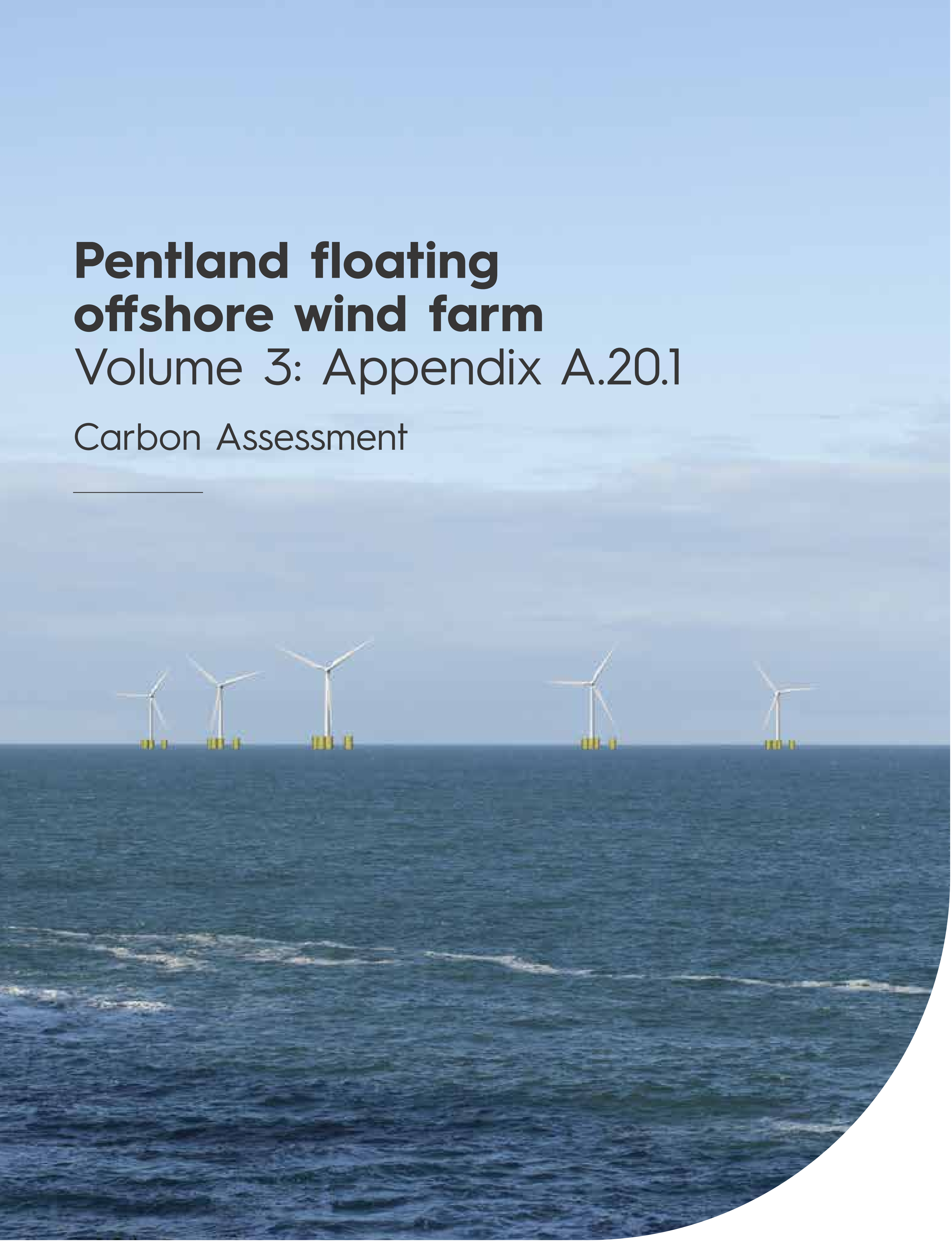
Pentland floating offshore wind farm

Volume 3: Appendix A.20.1

Carbon Assessment



PENTLAND
FLOATING
OFFSHORE
WIND FARM

OFFSHORE EIAR (VOLUME 3): TECHNICAL APPENDICES

APPENDIX 20.1: CARBON ASSESSMENT

Document Title:	Pentland Floating Offshore Wind Farm Offshore EIAR
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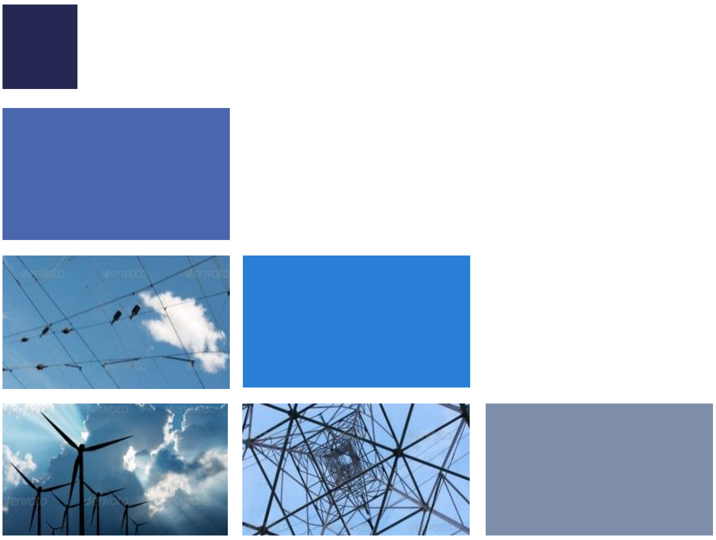

CONTENTS

EXECUTIVE SUMMARY

The Pentland Floating Offshore Wind Farm (PFOWF) Array is being developed in an area of 10 km^2 located approximately 7.5 km off the north coast of Dounreay, Caithness. The PFOWF Array and Offshore Export Cable(s) (which bring the power generated to shore) together comprise the Offshore Development.

This Carbon Assessment (CA) report has been commissioned to determine the carbon life cycle emissions which will result from the Offshore Development. The assessment includes a carbon dioxide equivalent (CO_2e) emission inventory for the Offshore Development, using an Xodus-developed carbon tool. The inventory provides a quantification of total CO_2e emissions attributed to the Offshore Development, within the scope, which is used to calculate the net CO_2e emissions, and carbon payback period.

This CA has adopted a Design Envelope approach to the assessment. At this early stage in the development process, it is not possible to finalise the specifics of the project design. The level of uncertainty of the final Offshore Development design necessitates that this assessment provides a reasonable reflection of the approximate range, rather than a definitive total, for the total CO_2e emissions and carbon payback period of the Offshore Development. This report makes no attempt to assess the level of impact (positive or negative) from the results of the CA as this is included in the Environmental Impact Assessment Report (Chapter 20: Climate Change and Carbon Assessment).

The assessment boundary encompasses the Offshore Development, comprising the PFOWF Array and the Offshore Export Cable(s). The assessment includes the lifecycle of the Offshore Development, from pre-construction (surveys), through construction and operation and maintenance to decommissioning.

Emissions associated with the production of the materials used in the various components are included within the CA, however, emissions associated with the delivery of these materials to the manufacturing plants and additional emissions from assembly of the various components are not included. Given the complexity and level of detail required to determine potential methods of manufacture and delivery for individual suppliers of components at this early stage in the development process, it is assumed these emissions would represent a small percentage of the total emissions relative to the emissions associated with the embodied carbon of the components and with delivery to the Offshore Development.

To help refine the potential scenarios, emissions from each component were assessed through each phase (pre-construction, construction, operations and maintenance, and decommissioning), and the potential combinations combined to identify High and Low emissions scenarios. The High emissions scenario which represents the 'worst-case scenario' in terms of the highest associated carbon, incorporates the maximum number of WTGs, the greatest mass of floating substructures, moorings and anchors, the maximum length of export and inter-array cables and the maximum vessel activity. The scenarios are summarised in Table S.1.

Table S. 1 Emissions Scenarios used in the Carbon Assessment

EMISSIONS SCENARIO	WTG	WTG FOUNDATION	EXPORT CABLE	ARRAY CABLE	VESSEL ACTIVITY
Worst case (High emissions)	7 of 10 MW	7 Square Barge Structures	2 cables 12.5 km length	20 km length	Total of 10,095 days of working vessels
Comparison (Low emissions)	5 of 18 MW	5 Tension Leg Platforms	1 cable 12.5 km length	10 km length	Total of 8,011 days of working vessels

The pre-construction phase includes the vessels required for survey activities.

The construction phase considers the embodied carbon of materials required for the wind farm components, the offshore transport from the fabrication site to the Offshore Development, and the emissions associated with the installation of offshore components.

For the purposes of this assessment it is assumed that the operation and maintenance phase of the wind farm will not produce any emissions beyond those from vessels required in the maintenance of the various offshore components.

The decommissioning phase considers the vessel activity associated with the decommissioning and removal of all offshore components to shore.

The final calculated worst case (High emissions) scenario, and comparison (Low emissions) scenario, total life cycle CO_2e emissions from the Offshore Development are presented in Table S.2. These emissions assume a 30 year operational life of the Offshore Development. Negative net CO_2e emissions represents the displaced equivalent emissions, i.e. the "avoided" emissions.

Table S.2 Net CO_2e emissions from the Offshore Development

EMISSIONS SCENARIO	EMISSIONS (Mt CO_2e)			
	CONSTRUCTION	OPERATION	DECOMMISSIONING	LIFE CYCLE
Worst case (High emissions)	0.73	-3.43	0.14	-2.57
Comparison (Low emissions)	0.23	-4.47	0.07	-4.17

It is calculated that the Offshore Development will displace CO_2e emissions from other energy sources by between 2.57 and 4.17 million tonnes in the worst case (High emissions) and the comparison (Low emissions) scenarios respectively. The payback period has been calculated to be within two to seven years from the start of operations.

1 INTRODUCTION

Highland Wind Limited (HWL) is proposing to install and operate a floating offshore wind farm approximately 7.5 km off the north coast of Dounreay, Caithness, Scotland. The offshore aspects of the development are referred to throughout this document as the Offshore Development.

The Offshore Development will comprise:

- The PFOWF Array which is an array of up to seven offshore, Wind Turbine Generators (WTGs) installed on floating substructures and connected to one another by subsea inter-array cables; and
- Offshore Export Cable(s) which are continuations of the inter-array cables to bring power to shore, with associated cable and scour protection.

All industries, including the renewable energy industry, emit Greenhouse Gases (GHG). Renewable energy projects also avoid the emission of GHG by replacing other, more carbon intensive forms of electricity generation.

A Carbon Assessment (CA) for the Offshore Development has been carried out, as requested by consultees during Scoping, to estimate:

- The carbon lifecycle emissions which will result from the Offshore Development in terms of carbon dioxide equivalent (CO_2e) emissions;
- The CO_2e emissions which will be avoided as a result of the Offshore Development; and
- The length of time the Offshore Development will require to be operational, to payback the emissions resulting from the lifecycle of the Offshore Development (the ‘payback period’).

2 METHODOLOGY

Flexibility in the final design is required for the Offshore Development as some elements cannot be finalised due to, procurement and supply chain considerations associated with emerging technologies, the timing of investment decisions and until further site investigations are undertaken. This CA has been carried out by assessing a variety of possible design scenarios and reporting on the highest and lowest potential GHG emissions within the design envelope.

Due to the level of uncertainty within the final Offshore Development design, the carbon assessment will provide an approximate range, rather than a definitive total, for the total carbon dioxide equivalent (CO2e) emissions inventory and carbon payback period of the Offshore Development. Conservative assumptions have been used to reflect a High emissions, 'realistic worst case scenario' when calculating the emissions. An assessment of the level of impact (beneficial or adverse) from the results of the carbon assessment has not been undertaken within this document as this is included in the Environmental Impact Assessment Report (Chapter 20: Climate Change and Carbon Assessment). The assessment was undertaken using the Xodus-developed carbon tool.

The assessment boundaries define the scope of the inventory. The assessment boundary comprises the boundary (Figure 2-1) of the Offshore Development and all components contained therein, including offshore activities. Emissions associated with activities during pre-construction (surveys), construction (embodied carbon, transportation of components to the Offshore Development and offshore installation of components), operation and maintenance and decommissioning are included, to ensure all activities are captured in the carbon assessment.

Due to the stage of development of the industry and the availability of validated embodied carbon data, assumptions are developed for the source location of the components which form the Offshore Development and the materials constituting these components. Two scenarios were utilised to estimate upper and lower bounds of emission scenarios associated with the Offshore Development. Estimates were made of the following:

- Pre-construction emissions from vessels associated with surveys;
- Embodied carbon of the components of the Offshore Development[1], their transport to site and installation, including:
    - WTGs, including nacelle, tower and blades;
    - Floating substructures;
    - Mooring systems;
    - Anchor systems;
    - Inter-array cables; and
    - Export cable(s).
- Operations and maintenance: emissions from vessels required to maintain offshore components during the 30 year operational period of the Offshore Development;
- Decommissioning: emissions from vessels removing and transporting components to shore, following the operational period of the Offshore Development.

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[1] *Emissions for the transport of the raw materials used in the construction of the components, or emissions associated with assembly of the components are excluded from the CA, due to a lack of knowledge about the potential manufacturer's supply chains and processes. These emissions are likely to represent a very small part of the total construction emissions for this assessment, and therefore are likely to have a low potential to alter the outcome or value of the assessment.*

The following categories of emissions were excluded from the emissions inventory due to the complexity of estimation and the availability of data given the level of maturity of the industry. These emissions are likely to represent a very small part of the total emissions for this assessment, and therefore are likely to have a low potential to alter the outcome or value of the assessment:

- Delivery of materials to the manufacturing plants;
- Assembly of materials at the manufacturing plants;
- Onshore transportation (if any); and
- Office activity and worker travel.

Emissions associated with activity beyond the return of components to shore for decommissioning at the end of the lifecycle of the Offshore Development are outwith the assessment boundary, however, it is considered that up to 90% of the material may be recycled (Spyroudi, 2021).

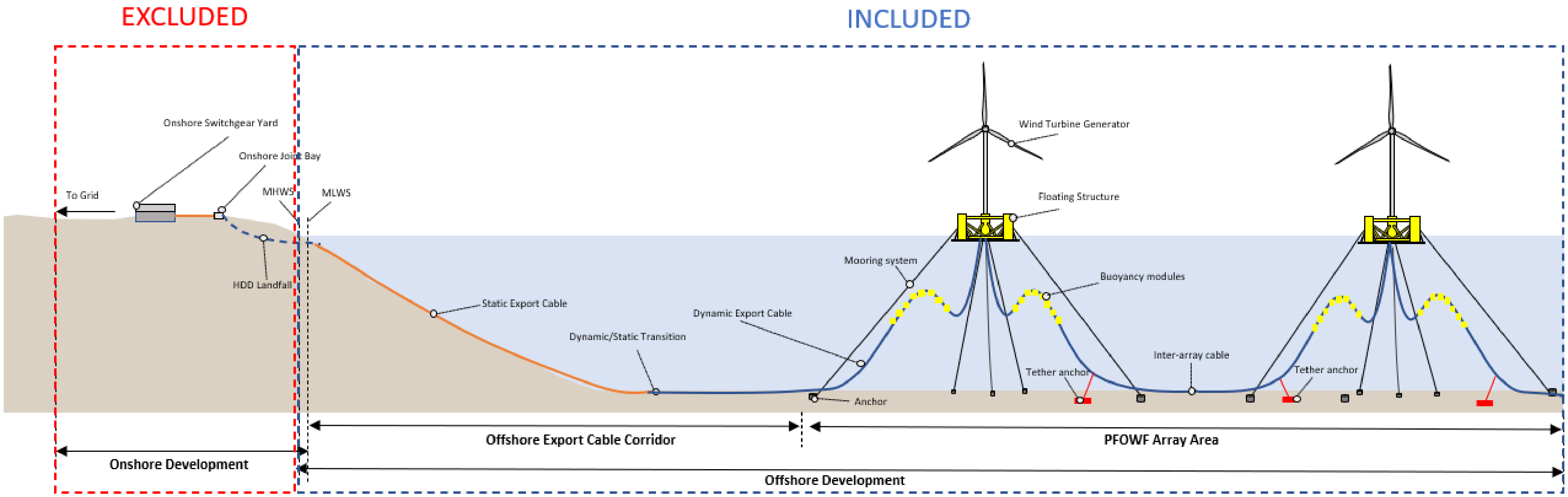

Figure 2-1 Schematic of assessment boundary for the Offshore Development

3 DEVELOPMENT SCENARIOS

Within the design envelope a range of options exist for each component of the Offshore Development (Chapter 5: Project Description). To help refine the potential scenarios, emissions from each component were assessed through each phase, and the potential combinations combined to identify High and Low emissions scenarios. The High emissions scenario which represents the 'worst-case scenario' in terms of the highest associated carbon, incorporates the maximum number of WTGs, the greatest mass of floating substructures, moorings and anchors, the maximum length of export and inter-array cables and the maximum vessel activity.

The scenarios selected to calculate the CO_2e emission range and payback periods are identified in Table 3-1.

Table 3-1 Worst case (High emissions) and comparison (Low emissions) scenarios used in the Carbon Assessment

EMISSIONS SCENARIO	WTG	WTG FOUNDATION	EXPORT CABLE	ARRAY CABLE	VESSEL ACTIVITY[2]
Worst case (High emissions)	7 of 10 MW	7 Square Barge Structures	2 cables 12.5 km length	20 km length	Total of 10,095 days of working vessels
Comparison (Low emissions)	5 of 18 MW	5 Tension Leg Platforms (TLP)	1 cable 12.5 km length	10 km length	Total of 8,011 days of working vessels

3.1 ASSUMPTIONS

The following assumptions have been made when calculating and presenting the CO_2e emissions for the Offshore Development

- The WTG are made up of the tower, nacelle, and blades;
- The total mass of the major materials which make up the WTG (steel, copper, aluminium, and fibreglass) has been estimated. The mass of materials within a Haliade-X 14 MW WTG was pro-rata'd to a 10 MW (High emissions scenario) and 18 MW (Low emissions scenario) WTG;
- The Square Barge Structure, mooring and anchor system consists of concrete, steel and scour protection. The Square Barge Structure system was calculated as having the greatest mass of the floating substructures under consideration and is therefore associated with the highest quantities of embodied carbon. This system is incorporated within the High emissions scenario, representing the 'worst case scenario';
- The TLP foundation, mooring and anchor system consists of steel and scour protection. The TLP system was calculated as having the lowest mass of the floating substructure systems under consideration and is therefore associated with the lowest quantities of embodied carbon. This system is incorporated within the Low emissions scenario;
- Scour protection has been assumed to be gravel/rock;

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[2] *Appendix A provides detail on the vessel types, activity undertaken and duration of activity for the Offshore Development*

- The export and inter-array cables are assumed to consist of 0.0187 te/m steel, 0.00968 te/m corrosion resistant alloy, 0.0312te/m plastics and 0.000337 te/m copper;
- Transportation from the fabrication location to the Offshore Site assumes (further details on the transportation assumptions made in the two emission scenarios are provided in Appendix A):
    - Components fabricated in the UK are shipped from Aberdeen;
    - Components fabricated in Europe are shipped from Rotterdam;
    - Components fabricated in China are shipped from Shanghai, via Rotterdam.
- Decommissioning
    - Emissions from vessels used for offshore decommissioning are assumed to be equivalent to those required for construction;
    - All the removed components will be returned to the UK for subsequent management.
    - Management and subsequent recycling of the components lies outwith the assessment boundary. Components are expected to be recycled at a 90% recycling rate (Spyroudi, 2021);

4 EMISSIONS INVENTORY

4.1 INTRODUCTION

The emissions inventory for the Offshore Development is divided into three phases:

- Construction CO_2e - the embodied carbon of the main components, their transportation to the Offshore Development and emissions associated with pre-construction and construction vessels;
- Operational CO_2e - the emissions from vessels associated with operation and maintenance;
- Decommissioning CO_2e - the emissions from vessels associated with the removal of components, following the operational period of the Offshore Development.

Each of these phases is then divided three further times into a category, a component, and finally an activity or material. For example, CO_2e emissions associated with the steel used in the manufacture of the WTG would be captured as shown in Figure 5.1.

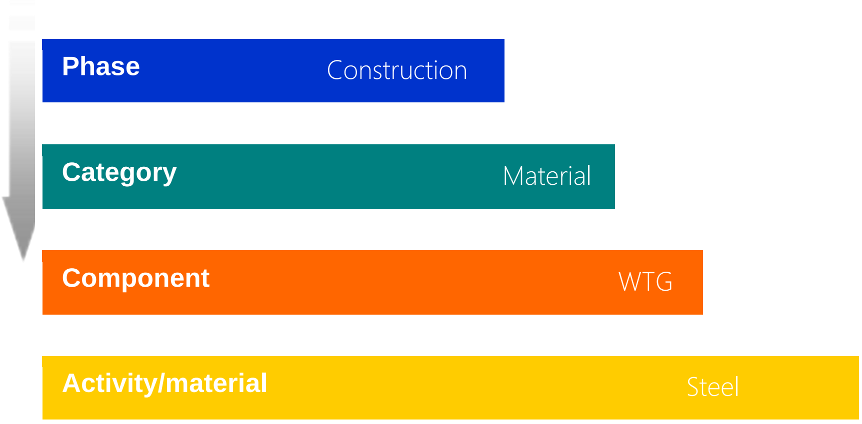

Figure 5.1 Process for identifying component materials

Each activity or material has an assigned unit of measurement and an associated emission factor. The primary data sources used to inform the assessment, in addition to the Offshore Development description, include:

- Bath Inventory of Carbon and Energy (ICE) [Embodied carbon for standard materials and processes];
- IP 2000 [Standardised vessel fuel use];
- Digest of UK Energy Statistics (DUKES) [Emission factors for generation sources; most recent version e.g. 2021]; and
- Defra Greenhouse gas reporting: conversion factors 2022.

The details provided below set out the activities and materials accounted for in each component, within each phase. Appendix A presents the data used to carry out the carbon assessment.

4.2 CARBON ASSESSMENT TYPES

4.2.1 Embodied carbon

The production of materials (mining raw materials, refining, forming, etc.) incurs emissions of CO_2e, termed "embodied carbon". Embodied carbon in the context of the Offshore Development relates to the emission of CO_2e associated with the production of new infrastructure, i.e., WTGs, floating substructures and their moorings and anchors, cables and remedial protection. This has been included according to the boundaries shown in Figure 2-1.

Description

Wind Turbine Generators

Each WTG has been considered as a single unit consisting of the tower, nacelle and blades. There are two potential options for the WTGs considered in the assessment: a worst case (High emissions) scenario of 7 of 10 MW WTGs and the comparison (Low emissions) scenario of 5 of 18 MW WTGs. The total mass for the primary materials which make up the WTGs (steel, copper, aluminium, and glass fibre) have been estimated based on details provided by HWL and are included in Appendix A.

Floating Substructure

Floating substructures (foundations) are required to support each WTG within the array. Each substructure requires a mooring and an anchor system and may require scour protection to prevent the removal of local sediment within the vicinity of the foundation. One substructure is required for each WTG, therefore for the worst case (High emissions) scenario, there are 7 floating substructures of a Square Barge Structure and for the Low case, there will be 5 TLP (further details are provided in Chapter 5. Project Description). The Square Barge Structure system was calculated as having the greatest mass of the floating substructures under consideration and is therefore associated with the highest quantities of embodied carbon. The TLP system was calculated as having the lowest mass of the floating substructures under consideration and is therefore associated with the lowest quantities of embodied carbon.

Offshore cables

Either one or two export cables of up to 12.5 km each in length is required to transfer electricity to shore. The cables are assumed to be 3 core, cross-linked polyethylene (XPLE) submarine cables, with their major materials being copper, steel and polyethylene (plastic). The mass of these components is assumed to be 0.0187 t/m steel, 0.00968 t/m corrosion resistant alloy (CRA), 0.0312te/m plastics and 0.000337 t/m copper.

Inter-array cabling is required to transfer the electricity generated from each WTG. The worst case (High emissions) scenario assumes 20 km of cable is required and the comparison (Low emissions) scenario assumes 10 km of cable. The materials for the inter-array cabling, both dynamic and static cabling, are assumed to be the same as those for the export cable(s).

In the worst case (High emissions) scenario, it is assumed that the export and inter-array cables may require remedial protection which is assumed to be rock as a 'worst case' assumption.

4.2.2 Construction CO_2e

Construction encompasses:

- The embodied carbon of the components (Section 4.2.1);
- The vessels used in offshore transport from the fabrication site to the Offshore Development;
- Pre-construction vessel activity; and
- All offshore construction activity.

The assessment excludes emissions associated with the transport of materials used in components and additional emissions associated with assembly or manufacturing of the components. For example: the emissions associated with WTG manufacture includes the mass of copper used and emissions associated with the manufacturing of copper as a material, but excludes the delivery of copper to the WTG manufacturer, and the additional emissions associated with combining the copper with other materials within the WTG.

The emissions associated with these two activities are excluded because information about the manufacturing supply chains and processes is unknown, as suppliers have not yet been selected. As these emissions are likely to represent a small part of the total emissions their exclusion does not alter the fundamental outcome or value of this assessment.

For the offshore components, the embodied carbon, delivery to site, and installation CO_2e emissions have been considered for WTGs and their associated foundations and moorings, cables (export and inter-array) and cable remedial protection.

For the purposes of this assessment only, it is assumed that all emissions associated with construction occur over the indicative time period 2024-2026.

Description

Emissions from the installation activities have been provided and summaries of the vessels required are presented below. Further details are provided in Appendix A.

Transportation vessels

The number of trips and the distances assumed to be travelled by offshore transportation vessels carrying components from their fabrication location to the Offshore Development are summarised in Appendix A.

Pre-construction vessels

Vessels for the survey activities required prior to the start of construction have been considered as multi support vessels.

Construction vessels

Emissions resulting from construction vessels installing the components were determined for the two emission scenarios (Appendix A). The vessel types included construction support vessel/cable install, anchor handling tug, survey vessel, pre-lay grapnel run, rock placement, guard vessel and crew transfer vessel (CTV)/walk to work (W2W) vessel. The Xodus database uses the Institute of Petroleum (2000) guidelines to quantify emissions from different types of vessels. To align the vessels utilised for the Offshore Development with those contained within the Xodus database, the construction support vessel/cable install and anchor handling tug were considered to be multi support vessels. The survey, the guard vessel and the CTV/W2W were considered to be multi support vessels and the pre-lay and the rock placement vessels assumed to be a lay barge and a rock lay vessel respectively. The comparison (Low emissions) scenario assumed around half the number of vessel days of the worst case (High emissions) scenario.

4.2.3 Operational CO_2e

It has been assumed that the operation and maintenance phase of the Offshore Development will not produce any emissions beyond the emissions from vessels required in the maintenance of the various offshore components.

Description

Emissions from the offshore operation and maintenance activities have been calculated for the Offshore Development. The vessel requirements for operation and maintenance activities were influenced by the number of WTGs and substructures and the type of activity e.g. component maintenance, component replacement or cable repairs. The total emissions from the vessels were divided by the operational lifetime of the Offshore Development of 30 years to calculate emissions per year. This is a conservative assumption as vessels are likely to become more efficient over the next 30 years.

4.2.4 Decommissioning CO_2e

Decommissioning considers the decommissioning and removal of the infrastructure to the shore at the end of the Offshore Development's lifetime.

Description

In line with the Scottish Government's default position for the decommissioning of Offshore Renewable Energy Installations (BEIS, 2019; Scottish Government, 2019), the starting presumption is that at the end of the operational lifetime of the Offshore Development, there will be a requirement for all offshore components (above and below seabed) to be completely removed to shore for re-use, recycling, incineration with energy recovery, or disposal at a licensed site. As the Offshore Development's anticipated lifetime is up to 30 years from full commissioning, there may have been advances in technological capabilities for decommissioning and/or changes to legislation by this time, therefore decommissioning best practice and legislation will be applied at that time of the Offshore Development's decommissioning. Under international standards such as those published by the IMO, there is the potential to consider leaving components in situ, however it is understood that this would require a robust and compelling justification to be presented to Marine Scotland in order to be granted approval for partial removal of the Offshore Development. In this instance, a comparative assessment would be undertaken to provide a recommendation, based on the performance against five main criteria: Safety, Environmental, Societal, Technical Feasibility and Economic.

For the purposes of this assessment, emissions from the offshore decommissioning vessels have been assumed to be equivalent to those required for construction. This is a conservative assumption as vessels are likely to become more efficient over the next 30 years.

5 AVOIDED EMISSIONS

The carbon payback period is analogous to the financial payback period and represents the period of time before a product or development has saved more CO_2e emissions than has been produced by its construction, operation and decommissioning.

To establish the carbon payback period, the potential CO_2e savings of the Offshore Development needs to be established. This has been ascertained by comparing the equivalent CO_2e emissions that would be generated from other forms of electricity generation, under the assumption that the Offshore Development will displace the requirement for generation from these other sources. It is assumed that electricity generated by the Offshore Development will be used to displace electricity generated from fossil fuels, rather than from nuclear or other renewable energy sources which have a relatively lower carbon intensity.

The total annual generation predicted from the Offshore Development is:

Annual generation – Worst case (High emissions) scenario = 331 GWh

Annual generation – Comparison (Low emissions) scenario = 415 GWh

The equivalent CO_2e emissions produced by fossil fuel generation sources was assumed to be 400 tonnes of CO_2e per gigawatt hour (GWh) (BEIS, 2021). This value represents the 2020 estimate by the Office of National Statistics of actual UK emissions per unit of electricity generated from fossil fuels (BEIS, 2021). The predicted annual electricity production of the Offshore Development is multiplied by this emission factor to calculate the annual CO_2e emissions avoided as a result of the Offshore Development.

Annual generation, Worst case (High emissions) scenario = 331 GWh

Emission factor = 400 tCO_2e/GWh

Annual CO_2e emissions avoided = 331 GWh x 400 tCO_2e/GWh

= 132,400 tCO_2e

Annual generation, Comparison (Low emissions) scenario = 415 GWh

Emission factor = 400 tCO_2e/GWh

Annual CO_2e emissions avoided = 415 GWh x 400 tCO_2e/GWh

= 166,000 tCO_2e

6 RESULTS

6.1 TOTAL CO$_2$E EMISSIONS

The final calculated worst case (High emissions) scenario, and comparison (Low emissions) scenario, total life cycle CO$_2$e emissions from the Offshore Development are presented in Table 6-2 and graphically in Figure 6-1.

Table 6-1 CO$_2$e emissions from the Offshore Development

		TOTAL CO$_2$e (t)	
		WORST CASE (HIGH EMISSIONS) SCENARIO	COMPARISON (LOW EMISSIONS) SCENARIO
Construction	Embodied carbon	543,908	158,830
	Component transport from fabrication sites	36,372	640
	Pre-construction vessel emissions	9,203	3,780
	Construction vessel emissions	136,333	70,024
	TOTAL	*752,816*	*233,273*
Operation	Vessel emissions	541,766	511,200
Decommissioning	Vessel emissions	136,333	70,024
Total		1,403,915	814,496

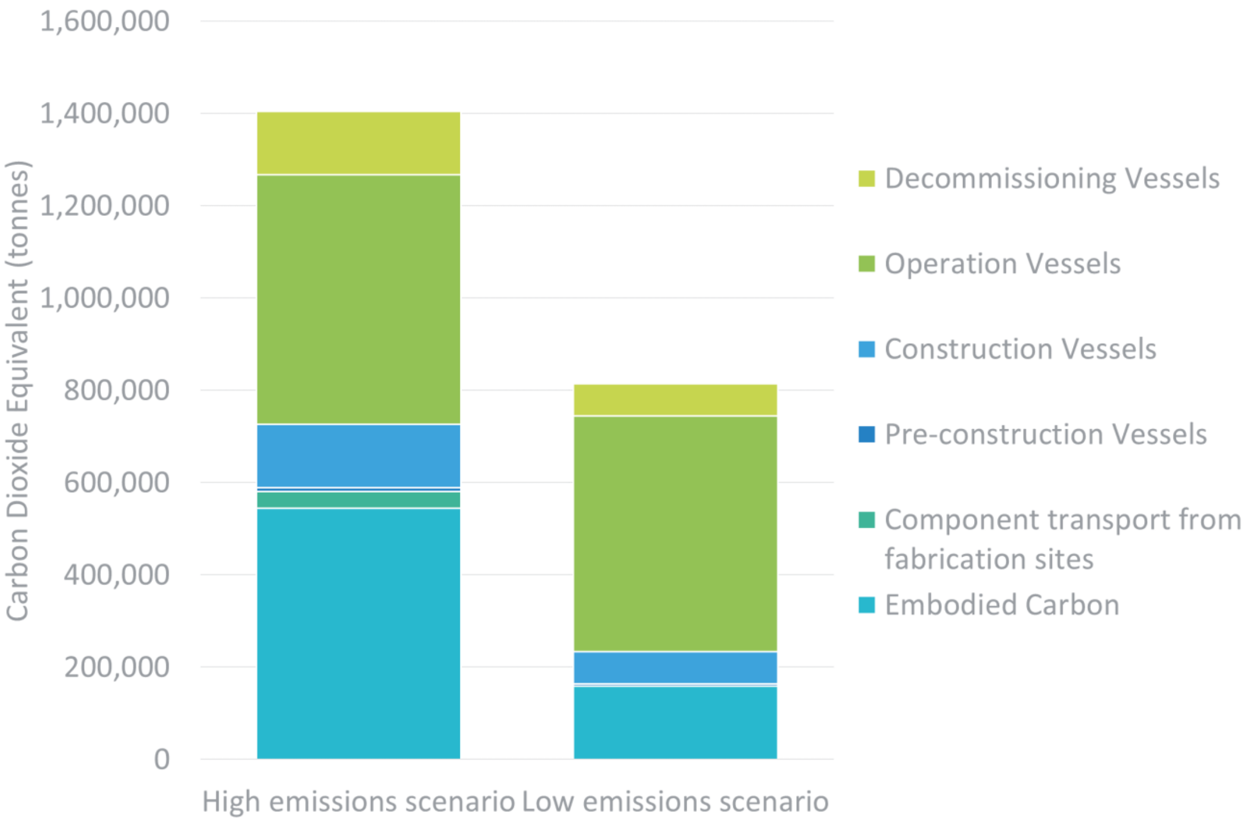

Figure 6-1 Total emissions from the Offshore Development, by phase, for worst case (High emissions) and comparison (Low emissions) scenario

6.2 CARBON PAYBACK

Table 6-2 presents the net CO_2e emissions from the Offshore Development, considering the emissions associated with the Offshore Development (Table 6-1) and the displacement of energy from other sources with a higher carbon intensity (Section 5).

Assuming a 30-year life of the Offshore Development, between 2.57 and 4.17 Mt CO_2e emissions will be displaced from other energy sources in the worst case (High emissions) and comparison (Low emissions) scenarios respectively (Figure 6-2 and Figure 6-3). Negative net CO_2e emissions represent the displaced equivalent emissions, i.e. the “avoided” emissions.

Table 6-2 Net CO_2e emissions from the Offshore Development

EMISSIONS SCENARIO	EMISSIONS (Mt CO_2e)			
	CONSTRUCTION	OPERATION	DECOMMISSIONING	LIFE CYCLE
Worst case (High emissions)	0.73	-3.43	0.14	-2.57
Comparison (Low emissions)	0.23	-4.47	0.07	-4.17

The comparison (Low emissions) scenario is calculated to avoid nearly double the emissions compared to the Worst case (High emissions) scenario. The difference can be attributed primarily to the reduction in embodied carbon in the construction phase, which is lower due to the smaller number of turbines (and hence foundations, moorings and anchors) and the greater power generation capacity of each WTG in the comparison (Low emissions) scenario.

The payback period for Offshore Development is presented in Table 6-3 and has been calculated to be within two to seven years from commencement of the operations phase.

Table 6-3 Carbon payback period

EMISSIONS SCENARIO	PAYBACK PERIOD (WITHIN)
Worst case (High emissions)	7 years
Comparison (Low emissions)	2 years

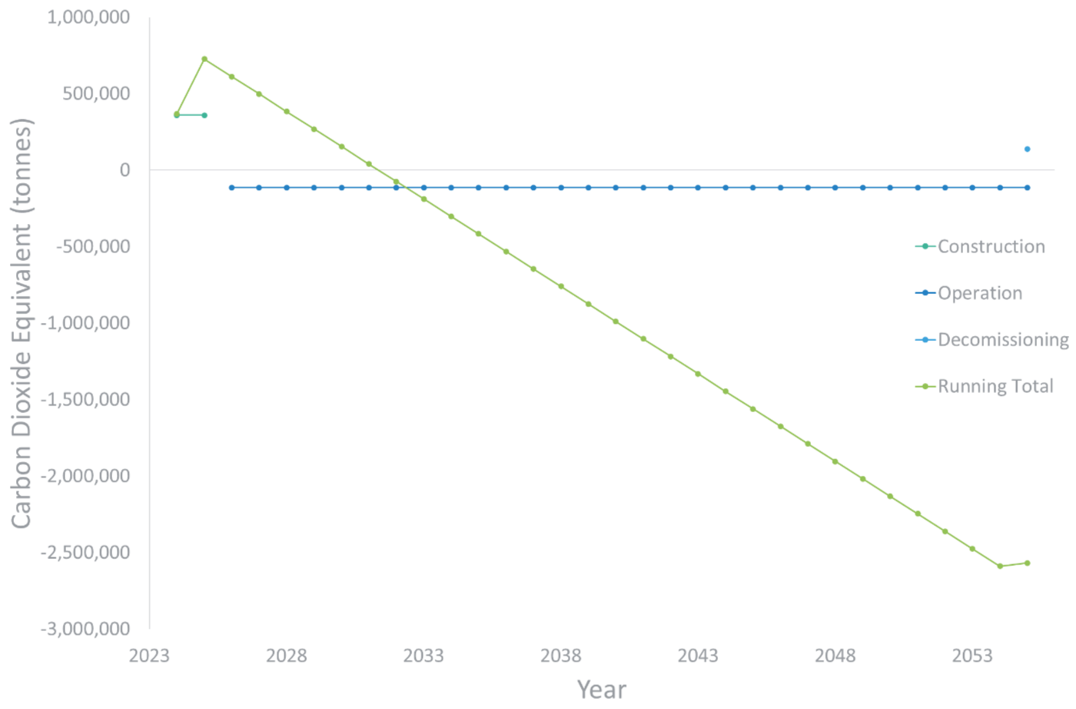

Figure 6-2 Worst case (High emissions) scenario: CO_2e emissions from the Offshore Development, including avoided emissions

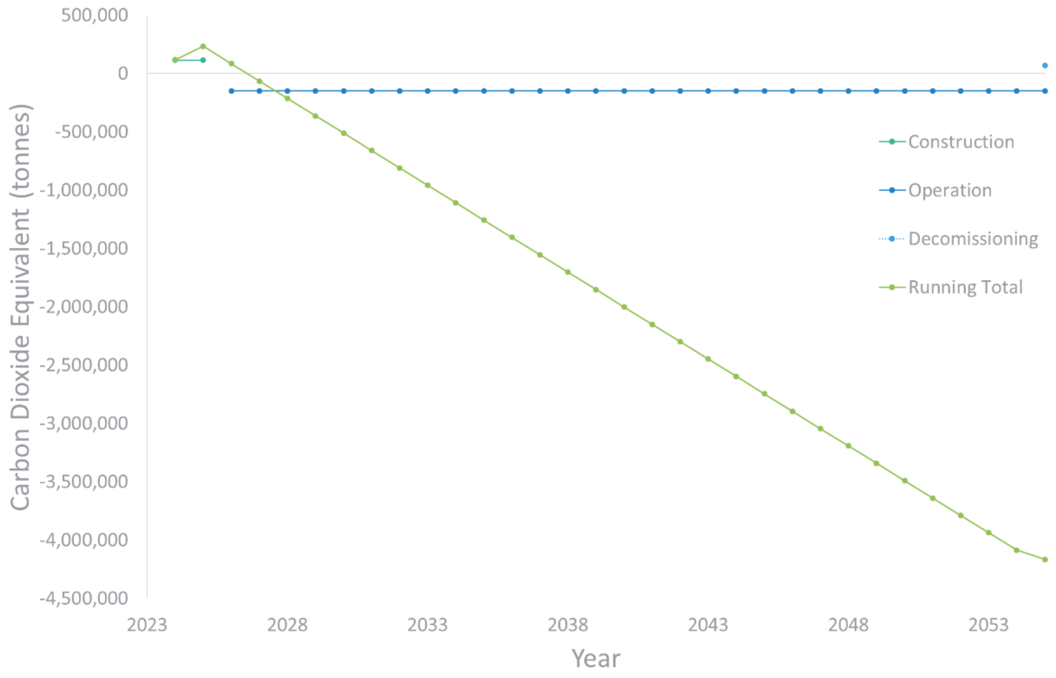

Figure 6-3 Comparison (Low emissions) scenario: CO_2e emissions from the Offshore Development, including avoided emissions

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ANNEX A: COMPONENT DESCRIPTION

Table 7-1 Assumptions used in the Offshore Development scenarios

			Worst case (High emissions) scenario		Comparison (Low emissions) scenario	
			Quantity	Vessel type/material	Quantity	Vessel type/material
Construction	Pre-Construction	ROV surveys	10 days	Multi support vessel	6 days	Multi support vessel
		Geotech	60 days	Multi support vessel	30 days	Multi support vessel
		UXO/Magnetometer	42 days	Multi support vessel	10 days	Multi support vessel
	WTG	Steel	6,853 tonnes	Steel	590 tonnes	Steel
		Aluminium	91 tonnes	Aluminium	115 tonnes	Aluminium
		Copper	147 tonnes	Copper	5,490 tonnes	Copper
		Glass Fibre	826 tonnes	Glass fibre	8,900 tonnes	Glass fibre
	Floating substructure		49,000 tonnes	Steel		
			140,000 tonnes	Concrete	20,000 tonnes	Steel
	Mooring system		103,950 tonnes	Steel	563 tonnes	Steel
	Scour & rock protection (marine aggregate)		315,000 tonnes	Rock	26,250 tonnes	Rock
	Anchor system (anchor or piles)		113,400 tonnes	Concrete		
			12,600 tonnes	Steel	610 tonnes	Steel
	Vessels (install and commissioning) – the same values have been used for Decommissioning	CSV/Cable install	51 days	Multi support vessel	27 days	Multi support vessel
		Anchor handling Tug	640 days	Multi support vessel	350 days	Multi support vessel
		Survey vessel	51 days	Multi support vessel	27 days	Multi support vessel
		Pre-lay grapnel run	20 days	Lay barge	8 days	Lay barge
		Rock placement	42 days	Rocklay	10 days	Rocklay
		Guard vessel	730 days	Multi support vessel	365 days	Multi support vessel

		CTV/W2W vessel	134 days	Multi support vessel	66 days	Multi support vessel
	Export cable		25,000 m	Considered small umbilical	12,500 m	Considered small umbilical
	Inter-array cable (dynamic & fixed)		20,000 m	Considered small umbilical	10,000 m	Considered small umbilical
Operation		CSV	63 days	Multi support vessel	63 days	Multi support vessel
		Anchor handling Tug	392 days	Multi support vessel	280 days	Multi support vessel
		Survey Vessel	150 days	Multi support vessel	150 days	Multi support vessel
		Pre-lay grapnel run	6 days	Lay barge	6 days	Lay barge
		Rock placement	140 days	Rocklay	100 days	Rocklay
		Guard vessel	900 days	Multi support vessel	720 days	Multi support vessel
		CTV/W2W vessel	4,996 days	Multi support vessel	4,996 days	Multi support vessel

Table 7-2 Trip assumptions used in the Offshore Development scenarios

	Worst case (High emissions) scenario		Comparison (Low emissions) scenario	
	Origin	Number of trips	Origin	Number of trips
WTG	China	1 trip	Europe	2 trips
Floating substructure	Europe	10 trips	UK	2 trips
Mooring system	China	10 trips	UK	1 trip
Scour & cable protection	Europe	30 trips	Europe	3 trips
Anchor system	Europe	6 trips	UK	1 trip
Cables (export and inter-array)	Europe	2 trips	UK	1 trip