Pentland floating offshore wind farm

Volume 2: Offshore EIAR

Chapter 20: Climate Change and Carbon

OFFSHORE EIAR (VOLUME 2): MAIN REPORT

CHAPTER 20: CLIMATE CHANGE AND CARBON

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GLOSSARY OF PROJECT TERMS

Key Terms	Definition
Dounreay Trì Floating Wind Demonstration Project (the 'Dounreay Trì Project')	The 2017 consented project that was previously owned by Dounreay Trì Limited (in administration) and acquired by Highland Wind Limited (HWL) in 2020. The Dounreay Trì Project consent was for two demonstrator floating Wind Turbine Generators (WTGs) with a marine licence that overlaps with the Offshore Development, as defined. The offshore components of the Dounreay Trì Project consent are no longer being implemented.
Highland Wind Limited	The Developer of the Project (defined below) and the Applicant for the associated consents and licences.
Landfall	The point where the Offshore Export Cable(s) from the PFOWF Array Area, as defined, will be brought ashore.
Offshore Export Cable(s)	The cable(s) that transmits electricity produced by the WTGs to landfall.
Offshore Export Cable Corridor (OECC)	The area within which the Offshore Export Cable(s) will be located.
Offshore Site	The area encompassing the PFOWF Array Area and OECC, as defined.
Onshore Site	The area encompassing the PFOWF Onshore Transmission Infrastructure, as defined.
Pentland Floating Offshore Wind Farm (PFOWF) Array and Offshore Export Cable(s) (the 'Offshore Development')	All offshore components of the Project (WTGs, inter-array and Offshore Export Cable(s), floating substructures, and all other associated offshore infrastructure) required during operation of the Project, for which HWL are seeking consent. The Offshore Development is the focus of this Environmental Impact Assessment Report.
PFOWF Array	All WTGs, inter-array cables, mooring lines, floating sub-structures and supporting subsea infrastructure within the PFOWF Array Area, as defined, excluding the Offshore Export Cable(s).
PFOWF Array Area	The area where the WTGs will be located within the Offshore Site, as defined.
PFOWF Onshore Transmission Infrastructure (the 'Onshore Development')	All onshore components of the Project, including horizontal directional drilling, onshore cables (i.e. those above mean low water springs), transition joint bay, cable joint bays, substation, construction compound, and access (and all other associated infrastructure) across all project phases from development to decommissioning, for which HWL are seeking consent from The Highland Council.
PFOWF Project (the 'Project')	The combined Offshore Development and Onshore Development, as defined.

ACRONYMS AND ABBREVIATIONS

CBRA	Cable Burial Risk Assessment
CEMP	Construction Environmental Management Plan
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
GHG	Greenhouse Gas
GWh	Gigawatt Hour
HDD	Horizontal Directional Drilling
HWL	Highland Wind Limited
ICCI	In-combination climate impact
IEMA	Institute of Environmental Management and Assessment
km	kilometres
LCA	Life-cycle Analysis
LMP	Lighting and Marking Plan
m	metres
MARPOL	International Convention for the Prevention of Pollution from Ships
MCCIP	Marine Climate Change Impacts Partnership
mm	millimetres
MMMP	Marine Mammal Mitigation Plan
MS-LOT	Marine Scotland - Licensing Operations Team
MSS	Marine Scotland Science
MW	megawatt
OEMP	Operational Environmental Management Plan
Offshore EIAR	Offshore Environmental Impact Assessment Report
PFOWF	Pentland Floating Offshore Wind Farm
PSU	Practical Salinity Unit
RCP	Representative Concentration Pathway
RSPB	Royal Society for the Protection of Birds
SRES	Special Report on Emission Scenarios
SMWWC	Scottish Marine Wildlife Watching Code
THC	The Highland Council
UK	United Kingdom
UKCP18	UK Climate Projections 2018
UKCS	United Kingdom Continental Shelf
VMP	Vessel Management Plan
WTGs	Wind Turbine Generators

20 CLIMATE CHANGE AND CARBON

20.1 Introduction

The climate change and carbon impact assessment for the Pentland Floating Offshore Wind Farm (PFOWF) Array and Offshore Export Cable(s), hereafter referred to as the 'Offshore Development', during construction, operation and maintenance, and decommissioning is summarised in this chapter. The structure of this chapter differs from other Environmental Impact Assessment (EIA) topics, as it does not consider the impact of the Offshore Development on a specific receptor, but instead considers any potential impact of climate change on the Offshore Development and the impacts of the Offshore Development and climate change on the environment. The chapter is structured as follows:

> Future marine environment baseline (Section 20.4): Summarising the current evidence and future predictions for climate change, as relevant to the Offshore Development;

> Climate change resilience review (Section 20.6): Reviewing the ability of the Offshore Development to withstand, respond to and recover from changes in climate;

> In-combination climate impact (ICCI) assessment (Section 20.7): Assessing the impacts of the Offshore Development on the physical, biological and socio-economic environment, as assessed within the topic chapters of the EIA, in combination with any climate-induced changes to the environment;

> Blue carbon assessment (Section 20.8): Determining the effect of the Offshore Development on blue carbon habitats and sediments and the potential implications on carbon sequestration; and

> Carbon assessment (Section 20.8 and Offshore Environmental Impact Assessment Report [Offshore EIAR] [Volume 3]: Technical Appendix 20.1: Carbon Assessment): Estimates the carbon life cycle emissions resulting from the Offshore Development and calculates the carbon payback period for the Offshore Development.

Xodus Group has carried out this impact assessment. Further details of the Project Team's competency, including lead authors for each chapter, are provided in Offshore EIAR (Volume 3): Appendix 1.1: Details of the Project Team.

Table 20.1 below provides a list of all the supporting studies which relate to the climate change and carbon impact assessment. All supporting studies are appended to this Offshore EIAR.

Table 20.1 Supporting studies

Details of Study	Location of Supporting Study
Carbon Assessment (Xodus Group, 2022)	Offshore EIAR (Volume 3): Technical Appendix 20.1: Carbon Assessment (summarised in Section 20.9)

20.2 Legislation, Policy, and Guidance

This section sets out the relevant legislation and guidance applicable to the Climate and Carbon topic that is additional to the general legislation presented in Chapter 2: Planning Policy and Legislative Context.

20.2.1 Legislation

> The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019: This Act amends the Climate Change (Scotland) Act 2009 to set a new target for Scotland to reach net-zero emissions (i.e. 100% lower than the 1990 baseline) by 2045. Interim targets are also in place for 2030 and 2040 (75 and 90% reduction in emissions compared with the 1990 baseline, respectively);

- The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017 (as amended) and the Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017 (as amended): Schedule 4 of these regulations require that future changes in the baseline (without implementation of the Offshore Development) are described within the EIA and that any likely significant effects of the Offshore Development on climate and the vulnerability of the Offshore Development to climate change are described; and
- International frameworks that the United Kingdom (UK) is a signatory to, such as the UN Framework Convention on Climate Change, the Kyoto Protocol and the Paris Agreement. Further details are provided in Chapter 2: Planning Policy and Legislative Context.

20.2.2 Policy

- Scotland's National Marine Plan (MS, 2015): Sets out policies and objectives requiring marine planners and decision-makers to consider the potential impacts of a development on the marine environment and is useful to identify some of the key concerns and issues that should be addressed in any impact assessment. Policies relevant to this chapter include GEN 5 – '*Marine planners and decision makers must act in the way best calculated to mitigate, and adapt to, climate change.*' – and RENEWABLES 7 – '*Marine planners and decision makers should ensure infrastructure is fit for purpose now and in future. Consideration should be given to the potential for climate change impacts on coasts vulnerable to erosion.*'

20.2.3 Guidance

- Climate Change Resilience and Adaptation (IEMA, 2020): This guidance provides a framework to consider the vulnerability of the Offshore Development to climate change (i.e. climate change resilience) and the in-combination impacts of the Offshore Development and climate change; and
- Assessing Greenhouse Gas Emissions and Evaluating their Significance (IEMA, 2022): This guidance provides a framework for assessing greenhouse gas emissions in EIA.

20.3 Scoping and Consultation

Scoping and consultation have been ongoing throughout the EIA process and have played an important part in ensuring the scope of the baseline characterisation and impact assessment are appropriate with respect to the Offshore Development and the requirements of the regulators and their advisors.

Relevant comments from the EIA Scoping Opinion and Scoping Opinion Addendum specific to the Climate Change and Carbon Assessment and provided by Marine Scotland Licensing Operations Team (MS-LOT), Marine Scotland Science (MSS), Royal Society for the Protection of Birds (RSPB), The Highland Council (THC), and NatureScot are summarised in Table 20.2 below, which provides a high-level response on how these comments have been addressed within the Offshore EIAR.

Table 20.2 Summary of consultation responses specific to climate change and carbon

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
Scoping Opinion		
MS-LOT (on behalf of Scottish Ministers)	*The Scoping Report does not propose to include a standalone topic or chapter on climate. The Scottish Ministers recognise that in section 12.3 of the Scoping Report the Developer acknowledges that as well as the potential for a positive environmental impact with regard to carbon saving and avoidance of Greenhouse Gas ("GHG") emissions there will also be a carbon cost on account of the Proposed Development activities therefore, it is*	This climate and carbon chapter has been prepared to address this comment. Offshore EIAR (Volume 3): Technical Appendix 20.1: Carbon Assessment (summarised in Section 20.9) outlines the carbon emissions associated with the Offshore Development.

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	proposed that this will be considered within the Air Quality chapter in the EIA Report.	
	The Scottish Ministers highlight the IEMA Environmental Impact Assessment Guide "Assessing Greenhouse Gas Emissions And Evaluating Their Significance" ("IEMA GHG Guidance"), which states that "GHG emissions have a combined environmental effect that is approaching a scientifically defined environmental limit, as such, any GHG emissions or reductions from a project might be considered significant." The Scottish Ministers have considered this together with the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 and the requirement of the EIA Regulations to assess significant effects from the Proposed Development on climate.	A GHG assessment is provided in the Carbon Assessment, Offshore EIAR (Volume 3): Technical Appendix 20.1 (summarised in Section 20.9). This has been informed by the Institute of Environmental Management and Assessment (IEMA) GHG guidance.
	The Scottish Ministers therefore advise that the EIA Report must include a GHG Assessment which should be based on a Life Cycle Assessment ("LCA") approach and note that the IEMA GHG Guidance provides further insight on this matter. The Scottish Ministers highlight, however, that this should include the pre-construction, construction, operation and decommissioning phases, including consideration of the supply chain, as well as benefits beyond the life cycle of the Proposed Development. The extent to which the carbon cost of the wind farm (including supply chain) is offset through the production of green energy should also be addressed in the EIA Report, as per the representation received from NatureScot.	The Carbon Assessment provided in Offshore EIAR (Volume 3): Technical Appendix 20.1 (summarised in Section 20.9) has considered all phases of the Offshore Development, including manufacturing of materials and components through to decommissioning. This has been based on an LCA approach, as requested. The carbon payback, which represents the period of time before a product or Offshore Development has saved more carbon dioxide equivalent emissions than has been produced by its construction and operation, is provided in Section 20.9.
	The impact of climate change effects should be considered, both in future proofing the project design and how certain climate stressors may work in combination with potential effects from the proposed wind farm.	The impact of climate change effects on the Offshore Development is provided in Section 20.6. The in-combination climate impact assessment is provided in Section 20.7, which considers the impacts of the Offshore Development in-combination with the projected changes in the climate.
	With regard to climate change and ecosystem effects, the Scottish Ministers advise that the impacts of how certain climate stressors may work in combination with potential effects from the proposed wind farm is assessed in the EIA and recommend further discussion with MSS and NatureScot on how to assess this with respect to ornithology.	The in-combination climate impact assessment is provided in Section 20.7, which considers the impacts of the Offshore Development in-combination with the projected changes in the climate.
	The Scottish Ministers agree that carbon balance calculations should be undertaken and included in the EIA Report with a summary of the results provided focussing on the carbon	Carbon payback calculations are provided in Offshore EIAR (Volume 3): Technical Appendix 20.1 (summarised in Section 20.9).

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	payback period for the wind farm as suggested by the Highland Council.	
MSS	*Under their general comments (i.e. not in the Ornithology specific Appendix A), NS state a need to assess wider ecosystem-scale effects, including in relation to prey species for top predators (including seabirds). Furthermore NS state that consideration is given to how certain climate stressors may act in combination with project specific effects. These points are largely not developed in the ornithology specific section. Should these factors be considered in assessment, MSS suggests that further discussion will be required to inform on how these are assessed with respect to ornithology.*	The in-combination climate impact assessment is provided in Section 20.7, which considers the impacts of the Offshore Development in-combination with the projected changes in the climate.
RSPB	*The Environmental Impact Assessment should also consider the overall carbon payback period for the development, including any impacts on 'blue carbon' from habitats affected by the proposal.*	Carbon payback calculations are provided in Offshore EIAR (Volume 3): Technical Appendix 20.1 (summarised in Section 20.9). An assessment of the impact of the Offshore Development on blue carbon habitats is provided in Chapter 8: Benthic Ecology. The impact of the Offshore Development on the carbon sequestration potential of these habitats is provided in Section 20.3.
THC	*Carbon balance calculations should be undertaken and included within the EIAR with a summary of the results provided focussing on the carbon payback period for the wind farm.*	Carbon payback calculations are provided in Offshore EIAR (Volume 3): Technical Appendix 20.1 (summarised in Section 20.9).
NatureScot	*The impact of climate change effects should be considered, both in future proofing the project design and how certain climate stressors may work in combination with potential effects from the proposed wind farm. The EIAR should also consider the carbon cost of the wind farm (including supply chain) and to what extent this is offset through the production of green energy.*	The impact of climate change effects on the Offshore Development is provided in Section 20.6. The in-combination climate impact assessment is provided in Section 20.7, which considers the impacts of the Offshore Development in-combination with the projected changes in the climate. The carbon assessment, which considers the carbon cost of the Offshore Development, is provided in Section 20.9. Carbon payback calculations are also provided in Offshore EIAR (Volume 3): Technical Appendix 20.1 (summarised in Section 20.9).
Scoping Opinion Addendum		
MS-LOT (on behalf of Scottish Ministers)	*The Scottish Ministers are mindful that Greenhouse Gas ("GHG") emissions from all projects contribute to climate change and advice was provided in the 2021 Scoping Opinion in this regard. The Scottish Ministers advise that the previous advice remains extant however wish to highlight that the IEMA Environmental Impact Assessment Guide "Assessing Greenhouse Gas Emissions And*	Noted, this chapter has used the updated IEMA guidance.

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	Evaluating Their Significance" has been updated in 2022 and the assessment in the EIA Report should be based on the latest guidance.	
	The Developer has indicated in the Scoping Report that major accidents and disasters are to be considered in relation to the onshore development. The Scottish Ministers wish to highlight that this must also be considered in relation to the Proposed Offshore Development. *The Developer should make use of appropriate guidance, including the recent Institute of Environmental Management and Assessment ("IEMA") 'Major Accidents and Disasters in EIA: A Primer', to better understand the likelihood of an occurrence and the Proposed Development susceptibility to potential major accidents and hazards.* *The description and assessment should consider the vulnerability of the Proposed Development to a potential accident or disaster and also the Proposed Development potential to cause an accident or disaster.* *The Scottish Ministers advise that existing sources of risk assessment or other relevant studies should be used to establish the baseline rather than collecting survey data and note the IEMA Primer provides further advice on this. This should include the review of the identified hazards from your baseline assessment, the level of risk attributed to the identified hazards and the relevant receptors to be considered.* *The assessment must detail how significance has been defined and detail the inclusions and exclusions within the assessment. Any mitigation measures that will be employed to prevent, reduce or control significant effects should be included in the EIA Report.*	An assessment of the potential vulnerability of the Offshore Development to potential accidents, disasters or risks associated with climate change is provided in Section 20.6. Further details on the assessment of major accidents and disasters are provided in Chapter 21: Major Accidents and Disasters.
Cumulative Projects List		
THC	*Having reviewed the submitted document, I would suggest the following projects are also included in the cumulative assessment:* > *Space Hub Sutherland (in all chapters of the EIAR not just the SLVIA section).*	The assessment of cumulative effects for the receptors considered in the in-combination climate impact assessment is described in Chapters 7 to 19. No cumulative effects are anticipated from Space Hub Sutherland on Blue Carbon habitats and species, as this project is not associated with any marine or coastal infrastructure.

20.4 Future Baseline Characterisation

This section summarises the current evidence and future predictions for marine and coastal climate change, based on outputs from the Marine Climate Change Impacts Partnership (MCCIP), UK Climate Projections 2018 (UKCP18) and other publicly available data sources. This section, which focuses on changes over the 30-year operational period of the Offshore Development, differs from other EIA topics within this Offshore EIAR which describe the existing environment in the present.

The future marine environmental baseline is used to inform the climate change resilience review in Section 20.6 and the ICCI assessment in Section 20.7.

20.4.1 Study Area

The following areas are referred to across the assessment, as displayed in Figure 20.1:

> Offshore Site: The area encompassing the PFOWF Array Area and Offshore Export Cable Corridor (OECC), as defined;

> OECC: The area within which the Offshore Export Cable(s) will be located; and

> Offshore Development: All offshore components of the Project (Wind Turbine Generators [WTGs], inter-array and export cables, floating substructures, and all other associated offshore infrastructure) required during operation of the Project, for which Highland Wind Limited (HWL) are seeking consent. The Offshore Development is the focus of this Offshore EIAR.

The study area varies across the different assessments provided within this chapter, as set out below. Figure 20.1 presents the study areas identified for the climate change and carbon assessment:

> Climate Change Resilience Review: The Offshore Site;

> ICCI Assessment: The study areas for each EIA topic are defined as per Chapters 7 to 21 of this Offshore EIAR[i];

> Blue Carbon Assessment: The Offshore Site; and

> Carbon Assessment: The Offshore Site.

[i] Please note that the study areas presented in the Offshore EIAR Chapters 7 to 21 have not been displayed on Figure 20.1.

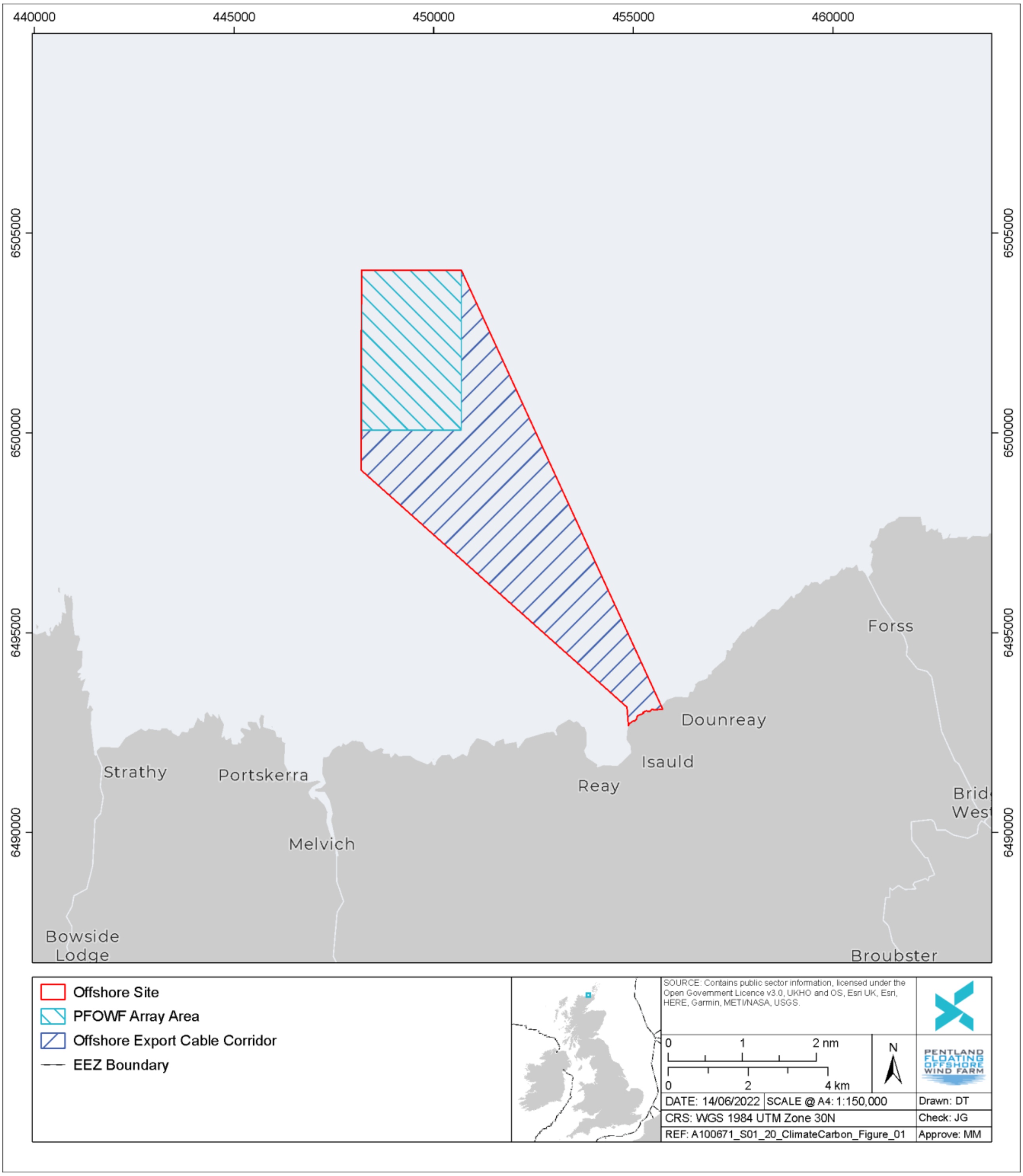

Figure 20.1 Study area for the climate change and carbon assessment

20.4.2 Sources of Information

A review was undertaken of the literature and data relevant to this assessment, relating to climate change and carbon and this was used to provide an overview of the future environment. The primary data sources used in the preparation of this chapter are listed below in Table 20.3. The UKCP18 climate projections are recommended for use in the IEMA environmental impact assessment guide to climate change resilience and adaptation (IEMA, 2020). This has been supplemented by the reports prepared and published under MCCIP, which provide a comprehensive overview of evidence and predictions for changes in the marine climate in the UK.

Table 20.3 Summary of key sources of information pertaining to climate and carbon

Title	Source	Year	Author
Reports prepared and published by MCCIP	https://www.mccip.org.uk/	2020	Various
UKCP18	https://www.metoffice.gov.uk/research/approach/collaboration/ukcp	2019	Met Office

The two key sources on climate projections include the MCCIP and UKCP18. The MCCIP publishes evidence reviews and summaries on marine climate change, focused on the UK, including regions such as the North Sea, the Celtic Sea, the Irish Sea, the English Channel and the North Atlantic (MCCIP, 2022). The UKCP18 is a climate analysis tool that forms part of the Met Office Hadley Centre Climate Programme. A summary of these two data sources is provided below:

> The MCCIP reports summarise the current evidence for climate change, based on observed and modelled trends in climate data and the physical, biological, and socio-economic environment. In addition, they also provide predictions for the physical, biological, and socio-economic environment, based on modelled climate projections. The emissions scenarios used for climate projections differ between the different modelling studies reviewed within the MCCIP report. The climate projections for the Offshore Development are based on different emissions scenarios or modelled predictions for the physical environment as applicable. Details are provided within each topic section within the future baseline description, in Section 20.4.4. Generally, the MCCIP predictions are provided for 2100; and

> The UKCP18 projections were downloaded from the Met Office website. The projections are based on the latest findings in climate science and, as per IEMA guidance, predictions associated with the highest emissions scenario (Representative Concentration Pathway [RCP] 8.5) are utilised in this assessment. RCP 8.5 assumes a change in global surface temperature of 4.3°C from 2081 to 2100 when compared to the pre-industrial period (1850 to 1900) (Met Office, 2018a). RCP 8.5 represents a scenario of high energy demand where there is slow income growth, some technological change, and increased energy intensity where greenhouse gas (GHG) emissions remain unmitigated (Riahi *et al.,* 2011). UK Climate Projections are most applicable to onshore and coastal areas (mean sea level and storm surge trends) (Met Office, 2021).

20.4.3 Site-specific Surveys

No site-specific surveys have been undertaken to inform the climate change and carbon assessment. The site-specific surveys used to delineate the existing environment for specific EIA topics are described in Chapters 7 to 21 of this Offshore EIAR.

20.4.4 Future Baseline Description

This section describes historic climate trends, future climate projections, and the potential indirect impact of climate change on biological and socio-economic receptors. The future climate projections described are based on modelled data and the timescales considered for the different receptors are dependent on the availability of the modelled data. Where available, changes over the 30-year operation and maintenance phase of the Offshore Development, are described. However, predictions to 2100 and beyond are considered for some climate variables, where the data is only available over this timeline.

20.4.4.1 Physical environment

20.4.4.1.1 Air temperature

Overall, an increase in air temperature is expected in the UK over the next century. However, natural variation will remain, meaning that short-term periods of cooler temperatures are expected within the overall increasing trend (Met Office, 2019a). In the UK, the annual temperature by 2070 is expected to increase by up to 0.7°C to 4.2°C in winter and 0.9°C to 5.4°C in summer, when compared to the 1981 to 2000 mean, under RCP 8.5 (Lowe *et al.,* 2018). Temperature increases in the north of Scotland, in the region where the Offshore Development is located, are expected to be comparatively lower than in some other areas of the UK, such as in the south of England (Met Office, 2019a).

The UKCP18 projections also indicate that hotter summers are likely to be more common, with the frequency of daytime temperature exceeding 30°C for two or more consecutive days increasing. Although this trend of temperature exceeding 30°C for two or more consecutive days is mainly confined to the southeast of the UK (Met Office, 2021), an increased frequency of hot summers is also expected to occur at the Offshore Development, albeit to a lesser extent.

20.4.4.1.2 Precipitation

Between 2008 and 2017, Scotland has been 4% wetter than between 1981 to 2010 mean (Lowe *et al*., 2018). Precipitation levels are expected to continue to increase in winter but decrease in summer. Under RCP 8.5, by 2070, it is predicted that the change in winter precipitation levels will range from a 1% decrease to a 35% increase and summer precipitation levels will range from a 47% decrease to a 2% increase, when compared to the 1981 to 2000 mean. The overall trend of reduced precipitation levels in summer is expected to be lower in the north of Scotland compared with the south of the UK (Met Office, 2019b).

The UKCP18 projections also indicate that the intensity and frequency of heavy rainfall events in summer and autumn are likely to increase (Met Office, 2021).

20.4.4.1.3 Wind, storms, and waves

Analysis of observed and modelled wind and wave data can be used to identify long-term trends in weather patterns. The frequency and intensity of storms within the north of the Atlantic Ocean are increasing, with a much weaker trend observed in the United Kingdom Continental Shelf (UKCS). However, there is low confidence in attributing these historical changes in weather patterns to climate change and the high degree of variability in the data also creates difficulties in identifying historic trends over time. Time-series data on mean significant wave height generally also shows an increase in wave heights in the northeast of the Atlantic Ocean, mainly attributed to Atlantic swell rather than increased wind speeds (Wolf *et al*., 2020).

Future predictions for storms and waves are uncertain, and it is expected that natural variability will continue to contribute to the trends observed in the frequency and intensity of waves and storms. In addition, the low confidence in attributing historic trends in storms and waves to climate change also presents difficulties in adequately predicting future trends. Nevertheless, climate change may influence storm tracks with knock-on effects on winds and wave heights. Climate projections, under the RCP 8.5 (high emissions scenario), indicate that there may be a reduced frequency of storms and a change in storm tracks, although there is considerable uncertainty in this prediction. The UKCP18 model outputs indicate that wind speeds are likely to increase between 2050 and 2100 across the UK, with an increase in the frequency of winter storms (Met Office, 2019c).

It is also projected that there is likely to be an overall reduction in mean significant wave height, and there is also likely to be an increase in the mean annual maximum wave height by 0.5 metres (m) (i.e. the height of extreme waves is increasing) and that wave height to the north of the UK are likely to increase as a result of a retreating Arctic Sea ice (Wolf *et al.,* 2020). Projections from UKCP18 also predict a general lowering of wave heights in the 21st Century. A change in extreme / severe wave heights is also predicted under the UKCP18 climate projections, but there was no agreement between models on whether there would be an increase or decrease in wave height (Palmer *et al*., 2018).

Overall, there is considered to be low confidence in the future predictions for wind, storms, and waves (Wolf *et al.,* 2020).

20.4.4.1.4 Sea surface and near-bottom temperatures

Tinker and Howes (2020) analysed the warming of sea-surface temperatures over approximately 30 years (1988 to 2017) (Figure 20.2). The analysis indicates that observed increases in sea-surface temperatures were strongest in the waters to the North of Scotland (north of Caithness and Sutherland) and in the North Sea, where temperatures have increased by up to 0.24°C per decade (Tinker and Howes, 2020).

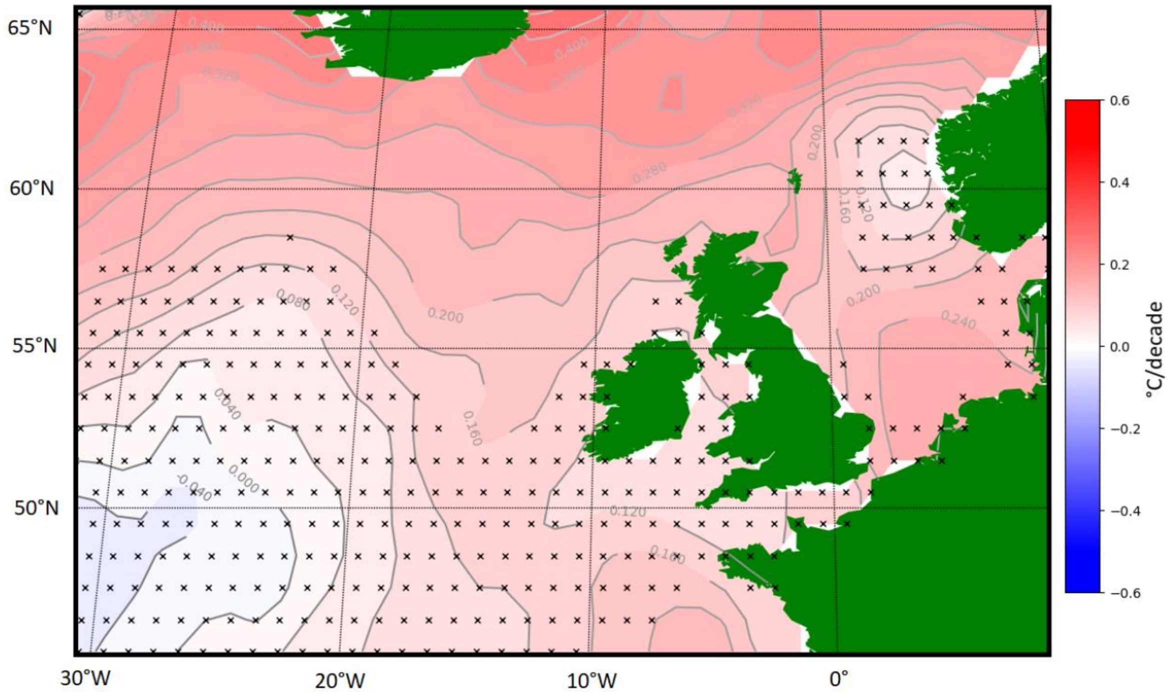

Figure 20.2 Trend in average sea-surface temperature (°C per decade) (1988 to 2017). Crosses indicate an insignificant increase in sea-surface temperature (Taken from Tinker and Howes, 2020)

It is predicted that increases in sea-surface temperatures by 2100 in the North Sea may range from 1°C to 4°C (depending on the area and the climate model used). Tinker *et al.,* (2016) simulated increases in sea-surface and near-bottom temperature under 11 different Atmosphere-Ocean General Circulation Models, which represent the physical processes which drive climate change, focussing on the changes in temperature between 1960 to 1989 and 2069 to 2098 periods under a medium emissions scenario (Special Report Emissions [SRE] A1B[ii]). The purpose of this was to account for the uncertainty in model projections by reporting the mean value across the different models, along with the standard deviation across the projected simulations.

The Offshore Development is located within the 'Shetland Shelf' area defined within Tinker *et al*., (2016). Specific temperature increases for this region are not provided by Tinker *et al*., (2016), and therefore, the predicted increase in sea-surface and near-bottom temperatures for the Northern North Sea region, located east of the Offshore Site, and the Shelf Region, which includes the Southern, Central and Northern North Sea, the English Channel, the Shetland and Irish Shelf areas, and Celtic Seas, has been provided in Table 20.4. This increase represents the predicted difference between 1960 to 1989 and 2069 to 2098. The confidence in these predictions is high (Tinker and Howes, 2020).

[ii] Details on the SRES A1B scenario are available here: https://www.ipcc.ch/site/assets/uploads/2018/03/emissions_scenarios-1.pdf. These have now been superseded by RCP emissions scenarios. SRES A1B is an 'on balance' emissions scenario in a world of rapid economic and population growth, where no one energy source is relied on too heavily.

Table 20.4 Predicted increases in sea surface and near-bottom temperatures (comparing the 1960 to 1989 and 2069 to 2098 period) (Tinker *et al.*, 2016)

Region	Sea Surface Temperature	Near-Bottom Temperature
Northern North Sea	+ 2.75°C (±0.75°C)	+ 2.53°C (±0.63°C)
Shelf Regions	+ 2.90°C (±0.82°C)	+ 2.71°C (±0.75°C)

20.4.4.1.5 Stratification, Dissolved Oxygen, and Salinity

There is some evidence that the timing of thermal stratification has changed over time, with a trend for earlier stratification (i.e. stratification beginning earlier in the year) across the North Sea. At present, there is no indication that this trend will be sustained, or that this trend is beyond what would be expected from natural variability (Sharples *et al.,* 2020). However, when considering modelled climate projections, based on the Special Report on Emission Scenarios (SRES) A1B emissions scenario, it is predicted that stratification across UKCS is likely to occur one week earlier by the end of 2100 and that the breakdown of seasonal stratification is likely to occur 5 to 10 days later than present, mainly attributed to increases in air temperature. Additionally, when the RCP 8.5 emissions scenario is considered, it is predicted that the UKCS is likely to become more strongly stratified, as a result of changes in seasonal heating cycles, and this could reduce the upward mixing of nutrients and therefore lead to reduced primary production (Sharples *et al*., 2020).

Within the North Sea, declines in dissolved oxygen levels have been documented in late summer, although no hypoxic conditions have been observed. Ocean warming is expected to account for one-third of the decrease in dissolved oxygen levels (due to reduced solubility of oxygen), with the remaining declines being attributed to increased biological oxygen consumption. Dissolved oxygen concentrations are expected to continue to decline through to the end of the century in the North Sea, by up to 11.5% when the period 2090 to 2100 is compared with the period 2000 to 2010 under the SRES A1B emissions scenario (Mahaffey *et al*., 2020).

Salinity has also shown a general decrease in the west of the UKCS in the last five years, although this trend is weaker in other regions of the UKCS, such as the North Sea, where there is no clear long-term trend (Dye *et al*., 2020). When the SRES A1B emissions scenario is considered, it is predicted that waters will be less saline in the North Sea by 2100, due to ocean circulation changes driven by climate change (Dye *et al*., 2020). This trend is weaker in waters to the southwest of the UKCS in the Celtic Sea, Irish Sea, and the English Channel. The predicted increase in sea surface and near-bottom salinity is provided in Table 20.5.

Table 20.5 Predicted increases in sea surface and near-bottom salinity (comparing 1960 to 1989 with 2069 to 2098 (Tinker *et al.,* 2016)

Region	Surface Salinity (change in Practical Salinity Unit [psu])	Near Bottom Salinity (change in psu)
Northern North Sea	-0.41 (±0.47)	-0.33 (±0.38)
Shelf Regions	-0.62 (±0.65)	-0.52 (±0.52)

The confidence in these predictions is medium for dissolved oxygen and salinity and low for stratification (Sharples *et al*., 2020; Mahaffey *et al.,* 2020; Dye *et al.,* 2020).

20.4.4.1.6 Ocean Acidification

Ocean acidification is also an impact of climate change which alters the physical properties of the ocean with associated impacts on marine biota. Ocean acidification occurs as increases in anthropogenic carbon dioxide (CO_2) absorbed by the ocean causes a decline in pH.

One-quarter of atmospheric CO_2 is absorbed by the ocean. When CO_2 is absorbed by the ocean, hydrogen ions are released (which therefore reduces pH) and are available to bond to carbonate ions, which consequently reduces the concentration of carbonate ions available for calcifying organisms. This also reduces the potential for the ocean to absorb and store atmospheric CO_2 in the future.

Atmospheric CO_2 now exceeds 400 parts per million (an increase of 2.3 parts per million per year between 2010 and 2020). Evidence of ocean acidification has been documented in the Atlantic Ocean which has sustained a decrease in pH at a rate of 0.0013 per year between 1995 and 2013. Measurements at Stonehaven, on the east coast of Scotland, between 2009 and 2013, showed that the pH declined by 0.1 in this period, with the reduction being most evident in summer between March and August (Humphreys *et al*., 2020).

Under a high-emissions scenario (RCP 8.5), pH in the UKCS could decrease at a rate of 0.0036 per year (pH in 2100 of 0.366). This decrease in pH is expected to vary by location, with the greatest decline occurring in coastal areas such as Bristol Channel, Moray Firth, Celtic Sea, and the Inner Hebrides (Humphreys *et al.,* 2020).

The confidence in the predictions for ocean acidification is medium (Humphreys *et al.,* 2020).

20.4.4.1.7 Sea level rise and coastal erosion

Sea-level rise and coastal erosion are also potential impacts of climate change. Sea level rise occurs as sea ice continues to decline and as seawater expands as it warms. The average rate of globally averaged sea level rise was recorded as 3.2 millimetres (mm) per year between 1993 and 2010 and a long-term increase in the rate of sea-level rise in the 20th century is well-documented (Horsburgh *et al*., 2020).

The rate of sea-level rise varies by location, based on regional and local conditions. At present, climate change is expected to contribute to a 1 to 2 mm increase in the sea level rise per year in the UK, and when vertical land movement is considered, this rate increases for the South of England by an additional 1 mm per year and decreases in some parts of Scotland. Sea level rise is expected to continue through to and beyond 2100. The predicted sea-level rise under the high-emissions scenario (RCP 8.5) in 2060 in London and Edinburgh is provided in Table 20.6. Sea level rise in England is expected to continue to exceed Scotland, and overall, the rise in sea level in the UK is expected to be slightly lower than the global average (Horsburgh *et al*., 2020).

Table 20.6 Projected increase (5th to 95th percentile) of sea-level rise in 2100 under the high-emissions scenario (R8.5) (Horsburgh *et al.,* 2020)

Location	Sea Level Rise (m) Under the RCP 8.5 Scenario by 2060 (Relative to Baseline Period of 1981 – 2000)
London	+ 0.26 – 0.52
Edinburgh	+ 0.13 – 0.38

Figure 20.3 shows the sea level projections over the operational phase of the Offshore Development, relative to a baseline period of 1981-2000. A mean sea level rise of 0.1 m is projected by the commencement of operations in 2026 and 0.27 m by cessation of operations in 2056. The range associated with the projection is shown in light blue (i.e. models[iii] project that there is a 95% likelihood that a mean sea level rise of more than 0.07 m will occur by 2026 and a 5% likelihood that a sea level rise of more than 0.27 m will occur by 2026), similarly, models project that there is 95% likelihood that a sea level rise of more than 0.18 m will occur by 2056 and 5% likelihood that a sea level rise of more than 0.40 m will occur by 2056[iv]. The projections are output at a 12-kilometre (km) resolution around the UK coast; the data shown in Figure 20.3 corresponds to the 12-km grid in which the Offshore Development is located.

[iii] The UKCP18 sea level projections are rooted in the climate model simulations of the Coupled Model Intercomparison Project Phase 5 (CMIP5) which formed the basis of the climate projections presented in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (UKCP, 2018b).
[iv] Note, as per UKCP18, there may be a greater than 10% chance that the real-world response lies outside these ranges and this likelihood cannot be accurately quantified.

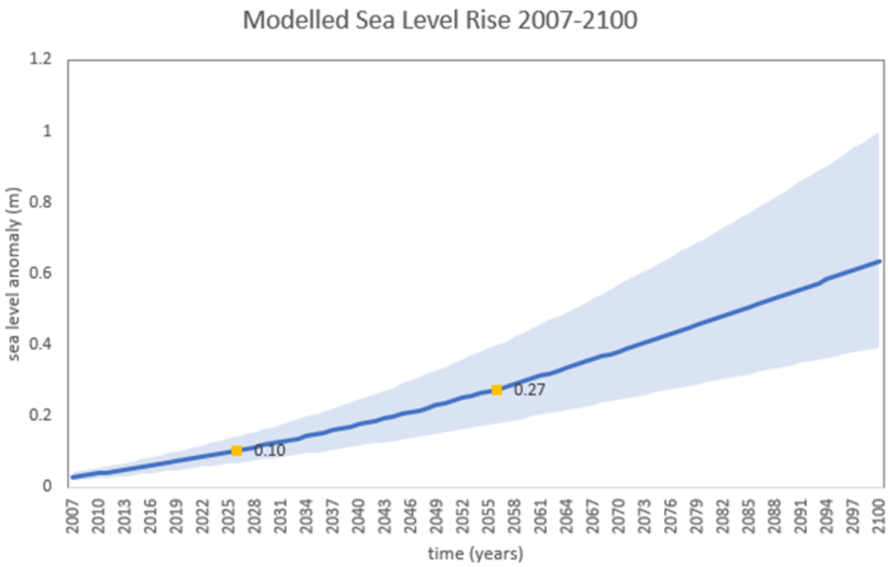

Figure 20.3 Mean sea level projections for the Offshore Site, relative to a baseline period of 1981 to 2000 (RCP8.5). The shaded region represents the projection range

Sea-level rise is expected to contribute to coastal erosion, and it is assessed that 17% of the UK coastline is currently experiencing erosion. In Scotland, the coastlines are generally less susceptible to erosion, as a greater proportion of the coastline is considered 'hard or mixed', and only 12% of the soft / erodible coastline has eroded landwards since the 1970s. In addition to sea-level rise, coastal erosion results from many factors, including reduced sediment supply, storms and anthropogenic disturbance (Masselink *et al*., 2020).

According to the results of the Dynamic Coast project, which provides an evidence base for the extent of coastal erosion in Scotland, 24% of the area between Duncansby Head and Cape Wrath has experienced accretion and 22% has experienced erosion between the 1970s and 2017 (Fitton *et al*., 2017).

It is predicted that coastal erosion will continue to increase due to the predicted increases in sea-level rise (Horsburgh *et al*., 2020).

The confidence in the predictions is medium-high for sea level rise and medium for coastal erosion (Horsburgh *et al.,* 2020; Masselink *et al.,* 2020).

20.4.4.2 Biological environment

The biological environment may be affected by changes in the physical environment. Indirect impacts of climate change may also arise through changes in habitats and predator-prey relationships.

Coastal, intertidal, and subtidal habitats may be directly affected by changes in the physical environment. Recent surveys indicate that dune slacks[v] are 'drying out' in England, with 30% of this habitat being lost between 1990 and 2012 (Burden *et al.,* 2020). Furthermore, changes in species composition have also been documented and may be linked to the thermal affinities of species (e.g. cold or warm-water species). For instance, declines in cold-water species, such as large brown algae, have occurred in the south of the UK, whereas warm-water kelp species (*Laminaria ochroleuca*) have increased in abundance (Mieskowsa *et al.,* 2020; Moore *et al*., 2020). A shift in the distribution of mobile species has also been observed in recent years, potentially linked to changes in temperature. The cold-water zooplankton species, *Calanus finmarchicus*, has declined by over 70% in the North Sea since the 1960s, whereas the distribution of warm-water species, such as *Calanus helgolandicus*, is shifting northwards (Edwards *et al.,* 2020). Similarly, increases in warm-water fish species (e.g. bluefin tuna [*Thunnus thynnus*]) have been documented, as well as shifts in the timing of fish spawning, hatching and migration.

[v] Low-lying areas within dune systems that are seasonally flooded and where nutrient levels are low.

Physiological impacts as a result of increased temperatures and reduced oxygen levels may also reduce fish growth as a result of increased metabolic costs (Wright *et al*., 2020). The impacts on plankton and fish may indirectly affect predator species, such as seabirds and marine mammals (Mitchell *et al*., 2020). Additionally, a shift in marine mammal distributions has also been observed with northward shifts of warm-water species such as the short-beaked common dolphin (*Delphinus delphis*) (Evans *et al*., 2020).

It has not been possible to undertake a further evaluation of potential climate-related biological effects, due to uncertainty in how the physical environment will respond to climate change and the associated complexity of identifying the impacts of climate change amongst other factors that can influence the physical environment and related biological receptors (Küpper and Kamenos, 2017).

20.4.4.3 Socio-economic environment

Impacts on the physical and biological environment may also affect human activities in the marine environment. For instance, any impacts on fish stocks will affect commercial fishing activity, potentially reducing the abundance of species or altering species composition. However, attributing these changes solely to climate change is difficult as other factors also influence fish stocks (Pinnegar *et al*., 2020). Climate change may also have effects on tourism and recreation, either positively or negatively. Positive effects may arise due to warmer weather conditions, thereby extending tourism seasons, whereas negative effects may result from flooding and coastal erosion (Coles, 2020).

It has not been possible to undertake a further evaluation of potential climate-related socio-economic effects, due to uncertainty in how the physical / biological environment will respond to climate change and the associated complexity of identifying the impacts of climate change amongst other factors that influence the physical / biological environment and related socio-economic receptors (Küpper and Kamenos, 2017).

20.4.5 Summary of Future Baseline Environment

A summary of the climate projections anticipated at the Offshore Site is provided in Section 20.4.4 and Table 20.7.

Table 20.7 Summary of climate projections

Climate Variable	Predicted Change
Extreme weather events	> Increased frequency in winter storms between 2050 and 2100 (Met Office, 2019c); > Increase in the frequency of heavy rainfall events when 2080 to 2099 is compared to the 1981 to 2000 mean (Met Office, 2019b); > Reduced mean significant wave height (comparing 2070 to 2099 with 1970 to 1999) (Wolf *et al*., 2020); and > Increased mean annual maximum wave height by 0.5 m (comparing 2070 to 2099 with 1970 to 1999) (Wolf *et al*., 2020).
Changing sea conditions (i.e. long-term shift in average climate conditions)	> Predicted rise in sea surface temperature of 2.75°C to 2.9°C and rise in near-bottom temperature by 2.53°C to 2.71°C (comparing 1960 to 1989 with 2069 to 2098) (Tinker *et al.,* 2016); > Predicted onset of stratification one week earlier by 2100 and breakdown of seasonal stratification predicted to occur 5 to 10 days later (Sharples *et al*., 2020); > Dissolved oxygen will decline by 11.5% when the period of 2090 to 2100 is compared with the 2000 to 2010 period (Mahaffey *et al*., 2020); > Predicted that waters will be less saline in the North Sea by 2100, with a reduction in the surface salinity psu by 0.4 to 0.62 and the near bottom salinity psu by 0.33 to 0.52 (Tinker *et al*., 2016); and > Predicted decrease in pH in the UKCS by a rate of 0.0036 per year (pH in 2100 of 0.366) (Humphreys *et al*., 2020).

Climate Variable	Predicted Change
Sea level rise and coastal erosion	> Increased sea level by 0.27 m by 2056.

20.4.6 Data Gaps and Uncertainties

The key uncertainties / difficulties associated with assessing the impact of climate change on the physical, biological and socio-economic environment include:

- Uncertainty in the modelled predictions: Based on the uncertainty around the assumptions for the future emissions scenario, uncertainty in other model inputs (e.g. current conditions etc.) and uncertainty in political and societal responses to climate change;
- Uncertainty around the response of the physical, biological and socio-economic environment to changes in climate variables;
- A paucity of high-resolution predictions for the future marine environment along timelines that are directly relevant to the Offshore Development; and
- Difficulties in attributing changes in the physical, biological and socio-economic environment to climate change.

20.5 Overview of Impacts Requiring Assessment

The various impacts that are assessed in each of the related climate assessments presented in this chapter are presented in Table 20.8 below. The impacts not assessed and further comments on the scope of the assessment are also provided.

Table 20.8 Impacts assessed for the climate assessments

Assessment	Impacts Assessed	Impact Assessment Section ID
Climate Resilience Review	> Direct impacts of climate change during the operation and maintenance phase of the Offshore Development: o Impacts of extreme weather events (e.g. storm surges and waves) on the Offshore Development; o Impacts from changes in weather patterns or sea conditions on the Offshore Development; and o Impacts from sea level rise and coastal erosion on the Offshore Development. These impacts are detailed further in Section 20.6.2.1.	Section 20.6.3 Table 20.14
In-combination Climate Impact Assessment	> The inter-related impacts of climate change and the Offshore Development on relevant receptors identified in this Offshore EIAR are considered during the operation and maintenance phase of the Offshore Development. The overarching impacts assessed include: o Inter-related impacts of extreme weather events (e.g. storm surges and waves) and the Offshore Development on relevant receptors assessed in this Offshore EIAR; o Inter-related impacts from changes in weather patterns or sea conditions and the Offshore Development on relevant receptors assessed in this Offshore EIAR; and	Section 20.7.3

Assessment	Impacts Assessed	Impact Assessment Section ID
	○ Inter-related impacts from sea level rise and coastal erosion and the Offshore Development on relevant receptors are assessed in this Offshore EIAR. The receptors assessed in relation to these impacts are detailed in Section 20.7.2.1. Details of impacts assessed are presented in Table 20.19.	
Blue Carbon Assessment	The following impacts are assessed for effects on blue carbon habitats within the Offshore Site: > Direct blue carbon habitat loss / disturbance from the placement of the Offshore Development subsea infrastructure during the lifecycle of the Offshore Development; and > Cumulative effects from the Offshore Development and other projects resulting in blue carbon habitat loss / disturbance from the placement of subsea infrastructure.	Section 20.8.5
Carbon Assessment	The impact of the Offshore Development on the global climate receptor is assessed, utilising: > Calculated carbon life cycle emissions resulting from the Offshore Development; and > The UK Carbon Budgets as a proxy for the global climate.	Section 20.9

20.6 Climate Resilience Review

20.6.1 Introduction

This section reviews the ability of the Offshore Development to withstand, respond to and recover from the projected changes in climate, as they are described in Section 20.4.4.

20.6.2 Assessment Methodology

This review has been conducted in accordance with the IEMA (2020) Environmental Impact Assessment Guide to Climate Change Resilience and Adaptation, specifically Step 0: "Building Climate Resilience into the Project" and Appendix 1: "Climate Change Risk Assessment".

20.6.2.1 Climate change impact identification

A climate change impact refers to the effect (i.e. damage or interference) of a projected change in a climate variable (e.g. temperature, precipitation) on the Offshore Development infrastructure, facilities or activities. The climate variables, as described in Section 20.4.4.1, with the potential to affect the Offshore Development include:

> Extreme weather events (e.g. storm surges and waves);

> Changes in weather patterns or sea conditions; and

> Sea level rise and coastal erosion.

Construction is expected to commence in 2024 with the commencement of horizontal directional drilling (HDD) activities; therefore, the climate variables during construction are expected to be consistent with current conditions. The starting position for offshore components is complete removal to shore for re-use, recycling, and disposal during decommissioning unless there is compelling evidence to leave the buried sections in situ. An exception to this is scour protection, which may not be practical to recover. Anchor piles may also be cut to a depth of 1 m below the seabed and left *in situ*. As more detailed information on the decommissioning of the Offshore Development infrastructure is limited at this time, a meaningful assessment of the resilience of the Offshore Development to climate change during the decommissioning phase is not possible. For these reasons, this review focuses on potential impacts posed by climate change on the Offshore Development during the operation and maintenance phase, including both the Offshore Development infrastructure and on operation and maintenance activities.

The potential impacts on the Offshore Development during the operation and maintenance phase associated with the projected changes for the climate variables listed above are listed in Table 20.9.

Table 20.9 Potential impacts of changing climate variables on the Offshore Development

Climate Variable		Potential Impact on the Offshore Development Design or Infrastructure
Extreme weather events	Increased frequency of heavy rainfall events	None identified.
	Increased frequency of high wind events.	> Potential damage, loss or reduced structural integrity of the Offshore Development infrastructure / facilities as a result of high wind events.
		> Potential increased downtime due to the cut-out speed exceedance.
		> Disruption (e.g. reduced accessibility) or increased safety risk to operation and maintenance procedures or equipment / vessels as a result of high wind events.
	Increased mean maximum wave heights.	> Potential damage, loss or reduced structural integrity of the Offshore Development infrastructure / facilities as a result of high waves.
		> Disruption (e.g. reduced accessibility) or increased safety risk to operation and maintenance procedures or equipment / vessels as a result of high waves.
	Increased frequency of heatwaves	None identified.
Changing weather patterns / sea conditions	Increased air and sea temperature.	> Potential damage, loss or reduced structural integrity of the Offshore Development infrastructure as a result of increased temperatures (e.g. thermal expansion).
		> Increased potential for biofouling of mooring lines and substructures as a result of increased temperatures.
		> Disruption or increased safety risk to operation and maintenance procedures or equipment as a result of and increased air temperatures (e.g. heat stress for staff).
	Decreased summer rainfall.	None identified.
	Increased winter rainfall.	None identified.
	Reduced mean wave height.	None identified / within current conditions. There is the potential that this could increase accessibility to the Offshore Development and reduce weather downtime.

Climate Variable		Potential Impact on the Offshore Development Design or Infrastructure
Sea level rise and coastal erosion	Sea level rise and coastal erosion.	> Potential damage, loss or reduced structural integrity of the Offshore Export Cable(s) and HDD infrastructure / facilities from coastal erosion (e.g. exposure of cables) or changing currents / wave patterns.

20.6.2.2 Embedded mitigation and management plans

As part of the Offshore Development design process, a number of designed-in measures and management plans have been proposed. The embedded mitigation measures that increase the resilience of the Offshore Development to climate change are shown in Table 20.10. As there is a commitment to implementing these measures which will likely be secured through Section 36 consent and Marine Licence conditions, they are considered inherently part of the design of the Offshore Development and have therefore been considered in the assessment presented below (i.e. the determination of the magnitude of impact and therefore the significance of effects assumes implementation of these measures). These measures are considered standard industry practise for this type of development.

Table 20.10 Embedded mitigation measures specific to climate resilience

Embedded Mitigation Measures	Justification
Embedded Mitigation	
Target Depth of Lowering	Static cables will be trenched and buried to a target depth of 0.6 m. Where this cannot be achieved, remedial cable protection will be applied. The cable burial target depth will be informed by a Cable Burial Risk Assessment (CBRA) and implemented through the Cable Plan (CaP) produced post-consent.
Removal of marine growth	The substructures will be designed to accommodate marine growth; however, to manage weight / drag induced fatigue, growth levels will be inspected regularly, and subsequent removal of this growth will be undertaken using water jetting tools if substantial accumulation is in evidence.

20.6.2.3 Defining the climate change risk

The risk posed by climate change on the Offshore Development is determined by defining the likelihood and magnitude of the potential climate change impact. Existing or embedded mitigations identified within the EIA are accounted for when determining impact likelihood and magnitude.

The definitions for likelihood and magnitude are provided in Table 20.11 and Table 20.12, respectively. It should be noted that likelihood refers to the impact occurring under the worst case assumption that the projected change does occur (i.e. that the confidence level for the projected change is high).

Table 20.11 Definitions for likelihood

Likelihood	Definition
Certain (>95%)	The event / impact will occur during the life-cycle of the Offshore Development (i.e. it is inevitable), potentially many times during the operation and maintenance phase.
Likely (66-95%)	The event / impact is likely to occur at some point during the life-cycle of the Offshore Development.
Possible (33-65%)	The event / impact is possible during the life-cycle of the Offshore Development.
Unlikely (10-32%)	The event / impact is unlikely to occur during the life-cycle of the Offshore Development.
Extremely Unlikely (0-9%)	The event / impact is extremely improbable during the life-cycle of the Offshore Development.

Table 20.12 Definitions for magnitude

Magnitude	Definition
High	> Permanent damage, loss or reduction in the structural integrity of the Offshore Development infrastructure and facilities; > Serious health and safety risk; and > Irreversible and irrecoverable financial or environmental impact.
Moderate	> Major damage, loss or reduction in the structural integrity of the Offshore Development infrastructure and facilities; > Major health and safety risk; and > Major financial or environmental impact.
Low	> Moderate damage, loss or reduction in the structural integrity of the Offshore Development infrastructure and facilities; > Moderate health and safety risk; and > Moderate financial or environmental impact.
Negligible	> Minimal damage, loss or reduction in the structural integrity of the Offshore Development infrastructure; > Low health and safety risk; and > Minimal financial or environmental impact.
No Change	> No damage or loss of the Offshore Development infrastructure; > No health and safety risks; and > No financial or environmental impact.

Having determined the likelihood and magnitude of the climate change impact, the risk level is determined, as either negligible, minor, moderate, or major, as shown in Table 20.13.

Table 20.13 Significance matrix

		Likelihood				
		Extremely unlikely	Unlikely	Possible	Likely	Certain
Magnitude	No change	Negligible	Negligible	Negligible	Negligible	Negligible
	Negligible	Negligible	Negligible	Minor	Minor	Minor
	Low	Negligible	Minor	Minor	Moderate	Major
	Moderate	Negligible	Minor	Moderate	Major	Major
	High	Minor	Moderate	Major	Major	Major

The risk level categories in Table 20.13 provide a threshold to determine whether or not the risk is assessed as being ‘significant’ in terms of the Offshore Development’s resilience to climate change. Moderate and Major risks are defined as ‘significant’ in terms of the Offshore Development’s resilience to climate change.

Where the assessment identifies a significant risk from the changing climate on the Offshore Development design, mitigation measures, or adaptations to design have been proposed to avoid or reduce impacts to an acceptable risk level.

20.6.2.4 Data gaps and uncertainties

The evidence base for climate change assessments and the confidence in future climate projections is increasing. However, there are still data gaps present and this is a growing area of research (Küpper and Kamenos, 2017). The MCCIP aim to continue to review and publish evidence on climate change risks and impacts as and when they occur, and therefore, it is expected that the understanding of the climate change projections and impacts presented within this assessment will continue to evolve in the forthcoming years (MCCIP, 2022). The assessment has been carried out using the most comprehensive and up-to-date data sources, as described in Section 20.4.2. It is acknowledged that this climate change resilience review is limited by the data available at the time of the assessment.

20.6.3 Assessment of Climate Resilience

Table 20.14 outlines the climate change resilience review for the Offshore Development, which has been undertaken using the methodology described in Section 20.6.2.

Table 20.14 Assessment of the Offshore Development resilience to climate change

Climate Variable		Impact on the Offshore Development	Likelihood	Magnitude	Risk Level	Significance	Mitigation / Adaptation Required?	Residual Significance
Extreme weather events	Increased frequency of high wind events.	Potential damage, loss or reduced structural integrity of the Offshore Development infrastructure / facilities as a result of high wind events.	Extremely Unlikely: The WTGs and floating substructures have been designed in accordance with the relevant design codes which have sufficient safety factors to account for the most extreme weather events and using site data extrapolated over the expected life-cycle of the Offshore Development. The WTG will also shut down at high wind speeds that exceed the cut-out speed to avoid structural damage. Regular maintenance of assets will also be carried out to identify and remediate any damage.	High: Although the impact is extremely unlikely, the potential damage to site infrastructure as a result of high wind events could cause significant damage, cost and health and safety risks.	Minor	Not Significant	No	Not Significant
		Potential increased downtime due to the cut-out speed exceedance.	Unlikely: The WTGs and floating substructures have been designed to withstand strong winds (e.g. the number of mooring lines per WTG has been designed to provide adequate stabilisation).	Negligible: Potential for profit reductions resulting from increased downtime during high wind events. However, this is unlikely to be a regular occurrence and will not result in significant cost or damage.	Negligible	Not Significant	No	Not Significant
		Disruption (e.g. reduced accessibility) or increased safety risk to operation and maintenance procedures or equipment / vessels as a result of high wind events.	Extremely Unlikely: Event is only likely to occur in extreme circumstances (i.e. the likelihood of extreme winds during operation and maintenance activities is low). Contractors will monitor weather patterns ahead of maintenance works to identify suitable weather windows to undertake operation and maintenance tasks, and health and safety protocols will be adhered to.	Moderate: Potential health and safety risks for personnel working in poor weather conditions.	Negligible	Not Significant	No	Not Significant
	Increased mean maximum wave heights.	Potential damage, loss or reduced structural integrity of the Offshore Development infrastructure / facilities as a result of high waves.	Extremely Unlikely: The WTGs and floating substructures have been designed in accordance with the relevant design codes which have sufficient safety factors to account for the most extreme weather events and using site data extrapolated over the expected life-cycle of the Offshore Development. Regular maintenance of assets will be carried out to identify and remediate any damage.	High: Although the impact is extremely unlikely, the potential damage to WTGs as a result of high waves (e.g. mooring failure) could cause significant damage, cost, and health and safety risk.	Minor	Not Significant	No	Not Significant
		Disruption (e.g. reduced accessibility) or increased safety risk to operation and maintenance procedures or equipment / vessels as a result of high waves.	Extremely Unlikely: Event is only likely to occur in extreme circumstances (i.e. the likelihood of extreme waves during operation and maintenance activities is low). Contractors will monitor weather patterns ahead of maintenance works to identify suitable weather windows to undertake operation and maintenance tasks, and health and safety protocols will be adhered to.	Moderate: Potential health and safety risks for personnel working in poor weather conditions.	Negligible	Not Significant	No	Not Significant
Changing weather patterns / sea conditions	Increased air and sea temperature.	Potential damage, loss, or reduced structural integrity of the Offshore Development infrastructure as a result of increased temperatures (e.g. thermal expansion).	Extremely Unlikely: Impact is unlikely to affect the Offshore Development infrastructure over the design life as cables will be buried or protected to reduce the potential for overheating. The infrastructure is designed to withstand heat stress.	Low: Overheating may affect the functioning of the Offshore Export Cable(s); however, this is not expected to result in significant cost or damage.	Negligible	Not Significant	No	Not Significant

Climate Variable		Impact on the Offshore Development	Likelihood	Magnitude	Risk Level	Significance	Mitigation / Adaptation Required?	Residual Significance
		Increased potential for biofouling of mooring lines and substructures as a result of increased temperatures.	Extremely Unlikely: Substructures will be designed to accommodate some marine growth and marine growth will be removed regularly, as required.	Low: Potential for increased marine growth to add weight / drag to mooring lines. However, this is unlikely to be of any significant magnitude considering the embedded mitigations in place.	Negligible	Not Significant	No	Not Significant
		Disruption or increased safety risk to operation and maintenance procedures or equipment as a result of increased air temperatures (e.g. heat stress for staff).	Extremely Unlikely: Although average air temperature is predicted to rise, this increase is not considered likely to be high enough to induce heat stress, except in extreme cases. Contractors will monitor weather patterns ahead of maintenance works and health and safety protocols will be adhered to.	Low: Adherence to health and safety protocols will adequately reduce any potential health and safety risks.	Negligible	Not Significant	No	Not Significant
Sea level rise and coastal erosion	Sea level rise and coastal erosion.	Potential damage, loss or reduced structural integrity of the Offshore Development infrastructure / facilities from coastal erosion (e.g. exposure of cables).	Extremely Unlikely: Regular surveys will be undertaken to monitor the condition of the cables. The cables will also be installed through an HDD and ducted conduit, surfacing in-land and thus reducing the potential for damage.	Moderate: Exposure of cables could increase the risk of cable to external threats, increasing the risk of damage or faults.	Negligible	Not Significant	No	Not Significant

20.7 In-combination Climate Impact Assessment

20.7.1 Introduction

The in-combination climate impact assessment considers how any of the predicted impacts from the Offshore Development alone could be exacerbated or reduced by any predicted future changes in the physical environment, as discussed in Section 20.4.

The in-combination climate impact assessment has been conducted in accordance with IEMA (2020) Environmental Impact Assessment Guide to Climate Change Resilience and Adaptation, specifically Step 2 to Step 7.

20.7.2 Assessment Methodology

The in-combination climate impact assessment considers all potential receptors which could be impacted by the Offshore Development, as outlined within this Offshore EIAR. It places the impact of the Offshore Development on relevant EIA receptors in the context of future climate conditions, as outlined in Section 20.4. The approach and methodology are outlined in Sections 20.7.2.1 to 20.7.2.4 below.

20.7.2.1 Receptor and impact identification

All EIA topics outlined in Chapters 7 to 21, of this Offshore EIAR are considered within the in-combination climate assessment. The impacts of the Offshore Development on the receiving environment are identified and assessed through the EIA process and reported in Chapters 7 to 21.

Only impacts associated with operation and maintenance are considered within the in-combination climate impact assessment, as the current climate conditions are considered to be applicable for the two-year construction phase. Furthermore, as detailed information on the decommissioning of the Offshore Development infrastructure is limited at this time, a meaningful assessment of the in-combination impact of climate change and the Offshore Development at the time of decommissioning is not possible. A Decommissioning Programme will be developed pre-construction to address the principal decommissioning measures for the Offshore Development, this will be written in accordance with applicable guidance and will detail the management, environmental management, and schedule for decommissioning of the Offshore Development. The decommissioning programme will be reviewed and updated throughout the life-cycle of the Offshore Development to account for changing best practices.

The future climate projections are summarised in Section 20.4 and this information has been reviewed to identify the potential impacts of climate change on the EIA topics assessed within this EIA Report. The impacts of the Offshore Development are then considered alongside any impacts associated with future climate projections, to understand whether the Offshore Development impact is exacerbated or reduced.

The following receptors have not been considered within the in-combination climate impact assessment for the following reasons:

> Aviation and Radar: Considered to have a negligible sensitivity to changes in climate, and therefore the likelihood of an ICCI is extremely unlikely;

> Shipping and Navigation: Considered to have a negligible sensitivity to changes in climate, and therefore the likelihood of an ICCI is extremely unlikely;

> Marine Archaeology: Considered to have a negligible sensitivity to changes in climate, and therefore the likelihood of an ICCI is extremely unlikely;

> Other Sea Users: Considered to have a negligible sensitivity to changes in climate, and therefore the likelihood of an ICCI is extremely unlikely;

> Seascape, Landscape, and Visual: The key impact to seascape, landscape, and visual from climate change is considered to be in relation to effects on coastal morphology. For this reason, the marine physical and coastal processes in-combination climate impact assessment should be referred to in order to understand the likelihood of an ICCI;

- Socio-economics, Recreation, and Tourism: Climate change may have a positive or negative effect on tourism and recreation. Positive effects may arise from increased temperature, whereas negative effects may arise from sea level rise and coastal erosion. For this reason, the marine physical and coastal processes in-combination climate impact assessment should be referred to in order to understand the likelihood of an ICCI;
- Commercial Fisheries: The key impact to commercial fisheries from climate change is considered to be in relation to effects on fish and shellfish (e.g. range shifts in commercially important species). For this reason, the fish and shellfish in-combination climate impact assessment should be referred to in order to understand the likelihood of an ICCI; and
- Major Accidents and Disasters: The vulnerability of the Offshore Development to climate change is discussed in Section 20.6, and this considers any climate hazards which could result in major accidents and disasters. The hazards and risks scoped into the major accidents and hazards chapter are not likely to be impacted by changing climate variables, with the exception of the potential for lightning strikes to damage the WTG. This risk is considered to be 'broadly acceptable' as the WTG infrastructure is being designed to withstand lightning strikes, as discussed in Chapter 21: Risk of Major Accidents and/or Disasters. Therefore, there is a limited potential for any climate change to affect this assessment.

20.7.2.2 Embedded mitigation and management plans

As noted in Section 20.6.2.2, embedded mitigation and management plans are proposed to form part of the design of the Offshore Development to reduce the potential impact of the Offshore Development on the receptors assessed in Chapters 17 to 21. These embedded mitigation and management plans have been considered in the in-combination impact assessment and are summarised in Table 20.15.

Table 20.15 Embedded mitigation specific to the in-combination climate assessment

Embedded Mitigation Measures and management plans	Justification
Management Plans	
Operational Environmental Management Plan (OEMP)	An OEMP will be developed to guide ongoing operations and maintenance activities during the life-cycle of the Project. The OEMP will also set out the procedures for managing and delivering the specific environmental commitments as per each technical chapter for each receptor over the operational period.
Environmental Clerk of Works (ECoW)	An independent ECoW will be appointed to audit site activities and will advise on implementation of mitigation.
Lighting and Marking Plan (LMP)	An LMP will be developed for the Offshore Development. This will provide that the Offshore Development be lit and marked in accordance with the current Civil Aviation Authority and Ministry of Defence aviation lighting policy and guidance. The LMP will also detail the navigational lighting requirements detailed in IALA R139 and G1162.
Marine Mammal Mitigation Plan (MMMP)	An MMMP will be developed and implemented throughout all phases of the Offshore Development to ensure the risk of injury to marine mammals is negligible and all possible disturbance effects are reduced. Best Available Technology will be employed along with due consideration of the local environment (e.g. protected sites or other important habitats) in line with the JNCC (2010) guidance: '*The protection of marine European Protected Species from injury and disturbance*' and the MS (2020) guidance: '*The protection of Marine European Protected Species from injury and disturbance, Guidance for Scottish Inshore Waters.'*

Embedded Mitigation Measures and management plans	Justification
	> The MMMP will follow the guidance from “Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise” (JNCC, 2010b), in relation to pilling activities; and > The MMMP will follow the guidance from “JNCC guidelines for minimising the risk of injury to marine mammals from geophysical surveys” (JNCC, 2017) in relation to geophysical surveys.
Vessel Management Plan (VMP)	A VMP will be developed and implemented throughout all Offshore Development phases. The VMP will follow the guidance from the Scottish Marine Wildlife Watching Code (SMWWC) (NatureScot, 2017) in relation to protecting marine wildlife from encounters. > Relevant vessel crew will be trained in the SMWWC to ensure the risk of injury to marine wildlife is negligible and all possible disturbance effects are reduced; and > A traffic management scheme will be included to reduce vessel overlaps reducing further disturbances to marine mammals.
Navigational Safety Plan (NSP)	A NSP will be developed for the Offshore Development which will detail all navigational safety measures, construction exclusion zones if required, notices to mariners and radio navigation warnings, anchoring areas, lighting and marking requirements and emergency response procedures during all phases of the project. The NSP sets out the WTG lighting requirements for shipping and navigational safety and will adopt good practice in respect of seabird attraction to lighting.
Cable Plan (CaP)	A Cable Plan will be prepared for the Offshore Development and will detail the location/ route and cable laying techniques of the inter-array and Offshore Export Cable(s) and detail the methods for cable surveys during the operational life of the cables for the Offshore Development. This will be supported by survey results from the geotechnical, geophysical and benthic surveys. The cable plan will also detail electromagnetic fields of the cables deployed. A Cable Burial Risk Assessment (CBRA) will also be undertaken and included within the Cable Plan which will detail cable specifications, cable installation, cable protection, target burial depths / depth of lowering and any hazards the cable will present during the life-cycle of the cable.
Marine Pollution Contingency Plan	Consent conditions will require a Marine Pollution Contingency Plan to outline procedures in the event of an accidental pollution event arising from activities associated with the Offshore Development. The Plan provides guidance to personnel and contractors on the action and reporting requirements. Adopting these protocols will reduce risk in relation to the spread of INNS across all phases of the Offshore Development.
Protocols for managing radioactivity risk	A Radioactive Risk Assessment has been completed to inform all stages of the Offshore Development. Associated with the risk assessment are a number of recommendations including protocols and procedures for managing and mitigating the risk of coming in contact with and spreading radioactive particles.

Embedded Mitigation Measures and management plans	Justification
	These protocols and procedures are to be adopted and implemented as part of Offshore Development operations and will form part of the Offshore Development environmental management plans.
Embedded Mitigation	
Adherence with the International Convention for the Prevention of Pollution from Ships (MARPOL)	All vessels will adhere to MARPOL requirements. Accordance with this will help to ensure that the potential for release of pollutants is minimised during operations.
Adherence with the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (the "BWM Convention')	Ballast water discharges from vessels will be managed under the BWM Convention which aims to prevent the spread of harmful aquatic organisms from one region to another, by establishing standards and procedures for the management and control of ships' ballast water and sediments. Measures will be adopted to ensure that the risk of Invasive Non-Native Species introduction during construction, operation and maintenance, and decommissioning is minimised.
Micrositing of WTGs and associated offshore infrastructure, including cable routes	The final Offshore Development layout will be presented within the Cable Plan and Design Specification and Layout Plan and conditions of the Section 36 Consent and/or Marine Licence. The final placement of infrastructure will be informed through micrositing based on available site survey data to ensure avoidance of sensitive habitats and structures where possible. Where this is not possible, the route will take the shortest distance possible through the sensitive areas to reduce environmental effects.
Removal of debris from floating lines and cables	The accumulation of marine debris on floating lines and cables has the potential to generate adverse interactions between mobile marine species and Offshore Development infrastructure. Derelict fishing gears are of particular concern due to the entanglement risk they introduce to marine megafauna, including marine mammals, sharks, and turtles. Mooring lines and floating inter-array cables will be inspected with a risk-based frequency during the operational life-cycle of the Offshore Development. Starting at a higher frequency and likely declining after several years. Any inspected or detected debris on the floating lines and cables will be recovered based on a risk assessment taking impact on the environment, risk to asset integrity and cost into account.
Removal of marine growth	The substructures will be designed to accommodate marine growth; however, in order to manage weight/ drag induced fatigue, growth levels will be inspected on a regular basis, and subsequent removal of this growth will be undertaken using water jetting tools if substantial accumulation is in evidence.
Minimum Air Gap	The minimum air gap increased to 35 m, which is a key measure to minimise collision risk to seabird species.
Use of HDD as the landfall cable installation option	HDD negates the need to pin the export cable to the disused water intake which raised concerns about potential effects on coastal morphology and impacts on Sandside Bay SSSI.

Embedded Mitigation Measures and management plans	Justification
Scour protection	The Design Envelope is to install scour protection around the anchor installations within the PFOWF Array Area. This will therefore negate the introduction of scour during the Offshore Development's operation and maintenance phase.
Minimum spacing between WTGs	The minimum spacing between each WTG (from the centre of each WTG structure) will be 800 m. This will reduce the likelihood of collision and entanglement with marine mammals.
Target depth of lowering	Static cables will be trenched and buried to a target depth of 0.6 m. Where this cannot be achieved, remedial cable protection will be applied. This will provide some separation between the cables and benthic ecology receptors, fish and shellfish ecology receptors, and basking sharks, therefore reducing the effect of EMF. The cable burial target depth will be informed by a CBRA and implemented through the CaP produced post-consent.

20.7.2.3 Defining likelihood and magnitude

The consequence of the in-combination climate impact is determined by defining the likelihood and magnitude of the impact. Existing or embedded mitigations and management plans identified within the EIA (as detailed in Chapter 5: Project Description) are accounted for when determining impact likelihood and magnitude.

The definitions for likelihood and magnitude are provided in Table 20.16 and Table 20.17, respectively. The likelihood of the in-combination impact occurring considers the potential for the climate projection to occur alongside the sensitivity of the receptor and is based on expert judgement. The magnitude considers the change in the significance of the effect from the Offshore Development when the in-combination effects of climate change are considered.

Table 20.16 Definitions for likelihood

Likelihood	Definition
Certain (>95%)	The event / impact will occur during the life-cycle of the Offshore Development (i.e. it is inevitable), potentially many times during the operational life.
Likely (66-95%)	The event / impact is likely to occur at some point during the life-cycle of the Offshore Development.
Possible (33-65%)	The event / impact is possible during the life-cycle of the Offshore Development.
Unlikely (10-32%)	The event / impact is unlikely to occur during the life-cycle of the Offshore Development.
Extremely Unlikely (0-9%)	The event / impact is extremely improbable, but the risk associated with the consequences of such an event is anticipated to be very serious so that contingency planning is essential.

Table 20.17 Definitions for magnitude

Magnitude	Definition
High	The consequence of the effect from the Offshore Development increases to major when the in-combination effects from climate change are considered.
Moderate	The significance of the effect from the Offshore Development increases to moderate when the in-combination effects from climate change are considered.
Low	The significance of the effect from the Offshore Development increases from negligible to minor when the in-combination effects from climate change are considered.
Negligible / No Change	There is no change in the effect from the Offshore Development in-combination with the projected change in the climate variable.

Having determined the likelihood and magnitude of the in-combination climate impact, the consequence is determined, as either negligible, minor, moderate, or major, as shown in Table 20.18.

Table 20.18 Significance Matrix

		Likelihood				
		Extremely unlikely	**Unlikely**	**Possible**	**Likely**	**Certain**
Magnitude	**Negligible**	Negligible	Negligible	Minor	Minor	Minor
	Low	Negligible	Minor	Minor	Moderate	Major
	Medium	Negligible	Minor	Moderate	Major	Major
	High	Minor	Moderate	Major	Major	Major

The consequence categories in Table 20.18 provide a threshold to determine whether or not the in-combination impact is deemed 'significant' in EIA terms. Moderate and Major consequences are defined as a 'significant' impact in EIA terms.

Where the assessment identifies a significant impact climate on the Offshore Development design, mitigation measures or design changes have been proposed to avoid or reduce impacts to an acceptable level.

20.7.2.4 Data gaps and uncertainties

The evidence base for climate change and the confidence in future climate projections is increasing. However, there are still data gaps present and this is a growing area of research. The assessment has been carried out using the most comprehensive and up-to-date data sources, as described in Section 20.4.2. It is acknowledged that this in-combination climate impact assessment is limited by the data available at the time of the assessment.

20.7.3 In-combination climate impact assessment

Table 20.19 summarises the in-combination climate impact assessment, which has been undertaken using the methodology described in Section 20.6.2.

Table 20.19 In-combination climate impact assessment

EIA Topic	Offshore Development Impact (operation and maintenance)	Relevant Embedded Mitigation Measures	Potential Climate Change Projection and Impact (Impact numbers refer to column 2; Projection from Table 20.7)	Likelihood of In-combination Climate Impact	Magnitude of In-combination Climate Impact	Consequence of In-combination Climate Impact	Significance	Additional Mitigation required?	Significance of Residual Consequence
Offshore									
Marine physical processes	1. Changes to tide and wave regime; 2. Changes to sediment transport regime; 3. Introduction of scour; and 4. Impacts on fronts and stratification.	> Use of HDD as the landfall cable installation option; and > Scour protection.	> Impacts 1 and 2: Predicted changes in wave regime, including a reduction in mean significant wave height and increase in mean annual maximum wave height may alter the predicted impact of the Offshore Development on the tide and wave regime as well as onward impacts to the sediment transport regime.	Extremely Unlikely: The Offshore Development is predicted to have a low magnitude of impact on waves with no measurable change to wave energy transmission reaching the coast. Therefore, no in-combination impact is expected.	Negligible: The predicted effect of climate change is not expected to exacerbate the impact of the Offshore Development.	Negligible	Not Significant	No	Not Significant
			> Impact 4: Predicted change in stratification as a result of climate change could enhance any change in stratification predicted from the Offshore Development.	Extremely Unlikely: The area already experiences variable tides and waves and the PFOWF Array Area is not likely to introduce mixing throughout the water column. Therefore, no in-combination impact is expected.	Negligible: Predicted effect of climate change is not expected to exacerbate the impact of the Offshore Development.	Negligible	Not Significant	No	Not Significant
Water and sediment quality	1. Changes in water and sediment quality due to operational cleaning and maintenance activities.	> Preparation and adherence to OEMP; and > Adherence with the International Convention for the Prevention of Pollution from Ships (MARPOL).	> Impact 1: Increased frequency of heavy rainfall events and increased winter rainfall may result in reduced water quality from surface runoff.	Possible: Projected increase in rainfall could cause additional pollutants to enter coastal waters as a result of increased surface run-off.	Negligible: The effects are uncertain but expected to be small, given the projected increase in rainfall compared with current conditions. Embedded mitigations are in place to reduce the risk of contamination from the Offshore Development.	Minor	Not Significant	No	Not Significant
Benthic and intertidal ecology	1. Hydrodynamic changes leading to scour and abrasion; 2. Introduction of marine invasive and non-native species; 3. Colonisation of subsea infrastructure, scour protection and support structures; and 4. Impact to benthic communities from	> Preparation and adherence to OEMP; > Adherence with the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (BWM Convention); > Micrositing of WTGs and associated	> Impact 1: The increased frequency of heavy rainfall events and increased winter rainfall may result in increased concentrations of suspended solids in the water column.	Unlikely: Projections indicate that rainfall levels will increase, although the extent of this increase is uncertain. The key sensitive species is ocean quahog which is tolerant to smothering and siltation rate changes.	Negligible: The effects are uncertain but expected to be small, given the projected increase in rainfall compared with current conditions.	Minor	Not Significant	No	Not Significant
			> Impacts 2 to 4: Potential for habitat or species to be unable to tolerate projected changes in temperature, salinity, oxygen and pH (i.e. ocean acidification) which could exacerbate other	Unlikely: Although uncertain, benthic species are expected to be relatively tolerant to the projected changes in temperature, salinity, oxygen and pH within the life-cycle	Low: The climate change impact is uncertain but would be long-lasting. The risks from the Offshore Development will be	Minor	Not Significant	No	Not Significant

EIA Topic	Offshore Development Impact (operation and maintenance)	Relevant Embedded Mitigation Measures	Potential Climate Change Projection and Impact (Impact numbers refer to column 2; Projection from Table 20.7)	Likelihood of In-combination Climate Impact	Magnitude of In-combination Climate Impact	Consequence of In-combination Climate Impact	Significance	Additional Mitigation required?	Significance of Residual Consequence
	any thermal load or EMF arising from the cables during operation.	offshore infrastructure, including cable routes; and > Removal of marine growth.	external impacts (Moore *et al*., 2020).	of the Offshore Development. Some species may be impacted but this is not anticipated to have a widespread effect on the benthic community.	localised and reduced through the implementation of embedded mitigation measures.				
Fish and shellfish	1. Habitat loss of spawning and nursery grounds due to presence of anchors and export cable on the seabed; 2. Effects of EMFs from subsea and dynamic cables on sensitive species; 3. Fish aggregation around the floating structure and associated infrastructure; and 4. Ghost fishing due to lost fishing gear becoming entangled in installed infrastructure.	> Preparation and adherence to OEMP; > Adherence with the International Convention for the Prevention of Pollution from Ships (MARPOL); and > Removal of marine growth.	> Impacts 1 to 4: Potential for habitat or species to be unable to tolerate projected changes in temperature, salinity, oxygen, and pH (i.e. ocean acidification), enhancing other external impacts (Wright *et al*., 2020);	Unlikely: Although uncertain, fish and shellfish are expected to be relatively tolerant to the projected changes in temperature, salinity, oxygen and pH within the life-cycle of the Offshore Development, given the wide distribution of the species present in the Offshore Site.	Low: The climate change impact is uncertain but would be long-lasting. The risks from the Offshore Development will be localised and reduced through the implementation of embedded mitigation measures.	Minor	Not Significant	No	Not Significant
			> Impacts 1 to 4: Indirect effects in relation to impacts on prey species (e.g. reduced availability and distribution);	Unlikely: Although there may be a potential reduction in prey species, this is highly uncertain.	Low: There may be a reduction in some prey species due to climate changes, however, there may also be an increase in other prey species.	Minor	Not Significant	No	Not Significant
			> Impact 1: Change in phenology (e.g. spawning periods) as a result of changes in temperature (Wright *et al*., 2020).	Possible: Rising sea temperatures may impede spawning and recruitment success, as the synchrony between hatching fish larvae and plankton prey is changing (Wright *et al*., 2020).	Low: The impact will be long-lasting but is uncertain. The area of spawning habitat lost from the Offshore Development is low.	Minor	Not Significant	No	Not Significant
Marine mammals and megafauna	1. Noise-related impacts to marine mammals from operation and maintenance; 2. Entanglement risk to marine mammals and basking sharks; 3. Collision risk to marine mammals and basking sharks; 4. Displacement or barrier effects; and 5. Long-term habitat change.	> Preparation and adherence to OEMP; > Preparation and adherence to MMMP; > Preparation and adherence to VMP; > Minimum Spacing between WTGs of 800 m; > Removal of marine growth; and > Cable target burial depth of 0.6 m.	> Impacts 1 to 3: Projected changes in temperature, salinity, oxygen, and pH could increase sensitivity to impacts from the Offshore Development	Low: The additional stresses associated with climate change (e.g increased exposure to algal toxins and increased susceptibility to disease) may increase the vulnerability of marine mammals to physiological impacts / injury associated with underwater noise, entanglement risk and collision risk. However, climate change impacts to marine mammals are most likely to result from impacts on prey and the effect of the change in physical conditions in the marine environment on marine	Low: The climate change impact is uncertain but would be long-lasting. The risks from the Offshore Development will be localised and reduced through the implementation of embedded mitigation measures.	Minor	Not Significant	No	Not Significant

EIA Topic	Offshore Development Impact (operation and maintenance)	Relevant Embedded Mitigation Measures	Potential Climate Change Projection and Impact (Impact numbers refer to column 2; Projection from Table 20.7)	Likelihood of In-combination Climate Impact	Magnitude of In-combination Climate Impact	Consequence of In-combination Climate Impact	Significance	Additional Mitigation required?	Significance of Residual Consequence
				mammals remains uncertain (Evans and Waggit, 2020).					
			> Impacts 1 to 5: Migratory species may arrive earlier or remain in high latitudes for longer as a result of increasing sea temperatures (Evans and Waggitt, 2020).	Low: Migratory species, such as minke whale and basking shark, may be impacted by changes in sea temperature, remaining at higher latitudes for longer and potentially increasing the likelihood to be impacted by the Offshore Development.	Negligible: The risks from the Offshore Development will be localised and reduced through the implementation of embedded mitigation measures. Therefore, the potential change in migratory patterns is not expected to have a material impact on the assessment of impacts.	Minor	Not Significant	No	Not Significant
			> Impacts 4 and 5: Indirect effects in relation to impacts on prey species (e.g. reduced availability and distribution) (Evans and Waggitt, 2020).	Unlikely: A range of shifts of marine mammal prey species may occur, impacting the availability of prey, potentially exacerbating any impact of displacement or barrier effects and long-term habitat change. However, this impact on marine mammals is highly uncertain and poorly understood.	Low: There may be a reduction in some prey species due to climate changes. However, the Offshore Development may act as a fish aggregation area, potentially increasing prey abundance. Therefore, the effect of the Offshore Development is not expected to be majorly impacted by climate change.	Minor	Not Significant	No	Not Significant
Marine ornithology	1. Potential collision risk with WTGs; 2. Potential displacement due to physical presence of WTGs; 3. Potential for entanglement with debris caught on mooring lines; 4. Potential disturbance / exclusion due to marine noise and maintenance works; 5. Potential change in habitat / prey availability due to physical presence of WTGs;	> Minimum air gap; > Lighting and Marking Plan; > Preparation and adherence to OEMP.	> Impacts 1 to 5 and 7: Increased frequency of heavy rainfall events may impact breeding bird success or impact foraging success at sea and enhance any other survival impairment (Mitchell *et al*., 2020).	Unlikely: Projections indicate that rainfall levels will increase, although the extent of this increase is uncertain. The reduced foraging success could put additional pressure on birds and reduce the ability to tolerate the impacts from the Offshore Development. However, birds utilising the Offshore Site will be tolerant to rainfall.	Negligible: The effects are uncertain but expected to be small, given the projected increase in rainfall compared with current conditions.	Minor	Not Significant	No	Not Significant
			> Impacts 1 to 5 and 7: Increased air temperatures may result in migratory species arriving earlier or remaining in high latitudes for longer, enhancing any other survival impairment.	Unlikely: The potential impact of climate change on migration is uncertain (Mitchell *et al*., 2020). Several migratory species are present in the Offshore Site.	Low: The impact is long-lasting. Changes in migratory patterns may make seabirds more vulnerable to impacts from the Offshore Development, however, the effects from the Offshore Development will be	Minor	Not Significant	No	Not Significant

EIA Topic	Offshore Development Impact (operation and maintenance)	Relevant Embedded Mitigation Measures	Potential Climate Change Projection and Impact (Impact numbers refer to column 2; Projection from Table 20.7)	Likelihood of In-combination Climate Impact	Magnitude of In-combination Climate Impact	Consequence of In-combination Climate Impact	Significance	Additional Mitigation required?	Significance of Residual Consequence
	6. Potential increase in suspended sediment affecting visibility during operations and maintenance; and 7. Creation of roosting habitat or foraging opportunities.				mitigated through embedded measures.				
			> Impacts 1 to 5 and 7: Loss of coastal habitats due to rising sea level, potentially reducing the availability of nesting habitat and enhancing any other survival impairment.	Possible: Coastal erosion and sea level rise is predicted, which could reduce or damage nesting habitat for seabirds.	Low: The impact is long-lasting. However, impacts from the disturbance from the Offshore Development will be short-term and will be mitigated through embedded measures.	Minor	Not Significant	No	Not Significant
			> Impact 5: Indirect effects in relation to impacts on prey species (e.g. reduced availability and distribution).	Unlikely: Although there may be a potential reduction in prey species, this is highly uncertain.	Low: There may be a reduction in some prey species due to climate changes, however, there may also be an increase in other prey species.	Minor	Not Significant	No	Not Significant
			> Impact 6: Increased frequency of heavy rainfall events may result in increased surface runoff and increased suspended sediment concentrations.	Unlikely: Projections indicate that rainfall levels will increase, although the extent of this increase is uncertain. Diving seabirds may be sensitive to increases in suspended sediment concentrations. However, those in association with rainfall will be temporary.	Negligible: The effects are uncertain but expected to be small, given the projected increase in rainfall compared with current conditions.	Minor	Not Significant	No	Not Significant

20.8 Blue Carbon Assessment

20.8.1 Introduction

Marine sediments, and particularly deep-sea sediments, are the primary store of biologically derived carbon (mostly as inorganic carbon). Scotland's biogenic marine habitats are highly productive places, with a very high rate of assimilation of carbon into plant material (662 grams of carbon per metre squared per year [gC/m^2/yr]), mostly in coastal areas. Yet their overall contribution to the carbon budget is relatively small compared to sediments (Burrows *et al*., 2014; 2017).

The assessment provided in this chapter expands on the information and assessment conducted in Chapter 9: Benthic Ecology to focus on the potential effect of the Offshore Development on blue carbon.

20.8.2 Impacts Assessed

The principal threat to long-term carbon storage is any process or work that disturbs the top layers of sediment (including construction activities relating to the placement of the inter-array and offshore export cables or anchor installation). Resuspension of sediment allows rapid consumption of buried carbon by organisms and its subsequent release as CO_2. This effectively reduces the carbon burial rate significantly and reduces the blue carbon inventory.

The following impacts are assessed for effects on blue carbon habitats within the Offshore Site:

> Direct blue carbon habitat loss / disturbance from the placement of the Offshore Development subsea infrastructure during the lifecycle of the Offshore Development; and

> Cumulative effects from the Offshore Development and other projects resulting in blue carbon habitat loss / disturbance from the placement of subsea infrastructure.

20.8.3 Assessment Methodology

The assessment methodology for the blue carbon impact assessment is consistent with the EIA methodology presented in Chapter 9: Benthic Ecology.

20.8.4 Baseline

The total standing stock of organic carbon in Scotland's marine sediments was estimated as 18.1 megatonnes of carbon, and the total sequestration capacity of Scottish seas as 7.2 megatonnes of carbon per year. Patterns of standing stocks and sequestration capacity of organic carbon follow the distribution of mud and mud-sand-gravel combinations. Most organic carbon, and the largest capacity for sequestration of organic carbon, appears to be in deep mud off the continental shelf (Burrows *et al*., 2014).

A review of sediment accumulation rates showed that the burial rates for organic carbon are strongly dependent on sediment type (Burrows *et al*., 2014). As described in Chapter 9: Benthic Ecology, the European Nature Information System classification for the Offshore Site is A5.27: Deep circalittoral sand, A5.25: Circalittoral fine sand and A5.26 Circalittoral muddy sand, with areas of A3.2 Atlantic and Mediterranean moderate energy infralittoral rock and A5 Sublittoral sediment. Burial rates for organic carbon into sand and sand/mud sediments are moderate compared to other sediment types (sand: 0.2 gC/m^2/yr and sand/mud 50.6 gC/m^2/yr) (Burrows *et al*., 2014). Organic and inorganic density within the top 10 centimetres of sediment in the Offshore Site is predicted to be relatively low (approximately 0 to 20 tonnes per hectare of inorganic carbon and 3 to 4 tonnes of organic carbon per hectare), according to carbon density maps produced by Smeaton *et al*. (2020). The overall percentage of carbonate in the top 10 centimetres of superficial sediments at the Offshore Site, interpolated from British Geological Survey sediment records, is less than 30% (NMPi, 2022). As noted in Chapter 7: Marine Physical Processes, the geotechnical survey at the PFOWF Array Area identified the potential for organic / peat deposits at depths between 4 m and 8 m below the seabed.

Chapter 9: Benthic Ecology summarises the blue carbon habitats likely to be present in the Offshore Site and identifies kelp beds present in the OECC as being the only key blue carbon habitat present. No kelp beds were identified in the PFOWF Array Area (MMT, 2021).

20.8.5 Impact Assessment

Kelp beds are a key blue carbon habitat and are present across the Offshore Site within the Offshore Export Cable Corridor. Kelp beds are a **high-value** receptor and are assessed as being **highly sensitive** to changes in habitat (as detailed in Chapter 9: Benthic Ecology). However, overall, the sediments across the Offshore Site are considered to have a **low carbonate value**, and although kelp beds are present in the OECC, any habitat loss or disturbance from the placement of Offshore Export Cable(s) and HDD operations will be minimal, based on the localised spatial change and low frequency of disturbance / loss expected to occur through the life-cycle of the Offshore Development. Furthermore, HWL will endeavour to microsite around sensitive habitats, such as kelp beds, wherever possible, to minimise any disturbance or loss.

In Chapter 7: Marine Physical Processes, it is predicted that 4% of the total sediment released during the anchor drilling activities (22,000 cubic metres in total) will comprise peat deposits. This represents a small volume of peat that will eventually be integrated into the sediment transport regime in the long term.

Consequently, the activities associated with the Offshore Development are unlikely to affect the carbon sequestration potential of the immediate seabed and associated habitats, and as such, in line with the impacts assessed on kelp beds in Chapter 9: Benthic Ecology, the **magnitude of impact** on blue carbon is assessed as **negligible or low** during construction, operation and maintenance, and decommissioning of the Offshore Development.

Therefore, in line with the effects assessed on kelp beds, the overall effect on blue carbon from the placement of the Offshore Development is assessed as **minor** and **not significant**.

20.8.6 Assessment of Cumulative Effects

As detailed in Chapter 9: Benthic Ecology, only two projects are considered to potentially result in cumulative effects with the Offshore Development on benthic ecology receptors. These are detailed below in Table 20.20 and shown in Figure 20.4.

Table 20.20 List of projects considered for the benthic ecology cumulative impact assessment

Development Type	Project Name	Status	Phase	Location	Data Confidence	Relevant Receptors
Cable	SHE Transmission Orkney-Caithness Project	Consented	Consented (construction timelines unknown)	Pentland Firth (overlap with OECC)	Medium	All
Dredge disposal site	Scrabster Extension dredge disposal site	Open	Open with intermittent activity taking place.	Located within 20 km of the Offshore Development,	High	All

As detailed above, kelp beds are the only key blue carbon habitat identified within the Offshore Site and are assessed as being a **high-value** and **highly sensitive** receptor.

Considering the overlap of the Offshore Development with the SHE Transmission Orkney-Caithness Project there is the potential for cumulative impacts to occur on blue carbon habitats, such as the kelp beds, from direct habitat loss or disturbance from the placement of subsea infrastructure. The construction period for this cable is unknown. Installation of the Offshore Export Cable(s) is anticipated to take place in Stage 1 or Stage 2 and HDD works are expected to commence the year before Stage 1 (anticipated to be in 2024). It is therefore not known whether the construction timeline of the Offshore Development will overlap with that of the SHE Transmission Orkney-Caithness Project; however, this cannot be ruled out.

The Scrabster Extension dredge disposal site does not overlap with the Offshore Site and is already operational, and therefore no cumulative impacts are anticipated as this activity forms part of the existing baseline.

Therefore, in line with the impacts assessed on carbon sequestration potential of the immediate seabed and associated habitat, including kelp beds, there will be **no change** to the magnitude of impact and as such the **magnitude of impact** is still considered to be **negligible or low**, making the overall effect **minor** and **not significant**.

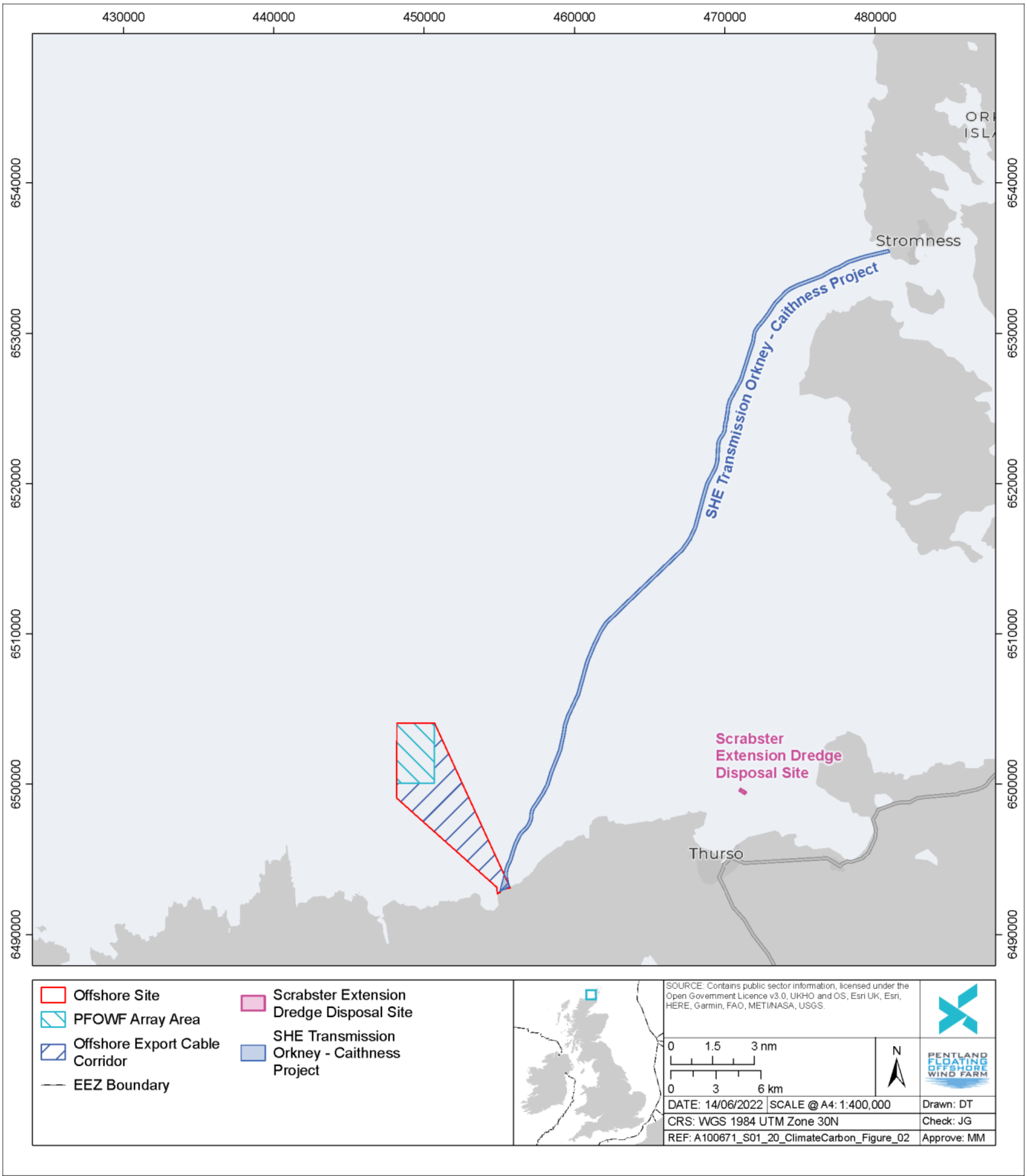

Figure 20.4 Projects considered for the blue carbon cumulative impact assessment

20.9 Carbon Assessment

20.9.1 Introduction

All industries, including the renewable energy industry, emit GHGs. Renewable energy projects also avoid the emission of GHGs by replacing other, more carbon-intensive forms of electricity generation.

An assessment of the Offshore Development has been carried out to evaluate:

- The carbon lifecycle emissions which will result from the Offshore Development in terms of carbon dioxide equivalent (CO_2e) emissions;
- The CO_2e emissions which will be avoided as a result of the Offshore Development;
- The length of time the Offshore Development will require to be operational to 'pay back' the emissions resulting from construction, operation and maintenance, and decommissioning (the 'payback period'); and
- The impact of the Offshore Development on the global climate, using the UK Carbon Budget as a proxy.

The carbon assessment is summarised in this section and presented in full in Offshore EIAR (Volume 3): Technical Appendix 20.1: Carbon Assessment.

20.9.2 Assessment Methodology

20.9.2.1 Defining magnitude and sensitivity

Institute of Environmental Management and Assessment (IEMA, 2022) guidance states that

> *"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."*

In the absence of sector-based, or local emissions budgets, the UK Carbon Budgets can be used to contextualise the level of significance. As per IEMA (2022) guidance, all GHG emissions are classed as having the potential to be significant as all emissions contribute to climate change. In establishing the scope and boundary of emission assessment, it is standard accounting practice to exclude minor sources as these are not material. Inventories that exclude these minor sources are still considered complete for verification purposes. This exclusion of emission sources that are less than 1% of a given emissions inventory is based on a 'de minimis' (relatively minimal) contribution (BSI, 2019).

On this basis, where emissions from the Offshore Development are greater than 1% of the relevant annual UK Carbon Budgets the impact of the Offshore Development on the climate is considered to be major. This is summarised in Table 20.21 and Table 20.22.

There is currently no published standard definition for receptor sensitivity of GHG emissions. The global climate has been identified as the receptor for the assessment. The sensitivity of the climate to GHG emissions is considered to be 'high' (IEMA, 2022). The rationale supporting this includes:

- Any additional GHG impacts could compromise the UK's ability to reduce its GHG emissions and therefore the ability to meet its future carbon budgets; and
- The importance of meeting the Paris Agreement goal of limiting global average temperature increase to well below 2°C above pre-industrial levels. Additionally, a recent report by the Intergovernmental Panel on Climate Change highlighted the importance of limiting global warming below 1.5°C (IPCC, 2021).

Table 20.21 Magnitude criteria for impact assessment

Magnitude	Magnitude Criteria Description
Beneficial reduction	Estimated emissions equate to a reduction of >0.1% of total emissions across the relevant five-year UK Carbon Budget period in which they arise.
Negligible change	Estimated emissions equate to ± 0.1% of total emissions across the relevant five-year UK Carbon Budget period in which they arise.
Small increase	Estimated emissions equate to between 0.1 and 1% of total emissions across the relevant five-year UK Carbon Budget period in which they arise.
Large increase	Estimated emissions equate to >1% of total emissions across the relevant five-year UK Carbon Budget period in which they arise.

Table 20.22 Consequence matrix for impact assessment

Magnitude of Emissions	Sensitivity of Receptor: High
Beneficial reduction	Beneficial
Negligible change	Minor beneficial / adverse
Small increase	Moderate adverse
Large increase	Major adverse

The UK Government has set a target of reducing the UK's overall GHG emissions to net zero by 2050 as part of the Climate Change Act 2008 and a series of phased, legally binding budgets have been implemented (Table 20.23), with the sixth carbon budget setting a 78% reduction by 2035. The UK is currently in the third carbon budget period.

Table 20.23 UK Carbon Budget (Committee on Climate Change, 2020)

Budget	Annual Carbon Budget (million tonnes CO_2e)	% Reduction Below Base Year (1990)
3rd carbon budget (2018 to 2022)	2,544	35% by 2020
4th carbon budget (2023 to 2027)	1,950	50% by 2025
5th carbon budget (2028 to 2032)	1,765	57% by 2030
6th carbon budget (2033 to 2037)	965	78% by 2035

20.9.2.2 Design Envelope parameters

As detailed in Chapter 5: Project Description, this assessment considers the Offshore Development parameters which are predicted to result in the greatest environmental impact, known as the 'realistic worst case scenario'. The realistic worst case scenario represents, for any given receptor and potential impact on that receptor, various options in the Design Envelope that would result in the greatest potential for adverse change (or the least potential for beneficial change) to the receptor in question.

Given that the realistic worst case scenario is based on the design option (or combination of options) that represents the greatest potential for change, confidence can be held that the development of any alternative options within the design parameters will give rise to no effects greater or worse than those assessed in this impact assessment.

The realistic worst case scenario for the carbon assessment is associated with the High emissions scenario. For context, a Low emissions scenario is also calculated to estimate a lower bound of emission scenarios associated with the Offshore Development. Table 20.24 presents the key features of the design envelope scenarios assessed for the carbon assessment.

Table 20.24 Design parameters specific to the carbon assessment

Component	Design Envelope Scenario Assessed	
	Worst case scenario: High emissions	Comparison scenario: Low emissions
WTGs	7, each 10 megwatts (MW)	5 of 18 MW
WTG Foundation	Square Barge Structure	Tension Leg Platform
Offshore Export Cable(s)	2, each 12.5 km in length	1 of 12.- km length
Inter-array Cables	20-km length	10-km length
Vessel Activity	10,095 vessel working days	8,011 vessel working days

A range of key assumptions was made to derive the emissions inventory for the Offshore Development using the worst case (High emissions) and comparison (Low emissions) scenarios and to calculate the payback period. These assumptions are summarised as follows and presented in detail in Offshore EIAR (Volume 3): Technical Appendix 20.1:

- Assessment Boundary:
  - Offshore Development: All offshore components of the PFOWF Array and the OECC (WTGs, inter-array and export cables, floating substructures and all other associated offshore infrastructure); and
  - Lifecycle of the Offshore Development from pre-construction to decommissioning, including:
    - Embodied carbon (i.e. the CO_2e emissions associated with the production of materials [mining raw materials, refining, forming etc.]);
    - Delivery of WTGs and their associated substructures, moorings and anchors and cables (export and array) and cable protection from the manufacturing location to the Offshore Development; and
    - Vessel emissions associated with pre-construction activity, construction, operations and maintenance and decommissioning.
- Scenario Definition:
  - To calculate the embodied carbon of the components, the mass of the major materials was estimated. The CO_2e associated with the production of these raw materials was calculated;

- The mass of materials within a Haliade-X 14 megawatt (MW) WTG was prorated to a 10 MW (worst case scenario) and 18 MW (comparison scenario) WTG. This enabled comparison between a 10 MW WTG (currently available on the market) and an 18 MW WTG (not currently available on the market);
- The Square Barge Structure, mooring and anchor system consists of concrete, steel, and scour protection. This system was calculated as having the greatest mass of the floating substructures under consideration and is therefore associated with the highest quantities of embodied carbon, representing the 'worst case scenario'. Conversely, the Tension Leg Platform was calculated as having the lowest mass of the floating substructure systems under consideration and is incorporated within the comparison scenario; and
- In the worst case scenario, the WTG and mooring system were assumed to be transported to the Offshore Development from China with other components being transported from Europe. In the comparison scenario, the WTG and cable protection were assumed to be transported from Europe with other components being transported from the UK.

> Avoided Emissions over the 30-year operational period due to the electricity generated by the Offshore Development:

- It is assumed that 400 tonnes of CO_2e would be avoided per gigawatt hour (GWh) of electricity generated from the Offshore Development. This value represents the 2020 estimate by the Office of National Statistics of actual UK emissions per unit of electricity generated from fossil fuels (BEIS, 2021). Electricity generated by the Offshore Development is assumed to displace electricity generated from fossil fuels, rather than from less carbon-intensive sources such as nuclear or other renewable energy sources; and
- Generation Capacity of the Offshore Development
  - Worst case (High emissions) scenario: 331 GWh; and
  - Comparison (Low emissions) scenario: 415 GWh.

Vessel activity associated with decommissioning is assumed to be equivalent to that required for construction. This is a conservative assumption as vessels are likely to become more efficient over the next 30 years. Emissions associated with decommissioning activity, beyond the return of materials to shore, are outwith the assessment boundary, however, it is likely that based on current industry practice, up to 90% of the material may be recycled (Spyroudi, 2021).

20.9.2.3 Embedded mitigation and management plans

As noted in Section 20.6.2.2, embedded mitigation and management plans will form part of the design of the Offshore Development to further reduce the potential impact of the Offshore Development on the global climate. These embedded mitigation and management plans have been considered in the carbon assessment.

Table 20.25 Embedded mitigation specific to the in-combination climate assessment

Embedded Mitigation Measures and management plans	Justification
Management Plans	
Construction Environmental Management Plan (CEMP)	A CEMP will be developed for the Offshore Development, this will set out procedures to ensure all activities with the potential to affect the environment are appropriately managed and will include: a description of works and construction processes, roles and responsibilities, description of vessel routes and safety procedures, pollution control and spillage response plans, incident reporting, chemical usage requirements, waste management plans, plant service procedures, communication, and reporting structures and timeline of work. It will detail the final design selected and take into account Marine Licence Conditions.

20.9.2.4 *Data gaps and uncertainties*

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

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

20.9.3 Impact Assessment

Using the scenarios and assumptions established in Section 20.9.1.2, Figure 20.5 presents the CO_2e emissions associated with the Offshore Development.

Figure 20.5 Total emissions from the Offshore Development, by phase, for worst case (High emissions) and comparison (Low emissions) scenario

The potential CO_2e savings of the Offshore Development (i.e. the displacement of CO_2e emissions from other more carbon-intensive forms of electricity generation by the Offshore Development during the operation and maintenance phase) are calculated as shown in Table 20.26.

Table 20.26 Avoided CO_2e emissions from the Offshore Development for worst case (High emissions) and comparison (Low emissions) scenario

Emission Scenario	Annual Generation (GWh)	Emission Factor (tCO_2e/GWh)	Annual CO_2e Emissions Avoided (t)
Worst case (High emissions)	331	400	132,400
Comparison (Low emissions)	415		166,000

Table 20.27 incorporates the CO_2e emissions associated with the Offshore Development (Figure 20.5) and the avoided emissions to present the net CO_2e emissions from the Offshore Development. Negative net CO_2e emissions represent the displaced equivalent emissions (i.e. the “avoided” emissions). The greater the negative number the greater the emissions avoided.

Table 20.27 Net emissions from the Offshore Development for worst case (High emissions) and comparison (Low emissions) scenario

Emission Scenario	Emissions (million tonnes CO_2e)			
	Installation	Operations	Decommissioning	Life-cycle
Worst case (High emissions)	0.73	-3.43	0.14	-2.57
Comparison (Low emissions)	0.23	-4.47	0.07	-4.17

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

The payback period is calculated as seven years for the worst case (High emissions) scenario and two years for the comparison (Low emissions) scenario. This is illustrated in Figure 20.6 and Figure 20.7. The actual payback period is likely to occur within the range of these estimates.

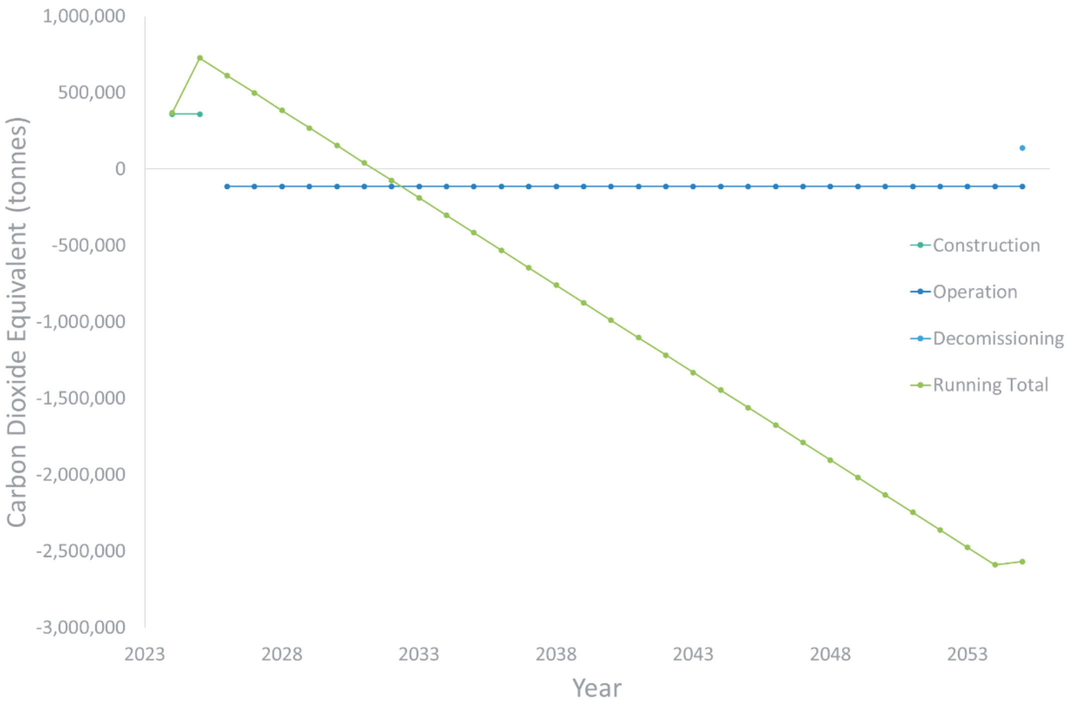

Figure 20.6 Worst case (High emissions) scenario: CO_2e emissions from the Offshore Development, including avoided emissions

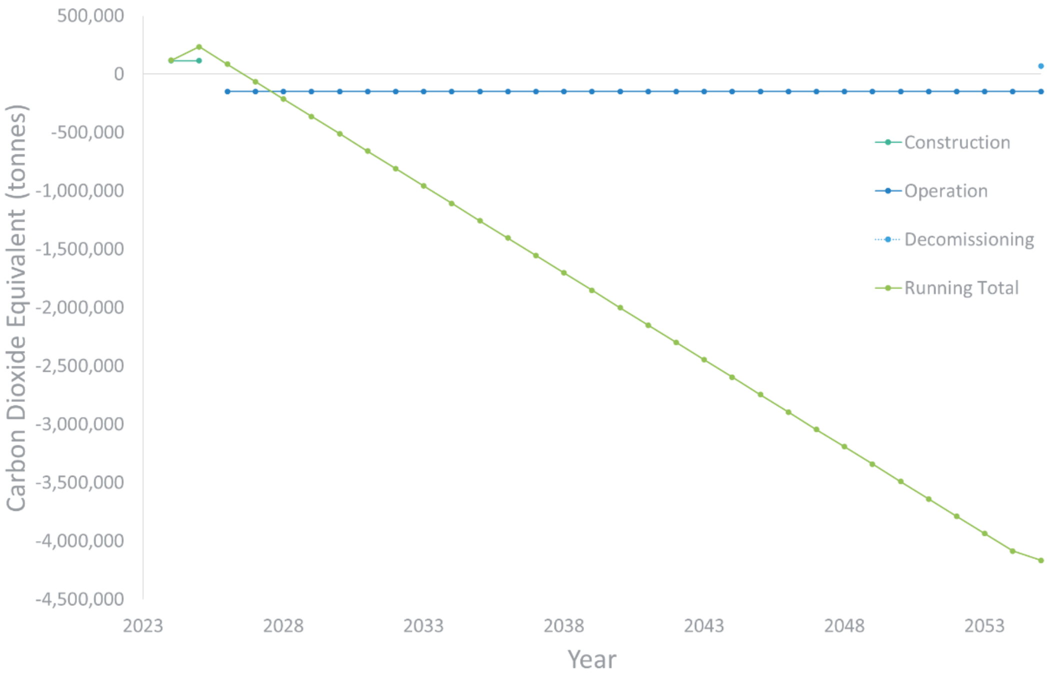

Figure 20.7 Comparison (Low emissions) scenario: CO_2e emissions from the Offshore Development, including avoided emissions

Table 20.28 presents the Offshore Development's net CO_2e emissions (vessels and embodied carbon) against the UK Carbon Budgets. During the 2023 to 2027 carbon accounting period, emissions associated with pre-construction and construction phases of the Offshore Development and initial electricity generation are assumed to occur from the Offshore Development. As carbon budgets are not yet determined past 2037, it is not possible to quantify the percentage of the Offshore Development's CO_2e emissions between 2038 and 2056 (the estimated end date for the operational phase of the Offshore Development). Overall, the Offshore Development under either scenario will make a positive contribution to the UK Carbon Budgets, avoiding emissions that would have been associated with more carbon-intensive forms of electricity generation.

Table 20.28 Offshore Development net CO_2e emissions against the UK Carbon Budget (Committee on Climate Change, 2020)

Emission Item		Carbon Accounting Period		
		2023 to 2027	2028 to 2032	2033 to 2037
UK Carbon Budget for Period (tonnes CO_2e)		1,950,000,000	1,765,000,000	965,000,000
Offshore Development emissions for period (net tonnes CO_2e)	Worst case (High emissions)	497,134	- 571,706	- 571,706
	Comparison scenario (Low emissions)	-64,647	- 744,800	- 744,800
Development CO_2e emissions as a % of UK budget	Worst case (High emissions)	0.03%	-0.03%	-0.06%
	Comparison scenario (Low emissions)	-0.003%	-0.04%	-0.08%

Based on Table 20.21 and Table 20.28, the overall magnitude of emissions from the Development would be **negligible** (decrease) and therefore any consequence would be expected to be **minor** (beneficial).

20.10 Assessment of Transboundary Effects

The potential for transboundary effects on the receptors considered within the in-combination climate assessment in Section 20.7.3 has been considered in Chapters 7 to 21. No in-combination climate impacts were assessed as significant, therefore there are no anticipated changes to the assessment of transboundary effects conducted in Chapters 7 to 21.

As demonstrated by the carbon assessment in Section 20.9.1, the Offshore Development contributes to the avoidance of emissions which would otherwise be released into the atmosphere from the burning of fossil fuels to generate electricity. This reduces any potential transboundary effects which would otherwise occur.

20.11 Assessment of Impacts Cumulatively with the Onshore Development

The Onshore Development components are summarised in Chapter 5: Project Description. These Project aspects have been considered in relation to the impacts assessed within this Chapter.

The potential cumulative impacts with the Onshore Development on the receptors considered within the in-combination climate assessment in Section 20.7.3 has been considered in Chapters 7 to 21. No in-combination climate impacts were assessed as significant, therefore, there are no anticipated changes to the assessment of impacts cumulatively with the Onshore Development conducted in Chapters 7 to 21.

20.12 Monitoring and Mitigation Requirements

There is no requirement for additional mitigation over and above the embedded mitigation, management plans and specific measures proposed for the Offshore Development in Chapters 7 to 21.

20.13 Inter-relationships

Interrelated effects describe the potential interaction of multiple project impacts upon one receptor which may interact to create a more significant impact on a receptor than when considered in isolation. Interrelated effects may have a temporal or spatial element and may be short-term, temporary, or longer-term over the life-cycle of the Offshore Development.

In line with the Scoping Opinion and Scoping Addendum Opinion received, this chapter has assessed impacts relating to climate and carbon, as outlined in Section 20.5. Therefore, it is considered that the assessment and conclusions presented in Sections 20.6, 20.7, 20.8, and 20.9 provide a complete and robust assessment of all potential impacts assessed. The potential for interrelated effects on the receptors considered within the in-combination climate assessment in Section 20.7.3 has been considered in Chapters 7 to 21. No interrelated effects, beyond those presented in Chapters 7 to 21 have been identified.

Where the assessment contained in this chapter is considered within other assessment chapters, a summary of these inter-relationships is presented below in Table 20.29.

Table 20.29 Inter-relationships identified with Commercial Fisheries and other receptors in this Offshore EIAR

Receptor	Impact	Description
Marine Physical and Coastal Process	All impacts resulting from the operation and maintenance of the Offshore Development on marine and physical processes.	The potential for the impacts from the Offshore Development to be reduced or exacerbated by climate change has been considered in Section 20.7.
Water and Sediment Quality	All impacts resulting from the operation and maintenance of the Offshore Development on water and sediment quality	The potential for the impacts from the Offshore Development to be reduced or exacerbated by climate change has been considered in Section 20.7.
Benthic Ecology	All impacts resulting from the operation and maintenance of the Offshore Development on benthic ecology receptors.	The potential for the impacts from the Offshore Development to be reduced or exacerbated by climate change has been considered in Section 20.7.
	Impact of the loss or disturbance of benthic habitats on blue carbon.	Loss or disturbance of blue carbon habitats such as kelp beds may occur as a result of the Offshore Development activities. The impact of loss or disturbance of benthic habitats is assessed in Chapter 9: Benthic Ecology and assessed in further detail in this chapter in relation to blue carbon.
Fish and Shellfish Ecology	All impacts resulting from the operation and maintenance of the Offshore Development on fish and shellfish ecology.	The potential for the impacts from the Offshore Development to be reduced or exacerbated by climate change has been considered in Section 20.7.
Marine Mammals and other Megafauna	All impacts resulting from the operation and maintenance of the Offshore Development on marine mammals and megafauna.	The potential for the impacts from the Offshore Development to be reduced or exacerbated by climate change has been considered in Section 20.7.
Marine Ornithology	All impacts resulting from the operation and maintenance of the Offshore Development on fish and shellfish ecology.	The potential for the impacts from the Offshore Development to be reduced or exacerbated by climate change has been considered in Section 20.7.

20.14 Summary and Residual Effects

Table 20.30 summarises the climate change resilience review, in-combination climate impact assessment, the blue carbon assessment and the life-cycle analysis.

Table 20.30 Summary of assessments

Assessment	Summary	Significance	Mitigation Identified	Significance of Residual Effect
Climate Resilience Review	The Offshore Development infrastructure was assessed as having a minor risk level for resilience against projected changes from: > Increased frequency of high wind events; > Increased mean maximum wave heights; > Increased air and sea temperature; and > Sea level rise and coastal erosion.	No significant effects identified.	There is no requirement for additional mitigation over and above the embedded and specific mitigation measures proposed in Chapters 7 to 21.	No significant effects identified.
In-combination Climate Impact Assessment	The consequence of the in-combination climate impact for the receptors considered within the EIAR was assessed as minor for all receptors.	No significant effects identified.	There is no requirement for additional mitigation over and above the embedded and specific mitigation measures proposed in Chapters 7 to 21.	No significant effects identified.
Blue Carbon Assessment	The activities associated with the Offshore Development are unlikely to impact the carbon sequestration potential of the immediate seabed and associated habitats, based on the localised spatial change and low frequency of disturbance / loss expected to occur through the life-cycle of the Offshore Development. As such effects are assessed as minor.	No significant effects identified.	There is no requirement for additional mitigation over and above the embedded and specific mitigation measures proposed in Chapters 7 to 21.	No significant effects identified.
Carbon Assessment	The carbon assessment demonstrates that the Offshore Development under either scenario, will make a positive contribution to the UK Carbon Budgets, avoiding emissions that would have been associated with more carbon-intensive forms of electricity generation. As such effects are assessed as minor	No significant effects identified.	There is no requirement for additional mitigation over and above the embedded and specific mitigation measures proposed in Chapters 7 to 21.	No significant effects identified.

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