Morecambe Offshore Windfarm: Generation Assets

Environmental Statement

Volume 5

Appendix 21.1 Greenhouse Gas Assessment Methodology

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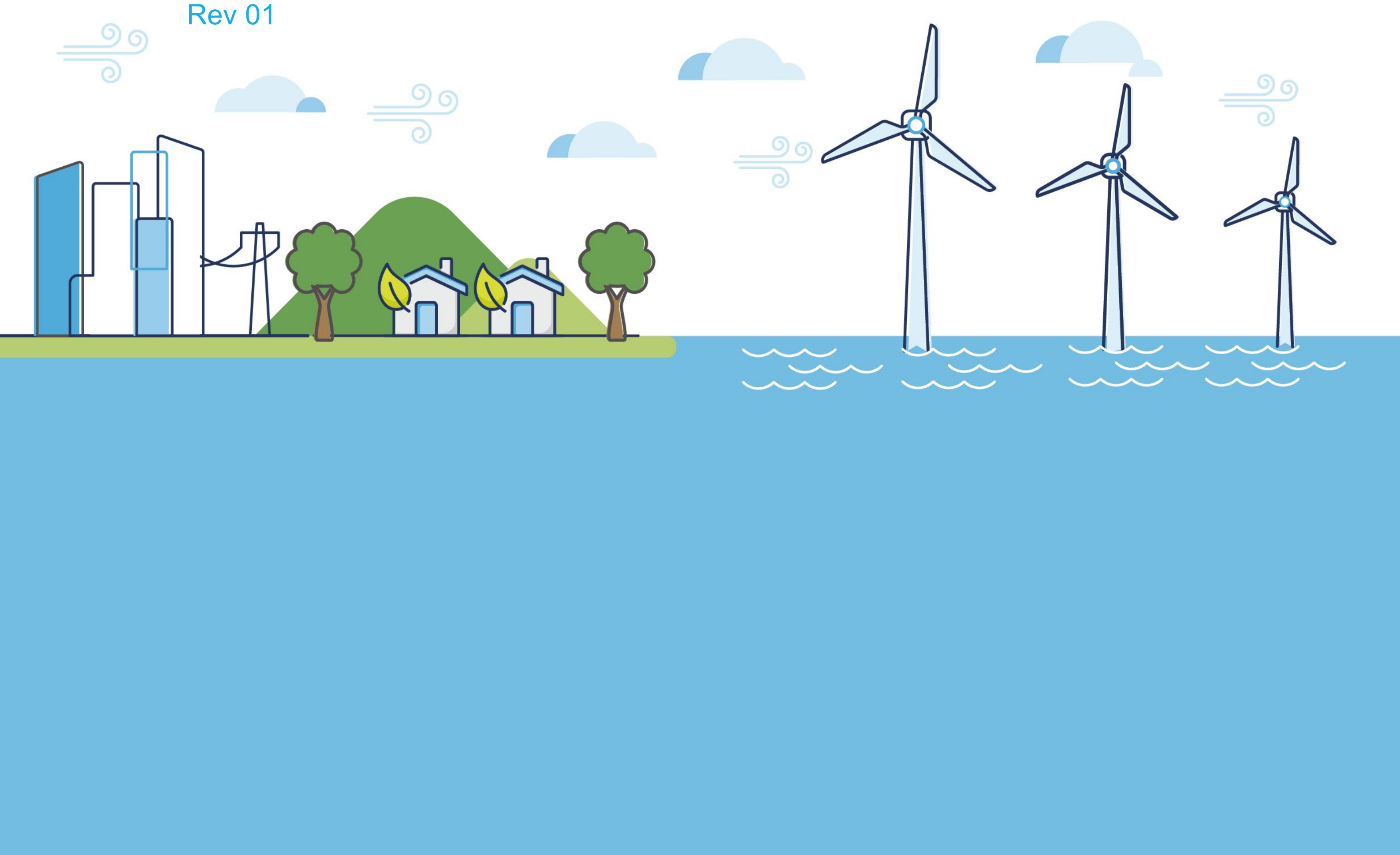

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Glossary of Acronyms

CCRA	Climate Change Resilience Assessment
CEA	Cumulative Effect Assessment
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CTV	Crew Transfer Vessels
DESNZ	Department for Energy Security and Net Zero
ES	Environmental Statement
GBS	Gravity-Based Structures
GHG	Greenhouse Gas
GloMEEP	Global Maritime Energy Efficiency Partnerships Project
GRP	Glass Reinforced Plastic
GWP	Global Warming Potential
HLV	Heavy Lift Vessels
IAC	Inter-array cable
ICE	Inventory of Carbon and Energy
IOM	Isle of Man
JUV	Jack-Up Vessels
LNG	Liquefied Natural Gas
MGO	Marine Gas Oil
OSP	Offshore substation platform
PEIR	Preliminary Environmental Information Report
SOV	Service Operations Vessels
TSS	Traffic Separation Scheme
US EPA	United States Environmental Protection Agency
WTG	Wind turbine generator
XLPE	Cross-Linked Polyethylene

Glossary of Unit Terms

kg CO_2e/kWh	Kilograms carbon dioxide equivalent per kilowatt-hour
Kg/hr	Kilograms per hour
Kg/L	Kilograms per litre
kW	Kilowatt
kWh	Kilowatt hour
nm	Nautical mile

Glossary of Terminology

Applicant	Morecambe Offshore Windfarm Ltd
Application	This refers to the Applicant's application for a Development Consent Order (DCO). An application consists of a series of documents and plans which are published on the Planning Inspectorate's (PINS) website.
Carbon Dioxide Equivalent (CO_2e)	Carbon dioxide equivalent is a term for describing different greenhouse gases in a common unit. The unit takes the different global warming potentials of greenhouses gases into account. CO_2e is signifies the amount of Carbon dioxide (CO_2) which would have the equivalent global warming impact.
Capacity factor	The ratio of average power generated by the windfarm under real-world conditions to its theoretical maximum output.
Cradle-to-factory or cradle to (factory) gate	A term which includes the extraction, manufacture and production of materials to the point at which they leave the factory fate of the final processing location.
Embodied emissions	Embodied (or embedded) carbon or emissions are the greenhouse gas emission associated with the manufacturing of construction or infrastructure materials (i.e., material extraction, material processing, transport to manufacturer, manufacturing) and the transport of those materials to the Project site.
Generation Assets (the Project)	Generation assets associated with the Morecambe Offshore Windfarm. This is infrastructure in connection with electricity production, namely the fixed foundation wind turbine generators (WTGs), inter-array cables, offshore substation platform(s) (OSP(s)) and possible platform link cables to connect OSP(s).
Global Warming Potential (GWP)	Global Warming Potential of a greenhouse gas is a measure of how much heat is trapped by a certain amount of gas in the atmosphere relative to carbon dioxide.
Greenhouse effect	The greenhouse effect is the way that some of the heat from the sun is trapped close to the earth's surface by greenhouse gases.
Greenhouse gas (GHG)	A greenhouse gas is a gas that traps heat in the atmosphere and causes the greenhouse effect.
Inter-array cables	Cables which link the WTGs to each other and the OSP(s).
Landfall	Where the offshore export cables would come ashore.

Morgan and Morecambe Offshore Wind Farm: Transmission Assets	The Transmission Assets for the Morgan Offshore Wind Project and the Morecambe Offshore Windfarm. This includes the OSP(s)[1], interconnector cables, Morgan offshore booster station, offshore export cables, landfall site, onshore export cables, onshore substations, 400kV cables and associated grid connection infrastructure such as circuit breaker infrastructure. Also referred to in this chapter as the Transmission Assets, for ease of reading.
Offshore export cables	The cables which would bring electricity from the OSP(s) to the landfall.
Offshore substation platform(s) (OSP(s))	A fixed structure located within the windfarm site, containing electrical equipment to aggregate the power from the WTGs and convert it into a more suitable form for export to shore.
Onshore export cables	The cables which would bring electricity from landfall to the onshore project substation and from the onshore project substation to a National Grid substation.
Onshore substation	Part of an electrical transmission and distribution system. Substations transform voltage from high to low, or the reverse by means of electrical transformers.
Platform link cable	An electrical cable which links one or more OSP(s).
Scour protection	Protective materials to avoid sediment being eroded away from the base of the foundations due to the flow of water.
Study area	This is an area which is defined for each Environmental Impact Assessment (EIA) topic which includes the offshore development area as well as potential spatial and temporal considerations of the impacts on relevant receptors. The study area for each EIA topic is intended to cover the area within which an effect can be reasonably expected. The study area of the GHG assessment is not geographically defined, whilst the study area for the Climate Change Resilience Assessment (CCRA) is spatially bounded and defined by the windfarm site in which the Generation Assets will be located.
Windfarm site	The area within which the WTGs, inter-array cables, OSP(s) and platform link cables will be present.
Wind turbine generator (WTG)	A fixed structure located within the windfarm site that converts the kinetic energy of wind into electrical energy.

[1] At the time of writing the Environmental Statement (ES), a decision had been taken that the offshore substation platforms (OSP(s)) would remain solely within the Generation Assets application and would not be included within the Development Consent Order (DCO) application for the Transmission Assets. This decision post-dated the Preliminary Environmental Information Report (PEIR) that was prepared for the Transmission Assets. The OSP(s) are still included in the description of the Transmission Assets for the purposes of this ES as the Cumulative Effects Assessment (CEA) carried out in respect of the Generation/Transmission Assets is based on the information available from the Transmission Assets PEIR.

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21.1

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1 Introduction

1. This appendix of the Environmental Statement (ES) presents the greenhouse gas (GHG) assessment methodology, specifically in relation to the activity data, emission factors and assumptions used for calculating GHG emissions arising from the proposed Morecambe Offshore Windfarm Generation Assets ('the Project').

2. The scope of this document includes the calculation approach used for the following emission source groups:

   - Embodied carbon in construction material and spare parts
   - Emissions arising from marine vessels in transit and undertaking construction and operation and maintenance activities at the windfarm site
   - Emissions arising from helicopter movements for construction personnel transport.

3. The calculation approach and assumptions underlying the estimation of emissions from increased journey times to ferry and commercial vessel routes are also outlined within this appendix. As stated in Table 21.1 of **Chapter 21 Climate Change** (Document Reference 5.1.21), emissions from vessel diversions are minimal in magnitude and an indirect effect of the Project. Therefore, these emissions have not been included in the GHG assessment.

4. A number of assumptions were made for the GHG assessment, and these are summarised in Table 21.12 of **Chapter 21 Climate Change** and detailed in this appendix. Updates to project parameters and assumptions between the Preliminary Environmental Information Report (PEIR) stage and the ES stage are reflected within this document.

2 Embodied carbon in materials

5. Emissions from 'cradle-to-factory gate' for the main materials to be used in construction phase were calculated for the Project. The term 'cradle-to-factory gate' includes raw material extraction, transport, manufacturing and packaging of materials (required for the construction of the Project) to the point at which they leave the site of the final processing location. GHG emissions were derived from quantities or volumes of known materials that would be used during construction, and their likely material composition.

6. The key infrastructure components (and their main material components) of the Project comprise:

   - Wind turbine generators (WTGs)
   - Offshore substation platforms (OSP(s))

- Transition pieces
- Foundations
- Scour protection
- Inter-array cables and protection
- OSP(s) platform link cables and protection

7. Quantities for all materials to be used during construction were not available at the time of the assessment, due to the design maturity that would take place post-consent, therefore estimated quantities of the main and most GHG-intensive materials were included in the assessment. To provide a precautionary assessment, it was assumed that there would be no reduction in the emission intensity of the upstream supply chains of windfarm components (e.g., emission reduction in manufacturing methods, low carbon material alternatives) up to and during the construction phase of the Project. The construction start year is estimated to be 2027.

8. It was assumed that all materials used for the Project's construction would require raw material extraction, e.g., virgin steel and not recycled steel, to present a conservative assessment. However, it is likely that materials that would be used in construction would have a higher recycled content, and thus a lower embodied carbon content than what has been assumed for the assessment.

9. Worst-case assumptions were also adopted with respect to material quantities to be used for each component of the Project, which accounts for contingencies to build flexibility into the design envelope (e.g., the maximum number of WTGs or OSP(s)). The specific nature and composition of some materials, such as the type of steel to be used, was unknown, which may affect the embodied carbon content considered in the assessment. Assumptions with respect to material composition were developed based on industry benchmarks and professional judgment using information provided by the Project's design team, as outlined in **Table 2.1**.

10. Realistic worst-case scenarios for the GHG assessment are outlined in Table 21.2 of **Chapter 21 Climate Change**.

11. Relevant emission factors sourced from the Inventory of Carbon and Energy (ICE) database (Jones & Hammond, 2019), where available, were applied to the material quantities to calculate total tonnes of carbon dioxide equivalent (CO_2e). CO_2e is a common unit used to express the magnitude of GHG emissions, accounting for the difference in global warming potentials between GHGs. Where emission factors for specific windfarm components were not available in the ICE database (e.g., cables), the relevant emission factors were obtained from other literature sources.

12. **Table 2.1** outlines the materials assumed for each key windfarm component, their emission factors and data source(s), and any assumptions or caveats used in the GHG assessment.

Table 2.1 Emission factors for embodied carbon in materials

Component(s)	Material	Emission factor*	Data source	Assumptions and caveats
WTGs, OSP(s), and transition pieces	Steel (average)	2.47	ICE Database, v3.0 November 2019 (Jones & Hammond, 2019)	Average of embodied carbon content of various types of steel provided in the ICE database.
WTGs	Glass-reinforced plastic (GRP) – Fibreglass (proxy)	8.1		Emission factor available for carbon dioxide (CO_2) only.
WTGs	Iron (cast iron proxy)	2.03		N/A
WTGs	Aluminium	6.67		Aluminium general, based on European mix.
WTGs, inter-array cables and OSP platform link cables	Copper (average)	2.71		Average of embodied carbon content of virgin and recycled copper provided in the ICE database.
Scour protection	Stone (general)	0.079		Assumed to be quarried rock for scour protection.
Foundations**	Concrete	0.16	ICE Database, v3.0 November 2019 (Jones & Hammond, 2019). Likely material specifications assumed based on available engineering sheets (Widianto *et al.*, 2016)	40/50 megapascal (MPa) in-situ concrete.
Foundations**	Sand	0.01		Gravity-based substructures (GBS) assumed to require a solid ballast material.
Foundations**	Reinforcement steel (rebar)	1.99		Reinforcement steel bars and skirts assumed.

Component(s)	Material	Emission factor*	Data source	Assumptions and caveats
Inter-array cables and OSP platform link cables	Cross-linked polyethylene (XLPE)	1.93	Cableizer (2021)	N/A
Inter-array cables and OSP platform link cables	Semiconductor	1.49		Conductor screen and insulation screen.
Inter-array cables and OSP platform link cables	Polyethylene sheath	2.54		Assumed on all power cores.
Inter-array cables and OSP platform link cables	Armouring	1.46		Only for submarine cables.
Inter-array cables and OSP platform link cables	Polypropylene yam	3.69		Only for submarine cables. Emission factor available for CO_2 only.
Inter-array cables and OSP platform link cables	Polyethylene filler	2.54		Based on assumed volume.
* In kg CO_2e per kg material (unless otherwise stated) ** Worst case scenario assumes GBS as the most GHG intensive foundation option.				

13. The emission factors from the ICE database are 'cradle-to-factory gate' and, therefore do not account for GHG emissions from the transportation of materials to the windfarm site via road or marine vessel.

14. As detailed in **Chapter 22 Traffic and Transport** (Document Reference 5.1.22), it is the Applicant's position that they would not be able to confirm which port(s) would be used for each of the Project phases until post-consent and therefore a meaningful assessment of traffic and transport impacts, including the quantification of GHG emissions from road vehicle movements related to offshore activities, cannot be presented at this stage. Based on previous experience on comparable offshore wind projects, emissions from road vehicle movements bringing materials to port(s) used for offshore construction, operation and maintenance and decommissioning activities are likely to constitute a very minor contribution to the overall GHG footprint, when compared to embodied carbon in materials and marine vessel emissions.

15. Emissions associated with marine movement of materials from origin ports to the windfarm site were quantified under the marine vessels source group

based on information available at the time of assessment, as described below in **Section 3**.

16. Material quantities associated with spare parts to be used during repair and replacement events over the Project's operational lifetime are unknown at this stage. Embodied carbon from spare parts was assumed to be 3.7% of construction, and operation and maintenance emissions based on benchmarks available in literature sources (Thomson & Harrison, 2015).

3 Marine vessels

17. Marine vessels would be used to bring materials and components to the windfarm site, install infrastructure (WTGs, OSP(s), foundations and cables), and provide crew accommodation and support during construction, commissioning, and operation and maintenance activities.

3.1 Indicative vessel logistics – current working assumptions

18. Two vessel operating modes were covered in the GHG assessment: (1) in transit; and (2) onsite offshore construction at the windfarm site. The current working assumptions for the Project's construction phase are outlined in **Table 3.1** and **Table 3.2** for the two operating modes, while assumptions for the operation and maintenance phase are outlined in **Table 3.3** and **Table 3.4**.

19. Vessels used during the construction, and operation and maintenance phases were assumed to travel to the windfarm site from various locations, such as the marshalling port, the windfarm component's originating sites and the operation and maintenance base.

20. To avoid double counting, vessel movements associated with the collection and transport of windfarm components to the marshalling port are assumed to have no on-site time. It is anticipated that installation activities would be covered by vessels transiting from the marshalling port to the windfarm site.

Table 3.1 Vessel movement assumptions during construction (in transit)

Vessel type	Maximum number of return trips	Maximum return distance (nm)	Approximate distance covered over entire construction period (nm)	Assumptions
Tugs	228	200	45,600	▪ All barges assumed to be unpropelled, and therefore no emissions are anticipated from these vessels. Emissions assumed to be released by tugs transporting the barges. ▪ Transit from marshalling port to windfarm site. ▪ Marshalling port assumed to be in Belfast.
Heavy Lift Vessels (HLV) and Jack-up Vessels (JUV)	21	200	4,200	▪ Transit from marshalling port to windfarm site. ▪ Marshalling port assumed to be in Belfast.
Cable lay & burial vessels	20	200	4,000	
Crew Transfer Vessels (CTV)	3,600	70	252,000	▪ Support vessels to primary construction vessels assumed to transit from operation and maintenance base to windfarm site. ▪ Operation and maintenance base assumed to be 35 nm from windfarm site.
Service Operations Vessel (SOV)	68	70	4,760	
Guard vessels	108	70	7,560	
Survey vessels	40	70	2,800	
Rock placement vessels	12	2,200	26,400	▪ Transit from scour protection collection point to windfarm site. ▪ Collection point assumed in be in Stavanger or elsewhere in

Vessel type	Maximum number of return trips	Maximum return distance (nm)	Approximate distance covered over entire construction period (nm)	Assumptions
				Norway, contingency distance included.
HLV	18	1,900	34,200	▪ Transit from WTG collection point to marshalling port. ▪ Two WTGs loaded per trip assumed.
HLV	10	14,000	140,000	▪ Transit from substructure collection point to marshalling port. ▪ Four substructures loaded per trip assumed.
HLV	1	1,560	1,560	▪ Transit from OSP collection point to marshalling port. ▪ Two OSPs loaded per trip assumed.
Cable lay & burial vessels	2	6,400	12,800	▪ Transit from cable collection point to marshalling port. ▪ Collection assumed to be in Greece.

Table 3.2 Vessel on-site duration assumptions during construction

Vessel type	Assumed duration on-site (hours)	Assumptions
Tugs	13,149	▪ All barges assumed to be unpropelled, and therefore no emissions are anticipated. Emissions assumed to be released by tugs transporting the barges.
HLV and JUV	13,149	▪ Assumed to cover installation associated with substructures, OSP(s) and WTGs.
CTV	19,723	N/A
Cable lay & burial vessels	14,610	▪ Assumed to cover installation and burial associated with inter-

Vessel type	Assumed duration on-site (hours)	Assumptions
		array cables and OSP platform link cables.
SOV	15,340	n/a
Guard Vessels	19,723	n/a
Survey Vessels	10,227	n/a
Rock placement vessels	4,383	▪ Assumed to cover installation associated with scour protection.

Table 3.3 Annual vessel movement assumptions during operation and maintenance (in transit)

Vessel type	Maximum number of return trips	Maximum return distance (nm)	Approximate distance covered over entire construction period (nm)	Assumptions
Standard maintenance year				
SOV	24	70	1,680	▪ Transit from operation and maintenance base to windfarm site. ▪ Operation and maintenance base assumed to be 35nm from windfarm site.
CTV	360	70	25,200	
Heavy maintenance year (every five years)				
SOV	24	70	1,680	▪ Transit from operation and maintenance base to windfarm site. ▪ Operation and maintenance base assumed to be 35nm from windfarm site.
CTV	780	70	54,600	
Cable repair & re-burial vessels	12	70	840	
Pushbusters	6	70	420	▪ Excavator vessels assumed to be unpropelled, and therefore required to be transported by pushbusters. ▪ Transit from operation and

Vessel type	Maximum number of return trips	Maximum return distance (nm)	Approximate distance covered over entire construction period (nm)	Assumptions
				maintenance base to windfarm site. ▪ Operation and maintenance base assumed to be 35nm from windfarm site.
Rock placement vessels	4	2,200	8,800	▪ Transit from scour protection collection point to windfarm site. ▪ Collection point assumed in be in Stavanger or elsewhere in Norway, contingency distance included.
HLV and JUV	6	200	1,200	▪ Assumed to be from Belfast to windfarm site.

Table 3.4 Annual vessel on-site duration assumptions during operation and maintenance

Vessel type	Assumed duration on-site (hours)	Assumptions
Standard maintenance year		
SOV	8,766	N/A
CTV	8,766	N/A
Heavy maintenance year (every five years)		
SOV	8,766	N/A
CTV	18,992	N/A
Rock placement vessels	1,461	▪ Assumed to cover maintenance associated with scour protection.
Cable repair and re-burial vessels	4,383	▪ Assumed to cover maintenance and re-burial associated with inter-array cables and OSP platform link cables.
HLV and JUV	4,383	▪ Assumed to cover maintenance associated with substructures, OSP(s) and WTGs.
Excavator Vessels	2,191	n/a

21. Emissions from dredging activities during the construction of the Project have not been included in the assessment, as a breakdown of information regarding dredging activities is not known to the Applicant at this stage. Emissions from dredgers are anticipated to form a low contribution compared to emissions from other marine vessels used for the Project, and therefore this omission is not considered likely to affect the outcome of the assessment.

3.2 Emission calculations

22. Emission calculation methodologies adopted for the Project are based on best practice guidance documents, including the United States Environmental Protection Agency's (US EPA) 'Port Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions' (2022) and the Global Maritime Energy Efficiency Partnerships Project's (GloMEEP) 'Port Emissions Toolkit' (2018).

23. Indicative vessel types that would be used during construction, and operation and maintenance activities were assumed from information provided by the Project's design team and experience on comparable offshore wind projects. Based on the estimated vessel specifications, vessel parameters relevant to GHG emission calculations were obtained such as transit speed and engine sizes.

24. Vessel emissions during transit were calculated by dividing the total distance covered with the average transit speed to derive total transit time, which was multiplied by the propulsion and auxiliary engine power, their respective load factors and the emission factor. This calculation can be summarised as the following formula:

$$E_{transit} = \left((A_{transit} * PE * LF_{prop}) + (A_{transit} * AE * LF_{aux}) \right) * EF$$

Where:

$E_{transit}$ = GHG emissions during transit (CO_2e)

$A_{transit}$ = Activity (hours), defined as the product of the number of return trips and distance per return trip, divided by the vessel's average transit speed

PE = Propulsion engine size (kW)

AE = Auxiliary engine size (kW)

LF = Load factors, for propulsion and auxiliary engines

EF = Emission factor (tonnes CO_2e/kWh)

25. Vessel emissions for offshore construction activities were calculated by multiplying the total on-site time provided with the propulsion and auxiliary engine power, their respective load factors and the emission factor. This calculation can be summarised as the following formula:

$$E_{site} = \left(\left(A_{site} * PE * LF_{prop} \right) + \left(A_{site} * AE * LF_{aux} \right) \right) * EF$$

Where:

Etsite = GHG emissions from offshore construction activities (CO_2e)

Atransit = Activity (hours), defined by the total time on-site as provided by the Project

PE = Propulsion engine size (kW)

AE = Auxiliary engine size (kW)

LF = Load factors, for propulsion and auxiliary engines

EF = Emission factor (tonnes CO_2e/kWh)

26. Vessel emissions during construction were derived from the sum of all in transit and offshore construction emissions, for all vessel types specified across the entire construction period. Operation and maintenance vessel emissions were calculated as the product sum of all in transit and offshore construction emissions, for all vessel types specified during standard and heavy maintenance years and their respective number of occurrences within the Project's operational lifetime of 35 years. Heavy maintenance years were assumed to occur every five years, with the exception of the final operational year, otherwise standard maintenance years were assumed.

27. The emission factor for marine gas oil (MGO) used in the vessel emission calculations was 0.26 CO_2e/kWh, which was obtained from the Department for Energy Security and Net Zero's (DESNZ) emission conversion factors (2023). It should be noted, however, that the maritime sector is expected to decarbonise over the Project's operational lifetime, although projections regarding the rate and extent that such emission reduction will take place still hold considerable uncertainties. As a conservative estimate, it was therefore assumed that construction and operation and maintenance vessels would continue to use MGO. However, this is likely to result in an overestimation of GHG emissions, especially with respect to vessels used towards the latter end of the operation and maintenance phase.

28. Vessel engine sizes were obtained from public vessel specification sheets, where available. Propulsion engine sizes were assumed to include the main engine and thrusters. However, auxiliary engine sizes tend to be undisclosed. Therefore, they were estimated based on the total installed power, less the propulsion engine size, or calculated using a ratio provided in US EPA's report on vessel emissions (2009). The majority of vessels included in the GHG assessment could be categorised as bulk carriers, whose auxiliary to propulsion ratio is estimated at 0.222. For vessels without total installed power

specified and whose type falls outside of the US EPA's ratio table, an indicative estimate of 10% of the propulsion engine size was assumed for the auxiliary engine (US EPA, 2009).

29. Vessels have various operating modes such as cruising, manoeuvring and hotelling, which affect how much work is being undertaken by the propulsion and auxiliary engines. For the emission calculations, this is captured by the load factor, which represents the percentage of a vessel's maximum engine load while undertaking a specific activity. A vessel's engines are rarely operated at 100% or more of its maximum load due to fuel consumption costs, efficiency and engine maintenance requirements, therefore most vessel operators limit their engine load to around 83% or less (GloMEEP, 2018). During transit, load factors would be higher for propulsion than auxiliary engines, and vice versa for offshore construction activities. Load factors used in the vessel emission calculations are detailed in **Table 3.5**.

Table 3.5 Load factors assumed for Project vessels

Engine type	Activity	Load factor	Data source	Assumptions
Propulsion engine	In transit	0.75	Provided by the Project's design team	▪ Vessels assumed to be in cruising mode.
	Offshore construction	0.31 (tugs) 0.38 (work boats and miscellaneous)	GloMEEP (2018)	▪ Vessels assumed to be in manoeuvring mode as worst case scenario. ▪ All vessels assumed to be work boats and miscellaneous, with the exception of tugs.
Auxiliary engine	In transit	0.17	US EPA (2009)	▪ Vessels assumed to be in cruising mode. ▪ All vessels assumed to be bulk carriers, tugs or miscellaneous vessels.
	Offshore construction	0.26		▪ Vessels assumed to be in manoeuvring mode as worst case scenario. ▪ All vessels assumed to be bulk carriers, tugs or miscellaneous vessels.

30. Some elements of the data used to calculate GHG emissions from marine vessels are confidential at this stage due to commercial sensitivities, therefore a full breakdown of information used to derive GHG emissions from this source group is unavailable.

4 Helicopters

31. Helicopter movements associated with the construction phase of the Project would result in the release of GHG emissions. The amount of GHG emissions from helicopters was calculated by determining the expected fuel consumption based on the number of return flights estimated by the Applicant. Helicopters are unlikely to be used for routine maintenance activities and would only be used in exceptional circumstances during the operation and maintenance phase, therefore these movements have not been considered as part of the GHG assessment.

32. An indicative number of return flights, plus contingency distances (800 return flights) travelled by helicopters during the construction phase and the likely helicopter base (where the average flight distance of 36.6km was measured as a straight-line distance to the approximate centre of the windfarm site) was provided by the Applicant's design team. In addition, as advised, it was assumed that three types of helicopter would be used during construction: Sikorsky S-76, AS365 Dauphin and AgustaWestland AW139. The average cruise speed, fuel consumption (kg/hr) and/or fuel economy (km/L) data for each of these helicopters were obtained from manufacturers' specification sheets to estimate fuel consumption during construction.

33. Emission factors for aviation turbine fuel (or jet fuel) were obtained from DESNZ (2023), which were 3,181 kg CO_2e/tonne and 2.5kg CO_2e/L respectively. GHG emissions from helicopters were calculated using the following equations, depending on the specification data available for each helicopter:

$$(1)\ E = \left(\frac{\frac{D}{S} * \mathrm{F}}{1{,}000}\right) * EF$$

Where:

E = GHG emissions (CO_2e)

D = Average trip distance (km)

S = Cruise speed (km/hr)

F = Fuel burn (kg/hr)

EF = Emission factor (kg CO_2e per tonne)

$$(2)\ E = \frac{D}{FE} * EF$$

Where:

E = GHG emissions (CO_2e)

D = Average trip distance (km)

FE = Fuel economy (km/L)

EF = Emission factor (kg CO_2e per litre)

5 Vessel diversions

34. The ferry and cargo routes affected by the Project, total annual vessel counts (2022 data) and additional route distances were obtained from **Chapter 14 Shipping and Navigation** (Document Reference 5.1.14), and **Appendix 14.1 Navigation Risk Assessment** (Document Reference 5.2.14.1) and provided in **Table 5.1**.

Table 5.1 Ferry and commercial vessel route diversions

Vessel Route	Total annual vessel count (2022)	Additional route distance (nm)	Total annual deviation distance (nm)
Ferry route			
Stena Line LIV-BEL (East of Isle of Man (IOM) – East of Calder)	196	1.6	314
Commercial vessel routes			
Liverpool East of IoM (East of Calder)	14	2.4	34
Liverpool East of IoM (West of Calder)	13	0.1	1
Heysham Off Skerries TSS (Eastwards)	10	2.4	21
Heysham Off Skerries TSS (Westwards)	7	1.4	10
Barrow Off Skerries TSS (Eastwards)	13	1.7	22
Barrow Off Skerries TSS (Westwards)	4	-0.4	-2

35. Indicative vessel types for the ferry and commercial vessel routes were assumed based on the unique vessels intersecting the windfarm site, as reported in **Appendix 14.1**, and vessel parameters such as propulsion and auxiliary engine sizes were obtained from publicly available specifications.

36. Indirect emissions from diversions to ferry and commercial vessel routes have been calculated using the same calculation methodologies for Project vessels, as presented in **Section 3.2.**

37. Affected ferries were assumed to be powered by Liquefied Natural Gas (LNG), and an emission factor of 0.17 CO_2e/kWh was obtained from DESNZ's emission conversion factors (2023). Commercial vessels were assumed to be powered by MGO, and an emission factor of 0.26 CO_2e/kWh was used.

38. Load factors used in the emission calculation are provided in **Table 5.2**.

Table 5.2 Load factors assumed for affected ferry and commercial vessel routes

Engine type	Activity	Load factor	Data source
Ferries			
Propulsion engine	In transit	0.42 (ferry)	GloMEEP (2018)
Auxiliary engine		0.8 (cruise ship)	US EPA (2009)
Commercial vessels			
Propulsion engine	In transit	0.38 (work boat)	GloMEEP (2018)
Auxiliary engine		0.17 (general cargo)	US EPA (2009)

39. As noted in **Section 3.2**, vessel emissions, including those from diversions, are likely to an overestimate, as emission factors do not reflect the uptake of zero- or low-carbon fuel alternatives and other decarbonisation initiatives in the maritime sector. Furthermore, such affected vessels are owned and operated by third parties, and therefore, the Applicant has no control or influence over the decision to avoid or minimise any increase in emissions.

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