Morecambe Offshore Windfarm: Generation Assets

Environmental Statement

Volume 5

Chapter 21 Climate Change

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Glossary of Acronyms

BEIS	Department for Business, Energy and Industrial Strategy[1]
CCC	Climate Change Committee
CCRA	Climate Change Resilience Assessment
CEA	Cumulative Effects Assessment
CH_4	Methane
CO_2	Carbon Dioxide
CoCP	Code of Construction Practice
COP	Conference of the Parties
CTV	Crew Transfer Vessels
DCO	Development Consent Order
DESNZ	Department for Energy Security and Net Zero
EIA	Environmental Impact Assessment
ES	Environmental Statement
GHG	Greenhouse Gas
GWP	Global Warming Potential
HFCs	Hydrofluorocarbons
ICE	Inventory of Carbon and Energy
IEMA	Institute of Environmental Management and Assessment
IPCC	Intergovernmental Panel on Climate Change
JUV	Jack-Up Vessels
LCA	Life Cycle Analysis
LSE	Likely Significant Effects
MCCIP	Marine Climate Change Impacts Partnership
MMO	Marine Management Organisation
N_2O	Nitrous Oxide
NAP	National Adaptation Programme
NE	Natural England
NF3	Nitrogen Trifluoride
NPPF	National Planning Policy Framework
NPS	National Policy Statement
NREL	National Renewable Energy Laboratory

[1] As of February 2023, the Department of Business, Energy and Industrial Strategy (BEIS) is known as the Department for Energy Security and Net Zero (DESNZ).

OSP	Offshore substation platform
PDE	Project Design Envelope
PEIR	Preliminary Environmental Information Report
PEMP	Project Environmental Management Plan
PFCs	Perfluorocarbons
PINS	Planning Inspectorate
RCP	Representative Concentration Pathways
RSPB	Royal Society for the Protection of Birds
SF_6	Sulphur Hexafluoride
SOV	Service Operation Vessels
UK	United Kingdom
UKCP	United Kingdom Climate Projection
UNFCCC	United Nations Framework Convention on Climate Change
WTG	Wind turbine generator

Glossary of Unit Terms

°C	Degrees Celsius
cm	Centimetre
CO_2e	Carbon Dioxide Equivalent
CO_2e/kWh	Carbon Dioxide Equivalent per Kilowatt-hour
g	Gram
GW	Gigawatt
GWh	Gigawatt hour
km	Kilometre
kv	Kilovolt
kWh	Kilowatt hour
mm	Millimetre
MW	Megawatt
MWh	Megawatt hour

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.
Capacity factor	The ratio of average power generated by the windfarm under real-world conditions to its theoretical maximum output.
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 CO_2 which would have the equivalent global warming impact.
Climate	The general weather conditions prevailing over a long period of time, which include seasonal averages and extremes.
Climate change impact	An impact from a climate hazard which affects the ability of the receptor to maintain its functions or purpose.
Climate change resilience	The ability of a project and its receptors to prepare for, respond to, recover from and adapt to changes in the climate in a manner that ensures it retains much of its original function and purpose.
Climate hazard	A weather or climate-related event or trend in climate variable, which has potential to do harm to receptors such as increased precipitation or storms.
Climate projection	A possible climate outcome defined by the modelling of various climate variables.
Climate variable	A measurable, monitorable aspect of the weather or climate conditions such as temperature and wind speed.
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.
Likely Significant Effect (LSE)	Meaning that there may be (as opposed to is likely to be) a significant effect of a proposal on the integrity of the site and its conservation objectives.
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)[2], 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 document 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).
Representative Concentration Pathways	Greenhouse gas concentration trajectories adopted by the IPCC, which are used in the UK Climate Projection (UKCP) database to predict potential future climate scenarios.
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 EIA topic which includes the offshore development area as well as potential spatial and temporal

[2] 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 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.

	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 Project windfarm site in which the Generation Assets will be located.
Technical stakeholders	Technical consultees are organisations with detailed knowledge or experience of the area within which the Project is located and/or receptors which are considered in the EIA and habitats regulations assessment (HRA). Examples of technical stakeholders include Marine Management Organisation (MMO), local authorities, Natural England (NE) and the Royal Society for the Protection of Birds (RSPB).
Weather	Atmospheric conditions prevailing at specific moments in time or over short time periods, defined by climate variables such as temperature and precipitation.
Wind turbine generator (WTG)	A fixed structure located within the windfarm site that converts the kinetic energy of wind into electrical energy.
Windfarm site	The area within which the wind turbine generators, inter-array cables, OSP(s) and platform link cables will be present.

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21 Climate Change

21.1 Introduction

21.1 This chapter of the Environmental Statement (ES) considers the potential effects of the Morecambe Offshore Windfarm Generation Assets (the Project) on climate change, as well as the potential environmental effects of climate change on the Project. The chapter comprises a Greenhouse Gas (GHG) assessment and a Climate Change Resilience Assessment (CCRA) to consider the potential effects related to climate change during the construction, operation and maintenance and decommissioning phases of the Project.

21.2 The GHG assessment predicts the contribution of the Project to levels of GHG emissions in the UK, and its 'net effect' compared to a baseline of 'Do Nothing'. The CCRA considers the Project's adaptive capacity to climate change, defined by the potential or ability to adapt to the effects of climate change such as sea level rise. The CCRA is based on the resilience of the Project to the projected effects of climate change over its lifespan.

21.3 The GHG assessment was undertaken in accordance with the Institute of Environmental Management and Assessment (IEMA) guidance 'Guide: Assessing Greenhouse Gas Emissions and Evaluating their Significance' (2022). This guidance document provides a topic-specific methodology for assessment of GHGs and determining the significance of emissions generated by a project, and therefore the assessment methodology differs from that presented in **Chapter 6 EIA Methodology** (Document Reference 5.1.6).

21.4 The CCRA was undertaken in accordance with IEMA's 'Environmental Impact Assessment Guide to Climate Change Resilience and Adaptation' (2020). This guidance document provides a methodology for identifying relevant current and future climate baseline conditions and assessing a project's vulnerability and resilience to the effects of climate change. As the CCRA considers climate change impacts on the Project, its assessment methodology is also topic-specific and differs from that presented in **Chapter 6 EIA Methodology**.

21.5 The Environmental Impact Assessment (EIA) of the Transmission Assets, including offshore export cables to landfall and onshore infrastructure, is part of a separate Development Consent Order (DCO) application as outlined in **Chapter 1 Introduction** (Document Reference 5.1.1).

21.6 **Appendix 21.1 Greenhouse Gas Assessment Methodology** (Document Reference 5.2.21.1) has been prepared to provide supplementary information on the approach to undertaking the GHG calculations and assessment process and should be read in conjunction with the climate change chapter.

21.2 Consultation

21.7 Consultation with regard to climate change has been undertaken in line with the general process described in **Chapter 6 EIA Methodology**. The key elements undertaken to inform this ES have included Scoping (Scoping Opinion from the Planning Inspectorate (PINS) received on 2nd August 2022) and comments received on the Preliminary Environmental Information Report (PEIR) which was published in April 2023 for statutory consultation. The key comments pertinent to climate change are shown in **Table 21.1**. This details how the Project team has had regard to the comments and how these have been addressed within this chapter.

21.8 The consultation process is described further in **Chapter 6 EIA Methodology**. Full details of the consultation undertaken throughout the EIA process is presented in the Consultation Report (Document Reference 4.1), submitted as part of the DCO Application.

Table 21.1 Consultation responses in relation to climate change and how these have been addressed in the ES

Consultee	Date	Comment	Response/where addressed in the ES
Scoping Opinion responses			
PINS (ref. 3.17.2)	2nd August 2022	The ES should include a description and assessment (where relevant) of the Likely Significant Effects (LSE) the Proposed Development would have on climate (for example having regard to the nature and magnitude of greenhouse gas emissions) and the vulnerability of the project to climate change.	A GHG assessment is presented in this chapter (see **Section 21.7.1**) and within **Appendix 21.1**. A CCRA has been undertaken for the ES and is presented in this chapter (see **Section 21.7.2**). The assessment evaluates the Project's adaptive capacity and describes mitigation measures which have been incorporated to ensure that the design is resilient to the projected effects of climate change.
PINS (ref. 3.17.2)	2nd August 2022	Where relevant, the ES should describe and assess the adaptive capacity that has been incorporated into the design of the Proposed Development. This may include, for example, alternative measures such as changes in the use of materials or construction and design techniques that will be more resilient to risks from climate change. The assessment should be based on the latest published projections. The ES should also describe and assess the adaptive capacity that has been incorporated into the design of the Proposed Development.	
Statutory consultation feedback on the PEIR			
Isle of Man Government	2nd June 2023	The PEIR report is comprehensive and ties into UK National Planning policy, plus energy and climate policy. The GHG emissions are clearly stated across stage: construction, operation and decommissioning. The whole-life avoided emissions are clearly stated and show that the developments, despite being emitters, are positive for overall global emissions when comparing them to fossil fuels. Adaptation risks have been considered. The PEIR report is a fair and reasonable assessment.	Noted with respect to the GHG assessment. For potential effects on shipping and navigation, see **Chapter 14 Shipping and Navigation** (Document Reference 5.1.14).

Consultee	Date	Comment	Response/where addressed in the ES
		In addition, noting the concerns regarding the potential effects on shipping and navigation route as a result of this proposed development; from a climate change point of view the shipping and navigation section seems to be well assessed, and since ferries are by far the lowest emitting way to travel to and from the Island, it is very important that these routes are not significantly affected by this development proposal.	
Stena Line	2nd June 2023	(a) Stena Line acknowledges that the Windfarms will likely have an overall beneficial effect in respect of climate change. (b) However, the figures estimated do not provide an accurate and complete assessment of the cumulative or individual impact of the Mona, Morecambe Morgan Offshore Wind Project Generation Assets on direct/indirect greenhouse gas emissions ("GHG Emissions"): (i) The GHG Emissions for the Transmission Assets for Morecambe and Morgan Windfarms have not been considered in the assessments. There are GHG Emissions associated with the Transmission Assets for Morecambe and Morgan Windfarms which should be considered in determining the overall GHG Emissions footprint and carbon payback periods (see Morecambe PEIR Chapter 21, paragraph 21.44). (ii) Indirect GHG Emissions have not been fully considered. Importantly, the increase in GHG Emissions resulting from the additional time spent by vessels (including Stena Line's vessels) in transiting the Windfarm areas has not been considered. It appears that only GHG Emissions associated with the Windfarms have been considered (i.e., GHG Emissions from vessels transporting	The GHG assessment has been updated for the ES to consider the GHG emissions arising from the Transmission Assets for the Morgan Offshore Wind Project and the Morecambe Offshore Windfarm. The Project's whole lifecycle impacts combined with the Transmission Assets are presented in **Section 21.7.1.5**. This has been undertaken to account for indirect GHG emissions from the Transmission Assets, which along with the Project form the windfarm development in its entirety and enables its function of providing renewable energy to the grid. GHG emissions arising from the construction, operation and maintenance, and decommissioning of the Morgan Offshore Wind Project Generation Assets and the Mona Offshore Wind Project fall beyond the system boundary for the Project's GHG assessment. These projects are

Consultee	Date	Comment	Response/where addressed in the ES
		materials to the Windfarms) (see Morecambe PEIR Chapter 21, Table 21.9). (iii) There have been no cumulative assessments on the impact of the Mona, Morecambe and Morgan Offshore Wind Project Generation Assets on direct/indirect GHG Emissions or the climate generally. This is particularly relevant where different phases of the projects are predicted to produce different levels of GHG Emissions (i.e., as the construction phase of the Windfarms are anticipated to produce the most direct GHG Emissions (see, for example, Morecambe PEIR Chapter 21, paragraph 21.57)), this means that there may be a cumulative adverse impact for a significant period across the projects before any cumulative net benefit is seen. It is impossible to make an assessment on this point given that insufficient information is available on the Morgan and Morecambe Transmission Assets (see Morgan PEIR Chapter 17, paragraph 17.13.1.2). (c) Stena Line is committed to reducing its emissions both onshore and at sea and invests in clean energy technology. The increased time it will take for Stena Line to perform its routes (in normal and adverse weather conditions) as a result of the footprint of the Windfarms will lead to increased GHG Emissions and will be counter-productive to Stena Line's current policies, and the purpose and intent of the Windfarms. (d) This increase in GHG Emissions is not anticipated to be insubstantial. Indeed, in considering increased shipping movements in respect of vessel movements related solely to the operation and maintenance of an example windfarm, the Morecambe PEIR suggests that these movements alone contribute 14.3% to total GHG emissions of the	seeking consent under separate DCO applications by a different developer to the Project, and therefore the Applicant does not have control or influence over their project design and associated GHG emission sources. In line with IEMA's guidance (2022), the effects of GHG emissions from non-Project related developments are not individually assessed, as there is no basis for selecting which developments should be assessed cumulatively over any other. The GHG assessment within this chapter considers emission sources directly associated with the Project, and therefore indirect effects such as the diversion of vessels have not been included. Any changes to vessel travel associated with the provision of the Project-alone is likely to result in a non-significant increase in journey times, as detailed in **Chapter 14 Shipping and Navigation**. Therefore, inclusion of indirect effects such as changes to vessel journey times is not considered to change the outcomes of the assessment. Indirect emissions arising from increased journey times to ferry and commercial vessel routes affected by the Project are estimated at 37.2 tonnes CO_2e/year, which is considered

Consultee	Date	Comment	Response/where addressed in the ES
		example windfarm (Morecambe PEIR Chapter 21, paragraph 21.16). (e) Inaccurate GHG Emissions statistics make it impossible to assess the efficacy of the Windfarms and their net climate benefit.	negligible compared to other emission sources. Emission calculation and assumptions behind this figure are provided in **Appendix 21.1**. The GHG assessment, provided in **Section 21.7.1** contains a number of conservative assumptions, particularly during the operational and maintenance phase, and therefore predicted emissions are considered likely to be an overestimation. For potential effects on shipping and navigation, see **Chapter 14 Shipping and Navigation**.
Isle of Man Government	2nd June 2023	In addition, the Manx Natural Heritage provides the following general comments: The need for protection of the seabed with particular reference to areas of high conservation or carbon sequestration value, such as sea grass beds, Zostera marina, as highlighted in the Manx Marine Nature Reserves.	The Project does not extend into Manx territorial waters or overlap with any Manx Marine Nature Reserves. The site does not overlap with biogenic reefs, sea grass beds, saltmarshes, kelp forests or maerl beds or other marine habitats with high carbon sequestration potential, therefore no LSE on blue carbon storage is expected due to the Project. For more information, see **Chapter 9 Benthic Ecology 9** of the ES (Document Reference 5.1.9).

21.3 Scope

21.3.1 Study area

21.9 The windfarm site (encompassing all Project infrastructure) is located in the Eastern Irish Sea and encompasses a seabed area of approximately 87km^2. The nearest point from the windfarm site to shore (coast of northwest England) is approximately 30km.

21.3.1.1 GHG assessment

21.10 The GHG assessment considers emissions and removals associated with the Project which contributes to its total GHG footprint. Emissions which are released or avoided due to the Project have the same effect on atmospheric GHG concentrations and its net effect on climate change regardless of where they occur, therefore the study area of the GHG assessment is not geographically defined.

21.11 The scope of the GHG assessment is limited to quantifying direct and indirect GHG emissions directly arising from the Project, including processes inherent in its construction (which includes raw material extraction, manufacturing, transport and installation), operation and maintenance, end of life and eventual decommissioning. Key emission sources associated with the Project are defined by a list of GHG emitting activities provided in **Table 21.10**. GHG emissions are quantified by each phase of the Project and combined to present total emissions over the whole lifecycle.

21.12 In addition, GHG emissions arising from the development of the Transmission Assets are also presented within the chapter and are considered in-combination with the Project's lifecycle emissions to contextualise the outcomes of the assessment and determine the net contribution to climate change of the windfarm development in its entirety.

21.3.1.2 CCRA

21.13 The scope of the CCRA is focused on evaluating the vulnerability and resilience of Project receptors to the effects of climate change. Therefore, the study area for the CCRA is spatially bounded and defined by the Project windfarm site in which the Generation Assets will be located.

21.14 The temporal scope of the CCRA is the operation and maintenance phase, as the length of the Project's lifetime coincides with longer term climate change and is of sufficient duration to potentially give rise to LSE. The Project's 35-year operational lifetime will be segmented into representative time slices for the purpose of characterising the future baseline climate using climate projection data.

21.15 The construction phase of the Project has been scoped out of the CCRA, as it is considered that receptors are likely to have low vulnerability to climate related hazards due to the short construction timescale (up to 2.5 years, with an estimated start date as 2027). Furthermore, the only climate hazards with potential to effect receptors associated with the Project during construction are extreme weather events in the short term, as chronic hazards that involve gradual changes to climate averages and extremes would occur over the medium to long term. The Project will include climate resilience measures in construction phase management plans, which is standard health and safety practice, as noted in **Section 21.3.3.2**.

21.16 Extreme weather events during the construction phase would likely resemble those currently experienced, and based on best practice in the construction sector, it can be assumed that mitigation measures will be incorporated into construction management plans to minimise the likelihood of climate change impacts, as discussed further in **Section 21.3.3.2**.

21.17 The decommissioning strategy and specific nature of activities required for the Project are not yet known and will be developed at a later stage. As such, the decommissioning phase has also been scoped out of the CCRA. It is assumed that suitable climate change adaptation measures would be developed in the future once it becomes clear how long-term climate change would affect the Project, and secured in suitable management plans. This approach is in alignment with IEMA's guidance (2020) with respect to adaptive management.

21.3.2 Realistic worst-case scenario

21.18 The final design of the Project will be confirmed through detailed engineering design studies that will be undertaken post-consent to enable the commencement of construction. To provide a precautionary, but robust impact assessment at this stage of the development process, realistic worst-case scenarios have been defined. The realistic worst-case scenario (having the most impact) for each individual impact is derived from the Project Design Envelope (PDE) to ensure that all other design scenarios will have less or the same impact. Further details are provided in **Chapter 6 EIA Methodology**. This approach is common practice for developments of this nature, as set out in Planning Inspectorate Advice Note Nine: Rochdale Envelope (v3, 2018).

21.19 The realistic worst-case scenarios for the assessment for climate change are set out in **Table 21.2**. These are based on the PDE described in **Chapter 5 Project Description** (Document Reference 5.1.5), which provides further details regarding specific activities and their durations. The envelope presented has been refined as much as possible between PEIR and ES, presenting a project description with design flexibility only where it is needed.

Table 21.2 Realistic worst-case scenarios for climate change

Potential impact	Worst-case scenario	Notes and rationale
Construction phase		
GHG emissions during construction	Installation of up to 35 WTGs and 2 OSPs.	Maximum amount of construction materials required.
	Up to 37 Transition Pieces and 37 gravity base structures for the substructure (35 x WTGs and 2 x OSPs).	Maximum amount of construction materials required.
	Up to 70km inter-array cables.	Maximum amount of construction materials required.
	Up to 10km of platform link cables.	Maximum amount of construction materials required.
	Up to 538,680m^3 of scour and cable protection (including cable protection for inter-array and platform link cables due to ground conditions, entries to WTGs/OSPs and at 15 cable crossings).	Maximum amount of construction materials required.
	Vessels required include: ▪ Tugs and Barges ▪ Heavy Lift Vessels, including Jack-Up Vessels (JUV) ▪ Crew Transfer Vessels (CTV) ▪ Cable Lay and Burial Vessels ▪ Service Operation Vessels (SOV) ▪ Guard Vessels ▪ Rock Dump Vessels ▪ Survey Vessels **4,128** vessel return trips assumed over the construction period (including transport of infrastructure components from origin to marshalling port and excluding barge movements as vessel emissions are assumed to be covered by tugs). Helicopter movements during construction phase, 800 return flights	Indicative vessel and helicopter quantities, trips and types included in the GHG assessment.

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Potential impact	Worst-case scenario	Notes and rationale
	assumed.	
	Quantities of the main and most GHG-intensive materials were included in the assessment. Furthermore, precautionary assumptions were adopted for quantities of known materials (i.e., using the maximum quantity). It was assumed that all material used for the Project's construction would require raw material extraction, e.g., virgin steel, to present a conservative assessment. However, it is likely that materials that will be used in construction will have a higher recycled content, and thus a lower embodied carbon content than what has been assumed for the assessment. The specific nature and composition of some materials, such as the type of steel to be used, were unknown at the time of assessment, which may affect the embodied carbon content contained within the material: ▪ Where project-specific information on the material composition of cables for the Project could not be supplied, assumptions were made based on the cable diameter and the breakdown of cable composition typically used on other offshore wind projects. ▪ If there was variation in terms of the emissions intensity of the emission factors used to calculate emissions across different compositions of the same material, the 'General' option within the Inventory of Carbon and Energy (ICE), 2019, database was chosen. If a 'General' option was not available, a median value was assumed.	
Operation and maintenance phase		
GHG emissions during operation and maintenance	▪ Assumed operation and maintenance activities at up to 35 x WTGs and 2 x OSPs. ▪ Nominal capacity: 480MW. ▪ Operation and maintenance lifetime: 35 years Embodied carbon from spare parts used during repair and replacement events assumed to be 3.7% of construction, and operational and maintenance emissions based on literature sources (see **Section 21.5.1.2**).	This results in the greatest quantity of materials required for operation and maintenance phase.

Potential impact	Worst-case scenario	Notes and rationale
	Vessels required: ▪ SOVs ▪ CTVs ▪ Rock Dump Vessels ▪ JUVs ▪ Cable Repair and Re-Burial Vessels ▪ Excavator Vessels **384** maximum vessel round trips per year assumed during standard maintenance years. It was assumed that 29 standard maintenance years would occur over operational lifetime. **832** maximum vessel round trips assumed per year during heavy maintenance years. It was assumed that six heavy maintenance years would occur over the 35-year operational lifetime. No planned routine helicopter movements assumed for operation and maintenance activities.	Indicative vessel quantities, trips and types included in the GHG assessment.
GHG savings from the Project	Two 'Do Nothing' scenarios assumed (see **Section 21.6.1** for further details) with respect to alternative forms of electricity generation which would be displaced by the Project's provision of renewable energy: ▪ 'Non-renewable fuel sources', i.e., fossil fuels ▪ All forms of energy sources represented in the future UK grid mix	To help determine the GHG savings as a result of the Project, i.e. the emissions avoided due to the provision of renewable energy to the United Kingdom (UK) grid.
Climate change resilience during operation	Consideration of high emissions scenario (Representative Concentration Pathway (RCP) 8.5) for future climate baseline (see **Section 21.6.2.2** for further information). Earliest operational start date: 2029	Climate projection data is available for various emission scenarios. RCP8.5 is commonly used to represent worst-case climate change outcomes.
Decommissioning phase		
The contribution from decommissioning was scaled based on the total GHG emission footprint.		

21.3.3 Summary of mitigation embedded in the design

21.3.3.1 GHG assessment

21.20 IEMA GHG guidance (2022) notes the importance of embedded mitigation in minimising GHG emissions from a development. The IEMA GHG Management Hierarchy sets out a structure to eliminate, reduce, substitute and compensate these emissions (IEMA, 2022).

21.21 In response to these principles, the need for the Project in relation to achieving net zero targets by 2050 for the UK and decarbonisation of the power sector is well established and set out within **Chapter 2 Need for the Project** (Document Reference 5.1.2). Furthermore, Project-level GHG mitigation is being incorporated into the design development process for the Project wherever it is practicable to do so. The process of reducing GHG emissions from the Project itself is guided by the hierarchy summarised in **Table 21.3**.

Table 21.3 GHG mitigation hierarchy specific to the Project

Mitigation hierarchy		Principle	Project response
↓	**Do not build (eliminate)**	Evaluate the basic need for the proposed project and explore alternative approaches to achieve the desired outcome(s).	The purpose and rationale for the Project is to mitigate against climate change by replacing existing high-carbon energy generation within the UK electricity mix. Therefore, not building could have the effect of perpetuating and exacerbating climate change.
	Build less (reduce)	Realise the potential for re-using and/or refurbishing existing assets to reduce the extent of new construction required.	Offshore windfarms by their design are efficient in their use of materials. Minimising the use of steel and other materials is a key design feature of the approach to Project design.
	Design clever (substitute)	Apply low-carbon solutions (including technologies, materials and products) to minimise resource consumption and embodied carbon during the construction, operation and maintenance, and at end-of-life.	The Project will utilise, as appropriate, the latest, most efficient and effective technologies and methodologies.
	Construct efficiently (compensate)	Use techniques (e.g., during construction, and operation and maintenance) that reduce resource consumption and associated GHG emissions	Construction of offshore components of windfarms is by its nature expensive and relies on the use of highly specialised vessels and equipment with dedicated skilled workforces. The Project will

Mitigation hierarchy		Principle	Project response
		over the life cycle of the Project.	utilise, as appropriate, new available proven technology.

21.3.3.2 CCRA

21.22 In accordance with the Applicant's technical requirements and specifications which are built upon best practice engineering codes and standards in the offshore wind sector, the Project will be designed to be resilient to hazards arising from current extreme weather events and climatic conditions and adapted to future climate change impacts where appropriate.

21.23 Climate change resilience measures which are embedded into the Project design include:

- Based on standard industry practice and occupational health and safety regulations and standards, construction management plans, developed post-consent, such as the Project Environmental Management Plan (PEMP) will include risk assessments and health and safety protocols, which will be prepared prior to the commencement of construction works. These management plans will account for exposure of site workers and construction plant to extreme weather events and ensure appropriate preparation and response measures are in place to minimise their impacts. These measures would include, but not be limited to, the following:
    - Scheduling construction activities based on seasonality and timely weather forecasts
    - Monitoring of on-site weather conditions and severe weather alert services
    - Incorporating a severe weather protocol into construction management plans and assigning clear responsibilities in the event of an emergency
    - Requiring contractors to include additional provisions in their management plans based on weather conditions at the time of works such as additional rest breaks during heatwaves, securing stored equipment and material during high wind events and specifying de-icing equipment during cold spells.
- The WTGs and fixed substructures are being designed with sufficient safety margins to account for extreme weather events such as storm surges and high winds. The substructures, WTGs, OSP(s), and inter-array and platform link cables will all be designed using metocean hindcast data as the basis for all loadcases. Hindcast models synthesise long-term time series of wind, waves and current data and are correlated with satellite observations and real-time measurements. Based on the models, wind, wave and current parameters for 10-year, 50-year and 100-year extreme weather events are being extrapolated and accounted for in the Project design.

The turbine controller monitors the operational health of the WTGs and adjusts the pitch and orientation based on the site conditions. At wind speeds above the design operational load limit, the WTGs will shut down and be yawed so as to remain in idle configuration to prevent structural damage during gusts or sustained high winds. Normal operations will resume once the wind speed returns below the cut-out speed (Weisenfeld *et al.*, 2021)

- Regular inspections and maintenance of offshore infrastructure will be carried out over the Project's operational lifetime to identify and remediate any damage and maintain good working conditions. Similar to construction works, prior to the commencement of operation and maintenance activities, risk assessments and health and safety protocols will be prepared, which will include the identification of suitable windows for works based on timely weather forecasts and the monitoring of weather conditions on-site. The Project's operation and maintenance personnel will monitor emerging climate change data and observed climate change impacts, such as extreme weather incidents on-site, and develop appropriate risk management measures on a rolling basis
- Prior to the commencement of decommissioning activities, as part of health and safety protocols, a review of recent climate hazards and up-to-date climate projection data will be undertaken to develop suitable mitigation and management measures, which will be secured in management plans for this stage of works

21.4 Policy, legislation and guidance

21.4.1 International agreements

21.4.1.1 United National Framework Convention on Climate Change (UNFCCC)

21.24 The United Nations Framework Convention on Climate Change (UNFCCC) is an international environmental treaty addressing climate change which entered into force on 21st March 1994. Its main objective is 'to stabilize greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous human interference with the climate system'. In its early years, it facilitated intergovernmental climate change negotiations and now provides technical expertise. Its supreme decision-making body, the Conference of the Parties (COP), meets annually to discuss and assess progress in addressing climate change.

21.25 The first agreement was the Kyoto Protocol which was signed in 1997 and entered into force in 2005, which committed industrialised countries to limit and reduce GHG emissions in accordance with individual targets to reduce the rate and extent of global warming. It applies to seven GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3), which was incorporated into the second Kyoto Protocol compliance period in 2012. The Kyoto Protocol recognises that the economic development of a country is an important determinant in that country's ability to combat and adapt to climate change. Therefore, developed countries have an obligation to reduce their current emissions, particularly due to their historic responsibility for the current concentrations of atmospheric GHGs.

21.26 Subsequently, the meetings of COP have resulted in several important and binding agreements, including the Copenhagen Accord (2009), the Doha Amendment (2012), the Paris Agreement (2015) and the Glasgow Climate Pact (2022).

21.27 The Copenhagen Accord raised climate change policy to the highest political level and expressed a clear political intent to constrain carbon and respond to climate change in the short and long term. It introduced the potential commitment to limiting global average temperature increase to no more than 2°C above pre-industrial levels.

21.28 The Doha Amendment to the Kyoto Protocol in 2012 included a commitment by parties to reduce GHG emissions by at least 18% below 1990 levels in the eight-year period from 2013 to 2020. The UK Climate Change Act 2008 has an interim 34% reduction target for 2020, which would allow the UK to meet and exceed its Kyoto agreement target.

21.29 The United Nations Climate Change Conference in Paris in 2015 (known as 'COP21') led to the following key areas of agreement (the Paris Agreement):

- Limit global temperature increases to below 2°C, while pursuing efforts to limit the increase to 1.5°C above the pre-industrial average temperature
- Parties to aim to reach a global peak of GHG emissions as soon as possible alongside making commitments to prepare, communicate and maintain a Nationally Determined Contribution
- Contribute to the mitigation of GHG emissions and support sustainable development whilst enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change
- Commitment to transparent reporting of information on mitigation, adaptation and support which undergoes international review
- In 2023 and every five years thereafter, a global stocktake will assess collective progress toward meeting the purpose of the Agreement

21.30 At the 22nd Climate Change COP (COP22) in November 2016, the UK ratified the Paris Agreement to enable the UK to "*help to accelerate global action on* *climate change and deliver on our commitments to create a safer, more prosperous future*" (Department for Business, Energy and Industrial Strategy (BEIS), 2016a). At the COP24 meeting, held in Katowice, Poland in December 2018, a set of rules for the Paris climate process were agreed upon.

21.31 COP26 was held in 2021 in Glasgow. The four specific objectives that were aimed to be achieved for COP26 were (UK Parliament, 2022):

- Securing global net zero by mid-century and keep 1.5°C within reach by:
  - Accelerating the phase-out of coal
  - Curtailing deforestation
  - Speeding up the switch to electric vehicles
  - Encouraging investment in renewables
- Adapt to protect communities and natural habitats
- Mobilise at least $100 billion in climate finance per year
- Further working together through actions such as finalising the Paris Rulebook and accelerating action to tackle the climate crisis through collaboration between governments, businesses, and civil society

21.32 For the first time, nations have been called upon to 'phase down' unabated coal power and inefficient subsidies for fossil fuels (UNFCCC, 2022). The main headlines of COP26 were:

- The signing of the Glasgow Climate Pact, which is a series of decisions and resolutions that build on the Paris Agreement setting out what needs to be done to tackle climate change, but does not specify what each country must do and is not legally binding
- Agreeing on the Paris Rulebook, which gives the guidelines on how the Paris Agreement is delivered. Agreements in the finalised Rulebook include an enhanced transparency framework for the reporting of emissions, common timeframes for emissions reduction targets and mechanisms and standards for international carbon markets (UK Parliament, 2022)

21.33 The most recent COP (COP28) was held in Dubai in November/December 2023. Some of the most significant outcomes of COP28 included a consensus being reached on the need for a global transition away from fossil fuels (however this did not not amount to a commitment to phase them out completely), the conclusion of the first Global Stocktake, the Food and Agriculture Organization roadmap to 1.5°C, in addition to the Global Renewables and Energy Efficiency Pledge, the latter of which is a commitment to triple the worlds renewable energy generation capacity by 2030.

21.4.2 National Policy Statements

21.34 The specific assessment requirements for climate change are set out with reference to the relevant National Policy Statement (NPS). These are the principal decision-making documents for Nationally Significant Infrastructure Projects (NSIPs). Those relevant to the Project are:

- Overarching NPS for Energy (EN-1) (Department for Energy Security and Net Zero (DESNZ), 2023a)
- NPS for Renewable Energy Infrastructure (EN-3) (DESNZ, 2023b)

21.35 The specific assessment requirements for climate change, as detailed in the NPS, are summarised in **Table 21.4**, together with an indication of the section of the ES chapter where each is addressed.

Table 21.4 NPS assessment requirements for climate change

Summary	NPS reference	ES reference
NPS for Energy (EN-1)		
The need for new nationally significant energy infrastructure projects To ensure that there is sufficient electricity to meet demand, new electricity infrastructure will have to be built to replace output from retiring plants and to ensure we can meet increased demand. Our analysis suggests that even with major improvements in overall energy efficiency, and increased flexibility in the energy system, demand for electricity is likely to increase significantly over the coming years and could more than double by 2050 as large parts of transport, heating and industry decarbonise by switching from fossil fuels to low carbon electricity. Wind and solar are the lowest cost ways of generating electricity, helping reduce costs and providing a clean and secure source of electricity supply (as they are not reliant on fuel for generation). Our analysis shows that a secure, reliable, affordable, net zero consistent system in 2050 is likely to be composed predominantly of wind and solar. As part of delivering this, UK government announced in the British Energy Security Strategy an ambition to deliver up to 50 gigawatts (GW) of offshore wind by 2030, including up to 5GW of floating wind, and the requirement in the Energy White Paper for sustained growth in the capacity of onshore wind[47] and solar in the next decade. Applications for offshore wind above 100MW or solar above 50 MW in England, or 350 MW for either in Wales, will continue to be defined as NSIPs, requiring consent from the Secretary of State (see EN-3).	Paragraph 3.3.3 Paragraphs 3.3.20, 3.3.21 and 3.3.24	The purpose of the Project is to contribute to climate change mitigation by replacing existing high-carbon energy generation, with a renewable form of energy, which will improve energy security and help the UK meet its net zero commitments.

Summary	NPS reference	ES reference
Climate Change Adaptation and Resilience *Applicant assessment* New energy infrastructure will typically need to remain operational over many decades, in the face of a changing climate. Consequently, applicants must consider the direct (e.g. site flooding, limited water availability, storms, heatwave and wildfire threats to infrastructure and operations) and indirect (e.g. access roads or other critical dependencies impacted by flooding, storms, heatwaves or wildfires) impacts of climate change when planning the location, design, build, operation and, where appropriate, decommissioning of new energy infrastructure. The ES should set out how the proposal will take account of the projected impacts of climate change, using government guidance and industry standard benchmarks such as the Climate Change Allowances for Flood Risk Assessments, Climate Impacts Tool, and British Standards for climate change adaptation, in accordance with the EIA Regulations. Applicants should assess the impacts on and from their proposed energy project across a range of climate change scenarios, in line with appropriate expert advice and guidance available at the time. Applicants should demonstrate that proposals have a high level of climate resilience built-in from the outset and should also demonstrate how proposals can be adapted over their predicted lifetimes to remain resilient to a credible maximum climate change scenario. These results should be considered alongside relevant research which is based on the climate change projections. *Secretary of State decision making*	Paragraphs 4.10.8 to 4.10.13	The CCRA presents the projected impacts of climate change across a range of scenarios and considers the direct impacts of climate change on the Project, as provided in **Section 21.6.2** and **Section 21.7.2** respectively. Climate change resilience measures have been considered as part of the assessment and outlined in **Section 21.3.3.2**.

Summary	NPS reference	ES reference
The Secretary of State should be satisfied that applicants for new energy infrastructure have taken into account the potential impacts of climate change using the latest UK Climate Projections and associated research and expert guidance (such as the EA's Climate Change Allowances for Flood Risk Assessments [or the Welsh Government's Climate change allowances and flood consequence assessments)] available at the time the ES was prepared to ensure they have identified appropriate mitigation or adaptation measures. This should cover the estimated lifetime of the new infrastructure, including any decommissioning period.		
Greenhouse Gas Emissions *Secretary of State decision making* The Secretary of State must be satisfied that the applicant has as far as possible assessed the GHG emissions of all stages of the development. The Secretary of State should be content that the applicant has taken all reasonable steps to reduce the GHG emissions of the construction and decommissioning stage of the development.	Paragraphs 5.3.8 to 5.3.10	The GHG assessment and any recommended mitigation measures are presented in **Section 21.7.1**.
NPS for Renewable Energy Infrastructure (EN-3)		
Climate change adaptation and resilience Part 2 of EN-1 covers the Government's energy and climate change strategy, including policies for mitigating climate change. Section 4.10 of EN-1 sets out generic considerations that applicants and the Secretary of State should take into account to help ensure that renewable energy infrastructure is safe and resilient to climate change, and	Paragraphs 2.4.1 to 2.4.3, and 2.4.8	As detailed above, a CCRA has been undertaken, which is presented in **Section 21.7.2**. The EIA of the Transmission Assets for the Morecambe Offshore Windfarm and the Morgan Offshore Wind Project, including offshore export cables to landfall and onshore infrastructure (including onshore substations) is part of a separate DCO application as outlined in **Chapter 1 Introduction**. This would include a CCRA for

Summary	NPS reference	ES reference
that necessary action can be taken to ensure the operation of the infrastructure over its estimated lifetime. Section 4.10 of EN-1 advises that the resilience of the project to climate change should be assessed in the Environmental Statement (ES) accompanying an application. *Offshore wind* Offshore wind farms will not be affected by flooding. However, applicants should demonstrate that any necessary land-side infrastructure (such as cabling and onshore substations) will be appropriately resilient to climate-change induced weather phenomena. Similarly, applicants should particularly set out how the proposal would be resilient to storms		the Transmission Assets, covering the onshore infrastructure.
Mitigation A GHG assessment should be used to drive down GHG emissions at every stage of the proposed development and ensure that emissions are minimised as far as possible for the type of technology, taking into account the overall objectives of ensuring our supply of energy always remains secure, reliable and affordable, as we transition to net zero. Applicants should look for opportunities within the proposed development to embed nature-based or technological solutions to mitigate or offset the emissions of construction and decommissioning. Steps taken to minimise and offset emissions should be set out in a GHG Reduction Strategy, secured under the development consent order. The GHG Reduction Strategy should consider the creation and preservation of carbon stores and sinks including through woodland creation, peatland restoration and through other natural habitats.	Paragraphs 5.3.5 to 5.3.7	Mitigation measures to curb GHG emissions have also been considered as part of the assessment and outlined in **Section 21.3.3.1**.

21.4.3 Other legislation, policy and guidance

21.4.3.1 Legislative background

21.36 The requirement to consider climate and GHG emissions has resulted from the 2014 amendment to the EIA Directive (2014/52/EU) and the Infrastructure Planning (EIA) Regulations 2017 (the 'EIA Regulations'). This includes the requirement to include an estimate of expected emissions and the impact of a project on climate, including consideration of the nature and magnitude of the release of GHGs during construction and operation.

21.4.3.2 National Planning Policy Framework (NPPF)

21.37 The National Planning Policy Framework (NPPF) was first published on 27th March 2012 and most recently updated in 20th July 2021. The revised NPPF advises that the planning system should support the transition to a low-carbon future. With respect to planning for climate change, the NPPF states:

"Plans should take a proactive approach to mitigating and adapting to climate change, taking into account the long-term implications for flood risk, coastal change, water supply, biodiversity and landscapes, and the risk of overheating from rising temperatures"

21.38 The NPPF also states:

"New development should be planned for in ways that:

a) avoid increased vulnerability to the range of impacts arising from climate change. When a new development is brought forward in areas which are vulnerable, care should be taken to ensure that risks can be managed through suitable adaptation measures, including through the planning of green infrastructure; and

b) can help to reduce greenhouse gas emissions, such as through its location, orientation and design. Any local requirements for the sustainability of buildings should reflect the Government's policy for national technical standards."

North West Inshore and North West Offshore Marine Plan

21.39 The North West Inshore and North West Offshore Marine Plan (NW-CC-2), June 2021, states:

"Proposals in the north west marine plan areas should demonstrate for the lifetime of the project that they are resilient to the impacts of climate change and coastal change."

21.4.3.3 The Climate Change Act 2008

21.40 The Climate Change Act 2008 established a legally binding target to reduce the UK's GHG emissions by at least 80% in 2050 from 1990 levels, and a system of carbon budgets was introduced in order to drive progress towards this target.

21.41 On the 12th December 2015, the UK along with 195 other parties signed the 'Paris Agreement', a legally binding international treaty on climate change, committing all parties to the goal of limiting global warming to well below 2°C, preferably to 1.5°C, compared to pre-industrial levels. The Agreement requires all parties to submit plans to reduce their emission (along with other climate actions) every five years, starting in 2020. The carbon budgets are set by the Climate Change Committee (CCC) and provide a legally binding five-year limit for GHG emissions in the UK. The six carbon budgets that have been placed into legislation and will run up to 2037 are identified in **Table 21.5**, which demonstrates the phased reduction in future permissible GHG emissions. Therefore, any emission sources will have an increasing impact on the UK's ability to meet its carbon budget, the further they are in the future.

Table 21.5 The Six UK Carbon Budgets

Budget	Carbon Budget Level (Mt CO_2e)	Reduction below 1990 level	
		UK Targets	Achieved by the UK
1st Carbon Budget (2008 to 2012)	3,018	26%	30%
2nd Carbon Budget (2013 to 2017)	2,782	32%	38%
3rd Carbon Budget (2018 to 2022)	2,544	38% by 2020	44%
4th Carbon Budget (2023 to 2027)	1,950	52% by 2025	-
5th Carbon Budget (2028 to 2032)	1,725	68% by 2030	-
6th Carbon Budget (2033 to 2037)	965	77% by 2035	-

21.42 The UK outperformed its emission reduction targets set by the first, second and third Carbon Budgets, achieving a 30%, 38% and 44% reduction compared to 1990 levels in 2011, 2015 and 2019 respectively.

In December 2020, the UK set a Sixth Carbon Budget, recommending a reduction in UK GHG emissions of 77% by 2035, relative to a 1990 baseline (a 63% reduction from 2019) (CCC, 2020). This target, which has already been enshrined in UK law, has been set in line with the UK commitments in relation to the Paris Agreement and with the goal of achieving a target of reaching net zero GHG emissions by 2050.

21.43 As part of this Budget, the role of the offshore wind sector and the construction industry are both the focus of action to contribute to meeting these targets. The seventh Carbon Budget is expected to be announced in early 2025.

In addition, the UK has an international commitment to reduce emissions by 68% in 2030 compared to 1990 levels (excluding emissions from international aviation and shipping). This is the UK's 2030 Nationally Determined Contribution (NDC), that was submitted to the UNFCCC and it is also consistent with a pathway to Net Zero by 2050 (BEIS, 2020).

21.44 The CCC publishes annual progress reports on UK's progress against GHG emissions reduction targets to 2050. The most recent published report 'Progress in reducing emissions: 2023 Report to Parliament' (CCC 2023) identified that emissions in 2022 rose by 0.8% since 2021 but remain 9% below the Covid-19 pre-pandemic (2019) levels. The report outlined the key challenges in achieving net zero targets, including highlighting the need for further policy progress to ensure the Government's commitment to 95% low-carbon generation by 2023 and electricity generation being fully decarbonised by 2035. The report also acknowledged the Government's ambition for 50 gigawatt (GW) offshore wind generation by 2030. However, an additional provision of 2.7GW of offshore wind in 2022 is slightly off track to meet the Government's 50GW target. The report outlines that an average annual deployment rate of 4.5GW is required to deliver the targets 50GW of offshore wind by 2030.

21.4.3.4 Climate Change Risk Assessment 2022

21.45 In compliance with the requirement in the Climate Change Act 2008 to undertake a Climate Change Risk Assessment every five years, the UK Government produced its latest Climate Change Risk Assessment in 2022 (Department for Environment, Food and Rural Affairs (Defra), 2022). This is the third assessment to be produced for the UK following the first and second releases in 2012 and 2017 respectively. The report concluded that among the most urgent risks for the UK are risks to people and the economy from climate-related failure of the power systems and multiple risk to the UK from climate change impacts overseas. It identifies suggestions for reducing these risks, including the consideration of climate change in developing new infrastructure.

21.4.3.5 National Adaptation Programme

21.46 The third National Adaptation Programme (NAP) (Defra, 2023) sets the actions that the UK Government will undertake to adapt to the challenges of climate change in the UK as identified in the Climate Change Risk Assessment. The NAP forms part of the five-yearly cycle of requirements detailed in the Climate Change Act 2008. The NAP details the range of climate risk which may affect infrastructure, the natural environment, health, communities and the built environment, business and industry, and international affairs. The third NAP covers key actions for 2023 to 2028 and includes the UK's fourth Strategy for Climate Adaptation Reporting.

21.4.4 Guidance

21.4.4.1 GHG assessment

21.47 The IEMA 'Assessing Greenhouse Gas Emissions and Evaluating their Significance' guidance (2022) has been used in this ES chapter for evaluating and determining the significance of GHG emissions from the Project. This is a revision of the first iteration of the guidance released in 2017 (IEMA, 2017).

21.48 The 2022 IEMA guidance presents guidelines for undertaking GHG assessments and distinguishing different levels of significance. The guidance does not update the IEMA's position that all emissions contribute to climate change, however, it now provides relative significance descriptions to assist assessments specifically in the EIA context (detailed further in **Section 21.5.1.6**).

21.49 The updated 'PAS 2080: Carbon Management in Buildings and Infrastructure' (2023) published by the British Standards Institution provides requirements for the management of whole life carbon in built environment projects in alignment with transitioning to a net zero carbon economy by 2050. Best practice measures have been reviewed and identified as part of the GHG assessment as potential opportunities for reducing whole life carbon through the adoption of an effective carbon management process.

21.4.4.2 CCRA

21.50 IEMA has published 'Environmental Impact Assessment Guide to Climate Change Resilience and Adaptation' (2020), which provides a framework for the consideration of climate change resilience and adaptation in the EIA process. The guidance advises that future climate conditions within the study area should be identified and assessed with consideration of how adaptation and resilience measures have been built into the design of a development.

The European Commission published the 'Technical Guidance on the Climate Proofing of Infrastructure in the Period 2021 – 2027' (2021), which outlines climate adaptation considerations for infrastructure projects and a risk assessment methodology for integration into impact assessments.

21.5 Impact assessment methodology

21.51 The climate change assessment comprises two separate assessments: a GHG assessment and a CCRA. The methodologies for both assessments are detailed in the following sections.

21.5.1 GHG assessment methodology

21.52 The assessment has been undertaken in accordance with IEMA guidance 'Guide: Assessing Greenhouse Gas Emissions and Evaluating their Significance' (2022). This guidance document provides a topic-specific methodology for the assessment of GHGs and determining the significance of emissions generated by a project, and therefore the assessment methodology differs from that presented in **Chapter 6 EIA Methodology**.

21.53 The purpose of this assessment is to consider the potential effects of the Project on climate change via GHG emissions created and avoided by project activities during the construction, operation and maintenance, and decommissioning phases. Emissions and their effect significance are presented separately per Project phase. Total emissions arising over the project lifecycle and combined with the Transmission Assets are also provided to determine the effect significance of the windfarm in its entirety.

21.54 To contextualise the outcomes of the GHG assessment, emissions from two 'Do Nothing' scenarios were also quantified and compared to the Project's GHG emissions during the operation and maintenance phase to determine the Project's GHG savings as a result of avoided emissions. These scenarios are defined in **Section 21.6.1.2**.

21.5.1.1 Data and information sources

Site-specific surveys

21.55 No site-specific surveys were undertaken for the GHG assessment.

Other available sources

21.56 Data sources used to inform the GHG assessment are highlighted in **Table 21.6**.

21.57 Given the interconnected nature of the Project and the Morgan and Morecambe Offshore Wind Farms: Transmission Assets, the environmental information for the Transmission Assets PEIR has also been used to inform this chapter (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023a).

Table 21.6 Existing data sources used in the GHG assessment

Data source	Date	Data contents
DESNZ, Conversion factors GHG reporting	2023	Emission factors for use in the GHG assessment, particularly for fuel consumption.
DESNZ, Digest of UK Energy Statistics: Electricity	2023	Up-to-date energy statistics for the UK, including the estimated carbon intensity of current grid-supplied electricity
DESNZ Treasury Green Book supplementary appraisal guidance on valuing energy use and GHG emissions supporting data tables	2023	Grid-average emission factors for the UK grid and future projections
Dolan and Heath, Life Cycle Greenhouse Gas Emissions of Utility Scale Wind Power	2012	Benchmarking of results from the GHG assessment.
Inventory of Carbon and Energy Database v3.0	2019	Emission factors for embodied materials used in construction.
Thompson and Harrison, Life Cycle Costs and Carbon Emissions of Offshore Wind Power	2015	Benchmarking of results from the GHG assessment and likely contribution of decommissioning activities to the overall Project footprint.

21.5.1.2 Context

Climate change benefit of offshore wind

21.58 Emissions from electricity generation in the UK have decreased by 68% since 1990, the majority of which occurred within the last decade (CCC, 2022). This decrease reflects a move away from coal to gas and low-carbon generation, of which the renewables and offshore wind sector has been a key player. Further reductions are necessary, however, which will require an increase in the role of renewables, along with other supply and demand-side responses.

21.59 According to the UK Wind Energy Database, the UK has an offshore wind operational capacity of 14.7GW, with another 5.1GW under construction at the time of writing (RenewableUK, 2024). The UK government has a target to achieve 50GW of offshore wind capacity by 2030 (CCC, 2022), which will include developments such as this Project.

21.60 Recent advances in technology and improved construction, and operation and maintenance practices have led to an increase in the efficiency of electricity generation. In particular, increases in turbine size yield higher capacity factors. As a result, Department for Business, Energy and Industrial Strategy (BEIS) (now DESNZ) advises that the load factor for new build offshore wind from

2023-2025 is likely to be 58.4%, which is a significant improvement from 10 years ago (BEIS, 2021a).

21.61 Offshore wind is therefore considered to be the backbone of electricity generation in the CCC's scenarios for net zero pathways, contributing 65 – 70% of total generation by 2050 (CCC, 2022).

GHG emission sources for offshore windfarms

21.62 The construction, operation and maintenance, and decommissioning of windfarm projects entail the generation of GHG emissions, from the standpoint of both:

- Embedded carbon and GHGs from the offshore components. These are the emissions caused by the extraction and refinement of raw materials and their manufacture into the commodities and products that make up the components of the WTGs, OSP(s) and associated infrastructure, and their associated physical infrastructure
- Carbon and other GHG emissions arising from the combustion of fuels and energy used in constructing, operating and maintaining windfarm components over a project's lifetime and in decommissioning. These emissions in this assessment are associated with marine vessels.

21.63 The release of emissions from these sources is small in comparison to emissions from the fossil fuel generation of energy, and the emissions saved during the generation of electricity from wind resources (when compared to fossil fuel sources) outweigh those released from construction, operation and maintenance, and decommissioning activities.

21.64 There are inherent uncertainties associated with carrying out GHG footprint assessments for offshore wind energy projects, although the approach to determine emissions from individual source groups is well-defined.

21.65 A report published by the University of Edinburgh in 2015 (Thomson & Harrison, 2015) examined the lifecycle costs and GHG emissions associated with offshore wind energy projects, comparing data gleaned from the analysis of some 18 studies carried out over the period 2009 to 2013. This report supplies useful context for the Project's GHG assessment, and provides benchmark figures which were used to verify the outcomes of the assessment. It is acknowledged that advancements and efficiencies have been gained in the offshore wind sector since this study was undertaken; however, the figures and details within this study still provide useful context for the GHG assessment.

21.66 **Table 21.7** provides a summary of the percentage of total GHG emissions associated with the different phases of an offshore windfarm development as provided within the report.

Table 21.7 Summary of offshore windfarm GHG emissions (Thomson & Harrison, 2015)

Phase	% of total GHG emissions
Manufacture and installation	78.4
Operation and maintenance	20.4
Decommissioning	1.2

21.67 The report highlighted that the greatest proportion of emissions is associated with the manufacture and installation of the windfarm components. Decommissioning accounted for the smallest proportion, only 1.2%, of total life cycle GHG emissions. A more detailed breakdown of emissions is given in Thomson & Harrison (2015) for an offshore windfarm with steel foundations. This is reproduced in **Plate 21.1**.

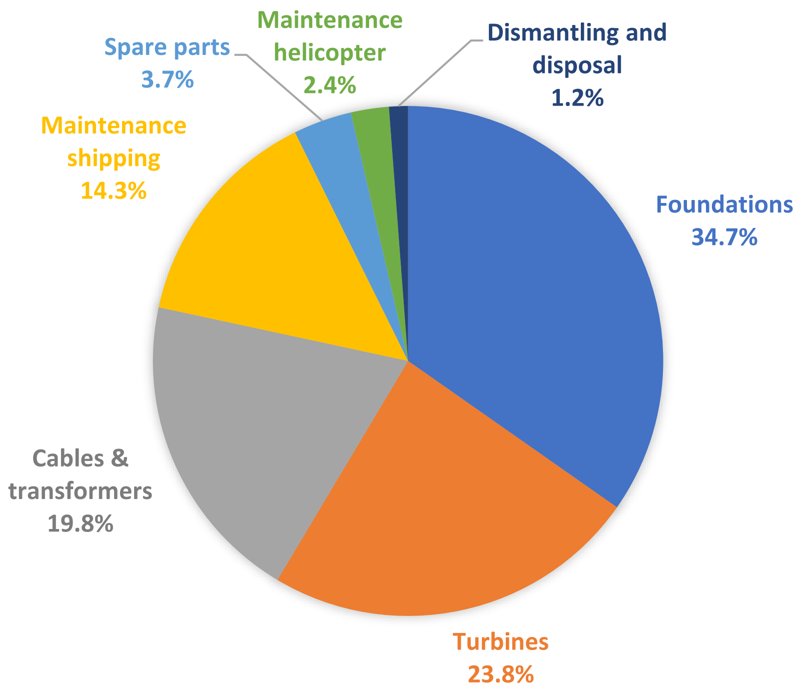

Plate 21.1 Summary of offshore windfarm GHG emissions (Thomson & Harrison, 2015)

21.68 Of the components, or phases, shown in **Plate 21.1**, GHG emissions associated with foundation fabrication and installation accounted for the largest proportion of emissions (34.7%), followed by manufacture and installation of the turbines (23.8%) and the cables and transformers (19.8%).

21.69 GHG emissions from shipping movements during maintenance operations over the operational lifetime of the example windfarm contributed 14.3%. This value may appear to be unexpectedly high, but the vessel movements contribution is associated with an assumed 20-year operational lifetime of the windfarms considered in the studies. Emissions derived from spare parts

(3.7%), helicopter movements (2.4%) and dismantling and disposal (1.2%) are all small in comparison.

21.70 A report by Catapult (Spyroudi, 2021) investigated the carbon and GHG implications of end-of-use management after decommissioning, as well as some context to carbon Life Cycle Analysis (LCA) of offshore windfarms. Within the studies considered, turbines were predicted to contribute to 50% of the total GHG footprint of materials used in windfarm components. The Catapult report references the National Renewable Energy Laboratory (NREL) report (NREL, 2015), which states that wind turbines are predominantly made of steel (71 to 79% of total turbine mass), fiberglass, resin or plastic (11 to 16%), iron or cast iron (5 to 17%), copper (1%) and aluminium (0 to 2%). The Catapult report (Spyroudi, 2021) advises that recycling can save, on average, at least 35% of CO_2e per kilowatt-hour (kWh) of generation from assets in an offshore windfarm (operating 6MW and 10MW turbines), as opposed to new manufacturing of components.

GHG intensity of offshore wind energy

21.71 In the University of Edinburgh report (Thomson & Harrison, 2015), additional analysis of the data extracted from the 18 technical studies expressed the GHG emissions as grams (g) of CO_2e per kWh of electricity generated. These were found to vary quite widely, between approximately 5 and 33g CO_2e/kWh. There was no clear relationship between the metrics for either turbine rating (in MW) or capacity factor.

21.72 A further study (Dolan & Heath, 2012) amassed the results of over 200 studies of carbon emissions from wind power and attempted to 'harmonise' the results to use only the most robust and reliable data and to align methodological inconsistencies. The harmonised results of this study revealed that the range in GHG emissions per kWh of electricity generated varied between approximately 7 and 23g CO_2e/kWh, with a mean value of around 12g CO_2e/kWh.

It is noted that these studies were undertaken in 2012 and 2015, and there have been significant advances in the technology, infrastructure and components used for offshore windfarms since that time. Therefore, other available published sources were reviewed to evaluate the average GHG intensity of energy produced for offshore windfarms (**Table 21.8**). As shown, the range of energy intensities for offshore windfarms across the range of studies is 7.8 to 32 g CO_2e/kWh.

Table 21.8 Review of offshore windfarm GHG emission intensity figures

Windfarm sizes	Energy intensity (gCO_2e/kWh)	Source
12 x 5MW	32	Chen *et al*. (2011), referenced in Bhandari *et al.* (2020)
N/A	6	IEA World Energy Outlook (2012), referenced in Siemens Gamesa (undated) and a (2021)
100 x 2.5MW	13.7	Arvesen & Hertwich (2012), referenced in Bhandari *et al*. (2020)
80 x 4MW	10.9*	Bonou *et al*. (2016), referenced in Bhandari *et al.* (2020)
100 x 6MW	7.8*	Bonou *et al*. (2016), referenced in Bhandari *et al.* (2020)
28 x 3.6MW	25.5*	Yang *et al*. (2018), referenced in Bhandari *et al.* (2020)
*Offshore windfarm studies published from 2016 onwards.		

21.73 To place these metrics into context, comparable values for electricity generation by gas and coal are around 372 and 1,002g CO_2e/kWh (31 and 83.5 times that of offshore wind respectively, using the mean value from Dolan & Heath (2012)) (BEIS, 2022). These values are for the generation only and are unlikely to account for the construction of the power station infrastructure (i.e., the construction materials such as concrete or steel), or the extraction and processing of the fossil fuels to generate power.

Although robust and fit for the purposes of an EIA, this assessment should not be taken to be a comprehensive, detailed LCA of the Project, the reason being that it is not possible to fully define the supply chain for the Project and undertake the relevant detailed assessments at this stage in the Project. Therefore, assumptions and simplifications to the methodology were made in certain areas and a precautionary approach was adopted for the assessment to allow for this. These assumptions and simplifications are outlined in **Section 21.5.1.6** and the worst-case scenario set out in **Table 21.2**.

21.5.1.3 Assessment approach

21.74 In this assessment, the term 'GHG', or often referred to its shorthand 'carbon', encompasses CO_2 and the six other gases as referenced in the Kyoto Protocol (CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3). The results in this assessment are expressed in CO_2 equivalent (CO_2e), a common unit which accounts for the different Global Warming Potential (GWP) of each gas.

GHG emissions arising from the construction, operation and maintenance, and decommissioning phases of the Project were assessed within a defined system boundary, as outlined in**Table 21.10**. GHG emissions were quantified using a standard calculation-based methodology, which involves multiplying activity data gathered for the Project, with the relevant emission factors, and where applicable calorific and GWP factors. Where full details of activity data were not available, industry benchmarks and assumptions using professional judgement were utilised where information gaps exist.

This chapter provides a GHG assessment for the Project, as well as a combined GHG assessment with the Transmission Assets using the assessment outputs of the Morgan and Morecambe Offshore Windfarms: Transmission Assets PEIR (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023). This is to consider emissions released by the Morecambe Offshore Windfarm in its entirety and therefore its net contribution to climate change.

21.75 To account for differences in project activities, GHG emissions were calculated by Project phase and also combined across the whole Project lifecycle. To assist with the determination of the Project's significance, additional parameters were calculated to contextualise the GHGs emitted and avoided, and the Project's benefits of supplying renewable energy to the UK electricity grid, as listed in **Table 21.9**.

Table 21.9 Additional parameters for the GHG assessment

Parameter	Phase	Description
Comparison to UK carbon budgets	▪ Construction ▪ Operation and maintenance	Construction, and operation and maintenance emissions were calculated as a percentage of the UK carbon budget to which the project phase corresponds.
Avoided emissions	▪ Operation and maintenance	GHG savings from renewable energy provision, or the avoidance of emissions from displacing electricity which would have otherwise been generated using non-renewable fuel sources or the energy mix considered in future UK grid scenarios. The DESNZ's GHG intensity projections of electricity generation (DESNZ, 2023c) only considers operational emissions and therefore do not account for other lifecycle carbon impacts. To enable a like-for-like comparison, the Project's construction and decommissioning emissions are excluded from this calculation.
GHG intensity	▪ Operation and maintenance ▪ Whole lifecycle combined with the	The amount of GHGs released per unit of electricity generated, typically expressed as grams (g) of CO_2e per kWh. The CCC's GHG intensities (CCC, 2013) of various forms of electricity generation are based

Parameter	Phase	Description
	Transmission Assets	on lifecycle emissions. To enable a like-for-like comparison, an overall GHG intensity using the Project's lifecycle emissions combined with the Transmission Assets is also calculated.
GHG payback period	▪ Whole lifecycle combined with the Transmission Assets	The time it would take for electricity generated by the Project to offset its whole life emissions by displacing an equivalent amount of grid electricity generated using non-renewable fuel sources.

Emission calculations

21.76 GHG emission sources arising from the Project were categorised into three main source groups, as detailed in **Table 21.10**.

Table 21.10 Emission source groups considered in the GHG assessment

Source group	Phase	Definition	Project sources
Embodied emissions in materials	▪ Construction ▪ Operation and maintenance	Embodied emissions within materials, comprising GHGs released throughout the product supply chain. This includes the extraction of raw materials, transport, manufacturing, assembly and their end-of-life profile.	Embodied emissions were quantified for the main construction materials to be used for the Project, including WTGs (including blades), OSP(s), transition pieces, foundations, cables and scour protection. Most of the materials used for the Project will be recycled at decommissioning. The requirement for spare (or replacement) parts during operation is not known at this stage, therefore the likely contribution of emissions in relation to the overall footprint of the Project was obtained from existing literature.
Marine vessels	▪ Construction ▪ Operation and maintenance	Emissions released as exhaust gases from the combustion of fossil fuels by marine vessels.	Emissions associated with the movement of marine vessels for the Project were calculated. Emissions include vessels used during construction activities such as the installation of wind turbines, foundations and cables and for the transport of material supplies from the manufacturing site to the windfarm site and vessels used during operation and maintenance activities such as cable repairs and crew transfer.

Source group	Phase	Definition	Project sources
Helicopters	▪ Construction	Emissions released as exhaust gases from the combustion of fuel by helicopters.	Emissions associated with the movement of helicopters from an onshore base during construction were calculated. Helicopters will only be used 'by exception' during operation and maintenance, therefore these movements have been scoped out.

21.77 Details of all activities that will take place during the operation and maintenance and decommissioning phases are not fully known at this stage, therefore some assumptions have been made in order to quantify GHG emissions, as detailed in **Section 21.5.1.6**. These assumptions are based on indicative data provided by the Applicant's design team or professional judgement.

21.78 Emissions from decommissioning were derived from previous studies (Thomson & Harrison, 2015), where it was established that this phase would contribute 1.2% of an offshore windfarm's carbon footprint.

21.79 The approach to quantifying GHG emissions for each of the source groups detailed in **Table 21.10** is provided in **Appendix 21.1**. The total operational lifetime of the Project is anticipated to be 35 years.

Embodied emissions in materials

21.80 Emissions of 'cradle-to-factory gate' 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 will be used during construction and their likely material composition.

21.81 The key infrastructure components of the Project (and examples of their main material components) comprise:

- WTGs (e.g., steel, fibreglass, cast iron, aluminium, copper)
- OSP(s) (e.g., steel)
- Transition pieces (e.g., steel)
- Foundations (e.g., steel, concrete, ballast (rock)
- Scour protection (e.g., rock)
- Inter-array cables (e.g., copper)

- OSP link cables (e.g., copper)

21.82 The approach to determining embodied emissions from materials used for the Project is detailed in **Appendix 21.1**.

21.83 Emissions associated with the movement of materials to the windfarm site were quantified under the marine vessel source group, as detailed below.

Marine vessels

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

21.85 Full details of the approach undertaken to determine GHG emissions from marine vessels is detailed in **Appendix 21.1**, which includes assumptions for offshore vessel logistics during the construction, and operation and maintenance phases.

Helicopters

21.86 Helicopters will be used during construction of the Project to transport personnel to and from the windfarm site. Full details of the approach undertaken to determine GHG emissions from helicopters is detailed in **Appendix 21.1**.

Definitions of sensitivity, value and magnitude

21.87 The GHG assessment was undertaken in accordance with a topic-specific assessment methodology and approach to determining the significance of effect as provided within IEMA guidance (2022) and set out in the following sections.

Sensitivity

21.88 The receptor for the GHG assessment is the global atmosphere. As such, it is affected by all global sources of GHGs, and is therefore considered to be of ‘high’ sensitivity to additional emissions across all project phases.

Magnitude

21.89 The magnitude of impact is not defined, as the effect significance for the GHG assessment is not determined by the magnitude of GHG emissions alone (IEMA, 2022). However, the Project’s construction, operation and maintenance, and decommissioning emissions have been calculated as part of the assessment, both by Project phase and combined over the whole lifecycle.

21.90 The impact of GHG emissions is, by nature, global and long term with low reversibility, owing to the long atmospheric lifetime of GHGs and their prolonged effect on the climate system.

Effect significance

21.91 Guidance on the assessment of GHG emissions was first released by IEMA in 2017 (IEMA, 2017), which stated that "…*in the absence of any significance criteria or defined threshold, it might be considered that all GHG emissions are significant*…". However, the updated IEMA guidance (2022) recognises "*when evaluating significance, all new GHG emissions contribute to a negative environmental impact; however, some projects will replace existing development or baseline activity that has a higher GHG profile. The significance of a project's emissions should therefore be based on its net impact over its lifetime, which may be positive, negative or negligible*".

21.92 Significance can be evaluated in a number of ways depending on the context of the assessment (i.e., sector-based, local, national, policy goals or against performance standards). The IEMA guidance (2022) recommends that significance criteria align with Paris Agreement, the UK's Carbon Budgets up to 2037 and net zero commitments: "*the crux of significance is not whether a project emits GHG emissions, nor even the magnitude of GHG emissions alone, but whether it contributes to reducing GHG emissions relative to a comparable baseline consistent with a trajectory towards net zero by 2050*".

21.93 The 2022 IEMA guidance provides relative significance descriptions to assist assessments, specifically in the EIA context. Section VI of the updated IEMA guidance (2022) describes five distinct levels of significance which are not solely based on whether a project emits GHG emissions alone, but on how the project makes a relative contribution towards achieving a science-based 1.5°C aligned transition towards net zero. These are presented in **Table 21.11**.

Table 21.11 Assessment significance criteria

Significance	Definition
Major adverse	The Project's GHG impacts are not mitigated or are only compliant with do-minimum standards set through regulation, and do not provide further reductions required by existing local and national policy for projects of this type. A project with major adverse effects is locking in emissions and does not make a meaningful contribution to the UK's trajectory towards net zero.
Moderate adverse	The Project's GHG impacts are partially mitigated and may partially meet the applicable existing and emerging policy requirements but would not fully contribute to decarbonisation in line with local and national policy goals for projects of this type. A project with moderate adverse effects falls short of fully contributing to the UK's trajectory towards net zero.

Significance	Definition
Minor adverse	The Project's GHG impacts would be fully consistent with applicable existing and emerging policy requirements and good practice design standards for projects of this type. A project with minor adverse effects is fully in line with measures necessary to achieve the UK's trajectory towards net zero.
Negligible	The Project's GHG impacts would be reduced through measures that go well beyond existing and emerging policy and design standards for projects of this type, such that radical decarbonisation or net zero is achieved well before 2050. A project with negligible effects provides GHG performance that is well 'ahead of the curve' for the trajectory towards net zero and has minimal residual emissions.
Beneficial	The Project's net GHG impacts are below zero and it causes a reduction in atmospheric GHG concentration, whether directly or indirectly, compared to the without-project baseline. A project with beneficial effects substantially exceeds net zero requirements with a positive climate impact.

21.94 The effect significance of the Project's GHG emissions was evaluated by Project phase. For the construction phase, significance was determined by comparing the magnitude of emissions with the 5th UK carbon budget (2028 to 2032) and considered its effect on the UK's ability to meet its future carbon budgets and, by proxy, the emission reduction needed to achieve its international climate commitments and a science-based 1.5°C transition towards net zero.

21.95 For the operation and maintenance, and decommissioning phases, the relevant UK carbon budgets have not been set or do not apply, as the Project's operational lifetime extends beyond 2037 (the latest current date the Carbon Budgets extend to) and 2050 by which the UK commits to achieving net zero. Therefore, effect significance for these phases was determined by considering the Project's effects on the UK's ability to achieve and maintain its net zero status. The first five years of the Project's operation and maintenance phase aligns with the 6th carbon budget (2033 to 2037). Emissions over this budget period have also been compared for further context.

21.96 In addition to evaluating each Project phase, overall significance was also determined by considering the Projects life cycle emissions combined with the Transmission Assets. It is recognised that the Project requires the Transmission Assets to be implemented to supply renewable energy to the UK electricity grid, and achieve the potential GHG benefits the provision of offshore windfarm enables. Therefore, whole life cycle and combined emissions of the Project along with the Transmission Assets was also considered in the assessment. The whole life cycle and combined emissions total was contextualised with a high level comparison to emissions avoided from the displacement of electricity, which would have otherwise been generated from other forms of generation. The overall effect significance considers all emissions released by the windfarm in its entirety and therefore the net contribution to climate change.

21.97 LSE identified within the assessment as major/moderate adverse or beneficial are deemed to be significant in EIA terms within this chapter. Whilst only one level of significance criteria is provided where there is a net reduction in emissions, further context with respect to the level of emissions avoided compared to the baseline scenarios is provided in **Section 21.6.1.2.**

21.5.1.4 Cumulative effects assessment methodology

21.98 The global atmosphere is the receptor for the GHG assessment, as such, there are no common receptors between this assessment and other disciplines considered in the ES. GHG emissions have the potential to contribute to climate change, and therefore the effects are global and cumulative by nature. This is taken into account in defining the receptor (i.e., the global atmosphere) as high sensitivity. The IEMA guidance (2022) states that the effects of GHG emissions from specific cumulative projects should therefore not be individually assessed, as there is no basis for selecting which projects to assess cumulatively over any other. The GHG assessment is considered to be inherently cumulative, and no additional consideration of cumulative effects is required.

21.5.1.5 Transboundary effects assessment methodology

21.99 As noted above for cumulative effects, the receptor for the GHG assessment is the global atmosphere, and therefore emissions of GHGs have an indirect transboundary effect. As the GHG emissions are assessed in context of the UK carbon budgets and the aspirations to reduce GHG emissions in line with climate agreements, the cumulative transboundary effects of GHGs emitted by the Project are not considered to require specific consideration.

21.5.1.6 Assumptions and limitations

21.100 A number of assumptions were made in the GHG assessment, as set out in **Table 21.12**.

Table 21.12 Assumptions and limitations of the GHG assessment

ID	Assumption/limitation	Discussion
1	Lack of emission factors for future year activities, such as fuel consumption and material extraction	The most recent and available emission factors at the time of assessment were used to provide a precautionary assessment. Many sectors are anticipated to decarbonise over the next 35 years, and during operation and maintenance and decommissioning, it is likely that

ID	Assumption/limitation	Discussion
		the emissions intensity of manufacturing windfarm components and the movement of marine vessels will be less than the present day. Therefore, emissions associated with the operation and maintenance and decommissioning phases of the Project are likely to be a significant overestimation.
2	The assessment does not quantify the movement of road vehicles associated with the delivery of materials to the export port	As detailed in **Chapter 22 Traffic and Transport** (Document reference 5.1.22), it is the Applicant's position that they will not be able to confirm which port(s) will be used for each of the Project phases until the post-consent stage, and therefore a meaningful assessment of traffic and transport impacts, including the quantification of road vehicle GHG emissions, cannot be presented at this stage. Based on previous experience on projects of a similar nature, emissions from road vehicle movements bringing materials to port(s) used for Project phases are likely to constitute a very minor contribution to the overall GHG footprint, when compared to embedded GHG emissions in materials and marine vessel GHG emissions.
3	Emissions from vessels undertaking dredging activities were not included in this assessment	Emissions associated with dredging activities during construction, and operation and maintenance have not been quantified, as this level of information is not yet known. 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.
4	Energy displaced by the Project would otherwise be produced by non-renewable fuels (Scenario 1) or displace electricity from the future UK grid (Scenario 2), as discussed in **Section 21.6.1.2**.	The approach for Scenario 1 (see **Section 21.6.1**), which was advocated by RenewableUK (2022), was used to determine emissions for the 'Do Nothing' scenario in which the Project is not developed based on DESNZ emission factor for all 'non-renewable fuels' (DESNZ, 2023c). This non-renewable fuel mix may change in the future, but it is considered a valid approach for determining avoided emissions as a result of renewable energy projects. Scenario 2 (see **Section 21.6.1**) was also considered to determine the displacement of all sources of electricity generation as part of the UK's future grid mix.
5	Updates since PEIR	GHG emissions for the Project which were presented at PEIR stage have been updated where relevant in accordance with refinements to the design of the Project, and additional information that has emerged regarding the construction, and operation and maintenance activities. A combined assessment with emissions from the Transmission

ID	Assumption/limitation	Discussion
		Assets (using information derived from the Transmission Assets PEIR (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023) has also been included to determine the effects of the windfarm in its entirety.

21.5.2 CCRA methodology

21.101 The CCRA was undertaken in accordance with IEMA Environmental Impact Assessment Guide to: Climate Change Resilience and Adaptation (2020). This guidance document provides a topic-specific methodology for the assessment of climate change resilience in an EIA context, and therefore the assessment methodology differs from that presented in **Chapter 6 EIA Methodology**.

21.102 The purpose of this assessment is to evaluate the vulnerability and resilience of the Project's design and infrastructure to the projected effects of climate change over its operational lifetime. Climate change impacts are considered to be most relevant during the operation and maintenance phase due to its long duration and thus higher potential for the Project to be exposed to climate hazards. The CCRA identifies the key climate hazards occurring within the study area, and the risk which they pose to the Project highlighted.

21.5.2.1 Data and information sources

Site-specific surveys

21.103 No site-specific surveys were undertaken for the CCRA.

Other available sources

21.104 Data sources used to inform the CCRA are presented in **Table 21.13**.

Table 21.13 Existing data sources used in the CCRA

Data source	Date	Data contents
BEIS Offshore Energy Strategic Environmental Assessment 3 Appendix 1F: Climate & Meteorology	2016	Context on observed meteorological conditions at sea
Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report	Various	Current state of knowledge on climate science and possible future emission scenarios
Marine Climate Change Impacts Partnership (MCCIP) Reports	Various	A collection of evidence reviews and summary reports on climate change effects in the marine environment.
Met Office UK Climate Averages, Regional Climate Summaries	Various	Historical climate observations and current climate conditions for the UK

Data source	Date	Data contents
		Note: The Met Office data is based on observations over land recorded by onshore climate stations.
Met Office UK Climate Projections (UKCP) Database	Various	Climate projection data for the UK, as recommended by IEMA's (2020) guidance. Note: UKCP data is most applicable to onshore and coastal areas.
Weisenfeld *et al.*'s Offshore Wind Climate Adaptation and Resiliency Study	2021	Review of key relevant climate factors to the offshore wind sector and opportunities for offshore wind resilience

21.5.2.2 Assessment approach

21.105 A four-step methodology was adopted for the CCRA in line with best practice for assessments of climate resilience. The initial stages of the assessment aim to identify the climate hazards to which the Project could be vulnerable to during its operational lifetime. If deemed necessary, a more detailed risk assessment would then be undertaken on climate hazards which are considered to be material to the Project, which will assess the level of risk associated with the hazards posed to the Project based on projected changes in climate variables. A step-by-step approach to the CCRA is provided below.

21.106 For the purpose of the CCRA, the following key terms were adopted:

- Climate variable: a measurable, monitorable aspect of the weather or climate conditions such as temperature and wind speed
- Climate hazard: a weather or climate-related event or trend in climate variable, which has potential to do harm to receptors such as increased precipitation or storms
- Climate change impact: an impact from a climate hazard which affects the ability of the receptor to maintain its functions or purpose

Step 1: Identifying receptors, climate variables and hazards

21.107 The first step of the CCRA identified receptors associated with the Project which may potentially be impacted by climate hazards. These receptors included those known to have already experienced climate change impacts (e.g., receptors in known flood zones) and unknown receptors which are likely, but yet to be impacted based on available data and literature.

21.108 Key climate hazards relevant to the study area were identified based on desk-based sources, along with climate variables which could be used to quantify or contextualise the climate hazard under current and future climate conditions and the receptors which they affect.

Climate projection data was obtained from the UKCP database, which was used to identify trends in climate variables and describe potential climate hazards within the study area. Data was retrieved for two RCP, RCP4.5 and RCP8.5, which represents different possible climate futures based on different GHG concentration trajectory. For each RCP, data was presented for the 10^{th}, 50^{th} (median) and 90^{th} percentile to provide a comprehensive outlook on the future climate baseline in accordance with the requirements of the NPS. The climate projection data are provided in **Section 21.6.2.2**.

21.109 Climate projection data was also supplemented with other literature sources and future baseline trends and relevant impact assessments discussed in **Chapter 7 Marine Geology, Oceanography and Physical Processes** (Document Reference 5.1.7).

21.5.2.3 Definitions of sensitivity, value and magnitude

Step 2: Climate vulnerability assessment

21.110 The second step consisted of a qualitative vulnerability assessment of the Project to key climate hazards, informed by professional judgment and supporting literature. Vulnerability was defined as the degree of response to a change in the environment and based on the capacity to accommodate or recover from change, and considered to be a function of:

- Sensitivity: the potential to be affected by change
- Exposure: exposure, both spatially and temporally, to climate hazards

21.111 Both the sensitivity and exposure of the Project to climate hazards were considered to determine vulnerability. This approach attributes either a high, medium or low vulnerability rating to each climate hazard identified based on the interrelationships between sensitivity and exposure. The matrix used for the vulnerability assessment is set out in **Table 21.14**.

Table 21.14 Sensitivity-Exposure matrix for determining climate vulnerability

Sensitivity	Exposure		
	Low	**Moderate**	**High**
Low	Low Vulnerability	Low Vulnerability	Low Vulnerability
Moderate	Low Vulnerability	Medium Vulnerability	Medium Vulnerability
High	Low Vulnerability	Medium Vulnerability	High Vulnerability

21.112 Climate change impacts to the Project only arise when receptors have a level of sensitivity and/or exposure and are therefore vulnerable to climate hazards. The nature of any climate change impacts were also described alongside the vulnerability assessment to specify how the Project and its receptors are likely to experience the climate hazard and the outcomes.

For hazards categorised as medium or high vulnerability, the risk of climate change to the Project, and consequently to its operations, was then determined through Steps 3 and 4 of the CCRA process. Hazards with low vulnerability were screened out from further assessment due to low potential for LSE. This is in line with risk assessment approach proposed by the European Commission in its guidance note whereby only potentially significant risks from climate change are taken forward for detailed analysis (2021).

Step 3: Climate risk assessment

21.113 The magnitude of the climate change impact, or the climate risk, was then qualitatively evaluated based on its likelihood and consequence, which were defined as follows:

- Likelihood: the probability or frequency of the climate change impact occurring during the operational lifetime of the Project
- Consequence: the degree of harm of the climate change impact based on factors such as its spatial extent, duration, complexity or the number of receptors affected

21.114 Both the likelihood and consequence of climate change impacts were considered to determine the level of risk to the Project. This approach attributes either an extreme, high, medium or low risk rating based on the interrelationships between likelihood and consequence. The matrix used for the risk assessment is set out in **Table 21.15.**

Table 21.15 Likelihood-Consequence matrix for determining climate risk

Likelihood	Consequence				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Low Risk	Medium Risk	High Risk	Extreme Risk	Extreme Risk
Likely	Low Risk	Medium Risk	Medium Risk	High Risk	Extreme Risk
Moderate	Low Risk	Low Risk	Medium Risk	High Risk	Extreme Risk
Unlikely	Low Risk	Low Risk	Medium Risk	Medium Risk	High Risk
Very Unlikely	Low Risk	Low Risk	Low Risk	Medium Risk	Medium Risk

21.115 For climate risks identified as medium, high or extreme, additional mitigation measures would be required based on professional judgment, and the residual risk reassessed.

Step 4: Resilience rating

21.116 For climate risks identified as 'medium' or 'high' in the likelihood/consequence matrix in Step 3 (see **Table 21.15**) secondary mitigation measures were identified. With the proposed mitigation measures taken into consideration, a residual risk rating was then assessed. For each hazard, a resilience rating was identified as one of the following:

- High - strong degree of climate resilience. Remedial action or adaptation may be required but is not a priority
- Moderate - a moderate degree of climate resilience. Remedial action or adaptation is recommended
- Low - a low level of climate resilience. Remedial action or adaptation is required as a priority

Effect significance

21.117 The significance of the CCRA was determined through consideration of the residual risk (identified in Step 3) and resilience rating (identified in Step 4) for each climate change impact assessed. **Table 21.16** presents the matrix used to determine the overall significance of the CCRA. The risk-resilience matrix was obtained from best practice risk assessment procedures with respect to climate resilience.

Table 21.16 CCRA significance criteria

Risk Rating	Resilience rating		
	High	Moderate	Low
Extreme	Significant	Significant	Significant
High	Not Significant	Significant	Significant
Medium	Not Significant	Not Significant	Significant
Low	Not Significant	Not Significant	Not Significant

21.5.2.4 Cumulative effects assessment methodology

21.118 The Cumulative Effects Assessment (CEA) for a CCRA considers the potential for other projects or plans to act collectively to exacerbate a project's climate vulnerability and risk. Likewise, there is also potential for a project to influence the climate change resilience of other projects or plans. However, due to the location of the windfarm site, it is highly unlikely for the Project to affect or be affected by neighbouring developments with respect to climate change resilience.

21.119 In addition, whilst there is a clear link with the Transmission Assets, the vulnerabilities and risks from climate change to identified receptors would be different compared to those associated with the Project. Therefore, a CEA was not undertaken for this CCRA.

21.5.2.5 Transboundary effects assessment methodology

21.120 It is not relevant to assess transboundary effects relating to climate change resilience, since the assessment focusses on the effects of climate change on the Project itself. Therefore, a transboundary effect assessment was not undertaken for the CCRA.

21.5.2.6 Assumptions and limitations

21.121 Assumptions made for the CCRA are detailed in **Table 21.17**.

Table 21.17 Assumptions and limitations of the CCRA

ID	Assumption/ limitation	Discussion
1	Climate change projections	A key assumption of the climate projection data from the UKCP is that the model is strongly dependent on future global GHG atmospheric concentrations and emission trajectories. The RCP scenarios cover a recent set of assumptions based upon future population dynamics, economic development and account for international targets on reducing GHG emissions. Each RCP scenario has a different climate outcome, given that they are based upon a different set of assumptions. The two RCP scenarios presented within this chapter present a range of outcomes in terms of climate projection data. However, the UKCP user guidance cautions that the scientific community cannot reliably place probabilities on which scenario of GHG emissions is most likely. Due to the intrinsic uncertainty within climate change projections, the UKCP data is based upon probabilistic projections, generating a normally-distributed model per output. The model outputs values for the 10th, 50th and 90th percentiles, which represents the range of uncertainty, and is therefore presented as such in the chapter. In addition, UKCP data do not cover all climate variables which may be relevant to the study area. Where information gaps exist, these are supplemented with other available literature sources.
2	Spatial resolution of the climate baseline	Climate change projections are provided by grid cells in the UKCP database. The size of the grid cell determines the spatial resolution of the projection data and how it corresponds to the study area. It is assumed that the climate baseline across the study area is adequately described by the selected grid cell. It is important to note that the majority of climate observation and projection data is for onshore areas, with less information available for marine areas.

ID	Assumption/ limitation	Discussion
		To supplement the land-based climate change projections from the UKCP database, MCCIP Reports have been reviewed and summarised where relevant to further characterise the future climate baseline over sea.
3	Temporal resolution of the climate baseline	The climate change projections are provided as time series. For the purpose of the CCRA, the data is summarised and presented as climate averages for the selected time slices. It is assumed that these time slices are representative of current and future conditions within the study area and provide sufficient temporal coverage. The CCRA is undertaken on the basis of historical observations, most recent climate change projections and existing climate change literature and research. Thus, information which has been made available after the time of assessment is not reflected within this chapter.

21.6 Existing environment

21.6.1 GHG assessment

21.122 To help determine the significance of effects and contextualise the outcomes of the GHG assessment, consideration of a baseline or 'Do Nothing' scenario is required which assumes that the Project is not constructed.

21.123 UK electricity is currently generated from a number of different energy sources, including gas, nuclear, onshore and offshore wind, coal, bioenergy, solar and hydroelectric. However, it is recognised that the growth of renewable energy is key to the UK's Energy Strategy and net zero targets, coupled with a transition away from electricity generated from fossil fuels.

21.124 Therefore, to evaluate the impacts of the Project, two 'Do Nothing' scenarios were established, which consider the displacement of emissions associated with the provision of renewable energy from the Project. These scenarios are summarised below:

- Scenario 1 – where it was assumed that electricity from the Project displaces generation from 'non-renewable fuel' sources. This approach is advocated for offshore windfarms by RenewableUK (2022) and is considered to account for the UK's transition from fossil fuel-based generation sources to renewables.
- Scenario 2 – where it was assumed that electricity from the Project displaces all forms of generation as part of the future UK grid mix, using the long-run marginal emission factors (DESNZ, 2023c).

21.125 The consideration of Scenario 1 is in line with NPS for Energy EN-1, which requires a step change in the decarbonisation of the UK's energy system, and to "*dramatically increase the energy supplied from low carbon sources*" to replace fossil fuel generation.

21.126 It is recognised that the long run marginal emission factors for the UK grid, which are considered in Scenario 2, accounts for the adoption of renewable energy projects such as the Project becoming operational and decarbonising the UK electricity grid. Therefore, the use of future UK grid scenarios as the 'Do Nothing' scenario is considered to be a conservative approach when establishing a baseline for the GHG assessment, and is indicatively used to provide wider context to the outcome of the assessment.

21.127 Furthermore, the long run marginal electricity emissions factor was derived from modelling undertaken by BEIS (now DESNZ) using a Dynamic Dispatch Model (DDM) to analyse the impact of power sector decarbonisation (DESNZ, 2023). The scenarios are indicative of what a future energy generation may look like rather than prescriptive forecasts, and are subject to a level of uncertainty, including the pace of innovation in the market, technological feasibility, demand levels and investment decisions. (DESNZ, 2023). These uncertainties increase into the 2030's and 2040's, which covers a large portion of when the Project will be operational.

21.128 The Project's construction phase (2027 to 2029) falls broadly under the UK's 5th carbon budget period (2028 to 2032), while the first five years of the operation and maintenance phase (2029/2030 to 2034/2035) also overlap the period of the 6th carbon budget period (2033 to 2037). The Project's operational lifetime will extend into future carbon budgets which have not yet been set, as well as beyond the UK's target net zero year of 2050.

21.6.1.1 Energy produced by the Project

21.129 The estimated quantity of electricity produced by the Project during the operation and maintenance phase was quantified in accordance with the approach advocated for offshore windfarms by RenewableUK (2022), where the anticipated installed capacity (480MW) was multiplied by the hours in the year and by the appropriate capacity factor[3]. The capacity factor for the Project is anticipated to be 58.4%. This capacity factor is in alignment with BEIS Round 3 Allocation Framework (BEIS, 2019) which provides predicted capacity factors for new build offshore windfarms.

[3] Capacity factor is defined as the ratio of average power generated by the windfarm under real-world conditions to its theoretical maximum output.

21.130 The anticipated electricity produced by the Project is:

- Approximately 2,455,603MWh per year
- Approximately 85,946,112MWh over the 35-year lifetime of the Project

21.6.1.2 GHG emissions for the 'Do Nothing' scenarios

21.131 In 'Do Nothing' Scenario 1, it has been assumed that the energy produced by the Project would instead be produced using 'non-renewable fuels' in accordance with the RenewableUK methodology (RenewableUK, 2022). GHG emissions in this scenario were quantified by multiplying the electricity generated by the Project per year by an emission factor for 'all non-renewable fuels' (424 tCO_2/GWh) (DESNZ, 2023d). It is noted that this emission factor is in units of CO_2 rather than CO_2e, however, CO_2 is likely to form the main contribution to total GHG emissions from electricity generation using 'non-renewable fuels'. Therefore, this factor is likely to be higher, were other GHGs included.

The 'Do Nothing' Scenario 2 considers emissions from electricity generated using the future UK grid mix. It has been assumed that the Project will be operational from 2029 and is expected to have a lifetime of 35 years. GHG emissions were quantified in this scenario by multiplying the electricity generated by the Project per year by the long run marginal emission factor for the corresponding year (DESNZ, 2023c).

21.132 The anticipated energy generated by the Project and the associated emissions savings for both 'Do Nothing' scenarios considered in the GHG assessment are presented in **Table 21.18**.

Table 21.18 'Do Nothing' scenarios for the GHG assessment's baseline

Duration	Anticipated energy produced by Project (GWh)	Do Nothing Scenario 1 GHG emissions from electricity generated using 'non-renewable fuels' (tonnes CO_2)	Do Nothing Scenario 2 GHG emissions from the long run marginal emission factor (tonnes CO_2e)
Per year	2,456	1,041,176	Variable Ranges from 224,549 in 2030 to 5,607 from 2050 onwards
Operational lifetime (35 years)	85,946	36,441,152	1,418,906

21.6.2 CCRA

21.6.2.1 Current baseline climate

21.133 The Project is located in the Eastern Irish Sea, approximately 30 km west of the Lancashire coast. Existing climate data was obtained from the Met Office's 'UK Climate Averages' (The Met Office, 2023), which summarise various climate variables over 30-year time slices based on historical observations recorded by climate stations. The nearest onshore climate station to the Project is Blackpool Squires Gate (53.776, -3.037), which is located approximately 31km from the Project at its closest location. The most recent time slice available was for the period of 1991 to 2020. This data is supplemented with a review of the Met Office's 'Regional Climate Summaries', which presents the climate characteristics of 11 different regions in the UK using observations over the 1981 to 2010 period (not yet updated to the 1991 to 2020 reference period).

21.134 Annual average temperatures over the most recent decade (2009 to 2018) have been on average 0.3°C warmer than the 1981 to 2010 average and 0.9°C warmer than the 1961 to 1990 average. All the top ten warmest years for the UK from 1984 onwards have occurred since 2002. In addition, the most recent decade (2009 – 2018) has been on average 1% wetter than 1981 to 2010 and 5% wetter than the 1961 to 1990 average for the UK, both in the summer and winter months. Mean sea level around the UK has risen about 17cm since the start of the 20th century (The Met Office, 2022).

21.135 Current climate conditions for Blackpool Squires Gate, England (North West) and the UK are presented in **Table 21.19**. North West England is characterised by the Pennines on the eastern border of the region and the Irish Sea on the western border. The range of topography and altitude results in variations in climates within the region and the wettest place in England. Mean annual temperatures tend to be higher along the low-lying coastal areas and lower inland with increasing altitude. The coldest month of year is January, and the warmest month is July (The Met Office, 2016).

21.136 North West England's exposure to westerly maritime air masses, coupled with the presence of extensive areas of high ground, results in a climate that is particularly wet. Rainfall is generally well-distributed throughout the year, but the driest season is spring while the wettest is around autumn to winter. Snowfall is normally confined to the months from November to April. North West England is also among the more exposed parts of the UK to strong winds due to its proximity to the Atlantic and large upland areas, with mean wind speeds and gusts strongest from December to February (The Met Office, 2016). The regional characteristics of North West England are reflected in the observed climate conditions as listed in **Table 21.19**, although the amount of rainfall within the Study Area is substantially less than other parts of North

West England. This is due to the rain shadow effect of the high ground of North Wales and the Lake District.

Table 21.19 Current local, regional and national climate conditions for the period of 1991 to 2020 (The Met Office, 2023)

Climate variable	Units	Rolling annual average[4]			
		Blackpool Squires Gate	England Northwest	England	UK
Maximum temperature	°C	13.4	12.7	13.8	12.8
Minimum temperature	°C	7.01	5.79	6.12	5.53
Days of air frost	days	34.0	47.7	45.1	53.4
Rainfall	mm	886	1,338	870	1,163
Days of rainfall ≥ 1 mm	days	147	170	135	159
Mean wind speed at 10 m	knots	10.73	9.39	8.33	9.27

21.137 The Offshore Energy Strategic Environmental Assessments provide environmental baseline information on meteorological conditions at sea for various offshore regions surrounding the UK, of which the Project falls within Regional Sea 6. Average air temperature is 7°C in January and 14°C in July, with rainfall at sea expected around 18 days per month in the winter and between 10 to 15 days per month in the summer (based on 30 years of data from 1984 – 2014). Winds are generally from the west and southwest for most of the year, with a 20% chance of winds exceeding 14m/s to the east of the Isle of Man in the winter, reducing to 2% in the summer (BEIS, 2016b).

21.6.2.2 Future baseline climate

21.138 Climate change projections were used to identify future changes to climate variables within the study area. It is anticipated that the Project will have an operational lifetime of 35 years, starting as early as 2029 following completion of construction. For the CCRA, time slices presenting 20-year or 30-year

[4] Rolling annual average is defined as an average over 12 months within the defined time period.

averages, depending on data availability, are considered to be suitable for assessment.

21.139 The Met Office's UKCP database provides probabilistic climate change projections for the UK at a spatial resolution of 25km grid squares from the time period of 1961 to 2100. Probabilistic projections are based on possible changes in future climate based on an assessment of climate model uncertainties and are most suitable for characterising future extremes in risk assessments, as they provide the broadest range of climate outcomes.

21.140 The UCKP database uses RCP which align with the emission scenarios used in the IPCC's Fifth Assessment Report (IPCC, 2014). The likelihood of individual RCPs occurring is dependent on current and future GHG emissions and the implementation of mitigation strategies. For this CCRA, data was obtained for RCP4.5 and RCP8.5, which are described further in **Table 21.20**. For each RCP, where relevant and applicable, three probabilities were considered and presented in the chapter: 10th percentile, 50th percentile (median) and 90th percentile.

Table 21.20 Summary of RCP emission scenarios considered in the CCRA

RCP	Scenario name	Scenario description	Increase in global mean surface temperature (°C) by 2081 to 2100
RCP4.5	Intermediate scenario	GHG emissions peak around 2040 and then start to decline	2.4 (1.7 to 3.2)
RCP8.5 (Worst Case)	Very high GHG emission scenario	Increasing global GHG emissions throughout the 21st century	4.3 (3.2 to 5.4)

Air temperature, precipitation and wind

21.141 By the end of this century, all areas in the UK are projected to be warmer, with more warming expected in the summer than in the winter (Met Office, 2022). During the summer, probabilistic projections show a north/south contrast, with greater increases in maximum summer temperatures over the southern UK compared to northern Scotland (Met Office, 2019a). Under a high emissions scenario, by 2070 the frequency of hot spells (i.e., maximum daytime temperatures exceeding 30^{o}C for two or more consecutive days) increases. Currently, these are largely confined to south-east UK (Met Office, 2022). Under a RCP8.5 scenario, where global GHG emissions continue to increase throughout the 21st century, it is projected that annual temperatures by 2070 could increase by between 0.7^{o}C and 4.2^{o}C in the winter and 0.9^{o}C and 5.4^{o}C in the summer, compared to a 1981 to 2000 mean (Lowe *et al.*, 2018).

21.142 For precipitation, the probabilistic projections provide low (10% probability) to high (90% probability) changes across the UK. These project that by 2070, under RCP8.5, average changes to precipitation rates in the UK are -1% to +35% for winter, and -47% to +2% for summer, in comparison to the 1981 to 2000 mean. Negative and positive values indicate reduced and increased precipitation respectively. This means that precipitation levels are expected to continue to increase in the winter but decrease during the summer (Lowe *et al.*, 2018). Future climate change is expected to bring about a variation in the seasonality of extremes, such as increases in heavy hourly rainfall intensity in the autumn, and significant increases in hourly precipitation extremes (Met Office, 2022).

21.143 Global projections over the UK indicate that the second half of the 21st century will experience an increase in near surface wind speed during the winter season. This is also accompanied by an increase in the frequency of winter storms over the UK (Met Office, 2021).

21.144 As caveated previously, the majority of UKCP probabilistic projections are land-based and thus do not provide direct coverage of the offshore area in which the Project is located. However, to provide projections of climate variables at a local scale, data was retrieved from the UKCP database for the grid square closest to the windfarm site (337500, 437500) for mean, maximum and minimum air temperature and precipitation rate anomalies. Annual averages for these variables are presented in two 30-year time slices compared to a baseline period of 1981 to 2010, as shown in **Table 21.21**.

21.145 Across both RCP4.5 and RCP8.5, climate projections near the windfarm site indicate a trend of increasing annual mean, maximum and minimum air temperature and a likely increase in precipitation rate. Under RCP8.5, the mean air temperature rise will range from 0.32 to 1.44°C between 2020 and 2049 and from 1.03 to 3.12°C between 2050 to 2079. Under the same scenario, changes to precipitation rates appear more variable between probabilities, ranging from -4.20 to 6.93% from 2020 to 2049, and from -5.26 to 10.15% from 2050 to 2079.

Table 21.21 Projected rolling annual average temperature and precipitation anomalies near the windfarm site relative to the 1981 to 2010 baseline (The Met Office, 2018a)

Indicator	Unit	Climate projection scenarios													
		RCP4.5							RCP8.5						
		2020 to 2049			2050 to 2079			Trend	2020 to 2049			2050 to 2079			Trend
		10th	50th	90th	10th	50th	90th		10th	50th	90th	10th	50th	90th	
Mean air temperature	°C	+0.19	+0.67	+1.21	+0.55	+1.32	+2.17	↗	+0.32	+0.86	+1.44	+1.03	+2.04	+3.12	↗
Maximum air temperature	°C	+0.17	+0.67	+1.23	+0.52	+1.35	+2.24	↗	+0.31	+0.88	+1.47	+0.98	+2.07	+3.22	↗
Minimum air temperature	°C	+0.18	+0.69	+1.26	+0.55	+1.36	+2.29	↗	+0.29	+0.88	+1.51	+1.00	+2.10	+3.29	↗
Precipitation rate	%	-3.91	+1.10	+6.24	-4.18	+1.77	+7.72	↗	-4.20	+1.22	+6.93	-5.26	+2.24	+10.15	↗

Sea temperature

21.146 In addition to an increase in air temperatures, climate change is also likely to affect sea surface and near-bottom temperatures, which in addition to melting ice sheets and glaciers, contribute to global sea level rise due to thermal expansion of seawater (Fox-Kemper *et al.*, 2021). Over the last 40 years, average sea surface temperature around the UK has shown a significant warming trend of around 0.3°C per decade, with marked local and regional variations, as shown in **Plate 21.2**. Temperature series recorded at the Malin Head Coastal Station in Ireland shows a strong warming trend in the Irish Sea over the period of 1960 to 2020 of 0.3°C per decade, with values since 2000 being consistently above the 1991 to 2020 average (Cornes *et al.*, 2023).

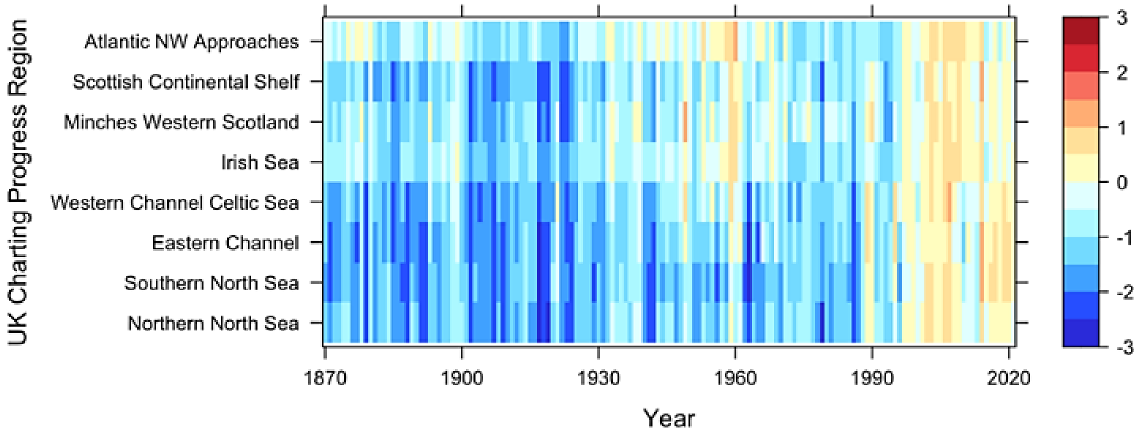

Plate 21.2 Observed changes in sea temperatures around the UK (sourced from Cornes et al., 2023)

21.147 Marine heat waves are periods of localised abnormally high sea temperatures above the long-term warming trend of the upper ocean. They last for several days or weeks, and potentially for several months, and can have significant adverse effects on the marine ecosystem. Marine cold waves represent the other end of the extreme of sea temperature conditions. A comparison of observations recorded between 1982 to 1998 and 2000 to 2016 indicate the marine heat waves have increased in frequency by an average of 3.8 events per year around the British Isles, with a regional variability ranging from 0 to 4.5 events. Data recorded at the Western Irish Sea (53.78ºN, 5.63ºW) indicates that 45 marine heat wave events have been recorded between 1997 and 2022 (Cornes *et al.*, 2023).

21.148 It is predicted that under RCP8.5, the average annual mean sea surface temperature change at the Irish Sea from 2079 to 2098 could be 3.22°C (± 1.03°C) compared to a 2000 to 2019 baseline, while projections for near-bottom temperature change sit around 2.87°C (± 0.97°C) (Cornes *et al.*, 2023).

Sea level rise and storm surge

21.149 Global sea levels have risen over the 20th century and are projected to continue rising over the coming centuries. Under all emission scenarios, sea levels around the UK will continue to rise to 2100 (The Met Office, 2022). Furthermore, sea levels are projected to continue rising beyond 2100 even with large reductions in GHG emissions over the 21st century (The Met Office, 2019c).

21.150 Although the majority of the UKCP database provides projections over land, marine projections for sea level rise around the UK is available. Data from the coastal grid square closest to the windfarm site (53.83ºN, -3.08ºE) was obtained for average sea level anomaly compared to a baseline period of 1981 to 2000. Sea level rise averages for the two RCP scenarios are presented in **Table 21.22**. Under RCP8.5, sea level rise will range from 0.17 to 0.32m (10th and 90th percentile respectively) by the mid-century.

Table 21.22 Projected rolling annual average sea level rise near the windfarm site relative to the 1981 to 2000 baseline (The Met Office, 2018b)

Time period		Climate projection scenarios						Trend
		RCP4.5			RCP8.5			
	Units	10th	50th	90th	10th	50th	90th	
2020 to 2039	m	+0.08	+0.11	+0.15	+0.09	+0.13	+0.16	↗
2040 to 2059	m	+0.14	+0.20	+0.27	+0.17	+0.24	+0.32	↗
2060 to 2079	m	+0.20	+0.30	+0.42	+0.28	+0.39	+0.52	↗

21.151 It is predicted that future extreme sea levels will be driven by changes in mean sea level, and not by the storm surge component or changes to tides. It is estimated that currently regional rates of sea level rise around the UK are between 1mm to 2mm per annum, and rates in the south of the UK are higher than some parts of Scotland when vertical land movement (glacial isostatic adjustment since the last ice age) is also taken into consideration (Horsburgh *et al.*, 2020).

21.152 Horsburgh *et al.* (2020) concluded that there is no observational evidence for long-term trends in either storminess across the UK or resultant storm surges, and storm surge stimulations for the 21st century suggest a best estimate of no significant changes to storm surges. Wolf *et al.*'s (2020) summary on future projections on storms and waves concluded that future projections in waters surrounding the UK are sensitive to climate model projections for the North Atlantic storm track, which contains considerable uncertainty. In the near future, natural variability dominates any climate-related trends in storms and waves, and towards the end of the 21st century, there is some consensus that mean significant wave height is decreasing while most extreme wave height is increasing (Palmer *et al.*, 2018).

21.7 Assessment of effects

21.7.1 GHG assessment

21.153 This section presents the GHG assessment which considers the construction, operation and maintenance, and decommissioning phases of the Project in isolation and combined over the whole lifecycle, along with their effect significance. The carbon benefits of the Project are also determined.

21.154 As discussed in **Section 21.5.1.3**, the receptor for the GHG assessment is the global atmosphere, which is defined as high sensitivity for all project phases. The magnitude of impact is not defined in EIA terms but represented by the magnitude of GHG emissions released or saved as a result of Project activities.

21.155 As noted in **Table 21.2** and **Appendix 21.1**, conservative assumptions have been adopted for the assessment with respect to the activity data and emission factors used, such as assuming the most GHG-intensive construction materials and the worst-case distance for vessel round trips. In addition, wider decarbonisation trends are not considered within the assessment. Emission factors used in the assessment are representative of present-day conditions. Specifically, the manufacturing of products and the movement of marine vessels are likely to be less GHG intensive over the Project's timeframe, as the UK electricity grid decarbonises, and organisations adopt emission reduction measures in line with their sectoral decarbonisation trajectories. Therefore, the calculated GHG emissions are likely to present an overestimate of actual emissions, particularly during the operational and maintenance, and decommissioning phases.

21.7.1.1 Potential impacts during construction

21.156 Emission source groups during construction that were identified and quantified for the Project include embodied carbon in materials utilised during construction, marine vessel movements associated with material and personnel transport and offshore construction activities, and helicopter emissions from personnel transport. Construction emissions are shown in **Table 21.23** by source group.

Table 21.23 Construction GHG emissions from the Project

Source group	GHG emissions (tonnes CO_2e)	Percentage of construction emissions
Embodied carbon	719,096	81.7%
Marine vessels	160,408	18.2%
Helicopters	238	<0.03%
Total (over entire construction phase)	**879,741**	

21.157 Total construction emissions were estimated to be 879,741 tonnes CO_2e. Embodied carbon in construction materials is expected to be the largest contributor to construction emissions, representing 81.7% of the total. The majority of embodied carbon is associated with the use of steel, fibre glass and concrete, due to the large quantities required to construct the infrastructure components and their high embodied carbon content. These materials account for 63.5%, 10.5% and 9.8% of total embodied carbon emissions respectively.

Comparison to UK carbon budgets

21.158 The Project's construction phase falls overlaps with the 5th carbon budget period (2028 to 2032). Estimated construction emissions would constitute around **0.05%** of the 5th carbon budget, which forms a relatively small proportion, and GHG emissions during construction would occur over a short duration as a single occurrence.

21.159 It should be noted that the some of the GHG emissions predicted in **Table 21.23** are likely to occur outside the territorial boundary of the UK, given the international nature of supply chains, and hence outside the scope of the UK's national carbon budget, policy and governance. However, considering that GHG emissions affect the climate system wherever they occur and the need to avoid 'carbon leakage' overseas when reducing UK emissions, all emission sources released during construction have been included in the assessment.

Significance of effect

21.160 Based on their low contribution to the 5th carbon budget, construction emissions arising from the Project are unlikely to affect the UK's ability to meet future carbon budgets and progress towards achieving a science-based net zero transition. Construction methods are expected to comply with applicable existing and emerging policy requirements and good practice design standards for offshore windfarms. Therefore, the Project's construction emissions are considered to have a **minor adverse** effect on climate change, which is **not-significant** in EIA terms. Moreover, it should be noted that construction emissions would be released once to enable the development of the Project and the provision of renewable energy to decarbonise the UK electricity grid in the long run, as detailed in **Section 21.7.1.2**.

21.161 There are opportunities for further reductions in construction phase emissions, which can be captured through the implementation of a standard carbon management process. The ‘PAS 2080’ document (2023) provides guidance to demonstrate leadership and establish effective governance mechanisms for reducing whole life carbon in built environment projects. The following management measures are considered best practice for further consideration at the Project develops but are not required as additional mitigation:

- Optimise the efficiency of construction activities to reduce fuel and material consumption and promote resource efficiency, e.g., inclusion of delivery and transport coordination requirements in Vessel Management Plans (an Outline Vessel Traffic Management Plan is provided with the DCO Application; Document Reference 6.9), adoption of waste hierarchy in construction management plans.
- Explore opportunities to reduce embodied carbon and other construction emissions by developing carbon-focused procurement criteria and incentive mechanisms for material suppliers and project partners, such as low carbon and recycled materials, circular construction methods and performance benchmarking.
- Review and include key principles of PAS 2080 with respect to carbon management in the relevant project documents or a project-specific Carbon Management Plan, such as:
    - Establish and communicate carbon management goals, roles and responsibilities, requirements and procedures to parties involved in the delivery of the Project.
    - Practise the GHG mitigation hierarchy over the Project’s lifetime (see **Section 21.3.3.1**).
    - Promote collaboration and information sharing across the Project’s value chain to encourage whole life carbon reductions and continual improvement.
    - Provide training and raise awareness among the Project team and partners on key carbon emission sources and low carbon solutions.

21.7.1.2 Potential impacts during operation and maintenance

21.162 Operation and maintenance emission source groups identified and quantified for the Project include marine vessel emissions from maintenance activities and embodied carbon from spare parts used in the repair and replacement of offshore infrastructure. Operation and maintenance emissions are shown in **Table 21.24** by source group.

Table 21.24 Operation and maintenance GHG emissions from the Project

Source group	GHG emissions (tonnes CO_2e)	Percentage of operation and maintenance emissions
Marine vessels	497,858	96.3%
Spare parts	19,286	3.7%
Total (over a 35-year operational lifetime)	**517,145**	
Annual (average per year)	**14,776**	

21.163 Total operation and maintenance emissions were estimated to be 517,145 tonnes CO_2e over the 35-year operational lifetime, and on average, 14,776 tonnes CO_2e per year. Marine vessels emissions constitute the majority of operation and maintenance emissions, accounting for 96.3% of the total. Vessel emissions will vary year-by-year over the operational lifetime, with emissions of 9,437 tonnes CO_2e during standard maintenance years, and 37,367 tonnes CO_2e during heavy maintenance years due to more vessel movements and on-site time.

21.164 As noted in **Appendix 21.1**, as a conservative estimate, it was assumed that operation and maintenance vessels would use marine gas oil (MGO) throughout the 35 year operational life. 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, when it is likely that low or zero carbon fuels will be widely adopted in the shipping sector.

Operational GHG intensity and emission savings

21.165 As the Project will supply renewable energy to the UK grid, there will be GHG emission savings over the Project's operational lifetime from avoided emissions compared to other forms of generation. Based on the Project's anticipated lifetime electricity output and operation and maintenance GHG emissions, the operational GHG intensity per unit of electricity generated by the Project was determined to be 6.0 g CO_2e per kWh. As discussed in **Section 21.6.1**, this figure assumes an installed windfarm capacity of 480MW and a capacity factor of 58.4%.

21.166 Electricity generated by the Project is less GHG intensive than other forms of generation such as non-renewable fuels or alternative energy sources considered in the future UK grid mix, leading to avoided GHG emissions and thus savings over its operational lifetime. **Table 21.25** presents the quantity of emissions which would be produced under the two 'Do Nothing' scenarios in the Project's absence, along with the emissions saved from the implementation of the Project, accounting for operation and maintenance emissions which are released by the Project.

21.167 Under Scenario 1, assuming the Project displaces electricity generated using fossil fuel generation only, approximately 35.9 million tonnes CO_2 would be saved. Although the emission factor used for non-renewable generation is in units of CO_2 rather than CO_2e, this figure is still considered to be representative, as the majority of GHG emissions from fossil fuel combustion is from CO_2.

Under Scenario 2, assuming the Project displaces electricity generated using all energy sources considered in the future UK grid mix, including renewable and other low carbon generation sources, it is estimated that approximately 901,700 tonnes CO_2e would be saved. This scenario provides a conservative estimate, as the increasing uptake renewable energy projects such as the Project is accounted for in the DESNZ's long run marginal emission factors (2023).

21.168 Together, these figures provide a range of GHG emissions savings associated with the Project.

Table 21.25 GHG emissions saved by the Project

Baseline scenario	Project's total operation and maintenance GHG emissions (tonnes CO_2e)	GHG emissions from 'Do Nothing' scenarios (tonnes CO_2 / CO_2e)	GHG emissions saved by operation of the Project (tonnes CO_2e)
Do Nothing Scenario 1 GHG emissions from electricity generated using 'non-renewable fuels'	516,854	36,441,151	**-35,924,007**
Do Nothing Scenario 2 GHG emissions from the long run marginal emission factor		1,418,906	**-901,761**

Comparison to UK carbon budgets

21.169 The first five years of the Project's operation and maintenance phase overlaps with both the 5th carbon budget period (2028 to 2032) and 6th carbon budget period (2033 to 2037). To provide a conservative comparison, the 6th carbon budget period has been used. Operation and maintenance emissions that would be released from activities associated with the Project over this period would constitute around **0.008%** of the 6th carbon budget. Although operation and maintenance GHG emissions would occur continuously over the Project's operational lifetime, the magnitude of emissions would be negligible in comparison to the carbon budget.

21.170 In addition, when considering the emissions saved by the Project from the provision of renewable energy to the grid, the Project would result in an avoidance of emissions when compared to the two Do Nothing Scenarios considered in **Table 21.25.**

21.7.1.3 Significance of effect

21.171 The Project will contribute to the UK meeting the projected increase in electricity demand over the years due to population and economic growth (BEIS, 2022), as well as the supply of renewable energy to decarbonise the power sector and support emission reductions in other economic sectors. Given the low operational GHG intensity and emission savings associated with the Project's operations, the effect significance of Project during the operation and maintenance phase is considered to be **beneficial**, which is **significant** in EIA terms. Any operation and maintenance emissions released by the Project over its lifetime would be negligible and offsetted by the avoided emissions it enables.

21.7.1.4 Potential impacts during decommissioning

21.172 The decommissioning strategy for the Project is not known at this stage, and therefore quantification of Project-specific decommissioning emission sources was not undertaken. However, these emission sources are likely to include marine vessel emissions from the disassembly of offshore infrastructure and transport to its end of life destination, and emissions from waste processing, recycling and disposal. Using an industry benchmark obtained from the literature (Thomson & Harrison, 2015), the Project's decommissioning emissions was estimated at 16,972 tonnes CO_2e, which accounts for 1.2% of the Project's lifecycle GHG emissions.

It is anticipated that a large proportion of windfarm components would be recycled, repurposed or incinerated for energy recovery at the end of life stage, as opposed to being sent to landfill, with current estimates for wind turbines recyclability ranging from 85 to 90% (Schmid *et al.*, 2020). There are also alternatives to decommissioning of offshore windfarms with potentially lower GHG footprint such as partial or full repowering and life extension strategies, which could be explored as part of determining the preferred decommissioning strategy for the Project (Spyroudi *et al.*, 2021). Furthermore, emission calculations for other decommissioning activities for the Project are likely to be an overestimate, as they would not account for high levels of decarbonisation which will be achieved in the future. For example, as 2050 is the UK's target net zero year, new end of life strategies are likely to become commercially available which are likely to result in less emissions than equivalent activities undertaken in the present day.

Significance of effect

21.173 Decommissioning would result in a single occurrence of GHG emissions, and is an inherent process in the lifecycle of offshore wind projects. However, as the UK economy is likely to decarbonise over the lifespan of the Project, emission estimates based on present day activities are likely to result in an overestimation. The Project's decommissioning emissions are considered to have a **negligible** effect on climate change, which is **not significant** in EIA terms. Similar to construction, decommissioning activities are expected to comply with applicable policy requirements and good practice design standards for offshore windfarms at the time of its occurrence. Carbon management measures as detailed in PAS 2080 that are discussed in **Section 21.7.1.1** are also applicable to decommissioning activities.

21.7.1.5 Whole lifecycle and combined GHG emissions with Transmission Assets

Project lifecycle

21.174 The Project's GHG emissions over its whole lifecycle are presented in **Table 21.26**. Total GHG emissions resulting from the construction, operation and maintenance, and decommissioning phases of the Project were estimated to be 1,413,858 tonnes CO_2e. Construction emissions contributed the largest proportion of lifecycle emissions, accounting for 62.2% of the overall footprint.

21.175 **Plate 21.3** shows the temporal profile of the Project's lifecycle emissions, with construction emissions representing the highest peaks over the anticipated 2.5-year construction period, while emissions during operation and maintenance are relatively continuous over the Project's 35 year lifetime, albeit at a lower magnitude of emissions when compared to construction.

21.176 **Plate 21.3** also demonstrates the conservative approach to estimating emissions as during the operation and maintenance phase it is likely that annual emissions associated with the Project would decrease as the UK economy decarbonises. Decommissioning emissions were excluded from**,** as the timescales for this phase has not yet been confirmed.

Table 21.26 Whole lifecycle GHG emissions from the Project

Phase	GHG emissions (tonnes CO_2e)	Percentage of whole lifecycle emissions
Construction	879,741	62.2%
Operation and maintenance	517,145	36.6%
Decommissioning	16,972	1.2%

Phase	GHG emissions (tonnes CO_2e)	Percentage of whole lifecycle emissions
Total	**1,413,858**	

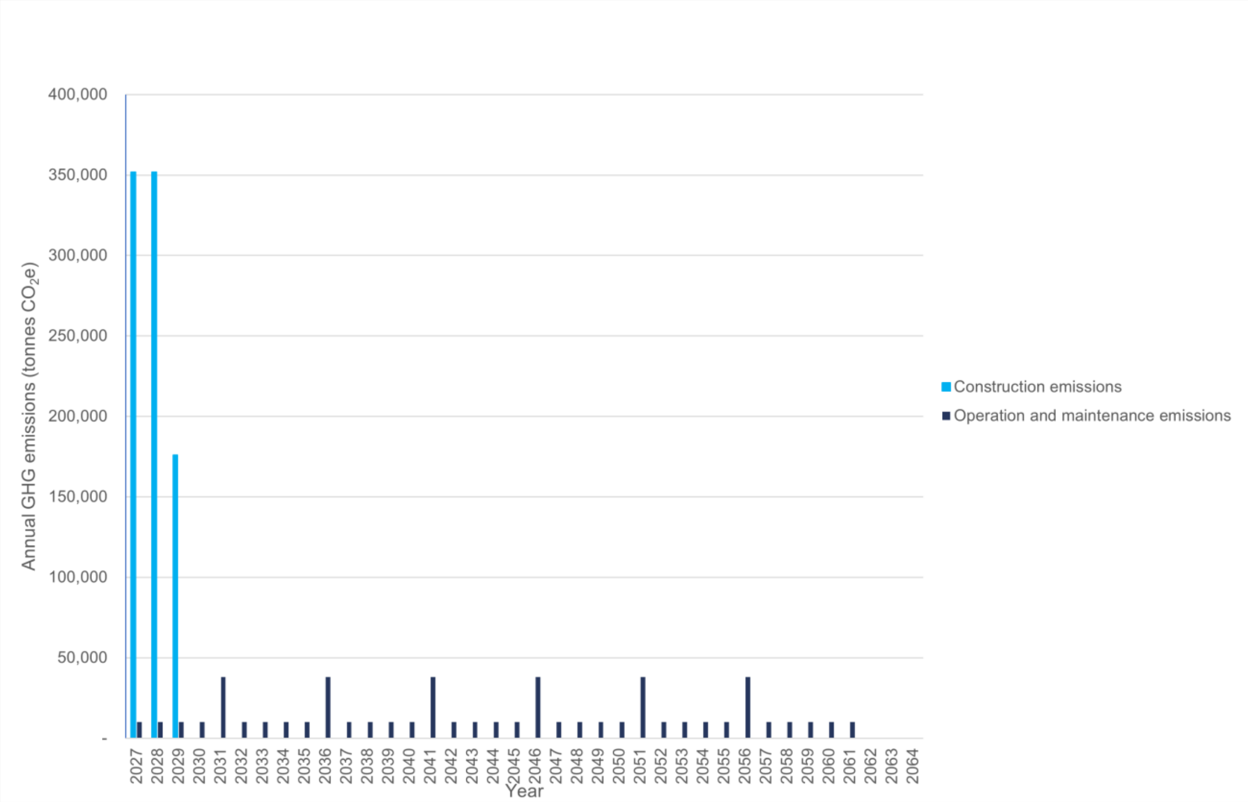

Plate 21.3 Lifecycle GHG emissions by year from the Project

21.177 As previously discussed, the emissions avoided by the operation of the Project under two 'Do Nothing' scenarios (where electricity is produced by other forms of generation) are presented in **Table 21.25.** Whole lifecycle emissions associated with the Project as presented in **Table 21.26** are lower than the avoided emissions under both scenarios.

21.178 Under Scenario 1, which assumes that the Project replaces electricity generated using fossil fuel generation only, whole life cycle carbon would be paid back within two years of operation. As detailed in **paragraph 21.125**, the consideration of Scenario 1 is in line with the NPS for Energy EN-1 and UK emission reduction and renewable energy policies to replace fossil fuel generation with renewable energy schemes within the power sector (**Section 21.4**).

21.179 Scenario 2 does not provide a meaningful analysis of carbon payback because the long run marginal factors are based upon modelled scenarios to reflect the decarbonisation of the UK power sector as a result of policies such as the NPS for Energy EN-1. The modelled scenarios are subject to considerable uncertainty relating to the roll out of renewable energy schemes, advances in technology and innovation and market demands. The predicted carbon intensity of the grid beyond 2050 under the long run marginal factor scenario is 0.002 kg CO_2e / kWh, which assumes that renewable energy schemes such as the Project have been widely adopted, which means that reporting carbon payback under this scenario has considerable limitations.

The Project and Transmission Assets – Combined Assessment

21.180 As noted in **Chapter 1 Introduction**, the Project only forms the Generation Assets of the Morecambe Offshore Windfarm. The Transmission Assets associated with the Morecambe Offshore Windfarm and the Morgan Offshore Wind Project (another proposed windfarm in the Irish Sea) are subject to a separate DCO application. The Transmission Assets will enable the export of electricity from both project windfarm sites to landfall and onwards to a connection point to the National Grid electricity transmission network. This would include installation and operaton and maintenance of offshore and onshore export cables and new onshore transmission infrstructure, including onshore substation(s).

21.181 Both Generation and Transmission Assets are required for the windfarm to supply renewable energy and contribute to the decarbonisation of the UK electricity grid, therefore GHG emissions associated with the windfarm in its entirety require consideration. As such, the Project's whole lifecycle emissions have been considered combined with the whole lifecycle emissions arising from the Transmission Assets.

21.182 Whole lifecycle GHG emissions for the Transmission Assets were obtained from Transmission Assets PEIR, Volume 4, Chapter 3 Climate Change (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023), which were estimated to be 1,407,105 tonnes CO_2e. The whole life emissions for the Project and the Transmission Assets are summarised in **Table 21.27.**

Table 21.27 Combined GHG emissions from the Project and Transmission Assets

Windfarm element	Whole lifecycle GHG emissions (tonnes CO_2e)
The Project (Morecambe Generation Assets)	1,413,858
Transmission Assets (Morgan and Morecambe)	1,407,105
Total	**2,820,963**

21.183 It should be noted that the total emissions for the Transmission Assets includes transmission infrastructure and activities for both the Morgan and Morecambe windfarms, and therefore the combined total emissions outlined in **Table 21.27** are an overestimation for the Morecambe Offshore Windfarm alone. The Transmission Assets PEIR does not detail/directly apportion emissions or activities for the Transmission Assets between the Morecambe and Morgan projects given the partially cordinated cable routes. An indicative proportion could be derived by using the proposed generation capacities of both offshore windfarms, which are nominally 480MW for Morecambe and 1,500MW for Morgan respectively. Therefore, indicative total emissions for the Morecambe Offshore Windfarm (i.e. the Project (Generation Assets) plus the associated Transmission Assets for Morecambe alone) could be theoretically derived by apportioning approximately one quarter of the Transmission Assets contribution to Morecambe.

21.184 As explained above, the whole lifecycle and combined emission totals presented in **Table 21.27** are an overestimation as they contain the full contribution from the Transmission Assets for both the Morecambe and Morgan projects. In addition, the total emissions for both the Project and Transmission Assets are calculated using a number of conservative assumptions, particularly during the operation and maintenance phase of the Project. Even with the whole lifecycle and combined emission totals representing an overestimation, there will be emission savings from the provision of renewable energy to the grid due to displacing more GHG intensive forms of electricity generation. This is demomstrated by the estimated emissions saved through the operation of the Project (ie up to 35,924,007 tonnes CO_2e saved when considering displacement of electricity generated using non-renewable fuels). Therefore, the Generation and Transmission Assets of the Morecambe Offshore Windfarm will result in a positive contribution to the UK meeting its emission reduction targets.

21.185 The whole lifecycle GHG intensity of the combined Generation and Transmission Assets (including the total contribution of both the Morecambe and Morgan transmission asset infrastructure) was estimated to be 32.8 g CO_2e per kWh. This overall GHG intensity of the Generation and Transmission Assets compares favourably with other forms of fossil fuel electricity generation based on their predicted lifecycle GHG intensities (CCC, 2013):

- Unabated Combined Cycle Gas Turbine: 380 to 500 gCO_2e per kWh
- Gas with Carbon Capture Storage: 90 to 245 gCO_2e per kWh
- Coal with Carbon Capture Storage: 80 to 310 gCO_2e per kWh

This shows that emissions associated with the whole lifecycle of both the Generation Assets and the Transmission Assets are far exceeded by the avoided emissions which they enable, and any GHG emissions released would be fully offset within the operational lifetime of the Project, assuming non renewable sources of electricity are replaced..

It should be noted that the lifecycle GHG emissions of the Morgan Offshore Wind Project Generation Assets and the potential avoided emissions associated with the operation of these Morgan Generation Assets have not been considered in the whole lifecycle GHG intensity figure presented above (despite the Morgan Transmission Asset emissions being accounted for in the GHG intensity figure). The inclusion of net emissions associated with the Morgan Generation Assets would further reduce this GHG intensity number and increase the overcall carbon benefits when considering the three projects together (i.e. Morecambe Generation Assets, Morgan Generation Assets and the Transmission Assets for both Morecambe and Morgan).

Overall significance of effect

21.186 Given the Generation and Transmission Assets will enable the provision of renewable energy to the UK electricity grid and contribute positively to the UK's progress in meeting its net zero targets and the climate system, the overall significance of effect is considered to be **beneficial**, which is **significant** in EIA terms.

21.7.2 CCRA

21.187 As noted in **Section 21.3.1.2**, the construction and decommissioning phases are scoped out of the CCRA. The construction phase of the Project is considered to have low vulnerability to climate change hazards due to the short construction timescale and best practice measures in the construction sector, as discussed in **Section 21.3.3.2**. Therefore, no LSE with respect to climate change resilience is anticipated during the construction phase. The decommissioning strategy of the Project is not yet known, thus, an informed assessment is not possible at this stage. It is expected that climate change impacts during decommissioning would be assessed closer to the date during the preparation of decommissioning programme, and suitable mitigation measures will be adopted to minimise the risks pose to the Project.

21.7.2.1 Potential impacts during operation and maintenance

21.188 The potential impacts of climate change to the Project during operation and maintenance have been assessed. This section provides a summary of changes to climate variables and associated climate hazards which are anticipated to interact with the Project over its operational lifetime.

Step 1: Identifying receptors, climate variables and hazards

21.189 As discussed in **Section 21.6.2**, observed and projected changes to the climate baseline at the windfarm site indicate that the key climate variables which could be affected by climate change in the study are temperature, precipitation, wind speed, sea temperature and sea conditions.

21.190 The Project may be exposed to a range of climate hazards, defined as extreme weather events and chronic (longer term) climatic changes with the potential to harm human, environmental or infrastructure receptors (IEMA, 2020). Exposure to climate hazards may lead to climate change impacts to the Project such as physical damages to infrastructure components or adverse working conditions during operation and maintenance activities.

21.191 The Project receptors, climate variables and hazards taken forward into Step 2 of the CCRA are detailed in **Table 21.28**.

Table 21.28 Project receptors, climate variable and hazard identified for the CCRA

Climate variable	Potential climate hazards	Receptors affected
Temperature Precipitation Wind speed Sea temperature	**Gradual changes in marine climate**: climate change is likely to increase the air and sea surface temperatures in the Irish Sea region, as well as a likely increase in year-round precipitation rates and near surface wind speed during the winter. **Extreme weather events**: climate change is likely to increase the frequency and severity of extreme weather events (Seneviratne *et al.*, 2021). Events relevant to the marine climate include stronger gusts or prolonged high wind events, increasing rainfall intensity, marine heat and cold waves, hot and cold spells above sea and storms.	▪ Built infrastructure such as WTGs, OSP(s), foundations and cables ▪ Operation and maintenance personnel ▪ Vessels and other equipment used during operation and maintenance activities
Sea conditions	**Sea level change**: climate change is likely to increase mean sea level globally due to melting ice sheets and glaciers and the thermal expansion of seawater, with projections for the Irish Sea ranging from an increase by 0.14 to 0.32 m by 2060. Other chronic changes in sea conditions due to climate change include increased mean maximum wave heights, reduced mean wave heights and changes to tidal range and other characteristics (Palmer *et al.*, 2018). **Extreme weather events**: climate change has the potential to increase the frequency and severity of storms, which are associated with turbulent sea conditions, although Horsburgh et al. (2020) concluded that there is no observational evidence for long-term trends in either storminess across the UK or resultant storm surges. Events relevant to the marine climate include turbulent waves, strong undercurrents and storm surges or ocean swelling caused by high wind	

Climate variable	Potential climate hazards	Receptors affected
	pushing the sea towards the coast and lower atmospheric pressure during storms (Palmer *et al.*, 2018).	

Step 2: Climate vulnerability assessment

21.192 The vulnerability of the Project and its receptors to the climate hazards identified are considered further in Step 2 of the CCRA and outlined in **Table 21.29**. A description of how the hazard translates into climate change impacts to the Project are also provided.

21.193 The sensitivity of the Project to the identified climate hazards (gradual changes in marine climate, sea level change and extreme weather events) is considered to be **low**. There is a low potential for the Project to be affected by changes associated with these hazards due to the climate change adaptation measures incorporated as part of the Project's embedded mitigation. Based on the future climate baseline described in **Section 21.6.2.2**, the Project is considered to have a **moderate** exposure to the identified climate hazards due to its offshore location and operation and maintenance lifetime, which results in a spatial and temporal overlap with the climate hazards.

21.194 Using the Sensitivity-Exposure matrix in **Table 21.14**, the Project is considered to have **low** vulnerability to all climate hazards identified. Further assessment of climate change impacts and associated risks (Steps 3 and 4 of CCRA) has not been undertaken, in line with the methodology set out in **Section 21.5.2.3**.

Table 21.29 Climate vulnerability assessment

Climate hazard	Potential climate change impact to the Project	Embedded mitigation	Sensitivity	Exposure	Vulnerability	Screened in for detailed climate risk assessment?
Gradual changes in marine climate	WTG and OSP foundations, cables and other support structures which are submerged are exposed to a corrosive and harsh environment due to strong waves and currents and the ocean's salinity. Increase in sea temperature beyond an infrastructure's operational temperature range could reduce the structural integrity of infrastructure, resulting in increased maintenance and shorter replacement cycles due to fatigue, corrosion damage and faster asset deterioration (Igwemezie *et al.*, 2018). Climate change induced changes in wind patterns are a key hazard for offshore wind projects, as it influences the wind resource and reliability of electricity generation and thus the commercial viability of a windfarm. Wind energy is directly proportional to air density, which is inversely proportional to air temperature. Long-term increases in air temperature can	The Project's offshore infrastructure are being designed with sufficient safety margins to account for extreme weather events and are based on information gathered from satellite observations, real-time measurements and metocean hindcast data, which synthesises long-term time series of wind, waves. An estimate for sea level rise of 3mm/year is made within the site Metocean report which will be considered in the design. Modern windfarm design consistent with best practice engineering codes and standards will be adopted, which will require resilience to extreme weather events at sea and longer term changes to the climate baseline. Design measures could include high wind ride out and climate change allowance of wind turbine support structures to avoid water damage and saltwater corrosion of non-resistant components and	Low	Moderate	Low	No

Climate hazard	Potential climate change impact to the Project	Embedded mitigation	Sensitivity	Exposure	Vulnerability	Screened in for detailed climate risk assessment?
	lead to slight declines in wind energy output by lowering air density. Other factors which influence wind energy include wind speed, direction, variability and shear at the site, which are influenced by the global energy balance and atmospheric circulation susceptible to the effects of climate change. Increases in precipitation, moisture and ice formation could also affect the functionality of the turbine blades and increase the risk of blade edge erosion, increasing maintenance costs (Weisenfeld *et al.*, 2021).	withstand stronger waves and currents. In addition, design measures may include application of corrosion protection appropriate for anticipated sea temperature and sea level increases and for the increased frequency of extreme events to prevent the fatigue of foundation structures. Real-time monitoring of WTG's operational health and site conditions, and regular inspections and maintenance of offshore infrastructure will be carried out over the Project's operational lifetime. This will ensure timely identification and remediation of asset degradation and damages and prevent prolonged periods of disruptions to electricity generation.				
Sea level change	Sea level rise, compounded by storm surges and tidal changes, could affect fixed foundation components by increasing the risk of water damage and saltwater corrosion of non-resistant components. Faster asset deterioration would increase maintenance and replacement costs. Stronger ocean waves and currents would increase loading and reduce the structural integrity of offshore		Low	Moderate	Low	No

Climate hazard	Potential climate change impact to the Project	Embedded mitigation	Sensitivity	Exposure	Vulnerability	Screened in for detailed climate risk assessment?
	infrastructure, and if design limits are exceeded may result in asset damage or failure (Weisenfeld *et al.*, 2021).					
Extreme weather events	Extreme weather events at sea such as storms and surges could damage offshore infrastructure and increase maintenance and replacement costs. Operational down time during gusts or prolonged high wind events would also disrupt electricity generation, with a risk of lower annual energy output with an increasing frequency of extreme weather events. Moreover, frequent or intense events of turbulent flow of wind may result in loss of low pressure and lift, diminishing wind energy output (Weisenfeld *et al.*, 2021). Extreme weather events could also constrain offshore operation and maintenance activities and present health and safety risks to personnel, vessels and other equipment.	In addition to the embedded mitigation discussed above, the WTGs will shut down and remain in idle configuration at wind speeds above the design limit to prevent structural damage. Normal operations will resume once the wind speed returns below the cut-out speed. Management plans prepared prior to the commencement of operation and maintenance activities will include weather forecasts, risk assessments and suitable health and safety protocols for extreme weather events to prioritise and safeguard the wellbeing of workers.	Low	Moderate	Low	No

Significance of effect

21.195 The CCRA identified the vulnerability of the Project and its receptors to key climate hazards that are likely to occur within the study area over its operational lifetime. The assessment determined that, accounting for the Project's embedded mitigation, the vulnerability rating of hazards identified would be low. Therefore, there is a low likelihood of climate change impacts to adversely affect the Project during its operation and maintenance phase, and any effects of climate change on the Project are considered likely to be **not significant**.

21.8 Cumulative effects

21.8.1 GHG assessment

21.196 As noted in **Section 21.5.1.4**, the global atmosphere is the only receptor for the GHG assessment (which is of high sensitivity), and IEMA guidance (2022) states that the effects of GHG emissions from specific cumulative projects should therefore not be individually assessed, as there is no basis for selecting which projects to assess cumulatively over any other. The impacts considered by the GHG assessment are inherently cumulative, as all developments which emit, avoid or sequester GHG emissions affect global atmospheric concentrations irrespective of their location. Thus, no specific cumulative assessment with other projects or plans was undertaken for the GHG assessment.

21.8.2 CCRA

21.197 As noted in **Section 21.5.2.4**, given the offshore setting of the Project, it is highly unlikely that the Project would affect or be affected by neighbouring developments with respect to climate change resilience. Therefore, a cumulative assessment with other projects or plans was not undertaken for climate change resilience.

21.9 Transboundary effects

21.198 As described in **Section 21.5.1.5** and **Section 21.5.2.5**, transboundary effects are not considered to require specific consideration for the GHG assessment and CCRA.

21.199 The receptor for the GHG assessment is the global atmosphere, and therefore GHG emissions have an indirect transboundary effect on climate change. Emissions released and avoided by the Project have been assessed in the context of UK carbon budgets, which have been set in accordance with international climate agreements. Therefore, the Project's effects on the climate commitments of states are inherently reflected in the GHG assessment.

21.10 Inter-relationships

21.200 The receptor for the GHG assessment is the global atmosphere. There are no other topics which have direct effects on this receptor, and therefore there are no inter-relationships with respect to the GHG assessment.

21.201 Similarly, the CCRA focusses on the effects of climate change on the Project itself, while other topics of the EIA assess the effects of the Project on other receptors. There are not considered to be any inter-relationships with other environmental effects related to the Project with respect to climate change resilience.

21.11 Interactions

21.202 The global atmosphere is the receptor for the GHG assessment, and the GHG assessment inherently considers the combination of emissions from various sources and the interaction between the emissions released by the Project and those saved from the provision of renewable energy. Therefore, no further assessment of interactions was undertaken for the GHG assessment.

21.203 The effects identified and assessed in the CCRA are not considered to have the potential to interact with one another. Therefore, an assessment of interactions between effects was not undertaken with respect to climate change resilience.

21.12 Potential monitoring requirements

21.204 There are not anticipated to be any specific monitoring requirements, beyond regular inspections and maintenance of offshore infrastructure, for the Project with respect to GHG emissions and climate change resilience.

21.13 Assessment summary

21.205 A summary of the effects on climate change identified in the assessment are provided in **Table 21.30**.

Table 21.30 Summary of potential effects on climate change

Potential impact	Receptor	Sensitivity	Magnitude	Effect significance	Additional mitigation measures proposed	Residual effect
GHG assessment						
Construction phase						
Construction GHG emissions	Global atmosphere	High	N/A*	Minor adverse	N/A	Minor adverse
Operation and maintenance phase						
Operation and maintenance GHG emissions and avoided GHG emissions from the provision of renewable energy	Global atmosphere	High	N/A*	Beneficial	N/A	Beneficial
Decommissioning phase						
Decommissioning GHG emissions	Global atmosphere	High	N/A*	Negligible adverse	N/A	Negligible adverse
Whole project lifecycle and combined with the Transmission Assets						
Combined GHG emissions and net effect on climate change	Global atmosphere	High	N/A*	Beneficial	N/A	Beneficial
Cumulative and Transboundary						
Cumulative effects in relation to GHGs do not require assessment. Transboundary effects were not explicitly considered within the assessment but can be assumed to be beneficial, as the Project results in net GHG emission savings and thus a mitigating impact on global atmospheric GHG concentrations and climate change.						
*Not defined as part of the assessment methodology						

Potential impact	Receptor	Vulnerability	Risk	Resilience	Effect significance	Additional mitigation measures proposed	Residual effect
CCRA							
Operation and maintenance phase**							
Gradual change in marine climate, sea level change and extreme weather events	▪ Built infrastructure ▪ Operation and maintenance personnel ▪ Vessels and other equipment	Low	N/A***	N/A***	Not significant	N/A***	Not significant
Cumulative and Transboundary							
Cumulative and transboundary effects in relation to CCRA do not require assessment.							
** Construction and decommissioning phases were scoped out of the CCRA. *** Steps 3 and 4 of the CCRA were not undertaken, as the Project was determined to have low vulnerability to all climate hazards identified.							

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