) by use of Dynamic Positioning (DP). A jack-up vessel could be utilised but it would need a crane capacity in excess of 1,000 tonnes to lift a jacket with suction cans. Once placed onto the seabed and settled under its own weight, water would then be pumped out of the suction pile. This creates a pressure differential, with the pressure inside the pile lower than the pressure in the sea, which pushes the pile into the seabed. Suction pile penetration typically takes about 8 hours but the whole operation, including setting up and positioning would take approximately 1 day. There are also 'self-installing' suction pile concepts using a pontoon barge towed by an Anchor Handling Tug (AHT).

Plate 5.20 Installation of a tripod jacket on suction piles

Source: SPT Offshore

5.144. Scour protection for the suction pile would be placed as required around the foundation from a fall pipe vessel (Plate 5.21).

Plate 5.21 Typical fall pipe vessel

Source: Xero Energy

Installation of Gravity Base Structures (GBS)

5.145. The GBSs will be manufactured onshore. If GBS is being used for the foundation it may be integrated with the substructure during fabrication so that both components are transported to site as a single structure. Alternatively, the GBS foundation may be transported to site on its own and the substructure attached once the foundation is in place. The buoyancy of a hollow GBS base is an advantage during transportation and installation.

5.146. A GBS can be transported to site by a towed pontoon barge and then lifted into place on site by a separate vessel (HLV or SSCV). Alternatively, the lifting vessel can also provide transport to site. If the GBS is designed to be self floating, it can be towed to site by an AHT and lowered to the seabed by controlled ballasting using seawater. This will be followed by the addition of suitable granular ballast material to resist the long term loading regime. Ballast material for the GBS is likely to consist of sand. The ballast can also be removed from the GBS to allow decommissioning.

5.147. A GBS usually requires seabed preparation over the footprint area to ensure a uniform load distribution and vertical alignment (Garrad Hassan, 2011). This typically involves dredging to remove superficial sediments followed by rock and/or gravel placement to form a level footing. Specialist dredgers and rock placement vessels and generally sand and gravel will be used for these operations which would be monitored using Remotely Operated Vehicles (ROVs). The dredging and ground preparation method adopted will be determined through the detailed ground investigations undertaken post consent.

5.148. Site selection will seek to minimise the extent of ground preparation required. The anticipated maximum depth of ground preparation is up to 5m below seabed level where weak soils are encountered (up to eight WTGs with GBS' each in Project Alpha and Project Bravo sites). However, for the majority of the site for average strength soils an average seabed preparation depth of up to 3m is assumed.

5.149. The surplus material produced during the ground preparation and seabed levelling will be disposed of in-situ, either on the seabed adjacent to the substructure or re-used as a ballasting medium for the substructure. The materials likely to be produced from the seabed preparation for GBS' comprise deposits of sand and gravel with occasional potential for clay where present close to the surface. A separate application will be made to Marine Scotland for a dredging licence, if required, following more detailed studies. Seagreen will investigate the potential to maximise reuse of arisings from ground preparation as ballast.

5.150. Skirts around the perimeter of the GBS (to a depth of 5m) can be used to minimise or even remove the requirement for seabed preparation. These skirts also assist in the protection of the structure from scour. When skirts are used, grout is required to fill any gaps under the base slab.

5.151. Other GBS installation methods are under development by a number of companies. For example, Gifford BMT Freyssinet (GBF) has proposed a new concept (Plate 5.22) designed to enable the installation of GBS' in a single operation. This concept also provides the capability of installing a fully ballasted GBS and WTG in a single operation. There would be a significant capital cost for the purpose-built barge(s) but this approach could eliminate the need for a HLV and WTG installation vessel.

Plate 5.22 GBS and WTG installation barge concept

Source: GBF

5.152. The maximum vessel requirement for installation of GBS and integrated substructures would be a tow to site by two AHTs and assisted placement. Following installation of the GBS, scour protection will be installed to prevent seabed scour about the base of the structure if necessary. The time lag between GBS installation and scour protection installation would be kept to a minimum to reduce the risk of scour occurring around the structure.

Installation of Scour Protection

5.153. Scouring of soft surficial sediments may occur around foundations where localised increases in the near bed currents occur, resulting in increased erosion forming scour holes or scour tails. The pre-construction geophysical survey will ascertain the level of scour protection required for each location. Scour surveys will continue beyond the construction stage of the project and may form part of the ongoing inspection regime and monitoring for the OWFs.

5.154. If scour protection is required this will be achieved by rock placement around the foundation and the base of the substructures after installation. Rock placement will infill any scour pit which may have developed after installation and will create a rock berm above seabed level. This will be designed to remain stable for the full lifetime of the structure under all forms of predicted environmental loading.

5.155. The rock placement will be achieved using a fall pipe vessel (Plate 5.21) or a vessel with a side tipping system. On a fall pipe vessel, the rock is conveyed to the side of the ship and freefalls down a chain-mail pipe. An ROV positioned at the end of the pipe is used to adjust the delivery point relative to the ship. The combined movements of the ship and ROV are used to form the required design of scour protection. The fall pipe ROV is used to survey the position and shape of structures created, using acoustic profilers and other devices. Alternatively the rock could be placed using a grab device from a suitable vessel.

5.156. Following installation, the foundation area and the base of the structure will be resurveyed to confirm that the required coverage and rock profile has been achieved.

WTG Installation

5.157. There are several options available for installing WTGs. These are described in the following sections, however it should be noted that it is likely that new innovations in large scale offshore installation methods will emerge to improve WTG installation efficiency and safety.

Single Lift Installation

5.158. The complete WTG and tower are lifted onto the pre-installed foundation and substructure in one operation. The main advantage with this method is that some WTG commissioning work can be conducted onshore, therefore providing considerable time and cost savings. Beatrice Demonstrator Project in the Moray Firth was the first time that the concept of using a single lift installation was undertaken, therefore proving the feasibility of such an approach.

5.159. Single lift operations can be done from floating or jack-up vessels. A number of specialist vessel concepts for single piece installation are also under development such as Huisman's Wind Turbine Shuttle (Plate 5.23) and W3G Marine's OWTIS vessel (Plate 5.24). The floating vessels in particular offer better installation efficiency due to their speed and flexibility. A single lift operation would generally take less than 12 hours on site from a floating vessel.

5.160. The single lift WTG installation method is likely to require a large quayside facility for the reception of the major WTG components (nacelles, blades, towers and hubs) and subsequent assembly, pre-commissioning and load out of entire WTGs.

Plate 5.23 WTG Shuttle installation vessel

Source: Huisman

Plate 5.24 OWTIS WTG installation vessel

Source: W3G Marine

Stick Build Installation

5.161. The stick build approach comprises the installation of components during separate offshore lifts. This is currently the most common approach to constructing WTGs offshore and requires a jack-up vessel (to ensure appropriate stability of blades, rotor etc. while bolted flange connections are made up) and takes longer than a single lift.

5.162. A nearby quayside facility may also be required for this method to allow delivery of WTG components throughout the year. The jack-up vessel could pick up components from this facility or from a floating barge. If there is sufficient storage capacity at the WTG manufacturer's facilities, it may be possible to deliver components directly from the manufacturer's facility to the installation vessel offshore.

Meteorological Mast Installation

5.163. The approach adopted for installation of the meteorological masts and their foundations will be as for installation of the WTGs, described previously.

Array Cable Installation

5.164. Array cables will generally be buried using trenching, jetting or ploughing techniques as dictated by the ground conditions. Array cable installation is unlikely to take place before installation of the WTG foundations and substructures. However, if pre-piled jackets are used array cable installation could take place after the piles are installed and before installation of WTG substructures.

Array Cable Installation Procedure

5.165. A cable barge or a specialist cable installation vessel is likely to be required to install the cable into the seabed. Cables will be supplied on reels or loaded onto the vessel in one continuous length. The vessel will then travel to site and take up a position adjacent to the start location, for example a WTG or OSP. The vessel will either hold station using DP, or set anchors in a stationary mooring pattern.

5.166. One end of the array cable will then be floated from the cable reel towards the WTG substructure. The cable is then laid away from the WTG towards the next WTG in the string or the OSP. The cable installation vessel will either move under DP control or by hauling on its anchors. If the secondary method is used redeploying the anchors will be required.

5.167. Depending on the design of the WTG or OSP substructure, the cable will be sunk, then either lifted or pulled onto the substructure. Pull-in operations will be carried out using a small ROV or construction vessel. This will take place either after substructure installation or immediately after WTG installation. This operation can be carried out at any time of year, although there will be more weather downtime in winter than in summer.

Pre-installation Works

5.168. The preferred array cable routes will be surveyed during the pre-construction geophysical survey to locate any obstacles that could obstruct cable laying, such as rocks, wrecks, metal objects or debris and UXO. If an obstruction is located it will be assessed and an appropriate strategy will be established to remove or avoid the obstruction. Where a suspected UXO is identified specialist mitigation will be employed to either avoid or make safe the obstruction.

5.169. The geophysical surveys will also serve to identify the location of sand waves along the cable routes so that an assessment can be made as to whether such features can be avoided or if not, what level of seabed preparation (pre-lay sweeping) is required to ensure burial depth is achieved in stable (i.e. non mobile) seabed conditions. Prior to the cable installation, burial trials may be conducted in advance of the main installation programme. This will ensure that the chosen equipment is suitable for the ground conditions encountered and that burial depth can be achieved, in the absence of an established track record of successful installations. If undertaken, this could involve tests to bury sections of cable up to 1km in length in the soil types likely to be encountered. Following the trials the test piece will be completely removed from the seabed.

Array Cable Installation Methods

5.170. Different approaches and techniques are available for cable installation. These are:

- simultaneous cable lay and burial, using a cable plough or a mechanical trencher; and
- cable lay with subsequent burial using a jetting ROV or a mechanical trencher.

5.171. A combination of methods may be used for cable installations, depending on ground conditions. The preferred approach will be confirmed on completion of the pre-construction geotechnical site investigation surveys.

5.172. The rate at which cables can be installed is dependent on many factors, including:

- the target cable burial depth;
- the selected installation technique and approach;
- the type and properties of soils encountered; and
- operational constraints (e.g. weather conditions).

5.173. Table 5.17 below provides some typical average cable installation rates for three trenching tools. However, these figures should be taken as indicative only at this stage given that the selection of trenching tool will take place following geotechnical site investigation surveys and the installation approach is still to be confirmed.

Table 5.17 Typical cable installation rates

Trenching tool	Soil Description	Average Ranges of Trenching Speed (metres per hour (m/hr))
Cable Plough	Very soft to hard clay Loose to very dense sand	225 – 550 150 - 450
Jet Trencher	Very soft to stiff clay Very loose to very dense sand	60- 250 80 – 560
Mechanical Cutter	Stiff to hard clay Loose Sand	200 – 400 500

Cable Burial by Ploughing

5.174. Cable burial ploughs cut through the seabed, lifting the soil from a trench into which the cable is laid (Plate 5.25). The plough is designed to cut a narrow trench, with a slot of material temporarily supported which then falls back over the cable. The advantage of this method is that burial can be achieved as the cable is laid, thus minimising risk to the cable. However, the number of vessels which can carry out this method and that have the required cable carrying capacity for heavy power cable is limited.

Plate 5.25 Cable plough illustration

Source: Xero Energy

5.175. The performance of a plough and the depth of burial which can be achieved are a function of plough geometry and seabed conditions, with dense or stiff soils providing the greatest challenge. This operation is relatively slow and can be interrupted if weather conditions deteriorate.

Cable Burial by Jetting

5.176. Where the seabed predominantly comprises soft sediments the array cables could be buried using a post-lay jetting technique, generally controlled from a DP vessel. The cable is laid on the seabed and a ROV fitted with high-pressure water jets is subsequently positioned above the cable (Plate 5.26). The jets fluidise a narrow trench into which the cable sinks under its own weight. The jetted sediments settle back into the trench and with typical tidal conditions the trench coverage is reinstated over several tidal cycles.

5.177. The advantage of this method is that the cable can be laid in a relatively rapid operation during suitable weather conditions. Cable burial can then be achieved separately with less concern over weather constraints disrupting operations. However, the performance of a jetting ROV is limited where sediments are more compacted.

Plate 5.26 A jetting ROV

Source: Xero Energy

Array Cable Burial Depths and Trench Widths

5.178. Cable burial depth will be determined by a detailed hazard identification survey, which will assess the different locations and the various shipping and dredging activities. It is possible that the hazard identification survey will identify places where the cable burial depth may vary due to local features, such as:

- sand waves;
- erosion of the seabed;
- intense dredge or trawl fishing activities; and
- existing infrastructure or observed seabed obstacles.

5.179. The array cable burial depth will be between 0.5m and 2.1m depending on ground conditions and the outcome of further burial risk assessments. Based on current understanding of ground conditions it is expected that at least 90% of the array cable will be buried.

5.180. If buried, the estimated maximum trench width will be 3m and the maximum width of the temporary zone of influence, due to plough or ROV tracks, will be 10m.

Alternative Array Cable Protection

5.181. Achieving satisfactory array cable burial depths may not be possible in some areas and in close proximity to the WTGs and OSPs. The measures which may be utilised for the cable protection where burial is not achieved are:

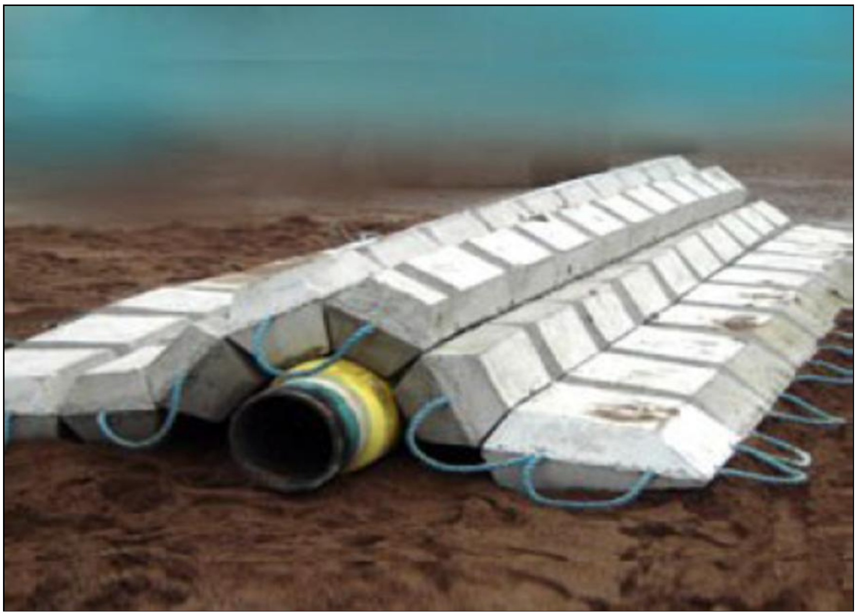
- placement of concrete mattresses over the cable;
- rock placement to cover the cable on the seabed; or
- placement of grout bags over the cables which are then inflated with structural grout. The grout cures to provide an effective over cover protection system for the cables.

Concrete Mattresses

5.182. Mattresses are generally made of concrete elements formed on a mesh of polypropylene rope, which will conform to changes in seabed morphology (Plate 5.27). Bevelled elements are used on the edges to create a lower profile to encourage, for example, trawl gear to roll over the mattress. Where appropriate, mattresses fitted with polypropylene 'fronds' can be used to enhance the protection provided. The fronds encourage sediment deposition, in the best case creating a protective sand bank. Mattresses require placement either by divers or ROV to ensure that they are positioned correctly, consequently this takes longer than other methods.

5.183. The maximum height of any mattressed array cable protection is expected to be 1m above the seabed, with a maximum width of 7m.

Plate 5.27 Cable protection using concrete mattresses



Source: Xero Energy

Rock Placement

5.184. Rock placement has long been established as a method for protecting cables. It is a relatively quick operation and is not as weather dependent as mattressing. The rock used is normally imported from land quarries, although sea aggregates can also be used, with grain sizes being tailored to achieve the necessary protection. Where water depth is not a limiting factor, rock is usually deposited by a fall pipe vessel as this is the most efficient method of getting the material onto the seabed (see Plate 5.21). In shallower waters (<10m) a specialist vessel fitted out with basic equipment for pouring the aggregate over the side may be used (Plate 5.28).

5.185. The maximum height of any rock placement array cable protection is expected to be 1m above the seabed, with the maximum width of up to 7m.

Plate 5.28 Rock dump vessel for shallow water

Source: Xero Energy

TRANSMISSION ASSET CONSTRUCTION

OSP Installation

5.186. The foundations and substructures for OSPs are likely to be installed in a similar manner to those for the WTGs, although the vessels involved are likely to be larger as the structures will be heavier. The use of pre-driven piles is unlikely for OSPs. The deck or topsides are likely to be installed using a floating crane vessel (HLV or SSCV), most likely with DP. It is possible that the same vessel may install all the components of an OSP, particularly if a steel jacket with driven piles is used.

5.187. In the event that driven piles are used, the maximum number of piles to be installed under Scenario 1 (one 1,075MW HVDC circuit) which includes the maximum number of OSPs required for Project Alpha and Project Bravo, would be 72 piles. This corresponds with:

- a jacket structure for the one DC convertor OSP, which would be supported by up to twelve legs with two piles per leg; and
- a jacket structure on each of the four AC collector OSPs, which would be supported by up to six legs with two piles per leg.

5.188. An alternative OSP installation method could use 'skid' beams to slide the deck across to the jacket from a jack-up alongside. This method does not require the topsides to be lifted and therefore allows a wider range of installation vessels to be considered as there is no requirement for a crane.

5.189. The major components could be transported from the fabrication yard to the OWF sites on the deck of the construction vessel. Alternatively, the topside could be floated into position on a barge and then lowered with jacks or the barge ballasted down to allow topside to locate on the substructure. For this method there is no lift requirement.

5.190. A further possible approach would be self installation whereby the platform is floated out to the OWF site using tugs and when in the required position it is ballasted down and ballast adjusted in position.

Export Cable Installation

5.191. The transmission asset export cables will comprise the power export cabling from the OSP to the landfall site. This also includes any inter-connecting cabling between OSPs and collector station within the OWFs sites. The export cables will be rated at up to 275kV AC or up to 220kV DC as defined previously in Section 'Transmission Asset Infrastructure' for the connection scenarios under consideration. Up to six export cables will be installed, depending on the electrical connection design selected. The distance between adjacent export cables is likely to be around two times the water depth. The export cable installation operations will take place sequentially due to their limited separation.

5.192. Installation of the export cables will utilise the same methods as for the array cables, described in Section 'Offshore Wind Farm Infrastructure, Meteorological Masts and Wave Buoys'. The export cable burial depth will be between 0.5m and 3m depending on ground conditions and the outcome of burial risk assessments. Based on current understanding of ground conditions it is expected that at least 90% of the total export cable length will be buried. For sections of the cable route where burial is not achievable, rock dumping or mattressing will be adopted as described previously.

5.193. The cable installation vessel's ability to get close to shore is dependent on an individual vessel's draft, but the depth limit is typically around 10m. At this point in the installation operation the vessel will hold its position either by use of DP or anchors while the cable is floated to shore. If a cable barge is used this will have a shallow draft that will enable access near to shore. Within the 2 year period identified in Table 5.15 it is anticipated that the total duration of construction activity to complete installation of the offshore export cable will be 9 months.

5.194. At the Carnoustie landfall location horizontal directional drilling (HDD) will be used to install ducts from the transition pit location (located above MHWS and subject to a separate planning application) under the existing sea defences and out to approximately MLWS tidal limit. The cables will be pulled to shore from an offshore vessel suspended by floats. The cables will be installed in ploughed or excavated trenches up to the entrance to the ducts, and then drawn through the ducts to the transition pit by winches.

5.195. In either the intertidal area or the shallow subtidal water, a backhoe excavator may be used to dig the trench at each duct entrance. Beach access may be required, particularly for trench excavation. This may be achieved via temporary local access over the coastal defence or by use of an existing point of access nearby.

5.196. For any HDD operations the maximum drill rig area is expected to be of the order of 50m by 50m (Plate 5.29). The equipment to be used includes a drilling rig, a mechanical excavator, and winches to install ducts and draw the cable. The drill rig will be located on shore at the position of the onshore transition pit.

Plate 5.29 Example of a HDD rig

Source: Xero Energy

OFFSHORE WIND FARMS AND TRANSMISSION ASSET COMMISSIONING

5.197. Commissioning will generally comprise the following process, with procedures formalising the different stages:

- a mechanical, visual and electrical continuity assessment;
- an energisation programme;
- testing mechanical, electrical and control functions;
- identification of faults;
- rectification of faults;
- re-testing; and
- certification.

5.198. The commissioning of Project Alpha and Project Bravo and the Transmission Asset Project, will be in accordance with approved commissioning procedures. This will be managed by the principal contractor(s) for construction of each project to the requirements of Seagreen and the OFTO, where applicable. All commissioning activities will be the subject of an approved safe system of work. Commissioning activities will include the WTGs performance and reliability testing and compliance with the Grid code standard.

OFFSHORE WIND FARMS AND TRANSMISSION ASSET O&M

5.199. The O&M information provided is based on best available information at the time of writing, as described in the Seagreen Operations EIA Input Report (Seagreen, 2012b). This is drawn from current operational knowledge in addition to reflecting regulatory requirements and industry best practice (Seagreen, 2012b). The information provided covers:

- likely navigation requirements and markings for operations stage;

- usual offshore operational lighting requirements;
- likely WTGs access facilities;
- OSPs likely colours, markings and signage;
- OSPs likely access facilities;
- pollution prevention;
- O&M outline strategy;
- onshore O&M requirements;
- onshore transport requirements;
- WTGs access by air; and
- O&M stage vessel movements.

5.200. The O&M port and onshore facilities may be shared by the operators of Project Alpha and Project Bravo. However it is possible that separate facilities will be used. The description of O&M port facilities, onshore O&M requirements and onshore transport requirements are provided for information only. Consideration of these is out with the scope of this ES (see Chapter 6: EIA Process of this ES).

5.201. Reliability and ease of maintenance are both design issues. Maintenance is required as a consequence of design, thus, it is crucial to address this at the early stages of the project. The primary objectives of the O&M activities will be to:

- operate OWFs in a safe manner, causing minimal impact on the environment;
- effectively convert wind energy to electricity and accurately measure and deliver electricity for sale;
- maximise output while controlling operating expense;
- safeguard the mechanical integrity of all facilities, substructures and installations;
- maximise the use of appropriate technologies to improve the efficiency, safety and effectiveness of all operations, transport technology and maintenance activities; and
- minimise manning and personnel transport to appropriate levels (as far as is reasonably practicable).

5.202. Once commissioned, the OWFs will operate automatically with each WTG operating independently of the other. The operation and control of the OWFs will be managed by a Supervisory Control And Data Acquisition (SCADA) system, connecting each WTG to the onshore control room(s). The SCADA system will enable the remote control of individual WTGs, the OWFs in general, as well as remote interrogation, information transfer, storage and the shutdown/ restart of any WTG if required. In addition to the WTGs, the OSPs and any meteorological masts will also be monitored and maintained.

OWF Marine Control and Safety

5.203. The following description applies to both Project Alpha and to Project Bravo.

OWF Lighting, Marking and Signage

5.204. NLB marine navigation requirements for WTG structures are covered in International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) Requirement O-139 'The Marking of Man-Made Offshore Structures' (IALA, 2008). At this stage it is assumed that all markings and signage will comply with these requirements as a minimum. It is also a requirement to include fog warning devices.

5.205. All lighting of WTGs and offshore structures will comply with IALA O-139 for marine lighting requirements and Civil Aviation Authority (CAA) Civil Aviation Publication (CAP) 393 and 764 (CAA, 2010 and CAA, 2012 respectively) for aviation lighting requirements. These standards should be used as the reference for any lighting requirements at this stage. Marine Guidance Note (MGN) 371 (Marine and Coastguard Agency (MCA), 2008) identifies the requirements for the design and construction of an OWF.

5.206. WTGs and OSPs will have Unique Identification Characters (UIC), including a numerical identification clearly visible from a vessel and from the air. UICs will be illuminated during the hours of darkness, if required. This lighting will be hooded or baffled to avoid confusion with navigation marks.

5.207. Wherever deemed necessary by the authority, buoys or beacons shall be placed to mark the perimeter of a group of structures, or to mark routes or channels through a group of structures. Significant Peripheral Structures (SPS) at the corner or other significant point and Intermediate Structures (IS) between these on the periphery of the OWF will be marked by yellow flashing lights as defined by IALA requirements. The separation between SPSs should not exceed 3 nautical miles (NM) and the separation to ISs should not exceed 2NM.

5.208. Each structure will be provided with fog horns that will operate automatically when the meteorological visibility is 2NM or less.

5.209. For any semi-permanent structures, markings will also comply with the NLB requirements, most likely IALA O-139.

Anchorage and Safety Zones

5.210. It is likely that Seagreen will apply for an operational safety zone of 50m around each OWF structure in accordance with the relevant guidance from DECC. Through the application for consent, Seagreen will seek to extinguish the rights of navigation within these distances of each structure in order to establish the desired safety zones. This will be done in accordance with section 36A of the Electricity Act 1989.

5.211. During maintenance operations this will be extended to 500m (the maximum permissible under international law) around the relevant structures. Once the OWFs are operational, an Automatic Identification System (AIS) and closed circuit television (CCTV) from an onshore O&M Control Centre(s) will be in place to monitor vessel movements within the OWFs. The fundamental principle is that vessels will be kept at a safe distance from commissioning and operational activities related to the OWF in order to avoid collisions.

5.212. During the operational stage it is likely that a larger support vessel may be required for planned and unplanned maintenance activities. It is likely that several pre-determined areas will be identified and marked as temporary anchorage areas, such that before manoeuvring into final position, an initial mobilisation point is widely known. As detailed planning moves forward it is possible that a mother vessel concept could be adopted whereby a larger vessel is semi-permanently positioned offshore and the day to day service activities are run from smaller daughter craft from the mother vessel saving transit time back and forth to a local port.

OWF Marine Control Centre

5.213. A Marine Control Centre(s) for the OWFs will have AIS, video surveillance and radar coverage which will identify vessels with AIS facilities entering into the safety zone during O&M activities. This will be in addition to any visual observation made by personnel on O&M vessels or guard vessels working within and around the area. Any vessel identified or observed to stray in to the safety zone will be contacted by a designated member of the crew of the O&M vessels or guard vessels or from the Marine Control via multi-channel Very High Frequency (VHF) radio, including digital selective calling, and warned that they have encroached the safety zone. They will be instructed to divert their course out of the safety zone. Vessels which ignore this warning and are considered to be causing a potential danger will be further requested and then the details of the vessel reported to the MCA enforcement unit.

5.214. AIS and CCTV from Marine Control Centre(s) will be in place during operation of the OWFs, which will be used to monitor vessel movements.

Access Strategy for Offshore Infrastructure

5.215. The WTGs will be designed to operate unmanned and are expected to be available to produce electricity for at least 95% of their installed life time. Planned outages for a WTG will be triggered primarily by routine maintenance requirements, but also occasionally at the request of the Maritime Rescue Co-ordination Centre (MRCC) in support of Search and Rescue (SAR) activities in the area. The WTGs will normally shut down during severe weather conditions when wind speeds exceed 35m/s to avoid damage to the WTG components. This will be controlled remotely.

5.216. Access strategies will be developed and will include both work boats and helicopters. The work boats will be used for routine maintenance operations and in weather conditions up to approximately 2m wave height. It is also expected that there will be provision for emergency accommodation on the OSPs for up to 12 personnel, with associated welfare facilities. Indicative work force numbers, vessel sizes and vessel movements are given in Table 5.18.

Table 5.18 O&M indicative parameters for Project Alpha and Project Bravo

O&M Range	Alpha		Bravo	
	Min	Max	Min	Max
Total number of offshore technicians	95	140	95	140
Number of service vessel required	6	8	6	8
Length of service vessels (m)	18	24	18	24
Average number of vessel movements* per annum	1,320	1,760	1,320	1,760
Size of support vessel (m) (2x daughter craft)	70	80	70	80
Size of helicopter pad (m)	11.9	12.7	11.9	12.7
Maximum number of wave buoys required	3	3	3	3

*One vessel movement is equal to one to- and from- OWF site trip.

5.217. In order to optimise site availability and generating capacity there may be a requirement to use helicopter access to ensure site availability requirements, through personnel and material transfer via winching operations. The OSPs could be fitted with a helipad and helicopter refuelling capability (see CAP 748 'Aircraft Fuelling and Fuel Installation Management' (CAA, 2004)), this will maximise the helicopters operational potential as a base for internal transfers within the OWFs and refuelling.

5.218. Larger spares and equipment could also be delivered directly to the OWF sites from land based manufacturers by sea, using a crane ship or alternative suitable lift vessel.

5.219. Detailed evaluation is planned to identify the best access strategies for the Seagreen Project. This will consider the experience and lessons learned from other constructed OWFs. The use of a 'mothership solution' will also be considered and modelled. Until this evaluation is complete it has been assumed that site access is likely to be a combination of the methods outlined below.

Access by Work Boat

5.220. Work boats, 18m - 24m in length, are typically used for daily transfer of personnel. Larger vessels are also now entering the market and will be considered (up to 50m in length). Personnel transfer to and from the WTG or OSP boat landing will be via a fender arrangement on the bow of the vessel.

Access from Mothership

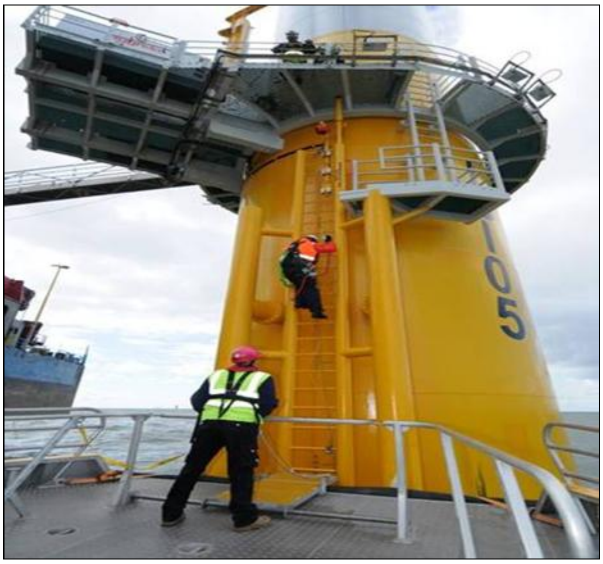
5.221. The mothership concept would operate from a larger port facility with personnel working a shift rota pattern. The mothership would be around 65m - 85m long and would accommodate the maintenance personnel, provide an onboard control room facility and provide the main stores location for the OWF sites. It would also be fitted out with a number of work boats and associated launch and recovery system, which would be the primary means of personnel transfer, supplemented by helicopter support when necessary. The mothership would be resupplied when alongside for crew changes.

Personnel and Access to WTGs

5.222. For maintenance purposes the WTGs are likely to be accessed primarily by work boats with helicopters providing a secondary means of access. The WTG substructure is likely to be equipped with one or more boat landings and ladders, dependant on a number of factors such as prevailing wave and tide conditions, acceptable foundation loadings and the potential use of helicopters as a secondary access method.

5.223. Plate 5.30 shows a workboat WTG landing operation at a monopile WTG tower design. The Seagreen Project will not use a monopile solution, but the principle of access still applies to the WTG foundation options being considered by Seagreen.

Plate 5.30 A workboat landing operation at Greater Gabbard OWF



Source: Greater Gabbard OWF

Personnel and Access to OSPs

5.224. It has been assumed that the OSP will be fitted with boat landing(s) and a helipad according to standard guidance CAA CAP 437 (CAA, 2012) for personnel access.

5.225. Helideck structures should be designed in accordance with International Civil Aviation Organization (ICAO) requirements (the Heliport Manual (ICAO, 1995)), relevant International Standards Organization (ISO) codes for offshore structures and, for a floating installation, the relevant International Maritime Organization (IMO) code. It has been assumed that the OSP will be fitted with boat landing(s) and a helipad that will comply with the CAA CAP 437 standard/ guidance for personnel access (CAA, 2012).

5.226. The maximum size and mass of helicopter for which the helideck has been designed should be stated in the Installation/ Vessel Operations Manual and Verification and/ or Classification document. Prior to operational use the landing pad will be certified by the Helideck Certification Agency (HCA). To maximise the safety and operational capability of potential helicopter use it is desirable to include on the OSP facilities that will allow refuelling of the helicopter. This will mean additional spill and fire protection systems being designed into the OSP from the outset.

5.227. OSP colour and marking are described earlier in this section. If the OSP is greater than 63.9m above LAT in height, for aviation purposes the CAA require that it should have at least one medium intensity steady red light positioned as close as possible to the top of the fixed structure primarily obstacle lighting for use at night.

Vessel and Helicopter Movements

5.228. For the daily transfer of personnel and materials from the onshore O&M base(s) to the OWF sites and back by work boat, an average potential of 1,760 vessel movements may be required per annum. This assumes vessels of the order of 24m for up to 30 personnel are used and assumes that a total of eight vessels are required to service each OWF site, based on accessibility of approximately 220 days per annum.

5.229. If a mothership is deployed, it is assumed that the vessel would undertake a crew change and resupply every two weeks.

5.230. If identified as appropriate for the project to supplement the workboat and mothership solution, helicopters may be used to transfer personnel and materials from the helipad at the O&M base or nearby airport. Based on current market data there is a conservative estimate that the WTGs will require an average of six visits per annum, it is assumed two of these visits will be by helicopter, however, this will need to be verified through modelling once the offshore layout is finalised.

5.231. A jack-up or crane barge will be required on an ad-hoc basis for potential maintenance of major components, such as replacement of a blade, gearbox or generator.

O&M Activities

5.232. O&M of the OWFs after commissioning will comprise of both scheduled and unscheduled events. Scheduled works on the WTGs and offshore electrical infrastructure will include annual or bi-annual maintenance, statutory inspection and routine inspection visits. When necessary, retrofitting and upgrading works may also take place. The scheduled works will normally be timetabled for the summer months, given the typically more settled weather and longer day light hours. 24 hour working will also be evaluated, as this type of solution could be delivered from a mothership stationed offshore.

5.233. The number of required technicians is expected to be between 95 and 140, dependant on the WTGs selected. Exact maintenance requirements for larger capacity WTGs are not known at this stage. There will also be a core operations team of approximately 40 staff based at the onshore O&M Control Centre to manage and support all aspects of OWF operation.

5.234. The current technology of WTGs will require a major service every 12 months; they will also require periodic visits in the event the WTG experiences a fault which cannot be remotely reset. In addition WTGs will require gearbox oil changes every 5 years. In certain circumstances large components such as gearboxes and blades may also need to be replaced. In this case a large crane vessel or jack-up, similar to that used for WTGs installation, will be used to carry out the necessary works.

5.235. Unscheduled repair activities will range from attendance on location to deal with the resetting of false alarms to major repairs. The frequency of unscheduled activities is expected to be highest in the early years of operation, when WTGs are first commissioned and require servicing.

5.236. At least two service personnel will be on an offshore structure during any visit for safety reasons. In order to achieve the maintenance programme, it is anticipated that O&M teams will be working simultaneously on several WTGs (and potentially also on the OSPs). It is therefore expected, that when access is being achieved by boat for O&M works, at least two vessels will be on-station within the OWF site at all times for safety reasons.

5.237. The Project Alpha and Project Bravo operators will have an O&M team in place for the day to day management and control of the OWF infrastructure. This is expected to be based in purpose built onshore O&M Control Centre facilities, ideally situated on the quayside at the chosen operations port location. If there is no local airport or heli-port available, this facility could also accommodate the helicopter hangar and heli-pad if required.

5.238. In order to manage the post consent and ongoing site monitoring requirements it is likely that a combination of dive support vessels and ROVs will be used to undertake inspection of foundations, scour protection, cables and any other subsea infrastructure.

5.239. Transport of the WTG major components for replacement will normally take place by sea. It is expected that these will be shipped from the manufacturing base and loaded onto the vessel from larger ports for transport directly to the OWF sites. There will therefore be a need to use large vessel mounted cranes in order to replace defective components such as generators, gearboxes and blades. Detailed planning of the work and travelling time will be undertaken to keep transit as short as possible and maximise available durations for lifting operations and installation activities.

Pollution Prevention and Waste Management

5.240. Pollution prevention should be controlled and mitigated from the design stage onwards. For example, the WTG nacelle frame typically will be designed and manufactured with a bund incorporated which can hold the full oil content of the gearbox in the event of a catastrophic failure. Additionally, if any oil filled transformers are used, the area will be bunded to contain any oil leaks.

5.241. The staff and vessel crew should be trained and equipped to use spill kits in the event of a break in containment occurring. This will be closely supported by a safe system of work which will be governed by a full risk assessment and method statement process. Additionally, the work relating to the WTGs will specifically be controlled and managed via the Wind Turbine Safety Rules. In the event of the safe system of work failing or a catastrophic incident occurring it is assumed that a spill response contract will be in place to control, manage, recover and dispose of any contaminants and dropped objects.

5.242. There will also be a waste management procedure which will be administered and managed to ensure it is strictly adhered to by site staff, contractors and visitors to the OWF sites and onshore O&M Control Centre(s).

5.243. All material used in the O&M of the OWFs, that is classified as waste when it reaches the onshore O&M Control Centre(s), will normally then be segregated and disposed of through a contract placed with an approved waste management company.

OSP Discharges

5.244. A sump with a separator will be incorporated on the OSP drainage system, as has been done at other constructed OWFs. The sump separates contamination from the waste water, with the oily waste stored ready for disposal and the clean water discharged overboard. There is an oil sensor in the discharge which will trip the discharge valve shut ensuring that no oil waste is discharged to sea above a defined threshold.

5.245. All other waste is contained and recovered and disposed of onshore. It should also be considered during the design stage for a macerator or treatment facility to be incorporated in the design to allow discharge of black water. This would greatly reduce site operational requirements and transfer of effluent at sea which is in itself a risk.

Weather and Sea Conditions Monitoring

5.246. Data from meteorological masts and wave buoys and current monitoring equipment will be used to support operations throughout the life of the OWFs. Aside from the normal requirement for the meteorological mast to be equipped with wind measurement devices, consideration will also be given to measuring wave height, direction, period and frequency and also tidal flow and direction and water temperature.

O&M Port Facilities

5.247. This information is provided for information only. The consideration of O&M port facilities is out with the scope of this ES (see Chapter 6: EIA Process of this ES).

5.248. For the Seagreen Project a number of ports could offer all the necessary services to locate the onshore O&M Control Centre(s). A port study will be commissioned to assist with determining the optimal location for the onshore O&M Control Centre(s) with the key factors in the choice being:

- close location to the OWF sites, thus minimising the time spent travelling to and from the OWF sites;
- protected harbour;
- good tidal access and depth of mooring;
- suitable and sufficient berthing for the service vessels; and
- knowledgeable workforce, experienced in offshore activities.

5.249. A further requirement would be the availability of sufficient space for construction of a building to house a control room and office space along with stores, a workshop, and wet/ dry room facilities. The selected onshore O&M Control Centre(s) location will also enable good infrastructure links, such as communication networks and transport links.

Onshore O&M Requirements

5.250. This information is provided for information only. The consideration of onshore O&M requirements is out with the scope of this ES (see Chapter 6: EIA Process of this ES).

5.251. It is estimated that the required onshore O&M Control Centre(s), including the onshore control room, would have a total floor space of approximately 2,800m^2. This would comprise approximately 1,600m^2 for warehousing and workshops, a holding depository for spares, consumables, repair equipment and personal protective equipment, with the remaining floor space dedicated to office space and amenities. A secure, external storage area (circa 4,000m^2), adjacent to the onshore O&M Control Centre(s) will also be required.

5.252. The following duties will be managed from the onshore control room:

- site monitoring (including CCTV);
- marine coordination;
- helicopter coordination (if required);
- work control;
- HV network management;
- logistics; and
- stores.

5.253. The onshore O&M Control Centre(s) will be located close to the quayside and will also have bunded fuel storage for the vessels and aviation fuel if helicopters are used. There is also a requirement for a quayside lifting capacity for transfer of material and spares to and from the service vessels. There will also be a pontoon and walkway as part of the infrastructure for vessel berthing and personnel access.

Onshore Transport Requirements

5.254. This information is provided for information only. The consideration of onshore transport requirements is out with the scope of this ES (see Chapter 6: EIA Process of this ES).

5.255. The onshore O&M Control Centre(s) will need suitable 24-hour access for deliveries by large road vehicles as well as for access by sea and potentially by air. The manning levels will increase as the OWFs enter their commissioning stage and peak during handover from construction to operations. Different types of vehicles will visit the onshore O&M Control Centre(s) location at different stages of development. These may include:

- large trucks used for delivery of spare parts and consumables during the initial set up and major maintenance campaigns;
- fuel deliveries, typically one tanker per week, to maintain the workboat supply. Deliveries may increase in frequency. This may increase to daily deliveries during periods of intensive maintenance activity;
- resupply of stores with spare parts and consumables on a daily and weekly basis, typically utilizing one truck per visit. Deliveries will peak during preparation for maintenance campaigns;
- during the onshore O&M Control Centre(s) set-up a large crane may be present onsite to provide material transfer around the centre(s); and
- during the onshore O&M Control Centre(s) stocking and completion stage there will be typically two medium to large delivery vehicle arrivals per day.

REPOWERING

5.256. The operational life of Project Alpha and Project Bravo is anticipated to be 25 years. All elements of the OWFs will be designed with a minimum operational life of 25 years. The Crown Estate site lease is for 50 years.

5.257. Towards the end of the operational life of the OWFs a decision will be made by the operating companies to proceed with decommissioning or to apply to the relevant Regulatory Authority at the time to repower the OWF. Should repowering be sought for either OWF then an investigation would be undertaken as to the possible options for repowering. This would be subject to a separate consenting process.

DECOMMISSIONING

5.258. The requirement to decommission is a condition of The Crown Estate lease and is also incorporated in the statutory consenting process through the provisions of the Energy Act 2004, (Part 2, Chapter 3). Under the statutory and licensing processes, Project Alpha and Project Bravo operators and the appointed OFTO will be required to prepare detailed decommissioning plans and set aside funds for the purposes of decommissioning in accordance with the Guidance Note for 'Decommissioning Offshore Renewable Energy Installations under the Energy Act 2004' (DECC, 2011).

5.259. The decommissioning plan will consider the latest technological developments, legislation and environmental requirements at the time that the work is due to be carried out. For the purposes of the current consenting framework and as a basis for the Seagreen Project EIA, a high level decommissioning programme based on the current technological and regulatory framework is outlined below.

Decommissioning of WTGs

5.260. The removal of the superstructure is expected to be the reverse of the installation procedure:

- conduct assessment on potential hazards during the decommissioning work and pollutants to the environment that may result from the decommissioning work;
- mobilise suitable vessels to the OWF sites;
- remove any potentially polluting or hazardous fluids/ materials from the WTGs (if identified in the risk assessment);
- remove rotor blades;
- remove nacelle;
- remove tower sections; and
- transport all components to an onshore site, where they will be processed for reuse / recycling / disposal.

Decommissioning of OSP Topsides

5.261. The methodology for removal of the OSP topsides is likely to be as follows:

- conduct assessment on potential hazards during the decommissioning work and pollutants to the environment that may result from the decommissioning work;
- isolate / disconnect from the grid and SCADA;

- remove any potentially polluting or hazardous fluids/ materials (if identified in the risk assessment);
- mobilise suitable HLVs to the OWF sites;
- remove main topside structure; and
- transport to an onshore site, where it will be processed for reuse / recycling / disposal.

Decommissioning of Substructures and Foundations

5.262. It is currently envisaged that piled foundations will be cut below seabed level (using methods such as abrasive water jet cutter or diamond wire cutting) with the protruding section being removed. Complete removal of driven piles is not expected to be practical or desirable. The use of explosives in removing the piles is discounted due to the likely damage to the environment.

5.263. Removal of GBS foundations will require removal of the ballast and the GBS refloated. It will then be towed to an approved destination for re-use, recycling or disposal as appropriate.

5.264. Suction pile foundations are likely to be lifted and removed using a HLV by reverse installation.

5.265. It may be preferable to leave any scour protection around the substructures bases or covering cables in-situ in order to preserve the marine habitat that has been established over the life of the OWF (subject to discussions with regulators and advisors at that juncture).

Removal of Offshore Cabling including Export Cabling

5.266. Discussions will be held with stakeholders and regulators to determine the exact locations where offshore cables should be removed. Cables may be left in situ if considered appropriate, or they may be wholly or partially removed. Throughout the project life-cycle, the burial depth will be closely monitored. A typical cable removal programme will include the following:

- identify the location where cable removal is required;
- removal of cables: Feasible methods include pulling the cable out of the seabed using a grapnel, pulling an under-runner using a steel cable to push the electrical cable from the seabed, or jetting the seabed material; and
- transport cables to an onshore site where they will be processed for reuse / recycling / disposal.

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