Appendix 17.1: Climatic Effects Greenhouse Gas Technical Report

Array EIA Report

2024

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1. INTRODUCTION

1. This Greenhouse Gas (GHG) Technical Report sets out the methodology and calculations of the GHG emissions for the Ossian Array (hereafter referred to as 'the Array'). These calculations inform the assessment of climate change impacts in volume 2, chapter 17. This Technical Report should be read in conjunction with the chapter as supporting information.

2. GHG emissions have been estimated by applying published emissions factors to activities in the baseline and to those required for the Array. The emissions factors relate to a given level of activity, or amount of fuel, energy or materials used, and therefore to the mass of GHGs released as a consequence. This Technical Report presents the technical calculations which relate to the potential magnitude of impact as assessed within volume 2, chapter 17.

3. The GHGs considered in this Technical Report are those in the 'Kyoto basket'[1] of global warming gases expressed as their carbon dioxide (CO_2)-equivalent (CO_2e) Global Warming Potential (GWP). This is denoted by CO_2e units in emissions factors and calculation results. The GWPs typically used are the 100-year factors in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (IPCC, 2013) or as otherwise defined for national reporting under the United Nations Framework Convention on Climate Change (UNFCCC).

4. The scope of this Technical Report relates to the Array during the construction, operation and maintenance and decommissioning phases. Key emissions sources included in the assessment are:
   - land use (seabed) change;
   - embodied carbon emissions in materials for the offshore infrastructure required (the wind turbines, (alongside their floating substructures, and mooring and anchoring systems), the fixed bottom Offshore Substation Platforms (OSPs) and inter-array and interconnector cables);
   - offshore transport emissions during the construction, operation and maintenance, and decommissioning phases; and
   - avoided emissions associated with the abatement of required fossil fuel generators and their associated emissions related with the United Kingdom (UK) electricity grid. Note that avoided emissions presented as part of the Array would be realised at the point of grid connection as part of the Proposed offshore export cable corridor(s) and the Proposed onshore transmission infrastructure, which are subject to separate applications.

2. STUDY AREA

5. Figure 2.1 illustrates the climatic effects study area for the Array which encompasses the proposed Array area (i.e. the area in which the wind turbines and associated infrastructure will be located) in the context of the domestic and international scope as developed on the basis of established Institute of Environmental Management and Assessment (IEMA) guidance (IEMA, 2022) utilised throughout this chapter. Domestic scope considers the local and national policy and targets concerning GHG and climate resilience.

6. GHG emissions have a global (international) effect rather than directly affecting any specific local receptor. The impact of GHG emissions occurring due to the Array on the global atmospheric concentration of the relevant GHGs, expressed in CO_2-equivalents (CO_2e), is therefore considered within this assessment.

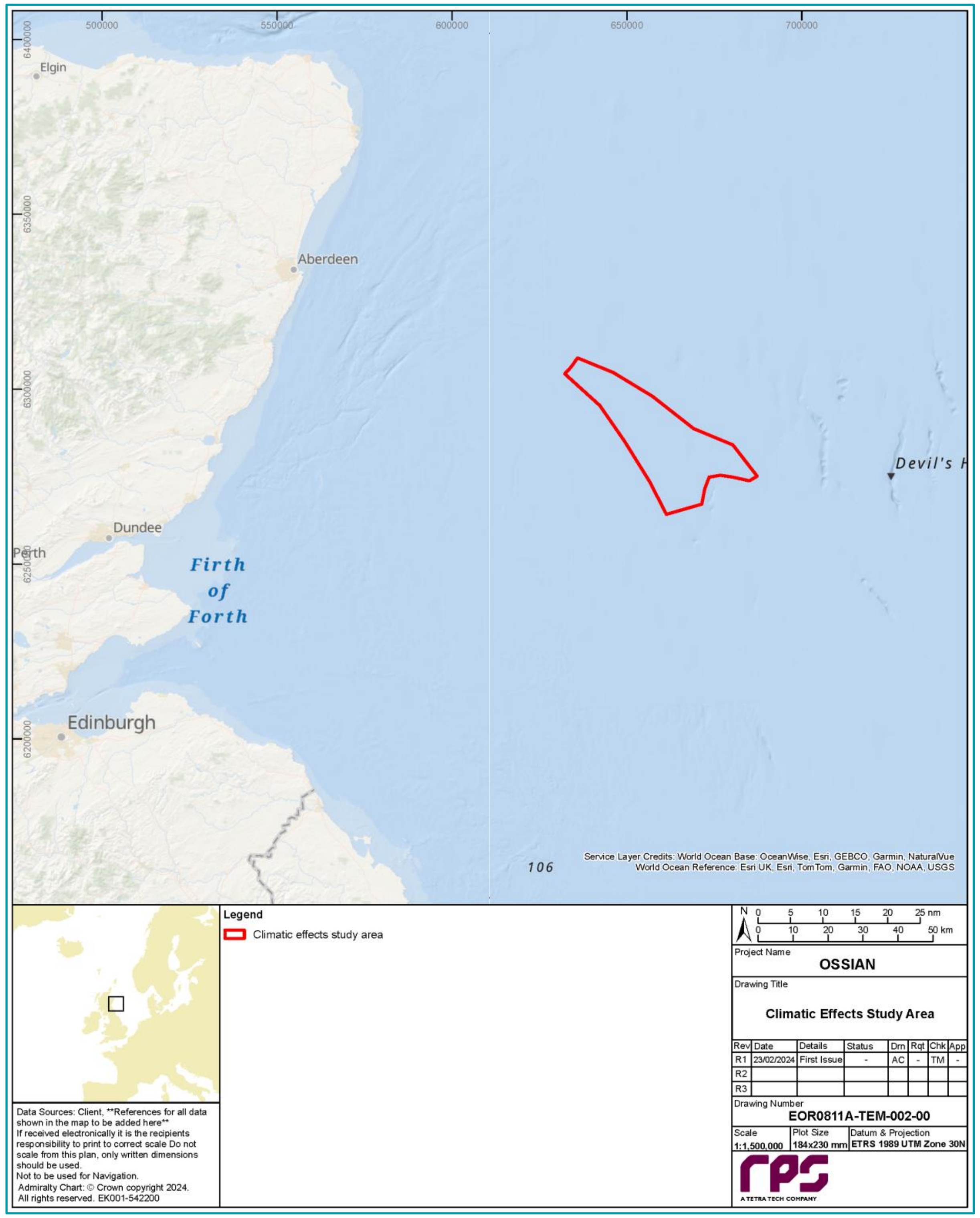

Figure 2.1: Climatic Effects Study Area

[1] The Kyoto Basket of global warming gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). The latter four are together termed 'F-Gases'.

3. METHODOLOGY

3.1. METHODOLOGY OVERVIEW

7. Published benchmarks have been used to establish the baseline of current and future grid-average carbon intensity for the UK. Baseline information for this, as well as other relevant activities for the Array have been informed via the following source:

- Department for Energy Security and Net Zero (DESNZ) (formerly Department for Business, Energy and Industrial Strategy (BEIS) (DESNZ, 2023a) Valuation of Energy Use and Greenhouse Gas: Supplementary guidance to the HM Treasury Green Book.

8. GHG emissions caused by an activity are often categorised into ‘scope 1’, ‘scope 2’ or ‘scope 3’ emissions, following the guidance of the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) Greenhouse Gas Protocol suite of guidance documents (WRI and WBSCD, 2004). These categories are as follows:

- scope 1 emissions: direct GHG emissions from sources owned or controlled by the company, e.g. from combustion of fuel at an installation;
- scope 2 emissions: caused indirectly by consumption of purchased energy, e.g. from generating electricity supplied through the national grid to an installation; and
- scope 3 emissions: all other indirect emissions occurring as a consequence of the activities of the company, e.g. in the upstream extraction, processing and transport of materials consumed or the use of sold products or services. Downstream use of products and services sold to customers would also be captured under scope 3 emissions.

9. This assessment has sought to include emissions from all three scopes, where this is material[2] and reasonably possible from the information and emissions factors available, to capture the impacts attributable most completely to the Array. These emissions are not separated out by defined scopes (scope 1, 2 or 3) in the assessment.

10. Due to the nature of the Array (i.e. it results in generated electricity from renewable sources being exported to the grid), its total gross GHG emissions includes displaced emissions that would have occurred as a result of predicted UK grid carbon intensity without the Array, i.e. avoided emissions.

11. The assessment has considered (a) the GHG emissions arising from the Array (during construction, operation and maintenance, and decommissioning phases), (b) any GHG emissions that it displaces or are avoided, compared to the current or future baseline, and hence (c) the net impact on climate change due to these changes in GHG emissions overall.

12. Consideration of GHG emissions over the lifetime of the Array is required in order to quantify its net contribution to climate change and as such the magnitude of change owing to the Array.

3.2. EMBODIED CARBON

13. A Life Cycle Assessment (LCA) comprises an evaluation of the inputs, outputs and potential environmental impacts that occur throughout the lifecycle of a particular project, in this case the Array, encompassing either a cradle-to-gate or a cradle-to-grave (accounting for construction, operation and maintenance, and decommissioning) approach. This can be further broken down into the following LCA phases of development:

- materials and construction (A1-A5);
- operation and maintenance (B1-B5); and
- decommissioning (C1-C4).

14. As the Array is currently in its early stages of design, data relating to specific metrics for site-specific design details including chosen design and manufacturer of wind turbines and OSPs are currently unavailable.

15. Therefore, emissions resulting from the manufacturing and construction of the wind turbines, cabling, OSPs and associated Array infrastructure have been calculated via the application of material or fuel emission factors to approximate material or fuel quantities, and published LCA literature. Key sources relied upon for the assessment are as follows:

- Environmental Product Declaration Power transformer TrafoStar 500 Megavolt amperes (MVA) (ABB, 2003);
- Inventory of Carbon and Energy (ICE) database (Jones and Hammond, 2019); and
- UK Government GHG Conversion Factors for Company Reporting (DESNZ and Department for Environment, Food and Rural Affairs (DEFRA), 2023).

16. Methodology specific to each element comprising the Array is detailed within section 5.2.

3.3. BLUE CARBON

17. The calculation of climate change effects for the Array considers the impact of temporary and permanent habitat loss and disturbance, affecting ‘blue carbon’ stocks within the baseline. The term ‘blue carbon’ refers to organic carbon that has been captured and stored through biological processes in the coastal and marine environment. Blue carbon can be stored within living biomass, root systems and sediments. Within the coastal and marine environment, there are a variety of habitat types that contribute to the global blue carbon stocks, including sediment habitats, such as those found in the climatic effects study area (Cunningham and Hunt, 2023).

18. Where habitats are disturbed or lost through impacts from a development, this affects the habitat’s ability to store and sequester blue carbon. For example, when organic sediments are disturbed and enter the water column, stored blue carbon within these organic sediments can be converted to CO_2 through a process called remineralisation (Cunningham and Hunt, 2023).

19. Site-specific benthic survey data (see volume 3, appendix 8.1, annex A) and published emission factors have been used to calculate the extent of blue carbon stocks within the climatic effects study area. The resulting impact of the Array upon the blue carbon stocks has been calculated based on the total area of disturbance by the construction, operation and maintenance, and decommissioning of the Array, alongside published literature values for the overall effects of disturbance. Key sources relied upon for the assessment are as follows:

- Scottish Blue Carbon – a literature review of the current evidence for Scotland’s blue carbon habitats. NatureScot Research Report 1326 (Cunningham and Hunt, 2023);
- Re-Evaluating Scotland’s Sedimentary Carbon Stocks. Marine Scotland Science (Smeaton *et al*., 2020); and
- Benthic and Subtidal Ecology Technical Report (volume 3, appendix 8.1).

[2] As defined in IEMA (2022), material emissions sources are those that are greater than 1% of total emissions, and result from activities that do not significantly change the result of the assessment.

3.4. OPERATIONAL AVOIDED EMISSIONS

20. The assessment also considers the GHG emissions that would not be generated (i.e. avoided) during the operation of the Array during the future baseline, using a variety of scenarios to characterise the future baseline (see section 6.2).

3.5. ASSUMPTIONS AND LIMITATIONS

21. Most of the construction phase GHG emissions associated with the manufacturing of components are likely to occur outside the territorial boundary of the UK and hence outside the scope of the UK's national carbon budget, policy and governance. However, in recognition of the climate change effect of GHG emissions (wherever occurring), and the need to avoid 'carbon leakage' overseas when reducing UK emissions, emissions associated with the construction phase have been presented within the assessment and quantification of GHG emissions as part of the Array.

22. There is uncertainty about future climate and energy policy and market responses, which affect the likely future carbon intensity of energy supplies, and thereby the future carbon intensity of the electricity generation being displaced by the Array. Government projections consistent with national carbon budget commitments have been used in the assessment ('long-run marginal' projections). It should be noted that latest Government projections include an increase in renewable energy generation, like the Array (DESNZ, 2023a), consistent with the Government's current policy of a low-carbon electricity grid by 2035, with no unabated fossil fuel generation (BEIS, 2021). As such, for the Array's operation and maintenance lifetime, the long-run marginal projections presented assume that the Array will displace low-carbon sources of electricity, essentially comparing the Array to projects similar to itself. Therefore, multiple scenarios have been considered to present a likely range of avoided emissions, including displacement of non-renewable fuels as an upper estimate for the likely avoided emissions, and comparison to the long-run marginal projections as a lower estimate.

23. The specific wind turbine technology and design of associated infrastructure that would be used by the Array have not yet been specified. Thus, there is a degree of uncertainty regarding GHG emissions at all project phases resulting from the manufacturing and construction of wind turbines and infrastructure. This assessment seeks to limit the impact this might have by using Maximum Design Scenario (MDS) material quantities and material types (i.e. those with the greatest carbon impact), as informed by engineering input, in the calculation of construction phase emissions and emissions resulting from repair and maintenance activities. It is unlikely that these MDS material quantities will be used in the final design of the Array, owing to improvements in wind turbine and associated infrastructure design and refinements to design assumptions. As such, calculated emissions represent a conservative MDS.

24. Blue carbon that is released as a result of marine habitat disturbance dissolves into coastal and marine ecosystems, such as the ocean. As such, this impact does not directly contribute to the global atmospheric mass of CO_2 (the receptor). However, it is likely to indirectly impact atmospheric CO_2 concentrations, as an increased concentration of dissolved CO_2 alters ocean and calcium carbonate ($CaCO_3$) chemistry. Though interactions between different states of carbon in the oceans is complex, it is likely that increased concentrations of ocean CO_2 will overall reduce the capacity of oceans to absorb CO_2 and cause a greater potential for the ocean to release CO_2 to the atmosphere under certain conditions (IPCC, 2021). As such, for the purposes of this assessment, remineralisation of blue carbon stocks has been assumed to have the same impact as the release of an equivalent mass of CO_2 to the global atmosphere.

25. The benthic survey data used in the assessment of impacts to blue carbon stocks (see volume 3, appendix 8.1, annex A) was collected based on industry standard sampling methodologies. It should therefore be noted that there is a natural limitation in the accuracy of interpretations from extrapolating habitat information from samples. However, the samples taken have been deemed sufficient to accurately characterise the habitats present within the site boundary.

26. Literature used to calculate the blue carbon value of habitats within the Array provide stored blue carbon factors for the top 10 cm of sediment only, as there are limited data available on sediment thickness and organic carbon content of deeper sediments (Cunningham and Hunt, 2023). As organic carbon contained within deeper sediments is likely to be more stable than that found in the top sediment layer, and less vulnerable to remineralisation following disturbance (Smeaton *et al.*, 2020), the baseline characterisation of the blue carbon value of the habitats within the Array is deemed to be sufficient.

27. It is important to note that the Array would not operate in isolation, as the Proposed offshore export cable corridor(s) and Proposed onshore transmission infrastructure are required to connect the Array to the grid. Without this transmission infrastructure (subject to separate consent applications), avoided emissions presented as part of this assessment would not be realised. As such, it is necessary to consider the embodied emissions of the transmission infrastructure within the cumulative assessment, so as to understand the whole life net effects of Ossian.

28. The design parameters of the Proposed offshore export cable corridor(s) and Proposed onshore transmission infrastructure required to connect the Array to the grid are not yet available. As such, calculations for the assessment of cumulative effects, in order to quantify whole life GHG emissions for both the Array and associated transmission infrastructure, have been based on high level, indicative parameters. These parameters will be refined in subsequent applications for the transmission infrastructure, alongside the associated calculations as more information becomes available.

4. BASELINE

4.1. CURRENT BASELINE

29. With regard to GHG emissions, the current baseline is the offshore sea surface, water column and seabed use for the Array, which will be impacted either through permanent seabed take (e.g. laying of interconnector and inter-array cables, installation of OSP foundations and wind turbine anchors), or through temporary seabed take and other disturbance (e.g. additional areas required during construction and the dragging of mooring lines across the seabed, dependent on technology type). Benthic surveys classified eight different sediment types within the climatic effects study area. Muddy sand comprises approximately 31% of the study area, sand comprises approximately 24% of the study area, slightly gravelly sand comprises approximately 18% of the study area and the remaining sediment types (gravelly sand, sandy gravel, muddy sandy gravel, slightly gravelly muddy sand and gravelly muddy sand) comprise the remaining 28% of the study area (refer to volume 3, appendix 8.1, annex A for more information).

30. The standing blue carbon stock in the subtidal sediments present within the Array is presented in section 5.1.

31. With regards to the current baseline concerning the UK electricity grid at the time of writing, the conversion factor for companies reporting UK electricity generation carbon intensity resides at 252.97 $kgCO_2e$/MWh (including scope 3 but as generated, i.e. excluding transmission and distribution losses) (DESNZ and DEFRA, 2023).

4.2. FUTURE BASELINE

32. The future baseline GHG emissions for existing land use (seabed) without the Array are expected to remain similar to the current baseline identified in section 4.1. There are limited published data available regarding blue carbon sequestration rates for sedimentary marine habitat types. However, it is acknowledged that blue carbon sequestration rates in marine habitats are lower than those of terrestrial habitats, in particular sediment-based habitats. Some sediment areas of the North Sea, for instance, experience almost no sediment accumulation and associated carbon sequestration (Cunningham and Hunt, 2023). As such, no material change to the blue carbon stocks currently present within the Array is anticipated in the future baseline.

33. The future baseline for electricity generation that would be displaced by the Array depends broadly on future energy and climate policy in the UK, and more specifically (with regards to day-to-day emissions) on the demand for the operation of the Array, compared to other generation sources available; this will be influenced by commercial factors and National Grid's needs.

34. The carbon intensity of baseline electricity generation is projected to reduce over time and so too would the intensity of the marginal generation source, displaced at a given time.

35. DESNZ publishes projections of the carbon intensity of long-run marginal electricity generation and supply that would be affected by small (on a national scale) sustained changes in generation or demand (DESNZ, 2023a). DESNZ projections over the operation and maintenance phase of the Array's lifetime (2039 to 2073) are used to estimate the potential emissions as a result of the Array.

36. Historically, Combined Cycle Gas Turbine (CCGT) plants have been the long-run marginal electricity generators, and previous marginal emissions factors reflect the as-generated emissions of a typical CCGT plant. However, as the power sector decarbonises in line with UK policy, low carbon generation will increase significantly both as a proportion of total and marginal generation. Long-run marginal projections reflect these anticipated changes, and as there remains much uncertainty in the pace of innovation, demand and technical feasibility, are indicative projections rather than prescriptive forecasts (DESNZ, 2023a).

37. DESNZ also publishes projections of the grid-average emissions factor, which is the carbon intensity of all sources of electricity generation, at the point of generation (i.e. excluding transmission and distribution losses). The marginal factor is assumed to converge to the grid average emissions factor by 2050 and both projections are assumed to be constant after that point.

38. National Grid publishes 'Future Energy Scenario' (FES) projections (National Grid Electricity System Operator (ESO), 2023) of grid-average carbon intensity under several possible evolutions of the UK energy market. The DESNZ grid-average projection sits generally above all the National Grid ranges, and as stated above, the marginal factor is assumed by DESNZ to converge with it (and hence with National Grid's scenarios) by 2040.

39. As illustrated in Figure 4.1, all of the FES grid-average carbon intensity projections achieve net negative values due to the sequestration of biogenic CO_2, via Bioenergy with Carbon Capture and Storage (BECCS). It has been assumed that the Array would not displace other forms of electricity generation with net adverse GHG effects. Figure 4.1 illustrates both the DESNZ and National Grid projected carbon intensity factors for displaced electricity generation.

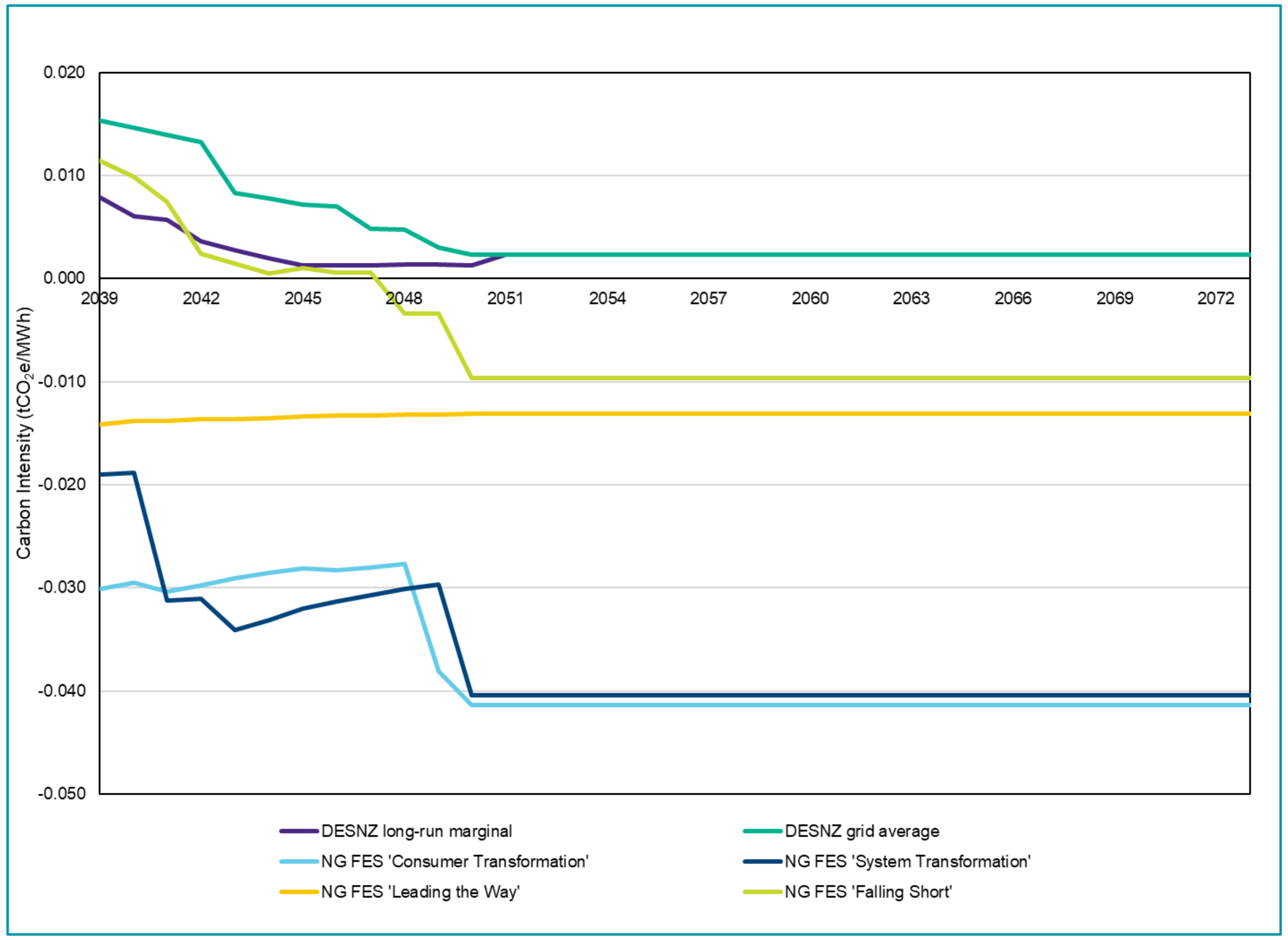

Figure 4.1: DESNZ and FES Future Grid Carbon Intensities

40. Table 4.1 lists the DESNZ grid-average and marginal factors for the 35 years of the Array operation and maintenance phase.

Table 4.1: DESNZ Grid Average and Long-Run Marginal Grid Intensities

Year of Operation	Year	DESNZ Long-run Marginal (tCO_2e/MWh)	DESNZ Grid Average (tCO_2e/MWh)
1	2039	0.008	0.015
2	2040	0.006	0.015
3	2041	0.006	0.014
4	2042	0.004	0.013
5	2043	0.003	0.008

Year of Operation	Year	DESNZ Long-run Marginal (tCO_2e/MWh)	DESNZ Grid Average (tCO_2e/MWh)
6	2044	0.002	0.008
7	2045	0.001	0.007
8	2046	0.001	0.007
9	2047	0.001	0.005
10	2048	0.001	0.005
11	2049	0.001	0.003
12	2050	0.001	0.002
13	2051	0.002	0.002
14	2052	0.002	0.002
15	2053	0.002	0.002
16	2054	0.002	0.002
17	2055	0.002	0.002
18	2056	0.002	0.002
19	2057	0.002	0.002
20	2058	0.002	0.002
21	2059	0.002	0.002
22	2060	0.002	0.002
23	2061	0.002	0.002
24	2062	0.002	0.002
25	2063	0.002	0.002
26	2064	0.002	0.002
27	2065	0.002	0.002
28	2066	0.002	0.002
29	2067	0.002	0.002
30	2068	0.002	0.002
31	2069	0.002	0.002
32	2070	0.002	0.002
33	2071	0.002	0.002
34	2072	0.002	0.002
35	2073	0.002	0.002

5. ASSESSMENT OF CONSTRUCTION EFFECTS

5.1. BLUE CARBON

41. Emissions associated with disturbance to blue carbon stocks during the construction phase of the Array have been calculated based on the total area of seabed disturbance, sediment types present in the Array, published associated carbon stock values and published literature values of the effect of disturbance on remineralisation.

42. During construction, it is anticipated that there will be disturbance from the installation of the anchors and mooring lines, OSP foundations, interconnector and inter-array cables, cable protection and scour. The total disturbance of the seabed within the Array is calculated to be 32.25 km^2, informed by values provided in the Project Description (volume 1, chapter 3).

43. Section 4.1 presents the sediment types and relative distribution across the Array. Blue carbon factors assigned to each sediment type, ranging from 7.3 tC/ha for slightly gravelly muddy sand to 1.8 tC/ha for sandy gravel (Smeaton *et al*., 2020) were scaled by the relevant areas, resulting in an average blue carbon content across the Array of 5.00 tonnes of carbon per hectare. It has been assumed that the composition of sediment types within the total area of disturbed seabed are consistent with the Array wide composition. When the average blue carbon content is scaled by the area of disturbed seabed, this corresponds to a total of 16,109 tonnes of carbon across the Array that has the potential to be disturbed during construction.

44. While a maximum of 16,109 tonnes of blue carbon stock (equivalent to 59,067 tCO_2 when converted from carbon to CO_2) may be disturbed during the construction phase, not all carbon disturbed will be remineralised to CO_2. Though estimates vary, the majority of blue carbon found in marine sediments further than 5 km from the shore is likely to be unreactive, and therefore unlikely to be remineralised following disturbance (Smeaton and Austin, 2022). Instead, following disturbance the blue carbon may be re-deposited elsewhere, with limited remineralisation of CO_2. Approximately 20% of the blue carbon stocks in marine sediments may be reactive and likely to be converted to CO_2 following disturbance (Smeaton and Austin, 2022).

45. Uncertainty remains with the values presented above however, as alternative studies have suggested a higher percentage of conversion to CO_2 (Cunningham and Hunt, 2023). Therefore, it is conservatively anticipated that between 20% and 100% of the blue carbon stock disturbed within the Array will be converted to CO_2, corresponding to an emissions value of between 11,813 tCO_2 and 59,067 tCO_2.

46. To provide a conservative assessment, the greatest emissions value of blue carbon has been reported below.

5.2. EMBODIED CARBON

47. The following sections detail the methodology used to calculate the construction phase emissions associated with the Array. Each section groups relevant elements of the Array by methodology used to calculate resultant emissions.

48. The construction phase emissions cover the LCA stages A1-A5, materials and construction, i.e. emissions associated with the extraction, processing and manufacturing of materials. In addition, emissions associated with the transport of materials and technology to site (within the UK) have been analysed.

49. The materials involved in the offshore components of the Array are the initial elements to consider within the cradle-to-grave approach towards completing this LCA. Emissions are derived from the raw material production required to manufacture the wind turbine generators, floating platforms, anchors and mooring lines, OSPs and OSP foundations, interconnector and inter-array cables and it is often the phase where the majority of embodied carbon is emitted.

5.2.1. WIND TURBINES, OFFSHORE SUBSTATION PLATFORMS AND CABLES

50. The construction phase emissions associated with the following elements of the Array have been calculated using approximate material quantities, and relevant material emission factors:

- wind turbines (including floating platforms, anchors and mooring lines);
- OSP topside structures and foundations;
- interconnector and inter-array cables (including cable protection);
- inter-array cable junction boxes; and
- scour protection.

51. Table 5.1 summarises the relevant material emission intensities sourced from the ICE database (Jones and Hammond, 2019), and corresponding emissions values.

Table 5.1: Emission Factors and Total Emissions for Embodied Carbon of Material Use

Item	Materials	Emissions Factor ($kgCO_2e/kg$)	Emissions Factor Source	Total Embodied Emissions (tCO_2e)	Contribution to Total (%)
Wind turbine floating platforms, anchors and mooring lines	Steel	2.47	Steel (average), ICE database	5,563,675	61%
Wind turbine blades and towers	Steel	2.47	Steel (average), ICE database	1,909,299	21%
	Fibreglass	8.10	Glass reinforced plastic, ICE database		
	Cast iron	2.03	Iron (general), ICE database		
	Aluminium	6.67	Aluminium (general), ICE database		
	Copper	2.71	Tube and sheet copper, ICE database		
	Epoxy resin	5.70	Epoxide resin, ICE database		
Cable protection	Rock	0.007	Aggregates and sand, ICE database	597,442	7%
	Cast iron	2.03	Iron (general), ICE database		
Inter-array and interconnector cables	Copper	2.71	Tube and sheet copper, ICE database	325,095	4%
	Galvanised steel	2.47	Galvanised steel (average), ICE database		
	Optical cable	8.10	Glass reinforced plastic, ICE database		
	Polyethylene	2.54	Polyethylene (general), ICE database		
OSP topside (excluding electrical equipment)	Steel	2.47	Steel (average), ICE database	264,092	3%
OSP foundations	Steel	2.47	Steel (average), ICE database	228,444	3%
Junction boxes	Steel	2.47	Steel (average), ICE database	140,790	2%
Scour protection	Rock	0.007	Aggregates and sand, ICE database	57,648	1%
	Concrete	0.103	Concrete (general), ICE database		

5.2.2. OFFSHORE SUBSTATION PLANT

52. There is limited design information concerning the offshore substation plant, and there are few published LCAs from which to calculate embodied carbon emissions associated with offshore substation equipment. Data from an Environmental Product Declaration (EPD) for a 16 kVA–1,000 MVA transformer (ABB, 2003) has therefore been used to provide an approximation of the potential order of magnitude of emissions from the offshore substation plant, as transformers are among the major substation plant components and have a relatively high materials and carbon intensity.

53. The LCA (ABB, 2003) listed a manufacturing GWP of 2,190 $kgCO_2e$ per MW. This was scaled by the current estimated Array output capacity of 3,600 MW to give an estimated embodied emission value of 7,884 tCO_2e. This value includes lifecycle stages A1-A3.

5.2.3. VESSEL AND HELICOPTER MOVEMENTS

54. Indicative vessel and helicopter movements were used to calculate emissions associated with their activities during the construction phase. Emissions associated with vessel movements were calculated using approximate fuel consumption rates alongside indicative vessel movements and typical activity timescales, using data provided by the project team and data contained within the Project Description (volume 1, chapter 3).

55. Where approximate fuel consumption rates were not available, emissions were calculated by estimating total main engine capacity requirements, vessel speed and distance from port, based on indicative vessel information and likely base ports provided by the project team.

56. These variables were used to calculate total fuel use for vessel movements during the construction phase of the Array. This value was then scaled by the emission factor for marine gas oil (0.258 kgCO_2e/kWh, or 3,245 kgCO_2e/tonne) (DESNZ and DEFRA, 2023), totalling 376,627 tCO_2e.

57. Helicopter movements and their associated emissions were calculated by determining the anticipated fuel consumption, informed by their predicted movements. An indicative number of return trips and assumed distance (280 km) from a potential helicopter base, alongside average fuel consumption (430 kg/hr) and fuel economy data (145 kn/hr) (obtained from manufacturers specifications) were used to estimate fuel consumption. Emission factors for aviation turbine fuel (2.54 kgCO_2e/l) (DESNZ and DEFRA, 2023) were then scaled by the fuel consumption to give associated emissions, totalling 8,988 tCO_2e for the Array.

5.3. SUMMARY

58. Table 5.2 summarises the calculated construction phase emissions associated with the Array, which totals 9,539,061 tCO_2e.

Table 5.2: Construction Phase Embodied Carbon Emissions Summary

Item	Value (tCO_{2e})
Wind turbines (blades and tower)	1,909,299
Wind turbines (floating platforms, mooring and anchors)	5,563,675
OSP (topside, including electrical equipment)	271,977
OSP (foundation)	228,444
Inter-array cables	273,844
Interconnector cables	51,251
Junction boxes	140,790
Cable protection	597,442
Scour protection	57,648
Transport	385,615
Blue carbon	59,067
Total	**9,539,051**

6. ASSESSMENT OF OPERATION AND MAINTENANCE EFFECTS

6.1. BLUE CARBON

59. The long term temporary (35 year) footprint of the Array, including from anchors and mooring lines, OSP foundations, cables and associated scour protection, has the potential to affect the sequestration of blue carbon over its 35 year operation and maintenance lifetime. However, as mentioned in section 3.3, evidence on sequestration rates in offshore sediments indicates little to no sediment accumulation in some areas of the North Sea (Cunningham and Hunt, 2023). Therefore, it is assumed that there will be negligible effects of loss of sequestration capacity within blue carbon habitats over the Array's 35 year lifetime.

60. During storms and rough weather, mooring lines may cause disturbance additional to the permanent footprint of the Array during the operation and maintenance phase, owing to dragging along the seabed. The additional areas of disturbance during this phase of the Array have been calculated to be 122 ha, based on values provided in volume 1, chapter 3.

61. Applying the same methodology detailed in section 5.1, the total emissions from disturbance to blue carbon habitats during the operation and maintenance phase of the Array lies between 447 tCO_2 and 2,233 tCO_2.

62. To provide a conservative assessment, the greatest emissions value of blue carbon has been reported below.

6.2. AVOIDED EMISSIONS

63. The magnitude of impact of the Array is determined by the quantity of marginal electricity generation sources it displaces and associated GHG impacts. The marginal energy generation displaced is determined by the total annual energy output values for the Array (see Table 6.1). The associated GHG emissions are determined by the GHG intensity of the displaced sources of generation.

64. Table 6.1 sets out the parameters for the Array and the associated annual energy output.

Table 6.1: Energy Flows from the Array

Parameter	Value	Unit	Source
Input parameter – anticipated rated power	3,600	MW	Volume 1, chapter 3
Input parameter – capacity factor	39.7	%	DESNZ (2023b)
Input parameter – degradation factor	1.6	%	Staffel and Green (2014)
Input parameter – total annual operating hours	8,760	hrs	Volume 1, chapter 3
Output parameter – annual energy output (year 1)	12,516,638	MWh	Calculated based on the input parameters

65. The input and output figures for the operation and maintenance phase of the Array are then calculated against the assumptions stated within the DESNZ long-run marginal (DESNZ, 2023a). This allows for a

direct presentation of the cumulative GHG emissions avoided throughout the operational lifetime of the Array and therefore, how the Array contributes towards reaching net zero targets in the UK and Scotland.

66. The marginal source displaced may in practice vary from moment to moment depending on the operation of the capacity market, i.e. led by commercial considerations and National Grid's needs at any given time. For the purpose of this assessment, longer-term trends (annual averages) have been used as it is not possible to predict shorter-term variations with confidence. It should be noted that as the UK and Scotland move towards their 2050 and 2045 net zero carbon targets, respectively, the marginal source of electricity generation will likely become a combination of renewables (predominately solar and wind) and storage. It is important to note therefore that from circa 2035 onwards, long-run marginal projections assume that there is no unabated fossil fuel generation, in line with UK Government policy. As such, comparing the Array's GHG impacts with the marginal source of generation is likely to represent an underestimation of its true avoided emissions.

67. The DESNZ long-run marginal grid carbon intensity factors do not properly consider the embedded construction phase GHG impacts of the sources of generation. It is therefore not a like-for-like comparison to compare the lifetime carbon impacts of the Array with the DESNZ long-run marginal or grid-average source.

68. Table 6.2 displays the annual power output and emissions avoidance of the Array when comparing the abated fossil fuel generation using the DESNZ (2023a) long-run marginal carbon intensity for the future UK Grid.

Table 6.2: Operational GHG Impacts

Year of Operation	Year	Output (MWh)	DESNZ Long-Run Marginal	Avoided Emissions (tCO_2e)	Cumulative Avoided Emissions (tCO_2e)
1	2039	12,516,638	0.008	98,262	98,262
2	2040	12,316,372	0.006	74,205	172,466
3	2041	12,119,310	0.006	68,887	241,353
4	2042	11,925,401	0.004	43,121	284,475
5	2043	11,734,595	0.003	32,610	317,085
6	2044	11,546,841	0.002	22,652	339,737
7	2045	11,362,092	0.001	14,273	354,010
8	2046	11,180,298	0.001	14,501	368,511
9	2047	11,001,414	0.001	14,318	382,829
10	2048	10,825,391	0.001	14,873	397,702
11	2049	10,652,185	0.001	14,994	412,696
12	2050	10,481,750	0.001	13,496	426,191
13	2051	10,314,042	0.002	23,552	449,743
14	2052	10,149,017	0.002	23,175	472,918
15	2053	9,986,633	0.002	22,804	495,722
16	2054	9,826,847	0.002	22,439	518,161
17	2055	9,669,617	0.002	22,080	540,241
18	2056	9,514,903	0.002	21,727	561,968
19	2057	9,362,665	0.002	21,379	583,347
20	2058	9,212,862	0.002	21,037	604,385
21	2059	9,065,456	0.002	20,701	625,085
22	2060	8,920,409	0.002	20,369	645,454
23	2061	8,777,683	0.002	20,043	665,498
24	2062	8,637,240	0.002	19,723	685,221
25	2063	8,499,044	0.002	19,407	704,628
26	2064	8,363,059	0.002	19,097	723,725
27	2065	8,229,250	0.002	18,791	742,516
28	2066	8,097,582	0.002	18,490	761,006
29	2067	7,968,021	0.002	18,195	779,201
30	2068	7,840,533	0.002	17,904	797,104
31	2069	7,715,084	0.002	17,617	814,721
32	2070	7,591,643	0.002	17,335	832,057
33	2071	7,470,176	0.002	17,058	849,114
34	2072	7,350,654	0.002	16,785	865,899
35	2073	7,233,043	0.002	16,516	882,416

6.2.1. SENSITIVITY ANALYSIS

69. The long-run marginal figures, which have been used in Table 6.2, are dynamic and show year-on-year decarbonisation of the UK electricity Grid towards the UK's committed net zero 2050 pledge. The long-run marginal carbon intensity figures account for variations over time for both generation and consumption

activity reflecting the different types of power plants generating electricity across the day and over time, each with different emissions factors.

70. However, as discussed in paragraphs 36 and 66, long-run marginal figures should be treated as indicative projections rather than prescriptive targets, and the projections assume abatement of fossil fuel generation sources within the UK electricity grid. By the time the Array is anticipated to be operational (2039), the UK is expected to have made significant progress towards a low-carbon electricity grid, with the current Government policy target year of 2035. Nevertheless, the UK Government has highlighted that some 'transition' fossil fuels will continue to play a part in the UK's energy supply. Therefore, it is likely that the true value of the avoided emissions displaced as a result of the Array's contribution to the UK electricity grid would be higher than that of avoided emissions detailed above.

71. As such, a sensitivity analysis has been carried out using the current UK electricity grid carbon intensity (252.974 $kgCO_2e$/MWh) and current estimated intensity from electricity supplied for 'all non-renewable fuels' (424 $kgCO_2e$/MWh) as detailed in section 4.1.

72. Although the use of the current UK electricity Grid average and DESNZ 'non-renewable fuels' carbon intensities would conclude greater avoided emissions and an ultimate reduction in carbon payback period, these are static baselines and do not account for future UK electricity grid decarbonisation. Further, as the Array's generation output would be dictated by day-to-day demand alongside commercial factors and the National Grid's needs, the benefit of provision of additional low carbon electricity capacity cannot be used to quantify avoided emissions. As such, the long-run marginal provides a conservative quantification of avoided emissions for the purpose of this assessment.

73. Table 6.3 details the potential avoided emissions for the assessment scenario (DESNZ long-run marginal) and two alternative scenarios as part of the sensitivity analysis (current UK electricity grid average as of 2023, and DESNZ 'non-renewable fuels' intensity as of 2023). These are presented for the entire assumed lifetime of 35 years for the purpose of the GHG calculations (whole life). The true avoided emissions value for the Array is likely to lie between the upper and lower limits shown in Table 6.3.

Table 6.3: Avoided Emissions Sensitivity Test

Operating Years	Output (MWh)	DESNZ Long-Run Marginal Avoided Emissions (tCO_2e)	Current UK Grid Average Avoided Emissions (tCO_2e)	DESNZ 'Non-Renewable Fuels' Avoided Emissions (tCO_2e)
35	337,457,750	882,416	69,878,823	143,082,086

74. Additionally, variations in load factors could have a similar effect on the avoided emissions in addition to other quantifications of emissions. Any change in the load factors would vary the MWh output accordingly. As the MWh output has been used as the base for the calculation of avoided emissions, any increase in emissions or avoided emissions would be proportionately similar to that of the above.

6.3. FUEL, ENERGY AND MATERIAL USE DURING OPERATIONS AND MAINTENANCE

75. The primary purpose of an offshore wind farm is to avoid the need for fossil fuel generation assets, reduce the national grid carbon intensity and provide additional electricity generation capacity. Emissions during the operation and maintenance phase of the Array refers to activities contributing to the high level management of the asset such as remote monitoring, maintenance activities, environmental monitoring, electricity sales, etc. Maintenance accounts for by far the largest portion and can be divided into preventative maintenance and corrective maintenance:

- Preventative maintenance: proactive repair to, or replacement of, known wear components based on routine inspections or monitoring systems.
- Corrective maintenance: includes the reactive repair or replacement of failed or damaged components. It may also be performed batch-wise when serial defects or other problems occur.

76. The Array's maintenance activities largely involve inspection, repainting, minor item repair and replacement, removal of marine growth, reburial of cables, and geophysical surveys. Emissions associated with such activities are largely captured with vessel or helicopter movements. Where materials are used (i.e. new paint and coatings, fuses, access ladders, etc.), associated emissions are negligible and immaterial, and as such have not been assessed further.

77. Emissions associated with the proposed maintenance vessels and helicopter movements (refer to volume 1, chapter 3) follow the methodology detailed in section 5.2.3. Such emissions total 808,057 tCO_2e over the lifetime of the Array.

78. Of greater magnitude are emissions associated with material replacement of electrical plant (replacement of transformers and switchgear), cables and scour protection.

79. Throughout the Array's lifetime major plant equipment, such as transformers, will be replaced no more than once every five years for each OSP as informed by the project description (volume 1, chapter 3). This corresponds to a maximum of seven replacements per OSP over the lifetime of the Array, given its 35 year lifetime. As such, the embodied carbon emissions associated with the OSP plant, detailed in paragraph 53 have been scaled up by a factor of seven to provide the operation and maintenance emissions for the OSP plant. Though it is unlikely that all electric plant will need to be replaced once every five years per OSP, this is treated as the most conservative (worst-case) scenario. Total emissions from major OSPs (transformers) over the project lifetime were calculated to be 55,189 tCO_2e.

80. It is anticipated that approximately 5% of the total length of the inter-array cable will be required to be repaired or replaced per year. It is anticipated that the interconnector cables will undergo one repair or replacement event every five years, with the longest length of cable to be replaced 20 km long. Emissions associated with the replacement of such cables were calculated using the methodology detailed at paragraph 50. Total emissions from cable replacement over the project lifetime were calculated to be 509,630 tCO_2e.

81. Finally, it is anticipated that scour protection will be required to be replaced twice over the lifetime of the Array. Emissions associated with the replacement of scour protection were calculated using the methodology detailed at paragraph 50. Total emissions from scour protection replacement over the project lifetime were calculated to be 115,296 tCO_2e.

6.4. SUMMARY

82. Table 6.4 summarises the calculated operation and maintenance phase emissions associated with the Array, which totals between 607,989 tCO_2e and -141,591,681 tCO_2e, depending on the avoided emissions scenario used. Note that negative values represent avoided emissions, i.e. emissions that would have occurred without the Array.

Table 6.4: Operation and Maintenance Phase Emissions Summary

Item	Value (tCO_{2e})
Avoided emissions	-882,416 (long-run marginal) to -143,082,086 (non-renewables mix)
Transport	808,057
OSP and wind turbine electrical equipment replacement and repair	55,189

Item	Value (tCO_{2e})
Cable protection replacement and repair	509,630
Scour protection replacement and repair	115,296
Blue carbon	2,233
Total	**607,989 to 141,591,681**

7. DECOMISSIONING

83. The majority of emissions during the decommissioning phase relate to the use of plant/equipment for the Array's decommissioning, disassembly, transportation to a waste site, and ultimate disposal and/or recycling of the equipment and other site materials.

84. At this stage, the approach to decommissioning the Array is still to be determined. However, it is anticipated that all floating structures, mooring lines, OSP topsides and foundations to the seabed level will be completely removed. Associated infrastructure, such as cables, scour protection and anchors and piles below the seabed may either be left *in situ* or removed, in accordance with the decommissioning plan. It may be decided, closer to the time of decommissioning, that removal will result in greater environmental impacts than leaving components *in situ.*

85. The components of the wind turbines are considered to be highly recyclable. When disposing of wind turbines, recycling is the preferred solution. This not only prevents the materials from being sent to landfills, but also reduces the need for the extraction of primary materials. Material which cannot be recycled might be used for incineration or energy from waste. It is considered the same approach can be applied to all mooring lines, OSP topsides and foundations and cables retrieved during decommissioning.

86. Cables and other infrastructure, such as anchoring systems, may be left *in situ* during decommissioning. This will not result in additional emissions during this phase. As such, emissions associated with the disposal of materials at the end of their lifetime is considered to be immaterial and may even result in future avoided emissions. This impact is not assessed further.

87. In the absence of detailed information regarding offshore transport movements during the decommissioning phase, it has been assumed that such emissions equal those associated with the construction phase, totalling 385,615 tCO_2e. Given carbon emissions associated with use of plant and fuel is expected to have achieved good levels of decarbonisation at the decommissioning phase of the Array, this is likely to present a conservative MDS.

88. Given the negligible rates of sediment accumulation and associated carbon sequestration in the Array area, there is not anticipated to be any material change to the blue carbon stocks over the Array's operational lifetime (as detailed in paragraph 32 and 59). As such, any disturbance to the seabed and blue carbon habitats that may result from infrastructure removal at the decommissioning phase is not likely to result in the release of additional emissions not captured by the range of likely emissions presented in the assessment of construction effects. Therefore, this impact is not assessed further.

8. CUMULATIVE ASSESSMENT

89. It is important to note that the Array cannot deliver the avoided emissions detailed in section 6.2 without associated transmission infrastructure to enable connection of the Array to the Grid. This transmission infrastructure has associated emissions for its construction, operation and maintenance and decommissioning phases that must be considered within the cumulative assessment for climatic effects.

90. However, detailed design parameters for the transmission infrastructure are not available at the time of writing. As such, the calculations presented below represent a high level estimate of total emissions with a high degree of uncertainty. Such emissions estimates have been informed by assumptions based on indicative parameters provided by the project team for the Array alongside available design information for the Proposed offshore export cable corridor(s) and Proposed onshore transmission infrastructure. As the future transmission projects and applications are brought forward in relation to the transmission infrastructure, the assessment presented below will be enhanced and refined. These updated assessments will be detailed within future climatic effects chapters.

91. Major elements of the transmission infrastructure are likely to comprise:

- offshore export cables and cable protection;
- onshore export cables;
- onshore converter stations; and
- cables from the converter stations to National Grid substations.

92. Throughout this assessment, it has been assumed that the total operational lifetime for the transmission infrastructure is the same as the Array (35 years).

93. The total length of the Proposed offshore export cable corridor(s) between the Array and the Proposed landfall location(s) is indicatively circa 400 km, and up to four offshore export cables may be required. The construction and operation and maintenance phase emissions for the offshore export cables associated with the Proposed offshore export cable corridor(s) have been calculated based on the methodology in paragraphs 50 and 80. Total emissions during the construction and operation and maintenance phases are shown in Table 8.1.

94. It has been assumed that the Proposed offshore export cable corridor(s) will have the same cable protection requirements as the inter-array and interconnector cables per kilometre. Total emissions during the construction phase are shown in Table 8.1.

95. Two onshore export cable corridors are planned for the Proposed onshore transmission infrastructure, one of which is approximately 15 km in length, and the other is approximately 60 km in length. Six cables are anticipated to be required for the each of the 15 km and 60 km onshore export cables. The construction and operation and maintenance phase emissions for the onshore export cables have been calculated based on the methodology in paragraphs 50 and 80 above. Total emissions during the construction and operation and maintenance phases are shown in Table 8.1.

96. Four converter stations are planned for the Proposed onshore transmission infrastructure, with an indicative power of 1 GW per converter station. Electrical equipment, such as transformers, busbars, etc are anticipated to comprise the majority of embodied emissions for the converter stations. As such, the emissions for the electrical equipment required for the converter stations have been calculated based on the methodology in paragraph 53. Total emissions during the construction phase are shown in Table 8.1. Maintenance schedules for these are not available at this stage, however it is anticipated that emissions associated with operation and maintenance of the converter stations would be captured within transport emissions, detailed in paragraph 101.

97. Grid connection cables are also anticipated to be required from the converter stations to the National Grid substations. Six cables are anticipated to be required per converter station, with an indicative length of 5 km. The construction and operation and maintenance phase emissions for the cables have been calculated based on the methodology in paragraphs 50 and 80 above. Total emissions during the construction and operation and maintenance phases are shown in Table 8.1.

98. Emissions resulting from disturbance to blue carbon habitats have been calculated based on the total length of offshore export cable for the Proposed offshore export cable corridor(s). In the absence of detailed information regarding the extent of disturbance during construction of the Proposed offshore export cable corridor(s), it is assumed that the offshore export cable(s) will have the same area of disturbance per kilometre as the inter-array and interconnector cables of the Array. Site-specific benthic surveys have not yet been undertaken for the Proposed offshore export cable corridor(s), and as such a site-specific blue carbon emissions factor is not possible. Instead, the Array blue carbon emissions factor

of 5.00 tC/ha has been used (see paragraph 43). Future applications will include detailed benthic surveys, which will enable a more refined calculation of the blue carbon stocks present within the Proposed offshore export cable corridor(s).

99. Total construction phase emissions resulting from disturbance to blue carbon habitats have been calculated following the methodology in paragraphs 41 to 45. Emissions shown in Table 8.1.

100. As stated in paragraph 88, there is not anticipated to be any material change in the blue carbon stocks over the operational lifetime of the Array. This is also assumed for the Proposed offshore export cable(s) in the absence of further detailed information. As such, it is not anticipated that there will be additional disturbance (and associated emissions) to blue carbon habitats for the Proposed offshore export cable corridor(s) during the operation and maintenance, and decommissioning phases, as activities are not likely to disturb blue carbon habitats additional to those accounted for during the construction phase.

101. Transport emissions have been calculated to make up 4% of total construction emissions, and 54% of total operation and maintenance emissions (excluding avoided emissions), for the Array. Corresponding uplifts have therefore been made to the total construction and operation and maintenance emissions of the transmission infrastructure respectively, in the absence of detailed transport information. Uplifts are presented in Table 8.1. As detailed in paragraph 87, decommissioning emissions are assumed to be equal to construction transport emissions for the Array, and this assumption has also been applied to the transmission infrastructure for the purposes of the cumulative assessment.

102. Table 8.1 summarises the calculated emissions associated with the transmission infrastructure, which totals 3,076,000 tCO_2e.

Table 8.1: Cumulative Assessment Emissions Summary – Proposed Offshore Export Cable Corridor(s) and Proposed Onshore Transmission Infrastructure

Item	Value (tCO_{2e})
Construction	
Offshore export cables, onshore export cables and grid connection cables	471,246
Cable protection	638,549
Converter stations	8,760
Transport	49,528
Blue carbon	57,097
Operation and Maintenance	
Cable repair and replacement	824,681
Transport	976,612
Decommissioning	
Transport	49,528

9. SUMMARY

103. Table 9.1 presents a summary of the lifetime emissions of the Array, contextualised against the cumulative emissions of the transmission infrastructure. Net emissions of the Array only are calculated to be between 10,532,655 tCO_2e and -131,667,016 tCO_2e, and net emissions including the transmission infrastructure (i.e. for Ossian as a whole) are calculated to be between 13,608,654 tCO_2e and -128,591,016 tCO_2e. Note that negative values represent avoided emissions, i.e. emissions that would have occurred without Ossian.

Table 9.1: Summary of Net GHG Emissions

Item	Value (tCO_{2e})
Array Emissions	
Construction emissions (including blue carbon)	9,539,051
Operation and maintenance emissions (including blue carbon)	607,989 (long-run marginal) to -141,591,681 (non-renewables mix)
Decommissioning emissions	385,615
Net emissions	**10,532,655 (long-run marginal) to -131,667,016 (non-renewables mix)**
Proposed Offshore Export Cable Corridor(s) and Proposed Onshore Transmission Infrastructure Emissions (Cumulative Assessment)	
Construction emissions (including blue carbon)	1,225,180
Operation and maintenance emissions	1,801,293
Decommissioning emissions	49,528
Net Emissions, Including Cumulative Emissions	
Net emissions	**13,608,654 (long-run marginal) to –128,591,016 (non-renewables mix)**

10. REFERENCES

ABB (2003). *Environmental Product Declaration: Power transformer TrafoStar 500 MVA*. Available at: https://library.e.abb.com/public/566748ad75116903c1256d630042f1af/ProductdeclarationStarTrafo500.pdf. Accessed on: 03 February 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 at: https://www.nature.scot/doc/naturescot-research-report-1326-scottish-blue-carbon-literature-review-current-evidence-scotlands Accessed on: 03 February 2024.

BEIS (2021). *Net Zero Strategy: Build Back Greener*. Available at: https://www.gov.uk/government/publications/net-zero-strategy Accessed on: 20 February 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.

DESNZ (2023a). V*aluation of Energy Use and Greenhouse Gas: Supplementary guidance to the HM Treasury Green Book [online].* Available at: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal Accessed on: 03 February 2024.

DESNZ (2023b). *Digest of UK Energy Statistics, Load factors for renewable electricity generation*. Available at: https://www.gov.uk/government/statistics/renewable-sources-of-energy-chapter-6-digest-of-united-kingdom-energy-statistics-dukes Accessed on: 03 February 2024.

DESNZ and DEFRA (2023). *Greenhouse gas reporting: conversion factors 2023*. Available at: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023 Accessed on: 03 February 2024.

IEMA (2022). *Environmental Impact Assessment Guide to: Assessing Greenhouse Gas Emissions and Evaluating their Significance*. 2nd Edition. Available at: https://www.iema.net/resources/blog/2022/02/28/launch-of-the-updated-eia-guidance-on-assessing-ghg-emissions Accessed on: 29 February 2024.

IPCC (2013). *Climate Change 2013: The Physical Science Basis*. Available at: https://www.ipcc.ch/report/ar5/wg1/ Accessed on: 03 February 2024.

IPCC (2021). *Climate Change 2021: The Physical Science Basis, Chapter 5: Global Carbon and other Biogeochemical Cycles and Feedbacks*. Available at: https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-5/ Accessed on: 03 February 2024.

Jones and Hammond (2019). *Inventory of Carbon and Energy (ICE)* Database. Available at: https://circularecology.com/embodied-carbon-footprint-database.html. Accessed on 20: February 2024

National Grid ESO (2023). *Future Energy Scenarios*. Available at: https://www.nationalgrideso.com/future-energy/future-energy-scenarios Accessed on: 03 February 2024.

Smeaton, C., Austin, W. and Turrel, W. (2020). *Re-Evaluating Scotland's Sedimentary Carbon Stocks. Marine Scotland Science Research Report*, Scottish Marine and Freshwater Science, 11 Available at: https://data.marine.gov.scot/sites/default/files//SMFS%201102.pdf Accessed on: 03 February 2024

Smeaton, C. and Austin, W. (2022) *Quality not Quantity: Prioritising the Management of Sedimentary Organic Matter Across Continental Shelf Seas.* Geophysical Research Letters. 49 Available at: https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2021GL097481. Accessed on: 03 February 2024

Staffell, I. and Green, R. (2014). *How does wind farm performance decline with age? Volume 66, Renewable Energy*. Available at: https://www.sciencedirect.com/science/article/pii/S0960148113005727. Accessed 03 February 2024.

WRI and WBSCD (2004). *A Corporate Accounting and Reporting Standard*. Available at: https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf. Accessed on: 03 February 2024.

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