Cenos Offshore Windfarm Limited

Cenos EIA

Chapter 20 – Carbon and Greenhouse Gases

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XODUS

Aberdeen

www.xodusgroup.com

5th Floor Capitol Building
429-431 Union Street . Aberdeen
AB11 6DA . UK

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ACRONYMS

ACRONYM	DEFINITION
Arg	Aragonite
AC	Alternating Current
AMOC	Atlantic Meridional Overturning Circulation
BEIS	Department for Business, Energy & Industrial Strategy
BSL	Benthic Solutions Ltd
CCC	Climate Change Committee
CES	Crown Estate Scotland
CMIP	Coupled Model Intercomparison Project
CMS	Construction Method Statement
CO_2e	Carbon Dioxide equivalent
cm	Centimetre
DC	Direct Current
DEFRA	Department for Environment Food and Rural Affairs
DESNZ	Department for Energy Security and Net Zero
DUKES	Digest of UK Energy Statistics
EEA	European Economic Area
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EICB	Export/Import Cable Bundle
EICC	Export/Import Cable Corridor
EMF	Electromagnetic Fields
EMP	Environmental Management Plan
FAD	Fish Aggregation Device
FTU	Floating Turbine Unit
$gC/m^2/yr$	Grams of carbon per metre squared per year
gCO_2e/kWh	Grams of CO_2e per kilowatt-hour
GHG	Greenhouse Gas
GWP	Global Warming Potential
HDD	Horizontal Directional Drilling
HRA	Habitats Regulations Appraisal

ACRONYM	DEFINITION
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IAC	Inter-Array Cable
ICCI	In-Combination Climate Impact
ICE	Inventory of Carbon and Energy
IEMA	Institute of Environmental Management and Assessment
IN	Innovation Projects
INNS	Invasive Non-Native Species
INNSMP	Invasive Non-Native Species Management Plan
INTOG	Innovation and Targeted Oil & Gas
IPCC	Intergovernmental Panel on Climate Change
JNCC	Joint Nature Conservation Committee
kg/m^2	Kilogramme per metre squared
km	Kilometre
kWh	Kilowatt-Hour
LCA	Life Cycle Assessment
MCCIP	Marine Climate Change Impact Partnership
MD-LOT	Marine Directorate – Licensing Operations Team
MD-MAU	Marine Directorate – Marine Analytical Unit
MD-SEDD	Marine Directorate – Science Evidence, Data and Digital
MHWS	Mean High Water Springs
MLA	Marine Licence Application
MLWS	Mean Low Water Springs
MPA	Marine Protected Area
MPCP	Marine Pollution Contingency Plan
Mt	Million tonnes
$MtCO_2e$	Million tonnes of CO_2e
MW	Megawatt
MWh	Megawatt Hour
NAO	North Atlantic Oscillation
NCMPA	Nature Conservation Marine Protected Area
NG	National Grid
NM	Nautical Mile

ACRONYM	DEFINITION
OSCP	Offshore Substation Converter Platform
PAS	Publicly Available Standard
PMF	Priority Marine Feature
PSU	Practical Salinity Unit
RCP	Representative Concentration Pathway
RICS	Royal Institution of Chartered Surveyors
RLB	Red Line Boundary
SAC	Special Area of Conservation
SPA	Special Protection Area
SLR	Sea Level Rise
SST	Sea Surface Temperature
SF_6	Sulphur Hexafluoride
tCO_2e	Tonnes of CO_2e
TLP	Tension Leg Platform
TOC	Total Organic Carbon
µmol	Micromole
UK	United Kingdom
UKCP	United Kingdom Climate Projections
UKCS	United Kingdom Continental Shelf
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WRI	World Resources Institute
WTG	Wind Turbine Generator

GLOSSARY

TERM	DEFINITION
2023 Scoping Opinion	Scoping Opinion received in June 2023, superseded by the 2024 Scoping Opinion.
2023 Scoping Report	Environmental Impact Assessment (EIA) Scoping Report submitted in 2023, superseded by the 2024 Scoping Report.
2024 Scoping Opinion	Scoping Opinion received in September 2024, superseding the 2023 Scoping Opinion.
2024 Scoping Report	EIA Scoping Report submitted in April 2024, superseding the 2023 Scoping Report.
Area of Opportunity	The area in which the limits of electricity transmission via High Voltage Alternating Current (HVAC) cables can reach oil and gas assets for decarbonisation. This area is based on assets within a 100 kilometre (km) radius of the Array Area.
Array Area	The area within which the Wind Turbine Generators (WTGs), floating substructures, moorings and anchors, Offshore Substation Converter Platforms (OSCPs) and Inter-Array Cables (IAC) will be present.
Cenos Offshore Windfarm ('the Project')	'The Project' is the term used to describe Cenos Offshore Windfarm. The Project is a floating offshore windfarm located in the North Sea, with a generating capacity of up to 1,350 Megawatts (MW). The Project which defines the Red Line Boundary (RLB) for the Section 36 Consent and Marine Licence Applications (MLA), includes all offshore components seaward of Mean High Water Springs (MHWS) (WTGs, OSCPs, cables, floating substructures moorings and anchors and all other associated infrastructure). The Project is the focus of this Environmental Impact Assessment Report (EIAR).
Cenos Offshore Windfarm Ltd. (The Applicant)	The Applicant for the Section 36 Consent and associated Marine Licences.
Cumulative Assessment	The consideration of potential impacts that could occur cumulatively with other relevant projects, plans, and activities that could result in a cumulative effect on receptors.
Developer	Cenos Offshore Windfarm Ltd., a Joint Venture between Flotation Energy and Vårgrønn As (Vårgrønn).

TERM	DEFINITION
Environmental Impact Assessment (EIA)	The statutory process of evaluating the likely significant environmental effects of a proposed project or development. Assessment of the potential impact of the proposed Project on the physical, biological and human environment during construction, operation and maintenance and decommissioning.
Environmental Impact Assessment Regulations	This term is used to refer to the Environmental Impact Assessment Regulations which are of relevance to the Project. This includes the Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017, the Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017 (as amended); and the Marine Works (Environmental Impact Assessment) Regulations 2007.
Environmental Impact Assessment Report	A report documenting the findings of the EIA for the Project in accordance with relevant EIA Regulations.
Export/Import Cable	High voltage cable used to export/import power between the OSCPs and Landfall.
Export/Import Cable Bundle (EICB)	Comprising two Export/Import Cables and one fibre-optic cable bundled in a single trench.
Export/Import Cable Corridor (EICC)	The area within which the Export/Import Cable Route will be planned and the Export/Import Cable will be laid, from the perimeter of the Array Area to MHWS.
Export/Import Cable Route	The area within the Export/Import Export Corridor (EICC) within which the Export/Import Cable Bundle (EICB) is laid, from the perimeter of the Array Area to MHWS.
Floating Turbine Unit (FTU)	The equipment associated with electricity generation comprising the WTG, the floating substructure which supports the WTG, mooring system and the dynamic section of the IAC.
Flotation Energy	Joint venture partner in Cenos Offshore Windfarm Ltd.
Habitats Regulations	The Habitats Directive (Directive 92/43/ECC) and the Wild Birds Directive (Directive 2009/147/EC) were transposed into Scottish Law by the Conservation (Natural Habitats &c) Regulations 1994 ('Habitats Regulations') (up to 12 NM); by the Conservation of Offshore Marine Habitats and Species Regulations 2017 ('Offshore Marine Regulations') (beyond 12 NM); the Conservation of Habitats and Species Regulations

TERM	DEFINITION
	2017 (of relevance to consents under Section 36 of the Electricity Act 1989); the Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001; and the Wildlife and Countryside Act 1981. The Habitats Regulations set out the stages of the Habitats Regulations Appraisal (HRA) process required to assess the potential impacts of a proposed project on European Sites (Special Areas of Conservation, Special Protection Areas, candidate SACs and SPAs and Ramsar Sites).
Habitats Regulations Appraisal	The assessment of the impacts of implementing a plan or policy on a European Site, the purpose being to consider the impacts of a project against conservation objectives of the site and to ascertain whether it would adversely affect the integrity of the site.
High Voltage Alternating Current (HVAC)	Refers to high voltage electricity in Alternating Current (AC) form which is produced by the WTGs and flows through the IAC system to the OSCPs. HVAC may also be used for onward power transmission from the OSCPs to assets or to shore over shorter distances.
High Voltage Direct Current (HVDC)	Refers to high voltage electricity in Direct Current (DC) form which is converted from HVAC to HVDC at the OSCPs and transmitted to shore over longer distances.
Horizontal Directional Drilling (HDD)	An engineering technique for laying cables that avoids open trenches by drilling between two locations beneath the ground's surface.
Innovation and Targeted Oil & Gas (INTOG)	In November 2022, the Crown Estate Scotland (CES) announced the Innovation and Targeted Oil & Gas (INTOG) Leasing Round, to help enable this sector-wide commitment to decarbonisation. INTOG allowed developers to apply for seabed rights to develop offshore windfarms for the purpose of providing low carbon electricity to power oil and gas installations and help to decarbonise the sector. Cenos is an INTOG project and in November 2023 secured an Exclusivity Agreement as part of the INTOG leasing round.
Inter-Array Cable (IAC)	The cables which connect the WTGs to the OSCPs. WTGs may be connected with IACs into a hub or in series as a 'string' or a 'loop' such that power from the connected WTGs is gathered to the OSCPs via a single cable.
Joint Venture	The commercial partnership between Flotation Energy and Vårgrønn, the shareholders which hold the Exclusivity Agreement with CES to develop the Cenos site as an INTOG project.

TERM	DEFINITION
Landfall	The area where the Export/Import Cable from the Array Area will be brought ashore. The interface between the offshore and onshore environments.
Marine Licence	Licence required for certain activities in the marine environment and granted under the Marine and Coastal Access Act 2009 and/or the Marine (Scotland) Act 2010.
Marine Protected Area (MPA)	Marine sites protected at the national level under the Marine (Scotland) Act 2010 out to 12 NM, and the Marine and Coastal Access Act 2009 between 12-200 NM. In Scotland MPAs are areas of sea and seabed defined so as to protect habitats, wildlife, geology, underseas landforms, historic shipwrecks and to demonstrate sustainable management of the sea.
Marine Protected Area (MPA) Assessment	A three-step process for determining whether there is a significant risk that a proposed development could hinder the achievement of the conservation objectives of an MPA.
Mean High Water Springs (MHWS)	The height of Mean High Water Springs is the average throughout the year, of two successive high waters, during a 24-hour period in each month when the range of the tide is at its greatest.
Mean Low Water Springs (MLWS)	The height of Mean Low Water Springs is the average throughout a year of the heights of two successive low waters during periods of 24 hours (approximately once a fortnight).
Mitigation Measures	Measures considered within the topic-specific chapters in order to avoid impacts or reduce them to acceptable levels. • Primary mitigation - measures that are an inherent part of the design of the Project which reduce or avoid the likelihood or magnitude of an adverse environmental effect, including location or design; • Secondary mitigation – additional measures implemented to further reduce environmental effects to 'not significant' levels (where appropriate) and do not form part of the fundamental design of the Project; and • Tertiary mitigation – measures that are implemented in accordance with industry standard practice or to meet legislative requirements and are independent of the EIA (i.e. they would be implemented regardless of the findings of the EIA). Primary and tertiary mitigation are referred to as embedded mitigation. Secondary mitigation is referred to as additional mitigation.

TERM	DEFINITION
Mooring System	Comprising the mooring lines and anchors, the mooring system connects the floating substructure to the seabed, provides station-keeping capability for the floating substructure and contributes to the stability of the floating substructure and WTG.
Nature Conservation Marine Protected Area (NCMPA)	MPA designated by Scottish Ministers in the interests of nature conservation under the Marine (Scotland) Act 2010.
Offshore Substation Converter Platforms (OSCPs)	An offshore platform on a fixed jacket substructure, containing electrical equipment to aggregate the power from the WTGs and convert power between HVAC and HVDC for export/import via the export/import cable to/from the shore. The OSCPs will also act as power distribution stations for the Oil & Gas platforms.
Onward Development	Transmission projects which are anticipated to be brought forward for development by 3rd party oil and gas operators to enable electrification of assets via electricity generated by the Project. All Onward Development will subject to separate marine licensing and permitting requirements.
Onward Development Area	The area within which oil and gas assets would have the potential to be electrified by the Project.
Onward Development Connections	Oil and gas assets located in the waters surrounding the Array Area will be electrified via transmission infrastructure which will connect to the Project's OSCPs. These transmission cables are referred to as Onward Development Connections.
Project Area	The area that encompasses both the Array Area and EICC.
Project Design Envelope	A description of the range of possible elements that make up the Project design options under consideration and that are assessed as part of the EIA for the Project.
Study Area	Receptor specific area where potential impacts from the Project could occur.
Transboundary Assessment	The consideration of impacts from the Project which have the potential to have a significant effect on another European Economic Area (EEA) state's environment. Where there is a potential for a transboundary effect, as a result of the Project, these are assessed within the relevant EIA chapter.

TERM	DEFINITION
Transmission Infrastructure	The infrastructure responsible for moving electricity from generating stations to substations, load areas, assets and the electrical grid, comprising the OSCPs, and associated substructure, and the Export/Import Cable.
Vårgrønn As (Vårgrønn)	Joint venture partner in Cenos Offshore Windfarm Ltd.
Wind Turbine Generator (WTG)	The equipment associated with electricity generation from available wind resource, comprising the surface components located above the supporting substructure (e.g., tower, nacelle, hub, blades, and any necessary power transformation equipment, generators, and switchgears).
Worst-Case Scenario	The worst-case scenario based on the Project Design Envelope which varies by receptor and/or impact pathway identified.

20 CARBON AND GREENHOUSE GASES

20.1 Introduction

This chapter of the Environmental Impact Assessment Report (EIAR) presents the Climate, Carbon and Greenhouse Gas (GHG)[1] assessment for the Project. The structure of this chapter differs from other topics within this EIAR, as it does not consider the impact of the Project on a specific receptor, but instead considers any potential impact of the Project on the climate, as well as the combined impact of climate and the Project on the environment. The structure of this chapter aligns with relevant legislation, policy and guidance (see Section 20.2):

- Future marine environment baseline – which describes the future climate baseline over the lifetime of the Project, focussing on key changes in climate variables that will affect the physical, biological and socio-economic environment (Section 20.4.6);
- Carbon and GHG assessment–- the carbon life cycle emissions resulting from the Project and the carbon payback period (Section 20.6.1);
- In-Combination Climate Impact (ICCI) assessment – which assesses the combined effects of the Project, as assessed in within this EIAR, and climate change on the physical, biological and socio-economic environment (Section 20.6.2); and
- Blue carbon assessment–- which assess the disturbance or loss of blue carbon stores[2] (Section 20.6.3).

Figure 20-1 shows the outline process for the assessments presented within this chapter, including the key aspects that have informed the assessments.

[1] *GHG refers to gases that absorb infrared radiation in the atmosphere, warming the earth. GHG include carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.*

[2] *Blue carbon refers to carbon captured by biological metabolic processes, i.e. in the soft tissues, shells, and skeletons of plants and animals, and buried in the marine environment in marine sediment (Porter et al., 2020).*

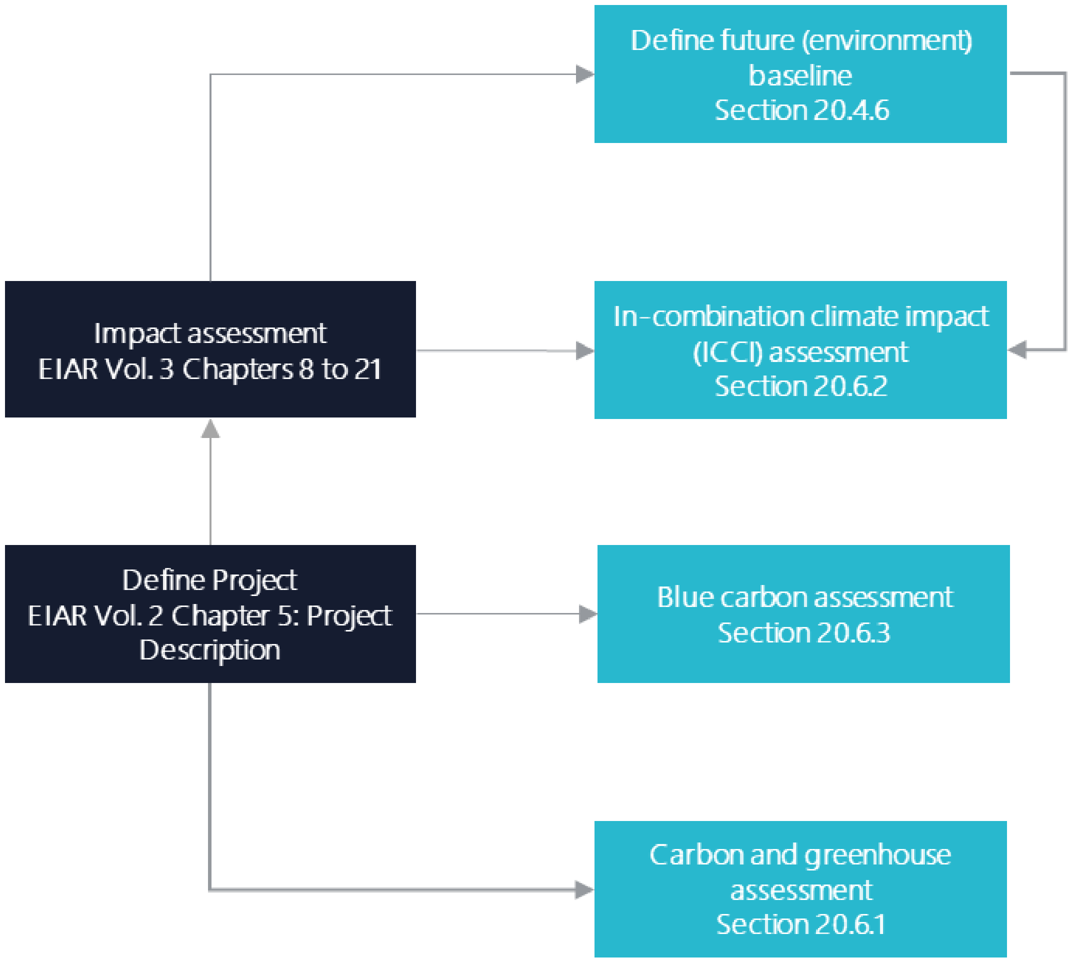

Figure 20-1 Outline process for the Climate, Carbon and GHG assessments

The impact assessment presented herein draws upon information presented within other impact assessments within this EIAR, including:

- EIAR Vol. 3, Chapter 8: Marine Geology, Oceanography and Coastal Processes – to inform the ICCI assessment for this topic;
- EIAR Vol. 3, Chapter 10: Benthic Ecology – provides an overview of the benthic habitats present within the Project Area (including potential blue carbon habitats) and also informs the ICCI assessment for this topic;
- EIAR Vol. 3, Chapter 11: Marine Mammal Ecology – to inform the ICCI assessment for this topic
- EIAR Vol. 3, Chapter 12: Ornithology – to inform the ICCI assessment for this topic; and
- EIAR Vol. 3, Chapter 13: Fish and Shellfish Ecology – to inform the ICCI assessment for this topic.

Where information is used to inform the impact assessment, reference to the relevant EIAR chapter is given.

This chapter does not consider the vulnerability of the Project to climate change, as this was scoped out of the EIAR within the 2024 Scoping Report (see Section 20.5.2).

The following specialists have contributed to the assessment:

- Jane Gordon, Xodus;
- Craig Stenton, Xodus; .
- Mairi Dorward, Xodus.

20.2 Legislation, policy, and guidance

The wider marine planning, legislation, policy and guidance is discussed in EIAR Vol. 2, Chapter 3: Policy and Legislative Context. The following legislation, policy, and guidance are relevant to the Climate, Carbon and GHG assessment:

- Legislation:
  - International:
    - United Nations (UN) Framework Convention on Climate Change (UNFCCC) (1992):
      - The UNFCCC was adopted with the ultimate aim of preventing dangerous human interference with the Climate system. The Kyoto Protocol and the Paris agreement then built on the Convention.
    - The Kyoto Protocol (1997):
      - The Kyoto Protocol committed industrialised countries and economies in transition to limit and reduced GHG emissions in accordance with agreed targets.
    - The Paris Agreement (2015):
      - The Paris Agreement aims to hold the increase in the global temperature average to well below 2°C above pre-industrial levels and limit the temperature increase to 1.5°C above pre-industrial levels.
  - National:
    - The Climate Change (Scotland) Act 2009: Section 1 of this legislation originally set a target for an 80% reduction in emissions by the year 2050. Subsequent amendments to this legislation were made (see below) to increase the ambition of Scotland's emissions reduction targets.
    - The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019: This legislation increased the ambition of Scotland's emissions reduction target within Section 1 of The Climate Change (Scotland) Act 2009 to net zero by 2045 and revised interim and annual emissions reduction targets). However, the Climate Change (Emissions Reduction Targets) (Scotland) Bill[3], introduced on 5th September 2024 aims to amend the Climate Change (Scotland) Act 2009 to account for advice from the Climate Change Committee (CCC) that the current targets are overly ambitious. At the time of writing (November 2024), the Bill has passed Stage 3 and the decision has been made to pass the Bill and will become an Act of the Scottish Parliament once it receives Royal Assent from the King. The Climate Change (Emissions Reduction Targets) (Scotland) Bill will replace the interim and annual targets and instead will make reference to Scottish carbon budget targets, which will cover total tonnes of carbon dioxide equivalent (CO_2e) for a given period. The Scottish carbon budgets will cover a five-year period, with the exception of the final budget period, and Scottish Ministers will be required to set these budgets via secondary legislation. The EIA Regulations for

[3] https://www.parliament.scot/bills-and-laws/bills/s6/climate-change-emissions-reduction-targets-scotland-bill

the Project, including The Marine Works (Environmental Impact Assessment) Regulations 2007 (for the Project); The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017 (as amended); The Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017 (as amended);:

- Schedule 3 of The Marine Works (Environmental Impact Assessment) Regulations 2007 and Schedule 4 of the other EIA Regulations requires:
  - A description of the relevant aspects of the current state of the environment (the "baseline scenario") and an outline of the likely evolution thereof without implementation of the project as far as natural changes from the baseline scenario can be assessed with reasonable effort on the basis of the availability of environmental information and scientific knowledge;
  - A description of the aspects of the environment likely to be significantly affected by the development, including, in particular, population, fauna, flora, soil, water, air, climatic factors, material assets, including the architectural and archaeological heritage, and landscape; and
  - A description of the likely significant effects of the development on the environment resulting from the impact of the project on climate (for example the nature and magnitude of GHG emissions) and the vulnerability of the project to climate change[4].

- Policy:
  - Climate change policy:
    - Blue Economy Vision (Scottish Government, 2022a): This plan sets out the long-term vision for Scotland's Blue Economy (the marine, coastal and the inter-linked freshwater environment) and identifies six outcomes up to 2045 to deliver on the aspirations for the marine environment. Of the six outcomes, those related to this chapter are:
      - Scotland's marine ecosystems are healthy and functioning, with nature protected and activities managed using an ecosystem-based approach to ensure negative impacts on marine ecosystems are minimised and, where possible, reversed; and
      - Scotland's blue economy is resilient to climate change, contributing to climate mitigation and adaptation, with marine sectors decarbonised, resource efficient and supporting Scotland's Net Zero and Nature Positive commitments.
    - Scottish biodiversity strategy post-2020: statement of intent (Scottish Government, 2020): Sets the direction for a new biodiversity strategy which will respond to the increased urgency for action to tackle the twin challenges of biodiversity loss and climate change.
    - British Energy Security Strategy (Department for Business, Energy & Industrial Strategy (BEIS), 2022a): A 10-point plan, primarily focussed on investment in the North Sea to reduce dependence on imported oil and gas and deliver an accelerated transition from fossil fuels.
    - United Kingdom (UK) Net Zero Strategy: Build Back Greener (BEIS, 2021): This document outlines the detailed long-term plan to achieve net zero by 2050. Specifically, it outlines the policies to ensure that the UK remains within the upcoming carbon budgets to place the UK on the path to achieve net zero.
  - Marine planning policy:
    - Scotland's National Marine Plan[5] (Scottish Government, 2015): This plan 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

[4] This chapter does not consider the vulnerability of the Project to climate change, as this was scoped out of the EIAR within the 2024 Scoping Report (see Section 20.3).

[5] Following the most recent review of the NMP in 2021, the Scottish Ministers announced, in 2022, their intention to update the National Marine Plan. This update is underway but has not yet reached a draft consultation stage.

in any impact assessment. A stakeholder engagement strategy and statement of public participation was published in August 2024. Policies relevant to this chapter include:

  - GEN 5 – *"Marine planners and decision makers must act in the best way calculated to mitigate, and adapt to, climate change"*.
  - Renewables 7 – "*Marine planners and decision makers should ensure infrastructure is fit for purpose now and in the future. Consideration should be given to the potential for climate change impacts on coasts vulnerable to erosion*".

- The Innovation and Targeted Oil & Gas (INTOG) Decarbonisation Sectoral Marine Plan (Scottish Government, 2022b): The INTOG Decarbonisation Sectoral Marine Plan provides a strategic framework for offshore wind projects in sustainable locations to help deliver net zero commitments, with a focus on the delivery of smaller innovation projects (IN) and the provision of low-carbon electricity to the offshore oil and gas sector (TOG).

- Guidance:
  - Institute of Environmental Management and Assessment (IEMA) Environmental Impact Assessment Guide to Climate Change Resilience and Adaptation (IEMA, 2020): This document serves as a reference point and guidance for considering climate change resilience and adaptation in EIA;
  - IEMA Environmental Impact Assessment Guidance to Assessing Greenhouse Gas Emissions and Evaluating their Significance – 2nd Edition (IEMA, 2022): This guide provides assistance with addressing GHG emissions assessment and mitigation in EIAs and complements the climate change guidance;
  - Offshore wind industry product carbon foot printing guidance (Carbon Trust, 2024);
  - Publicly Available Standard (PAS) 2080:2023 – Carbon management in buildings and infrastructure (BSI, 2023): PAS 2080:2023 is a standard that specifies the requirements for the management of whole-life carbon in buildings and infrastructure. It guides organizations in holistic carbon management, reducing costs, fostering industry leadership, and adapting to a low carbon future. The assessment methodology considers this framework, specifically for evaluating distinct phases in the project lifecycle;
  - The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (GHG Protocol) (World Resources Institute (WRI) and World Business Council for Sustainable Development, 2015): This resource establishes standards and guidance for creating a GHG emissions inventory. It encompasses the accounting and reporting of the six GHGs outlined in the Kyoto Protocol. In the assessment methodology, these six GHGs are collectively treated as CO_2e;
  - Whole life carbon assessment for the built environment (Royal Institution of Chartered Surveyors (RICS, 2024)): This guidance notes outlines standard's requirements when completing a whole life carbon assessment; and
  - Sixth Carbon Budget Report Sector Summaries – Electricity Generation (CCC, 2020). This document provides a summary of the content pertaining to the electricity generation sector in the Sixth Carbon Budget Advice from the CCC. The CCC's recommended carbon budget allocations for the electricity generation sector are as follows: Fourth carbon budget (2023 to 2027): 1,950 million tonnes of CO_2e ($MtCO_2e$); Fifth carbon budget (2028 to 2032): 1,725 $MtCO_2e$; and Sixth carbon budget (2033 to 2037): 965 $MtCO_2e$.

20.3 Scoping and consultation

Stakeholder consultation has been ongoing throughout the EIA and has played an important part in ensuring the scope of the baseline characterisation and impact assessment are appropriate with respect to the Project and the requirements of the regulators and their advisors.

The 2024 Scoping Report was submitted to Marine Directorate – Licensing Operations Team (MD-LOT) in April 2024; relevant stakeholders were consulted and the Scoping Opinion received in September 2024. The 2024 Scoping Report and the 2024 Scoping Opinion supersede the 2023 Scoping Report and the 2023 Scoping Opinion for the Project. Relevant comments from the 2024 Scoping Opinion and other consultation specific to the Climate, Carbon and GHG assessment are provided in Table 20-1 below, which provides a high-level response on how these comments have been addressed within the EIAR.

A Scoping Workshop was held on the 29th February 2024 (as detailed in EIAR Vol. 2, Chapter 1: Introduction). The Applicant sought feedback from stakeholders on the 2024 Scoping Report ahead of submission during this workshop, however, no responses were provided in relation to the Climate, Carbon and GHG assessment. No further consultation has been undertaken throughout the pre-application phase for the Climate, Carbon and GHG assessment.

Table 20-1 Comments from the Scoping Opinion relevant to the Climate, Carbon and GHG assessment

REGULATOR/CONSULTEE	COMMENT	RESPONSE
Scottish Ministers	The Developer considers the impacts of Greenhouse Gas ("GHG") emissions as a result of the Proposed Development in chapter 23 of the Scoping Report. The impacts proposed to be scoped into the EIA Report for the Proposed Development are detailed in table 23-5 in the Scoping Report. The Scottish Ministers note that the Developer sets out the proposed approach to the GHG assessment in section 23.11.2 of the Scoping Report and that it aligns with the IEMA Environmental Impact Assessment Guide "Assessing Greenhouse Gas Emissions And Evaluating Their Significance" ("IEMA GHG Guidance"). The Scottish Ministers are content with this approach noting that the GHG Assessment will be based on a Life Cycle Assessment ("LCA") approach. The Scottish Ministers acknowledge that this will include the pre-construction, construction, operation and decommissioning phases, however, highlight that this should also include consideration of the supply chain as well as benefits beyond the life cycle of the Proposed Development.	This carbon and GHG assessment has considered all phases of the Project, including manufacturing of materials and components through to decommissioning. This includes consideration of the supply chain. This has been based on an LCA approach, as requested. The Project will have a positive contribution to achieving the UK carbon budget and will avoid the use of more carbon-intensive forms of energy production, such as fossil-fuels, as outlined in Section 20.6.1.4.
Scottish Ministers	Alongside the GHG assessment, the Scottish Ministers highlight the NatureScot representation in relation to blue carbon assessment. The Scottish Ministers advise that consideration should be given to impacts on blue carbon as a result of the Proposed Development, as well as an expanded assessment for benthic ecology focusing on potential impacts on marine sediments.	The blue carbon assessment is included in Section 20.6.3. The assessment considers the potential disturbance or loss blue carbon habitats as well as the potential remineralisation of CO_2 as a result of disturbance of marine sediments.
Scottish Ministers	The Developer considers the potential impact of climate change to the Proposed Development in chapter 22 of the Scoping Report and proposes to scope out all potential impacts as detailed in table 22-11. In section 22.9 of the Scoping Report, the Developer proposes to scope in in-combination climate change impacts but this will be assessed within the relevant receptor chapters of the EIA Report as opposed to a standalone assessment. Transboundary effects relative to climate change resilience is proposed to be scoped out as	Noted, impacts relating to climate change resilience (i.e. the vulnerability of the Project to climate change) have been scoped out of the EIAR. Since the submission of the 2024 Scoping Report, the Applicant has decided to include the ICCI assessment within this chapter in Section 20.6.2.

REGULATOR/CONSULTEE	COMMENT	RESPONSE
	stated in section 22.10 of the Scoping Report. The Scottish Ministers are content with this approach.	
NatureScot	The impact of climate change effects should be considered, both in futureproofing the project design and how certain climate stressors may work in combination with potential effects from the proposed wind farm. The EIA Report 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 (noting our concerns above). We recognise that some aspects of this are addressed in Sections 22 and 23 (Climate Change Resilience and Carbon and Greenhouse Gases).	In terms of futureproofing Project design in relation to climate change, the 2024 Scoping Report outlines how the Project is resilient to climate change and this has been scoped out of the EIAR. The Applicant notes NatureScot's concerns regarding climate change raised in the Scoping Opinion and the potential role of green energy production, such as "*Our corporate plan – A nature-rich future for all 2022-2026, indicates the steps required to tackle the climate emergency and the nature crisis in Scotland. In addition, world events in 2022 continue to shine a spotlight on energy security requirements across Europe and beyond. However, we are in a climate-nature crisis because of our historic and continuing use of fossil fuels and our management actions on land and in water.*" The ICCI assessment, which assesses how climate stressors may exacerbate or diminish the effects of the Project, is included within this chapter in Section 20.6.2. The carbon and GHG assessment has considered all phases of the Project, including manufacturing of materials and components through to decommissioning. The Project will have a positive contribution to achieving the UK carbon budget and will avoid the use of more carbon-intensive forms of energy production, such as fossil-fuels, as outlined in Section 20.6.1.4.

REGULATOR/CONSULTEE	COMMENT	RESPONSE
NatureScot	In addition to the climate change assessments outlined in Section 22 of the EIA Scoping Report, we recommend that consideration is given to impacts on blue carbon and whether or not an assessment can be undertaken. This should expand on the information and assessment conducted for benthic ecology to focus on the potential impacts of the proposed development on marine sediments and coastal habitats.	The blue carbon assessment is included in Section 20.6.3. The assessment considers the potential disturbance or loss blue carbon habitats as well as the potential remineralisation of CO_2 as a result of disturbance of marine sediments.

20.4 Baseline characterisation

This Section outlines the current baseline for Climate, Carbon and GHGs within the Climate, Carbon and GHG Study Area. This baseline characterisation provides an overview of the blue carbon resources at the Project Area and describes the future marine environment over the lifetime of the Project to inform the ICCI assessment.

20.4.1 Study Area

The Study Area varies across the different assessments provided within this chapter, as set out below:

- Carbon and GHG assessment:
  - Project Area, including the Array Area and Export/Import Cable Corridor (EICC). However, emissions associated with the infrastructure and activities required for the construction, operation and maintenance and decommissioning phases of the Project are considered, and consequently, emissions which occur outside the Project Area are also considered as required (e.g. vessel movements and embodied carbon emissions). The impacts of GHG emissions are not geographically bounded and the carbon and GHG assessment is placed in the context of national carbon budgets;
- Blue carbon assessment:
  - Project Area, including the Array Area and EICC; and
- ICCI assessment:
  - The Study Area for each EIA topic is defined as per EIAR Vol. 3, Chapters 8 to 22.

The Climate, Carbon and GHG assessment temporal scope is defined as the entire lifetime of the Project including construction, operation and maintenance and decommissioning.

20.4.2 Data sources

The existing data sets and literature with relevant coverage to the Project, which have been used to inform the baseline characterisation for Carbon and Greenhouse Gases are outlined in Table 20-2. Project specific data obtained and used to inform this topic assessment are presented in Section 20.4.3.

Table 20-2 Summary of key datasets and reports

TITLE	SOURCE	YEAR	AUTHOR
Reports prepared and published by the Marine Climate Change Impact Partnership (MCCIP)	https://www.mccip.org.uk/all-uk/uk-impacts/hub	2020 – 2023	MCCIP
UKCP 18	https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/science/science-reports	2023	Met Office
NatureScot Research Report 1326 – Scottish Blue Carbon – a literature review of the current evidence for Scotland's blue carbon habitats	https://www.nature.scot/doc/naturescot-research-report-1326-scottish-blue-carbon-literature-review-current-evidence-scotlands	2023	Cunningham and Hunt
The United Kingdom's Blue carbon inventory: Assessment of marine carbon storage and sequestration potential in Scotland (including within Marine Protected Areas)	https://www.wildlifetrusts.org/sites/default/files/2024-09/Scotland%20-%20scientific%20report.pdf	2024	Burrows *et al.*
Assessment of carbon budgets and potential blue carbon stores in Scotland's coastal and marine environment	https://www.nature.scot/sites/default/files/Publication%202014%20-%20SNH%20Commissioned%20Report%20761%20-%20Assessment%20of%20carbon%20budgets%20and%20potential%20blue%20carbon%20stores%20in%20Scotland%27s%20coastal%20and%20marine%20environment.pdf	2014	Burrows *et al.*
Marine Sedimentary Carbon Stocks of the United Kingdom's Exclusive Economic Zone	https://www.frontiersin.org/journals/earth-science/articles/10.3389/feart.2021.593324/full	2021	Smeaton *et al.*
Re-Evaluating Scotland's Sedimentary Carbon Stocks	https://data.marine.gov.scot/dataset/re-evaluating-scotland%E2%80%99s-sedimentary-carbon-stocks	2020	Smeaton *et al.*
Assessment of Blue Carbon Resources in Scotland's Inshore Marine Protected Area Network	https://www.nature.scot/sites/default/files/Publication%202017%20-%20SNH%20Commissioned%20Report%20957%20-%20Assessment%20of%20Blue%20Carbon%20Resources%20in%20Scotland%27s%20Inshore%20Marine%20Protected%20Area%20Network.pdf	2017	Burrows *et al.*

20.4.3 Project site-specific surveys

A benthic and environmental survey including habitat assessment was completed in the Array Area and along the offshore EICC[6] by Rovco and Benthic Solutions Ltd (BSL) between July and September 2023 (EIAR Vol. 4, Appendix 11: Environmental Baseline Report – OWF and EIAR Vol. 4, Appendix 12: Environmental Baseline Report - EICC). A further habitat assessment survey for the inshore EICC[7] was carried out by SEP Hydrographic Ltd and BSL in March 2024 (EIAR Vol. 4, Appendix 10: Environmental Baseline and Habitat Assessment Report - Inshore EICC). As part of the survey campaign grab samples, video footage and geophysical survey data were collected across the Array Area and the EICC (see EIAR Vol. 3, Chapter 10: Benthic Ecology for further detail). The habitats and sediment types recorded during the Project site-specific surveys have been used to understand the distribution of potential blue carbon habitats and sediments across the Project Area.

20.4.4 Carbon and GHG assessment baseline

As outlined in IEMA (2022), the baseline for the carbon and GHG assessment is the reference point against which the impact of a new project can be compared against and considers the GHG emissions within the Project Area in the absence of the Project (i.e. the emissions prior to construction and operation of the Project). As there is no physical development or activity within the Project Area, the existing baseline emissions at the Project Area are assumed to be zero. Section 20.4.4 outlines the avoided emissions over the life cycle of the Project if the equivalent electricity generated from the Project was provided from the national grid.

20.4.5 Blue carbon baseline

Blue carbon is defined as the inorganic and organic carbon[8] stored in the coastal and marine environment, such as in marine sediment and blue carbon habitats (e.g. marshes, kelp forests, and seagrass meadows) (Cunningham & Hunt, 2023). Marine sediments, and particularly deep sea sediments, are the primary store of biologically derived carbon (mostly inorganic carbon). Carbon stored in organisms can be broadly defined as either 'transient' stores, such as the carbon that is temporarily stored in the living tissues of seagrass beds, kelp and macroalgae; and 'long-term' biological stores, such as biogenic structures (e.g. coral reefs, serpulid reefs, mussel beds). Biogenic structures release CO_2 during the process of calcification but also trap organic carbon, which if buried, may equal the CO_2 released (Burrows *et al.*, 2024). In Scotland, blue carbon habitats include vegetated coastal habitats (e.g. saltmarsh), vegetated inshore habitats (e.g. seagrass and kelp beds) and calcifying aggregations (e.g. maerl beds and biogenic reefs) as well as seabed sediments.

Seabed sediment holds the majority of the carbon stock in the Scottish seas (Cunningham & Hunt, 2023; Burrows *et al.*, 2024). Scotland's total standing stock of carbon in its marine sediment (surficial sediments in the top 10 centimetres (cm) of the seabed) was estimated as 152 million tonnes (Mt) of organic carbon and 1,021 Mt of inorganic carbon (Smeaton *et al.*, 2021; Burrows *et al.*, 2024). The total sequestration capacity of sediment long-term stores across

[6] The term 'offshore EICC' refers to the part of the EICC that extends beyond 12 NM limit.

[7] The term 'inshore EICC' refers to the part of the EICC that extends from HDD exit point to 12 NM limit.

[8] Organic carbon is carbon that originates from the fixing of carbon in living tissues and is found in living and dead tissues, in organic rich detritus, as dissolved organic carbon and particulate organic carbon. Inorganic carbon refers to carbon dioxide that is dissolved in seawater and is found in the form of calcium carbonate ($CaCO_3$) (Cunningham and Hunt, 2023).

Scottish seas was estimated as 9.5 Mt organic carbon per year and 0.8 Mt inorganic carbon per year (Burrows *et al.*, 2024).

Patterns of standing stocks and sequestration capacity of organic carbon follow the distribution of mud and mud-sand-gravel combinations. Finer muddy sediments generally have a higher concentration of particulate organic carbon. Coarser sediments are generally subject to more rapid carbon cycling due to water flowing more freely through the surface sediments, and therefore contain lower organic carbon concentrations (Burrows *et al.*, 2024) Carbon burial rates vary significantly by sediment type and location, with uncertainties in the estimates of the total standing stock of carbon based on the lack of available data to constrain burial rates across large shelf areas (Smeaton *et al.*, 2021; Burrows *et al.*, 2024). It is estimated that coastal sediment, muddy sediment, estuaries and Scottish fjords contain significantly more organic carbon than other habitat types, dominating carbon accumulation around the UK. Deep muds off the continental shelf of Scotland were found to have the largest stock of organic carbon of all sediment habitats (Smeaton *et al.*, 2021; Burrows *et al.*, 2024).

There is considerable uncertainty surrounding estimates of accumulation rates for organic carbon into sublittoral mud across Scottish seas. Generally, accumulation rates for organic carbon into sand and sand/mud sediments are moderate compared to rates in other sediment types such as muddy sediments (sand: average 0.2 grams of carbon per metre squared per year (gC/m^2/yr) and sand/mud – average 0.5 gC/m^2/yr) (Diesing *et al.*, 2021; Burrows *et al.*, 2024). Estimates for accumulation rates of muddy sediments are typically higher, and Burrows *et al.* (2014) estimated an average of 155 gC/m^2/yr, which is similar to rates in fjordic sediments (146 gC/m^2/yr; Burrows *et al.* 2024), although a more recent study by Diesing *et al*. (2021) suggests that offshore mud habitats, particularly in the North Sea, may accumulate organic carbon more slowly at a rate of 0.2-3 gC/m^2/yr (highest rates in the northern parts of the North Sea), which reflects the uncertainty in accumulation rates of organic carbon in Scotland's marine sediments.

As described in EIAR Vol. 3, Chapter 10: Benthic Ecology, the predicted habitats for the Array Area are primarily 'Offshore circalittoral mud' (SS.Smu.Omu/MD6) with relatively low levels of 'Offshore circalittoral mixed sediment' (SS.SMx.Omx/MD4). The majority of the offshore EICC is composed of 'Offshore circalittoral sand' (SS.Ssa.Osa/MD5) with moderate proportions of fines and minimal proportions of gravel. On the approach to the Array Area, sediments transition to 'Offshore circalittoral mud'. The inshore EICC is composed of the sediment types 'Offshore circalittoral sand' (SS.Ssa.Osa/MD521), 'Offshore circalittoral coarse sediment' (SS.SCS.OCS/MD321), 'Circalittoral muddy sand' (SS.Ssa.CmuSa/MC52), 'Circalittoral mixed sediment', 'Moderate energy circalittoral rock' (CR.MCR/MC12) and '*Sabellaria spinulosa* encrusted circalittoral rock' (CR.MCR.Csab.Sspi/MC2213) (EIAR Vol. 4, Appendix 10: Environmental Baseline and Habitat Assessment Report - Inshore EICC). 'Offshore deep-sea muds' were not found in the inshore EICC.

The carbon density of the surficial sediments (top 10 cm) in the Project Area is estimated to be relatively low (Figure 20-2; Smeaton *et al*., 2020). The Project Area contains <1 kilogramme per metre squared (kg/m^2) of organic carbon (Min = 0.073 kg/m^2, max = 0.7 kg/m^2). The inorganic carbon ranges from 0-4.1 kg/m^2 across the Project Area, with the highest carbon stock found in the EICC (mean organic carbon stock in the EICC = 0.76 kg/m^2) (Smeaton *et al.*, 2020). As presented in EIAR Vol. 3, Chapter 9: Marine Water and Sediment Quality, the Total Organic Carbon (TOC) was analysed in 50 locations during Project-specific surveys. The minimum values observed for TOC were in the EICC (0.13%), with maximum values of 0.51% in the Array Area. Overall, TOC ranged from 0.22% to 0.51% in the Array Area and 0.13% to 0.27% in the EICC.

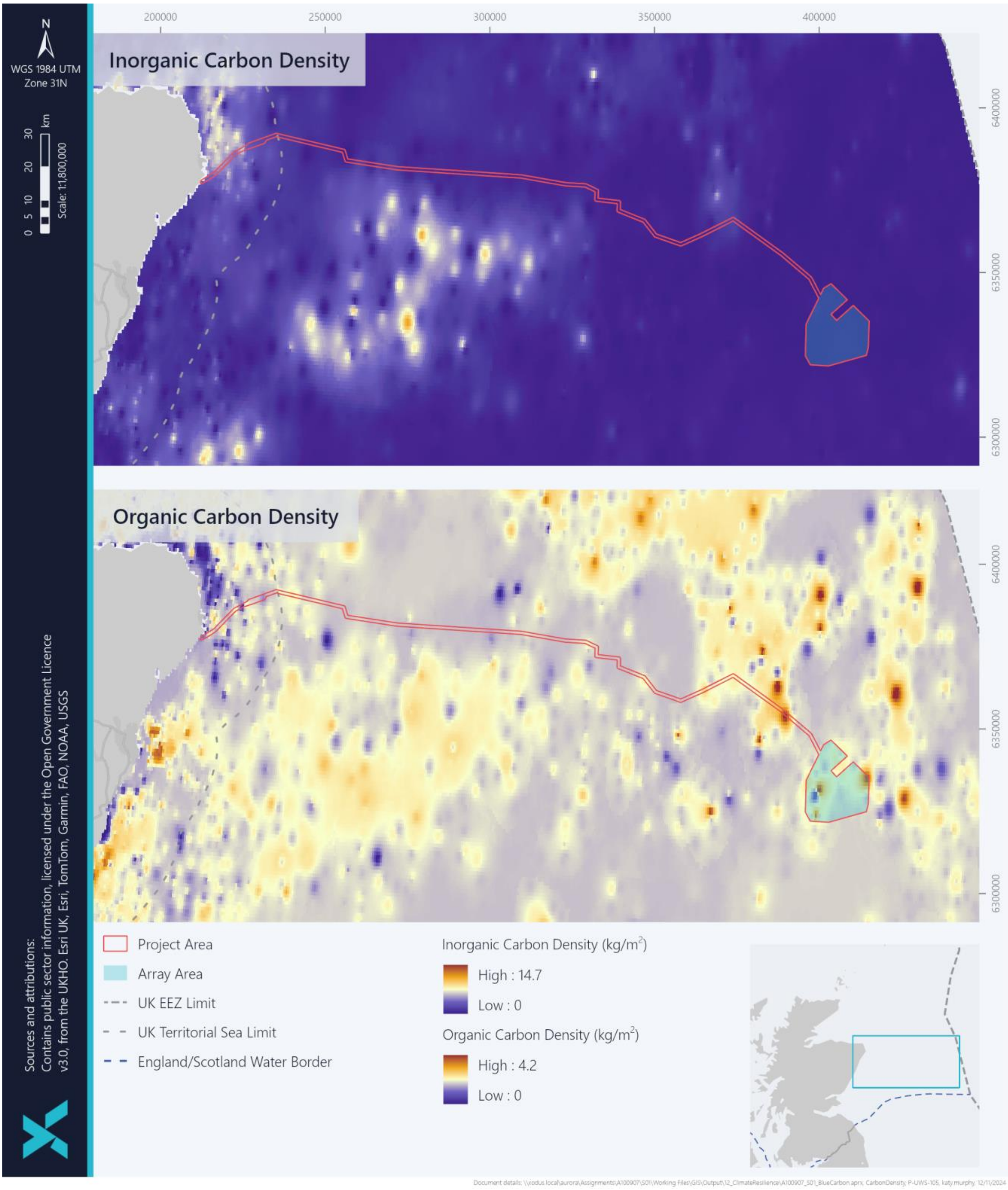

Figure 20-2 Carbon densities (kg/m^2) in the top 10 cm sediment layer of the Project Area (Smeaton et al., 2020)

Scotland's biogenic marine habitats are highly productive places, with a very high rate of assimilation of carbon into plant material (328 grams of 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.*, 2024). A summary of the benthic habitats identified within the Project Area during site-specific surveys is provided in EIAR Vol. 3, Chapter 10: Benthic Ecology. Brittlestars (*Ophiothrix fragilis*) were identified within the offshore EICC but are not noted as being present in extensive aggregations or 'beds'. Similarly, *Flustra foliacea* were also identified as being present within the inshore EICC. Both brittlestar beds and *F. foliacea* are calcifying organisms, and are therefore, potential blue carbon habitats. Recent studies estimated brittlestar bed carbon densities of 135 gC/m^2, representing an inorganic carbon density of 79.19 gC/m^2 and F. *foliacea* turf carbon densities of 503 gC/m^2, representing an organic carbon density of 473 gC/m^2 and an inorganic carbon density of 30 gC/m^2 (Porter *et al.*, 2020; Cunningham & Hunt, 2023). Neither of these species were observed extensively throughout the EICC, and the site-specific survey revealed the majority of the inshore EICC was relatively featureless. Therefore, the blue carbon contribution within the Project Area by 'autochthonous' blue carbon habitats (i.e. carbon directly captured by biological metabolic processes (e.g. photosynthesis and calcification) is considered to be negligible.

The EICC crosses the Southern Trench Nature Conservation Marine Protected Area (NCMPA), which has a total carbon stock of 5.28 Mt, largely attributed to inorganic carbon, and an accumulation rate of organic carbon of 52.35 gC/m^2/yr. Organic carbon densities are estimated at 0.326 kg/m^2, and inorganic carbon densities of 1.875 kg/m^2 (Burrows *et al.*, 2024). The blue carbon habitats within the NCMPA include sandy and muddy sediment, as well as brittlestar beds, kelp beds, and *Mytilus edulis* beds (Burrows *et al.*, 2017). Brittlestar beds provide the majority of the biological material for carbon fixation within the NCMPA (99.57%; 18,172 tonnes/year), although the standing stock is largely within the intertidal macroalgae and the kelp beds (Burrows *et al.*, 2017).

The Array Area is located within the East of Gannet and Montrose Fields NCMPA which is designated for the Priority Marine Feature (PMF) 'Offshore deep-sea muds'. The spatial extent of 'Offshore deep-sea muds' in the NCMPA is approximately 900 km^2. I spatial extent of the mapped 'Offshore deep-sea muds' feature of this NCMPA is 333 km^2 (i.e. the full extent of the Array Area). As noted above, the site-specific surveys mapped 'Offshore circalittoral mud' across the majority of the Array Area (a component biotope of the 'Offshore deep sea muds' PMF). The East of Gannet and Montrose Fields NCMPA has a total carbon stock of 0.9 Mt and an accumulation rate of organic carbon of 48.56 gC/m^2/yr. Average organic carbon densities are estimated at 0.329 kg/m^2, and inorganic carbon densities are estimated at 0.157 kg/m^2 (Burrows *et al.*, 2024).

20.4.6 Future marine environment baseline characterisation

This section describes historic climate trends, future projections, and the potential indirect impact of climate change on physical, biological and socio-economic receptors to inform the ICCI assessment presented in Section 20.6.2. 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. As a worst-case, values for Representative Concentration Pathway (RCP) 8.5 are reported[9]. RCP 8.5 represents the 'high' emissions for growth where GHG are unmitigated (Met Office, 2018). Therefore, climate projections for any other scenario should theoretically be within those of RCP 8.5 (noting the uncertainties around climate change projections in Section 20.4.8). Where available,

[9] *Representative Concentration Pathways represent climate change scenarios used in modelling possible future climate evolution. Based on a wide suite of assumptions, RCP pathways specify GHG concentrations that will result in defined radiative forcing by 2100. See here:* *https://www.ipcc.ch/report/ar5/syr/*

environmental changes over the 35-year operation and maintenance phase of the Project are described. However, predictions to 2100 and beyond are considered for some climate variables, where the data is only available over this timescale.

The two key sources of climate projections include the MCCIP and the United Kingdom Climate Projections (UKCP) 18. The UKCP18 is a climate analysis tool that forms part of the Met Office Hadley Centre Climate Programme and is recommended for use in the IEMA Environmental Impact Assessment Guide to Climate Change Resilience and Adaptation (IEMA, 2020). 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, 2024).

20.4.6.1 Physical environment

The sections below describe the future physical environment for the Study Area described in Section 20.4.1. The aspects of the physical environment considered include winds, storms and waves, sea surface and near bottom temperatures, dissolved oxygen, salinity and stratification, ocean acidification, and sea level rise (SLR) and coastal erosion. These elements of the physical environment are considered most relevant to the marine environment. Changes to average air temperature and precipitation levels are less influential on the marine environment, and more pertinent to terrestrial climate change impacts, and are therefore not considered in this chapter.

20.4.6.1.1 Winds, storms and waves

Analysis of observed and modelled wind and wave data can be used to identify long-term trends in weather patterns, however, the time period analysed has a strong influence on the trends identified. 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). Long-term changes in storminess and waves result from changes in atmospheric circulation (e.g. North Atlantic Oscillation; NAO), caused by natural variation or climate change. The North-east Atlantic experienced increases in wave heights between 1960 and the early 1990’s, whereas the reverse was experienced between 1992 and 2017, resulting from changes in the NAO over these periods. It is projected that the UK will experience increased storminess over this century and an intensified winter storm track and that the most extreme waves could increase in height by ~2100 under the high emissions scenario (RCP8.5).

Time-series data on mean significant wave height from 1980 – 2014 generally shows a decrease in summer and winter wave heights in the North Atlantic but an increase in the frequency of days where extreme wave heights are experienced by 0.5 days per year (Bricheno *et al.*, 2023). Trends in the UK are generally much weaker than the North East Atlantic, where changes in wave height are mainly caused by Atlantic swell rather than high wind speeds. Evidence suggests anthropogenic forcing will lead to increased storminess around the entirety of the UK coast (Bricheno *et al.*, 2023). Recent modelling studies predict that there will continue to be a general reduction in wave heights and swells, with a reduction in rough swell days by about 10% and wave-storm-spell duration by 10% consistent with end-of-century trends (Morim *et al.*, 2021 in Bricheno *et al.*, 2023). In a 1 in 100-year extreme significant wave height event scenario, Muecci *et al.* (2020) show there is statistically no significant changes in the North Atlantic but may be some significant changes for the North Sea. However, there is no firm agreement in the direction of change in extreme wave heights, and there could be an overall increase or reduction in extreme wave heights in the North Atlantic by ~10-20% (Palmer *et al.*, 2018). It is anticipated that natural variability will continue to contribute to the trends observed in the frequency and intensity of waves and storms within the North Atlantic.

With regards to wind speeds, which has a direct link to storm surges and wave projections, modelling has been limited to a handful of simulations with sufficient high frequency wind and pressure data necessary for storm surge and modelling, while wave models were limited to regional and global models (Palmer *et al.*, 2018). However, future trends in wind speeds indicate an increase particularly in winter months owing to the natural variability throughout the year (Palmer *et al.*, 2018). Coupled Model Intercomparison Project (CMIP) model projections indicate an increase in days of strong wind between 2070-2100 by 50-80% compared to past models from 1975-2005 (Palmer *et al.*, 2018).

Predictions of future UK storminess are uncertain. The limited ability of models to accurately simulate storm events may be attributed to poor representations of atmospheric blocking events or variations in jet stream latitude (Bricheno *et al.*, 2023). Overall, there is considered to be a low confidence in the future predictions for wind, storms and waves (Palmer *et al.*, 2018; Wolf *et al.*, 2020).

20.4.6.1.2 Sea surface and near bottom temperatures

Over the last 40 years, UK Sea Surface Temperature (SST) has increased by ~0.3ºC per decade. The period between 2012 and 2021 was 0.7°C warmer than the 19961-1990 average and the warmest SST on was recorded in 2020, which was 0.93ºC ±0.06°C above the average 1960-1990 baseline (Cornes *et al.*, 2023). Analysis of SST from 1981 to 2021 shows that some of the largest increases have been observed in the North Sea (the Project being located in the Central North Sea).

Under the RCP8.5 scenario, model simulations predict a continued warming trend around the UK to the end of the century (2079 – 2098). The warming is expected to be greatest across the North Sea in both SST and near-bottom temperatures, which is a continuation of the spatial pattern of the trends observed in recent decades. The increase in SST and near bottom temperatures between 2069 and 2098, relative to the 2000 to 2019 period for the Central North Sea is displayed in Table 20-3.

Table 20-3 Predicted increases in sea surface and near-bottom temperatures (comparing the 2000 and 2019 and 2069 to 2098 period) (taken from Cornes et al., 2023)

REGION	2069 – 2098 INCREASE RELATIVE TO 2000 - 2019	
	SST	NEAR BOTTOM TEMPERATURE
Central North Sea	+3.59°C (±1.07 °C)	+2.84°C (±0.96°C)

Figure 20-3 shows the sea temperature projections[10] during the operation and maintenance phase of the Project, rather than at a regional level as shown in Table 20-3. A mean seabed temperature of 8.7°C is projected at the start of the operation and maintenance phase in 2035 and of 10.4°C by cessation of operations in 2070. A mean SST of 11.8°C is projected at the start of the operation and maintenance phase in 2035, increasing to 13.8 °C by 2070. An indication of the variability in the projection is shown in light green[11].

[10] *The sea temperature projection is obtained from the NEMO-ESREM ocean model (Wakelin et al., 2020), one of the key models used to inform Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report.*

[11] *Note, 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.*

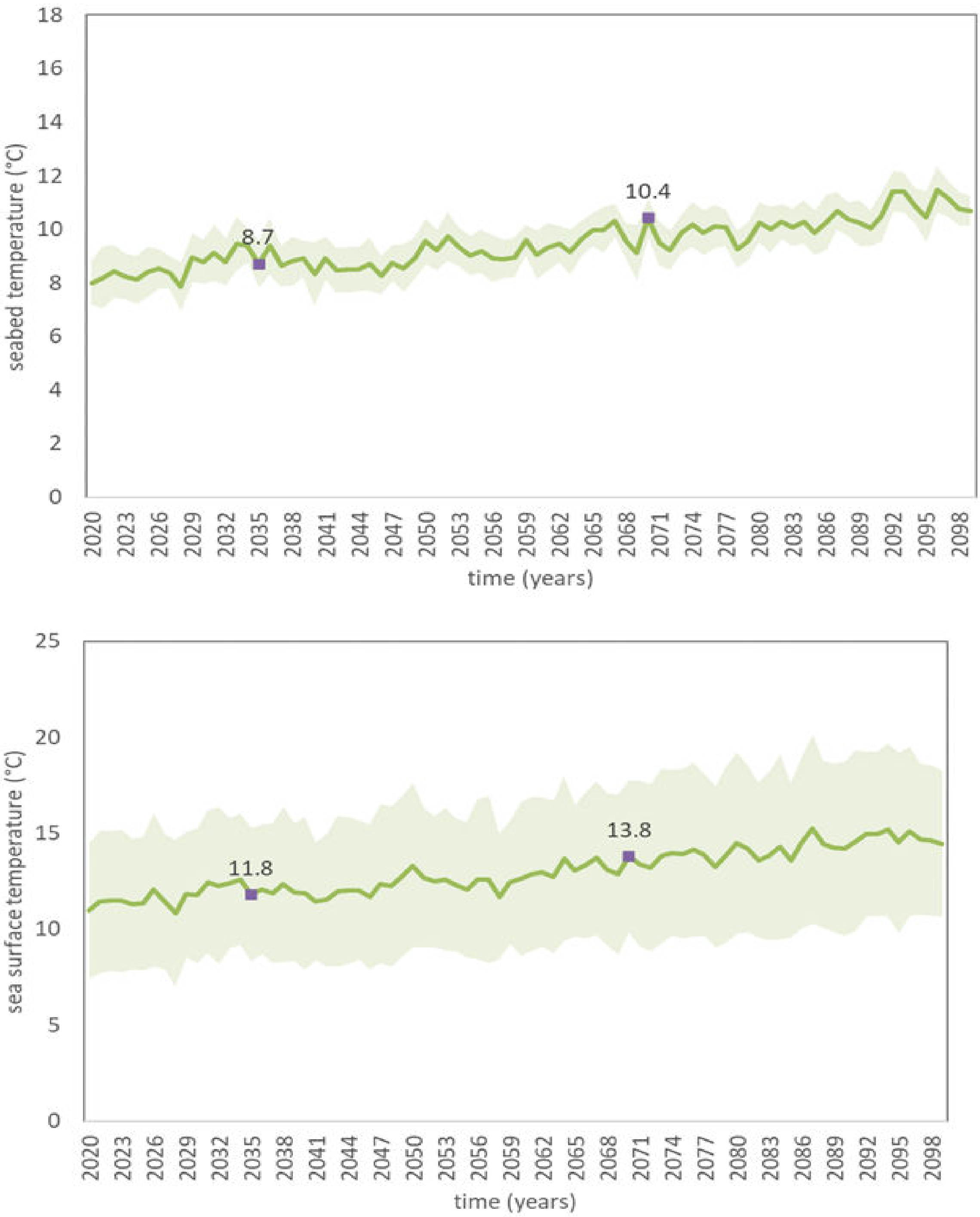

Figure 20-3 Mean seabed (top) and SST projections (bottom) for the Project Area (RCP8.5) showing predicted temperatures at the start of operations in 2035 and cessation of operations in 2070. The shaded region represents the standard deviation for each year calculated from monthly data (Wakelin et al., 2020)

20.4.6.1.3 Dissolved oxygen, salinity and stratification

The concentration of dissolved oxygen in the ocean is controlled by both physical and biological factors, for example through air-sea gas exchange and through the respiration of marine plants. Temperature plays an important role in the solubility of dissolved oxygen in water, with oxygen being more soluble in cold water and less in warm water. Globally there has been reduction in dissolved oxygen in the ocean since the mid-20th century. In coastal systems, eutrophication, the process by which a body of water becomes enriched with nutrients, leading to an increase in the growth of microorganisms and aquatic plants is a suggested factor in reduced dissolved oxygen. However, the global decline in dissolved oxygen concentrations has been attributed to warming oceans. Dissolved oxygen concentration in the North Sea typically ranges from 320 micromole (μmol)/kg (equivalent to ~ 10 mg/litre or over 100% saturation) in winter to ~192 μmol/kg in summer (equivalent to 6 mg/litre or 70% saturation) (Diaz and Rosenberg, 2008; Schmidtko *et al.*, 2017; Mahaffey *et al.*, 2023). Model predictions for the North Sea indicate a potential reduction in dissolved oxygen in the North Sea by ~5.3-9.5% by 2098. An increase in sea temperature would decrease dissolved oxygen concentrations in the water column and in bottom waters, an effect which is exacerbated by changes in stratification in the North Sea, which may result from a more rapid rise in SST compared with near-bottom temperatures[12] (Mahaffey *et al.*, 2023).

There has been evidence of a 'freshening trend' in the North Sea since the 1970s, with small areas conversely exhibiting increased salinity in line with long-term Atlantic Ocean trends. Based on information provided within the Scottish Ocean Climate Status Report (Scottish Government, 2016), the salinity in near shore regions of the Scottish coast show high variability between the 1970s and 2010s. Future salinity projections are uncertain, although confidence in these predictions is increasing (Dye *et al.*, 2020). It is expected that salinity decreases will be more pronounced for the North Sea compared with the Irish and Celtic Seas (Dye *et al.*, 2020). The predicted change in sea surface and near-bottom salinity in the Central North Sea is provided in Table 20-4.

Table 20-4 Predicted changes in sea surface and near bottom salinity (comparing 1960 to 1989 with 2069 to 2098) (taken from Dye et al. 2020)

REGION	2069 - 2098 INCREASE RELEVANT TO 1960 - 1989	
	SURFACE SALINITY (CHANGE IN PRACTICAL SALINITY UNIT (PSU))	NEAR BOTTOM SALINITY (CHANGE IN PSU)
Central North Sea	-0.48 (±0.53)	-0.47 (±0.48)

Stratification plays a role in regulating the vertical mixing in the water column of oxygen, heat, phytoplankton, salt and nutrients. The mixing is, in turn, directly linked to the functionality of marine biochemistry and ecology. Stratification occurs when a layer of less-dense water lies above denser water, due e.g. to differences in salinity. Seasonal stratification typically inhibits exchange from more mixed surface layers leading to a decrease in dissolved oxygen concentrations in surface layers during the summer. Mixing during winter months allows the layers throughout the water column to replenish their supplies of nutrients, oxygen etc. Therefore, changes in the duration and timing

[12] *Model results from Holt et al (2012) show a more rapid warming of SST than near-bottom temperatures between 1985 and 2004. This difference is expected to continue, resulting from changes in the seasonal heating cycle (Sharples et al 2023).*

of stratification could have potential negative effects on ocean biochemistry, ecology and overall health. Evidence suggests that stratification has been occurring 0.5 days earlier pear year in the North Sea since the late 1980's (Sharples *et al*., 2022). Recent model predictions indicate that stratification could occur ~ one week earlier and persist for 10-15 days longer per year for the period 2070 – 2098 compared to the 1961 – 1990 baseline, with increased strength due to increased air temperature and a more rapid warming of SST compared to near-bottom temperatures. An increase in the duration and strength of stratification could lead to dissolved oxygen deficiency in the summer months with consequences for ecosystems reliant on ocean mixing (Sharples *et al*., 2022; Mahaffey *et al*., 2023).

20.4.6.1.4 Ocean acidification

Ocean acidification occurs as increases in anthropogenic CO_2 absorbed by the ocean causes a decline in pH. The effects of ocean acidification vary. For example, invertebrates and fish species show a neutral to negative reaction to decreased pH and increased CO_2, while phytoplankton, seaweeds and algae have shown to exhibit a neutral to positive response to increased CO_2 (Findlay *et al*., 2022).

Hindcast models run by the DARE-UK project between 1990-2015 have shown that surface water pH in shelf regions has decreased by ~ -0.002 pH units per year while bottom waters in regions such as the North Sea have showed a potentially faster rates of decline at -0.005 pH units per year (Findlay *et al*., 2022).

Future predictions indicate that the shelf regions of the UK will exhibit faster rates of pH decline than have been experienced to date, due to changes in seasonal processes such as stratification (see Section 20.4.6.1.3). For example, declines in bottom water pH in areas of the North Sea where stratification is important such as the Central North Sea, as projected by RCP8.5, are between 10-15% faster than at the surface. It is predicted that by the middle of the century, as pH levels continue to decline at similar rates to the present day, shelf seas will have acidified, becoming more corrosive to calcium carbonate (argonite) with consequences for marine life in turn, leading to undersaturation (Findlay *et al*., 2022). Undersaturation occurs when the calcium carbonate saturation state of aragonite (ΩArg) is less than 1 and causes aragonite to be chemically dissolved, resulting in damage to exposed aragonite shells and skeletons. Between 1990 and 2015, the average ΩArg decline in the North Sea was modelled at -0.0079 per year. Comparatively, the 2015 – 2049 period is projected to have an average decline of ΩArg up to -0.0145 per year. By 2100, it is predicted that up to 90% of the North Sea may experience undersaturation for at least one month per year (OSPAR, 2022; Findley *et al*., 2022)

20.4.6.1.5 SLR and coastal erosion

SLR and coastal erosion are potential consequences of climate change. SLR occurs as sea ice continues to decline and as seawater expands as it warms. The global average rate of SLR has been recorded at 1.7 mm per year between 1901 and 2010. SLR at a particular location can be influenced by a range of geophysical variables discussed in other sections of this chapter such as salinity and temperature (see Sections 20.4.6.1.1 to 20.4.6.1.4) (Horsburgh *et al*., 2020).

UKCP18 projections of SLR vary regionally across the UK with the south of the UK being similar to the global mean, while the projections for the north of the UK, centred on the south east of Scotland, are much lower. Across the emissions scenarios, projected SLR by 2100 is ~0.3-0.9 mm rise for Edinburgh and Belfast and a ~0.5-1.1 m rise for London and Cardiff under RCP8.5 (Palmer *et al*., 2018; Horsburgh *et al*., 2020).

Figure 20-4 shows the sea level projections over the operation and maintenance phase of the Project, relative to a baseline period of 1981-2000. A mean SLR of 0.12 m is projected by start of operations in 2035 and of 0.35 m by cessation of operations in 2070. The range associated with the projection is shown in light blue, i.e. models project that there is 95% likelihood that a mean SLR of more than 0.07 m will occur by 2035 and 5% likelihood that a SLR of more than 0.18 m will occur by 2035. Similarly models project that there is 95% likelihood that a SLR of more than 0.20 m will occur by 2070 and 5% likelihood that a SLR of more than 0.53 m will occur by 2070[13].

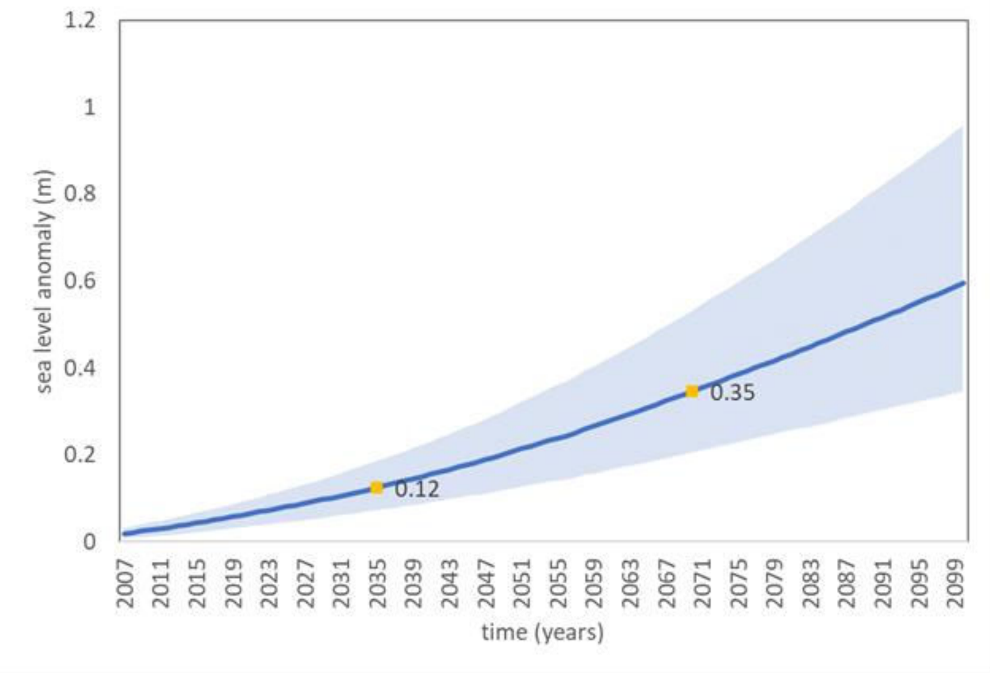

Figure 20-4 Mean sea level projections for the Project for 2007 – 2100. The shaded period represented the projected range (Source: multiple models used to inform the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report)

SLR and changes in coastal wave dynamics play a direct role in coastal erosion. Around 17% of the UK coastline is experiencing erosion >10 cm per year (Masselink *et al.*, 2020). Rates of erosion vary depending on region and coastal type, i.e., hard or mixed coastlines, soft/erodible and coastline with artificial defences. Scotland which is generally dominated by hard or mixed coastlines (~approx. 78% of Scotland's coast) is experiencing erosion along 1,298 km (11.6%) of a 11,154 km coastline (Masselink *et al.*, 2020). As explained in EIAR Vol. 3, Chapter 8: Marine Geology, Oceanography and Coastal Processes, it is predicted that 79 hectares of coastline could be lost between Cairnbulg Point to Fife Ness in the vicinity of the Project. However, at the EICC landfall specifically, erosion is unlikely to occur owing to the hard, unerodable cliffs.

20.4.6.2 Biological and socio-economic receptors

Biological and socio-economic receptors may be affected by the changes in the physical environment described in the preceding sections. Table 20-5 summarises the predicted impacts of climate change on relevant biological and socio-economic receptors.

[13] *Note, 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.*

Table 20-5 Summary of climate change impacts on biological and socio-economic receptors

RECEPTOR	SUMMARY OF FUTURE PREDICTIONS OF CLIMATE CHANGE IMPACTS	RELEVANT EIAR CHAPTER FOR FURTHER INFORMATION
Biological		
Coastal, intertidal, and subtidal habitats	Coastal, intertidal, and subtidal habitats may be directly affected by changes in the physical environment. With climate change, coastal habitats are at risk from changes in environmental conditions such as SLR, temperature and coastal erosion. SLR and coastal erosion are considered the greatest threat to coastal habitats which could cause habitat loss and degradation (Burden *et al.*, 2020). With regard to intertidal and subtidal species and habitats, observed fluctuations in abundance are consistent with changes in temperature. For example, northward shifts of warm-favouring rocky intertidal habitats have been observed and also shifts in North Sea infaunal species which correlate to temperature changes. It is predicted that further range shifts could occur with increased sea temperatures, with associated changes in community composition and the potential spread of invasive species. Some species may be subject to warmer conditions if range shifts cannot keep pace with temperature changes or if food availability increases, resulting in physiological stress. Ocean acidification may also affect intertidal and subtidal calcifying organisms (Mieszkowska *et al.*, 2020; Moore and Smale, 2020).	Further information on the coastal, intertidal, and subtidal habitats relevant to the Project Area are included in EIAR Vol. 3, Chapter 10: Benthic Ecology.
Marine mammals and megafauna	The key climate change impacts for marine mammals and megafauna include geographic range shifts, reduction or loss of suitable habitats, changes in prey abundance and distribution and increased susceptibility and spread of disease. There may be a range shift in the populations of marine mammal species as a result of increasing sea temperatures which limit or expand areas for foraging and breeding, depending on the species. This will mostly affect species closely tied to breeding or foraging grounds. For example, the reduction rising sea temperatures may lead to several humpback whale breeding grounds being at risk of increasing beyond the upper thermal	Further information on the marine mammals and megafauna receptors relevant to the Project Area are included in EIAR Vol. 3,

RECEPTOR	SUMMARY OF FUTURE PREDICTIONS OF CLIMATE CHANGE IMPACTS	RELEVANT EIAR CHAPTER FOR FURTHER INFORMATION
	limit, resulting a potential range shift. Conversely, a reduction in sea ice associated with rising sea temperatures may allow baleen whales to access more foraging grounds (Martin *et al.*, 2023). Increased temperatures at or exceeding thermal limits of marine mammals may result in physiological stress which could increase susceptibility to disease or reproductive failure (Martin *et al.*, 2023).	Chapter 11: Marine Mammal Ecology.
Ornithology	Seabirds may be affected by climate-related changes in prey abundance and distribution which affect reproductive success and overall survival. Additionally, nesting or overwintering seabirds may be affected by changes in extreme weather events, SLR and coastal erosion (Burton *et al.*, 2023). With increasing temperature, a northward shift of some species may occur. However, some species may remain at southerly latitudes and experience warmer conditions with potential physiological stress if they are unable to migrate northwards due to lack of prey (Burton *et al.*, 2023). Searle *et al.* (2022) modelled the breeding success of five seabed species (blacklegged kittiwake, common guillemot, Atlantic puffin, great black-backed gull and northern gannet) under future climate scenarios[14], and predicted declines in all species except northern gannet.	Further information on the ornithology receptors relevant to the Offshore Site are included in EIAR Vol. 3, Chapter 12: Ornithology.
Fish and shellfish ecology	Increases in the abundance of warm-water fish species have been observed across the UK and Ireland as a result of changing sea temperatures. There have been observed increases in warm-water fish species in UK waters while research into temperature changes and changes in sea chemistry (e.g. dissolved oxygen, salinity and stratification) may result in physiological effects, impacting fish growth and maturation, and also impacts on fish spawning, hatching and migration. Species that are close to or at their thermal maximum may experience higher rates of reproductive failure, and these effects will be species and region specific, with variations occurring across the UK. Future projections indicate that shifts in food-webs may occur, leading to changes in species abundance and composition, having onward effects on predator prey relationships (Fox *et al.*, 2023).	Further information on fish and shellfish ecology receptors relevant to the Project Area are included in EIAR Vol. 3, Chapter 13: Fish and Shellfish Ecology.

[14] *UKCP09 projections for the SRES Scenario A1B scenario was used, which represents the medium emission scenario.*

RECEPTOR	SUMMARY OF FUTURE PREDICTIONS OF CLIMATE CHANGE IMPACTS	RELEVANT EIAR CHAPTER FOR FURTHER INFORMATION
Socio-economic		
Commercial Fisheries	Commercial fisheries are one of the most important economic maritime activities in UK waters. To date studies have shown changes in distribution to commercially important fish and shellfish species around the UK as a result of climate change. A recent study by Wakelin *et al*. (2021) investigated the link between episodic climate events (e.g. cold spells and heatwaves) and fish stocks. Following cold spells, increased landings of cold-water species (e.g. sole and seabass) and decreased landings of warm-water species (e.g. red mullet and brown crab) were observed. Conversely, only a weak increasing trend for landings of warm-water species was observed for the years following marine heatwave events. Effects to fish stocks as a result of climate change are expected to negatively impact the fisheries industry. Townhill *et al*. (2023) projected the habitat suitability change in 2030 – 2070 compared with the 1997 – 2016 baseline for key commercial fish and shellfish species in UK waters under different emissions scenarios (RCP4.5 and RCP8.5). Approximately half of the species considered were predicted to have more suitable habitat in the future across all scenarios, whereas a significant decline of cold-water species was predicted. Some commercially important shellfish species may be affected by ocean acidification. It is expected that most species will be able to withstand the projected pH levels under the RCP8.5 scenario, although some sub-lethal effects may occur. For example, *Nephrops norvegicus* experience reduced immune response when exposed to lower pH levels (7.47 – 8.11) (Townhill *et al*., 2022). As the key impacts to commercial fisheries from climate changes are considered to be related to effects on commercially valuable fish and shellfish species which are targeted by fishers, the ICCI assessment undertaken for fish and shellfish ecology is considered applicable to the assessment of likelihood of ICCI on commercial fisheries receptors.	Further information on the commercial fisheries receptors relevant to the Project Area are included in EIAR Vol. 3, Chapter 14: Commercial Fisheries.

RECEPTOR	SUMMARY OF FUTURE PREDICTIONS OF CLIMATE CHANGE IMPACTS	RELEVANT EIAR CHAPTER FOR FURTHER INFORMATION
Shipping and Navigation	With regards to shipping and navigation (EIAR Vol. 3, Chapter 15: Shipping and Navigation), it is possible that climate change could have an effect on shipping and navigation receptors. However, given the temporal nature of climate change, any significant impacts are expected to develop in the long-term (post-operational life of the Project) rather than the short- or medium-term.	Further information on shipping and navigation receptors relevant to the Project Area are included in EIAR Vol. 3, Chapter 15: Shipping and Navigation.
Marine Archaeology	For marine archaeological receptors, climate change is not anticipated to affect buried marine archaeology sites. SLR and increased extreme weather events associated with climate change may result in the erosion and gradual destruction of coastal archaeological sites; however, overall marine archaeology receptors are considered to have a negligible sensitivity to changes in climate.	Further information on marine archaeology receptors relevant to the Project Area are included in EIAR Vol. 3, Chapter 16: Marine Archaeology.
Recreation and Tourism	Recreation and tourism activities are highly seasonal, driven by periods of optimal weather and tidal conditions. Climate change may result in unfavourable or more favourable weather and tidal conditions which may adversely or positively affect the recreation and tourism industry. Climate change may also impact recreational fishing and the wildlife tourism industry through declines in abundance of species and/or spatial and temporal changes in their distribution (Coles, 2020).	Further information on recreation and tourism receptors relevant to the Project Area are included in EIAR Vol. 3, Chapter 19: Socioeconomics, Tourism, and Recreation.

20.4.7 Summary and key issues

A summary of the key elements of the blue carbon baseline and future environment baseline are outlined in Table 20-6 below.

Table 20-6 Summary and key issues for the Climate, Carbon and GHG assessment

	PROJECT AREA
SUMMARY AND KEY ISSUES	• Blue carbon: – Carbon density in the surficial layer of sediments at the Project Area is considered to be relatively low based on modelled data. The Project Area contains a mixture of sediment types, including some mud sediments which typically have a higher organic carbon density; and – The only blue carbon habitats/species identified within the Project Area include brittlestars and *F. foliacea*. However, no extensive brittlestar beds were identified and the extent of *F. foliacea* was also low, suggesting that the blue carbon contribution of these features in the Project Area is minimal. • Future marine environment baseline: – Wind, waves and storms: ▪ Reduced mean significant wave height; ▪ Increased extreme wave heights; ▪ Increased frequency of storms; – Sea surface and near-bottom temperatures: ▪ Increased sea surface and near-bottom temperatures over the life time of the Project; ▪ Dissolved oxygen, salinity and stratification: ▪ Decreased dissolved oxygen; ▪ Decreased salinity; ▪ Earlier onset of stratification and delayed breakdown of seasonal stratification; – Ocean acidification: ▪ Decrease in pH; – SLR and coastal erosion: ▪ Increased sea level; ▪ Increased erosion of sedimentary shores along the north and east coasts of Scotland (noting the EICC landfall is located in an area of hard, unerodable cliffs); and – Biological and socio-economic receptors: ▪ Direct and indirect impacts associated with climate change.

20.4.8 Data gaps and uncertainties

In relation to the blue carbon assessment, there is uncertainty on the total annual sequestration capacity for Scotland's seabed sediments, due to a lack of available data to constrain burial rate estimates across the continental shelf (Cunningham & Hunt, 2023). Therefore, the total sequestration capacity of all seabed sediment may be significantly higher than estimated.

In relation to the future marine environment baseline, the key uncertainties associated with assessing the impact of climate change on the physical, biological and socio-economic environment include:

- Uncertainty around the assumptions for future emissions scenario and uncertainty in other model inputs and subsequent outputs of physical environmental responses, e.g., the uncertainty in projected increased storm events and extreme sea conditions;
- Uncertainty around the biochemical environmental responses, e.g., shifts in stratification timing and persistence and subsequent mixing of the water column;
- Uncertainty around the response of the biological and socio-economic environment to changes in climate variables e.g., the reaction of commercial fish stock may react differently to climate forcing creating a disparity within food webs and by extension specific commercial fisheries or the distribution, foraging and reproduction habits of differing marine megafauna; and
- Difficulties in attributing changes in the physical, biological and socio-economic environment to climate change.

20.5 Impact assessment methodology

20.5.1 Impacts requiring assessment

The impacts identified as requiring consideration for the Climate, Carbon and GHG assessment are listed in Table 20-7. Information on the nature of impact (i.e. direct or indirect) is also described.

As explained in Section 20.1, separate assessments are provided within this chapter to cover the following:

- Carbon and GHG assessment: assesses the carbon life cycle emissions (in CO_2e) resulting from the Project;
- ICCI assessment: assesses the combined impact of the Project, as assessed in within this EIAR, and climate change on the physical, biological and socio-economic environment; and
- Blue carbon assessment: assess the disturbance or loss of blue carbon stores.

Table 20-7 Impacts requiring assessment for the Climate, Carbon and GHG assessment

POTENTIAL IMPACT	NATURE OF IMPACT
Construction and decommissioning	
Carbon and GHG assessment: Construction CO_2e emissions	Direct
Blue carbon assessment: Direct, blue carbon habitat loss/disturbance (temporary)	Direct
Operation and maintenance	
Carbon and GHG assessment: Operational CO_2e emissions	Direct
ICCI assessment: The combined impact of the Project, as assessed in the EIAR, and climate change on the physical, biological and socio-economic environment	Direct
Blue carbon assessment: Direct, blue carbon habitat loss/disturbance (permanent)	Direct
Decommissioning	
Carbon and GHG assessment: Decommissioning CO_2e emissions	Direct
Blue carbon assessment: Direct blue carbon habitat loss/disturbance	Direct

20.5.2 Impacts scoped out of the assessment

The impacts scoped out of the assessment during EIA scoping, and the justification for this, are listed in Table 20-8.

Table 20-8 Impacts scoped out for the Climate, Carbon and GHG assessment

IMPACT SCOPED OUT	JUSTIFICATION
Construction	
Carbon and GHG assessment: CO_2e associated with planning activities	Pre-construction GHG emissions, originating from preliminary studies, strategy development, design, EIA, and cost planning, are expected to be negligible. Consequently, they have been deliberately excluded from the assessment. These pre-construction activities, predominantly office-based, are unlikely to have a significant impact on emissions. Adhering to IEMA (2022) guidance for GHG assessments, activities that contribute less than 1 percent to the total emissions can be omitted if they do not substantially affect the assessment results.
ICCI assessment: The combined impact of the Project, as assessed in the EIAR, and climate change on the physical, biological and socio-economic environment (i.e. ICCI assessment)	Only impacts associated with operation and maintenance are considered within the ICCI assessment, as the current climate conditions are considered to be applicable for the construction phase.
Operation and maintenance	
No operation and maintenance impacts scoped out.	
Decommissioning	
ICCI assessment: The combined impact of the Project, as assessed in the EIAR, and climate change on the physical, biological and socio-economic environment	As detailed information on the decommissioning of the Project infrastructure is limited at this time, a meaningful assessment of the in-combination impact of climate change and the Project at the time of decommissioning is not possible. An offshore Decommissioning Programme will be developed prior to decommissioning to address the principal decommissioning measures for the Project, these will be written in accordance with applicable guidance and will detail the environmental management measures and schedule for decommissioning of the Project. Any environmental management measures would reflect the environmental baseline at the time of decommissioning.

20.5.3 Assessment methodology

20.5.3.1 Carbon and GHG assessment

The carbon and GHG assessment is undertaken following the principles set out in IEMA (2022). IEMA (2022) 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 emissions assessments, 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).

In line with IEMA (2022) guidance, a development's GHG emissions should be contextualised against carbon budgets to determine the magnitude of effect and the significance of the impact, at the discretion of the practitioner. Accordingly, the Project's CO_2e emissions have been contextualised by considering the effect of Project's CO_2e emissions on the UK Carbon Budgets[15]. This is summarised in Table 20-9 and the UK Carbon Budgets are outlined in Table 20-11. Based on professional judgement, where emissions from the Project are greater than 1% of the relevant annual UK Carbon Budgets the impact of the Project on the climate is considered to be major. This is considered to be precautionary as IEMA (2022) sets an indicative threshold of a significant impact from GHG emissions as 5% of the UK or devolved administration carbon budget. The consequence of the impact further considers the contribution of the Project towards national policy targets and goals as per IEMA (2022). It should be noted that the carbon and GHG assessment considers the whole life cycle of the Project rather than drawing conclusions for individual phases.

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 (IPCC) highlighted the importance of limiting global warming below 1.5°C (IPCC, 2021).

[15] Considering the potential changes to Scotland's emission targets set by the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 as a result of the Climate Change (Emissions Reduction Targets) (Scotland) Bill (see Section 20.2), the magnitude of effect is determined by assessing the estimated emissions against the UK carbon budget.

Table 20-9 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 20-10 Consequence matrix for impact assessment

MAGNITUDE OF EMISSIONS	SENSITIVITY OF RECEPTOR: HIGH
Beneficial reduction	Beneficial: The Project's reduction in GHG emissions make a significant positive effect on UK's reduction goals.
Negligible change	Minor beneficial/adverse: The Project has minimal effects on emissions but exceeds the UK's reduction goals, demonstrating exceptional performance. The Project's GHG impacts align fully with design requirements and standards, in line with the UK's emissions reduction goals.
Small increase	Moderate adverse: The Project's GHG impacts are partially mitigated, and it only partially contributes to the UK's emissions reduction goals.
Large increase	Major adverse: The project's GHG impacts are unmitigated and do not significantly contribute to the UK's emissions reduction goals.

Table 20-11 UK carbon budget (Department for Energy Security and Net Zero (DESNZ), 2021)

BUDGET	ANNUAL CARBON BUDGET ($MtCO_2E$)	% REDUCTION BELOW BASE YEAR (1990)
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

20.5.3.2 In-combination climate impact assessment

The ICCI assessment considers how any of the predicted impacts from the Project alone could be exacerbated or reduced by any predicted future changes in the physical environment due to climate induced changes and is conducted in accordance with the IEMA (2020) Environmental Impact Assessment Guide to Climate Change Resilience and Adaptation.

The ICCI assessment considers all potential receptors outlined within the EIAR which could be impacted by the Project. The assessment considers potential impacts during the operation and maintenance phase of the Project on relevant receptors in the context of future climate conditions. It should be noted that the assessment of impacts within the topic-specific chapters of this EIAR already considers current climate conditions. As such the potential impact of the Project during the construction phase is not considered further as part of the ICCI assessment. Furthermore, in the absence of a detailed approach to Project decommissioning at this time, a meaningful ICCI assessment of potential impacts during the decommissioning phase is not possible.

All receptors assessed as part of the EIAR (EIAR Vol. 3, Chapters 8-22) are considered within the ICCI assessment. Based on the conclusions of the EIAR, the following receptors have not been considered further as part of the ICCI assessment for the following reasons:

- EIAR Vol. 3, Chapter 9: Marine Water and Sediment Quality – considered to have a negligible sensitivity to changes in climate, and therefore the likelihood of an ICCI is extremely unlikely. Marine water and sediment quality has not been considered further;
- EIAR Vol. 3, Chapter 14: Commercial Fisheries – the key impacts to commercial fisheries from climate changes are considered to be related to effects on commercially valuable fish and shellfish species which are targeted by fishers. For this reason the ICCI assessment undertaken for fish and shellfish ecology is considered applicable to the assessment of likelihood of ICCI on commercial fisheries receptors;
- EIAR Vol. 3, Chapter 15: Shipping and Navigation – considered to have a negligible sensitivity to changes in climate, and therefore the likelihood of an ICCI is extremely unlikely. Shipping and navigation has not been considered further;
- EIAR Vol. 3, Chapter 16: Marine Archaeology – considered to have a negligible sensitivity to changes in climate, and therefore the likelihood of an ICCI is extremely unlikely. Marine archaeology has not been considered further;
- EIAR Vol. 3, Chapter 17: Marine Infrastructure and Other Sea Users – considered to have a negligible sensitivity to changes in climate, and therefore the likelihood of an ICCI is extremely unlikely. Infrastructure and other users has not been considered further;
- EIAR Vol. 3, Chapter 18: Military and Civil Aviation – considered to have a negligible sensitivity to changes in climate, and therefore the likelihood of an ICCI is extremely unlikely. Military and civil aviation has not been considered further;
- EIAR Vol. 3, Chapter 19: Socio-economics, Tourism and Recreation – climate change may have a positive or negative impact on socio-economics, tourism and recreation (as outlined in Table 20-5). Positive effects may arise as a result of increased temperature, where negative effects may arise as a result of SLR and coastal erosion. For this reason the ICCI assessment undertaken for marine geology, oceanography and coastal processes is considered applicable to the assessment of likelihood of ICCI on socio-economics, tourism and recreation receptors;
- EIAR Vol. 3, Chapter 21: Major Accidents and Disasters – the vulnerability of the Project to climate was scoped out of the EIAR (see Section Table 20-1). EIAR Vol. 3, Chapter 21: Major Accidents and Disasters also considers climate hazards which could result in major accidents and disasters, including in relation to climate change. Therefore, the major accidents and disasters topic does not need included within the ICCI.

The consequence of the ICCI is determined by the likelihood and magnitude of the effect. Existing embedded mitigations and management plans (as presented in Table 20-16 below) are considered as part of the determination of likelihood and magnitude.

The definitions of likelihood and magnitude that are applicable to the ICCI assessment are presented in Table 20-12 and Table 20-13 respectively below. Defining the likelihood of ICCI occurring considers the potential for the climate projection to occur alongside the sensitivity of the receptor. Determining the likelihood of ICCI is based on expert judgement. Defining the magnitude of ICCI effects considers the change in the significance of the impact from the Project when the in-combination effects of climate change are considered.

Table 20-12 Definitions of likelihood

LIKELIHOOD	DEFINITION
Certain (>95%)	• The event or effect will occur during the life cycle of the Project (i.e., the event or effect is inevitable); and/or • The event or effect may potentially occur many times throughout the operation and maintenance phase of the Project.
Likely (66-95%)	• The event or effect is likely to occur at some point during the life cycle of the Project.
Possible (33-65%)	• The event or effect is possible during the life cycle of the Project.
Unlikely (10-32%)	• The event or effect is unlikely to occur during the life cycle of the Project.
Extremely unlikely (0-9%)	• The event or effect is extremely improbably during the life cycle of the Project.

Table 20-13 Definitions of magnitude

MAGNITUDE	DEFINITION
High	• The consequence of the impact increases to major when the in-combination effects from climate change are considered.
Moderate	• The consequence of the impact increases to moderate when the in-combination effects from climate change are considered.
Low	• The consequence of the impact increases to minor when the in-combination effects from climate change are considered.
Negligible	• The consequence of the impact will result in a very slight change from baseline conditions when the in-combination effects from climate change are considered.
No change	• There is no change in the impact when the in-combination effects from climate change are considered.

The consequence and significance of impact is then determined using the matrix provided in EIAR Vol. 2, Chapter 7: EIA Methodology. The consequence of significance provides a threshold for determining whether or not ICCI on a receptor can be concluded as 'significant' or 'not significant' in EIA terms. Any consequence that is defined as moderate or major is considered to be 'significant' in EIA terms.

Where the ICCI assessment concludes that a 'significant' impact on a receptor is likely to occur, additional mitigation measures, above those already identified in Table 20-16, will be adopted in order to reduce impacts to an acceptable, 'not significant' level, where possible.

20.5.3.3 Blue carbon assessment

It is not appropriate to quantify the carbon released or lost as a result of disturbance to blue carbon habitats or marine sediments. This is due to the uncertainties around the density of organic and inorganic carbon present in marine sediments and habitats and also the uncertainties around the fate of disturbed carbon (Cunningham and Hunt, 2023). Therefore, a qualitative assessment is provided for the blue carbon assessment, informed by the blue carbon baseline (Section 20.4.5) and the worst-case scenario Project parameters (Section 20.4.5). This is consistent with Carbon Trust guidance (Carbon Trust, 2024).

The assessment for blue carbon is undertaken following the principles set out in EIAR Vol. 2, Chapter 7: EIA Methodology. The sensitivity of the receptor is combined with the magnitude to determine the impact significance. Topic-specific sensitivity and magnitude criteria are assigned based on professional judgement, as described in Table 20-14 and Table 20-15.

Table 20-14 Sensitivity criteria

SENSITIVITY OF RECEPTOR	DEFINITION
High	• The receptor has a very low capacity to accommodate a particular effect with a low ability to recover or adapt; • The receptor has high vulnerability and low recoverability to accommodate a particular effect; and • The receptor is of high carbon stock or sequestration rate.
Medium	• The receptor has some capacity to absorb or accommodate change without significantly altering character; and • The receptor is of moderate carbon stock or sequestration rate.
Low	• The receptor has some tolerance to accommodate a particular effect or will be able to recover or adapt; and • The receptor is of low carbon stock or sequestration rate.
Negligible	• Very low importance and rarity, local receptor and is tolerant to change with no effect on its fundamental character; and • The receptor is of negligible carbon stock or sequestration rate.

Table 20-15 Magnitude criteria

MAGNITUDE CRITERIA	DEFINITION
High	• The effect occurs over a large spatial extent resulting in widespread, long-term, or permanent changes in baseline conditions or affecting a large proportion of receptor extent or population. The effect is very likely to occur and/or will occur at a high frequency or intensity.
Medium	• The effect occurs over a local to medium extent with a short- to medium-term change to baseline conditions or affects a moderate proportion of a receptor extent or population. The effect is likely to occur and/or will occur at a moderate frequency or intensity.
Low	• The effect is localised and temporary or short-term, leading to a detectable change in baseline conditions or a noticeable effect on a small proportion of a receptor extent or population. The effect is unlikely to occur or may occur but at low frequency or intensity.
Negligible	• The effect is highly localised and short-term, with full rapid recovery expected to result in very slight or imperceptible changes to baseline conditions or receptor population. The effect is very unlikely to occur; if it does, it will occur at a very low frequency or intensity.
No change	• No change from baseline condition.

The consequence and significance of the impact is then determined using the matrix provided in EIAR Vol. 2, Chapter 7: EIA Methodology.

20.5.4 Embedded mitigation

As described in EIAR Vol. 2, Chapter 7: EIA Methodology, certain measures (primary and tertiary mitigation) have been adopted as part of the Project development process to reduce the potential for impacts to the environment (Table 20-16). These have been accounted for in the assessment below. The requirement for additional mitigation measures (secondary mitigation) will be dependent on the significance of the impacts assessed.

Table 20-16 Embedded mitigation measures relevant to the Climate, Carbon and GHG assessment

CODE	MITIGATION MEASURE	TYPE	DESCRIPTION	SECURED BY
MM-002	Mooring and anchor design to ensure reduction of habitat loss and disturbance	Primary	Floating Turbine Unit (FTU) mooring designs considered for the project have excluded the catenary mooring which was identified as the design with the largest seabed footprint, therefore minimising footprint within the East of Gannet and Montrose Field NCMPA. Semi-taut and taut mooring designs options for semi-submersible substructure and tendon mooring designs for Tension Leg Platform (TLP) substructures have been retained as mooring design options for the Project because these design options produce the least disturbance and minimise potential for habitat loss. Additionally, anchor designs considered for the Project have excluded the drag embedment anchor, which was identified as the design with the greatest potential for seabed disturbance and habitat loss. Suction and driven pile anchor designs have been retained as anchor design options for the Project because they have the smallest footprint and minimise potential seabed disturbance during installation. Anchors will be installed through suction embedment or piling, rather than drilling, in order to minimise sediment disturbance. Novel anchor solutions with equivalent or similar seabed footprint have also been retained as options. Localised habitat loss during the installation phase is an unavoidable consequence of the Project. Best practices will be followed to ensure that potential habitat loss is reduced (e.g. micro-siting and reducing the benthic footprint of the Project), including during the operational phase (e.g. from mobile mooring chains on the seabed). The amount of rock armour, grout bags, and concrete mattresses used to protect the Export/Import Cable(s) and the IACs will be kept to a minimum where possible, especially in the NCMPAs.	Commitment made within Project design. The final design will be detailed within the Construction Method Statement (CMS), required under Section 36 Consent and/or Marine Licence conditions.
MM-006	Environmental Management Plan (EMP)	Tertiary	The EMP will set out procedures to ensure all activities with the potential to affect the environment are appropriately managed and will include a description of planned activities and procedures, roles and responsibilities, pollution control and spillage response plans, incident reporting, chemical usage requirements, waste management plans, plant service procedures,	The EMP, including the INNSMP and MPCP, will be required under Section 36

CODE	MITIGATION MEASURE	TYPE	DESCRIPTION	SECURED BY
			communication and reporting structures, and programme of work. It will detail the final design selected and take into account Marine Licence conditions and commitments. The EMP will additionally include an Invasive Non Native Species (INNS) Management Plan (INNSMP) and a Marine Pollution Contingency Plan (MPCP) and will be developed in consultation with stakeholders.	Consent and/or Marine Licence conditions. An outline EMP is provided as part of the Application EIAR Vol. 4 Appendix 32: Outline Environmental Management Report.
MM-009	Decommissioning Programme	Tertiary	The development of, and adherence to, a Decommissioning Programme, approved by Scottish Ministers prior to construction and updated throughout the Project's operational life. This will be written in accordance with applicable guidance and will detail the required activities, programme and environmental management for decommissioning.	The Decommissioning Programme will be required under Section 105 of the Energy Act 2004 (as amended) and a condition of the Section 36 Consent.
MM-049	Opportunities for the reduction of GHG emissions will be embedded throughout the Project lifecycle	Primary	These opportunities will be determined at each phase of the Project and include sustainable product selection and raw material use during the maintenance, repair and replacement periods. Details will be included within the EMP (see above).	This will be detailed within the EMP required under the Section 36 Consent and/or Marine Licence conditions.
MM-050	Optimisation of vessel movements associated with the Project	Tertiary	Transportation of components and materials should be optimised where possible. (e.g. reducing distance of travel). Details will be included within the EMP (see above).	This will be detailed within the EMP required under the Section 36 Consent and/or Marine Licence conditions.

20.5.5 Worst-case scenario

As detailed in EIAR Vol. 2, Chapter 7: EIA Methodology, this assessment considers the worst-case scenario for the Project parameters which are predicted to result in the greatest environmental impact, known as the 'realistic worst-case scenario'. The worst-case scenario represents, for any given receptor and potential impact on that receptor, the scenario that would result in the greatest potential for change.

Flexibility in the final design is required for the Project as some elements cannot be finalised due to procurement and supply chain considerations, the timing of investment decisions and until further site investigations are undertaken.

The carbon and GHG assessment has been carried out by assessing a variety of possible design scenarios and the output of the assessment represents an indicative value, rather than a definitive total, for the total CO_2e emissions inventory and carbon payback period. The assessment was undertaken using the Xodus-developed carbon assessment tool. Due to the stage of development of the Project, conservative assumptions have been applied for the materials constituting the components which form the Project, the source location of these components and activity durations required to construct the Project to develop the 'realistic worst-case scenario'.

Table 20-17 presents the realistic worst-case scenario for potential impacts for the Climate, Carbon and GHG assessment during construction, operation and maintenance and decommissioning.

Table 20-17 Worst-case scenario specific to the Climate, Carbon and GHG assessment

POTENTIAL IMPACT	WORST-CASE SCENARIO	JUSTIFICATION
Construction		
Carbon and GHG assessment: Construction CO_2e emissions	• Embodied carbon assumptions outlined in Section 20.6.1.3.1.1; • Component shipping assumptions outlined in Section 20.6.1.3.1.2; and • Construction vessel activity outlined in Section 20.6.1.3.1.3.	Conservative assumptions have been applied for the materials constituting the components which form the Project, the source location of these components and activity durations required to construct the Project.
Blue carbon assessment: Direct blue carbon habitat loss/disturbance	• Up to 10.63 km^2 of temporary impacts to blue carbon habitats. Please refer to the worst-case scenario for “temporary impacts to the seabed and benthic habitats” in EIAR Vol. 3, Chapter 10: Benthic Ecology.	Largest spatial area and duration of temporary impacts to blue carbon habitats during construction. Please refer to the justification for the worst-case scenario for “temporary impacts to the seabed and benthic habitats” in EIAR, Vol. 3, Chapter 10: Benthic Ecology.
Operation and maintenance		
Carbon and GHG assessment: Operational CO_2e emissions	• Operation and maintenance vessel activity, outlined in Section 20.6.1.3.2; and • Embodied carbon from component replacement, outlined in Section 20.6.1.3.2	Conservative assumptions have been applied requirement for crew transportation, routine surveys, and provision for component replacement. These emissions have been allocated across the 35-year operational lifetime of the Project accounting for the assumed frequency of certain maintenance activities. This is a conservative assumption as vessels are likely to become more efficient over the next 35 years.

POTENTIAL IMPACT	WORST-CASE SCENARIO	JUSTIFICATION
Blue carbon assessment: Direct blue carbon habitat loss/disturbance	Up to 1.90 km^2 of long-term impacts to blue carbon habitats. Please refer to the wort case scenario for "long-term impacts to the seabed and benthic habitats" in EIAR, Vol. 3, Chapter 10: Benthic Ecology.	Largest spatial area and duration of long-term impacts to blue carbon habitats during operation and maintenance. Please refer to the justification for the worst-case scenario for "long-term impacts to the seabed and benthic habitats" in EIAR, Vol. 3, Chapter 10: Benthic Ecology.
ICCI assessment: The combined impact of the Project, as assessed in the EIAR, and climate change on the physical, biological and socio-economic environment	Please refer to the worst-case scenario assessed within each topic-specific chapter presented within this EIAR (EIAR Vol. 3, Chapters 8 – 22).	
Decommissioning		
Carbon and GHG assessment: Decommissioning CO_2e emissions	1.2% of the total emissions for the Project was used to estimate the emissions associated with decommissioning.	Due to the uncertainty associated with decommissioning requirements associated with activity which will occur in ~ 42-45 years' time (in 2066-2069 – the estimated phased decommissioning period for the Project based upon a 35 year operational lifespan), a nominal value of 1.2% of emissions for the construction phase of the Project was used to estimate emissions associated with decommissioning (Thomson & Harrison, 2015).

POTENTIAL IMPACT	WORST-CASE SCENARIO	JUSTIFICATION
Blue carbon assessment: Direct blue carbon habitat loss/disturbance	In the absence of detailed information regarding decommissioning works, the implications for blue carbon are considered analogous to or likely less than those of the construction stage. Therefore, the worst-case parameters defined for the construction stage also apply to decommissioning. The decommissioning approach is set out in EIAR, Vol. 2, Chapter 5: Project Description.	

20.6 Assessment of potential effects

20.6.1 Carbon and GHG assessment

The carbon and GHG assessment has been carried out to evaluate:

- The carbon lifecycle emissions which will result from the Project in terms of CO_2e emissions;
- The CO_2e emissions which may be avoided as a result of the Project;
- The length of time the Project 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 Project on the global climate, using the UK Carbon Budget as a proxy.

The carbon and GHG assessment takes a life-cycle assessment approach. Therefore, it is not applicable to assess the impact significance for each individual phase of the Project (construction, operation and maintenance and decommissioning). Instead the impact assessment (Section 20.6) considers the whole life cycle of the Project, including manufacturing of materials through to decommissioning. The assessment considers the offshore components of the Project, however, a whole Project assessment is included in Section 20.9.

20.6.1.1 Emissions Inventory

The emissions inventory for the Project is divided into three phases:

- Construction CO_2e - the embodied carbon of the main components, their transportation to the Project and emissions associated with construction activities, i.e. the following phases as per PAS 2080:2023 (BSI, 2023):
  - A1-A3 - Product Stage: calculating embodied carbon;
  - A4 - Construction Transport: estimating GHG emissions during material and personnel transport during the construction period;
  - A5 - Construction Process Stage: Calculating GHG emissions during installation works;
- Operational CO_2e - the emissions from vessels associated with operation and maintenance and the embodied carbon associated with component replacement, i.e. the following phases as per PAS 2080: 2023 (BSI, 2023):
  - B2-B5 - Maintenance, Repair, Replacement, and Refurbishment: Estimating GHG emissions during the use stage, encompassing operation, maintenance, and replacement activities; and
- Decommissioning CO_2e - the emissions from vessels associated with the removal of components, following the operational period of the Project, i.e. the following phases as per PAS 2080: 2023 (BSI, 2023):
  - C1-C4 - End of Life Stage: Anticipating GHG emissions during decommissioning.

Each of these phases is then divided further into a category, a component, and finally an activity or material. For example, CO_2e emissions associated with the steel used in the manufacture of a Wind Turbine Generator (WTG) would be captured as shown in Figure 20-5.

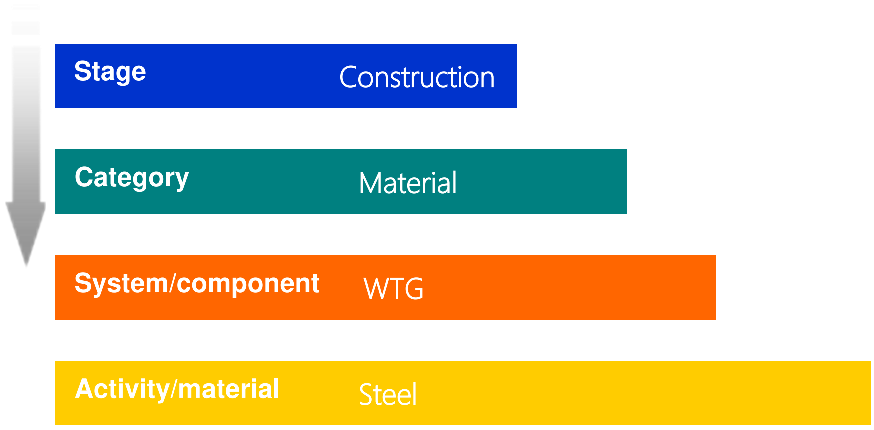

Figure 20-5 Process for identifying component materials

Each activity or material has an assigned unit of measurement and an emissions factor. The primary data used to inform the assessment, in addition to the Project-specific design information, include:

- Bath Inventory of Carbon and Energy (ICE) [Embodied carbon for standard materials and processes];
- IP 2000 [Standardised vessel fuel use]; and
- Digest of UK Energy Statistics (DUKES) [Emissions factors for generation sources; most recent version e.g. 2024].

The details provided in the following sections set out the activities and materials accounted for with respects to each component and/or system within each phase of the Project.

Due to design confidentiality, the detailed information on which assumptions were based cannot be presented within this chapter, rather a summary of the assumptions, calculations and results are presented.

20.6.1.2 Data Gaps and Uncertainties

To conduct the assessment, the information contained within the Project design has been supplemented with conservative assumptions and industry standard references.

The predicted payback period of the Project will be significantly influenced by assumptions about the future carbon intensity of the national grid (Section 20.6.1.4). Best available data has been utilised for this assessment, but it is acknowledged that actual carbon intensity of the national grid may differ from predictions.

Beyond the national grid carbon intensity assumptions, this assessment makes no assumptions around future decarbonisation. It is expected that decarbonisation may occur across several industries, such as in manufacturing practices (e.g. steel production), and in the maritime vessel industries (e.g. fuels and propulsion). Such initiatives would be expected to reduce emissions associated with the Project.

The following emissions were excluded from the emissions inventory given a lack of data to inform adequate assumptions. Furthermore, information regarding manufacturing supply chains and processes is uncertain, as component suppliers have not yet been selected.

- Delivery of materials to the manufacturing plants;
- Assembly of materials at the manufacturing plants; and
- Delivery of components between manufacturing plants and interim stockist.

These emissions are considered to represent a small part of the likely total emissions for the Project, and therefore are not expected to significantly influence the outcome or value of the assessment.

20.6.1.3 CO_2e emissions

20.6.1.3.1 Construction

20.6.1.3.1.1 Embodied carbon

The production of materials (mining raw materials, refining, forming, etc.) incurs emissions of CO_2e, termed “embodied carbon”. Embodied carbon in the context of the Project relates to the emission of CO_2e associated with the production of new infrastructure, i.e. WTGs, floating substructures and their moorings and anchors, Export/Import Cable, the IACs and remedial protection.

Specific assumptions and data sources associated with the various systems are outlined below in Table 20-18. As stated in Table 20-17, conservative assumptions have been applied for the materials that form the components of the Project.

Table 20-18 Embodied carbon assumptions

COMPONENT	ASSUMPTION
WTGs	Embodied carbon associated with the WTG was based on component (blades, nacelle, and tower) mass assumptions specified by the Applicant. 95 WTG, each including nacelle, tower, and blades: • Blades – 3 x 70 tonnes; • Nacelle – 605 tonnes; and • Tower – 1,000 tonnes. Material composition (steel, plastic, copper, aluminium, and fibreglass) estimated based on a Vestas WTG of similar specification (Allekotte and Garrett, 2024).
Floating substructure and anchors	Masses and materials for the floating substructures and anchor systems were provided by the Applicant, and include: • Floating substructures (steel) – 95 x 5,556 tonnes; • 6.5 m diameter suction piles (steel) – 570 (6 per FTU) x 225 tonnes; and • Mooring lines (steel chain and fibre rope)– 570 (6 per FTU) x 272 tonnes.
Offshore Substation and Convertor Platforms (OSCPs)	Masses for the OSCPs foundations and topsides were provided by the Applicant: • Jacket foundation (steel) – 2 x 10,000 tonnes; • Pin piles (steel) – 24 (12 per jacket) x 333 tonnes; and • OSCPs topside (steel) – 2 x 14,000 tonnes. It was assumed that 4 tonnes of sulphur hexafluoride (SF_6) would be utilised as insulation on each OSCPs and that no leakage of SF_6 would occur over the lifetime of the Project (Note 1).
IACs and the Export/Import Cable	Total cable lengths, and cable specifications (core number, core materials, and core masses), were provided for the IACs and the Export/Import Cable by the Applicant.

COMPONENT	ASSUMPTION
	• IACs – 350 km total length: – Three-core Copper (Cu) cable ; and – Cable unit mass – 65 kg/m. • Export/Import Cable – 230 km length: – Contains dual single-core cables; and – Cable unit mass – 60 kg/m.
Cable protection	Cable protection mass assumptions were provided by the Applicant: • Rock placement (including berms and cable/pipeline crossings): – Total volume 406,896 m^3; and – Assumed rock density of 1.65 tonnes/m^3. • Concrete mattresses – 17,100 m^2.

Note 1: SF_6 is a GHG which has been used for insulation in high voltage switchgears and in electricity substations. It is estimated that around 80% of the SF_6 used globally is used in electricity transmission (National Grid, 2024). SF_6 is an extremely potent fluorinated GHG with a Global Warming Potential (GWP[16]) of 22,800. The renewables and transmission industries are beginning to substitute SF_6 for low emission alternatives (e.g. Green Gas for Grid (G3), C4-FN, etc.). It is envisaged that by the time the Project is in the procurement phase, the insulation offerings that are commercially available will be enhanced significantly. Cenos will work with suppliers to ensure that the insulating gas selected for the Project has as low a GWP as practicable. For this assessment and to align with the precautionary principle, it has been assumed that the OSCPs and associated Gas Insulated Switchgear will utilise SF_6.

[16] *GWP is a comparison of the ability of each greenhouse gas to trap heat in the atmosphere. The chosen reference gas is carbon dioxide for consistency with the IPCC guidelines. 1 kg of SF_6 has the GWP of 22,800 kg of CO_2.*

20.6.1.3.1.2 Shipping

Shipping activity encompasses the vessel emissions associated with the transportation of major components sourced globally, to the UK-based assembly site.

Presently, procurement and supply chain decisions are not sufficiently advanced to enable a detailed assessment of shipping vessel emissions. The following assumptions have been made to provide a conservative assessment:

- The Port of Burntisland as the location of assembly, and thus the port of delivery for all major components. This port was selected as one of the potential assembly ports furthest from the Array Area;
- IACs and the Export/Import Cable assumed to be shipped from Algeciras, Spain; and
- All remaining major components assumed to be shipped from Shanghai, China as the worst-case scenario.

The number of trips required to ship the major components was estimated based on the construction schedule, the mass of components, the physical dimensions of the components, and vessel capacity. Shipping assumptions are detailed in Table 20-19.

Table 20-19 Number of shipping trips associated with major components of the Project

SYSTEM	COMPONENT	DELIVERY YEAR(S)	TOTAL NUMBER OF TRIPS	ASSUMPTIONS
Cables	Export/Import Cable	2030-2031	2	Assumes cable is delivered in two phases, aligned with two-year construction period.
	IACs	2031-2032	3	Assumes four-year installation, with one cable installation campaign per year.
OSCPs	Topsides	2031	1	Assumes a vessel can transport two OSCPs topsides concurrently
	Jackets and piles	2031	1	Assumes the two OSCPs foundations can be shipped together.
FTUs	Suctions piles and mooring lines	2031-2033	48	Assumes a vessel can transport 12 suction piles (and mooring lines) concurrently.
	Blades	2032-2035	48	Assumes a vessel can transport six blades concurrently.
	Nacelles	2032-2035	32	Assumes a vessel can transport three nacelles concurrently.
	Towers	2032-2035	32	Assumes a vessel can transport sections required for three towers concurrently.
	Floating substructures	2032-2035	32	Assumes a vessel can transport three floating substructures concurrently.

20.6.1.3.1.3 Construction vessel activity

Emissions resulting from construction vessels were determined. Vessel types used in construction align with that presented in EIAR, Vol. 2, Chapter 5: Project Description.

The assessment accounts for a six-year construction programme (including pre-construction surveys and site clearance activities) undertaken between 2030-2035, with the FTUs being installed and commissioned in a staggered approach over a four-year period using between 2032-2035.

Burntisland was assumed as the assembly location (Section 20.6.1.3.1.2), and as the port of origin for all construction vessels/assembled components.

20.6.1.3.2 Operation and Maintenance

Operation and maintenance emissions have been calculated based upon Applicant-provided assumptions relating to vessel activities, personnel transportation, routine survey activities and anticipated component maintenance/replacement requirements as provided in EIAR Vol. 2, Chapter 5: Project Description.

The replacement embodied carbon accounts for the following components and quantities over the operation and maintenance phase of the Project:

- 10% of IACs - i.e. 35 km of IACs;
- 10% of mooring lines – i.e. 57 mooring lines;
- Three major components (e.g. gearbox or transformer) per WTG (assuming 95 WTG) assumed to be 100 kg mass each and accounted for as a fractional equivalent of nacelle mass composition.

Due to the uncertainty of when these replacements may be required, the replacement embodied carbon was distributed equally across the operation and maintenance phase of the Project. For similar reasons, replacement shipping emissions were calculated as the appropriate fraction of the shipping emissions of each relevant component and distributed likewise.

Where more specific assumptions are available, such as the frequency of routine surveys, emissions have been assigned according to these assumptions. Consequently, the annual distribution of emissions differs slightly from year to year across the operation and maintenance period. This is a conservative assumption as vessels are likely to become less carbon intensive over the operation and maintenance phase of the Project.

It is assumed that the Project will have a 35-year operational lifetime[17]. As outlined in Section 20.6.1.4, a four-year staggered approach to FTU installation and commissioning is assumed, with 25% capacity added for each year starting in 2032 and reaching full operating capacity in 2035.

[17] *As outlined in Section 20.6.1.4, a four-year staggered approach to turbine installation, with 25% capacity added for each year starting in 2031 and reaching full operating capacity in 2034 is assumed.*

20.6.1.3.3 Decommissioning

Effects on Carbon and Greenhouse Gases receptors associated with decommissioning are anticipated to result from the full removal of the Project components. Decommissioning activities will be subject to consultations and further assessments closer to the time of decommissioning to understand technical feasibility, safety and risk, and environmental considerations in detail. These details will be included in a Decommissioning Programme which will be developed post-consent and updated over the life of the Project.

The decommissioning of the Project intends to complete the full removal of offshore infrastructure to below the mudline (where safe/practicable to do so), in line with the OSPAR Convention and forthcoming guidance from OSPAR's North-East Atlantic Environmental Strategy 2030. The majority of decommissioning works are likely to be undertaken in reverse to the sequence of construction works and involve similar or lesser levels of effects to construction.

A Decommissioning Programme will be prepared prior to construction, in line with the requirements of Section 105 of the Energy Act 2004 (as amended) and any applicable guidance available at the time. Currently it is assumed that:

- FTU substructure and WTG components will be removed and towed to port;
- Mooring lines will be removed, and where possible piles will be removed or cut to a suitable distance below the mudline such that the upper portion is removed;
- Cables no longer required will be removed where safe to do so; where they cross live third-party assets, they may be cut and left in situ to prevent damage to third-party operations; and
- The OSCP(s) will be decommissioned and the jacket and topside(s) will be towed to shore. The piles will be cut a suitable distance below the mudline.

Due to the uncertainty associated with decommissioning which will occur in over 40 years' time, a nominal value of 1.2% of the total emissions associated with the construction phase[18] of the Project was used to estimate the emissions associated with decommissioning (Thomson and Harrison, 2015).

20.6.1.3.4 Total CO_2e emissions

The final calculated total life cycle CO_2e emissions from the Project are presented in Table 20-20. The majority of CO_2e emissions (85 %) are associated with the offshore construction phase (Figure 20-6) with embodied carbon (Figure 20-7) and shipping vessel activity accounting for the majority of these emissions. CO_2e emissions during the operation and maintenance stage of the Project constitute 14 % of total Project emissions.

[18] *This method of estimating decommissioning emissions is based on the construction phase emissions only. Given emissions from the operation and maintenance phase are not included in this calculation, decommissioning would be expected to contribute less than 1.2 % of the total emissions associated with the Project.*

Table 20-20 CO_2e emissions from the Project

PHASE	ASPECT	TOTAL CO_2e (t)
Construction	Embodied carbon	3,166,176
	Component shipping	573,794
	Construction vessel emissions	292,009
	TOTAL	4,031,979
Operations and maintenance	Vessel emissions	276,233
	Replacement components (embodied carbon and shipping)	409,877
	TOTAL	686,110
Decommissioning	Estimated emissions	48,384
	TOTAL	48,384
Total		*4,766,473*

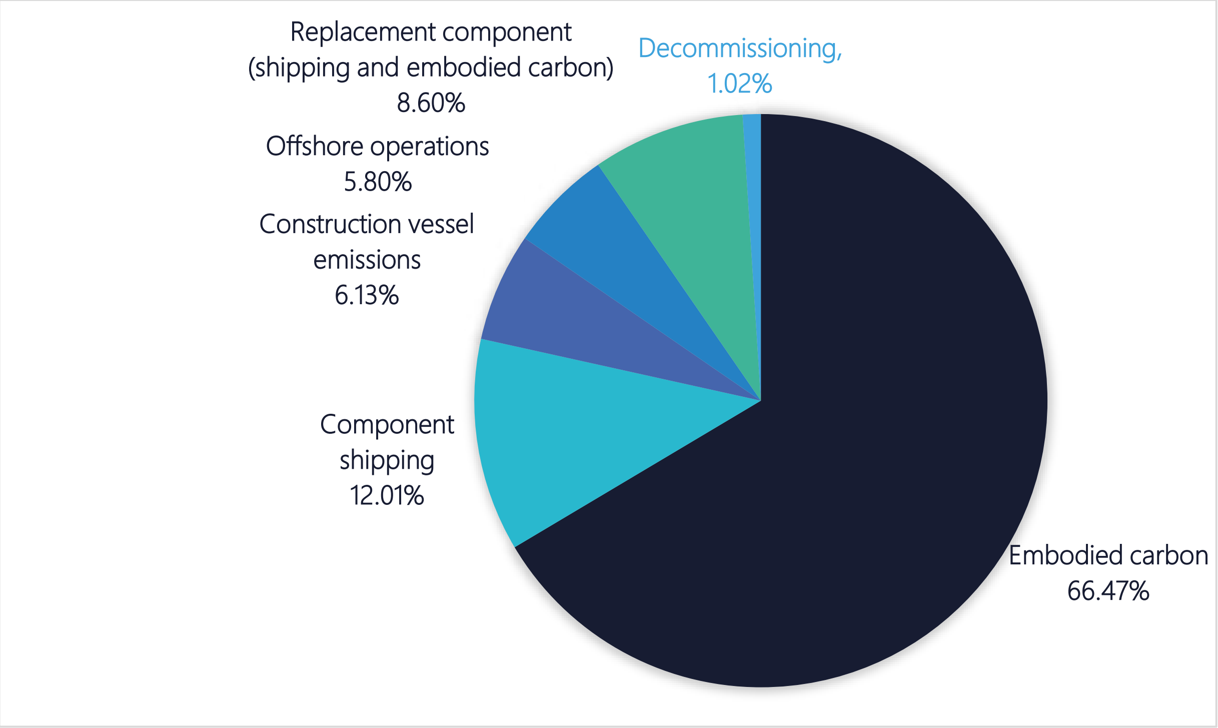

Figure 20-6 Proportion of total emissions from the Project by phase

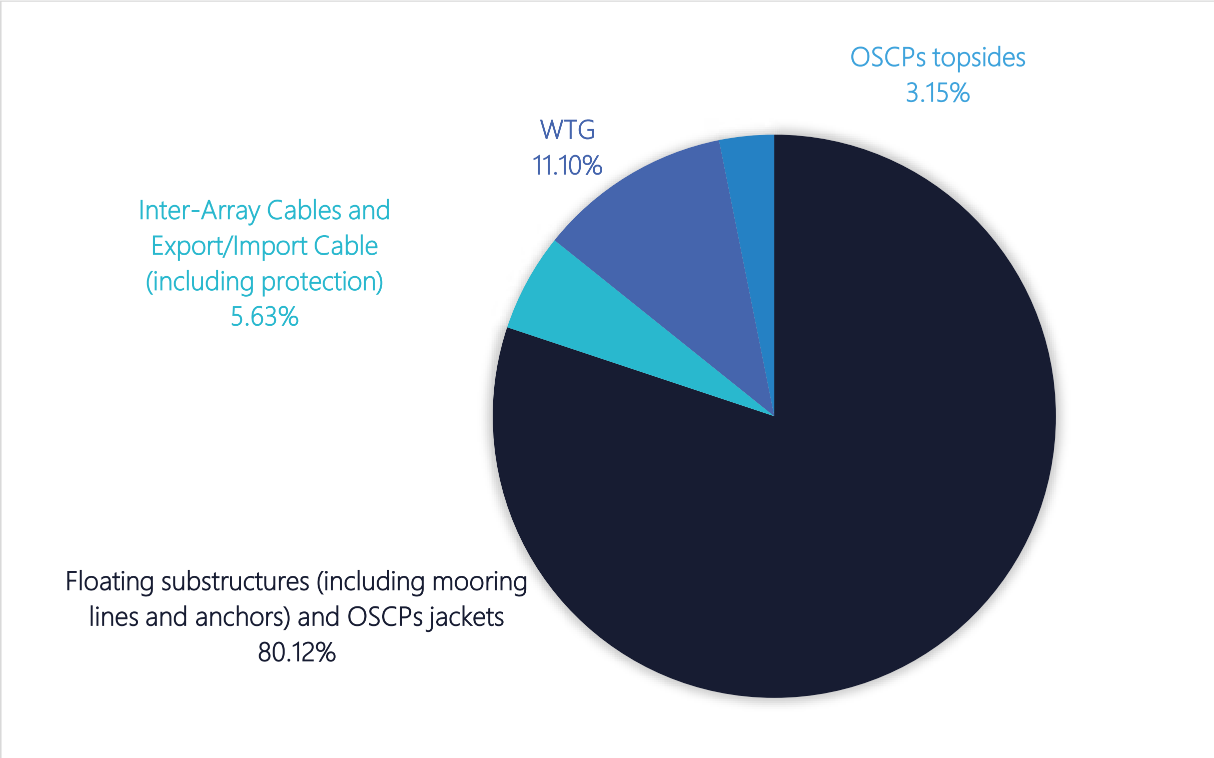

Figure 20-7 Proportional distribution of embodied carbon emissions across the Project

20.6.1.4 Avoided emissions

To establish the reduction in CO_2e attributable to the Project, the potential CO_2e savings of the Project were estimated (i.e. avoided emissions). This has been calculated by comparing the equivalent CO_2e emissions that would be generated from other forms of electricity generation, under the assumption that electricity generated by the Project will displace the requirement for generation from these other sources from the national grid.

To calculate electricity generation by the Project, the following assumption were provided by the Applicant:

- A capacity factor of 55%, i.e. a fractional correction accounting for the intermittent nature of the wind;
- An availability factor of 97%, i.e. a fractional correction accounting for anticipated down-time of the WTGs, such as during maintenance, etc;
- A four-year staggered approach to WTG installation, with 25% capacity added for each year starting in 2032 and reaching full operating capacity in 2035; and
- A four-year staggered approach to WTG decommissioning, with 25% capacity removed for each year starting in 2067, with decommissioning being completed by 2070.

When fully commissioned, annual electricity production is anticipated to be 6,659,681 megawatt hours (MWh) per annum, with this value pro-rata'd during the four-year commissioning and decommissioning periods respectively.

Annual electricity production (MWh per annum) is calculated as the product of installed capacity (MW) multiplied by the capacity factor (%), multiplied by the availability factor (%), multiplied by the number of hours in a year. To calculate total electricity production, annual electricity production is summed over the number of years of operations. Over the lifespan of the Project, total electricity production is estimated to be 235,542,384 MWh.

To calculate Project avoided emissions, an assumption must be made about the carbon intensity of the national grid over the corresponding period. This assumption is associated with considerable uncertainty which increases in the longer term as a number of factors influence future grid carbon intensity. These factors include but are not limited to: policy action taken to decarbonise the energy system, demand levels, the investment decisions of electricity generators and the effect of wind power on the operation of power systems.

This assessment presents alternative scenarios for the evolution of the UK national grid (Figure 20-8). It is assumed that electricity generated by the Project would not displace forms of electricity generation which made an overall contribution to reducing GHG emissions to atmosphere. The scenarios utilised are:

- Department for Energy Security and Net Zero (DESNZ) long-run marginal emissions factors (DESNZ, 2023) estimates the change in UK electricity sector emissions associated with policies that lead to sustained marginal changes in the consumption of electricity, including the adoption of offshore wind developments. It also includes initiatives such as decarbonisation of existing manufacturing, shipping, and construction industries. 'Marginal displacement' is the actual displacement of other forms of electricity generation i.e. the estimated volume of electricity displacement when also factoring in the regional growth in demand. Project displacement of grid electricity in this scenario will represent a lower estimate of avoided emissions.
- Counterfactual (National Grid (NG) ESO, 2024): published for the first time in 2024, this scenario uses similar assumptions to the previous "Falling Short" scenario. The counterfactual assumption assumes that relative to today, slow progress is made towards decarbonisation, such that 2050 net zero targets are not met. Project displacement of grid electricity in this scenario may represent an upper estimate of avoided emissions.

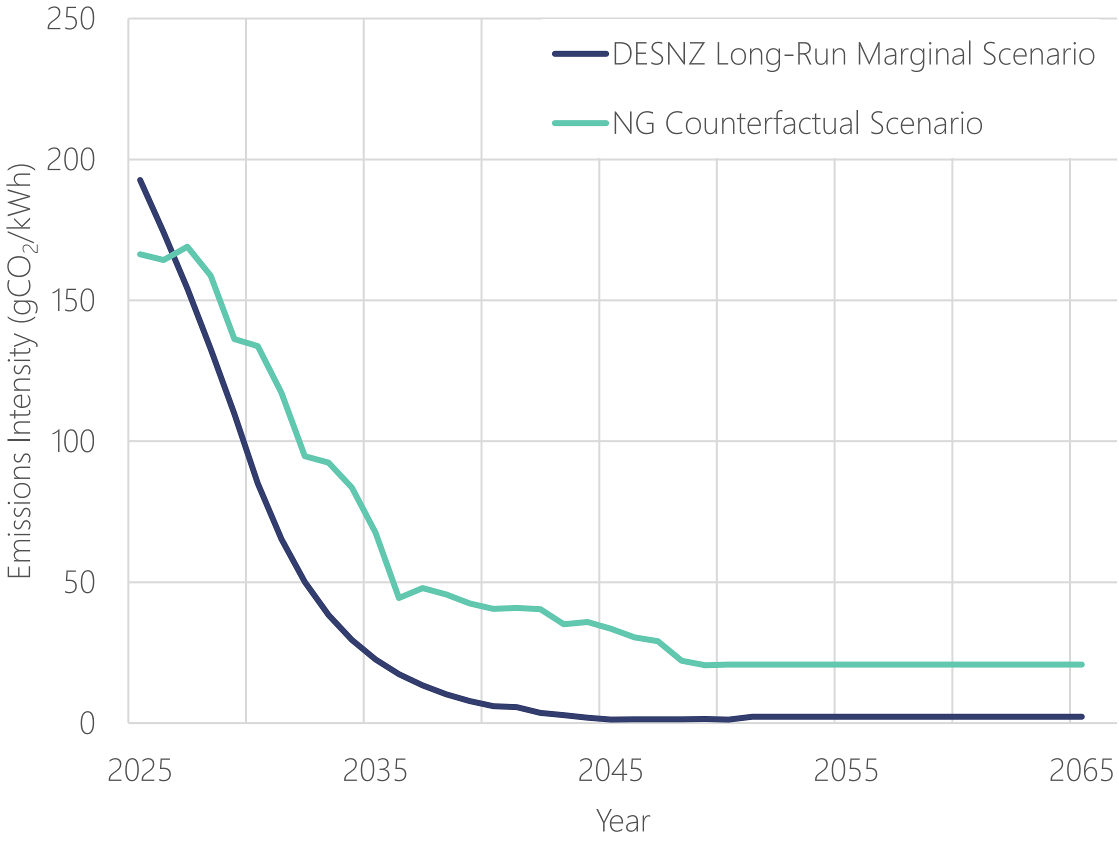

Figure 20-8 Emission projections of the UK national grid (DESNZ, 2023; National Grid ESO, 2024)

DESNZ emissions factors for electricity reflect the emissions from primary fuel use which is required to deliver the electricity consumed (DESNZ, 2023), i.e. the factors do not incorporate the embodied carbon or vessel emissions associated with the installation and construction of an offshore wind farm. Comparisons are therefore primarily made for the operation and maintenance phase.

Based on total generation of the Project, the emissions which would have resulted, had the generation occurred via the national grid are shown in Table 20-21. In DESNZ long-run marginal scenario, a total of 1.2 $MtCO_2e$ are displaced from the grid while in the counterfactual scenario, 7.4 $MtCO_2e$ are displaced from the grid.

Table 20-21 Net emissions associated with the Project's lifetime electricity production

PROJECTION SCENARIO	PROJECT EMISSIONS (TONNES OF CO_2e (tCO_2e))		DISPLACED GRID EMISSIONS (tCO_2e)	NET EMISSIONS (tCO_2e) (OPERATION AND MAINTENANCE PHASE)
	ALL PHASES (TOTAL)	OPERATION AND MAINTENANCE PHASE (ONLY)		
DESNZ long-run marginal	4,766,473	686,110	1,229,803	-543,693
NG counterfactual			7,356,493	-6,670,383

Within greater control of the Project is the carbon intensity of electricity generated by the Project (Section 20.6.1.5).

20.6.1.5 Carbon intensity and payback period

Carbon intensity is a measure of the emissions generated per unit of electricity produced. Carbon intensity is calculated as:

$$Carbon\ intensity\ (gCO_2e/kWh) = \frac{Emissions\ (gCO_2e)}{Electricity\ production\ (kWh)}$$

where:

- Emissions are calculated per phase (Section 20.6.1.3) and summed for the Project phase(s) under consideration; and
- Electricity production is calculated annually and summed for the operational lifetime of the Project (Section 20.6.1.4).

The carbon intensity of electricity generated by the Project is provided in Table 20-22. The carbon intensity is provided for both the Project in its entirety, but also that of only the operation and maintenance phase, with the latter being used to drawing comparisons relative to carbon intensity projections for the national grid.

Table 20-22 Calculated carbon intensity of electricity generated by the Project

SCENARIO	CARBON INTENSITY (GRAMS OF CO_2E PER KILOWATT-HOUR , gCO_2e/kWh)
All phases	20.24
Operation and maintenance phase	2.91

The projected net marginal carbon intensity of the national grid (i.e. operation and maintenance phase) is forecast to be 2.28 gCO_2e/kWh from 2050 onwards (DESNZ, 2023) while the carbon intensity of electricity generated by the Project (operation and maintenance phase) is estimated to be 2.91 gCO_2e/kWh (Table 20-22).

Renewable energies typically show lifecycle emissions that are an order of magnitude lower than fossil-fuel technologies (UNECE, 2021). Estimates of lifecycle offshore wind carbon intensities have produced interquartile ranges of 8 to 35 gCO_2e/kWh with a median of 12 (Schlömer *et al.*, 2014). In comparison, the IPCC Fifth Assessment Report estimates a median carbon intensity for coal power of 820 gCO_2e per kWh (ranging from 740–910 gCO_2e per kWh) (Schlömer *et al.*, 2014).

The calculated carbon intensity for the Project (all phases) is conservatively estimated, resulting in a carbon intensity of 20.24 gCO_2e/kWh, i.e. greater than the reported median, but within the typical range for offshore wind projects. It is also much lower than fossil fuel technologies. The 2.91 gCO_2e/kWh estimate for the carbon intensity associated with the operation and maintenance phase is greater than the 2.28 gCO_2e/kWh projection for 2050 under the DESNZ long-run marginal assumptions. However, the calculation undertaken for the Project is based on very conservative assumptions, and does not account for any decarbonisation in the maritime or construction industries. It is reasonable to assume – but cannot currently be quantified - that innovations in policies and technologies aimed at achieving net zero targets by 2050 will result in lower emissions for the operation and maintenance phase of the Project than currently calculated. Consequently, is likely that the Project would achieve a carbon intensity comparable to (or less than) the grid projections with the application of less conservative assumptions.

The payback period of a development is the time (years) required for a development to avoid more CO_2e emissions than has been produced by its construction and operation. The payback period for the Project was calculated by comparing emissions associated with the Project's electricity generation (Section 20.6.1.4) with grid carbon intensity forecasts outlined in Section 20.6.1.4.

When accounting for all Project phases, and using the DESNZ long-run marginal emission projections, the Project would not be predicted to payback emissions over its lifespan (Table 20-21). This predominantly reflects the low carbon intensity projections for the future grid and the conservative assumptions made in the calculation of Project lifecycle emissions. Where the carbon intensity of the national grid is assumed to remain greater – as in the NG counterfactual projections – the Project could reach payback in 2047, 12 years after being fully commissioned, even with the conservative assumptions made in the calculation of Project lifecycle emissions.

It is noted however, that any energy development seeking to add significant capacity to the national grid would be associated with construction-related emissions equivalent to those attributable to the Project. Therefore, it is valid to only consider the operation and maintenance phase of the Project when calculating the payback period. In this context, the Project achieves payback within the first year under both emission projection scenarios.

Payback assessments are highly sensitive to the assumptions made about the carbon intensity of the grid electricity displaced by the Project and it is suggested that the carbon intensity of the Project is a more meaningful comparator between developments.

20.6.1.6 Impact assessment

Table 20-23 presents net Project emissions per 5-year carbon budget against both national grid carbon intensity scenarios. Offshore construction is assumed to start in 2030. Full operations commence between 2032 to 2035 and continue beyond the 2050 net zero target date. As per the methodology outlined in Section 20.5.3.1, the magnitude of Project effect on the UK carbon budget under either scenario will be negligible in the 2028 to 2032 period. In the 2033 to 2037 period, the Project would have negligible effect on UK carbon budgets assuming NG counterfactual grid emission projections, but result in a small increase under DESNZ long-run marginal projections. This difference is directly attributable to differences in future grid projections. The Project is anticipated to start contributing to annual emission savings once construction is completed in 2035, although the 2033-2037 period predicts an increase in carbon emissions as avoided emissions during this period will not fully offset construction emissions. As carbon budgets are not yet determined past 2037, it is not possible to quantify the percentage of the Project's CO_2e emissions between 2038 and 2066 (the estimated end date for the operational stage of the Project). Overall, the Project will not affect the UK Government's ability to meet any individual carbon budget and will make a positive contribution to achieving the carbon budget.

Table 20-23 Whole-Project net CO_2e emissions against the UK carbon budget

SCENARIO		CARBON ACCOUNTING PERIOD	
	UK carbon budget ($MtCO_2e$)	2028 to 2032	2033 to 2037
		1,765	965
DESNZ long-run Marginal	Project emissions for period (net $MtCO_2e$)	1.60	1.82
	Project emissions as a % of UK budget	0.09%	0.19%
NG counterfactual	Project emissions for period (net $MtCO_2e$)	1.53	0.64
	Project emissions as a % of UK budget	0.09%	0.07%

20.6.2 ICCI assessment

Table 20-24 summarises the ICCI assessment which has been undertaken using the methodology described in Section 20.5.3.2.

Table 20-24 Summary of ICCI assessment

EIA TOPIC	PROJECT IMPACTS (OPERATION AND MAINTENANCE)	POTENTIAL CLIMATE CHANGE PROJECTION AND IMPACT	LIKELIHOOD OF ICCI	MAGNITUDE OF ICCI	CONSEQUENCE OF ICCI	SIGNIFICANCE	ADDITIONAL MITIGATION REQUIRED?	SIGNIFICANCE OF RESIDUAL CONSEQUENCE
Marine Geology, Oceanography and Coastal Processes	1. Potential changes to suspended sediment concentrations, bed levels and sediment type; 2. Potential changes to wave and tidal regimes; 3. Potential modifications to sediment transport pathways; 4. Modifications to stratification and frontal features; 5. Potential impacts to designated seabed interest features within protected sites; and 6. Potential changes to coastal / inshore seabed morphology.	Increased sea temperatures, increased frequency of marine heatwaves and changes related to the Atlantic Meridional Overturning Circulation (AMOC) system could change the extent or presence of stratification at the Project, altering the predicted impact of the Project on water column structure.	Unlikely – the Project is expected to have a very limited impact on stratification and frontal systems which will generally fall within natural variability. Any changes will be highly localised and there will be no significant influence on the timing of seasonal stratification or positioning of tidal fronts. Therefore, the influence of climate change is not predicted to significantly alter this effect.	No change – The predicted effect of climate change is not expected to exacerbate the impact of the Project on benthic ecology receptors.	No change	Not significant	No	Not significant
		Increased frequency of storms and SLR could alter the predicted impact of the Project on tidal, wave and sediment transport regimes.	Unlikely – the presence of infrastructure within the Array Area and EICC has the potential to result in changes to the wave and tidal regime and sediment transport pathways. However, the infrastructure in the Array Area is assessed as having no consequential effect on the overall rate or direction of sediment transport. Similarly the installation of cable protection will also be highly localised.	No change – The predicted effect of climate change is not expected to exacerbate the impact of the Project on benthic ecology receptors.	No change	Not significant	No	Not significant
		Increased frequency of storms and SLR could accelerate coastal erosion at the landfall, altering the predicted impact of the Project on coastal morphology.	Extremely unlikely – the presence of cable protection and landfall infrastructure has the potential to impact coastal morphology at the landfall site. However, only localised impacts are anticipated as a result of the presence of cable protection at Horizontal Directional Drilling (HDD) exit points and in the event that the Export/Import Cable were to become exposed. Due to the erosion resistant nature of the coastline, which consists of hard cliffs, the potential for coastal erosion is considered low.	No change – The predicted effect of climate change is not expected to exacerbate the impact of the Project on benthic ecology receptors.	No change	Not significant	No	Not significant
Benthic Ecology	1. Temporary impacts to the seabed and benthic habitats; 2. Long-term impacts to the seabed and benthic habitats;	Predicted change in sea conditions (e.g. increased sea temperatures and decreased dissolved oxygen) at the limits of tolerance for benthic ecology receptors may enhance other	Unlikely – the Project is located is in an area of relatively cold sea temperatures with a weaker increase in sea temperatures expected compared with some other regions of the UK (e.g. south coast). Species and habitats in the Project Area are not at their	No change – The predicted effect of climate change is not expected to exacerbate the effect of the Project on	No change	Not significant	No	Not significant

EIA TOPIC	PROJECT IMPACTS (OPERATION AND MAINTENANCE)	POTENTIAL CLIMATE CHANGE PROJECTION AND IMPACT	LIKELIHOOD OF ICCI	MAGNITUDE OF ICCI	CONSEQUENCE OF ICCI	SIGNIFICANCE	ADDITIONAL MITIGATION REQUIRED?	SIGNIFICANCE OF RESIDUAL CONSEQUENCE
	3. Introduction on hard substrates in a predominantly sedimentary environment/increased predation; 4. Potential changes to suspended sediment concentrations; 5. Potential effects from Electromagnetic Fields (EMF) and heat generated by cables; and 6. Introduction of INNS.	external impacts, including those of the Project.	northerly or southerly geographic distribution, which makes them less vulnerable to changing climatic conditions. Therefore, the scale of the projected changes in sea conditions across the operation and maintenance phase are not anticipated to be at the tolerance limit of the benthic species and habitats present, given the project's location. Furthermore, embedded mitigations will be applied to reduce the potential for habitat loss and disturbance (e.g. micro-siting).	benthic ecology receptors.				
		Potential increase in INNS presence under changing sea conditions may increase potential for any hard substrate at the Project to act as a stepping stone for the spread of INNS.	Unlikely – The hard infrastructure installed at the Project may act as a stepping stone for INNS with pelagic larvae that move passively under the influence of currents. It is possible that changing sea conditions could provide pathways for INNS spread, although this is currently unclear (MCCIP, 2024). With the implementation of an INNS Management Plan (see EIAR Vol. 3, Chapter 10: Benthic Ecology), the risk of INNS spread and introduction is considered to be effectively managed under current and future conditions.	No change – The predicted effect of climate change is not expected to exacerbate the impact of the Project on benthic ecology receptors.	No change	Not significant	No	Not significant
		Predicted effects of climate change on physical and coastal processes (described above) could exacerbate the predicted impact as a result of changes in the wave, tidal and sediment transport regime.	Unlikely – the Project is predicted to have minimal extent of change to physical and coastal processes (as described above).	No change – The predicted effect of climate change is not expected to exacerbate the impact of the Project on benthic ecology receptors.	No change	Not significant	No	Not significant
Fish and Shellfish Ecology	1. Long-term impacts to the seabed and sensitive fish habitats (e.g., spawning and/or nursery habitats); 2. Underwater noise and vibration;	Predicted change in sea conditions (e.g. increased sea temperatures) at the limits of tolerance for fish and shellfish ecology receptors may enhance other external impacts, including those of the Project.	Unlikely – change in sea conditions may exacerbate Project effects and alter the health and resilience of fish and shellfish ecology receptors present at the Project Area. However, the Project is located in an area of relatively cold sea temperatures with a weaker increase in sea temperatures expected compared with some other regions of the UK (e.g. south coasts). Furthermore, as	No change - The predicted effect of climate change is not expected to exacerbate the impact of the Project on fish and shellfish ecology receptors.	No change	Not significant	No	Not significant

EIA TOPIC	PROJECT IMPACTS (OPERATION AND MAINTENANCE)	POTENTIAL CLIMATE CHANGE PROJECTION AND IMPACT	LIKELIHOOD OF ICCI	MAGNITUDE OF ICCI	CONSEQUENCE OF ICCI	SIGNIFICANCE	ADDITIONAL MITIGATION REQUIRED?	SIGNIFICANCE OF RESIDUAL CONSEQUENCE
	3. Potential effects from EMF and heat generated by cables; 4. Operational windfarm may act as a Fish Aggregation Device (FAD); and 5. Secondary entanglement.		fish and shellfish receptors are mobile, they can adapt to changing sea conditions by changing their distribution. Therefore, the fish and shellfish ecology receptors within the Project Area are expected to be relatively tolerant to the projected changes in sea conditions across the operation and maintenance phase.					
		Predicted effects of climate change on physical and coastal processes (described above) could exacerbate the predicted effects as a result of changes in the wave, tidal and sediment transport regime.	Unlikely – the Project is predicted to have minimal extent of change to physical and coastal processes (as described above).	No change – The predicted effect of climate change is not expected to exacerbate the impact of the Project on benthic ecology receptors.	No change	Not significant	No	Not significant
		Indirect impacts in relation to effects on prey species (e.g. reduced availability and distribution) could enhance the predicted impact of the Project.	Unlikely – changes in sea conditions (in particular sea temperature) may result in a change in the distribution and abundance of prey species. However, as noted above, the change in sea temperature at the Project Area is expected to be weaker than other regions of the UK. Furthermore, it is not expected that all prey species will decline (for example there may be an increase in the abundance of warm-water species).	No change - The predicted effect of climate change is not expected to exacerbate the impact of the Project on fish and shellfish ecology receptors.	No change	Not significant	No	Not significant
Marine Mammal Ecology	1. Injury and disturbance from underwater noise-generating activities; 2. Long-term changes to prey resources; and 3. Secondary entanglement.	Predicted change in sea conditions (e.g. increased sea temperatures) at the limits of tolerance for marine mammal and megafauna receptors may enhance other external impacts, including those of the Project.	Unlikely – changes in sea conditions and additional stresses may increase the vulnerability of marine mammals to external impacts (e.g. increased physiological stress, reproductive failure and susceptibility to disease). However, the effects of the Project on marine mammal species are considered to be highly localised in extent and are not predicted to result in population level effects. Furthermore, as marine mammal receptors are mobile, they can adapt to changing sea conditions by changing their distribution. Overall, the effects of the Project are not predicted to be significantly altered by climate change.	No change - The predicted effect of climate change is not expected to exacerbate the impact of the Project on marine mammal ecology receptors.	No change	Not significant	No	Not significant

EIA TOPIC	PROJECT IMPACTS (OPERATION AND MAINTENANCE)	POTENTIAL CLIMATE CHANGE PROJECTION AND IMPACT	LIKELIHOOD OF ICCI	MAGNITUDE OF ICCI	CONSEQUENCE OF ICCI	SIGNIFICANCE	ADDITIONAL MITIGATION REQUIRED?	SIGNIFICANCE OF RESIDUAL CONSEQUENCE
		Indirect impacts in relation to effects on prey species (e.g. reduced availability and distribution) could enhance the predicted impact of Project.	Unlikely – the availability of prey may be impacted by range shifts of prey species, potentially exacerbating any Project impact on prey. However, this impact on marine mammals is highly uncertain and poorly understood. It is not expected that all prey species will decline (for example there may be an increase in the abundance of warm-water species). Additionally, any effect of the Project on prey species (e.g. resulting from habitat loss and disturbance impacts on key prey species such as sandeel and herring) will be highly localised with no long-term change in abundance and distribution.	No change - the predicted effect of climate change is not expected to exacerbate the impact of the Project on marine mammal ecology receptors.	No change	Not significant	No	Not significant
Ornithology	1. Disturbance and / or displacement of ornithology receptors from vessels; 2. Distributional responses from presence of FTUs; 3. Collision risk with turbines; 4. Changes to prey availability; and 5. Secondary entanglement.	Increased occurrence of extreme weather events (e.g. storms) and SLR and erosion may impact breeding bird success or impact foraging success at-sea and enhance any other survival impairment.	Unlikely – the frequency of extreme weather events is expected to increase alongside continued SLR and coastal erosion over the lifetime of the Project. Additional pressure on birds and reduced foraging success may occur as a result of these climate change impacts. The projected increase in frequencies of extreme weather are uncertain but are not anticipated to exacerbate the effects of the Project to an extent that would change the magnitude of the Project's impact. Impacts are also likely to be species-specific due to differing ecology and life history as well as varying with exposure and susceptibility of individuals.	No change - the predicted effect of climate change is not expected to exacerbate the impact of the Project on marine mammal ecology receptors.	No change	Not significant	No	Not significant
		Indirect impacts in relation to effects on prey species (e.g. reduced availability and distribution) could enhance the predicted impact of the Project.	Unlikely - the potential effect on prey species is uncertain. The availability of prey may be impacted by range shifts of prey species, potentially exacerbating any impact of displacement or barrier effects and long-term habitat change. In east Scotland, survival of over-wintering kittiwakes was observed to be lower following winters of higher sea-surface temperatures in addition to reduced breeding success a year later likely due to sandeel availability and quality (Carroll *et al.*, 2017). Generalist seabird species which feed on a variety of prey are likely to be more resilient to changes in prey availability than	No change - the predicted effect of climate change is not expected to exacerbate the impact of the Project on marine mammal ecology receptors.	No change	Not significant	No	Not significant

EIA TOPIC	PROJECT IMPACTS (OPERATION AND MAINTENANCE)	POTENTIAL CLIMATE CHANGE PROJECTION AND IMPACT	LIKELIHOOD OF ICCI	MAGNITUDE OF ICCI	CONSEQUENCE OF ICCI	SIGNIFICANCE	ADDITIONAL MITIGATION REQUIRED?	SIGNIFICANCE OF RESIDUAL CONSEQUENCE
			other more specialist species (Mitchell *et al.*, 2020). Those species with a more limited foraging range may be less resilient. Despite the potential climate change impacts on seabird prey, any effect of the Project on prey species (e.g. resulting from habitat loss and disturbance impacts on key prey species such as sandeel) will be highly localised with no long-term change in abundance and distribution.					

20.6.3 Blue carbon assessment

According to recent guidance (Carbon Trust, 2024), removal of blue carbon arising from a development do not need to be quantified. The fate of disturbed carbon is currently uncertain (Cunningham and Hunt, 2023). Therefore, a qualitative assessment only has been conducted in this chapter.

According to Smeaton *et al*. (2020), the carbon stock across the Project Area is low, where the top layer of sediments is anticipated to contain 0.07-0.7 kg/m^2 of organic carbon and 0-4.1 kg/m^2 of inorganic carbon. As per Section 20.4.5, the minimum values observed for TOC were in the EICC (0.13%), with maximum values of 0.51% in the Array Area, and therefore, TOC across the Project Area is considered to be low. The majority of the EICC is composed of 'Offshore circalittoral sand' with patches of 'Circalittoral mixed sediments'. There is also the presence of 'Offshore circalittoral mud' within the Array Area. The Array Area is classified primarily as 'Offshore circalittoral mud'. The sandy and coarse sediments present across the EICC are considered to be of low carbon value based on their carbon accumulation potential (see Section 20.4.5). Rates of carbon accumulation in muddy habitats tend to be higher than in sand and coarse sediment habitats (Diesing *et al.*, 2021). The 'Offshore circalittoral mud' present in the offshore EICC and the Array Area is therefore expected to have a higher accumulation rate.

No kelp beds or other key blue carbon habitats (e.g. seagrass) were identified in the Project Area during Project site-specific surveys. Brittlestar and *F. foliacea* were observed within the EICC, however, brittlestars are not noted as being present in dense beds and *F. folicea* were only present over a very limited extent in the inshore EICC, and therefore the blue carbon contribution of these features is minimal.

As explained in EIAR Vol. 3, Chapter 10: Benthic Ecology, offshore deep-sea muds (i.e. 'Offshore circalittoral mud') have a high sensitivity to seabed disturbance (i.e. surface abrasion, subsurface abrasion/penetration). Sand/coarse sediments have a higher resilience and are considered to have medium sensitivity to seabed disturbance. *F. foliacea* and brittlestar may be temporarily lost as a result of seabed disturbance. *F. foliacea* are able to regenerate damaged fronds following abrasion or sediment disturbance, and brittlestar also have the potential to accommodate temporary disturbance events through recolonisation (Jackson, 2008; Readman *et al.*, 2023). Therefore, both species are expected to exhibit a degree of recovery following temporary seabed disturbance. All features are considered to have a high sensitivity to long-term effects resulting from the presence of hard structures on the seabed (e.g. cable protection) as there is no potential for recovery.

As explained above, the carbon stock/density in the Project Area marine sediments is considered to be low, although it is acknowledged that muddy sediments have higher carbon accumulation rates than sandy and coarse sediments. The blue carbon habitats/species (*F. foliacea* and brittlestar) are only present over a limited extent of the Project Area (despite the wider offshore mud habitats) and are considered to have a low carbon stock when compared to other blue carbon habitats, such as maerl beds or seagrass beds. Therefore, overall, the blue carbon receptors of the Project Area are assessed as being of a medium sensitivity.

Up to 10.63 km^2 of the seabed will be temporarily disturbed during the construction phase of the Project. This represents 19% of the Project Area (estimated 553 km^2) and 0.002% of the Scottish Exclusive Economic Zone (EEZ) (estimated 462,263 km^2; Scottish Government, 2023) from which blue carbon could be released. Long-term habitat loss from the presence of infrastructure related to the Project will be 1.90 km^2, which results in a loss of minimal potential blue carbon habitat (0.002% of the Scottish EEZ).

The proportion of the habitat temporarily affected is relatively low compared to the Scottish EEZ, and the localised nature of the effect indicates that it will not result in a measurable release of carbon from disturbed or lost sediment. Based on localised spatial and temporal disturbance compared to their highly widespread distribution, and low frequency of construction/installation events, any effects are unlikely to affect the carbon sequestration potential of the seabed or result in a significant loss or disturbance of carbon in the Array Area and EICC. Any seabed disturbance during decommissioning has the potential to result in remineralisation of carbon in marine sediments, in the same manner as construction. Heinatz and Scheffold (2023) estimate that the carbon released during decommissioning is approximately equal to that during construction.

The presence of infrastructure on the seabed will also be highly localised during the operation and maintenance phase, resulting in a highly localised loss of any potential blue carbon habitat. During the operation and maintenance phase, disturbance to marine sediments will also be limited and less than that of construction, with a very low potential for CO_2 release as a result of carbon remineralisation. The mooring chains will be in contact with the seabed and will have a maximum swept area of 1.44 km^2 which could result in seabed disturbance throughout the operation and maintenance phase. However, this is a highly localised area which is approximately 0.0003% of the Scottish EEZ. The Project will result in the addition of artificial structures in the marine environment (1.90 km^2). It is noteworthy that the introduction of artificial structures has the potential to result in a source of carbon input, where organic material collects on structures, then dies and is assimilated into seabed sediments as carbon matter. For example, Heinatz and Scheffold (2023) estimated the net effect of offshore wind farms in the Southern North Sea on organic carbon in surrounding sediments. It was estimated that the organic carbon trapped in the sediments at offshore wind farms during the operation and maintenance phase was approximately 4.6 times higher than that of the carbon lost during construction and decommissioning.

In line with EIAR Vol. 3, Chapter 10: Benthic Ecology, the effect on blue carbon is thus defined as being of negligible magnitude across the construction, operation and maintenance, and decommissioning of the Project.

Therefore, the overall impact on blue carbon from the Project is assessed as minor and not significant.

20.6.4 Summary of potential effects

The carbon and GHG assessment has predicted that the Project (considered as a whole) would have negligible change to the both the 2028-2032 and 2033-2037 UK carbon budgets under the NG counterfactual grid emission projections. Accounting for the DESNZ long-run marginal grid emission projections, the Project would result in negligible change to the 2028-2032 carbon budget, and a small increase in the 2033-2037 carbon budget.

Under the NG counterfactual emission assumption, the Project (considered as a whole) is projected to reach payback within 12 years and contribute to net-decreases in CO_2e for the remainder of its operational lifespan. Under the DESNZ long-run marginal grid emission projections, the Project would not reach payback in its lifetime; however, achievement of these future grid targets are reliant on the developments such as the proposed Project. As such, direct benchmarking of payback period against future targets is not without its limitations.

Considering only the operations and maintenance phase, the Project would achieve net-decreases in CO_2e from the first year of being fully commissioned under both future grid emission projections. These savings would continue to accumulate across the operational lifespan of the Project.

Overall, it is concluded that the Project will not affect the UK Government's ability to meet any individual carbon budget and will make a positive contribution to achieving the carbon budget.

The ICCI assessment considered the potential for climate change to exacerbate or diminish the impacts assessed within the other topic-specific chapters of this EIAR. The comprehensive assessment, based on the best-available data on marine climate change has concluded that there would be no change to the significance assessed within each topic-specific chapter of this EIAR when the influence of climate change on Project impacts is considered.

The blue carbon assessment has assessed the potential for the Project to result in disturbance or loss of blue carbon stores, including in blue carbon habitats and marine sediments. Overall, the Project Area contains limited coverage of blue carbon habitats, including brittlestars and *F. foliacea* and a low carbon density in the surficial sediments based on the modelling conducted by Smeaton et al., (2020). Therefore, the sensitivity of the blue carbon stores within the Project Area are considered to be medium. The magnitude of effect was assessed as negligible, given the localised nature of any temporary or permanent disturbance or loss of blue carbon stores. Overall, the overall impact on blue carbon from the Project is assessed as minor and not significant.

20.7 Assessment of blue-carbon cumulative effects

Potential impacts from the Project have the potential to interact with those from other projects (developments), plans and activities, resulting in cumulative effects on Carbon and Greenhouse Gas receptors. The general approach to the cumulative effects assessment is described in EIAR Vol. 2, Chapter 7: EIA Methodology and in EIAR Vol. 4, Appendix 31: Cumulative Effects Assessment Methodology and further detail is provided below.

Only cumulative effects of the Project with other projects, plans and activities on blue carbon are considered within this chapter. As GHG emissions are not geographically bounded, it is not possible to set a ZoI to identify relevant cumulative projects, plans and activities. Therefore, in line with IEMA (2022), the GHG emissions of other individual projects, plans and activities have not specifically been considered alongside those of the Project. The assessment for the Project alone (Section 20.6.1) does consider the potential CO_2e savings from the Project compared with other forms of electricity generation. As the ICCI assessment has concluded that there is no potential for Project impacts to be exacerbated by climate change to a degree that would alter the magnitude of effect, it is also not necessary to conduct an additional cumulative effects assessment in the context of climate change, as the cumulative effects assessment for each topic-specific chapter (EIAR Vol. 3, Chapter 8 to 22) remain valid.

As detailed in EIAR Vol. 3, Chapter 10: Benthic Ecology, other plans and activities considered to potentially result in cumulative effects with the Project on benthic ecology receptors, and therefore, may result in cumulative disturbance or loss of blue carbon stores.

The list of relevant projects for inclusion within the cumulative effects assessment is outlined in Table 20-25. This has been informed by a screening exercise, undertaken to identify relevant developments for consideration within the cumulative effects assessments for each EIAR topic, based on defined ZoIs.

Only projects which overlap the Project Area are considered for the cumulative effect assessment for the blue carbon impact in relation to direct loss or disturbance to blue carbon stores, in line with the Study Area outlined in Section 20.4.1. This differs from the approach in EIAR Vol. 3, Chapter 10: Benthic Ecology which considers projects within a 20 km radius of the Project Area.

Table 20-25 List of developments considered for the blue carbon cumulative assessment

LOCATION	PROJECT TYPE	PROJECT NAME	DISTANCE TO PROJECT (km)	STATUS	CONFIDENCE[19]
United Kingdom	Cable	Eastern Green Link 3	0	Pre-Application (Scoping)	Low
United Kingdom	Offshore Wind	Muir Mhòr Offshore Wind Farm	0	Application	Low
United Kingdom	Offshore Wind	MarramWind	0	Pre-Application (Scoping)	Low

As outlined in EIAR Vol. 3, Chapter 10: Benthic Ecology, it is expected that for the above mentioned cable project (development), any temporary disturbance will be highly localised with good recovery of the seabed once the installation activities are completed. Furthermore, it is likely that the temporal overlap in the construction activities of these projects and the Project will be rather limited (i.e. the start date for the Eastern Green Link 3 and MarramWind is expected for 2033 and 2034, respectively). Furthermore, there may be long-term habitat loss associated with the introduction of hard substrate associated with the cable projects which will have a cumulative effect. At the moment only the Scoping Reports for the projects Eastern Green Link 3, Muir Mhòr Offshore Wind Farm and MarramWind are available and a high-level description of the infrastructures/hard substrates associated with these projects is provided in EIAR Vol. 3, Chapter 10: Benthic Ecology. Overall, the habitat loss of the cumulative projects will not substantially increase that which is associated with the Project.

Overall, the temporary and long-term impacts to the seabed and benthic habitats of the cumulative projects will not substantially increase those impacts to the seabed associated with the Project. Therefore, the effect remains as being at a negligible magnitude for blue carbon stores. Therefore, the overall impact on blue carbon is assessed to remain as minor and not significant in EIA terms.

[19] *Confidence ratings have been applied to each cumulative project where: 'Low' = pre-application or application, 'Medium' = consented and 'High' = under construction or operational.*

20.8 Inter-related effects

Inter-related effects are the potential effects of multiple impacts, effecting one receptor or a group of receptors. Inter-related effects include interactions between the impacts of the different phases of the Project (i.e. interaction of impacts across construction, operation and maintenance and decommissioning), as well as the interaction between impacts on a receptor within a Project phase. The potential inter-related effects for the carbon and greenhouse gas assessment are described below.

20.8.1 Inter-related effects

it is considered that the assessment and conclusions presented in Sections 20.6.1, 0 and 20.6.3 provide a complete and robust assessment of all potential impacts assessed, and there is considered no potential for inter-related effects. The potential for interrelated effects on the receptors considered within the ICCI assessment in Section 20.6.2 has been considered in EIAR Vol. 3, Chapters 8 to 22. No interrelated effects, beyond those presented in EIAR Vol. 3, Chapters 8 to 22 have been identified.

20.8.2 Inter-relationships

Inter-relationships are defined as the interaction between the impacts assessed within different topic assessment chapters on a receptor. The other chapters and impacts related to the Climate, Carbon and GHG assessment are provided in Table 20-26.

Table 20-26 Climate, Carbon and GHG assessment inter-relationships

CHAPTER	IMPACT	DESCRIPTION
EIAR Vol. 3, Chapter 8: Marine Geology, Oceanography and Coastal Processes	All impacts resulting from the operation and maintenance phase of the Project on marine geology, oceanography and coastal processes receptors.	The potential for the impacts from the Project to be reduced or exacerbated by climate change has been considered in Section 20.6.2.
EIAR Vol. 3, Chapter 10: Benthic Ecology	Impact of the loss or disturbance of benthic habitats on blue carbon.	Loss or disturbance of blue carbon habitats may occur as a result of the Project activities. The impact of loss or disturbance of benthic habitats is assessed in EIAR, Vol. 3, Chapter 10: Benthic Ecology and assessed in further detail in this chapter in relation to blue carbon.
	All impacts resulting from the operation and maintenance phase of the Project on benthic ecology receptors.	The potential for the impacts from the Project to be reduced or exacerbated by climate change has been considered in Section 20.6.2.
EIAR Vol. 3, Chapter 11: Marine Mammal Ecology	All impacts resulting from the operation and maintenance phase of the Project on marine mammal ecology receptors.	The potential for the impacts from the Project to be reduced or exacerbated by climate change has been considered in Section 20.6.2.
EIAR Vol. 3, Chapter 12: Ornithology	All impacts resulting from the operation and maintenance phase of the Project on ornithology receptors.	The potential for the impacts from the Project to be reduced or exacerbated by climate change has been considered in Section 20.6.2.
EIAR Vol. 3, Chapter 13: Fish and Shellfish Ecology	All impacts resulting from the operation and maintenance phase of the Project on fish and shellfish ecology receptors.	The potential for the impacts from the Project to be reduced or exacerbated by climate change has been considered in Section 20.6.2.

20.9 Whole Project Assessment

Please refer to EIAR Vol. 2, Chapter 7: EIA Methodology for the full description of the Whole Project assessment. CO_2e emissions associated with onshore developments are typically lower than those offshore (0.082 kg CO_2e per Megajoule (MJ) for onshore wind vs 0.130 kg CO_2e per MJ for offshore wind turbine (both 2 MW capacity) (Wang and Jinxiang, 2019). The onshore project comprises of landfall infrastructure (above MLWS), approximately 2 km of HVDC cabling to connect to a converter station south of Boddam, and High Voltage Alternating Current (HVAC) cabling from the converter station to the Scottish and Southern Electricity Networks – Transmission substation (NorthConnect, 2015; NorthConnect, 2018). The total CO_2e emissions associated with the construction of the converter station and HVAC cabling was determined as 11,925 tonnes (NorthConnect, 2015). The HVDC cabling and the subsea components of the NorthConnect project were determined to result in 10,000 tonnes of CO_2e emissions within the NorthConnect 2018 ES (NorthConnect, 2018). The scale of onshore infrastructure and installation emissions is considerably less than that of the offshore Project, and the CO_2e emissions associated with the onshore project represent a small proportion of the total CO_2e emissions for the whole Project. Overall, the Project as a whole is considered to contribute to achieving UK carbon budgets.

In relation to the ICCI assessment, please refer to the whole project assessments conducted for each relevant topic-specific chapter in EIAR Vol. 3, Chapters 8 to 22. Climate change is not anticipated to interact with whole Project impacts, and therefore, there would be no change to the significance assessed within each topic-specific chapter of this EIAR when the influence of climate change on Project impacts is considered.

In relation to the blue carbon assessment, as described in EIAR Vol. 3, Chapter 10: Benthic Ecology, there will not be any additional impacts from the onshore aspects of the Project on benthic ecology receptors, and this also applies to blue carbon. It is possible that onshore aspects of the Project could disturb onshore carbon stores (e.g. woodland or peatlands). However, the NorthConnect 2015 and 2018 EIARs state that there are no peatland systems within the Red Line Boundary (RLB) for the onshore project (NorthConnect, 2015; NorthConnect, 2018). The EIARs do note the presence of woodland areas, however, considering the length of the scale of the onshore project (2 km of HVDC cables from shore, 2 km of HVAC cabling and one converter station), any habitat loss caused by the onshore project would not result in a significant loss of carbon or carbon storage potential (NorthConnect, 2015; NorthConnect, 2018). Therefore, the onshore project is not anticipated to result in any substantial increase in the biological carbon lost from what has been assessed for the offshore Project.

20.10 Transboundary effects

Transboundary effects arise when impacts from a development within one European Economic Area (EEA) state's territory affects the environment of another EEA state(s).

The potential for transboundary effects on the receptors considered within the in-combination climate assessment in Section 20.6.1 has been considered in EIAR Vol. 3, Chapters 8 to 22. No ICCIs were assessed as significant, therefore there are no anticipated changes to the assessment of transboundary effects conducted in EIAR Vol. 3, Chapters 8 to 22.

As demonstrated by the carbon and GHG assessment in Section 20.6.1, the Project contributes to the avoidance of emissions which would otherwise be released into the atmosphere from the burning of fossil fuels to generate electricity. GHG emissions are not geographically bounded, and therefore, there is the potential to result in a transboundary effect. However, the carbon and GHG assessment presented within this chapter has been conducted using a conservative approach by contextualising project emissions as part of UK national carbon budgets (rather than at a global scale). As the effects of GHG emissions are global, the assessment is considered inherently transboundary in nature.

20.11 Summary of mitigation and monitoring

No secondary mitigation, over and above the embedded mitigation measures proposed in Section 20.5.3.2, is either required or proposed in relation to the potential effects of the Project for the carbon GHG assessment.

20.12 References

Allekotte, L., and Garrett, P. (2024). Life Cycle Assessment of Electricity Production from an offshore V236-15 MW Wind Plant. Vestas Wind Systems A/S.

BEIS (Department for Business, Energy & Industrial Strategy) (2021). Net Zero Strategy: Build Back Greener. Available online at: https://www.gov.uk/government/publications/net-zero-strategy [Accessed on 19/09/2024].

BEIS (2022a). British Energy Security Strategy. Available online at: https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy#renewables [Accessed on 19/09/2024].

BEIS (2022b). Energy and emissions projections: Annex B & G. Available online at: https://www.gov.uk/government/collections/energy-and-emissions-projections [Accessed on 20/09/2024].

BEIS (2023a). Updated energy and emissions projections 2021 to 2040. Available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1111625/updated-energy-and-emissions-projections-2021-2040.pdf [Access 19/09/2024].

BEIS (2023b). Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal Available online at: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal [Accessed on 19/09/2024].

Bricheno, L.M., Amies, J.D., Chowdhury, P., Woolf, D. and Timmermans, B. (2023). Climate change impacts on storms and waves relevant to the UK and Ireland. MCCIP Science Review 2023, 20pp.

BSI (2019). BS EN ISO 14064-2:2019. Greenhouse gases. Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements.

BSI (2023). Publicly Available Standard (PAS) 2080:2023 – Carbon management in buildings and infrastructure. Available online at: https://www.bsigroup.com/globalassets/localfiles/en-th/pas-2080/pas2080_final-th.pdf [Accessed on 19/09/2024].

Burden, A., Smeaton, C., Angus, S., Garbutt, A., Jones, L., Lewis H.D. and Rees. S.M. (2020) Impacts of climate change on coastal habitats relevant to the coastal and marine environment around the UK. MCCIP Science Review 2020, 228–255.

Burrows M.T., Kamenos N.A., Hughes D.J., Stahl H., Howe J.A. and Tett P. (2014). Assessment of carbon budgets and potential blue carbon stores in Scotland's coastal and marine environment. Scottish Natural Heritage Commissioned Report No. 761. Available online at: https://www.nature.scot/sites/default/files/Publication%202014%20-%20SNH%20Commissioned%20Report%20761%20-%20Assessment%20of%20carbon%20budgets%20and%20potential%20blue%20carbon%20stores%20in%20Scotland's%20coastal%20and%20marine%20environment.pdf [Accessed on 08/10/2024]

Burrows, M.T., Hughes, D.J., Austin, W.E.N., Smeaton, C., Hicks, N., Howe, J.A., Allen, C., Taylor, P. & Vare, L.L. (2017). Assessment of Blue Carbon Resources in Scotland's Inshore Marine Protected Area Network. Scottish Natural Heritage Commissioned Report No. 957.

Burrows, M.T., O'Dell, A., Tillin, H., Grundy, S., Sugden, H., Moore, P., Fitzsimmons, C., Austin, W., Smeaton, C. (2024). The United Kingdom's Blue Carbon Inventory: Assessment of Marine Carbon Storage and Sequestration Potential in UK Seas (Including Within Marine Protected Areas). A Report to The Wildlife Trusts, WWF and the RSPB. Scottish Association for Marine Science, Oban.
Available online at: https://www.wildlifetrusts.org/sites/default/files/2024-09/UK%20assessment%20-%20scientific%20report.pdf [Accessed on 03/10/2024].

Burton, N.H.K., Daunt, F., Kober, K., Humphreys, E.M. and Frost, T.M. (2023) Impacts of Climate Change on Seabirds and Waterbirds in the UK and Ireland. MCCIP Science Review 2023, 26pp.

Carroll M.J., Bolton, M., Owen, E., Anderson, G.Q.A., Mackley, E.K., Dunn, E.K. and Furness, R.W. (2017). Kittiwake breeding success in the southern North Sea correlates with prior sandeel fishing mortality. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 27(6), pp. 1164 – 1175.

Carbon Trust (2024). Offshore wind industry product carbon footprinting guidance. Available online at: https://www.carbontrust.com/our-work-and-impact/guides-reports-and-tools/standardising-offshore-wind-carbon-footprinting [Accessed on 08/10/2024].

CCC (2020). The Sixth Carbon Budget Electricity generation. Available online at: https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-Electricity-generation.pdf [Accessed on 19/09/2024].

Coles, T. (2020) Impacts of climate change on tourism and marine recreation MCCIP Science Review 2020, 593–615.

Cornes, R.C., Tinker, J., Hermanson, L., Oltmanns, M., Hunter, W.R., LloydHartley, H., Kent, E.C., Rabe, B. and Renshaw, R. (2023). Climate change impacts on temperature around the UK and Ireland. Marine Climate Change Impacts Partnership Science Review 2023,18pp. Available online at: https://www.mccip.org.uk/sites/default/files/2023-03/The%20Impacts%20of%20Climate%20Change%20on%20Sea%20Temperature%20around%20the%20UK%20and%20Ireland.pdf [Accessed on 03/10/2024].

Cunningham, C. and Hunt, C. (2023). Scottish Blue Carbon - a literature review of the current evidence for Scotland's blue carbon habitats. NatureScot Research Report 1326. Available online at: https://www.nature.scot/doc/naturescot-research-report-1326-scottish-blue-carbon-literature-review-current-evidence-scotlands [Accessed on 03/10/2024].

Department for Energy Security and Net Zero (DESNZ) (2021). Carbon Budgets. Available online at: https://www.gov.uk/guidance/carbon-budgets [Accessed on 26/09/2024].

Department for Energy Security and Net Zero (DESNZ) (2023). Valuation of energy use and greenhouse gas emissions. Available online at : https://assets.publishing.service.gov.uk/media/66c85e891f215d9f0a913536/guidance-on-valuation-of-energy-use-ghg-emissions-background-documentation.pdf [Accessed on 26/09/2024].

Diaz, R.J. and Rosenberg, R. (2008). Spreading dead zones and consequences for marine ecosystems. science, 321(5891), pp.926-929.

Diesing, M., Thorsnes, T. and Bjarnadóttir, L.R. (2021). Organic carbon densities and accumulation rates in surface sediments of the North Sea and Skagerrak. Biogeosciences, 18(6), pp.2139-2160.

Dye, S., Berx, B., Opher, J., Tinker, J.P. and Renshaw, R. (2020) Climate change and salinity of the coastal and marine environment around the UK. Marine Climate Change Impacts Partnership Science Review 2020, 76–102. Available online at: https://www.mccip.org.uk/sites/default/files/2021-07/04_salinity.pdf [Accessed on 07/10/2024].

Findlay, H.S., Artoli, Y., Birchenough, S.N.R., Hartman, S., León, P. and Stiasny, M. (2022) Climate change impacts on ocean acidification relevant to the UK and Ireland. Marine Climate Change Impacts Partnership Science Review, 2022 24pp. Available online at: https://www.mccip.org.uk/sites/default/files/2022-12/Ocean%20Acidification%20v2.pdf [Accessed on 07/10/2024].

Fox, C.J., Marshall, C., Stiasny, M.H. & Trifonova, N. (2023). Climate Change Impacts on Fish of Relevance to the UK and Ireland. MCCIP Science Review 2023, 17pp.

Heinatz, K. and Scheffold, M.I.E. (2023). A first estimate of the effect of offshore wind farms on sedimentary organic carbon stocks in the Southern North Sea. Frontiers in Marine Science, 9, p.1068967.

Horsburgh, K., Rennie, A. & Palmer, M. (2020). Impacts of climate change on sea-level rise relevant to the coastal and marine environment around the UK. MCCIP Science Review, 116-131.

IEMA (2020). Environmental Impact Assessment Guide to Climate Change Resilience and Adaption. Available online at: https://www.iema.net/resources/reading-room/2020/06/26/iema-eia-guide-to-climate-change-resilience-and-adaptation-2020 [Accessed on 19/09/2024].

IEMA (2022). Assessing Greenhouse Gas Emissions and Evaluating their Significant, 2nd Edition. Available online at: https://www.iema.net/resources/blog/2022/02/28/launch-of-the-updated-eia-guidance-on-assessing-ghg-emissions [Accessed on 19/09/2024].

IPCC (2021). AR6 Climate Change 2021. The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press.

Jackson, A. (2008). *Ophiothrix fragilis* Common brittlestar. In Tyler-Walters H. Marine Life Information Network: Biology and Sensitivity Key Information Reviews. Plymouth: Marine Biological Association of the United Kingdom. [cited 27-10-2024]. Available online at: https://www.marlin.ac.uk/species/detail/1198 [Accessed on 27/10/2024].

Mahaffey, C., Hull, T., Hunter, W., Greenwood, N., Palmer, M., Sharples, J., Wakelin, S. and Williams, C. (2023). Climate change impacts on dissolved oxygen concentration in marine and coastal waters around the UK and Ireland. Marine Climate Change Impacts Partnership Science Review, 31pp. Available online at: https://www.mccip.org.uk/sites/default/files/2023-

02/Climate%20Change%20Impacts%20on%20Dissolved%20Oxygen%20Concentration%20in%20Marine%20and%20Coastal%20Waters%20around%20the%20UK%20and%20Ireland%20.pdf [Accessed on 03/10/2024].

Martin, E., Banga, R. and Taylor, N.L. (2023). Climate change impacts on marine mammals around the UK and Ireland. MCCIP Science Review 2023, 22pp.

Masselink, G., Russell, P., Rennie, A., Brooks, S. and Spencer, T. (2020) Impacts of climate change on coastal geomorphology and coastal erosion relevant to the coastal and marine environment around the UK. MCCIP Science Review 2020, 158– 189.

Met Office (2018). UKCP18 Guidance: Representative Concentration Pathways. Available online at: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-guidance---representative-concentration-pathways.pdf [Accessed 20/11/2024].

Met Office (2023). UKCP science reports. Available online at: https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/science/science-reports [Accessed 22/11/2024].

MCCIP (2024). Marine Climate Change Impact Partnership. Available online at: https://www.mccip.org.uk/ [Accessed on 22/10/2024].

Meucci, A., Young, I.R., Hemer, M., Kirezci, E. and Ranasinghe, R., (2020). Projected 21st century changes in extreme wind-wave events. Science Advances, 6(24), p.eaaz7295.

Mieszkowska, N., Burrows, M. and Sugden, H. (2020) Impacts of climate change on intertidal habitats relevant to the coastal and marine environment around the UK. MCCIP Science Review 2020, 256–271.

Mitchell, I., Daunt, F., Frederiksen, M. and Wade, K. (2020). Impacts of climate change on seabirds, relevant to the coastal and marine environment around the UK. MCCIP Science Review, pp. 382 – 399.

Moore, P.J. and Smale, D.A. (2020) Impacts of climate change on shallow and shelf subtidal habitats relevant to the coastal and marine environment around the UK. MCCIP Science Review 2020, 272–292.

National Grid (2024) What is SF6? Sulphur hexafluoride explained. Available online at https://www.nationalgrid.com/stories/energy-explained/what-is-sf6-sulphur-hexafluoride-explained [Accessed on 19/09/24].

National Grid ESO (2024) 2024 FES: ESO Pathways 2024 Data Workbook. Available online at: https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.nationalgrideso.com%2Fdocument%2F322326%2Fdownload&wdOrigin=BROWSELINK [Accessed on 19/09/2024].

NorthConnect (2015). NorthConnect Interconnector Converter Station and High Voltage Alternating Current Cable Route Environmental Statement Volume 2, Main Document, April 2015.

NorthConnect (2018). NorthConnect High Voltage Direct Current Cable Infrastructure. UK Environmental Impact Assessment Report Volume 2, Main Document, July 2018.

OSPAR (2022). Quality Status Report 2023. Ocean Acidification. Available online at: https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/other-assessments/ocean-acidification [Available online at: 27/10/2024].

Palmer, M., Howard, T., Tinker, J., Lowe, J., Bricheno, L., Calvert, D., Edwards, T., Gregory, J., Harris, G., Krijnen, J., Pickering, M., Roberts, C., and Wolf, J. (2018). UKCP18 Marine Report. Marine Projections. November 2018. Available online at: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-marine-report-updated.pdf [Accessed on 03/10/2024].

Porter, J, S., Austin, W, E, N., Burrows, M, T., Clarke, T., Davies, G., Kamenos, N., Riegel, S., Smeaton, C., Page, C., Want, A., (2020). Blue carbon audit of Orkney waters. Scottish Marine and Freshwater Science Vol 11 No 3, 96pp. DOI: 10.7489/12262-1. Available online at: https://data.marine.gov.scot/dataset/blue-carbon-audit-orkney-waters [Accessed on 26/09/2024].

Readman, J.A.J., Lloyd, K.A., & Watson, A. (2023). *Flustra foliacea* and colonial ascidians on tide-swept moderately wave-exposed circalittoral rock. In Tyler-Walters H. Marine Life Information Network: Biology and Sensitivity Key Information Reviews, Plymouth: Marine Biological Association of the United Kingdom. Available online at: https://www.marlin.ac.uk/habitat/detail/1096 [Accessed on 27/10/2024].

RICS (2024). Whole life carbon assessment for the built environment. Available online at: https://www.rics.org/content/dam/ricsglobal/documents/standards/Whole_life_carbon_assessment_PS_Sept23.pdf [Accessed on 19/09/2024].

Schlömer S., T. Bruckner, L. Fulton, E. Hertwich, A. McKinnon, D. Perczyk, J. Roy, R. Schaeffer, R. Sims, P. Smith, and R. Wiser (2014). Annex III: Technology-specific cost and performance parameters. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Schmidtko, S., Stramma, L. and Visbeck, M., (2017). Decline in global oceanic oxygen content during the past five decades. Nature, 542(7641), pp.335-339.

Scottish Government (2015). Scotland's National Marine Plan. A single framework for managing our seas. Available online at: https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2015/03/scotlands-national-marine-plan/documents/00475466-pdf/00475466-pdf/govscot%3Adocument/00475466.pdf [Accessed on 19/09/2024].

Scottish Government (2016). Scottish Ocean Climate Status Report 2016. Scottish Marine and Freshwater Science Vol. 9, No. 4. Available online at: https://data.marine.gov.scot/dataset/scottish-ocean-climate-status-report-2016 [Accessed on 22/10/2024].

Scottish Government (2020). Scottish biodiversity strategy post-2020: statement of intent. Available online at: https://www.gov.scot/publications/scottish-biodiversity-strategy-post-2020-statement-intent/ [Accessed on 18/09/2024].

Scottish Government (2022a). A Blue Economy Vision for Scotland. Published March 2022. ISBN: 978-1-80435-258-8. Available online at: https://www.gov.scot/publications/blue-economy-vision-scotland/documents/ [Accessed on 18/09/2024].

Scottish Government (2022b). Sectoral marine plan - offshore wind for Innovation and Targeted Oil & Gas decarbonisation: initial plan framework. Available online at: https://www.gov.scot/publications/initial-plan-framework-sectoral-marine-plan-offshore-wind-innovation-targeted-oil-gas-decarbonisation-intog/documents/ [Accessed on 19/09/2024].

Scottish Government (2023). Reducing greenhouse gas emissions. Available online at: https://www.gov.scot/policies/climate-change/reducing-emissions/ [Accessed on 18/09/2024].

Searle, K.R., Waggitt, J., Evans, P., Bogdanova, M., Daunt, F. and Butler, A., (2022). Study to examine the impact of climate change on seabird species off the east coast of Scotland and potential implications for environmental assessments.

Sharples, J., Holt, J., Wakelin, S. and Palmer, M.R. (2022) Climate change impacts on stratification relevant to the UK and Ireland. MCCIP Science Review 2022, 11pp.

Smeaton, C., Austin, W. and Turrell, W.R. (2020). Re-Evaluating Scotland's Sedimentary Carbon Stocks. Scottish Marine and Freshwater Science Vol 11 No 2, 16pp. Available online at: https://data.marine.gov.scot/dataset/re-evaluating-scotland%E2%80%99s-sedimentary-carbon-stocks [Accessed on 22/11/2024].

Smeaton, C., Hunt, C.A., Turrell, W.R. and Austin, W.E.N. (2021). Marine sedimentary carbon stocks of the United Kingdom's exclusive economic zone. Front. Earth Sci, 9(593324), pp.10-3389.

Thomson, R.C. and Harrison, G.P. (2015). Life Cycle Costs and Carbon Emissions of Offshore Wind Power. Available online at: https://www.climatexchange.org.uk/media/1461/main_report_-_life_cycle_costs_and_carbon_emissions_of_offshore_wind_power.pdf [Accessed on 19/092024].

Townhill, B.L., Artioli, Y., Pinnegar, J.K. and Birchenough, S.N.R. (2022). Exposure of commercially exploited shellfish to changing pH levels: how to scale-up experimental evidence to regional impacts. ICES Journal of Marine Science, 79, 2362–2372.

Townhill, B.L., Couce, E., Tinker, J., Kay, S. and Pinnegar, J.K. (2023). Climate change projections of commercial fish distribution and suitable habitat around north-western Europe. Fish and Fisheries.

UNECE (2021). Carbon Neutrality in the UNECE Region: Integrated Life-cycle Assessment of Electricity Sources. Available online at: https://unece.org/sites/default/files/2022-04/LCA_3_FINAL%20March%202022.pdf [Accessed on 20/09/2024].

Wakelin, S.L., Artioli, Y., Holt, J.T., Butenschön, M. and Blackford, J., (2020). Controls on near-bed oxygen concentration on the Northwest European Continental Shelf under a potential future climate scenario. Progress in Oceanography, 187, p.102400.

Wakelin, S., Townhill, B., Engelhard, G., Holt, J. and Renshaw, R. (2021) Marine heatwaves and cold spells, and their impact on fisheries in the North Sea. Journal of Operational Oceanography (Copernicus Marine Service Ocean State Report, 5), s91.

Wang, S., Wang, S. and Liu, J. (2019). Life-cycle green-house gas emissions of onshore and offshore wind turbines. Journal of Cleaner Production, 210, pp.804-810.

Wolf, J., Woolf, D. and Bricheno, L., (2020). Impacts of climate change on storms and waves relevant to the coastal and marine environment around the UK. MCCIP Science Review, 2020, pp.132-157.

WRI and World Business Council for Sustainable Development (2015). The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (GHG Protocol). Available online at: https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf [Accessed on 19/09/2024].