XLINKS MOROCCO-UK POWER PROJECT

Preliminary Environmental Information Report

Volume 4, Appendix 1.1: Greenhouse Gas Assessment Technical Report

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Glossary

Term	Meaning
Applicant	Xlinks 1 Limited
Alverdiscott Substation Connection Development	The development required at the existing Alverdiscott Substation site, which is envisaged to include development of a new 400 kV substation, and other extension modification works to be confirmed by National Grid Electricity Transmission.
Climate change	A change in global or regional climate patterns, in particular a change apparent from the mid to late 20th century onwards and attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels.
Converter Site	The Converter Site is proposed to be located to the immediate west of the existing Alverdiscott Substation site in north Devon. The Converter Site would contain two converter stations (known as Bipole 1 and Bipole 2) and associated infrastructure, buildings and landscaping.
Converter station	Part of an electrical transmission and distribution system. Converter stations convert electricity from Direct Current to Alternating Current, or vice versa.
Environmental Impact Assessment	The process of identifying and assessing the significant effects likely to arise from a project. This requires consideration of the likely changes to the environment, where these arise as a consequence of a project, through comparison with the existing and projected future baseline conditions.
HVAC Cables	The High Voltage Alternating Current cables which would bring electricity from the converter stations to the new Alverdiscott Substation Connection Development.
HVDC Cables	The High Voltage Direct Current (HVDC) cables which would bring electricity to the UK converter stations from the Moroccan converter stations.
Landfall	The proposed area in which the offshore cables make landfall in the United Kingdom (come on shore) and the transitional area between the offshore cabling and the onshore cabling. This term applies to the entire landfall area at Cornborough Range, Devon, between Mean Low Water Springs and the Transition Joint Bay inclusive of all construction works, including the offshore and onshore cable routes, and landfall compound(s).
Maximum design scenario	The realistic worst case scenario, selected on a topic-specific and impact specific basis, from a range of potential parameters for the Proposed Development.
Offshore Cable Corridor	The proposed corridor within which the offshore cables are proposed to be located, which is situated within the United Kingdom Exclusive Economic Zone.
Preliminary Environmental Information Report	A report that provides preliminary environmental information in accordance with the Infrastructure Planning (Environmental Impact Assessment) Regulations 2017. This is information that enables consultees to understand the likely significant environmental effects of a project and which helps to inform consultation responses.
Proposed Development	The element of the Xlinks Morocco-UK Power Project within the UK, which includes the offshore cables (from the UK Exclusive Economic Zone to landfall), landfall site, onshore Direct Current and Alternating Current cables, converter stations, road upgrade works and, based on current assumptions, the Alverdiscott Substation Connection Development.
Proposed Development Draft Order Limits	The area within which all offshore and onshore components of the Proposed Development are proposed to be located, including areas required on a temporary basis during construction (such as construction compounds).
Study area	This is an area which is defined for each environmental topic which includes the Proposed Development Order Limits as well as potential spatial and temporal considerations of the impacts on relevant receptors. The study area for each topic is intended to cover the area within which an impact can be reasonably expected.

Term	Meaning
The national grid	he network of power transmission lines which connect substations and power stations across Great Britain to points of demand. The network ensures that electricity can be transmitted across the country to meet power demands.
Xlinks Morocco UK Power Project	The overall scheme from Morocco to the national grid, including all onshore and offshore elements of the transmission network and the generation site in Morocco (referred to as the 'Project').

Acronyms

Acronym	Meaning
AC	Alternating Current
CBS	Cement Bound Sand
DC	Direct Current
DESNZ	Department for Energy Security and Net Zero
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EPD	Environmental Product Declaration
FES	Future Energy Scenario
GB	Great Britain
GHG	Greenhouse Gas
GWP	Global Warming Potential
HGV	Heavy Goods Vehicle
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
NREL	National Renewable Energy Laboratory
PEIR	Preliminary Environmental Information Report
RICS	Royal Institution of Chartered Surveyors
UK	United Kingdom
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute

Units

Units	Meaning
CO_2e	Carbon dioxide equivalent
GW	Gigawatts
Km	Kilometres
Kg	Kilograms
kWh	Kilowatt hours
m^2	Metres squared

Units	Meaning
MW	Megawatt
MWh	Megawatt hours
MVA	Megavolt amperes
t	Tonnes

1 GREENHOUSE GAS TECHNICAL REPORT

1.1 Introduction

1.1.1 This document forms Appendix 1.1 of Volume 4 of the Preliminary Environmental Information Report (PEIR) prepared for the United Kingdom (UK) elements of the Xlinks Morocco-UK Power Project (the ‘Project’). For ease of reference, the UK elements of the Project are referred to throughout as ‘the Proposed Development’. The PEIR presents the preliminary findings of the Environmental Impact Assessment (EIA) process for the Proposed Development.

1.1.2 This greenhouse gas (GHG) technical report sets out the methodology and calculations of the GHG emissions for the Proposed Development. These calculations inform the assessment of the climate change impacts in Volume 4, Chapter 1: Climate Change of the PEIR. This appendix should be read in conjunction with the chapter as supporting information.

1.1.3 GHG emissions have been estimated by applying published emissions factors to activities in the baseline and to those required for the Proposed Development. The emission factors relate to a given level of activity, or amount of fuel, energy or materials used, to the mass of GHGs released as a consequence. This appendix presents the technical calculations which relate to the potential magnitude of impact as assessed within the climate change chapter (Volume 4, Chapter 1: Climate Change) of the PEIR.

1.1.4 The purpose of the Proposed Development is to connect the Moroccan generation assets (with cable infrastructure routed through Morocco, Spain, Portugal and France and UK waters) to the Great Britain national grid, which would help deliver an output of 3.6 GW (see Volume 1: Chapter 1: Introduction of the PEIR for further details). This would contribute to:

- the UK commitment to the global ambition of achieving net zero emissions by 2050;
- delivering much needed investment and securing construction and operations jobs in the UK;
- diversifying and securing our energy supply; and
- the UK’s response to the climate change crisis.

1.1.5 The Proposed Development focuses on the UK elements of the Xlinks Morocco-UK Power Project, thus connecting the Moroccan generation assets to the GB national grid (see Volume 1, Chapter 1: Introduction, of the PEIR for further details). Therefore, the focus of this appendix is on the impacts of the Proposed Development.

1.1.6 However, given its purpose, the Proposed Development would never operate in isolation. As such, the cumulative impact of the Proposed Development with the rest of the overall Project outside of the UK Exclusive Economic Zone (EEZ), including the generation assets, on the global atmospheric mass of CO_2 have been assessed. The cumulative Project includes the following components:

- Generation assets, comprising approximately 7.5 GW solar farm, 4 GW wind farm and 5 GW battery storage. In combination, and taking into account High Voltage Direct Current (HVDC) losses, generating 3.6 GW of power for the UK.
- Alternating Current (AC) cables connecting the generation assets to the converter stations.
- Converter stations to change electricity from AC to Direct Current (DC).
- Onshore HVDC Cables from the converter stations to the coast of western Morocco.
- Offshore cable route of approximately 3,520 km subsea HVDC cables from the Morocco landfall to the UK EEZ.

1.1.7 The findings of this cumulative assessment are set out within **section 1.9** of this appendix.

1.2 Scope

1.2.1 The GHGs considered in this assessment are those in the ‘Kyoto basket’ of global warming gases expressed as their CO_2-equivalent (CO_2e) global warming potential (GWP). This is denoted by CO_2e units in emissions factors and calculation results. GWPs used are typically 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.

1.2.2 The scope of this appendix considers the Proposed Development during the construction, operation and maintenance, and decommissioning phases. Key emissions sources included in the assessment are:

- onshore and offshore land use change;
- embodied carbon emissions in materials; and
- transport emissions both onshore and offshore.

1.2.3 The scope also considers the cumulative impacts of the Project, outside of the UK EEZ. Information relating to the generation assets of the Project has been sourced from Xlinks 1 Limited (the ‘Applicant’) in support of the Environmental and Social Impact Assessment (ESIA), which is being developed for the Moroccan generation site. At the time of this PEIR, the ESIA is yet to be published.

1.3 Methodology

1.3.1 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 WBCSD, 2004).

- 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.

- 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.

1.3.2 This assessment has sought to include emissions from all three scopes, where this is material and reasonably possible from the information and emissions factors available, to capture the impacts attributable most completely to the Proposed Development. These emissions shall not be separated out by defined scopes (scopes 1, 2 or 3) in the assessment.

1.3.3 Due to the nature of the Proposed Development, i.e., onshore and offshore infrastructure constructed to transport generated electricity from the generation assets in Morocco to the GB national grid, the gross GHG emissions total is dominated by embodied carbon emissions. As set out in **section 1.1**, details of the total emissions of the Proposed Development with the cumulative Project are set out within **section 1.9**.

1.3.4 The emissions resulting from the Proposed Development include those resulting from the manufacturing and construction of the converter stations, onshore cables and offshore cable infrastructure (e.g., cables, joint bays, etc.), in addition to fuel use by vehicle movements. They have been calculated via a range of methodologies, including published benchmark carbon intensities and life cycle analysis (LCA) literature, and the application of material or fuel emission intensities to material or fuel quantities.

1.3.5 Key sources relied upon for the assessment are as follows:

- Environmental Product Declaration Power transformer TrafoStar 500 MVA (ABB, 2003);
- RICS Professional Information, UK Methodology to calculate embodied carbon of materials RICS (2012);
- Inventory of Carbon & Energy database (Jones and Hammond, 2019);
- Life Cycle Greenhouse Gas Emissions of Utility-Scale Wind Power (Dolan and Heath, 2012); and
- Life Cycle Greenhouse Gas Emissions from Crystalline Silicon Photovoltaic Electricity Generation: Systematic Review and Harmonization (Hsu *et al.,* 2012).

1.3.6 The assessment has considered: (a) the GHG emissions arising from the Proposed Development, (b) any GHG emissions that is displaced by the cumulative part of the Project (cumulative part of the Project, outside of the UK EEZ), and hence (c) the net impact on climate change due to these changes in GHG emissions overall.

Embodied Carbon

1.3.7 An LCA comprises an evaluation of the inputs, outputs and potential environmental impacts that occur throughout the lifecycle of a particular project, in this case electricity transmission infrastructure associated with offshore wind farms, encompassing either a cradle-to-gate (project site) or a cradle-to-grave (accounting for in use 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).

1.3.8 As the Proposed Development is currently in the early stages of design, data relating to specific metrics for site specific design details, including converter station design etc. are currently unavailable. Therefore, data has been extracted from peer reviewed reports, or estimated based on approximate material quantities and associated materials carbon intensity figures, to provide estimate figures for each stage of this LCA. Methodology specific to each item assessed is summarised within **section 1.6**.

1.3.9 Given the early stage of the converter stations' design, there is some uncertainty regarding quantities of materials and in the grouping of the main categories of material. As a result, published benchmarks from RICS (2012) have been used to estimate possible emissions from the converter buildings materials and construction.

1.3.10 There is limited design data and few published LCAs from which to calculate the embodied emissions associated with the converter stations, etc. Data from an environmental product declaration (EPD) for a 16 kVA – 1000 MVA transformer (ABB, 2003) has therefore been used to provide an approximation of the potential order of magnitude of emissions. This is because transformers are among the major converter plant components and have a relatively high materials and carbon intensity, including the copper or aluminium winding.

Land Use Change

1.3.11 The calculation of climate change impacts as a result of land use change considers the impact of the Proposed Development on carbon sinks that may be required for temporary and permanent land take.

Cumulative Assessment

Embodied Carbon

1.3.12 The cumulative assessment considers the GHG emissions associated with the construction of the rest of the Project outside of the UK EEZ, which forms a cumulative scheme to the Proposed Development for this EIA assessment. This follows the approach detailed within **paragraphs 1.3.7** to **1.3.10**.

1.3.13 In relation to the generation assets in Morocco, the current literature surrounding LCAs for solar panels, wind turbines and battery storage is characterised by a high degree of variability in the published GHG figures and therefore, a high degree of uncertainty occurs in selecting any one of these figures as a means of analysing the embodied GHGs in constructing a wind/solar farm. As a means of dealing with this uncertainty, the primary sources of emissions factors used in assessing the embodied carbon effects of the cumulative Project were studies by the National Renewable Energy Laboratory (NREL, 2012; NREL, 2013) Life Cycle Assessment Harmonization Project, Dolan and Heath (2012), and Nicholson *et al.* (2021). These studies have reviewed and harmonized LCAs for electricity generation technologies.

Wind Farms

1.3.14 The primary sources of emissions factors used in assessing the embodied carbon effects associated with the cumulative wind farm were studies by the National Renewable Energy Laboratory (NREL, 2013) Life Cycle Assessment Harmonization Project and Dolan & Heath (2012).

1.3.15 The NREL (2013) study was based on the output of the Dolan & Heath (2012) paper and as such the Dolan & Heath has been referenced hereafter. This study (Dolan & Heath, 2012) analysed 126 distinct life cycle GHG emission assessments for both onshore and offshore wind power systems. However, these were from a small sample size of 49 different studies. The LCA Harmonization project conducted an exhaustive literature search, extracting normalized life cycle GHG emission estimates from published LCA literature. Data was screened to select only those references that met stringent quality and relevance criteria.

1.3.16 The report (Dolan & Heath, 2012) identified the median estimates of GHG emissions intensity figures for both onshore and offshore wind across the whole life-cycle, as being 11 gCO_2e/kWh. The NREL (2013) study further broke down and detailed the separation of intensity across the following life cycle stages relevant to this assessment:

- upstream including raw materials extraction, module manufacture, parts manufacture, wind farm construction (construction phase);
- operational stage including power generation, plant operation and maintenance (operation and maintenance phase); and
- downstream (decommissioning phase).

1.3.17 These estimated percentages have been applied to the Dolan & Heath intensity and are shown in **Table 1.1**. These intensity metrics are used in this assessment to calculate the embodied carbon for each stage of the LCA.

Solar Farms

1.3.18 The primary sources of emissions factors used in assessing the embodied carbon effects associated with the cumulative solar farm were '*Life Cycle Greenhouse Gas Emissions of Crystalline Silicon Photovoltaic Electricity Generation'* (Hsu *et al*., 2012) and '*Life Cycle Greenhouse Gas Emissions from Solar Photovoltaics'* (NREL, 2012).

1.3.19 The (Hsu *et al.,* 2012) study constituted a meta-analysis of over 397 LCAs regarding solar photovoltaic systems, all of which were subject to a screening process, and for those which passed the screening process, a subsequent harmonisation process. The screening process removed the majority of the considered studies, so that the meta-analyses considered in detail only 13 studies (containing a total of 42 Lifecycle GHG factors).

1.3.20 The report by Hsu *et al.* (2012) identified the median estimate of GHG emissions intensity figures for ground-mounted c-Si solar PV systems to be 48 gCO_2e/kWh. The NREL (2012) study further broke down and detailed the separation of intensity across the following life cycle stages relevant to this assessment:

- upstream including raw materials extraction, module manufacture, parts manufacture, wind farm construction (construction stage);
- operational stage including power generation, plant operation and maintenance; and

- downstream (decommissioning stage).

1.3.21 These estimated percentages have been applied to the Hsu *et al*., (2012) intensity and are shown in **Table 1.1**. These intensity metrics are used in this assessment to calculate the embodied carbon for each stage of the LCA.

Table 1.1: Normalised lifecycle GHG emission estimates

Technology	LCA Stage	Intensity	Unit
Wind	Upstream (A1-A5)	9.46	kg CO_2e/kWh
	Ongoing (B1-B5)	0.99	kg CO_2e/kWh
	Decommissioning (C1-C4)	0.55	kg CO_2e/kWh
Solar	Upstream (A1-A5)	31.20	kg CO_2e/kWh
	Ongoing (B1-B5)	11.04	kg CO_2e/kWh
	Decommissioning (C1-C4)	5.76	kg CO_2e/kWh

Battery Storage

1.3.22 The primary source of emissions factors used in assessing the embodied carbon effects associated with the cumulative battery storage was a study by Nicholson *et al.* (2021), which analysed and screened 61 LCA studies for lithium-ion battery storage. The screening process removed the majority of the considered studies, so that the meta-analyses considered in detail only 5 studies.

1.3.23 The study (Nicholson *et al.,* 2021) identified the median estimate of GHG emissions intensity figures for lithium-ion battery storage, which was broken down into upstream (construction) at 527,000 gCO_2e/kW, and downstream (decommissioning) at 99,000 gCO_2e/kW.

Operational Avoided Emissions

1.3.24 The assessment also considers the GHG emissions that would not be generated (i.e., avoided) during the operation of the overall Project during the future baseline (see **section 1.9**).

1.4 Assumptions and Limitations

1.4.1 The majority of the Proposed Development construction stage 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 stage have been presented within the assessment and quantification of GHG emissions as part of the Proposed Development.

1.4.2 Principal LCA sources relied upon for the quantification of GHG emissions for the Proposed Development are 10-plus years old (ABB, 2003 and RICS, 2012). It is acknowledged that the design and equipment available in the present day compared with pre-2012 is significantly different. Nevertheless, the pre-2012 benchmarks represent a conservative (worst case) assumption concerning GHG emissions for the purposes of the assessment.

1.4.3 The specific design of associated infrastructure (including onshore converter stations, onshore and offshore cabling etc.) that would be used by the Proposed Development has not yet been specified. Thus, there is a degree of uncertainty regarding all the Project stage GHG emissions resulting from the manufacturing and construction of such infrastructure.

1.4.4 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 Project (as assessed within cumulative assessment).

1.5 Baseline Environment

Current Baseline

1.5.1 The current baseline for the onshore elements primarily comprises agricultural land. This land has been broadly categorised as Grade 3 (good to moderate) land with comparatively smaller areas of Grade 4 (poor quality) land. However, this land does not have high soil or vegetation carbon stocks (e.g., peat) that would be subject to disturbance by construction (See Volume 2, Chapter 8: Land Use and Recreation of the PEIR).

1.5.2 The Proposed Development Draft Order Limits includes land occupied by existing and planned renewable energy development, including the following:

- Cleave Solar Farm: The Onshore HVDC Cable Corridor currently includes part of the existing solar farm, situated to the south of the Converter Site. The installation of the HVDC Cables may require the temporary or permanent removal of solar panels in this limited section of the solar farm.
- Planning application 1/1057/2021/FULM: The proposed Converter Site includes a small area of land that is subject to a permitted solar farm development yet to be constructed.

1.5.3 Although the Proposed Development only partially covers the existing Cleave Solar Farm and permitted application site (1/1057/2021/FULM), it would have potential to displace existing and potential UK-generated renewable energy that is delivered by the solar farms.

1.5.4 When considering the current baseline for the offshore elements, the baseline consists of various subtidal habitats of sand, mud, rock, coarse sediment, mixed sediment, biogenic reef, and diverse benthic communities (see Volume 3, Chapter 1: Benthic Ecology of the PEIR).

1.5.5 With regards to the current baseline concerning the UK electricity grid at the time of writing, the conversion factor for company reporting UK Electricity generation carbon intensity resides at 252.97 kg CO_2e/MWh (including scope 3 but as generated, i.e., excluding transmission and distribution losses) (DESNZ and Defra, 2023).

Future Baseline

1.5.6 The future baseline GHG emissions for existing land-use without the Proposed Development are expected to remain similar to the current baseline. This includes the existing Cleave Solar Farm, along with the permitted application (Reference:

1/1057/2021/FULM), which would continue to deliver UK-generated renewable energy that would contribute to the decarbonisation of the grid.

1.5.7 The future baseline for electricity generation that would be displaced by the Proposed Development and cumulative Project 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 Project, compared to other generation sources available; this will be influenced by commercial factors and National Grid's needs.

1.5.8 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.

1.5.9 Department for Energy Security and Net Zero (DESNZ) published 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, 2023). DESNZ's projections over the operating lifetime of the Proposed Development (2030 to 2080) are used to estimate the potential emissions as a result of the cumulative Project.

1.5.10 A grid-average emissions factor is projected by DESNZ for 2040 and the marginal factor is assumed to converge with it by that date, interpolated between 2030 and 2040. Both factors are then interpolated from 2040 to a national goal for carbon intensity of electricity generation in 2050 and assumed to be constant after that point.

1.5.11 National Grid publishes 'Future Energy Scenario' (FES) projections (National Grid, 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 range, and as stated above, the marginal factor is assumed by DESNZ to converge with it (and hence with National Grid's scenarios) over time.

1.5.12 As can be seen from **Figure 1.1** below, 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. It has been assumed that the Project would not displace other forms of electricity generation with net negative GHG effects. **Figure 1.1** illustrates both the DESNZ and National Grid projected carbon intensity factors for displaced electricity generation and **Table 1.2** lists the DESNZ grid-average and marginal factors for the 50 years of the Proposed Development's operation.

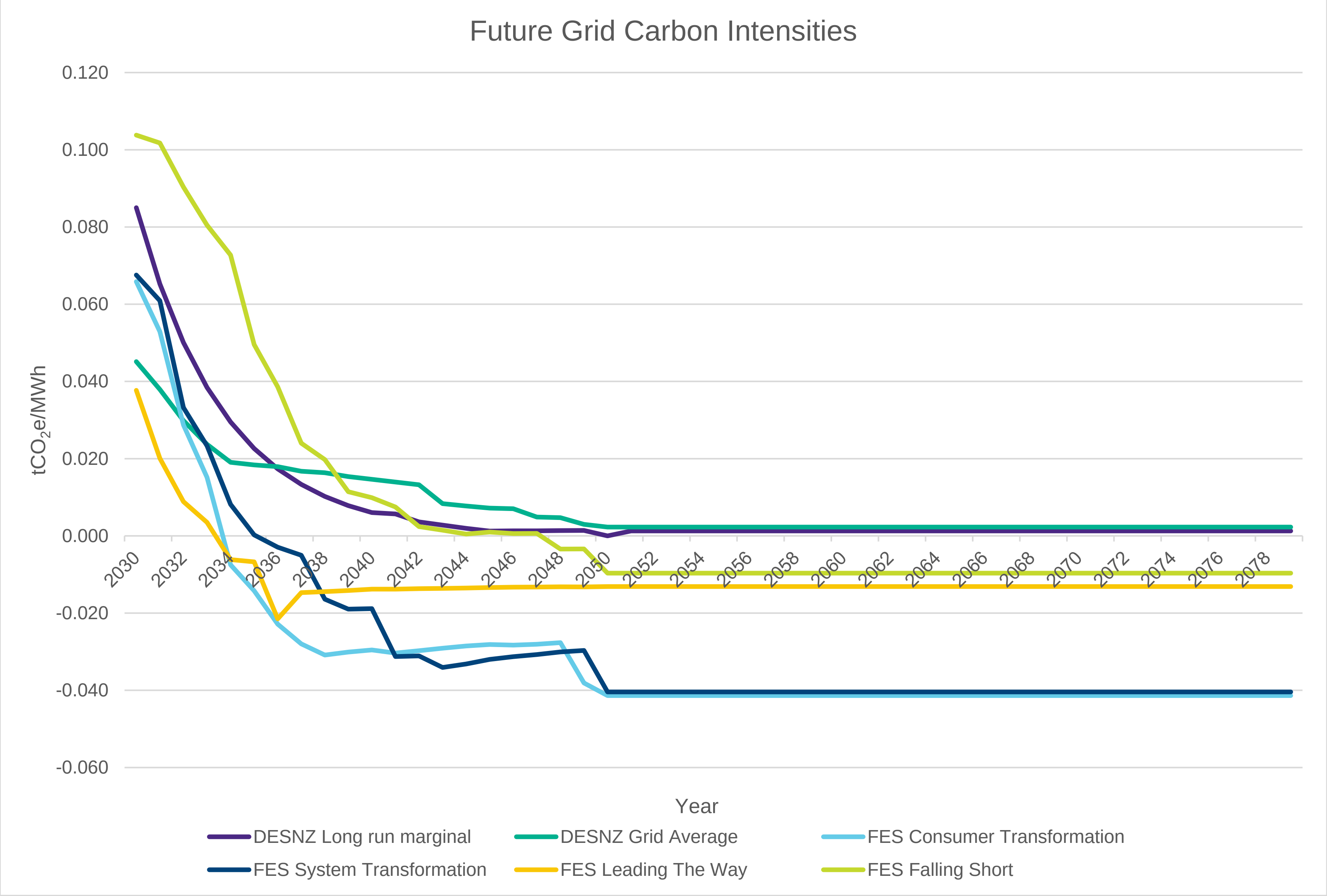

Figure 1.1: DESNZ and FES future grid carbon intensities

Table 1.2: DESNZ grid average and long-run marginal grid carbon intensities

Year of Operation	Year	DESNZ Long-Run Marginal (tCO_2e/MWh)	DESNZ Grid Average (tCO_2e/MWh)
1 (Bipole 1 commences operation)	2030	0.085	0.045
2	2031	0.065	0.038
3 (Bipole 2 commences operation)	2032	0.05	0.03
4	2033	0.038	0.024
5	2034	0.029	0.019
6	2035	0.023	0.018
7	2036	0.017	0.018
8	2037	0.013	0.017
9	2038	0.01	0.016
10	2039	0.008	0.015
11	2040	0.006	0.015
12	2041	0.006	0.014
13	2042	0.004	0.013
14	2043	0.003	0.008
15	2044	0.002	0.008
16	2045	0.001	0.007
17	2046	0.001	0.007
18	2047	0.001	0.005
19	2048	0.001	0.005
20	2049	0.001	0.003
21	2050	0.001	0.002
22	2051	0.002	0.002
23	2052	0.002	0.002
24	2053	0.002	0.002
25	2054	0.002	0.002
26	2055	0.002	0.002
27	2056	0.002	0.002
28	2057	0.002	0.002
29	2058	0.002	0.002
30	2059	0.002	0.002
31	2060	0.002	0.002
32	2061	0.002	0.002
33	2062	0.002	0.002
34	2063	0.002	0.002
35	2064	0.002	0.002
36	2065	0.002	0.002
37	2066	0.002	0.002
38	2067	0.002	0.002

Year of Operation	Year	DESNZ Long-Run Marginal (tCO_2e/MWh)	DESNZ Grid Average (tCO_2e/MWh)
39	2068	0.002	0.002
40	2069	0.002	0.002
41	2070	0.002	0.002
42	2071	0.002	0.002
43	2072	0.002	0.002
44	2073	0.002	0.002
45	2074	0.002	0.002
46	2075	0.002	0.002
47	2076	0.002	0.002
48	2077	0.002	0.002
49	2078	0.002	0.002
50	2079	0.002	0.002

1.6 Construction

Land Use Change

1.6.1 The infrastructure components of the Proposed Development that will alter the onshore and offshore land use comprise:

- onshore converter stations and associated infrastructure, including access roads;
- onshore and offshore cable corridors; and
- proposed highways improvements.

Onshore

1.6.2 Volume 2, Chapter 8: Land Use and Recreation and Volume 2, Appendix 8.1: Agricultural Land Classification of the PEIR outline the baseline conditions for the onshore components and any subsequent effects of the Proposed Development on land use.

1.6.3 The current land use for the onshore elements of the Proposed Development primarily comprises agricultural land. This land has been broadly categorised as Grade 3 (good to moderate) land with comparatively smaller areas of Grade 4 (poor quality) land (see Volume 2, Chapter 8: Land Use and Recreation of the PEIR). With regards to the assessment of GHG emissions, land with high carbon stock such as woodland and peat is of most relevance. British Geological Survey (2024) mapping indicates that there are no areas of peat situated within the Proposed Development Order Limits. The onshore elements of the Proposed Development include the area of Littleham Wood, which falls within the Proposed Development Draft Order Limits. However, the Proposed Development would use trenchless methods to drill under the woodland and not disturb the carbon storage. Furthermore, no soil or woodland of high carbon storage value has been identified for the Converter Site location.

1.6.4 However, it has been identified that existing and planned renewable energy developments are partially situated within the Proposed Development Draft Order Limits, including the following:

- Cleave Solar Farm: A section of this existing solar farm lies within the Onshore HVDC Cable Corridor, just south of the Converter Site.
- Planning application 1/1057/2021/FULM: An area of this permitted development falls within the Converter Site, and thus, would be required for the construction and operation of the converter stations.

1.6.5 Although the Proposed Development only partially covers the existing Cleave Solar Farm and permitted application site (1/1057/2021/FULM), it has the potential to displace existing and potential UK-generated renewable energy. At this stage in the design, it is not possible to quantify the amount of potential renewable UK-generation that might be lost due to the Proposed Development. Further quantification of this effect may be possible at the Environmental Statement stage. However, the Proposed Development would deliver up to 3.6 GW of renewable energy once operational, which would outweigh the impacts associated with the loss of this land (e.g. displacement of UK-generated renewable electricity).

1.6.6 Throughout the decommissioning process it is anticipated that the existing baseline environment would be restored. Should the onshore elements of the Proposed Development not directly affect any carbon stores, with the habitat anticipated to return back to its pre-development habitat after decommissioning, the change concerning the carbon storage value of the land use would be minimal. Should carbon stocks be affected, this impact will be accounted for within the assessment of construction effects.

Offshore

1.6.7 Volume 3, Chapter 1: Benthic Ecology of the PEIR outlines the baseline conditions for the offshore components of the Proposed Development and any subsequent effects of the Proposed Development on land use.

1.6.8 The offshore environment consists of sand, mud, rock, coarse sediment, mixed sediment, biogenic reef, and diverse benthic communities.

1.6.9 The land use change would be constrained to the Proposed Development Draft Order Limits and would not directly impact any carbon stores. The land use would be affected throughout the construction and operation and maintenance phases of the development. However, through the decommissioning process it is anticipated that the existing baseline environment would be restored. As no carbon stores are directly affected by the Proposed Development and the habitat is anticipated to return back to its pre-development habitat after decommissioning the change concerning the carbon storage value of the land use would be minimal.

Embodied Carbon

1.6.10 The following sections detail the methodology used to calculate the construction stage emissions associated with the Proposed Development.

1.6.11 The construction stage 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) has been analysed.

1.6.12 The materials involved in the offshore components of the Proposed Development are the initial elements to consider within the cradle-to-gate approach towards completing this LCA. Emissions are derived from the raw material production required to manufacture the offshore cables and it is often the stage where the majority of embodied carbon is emitted.

Converter Stations

1.6.13 The potential impact of the proposed converter stations has been estimated using an intensity for the manufacturing GWP of 2,190 $kgCO_2e$ per MW (ABB, 2003). This was scaled by the total combined output of the generation assets to the UK from the Project, totalling 3,600 MW, to give an estimated embodied carbon value of 7,884 tCO_2e (see **Table 1.3**).

Table 1.3: Information required for calculation of major converter plant

Stage	Value	Unit	Source
Input Parameter – Project Output	3,600	MW	Volume 1, Chapter 1: Introduction of the PEIR
Input Parameter – Intensity for manufacturing of major converter plant	2,190	$kgCO_2e$ per MW	Environmental Product Declaration: Power transformer TrafoStar 500 MVA (ABB, 2003).
Output – Embodied Carbon	7,884	tCO_2e	N/A – Output Parameter

1.6.14 It has been assumed that this calculation includes all electrical plant required to manage and transmit the capacity of the generation assets. The sections below detail the calculation of remaining emissions from the platform foundations and structures of the converter stations.

1.6.15 At this stage of design, material estimates have some uncertainty in terms of their quantities and specific products to be used in the final, detailed design. As such, a published benchmark (RICS, 2012) has therefore also been used to estimate possible emissions from the converter buildings. A carbon intensity of 545 $kgCO_2e/m^2$ was scaled by the total maximum area of proposed converter building footprint (130,000 m^2), to give an embodied carbon value of 70,850 tCO_2e.

Alverdiscott Substation Connection Development

1.6.16 Following the methodology detailed within paragraph **1.6.13**, the potential impact of the planned Alverdiscott Substation Connection Development has been estimated using an intensity for the manufacturing GWP of 2,190 $kgCO_2e$ per MW (ABB, 2003), and scaled using the total output of 3,600 MW to give an estimated embodied carbon value of 7,884 tCO_2e.

1.6.17 As there is a lack of detail regarding the potential design of the Alverdiscott Substation Connection Development it is not possible to cross refer to published GHG emissions. As such, it is necessary to estimate an embodied carbon associated with building materials, consistent with the methodology detailed in **paragraph 1.6.15**. A carbon intensity of 545 $kgCO_2e/m^2$ was scaled by the total maximum area of the substation (27,000 m^2), to give an embodied carbon value of 14,715 tCO_2e.

Joint Bays and Link Boxes

Joint Bays

1.6.18 Material quantities associated with the construction of joint bays (including the transition joint bays at landfall) were estimated using the maximum design parameters detailed within Volume 1, Chapter 3: Project Description of the PEIR, totalling 9,922 kg of concrete, and scaled by the relevant material intensity factor (0.103 $kgCO_2e/kg$, (Jones and Hammond, 2019)).

1.6.19 The GHG calculations also included material quantities of thermally suitable material, such as Cement Bound Sand (CBS), which would be required to backfill the joint bay structure, as detailed within Technical Specification 97-1 Special Backfill Material for Cable Installations (Energy Networks Association, 2016). The quantities of cement and sand making up the CBS have been determined at a 14:1 ratio, and scaled using relevant material intensity factors (cement at 0.103 $kgCO_2e/kg$ and sand at 0.017 $kgCO_2e/kg$, (Jones and Hammond, 2019))

1.6.20 Total emissions for the construction of joint bays were estimated at 1,167 tCO_2e.

Link Boxes

1.6.21 Material quantities associated with the construction of link boxes were estimated using the maximum design parameters detailed within Volume 1, Chapter 3: Project Description of the PEIR. This included 299 kg of concrete, which was scaled by the relevant material intensity factor (0.103 $kgCO_2e/kg$, (Jones and Hammond, 2019)), and 55 kg of iron (e.g., to be used in manhole covers for link boxes), which was scaled by 2.03 $kgCO_2e/kg$ (Jones and Hammond, 2019).

1.6.22 Total emissions for the construction of link boxes were estimated at 143 tCO_2e.

Cabling

Power Cables

1.6.23 Embodied carbon associated with the construction of onshore and offshore power cables, including AC and DC cables, was estimated through the analysis of indicative cable cross sections provided by the Applicant.

1.6.24 Quantities of the cable materials were estimated based on the proportion of material components, and the total length of each relevant cable. Emissions factors for each material (as detailed in **Table 1.4**, (Jones and Hammond, 2019)) were then scaled by the estimated quantities. Material quantities applied to this calculation are summarised within **Table 1.4** below.

1.6.25 **Table 1.4** also includes the material quantities associated with the onshore cable ducts, based on the dimensions set out within Volume 1, Chapter 3: Project Description of the PEIR.

Table 1.4: Power cables material quantities

Material	Cable Length (km)	Emissions Factor ($kgCO_2e/kg$)	Material Weight (kg)	Total Embodied Carbon (tCO_2e)
Onshore AC Cables				
Copper	1.2	2.71	546,216	1,480
Polyethylene		2.54	156,605	398
PVC		3.23	13,184	43
Lead		1.67	328,195	548
Cable Duct (PVC)		3.23	142,287	460
			Total	**2,928**
Onshore DC Cables				
Copper	14.5	2.71	1,850,421	5,015
Polyethylene		2.54	681,144	1,730
Aluminium		6.67	150,041	1,001
Cable Duct (PVC)		3.23	573,102	1,851
			Total	**9,597**
Offshore DC Cables				
Aluminium	370	6.67	15,144,087	99,664
Polyethylene		2.54	17,959,836	41,091
Lead		1.67	24,955,610	41,120
Steel Wire		2.27	57,522,954	128,836
			Total	**310,712**

1.6.26 As detailed within Volume 1, Chapter 3: Project Description of the PEIR, onshore trenches would be backfilled with stabilised material (e.g., CBS) up to a depth of 0.5 m. Thus, GHG calculations have also accounted for the materials required for the backfilling of trenches with CBS at a 14:1 ratio of sand to cement, and scaled using relevant material intensity factors (as detailed within **paragraph 1.6.19** above). This resulted in a total embodied carbon of 1,105 tCO_2e associated with onshore cable trenches, including 908 tCO_2e for onshore DC trenches and 197 tCO_2e for onshore AC trenches.

1.6.27 Overall, the total embodied carbon associated with the construction of power cables (including the use of CBS) has been estimated to be 310,712 tCO_2e for offshore DC cables, 3,125 tCO_2e for onshore AC cables and 10,504 tCO_2e for onshore DC cables.

Fibre Optic Cables

1.6.28 Embodied carbon associated with the construction of onshore and offshore fibre optic cables (including fibre optic ducts for onshore) was estimated based on the total length of cable required, and informed by technical product information for fibre optic cables (Emtelle, 2020). The main component of the fibre optic cables included medium density polyethylene, which was utilised to estimate the embodied carbon. Therefore, emissions factors for medium density polyethylene (2.54 $kgCO_2e/kg$ (Jones and Hammond, 2019)) were then scaled by the estimated quantities.

1.6.29 At the current stage of design for the Proposed Development, the diameter of fibre optic cables required have not been determined. Thus, a typical cable diameter for fibre optics has been assumed, informed by a construction method statement developed for HVDC infrastructure (NorthConnect, 2018). Material quantities applied to this calculation are summarised in **Table 1.5** below.

1.6.30 Total embodied carbon emissions associated with the construction of fibre optic cables for both the onshore and offshore environment has been estimated to be 2,846 tCO_2e.

Table 1.5: Fibre Optic Cables material quantities

Component	Number	Cable Length (km)	Emissions Factor ($kgCO_2e/kg$)	Material Weight (kg)	Total Embodied Carbon (tCO_2e)
Onshore					
Fibre Optic Cable (Medium density polyethylene)	6	14.5	2.54	106,047	269
Fibre Optic Cable Duct (High density polyethylene)	6	14.5	2.54	112,410	286
				Total	**555**
Offshore					
Fibre Optic Cable (Medium density polyethylene)	2	370	2.54	902,014	2,291
				Total	**2,291**

Temporary Haul Roads

1.6.31 Material quantities utilised in the construction of temporary haul roads were estimated using dimensions provided within Volume 1, Chapter 3: Project Description of the PEIR. As the haul route would provide access across the majority of the Onshore HVDC Cable Corridor, the proposed haul road dimensions have been calculated using the total length of the onshore HVDC Cables (14.5 km), resulting in a total of 68,208,000 kg of recycled aggregates. This was scaled using relevant material intensity factors (0.0075 $kgCO_2e/kg$ (Jones and Hammond, 2019)), resulting in an embodied carbon value of 509 tCO_2e.

Vehicle Movements

1.6.32 Indicative vessel and onshore traffic movements were used to calculate emissions associated with their movements during the construction phase.

1.6.33 Emissions associated with vessel movements were calculated by estimating their total main engine energy requirement through multiplying the engine size of the vessels by anticipated duration of activity hours. The total duration of vessel activity was estimated by multiplying the duration of works (e.g. 30 days) by an assumed working shift (12-hour or 24-hour shifts per day). Vessel information was sourced from specifications of likely vessel types consistent with those listed within Volume 1, Chapter 3: Project Description of the PEIR. Multiplying the engine size by duration of activity is used to work out the consumption of energy per hour (kWh). This value was then scaled by the emission factor for marine gas oil (0.258 $kgCO_2e/kWh$) (DESNZ, 2023), totalling 303,016 tCO_2e.

1.6.34 HGV movements and personnel vehicle movements associated with the construction of the onshore infrastructure were scaled by an assumed average distance of travel (120 km for HGVs, in line with RICS whole life carbon guidance (RICS, 2023), and 50 km for personnel) and an emissions factor for fully laden diesel HGVs (0.98496 $kgCO_2e/km$) and medium petrol car (0.19819 $kgCO_2e/km$) (DESNZ, 2023). Resultant emissions associated with the onshore vehicle movements total 9,002 tCO_2e.

Summary

1.6.35 **Table 1.6** summarises the calculated construction phase emissions associated with the Proposed Development, which totals 739,511 tCO_2.

Table 1.6: Construction phase embodied carbon emissions summary

Element	Emissions (tCO_2e)
Converter Station	78,734
Alverdiscott Substation Connection Development	22,599
Joint Bays and Link Boxes	1,310
Offshore and Onshore Cabling (including fibre optic cables and CBS)	324,342
Temporary Haul Roads	509
Vehicle Movements (including vessels and onshore vehicles)	312,017
Total	**739,511**

1.7 Operation and Maintenance

Land Use Change

1.7.1 This is considered within the construction stage impacts (see **paragraphs 1.6.1 to 1.6.8**).

Fuel and Energy Consumption Operation and Maintenance Activities

1.7.2 Emissions during the operation and maintenance phase of the Proposed Development refer to activities contributing to the high-level management of the asset. Maintenance can be divided into preventative maintenance and corrective maintenance.

- Preventative maintenance includes the 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.

1.7.3 The Proposed Development maintenance activities largely involve inspection, remote monitoring, removal of marine growth, reburial of cables, and geophysical surveys. Emissions associated with such activities are largely captured within vessel movements. Where materials are used (i.e., new paint and coatings), associated emissions are negligible and immaterial and as such have not been assessed further.

1.7.4 Emissions associated with the proposed maintenance vessel movements follow the methodology detailed at **paragraphs 1.6.32** to **1.6.34**. Such emissions total 29,593 tCO_2e.

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

1.7.6 Throughout the Projects lifetime it is assumed that major plant equipment, such as transformers, will be replaced once for both the converter stations and Alverdiscott Substation Connection Development. As such, the embodied carbon emissions detailed in **paragraph 1.6.13** have been used to account for the replacement of transformers over the lifetime of the Proposed Development. Total emissions from major converter plant and substation plant (transformers) over the Project lifetime were calculated to be 15,768 tCO_2e.

1.7.7 It is anticipated that each onshore HVDC Cable will have a maximum of two repairs over the Proposed Development lifetime resulting from faults, each repair covering up to 1 km of cable. It is also anticipated that each offshore HVDC Cable will have a maximum of two faults over the lifetime, with each repair covering up to 3 km of cable. Total emissions from cable replacement over the Proposed Development lifetime were calculated to be 6,107 tCO_2e.

Summary

1.7.8 **Table 1.7** summarises the calculated construction phase emissions associated with the Proposed Development, which totals 51,468 tCO_2.

Table 1.7: Operation and maintenance phase embodied carbon emissions summary

Element	Emissions (tCO_2e)
Converter Station – maintenance (e.g. replacement of materials)	7,884
Alverdiscott Substation Connection Development	7,884
Cable Replacement	6,107
Vehicle Movements (including vessel movements)	29,593
Total	**51,468**

1.8 Decommissioning

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

1.8.2 In the absence of detailed information regarding onshore and offshore transport movements during the decommissioning phase, it has been assumed that such emissions equal those associated with the construction phase, totalling 312,017 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 Proposed Development, this is likely to present a conservative worst case scenario.

1.8.3 It is anticipated that the offshore and onshore cables will be left in situ or removed via joint bays. No new excavation is anticipated. The remaining elements will be dismantled and removed for recycling and disposal. The components of the converter stations are considered to be highly recyclable. When disposing of such elements, 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. 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.

1.8.4 **Table 1.8** provides the total decommissioning phase emissions associated with the Proposed Development, which totals 312,017 tCO_2e.

Table 1.8: Decommissioning phase embodied carbon emissions summary

Element	Emissions (tCO_2e)
Vehicle movements (including vessel and onshore vehicles)	312,017
Total	**312,017**

1.9 Assessment of Cumulative Projects

1.9.1 The following sections detail the methodology used to calculate the GHG emissions associated with cumulative Project.

The Moroccan Generation Assets

Embodied Carbon

Onshore and Offshore HVDC Cables

1.9.2 In the absence of additional information on the offshore and onshore HVDC Cables outside of the UK EEZ, it has been assumed that material quantities would remain similar to the cable utilised in the Proposed Development. Therefore, the embodied carbon has been estimated by scaling up the GHG emissions that have been calculated within **Table 1.4**. The total embodied carbon associated with onshore and offshore cables are summarised within **Table 1.9** below.

Table 1.9: Embodied carbon of the cumulative cables (between UK EEZ and Morocco generation assets)

Cable Type	Embodied Carbon per km (tCO_2e)[1]	Length of Cable Route (km)	Total Embodied Carbon (tCO_2e)
Offshore HVDC Cables	839.76	3,520	2,955,963
Offshore Fibre Optic Cables	6.19	3,520	21,797
Onshore HVDC Cables	724.43	150	108,664

1 This has been determined from the Proposed Development calculations in **paragraphs 1.6.23** to **1.6.27** (total embodied carbon was divided by the total distance to get the embodied carbon per km).

Converter Stations

1.9.3 The potential impact of the proposed converter stations in Morocco has been estimated using an intensity for the manufacturing GWP of 2,190 kgCO_2e per MW (ABB, 2003). This was scaled by the total combined capacity of the generation assets, totalling 11,500 MW, to give an estimated embodied carbon value of 25,185 tCO_2e.

1.9.4 It has been assumed that this calculation includes all electrical plant required to manage and transmit the capacity of the Moroccan generation assets, i.e., including any electrical plant to be housed on the substations.

1.9.5 Information taken from the Environmental and Social Impact Assessment for the Moroccan generation site indicates that the total footprint of the converter stations and gas-insulated switchgear is expected to be up to 131,300 m^2. At the current stage, there is uncertainty with the material estimates and quantities to be used in the final design. Therefore, the calculation of embodied carbon has followed the methodology in **paragraph 1.6.15**, using the RICS benchmark (545 kgCO_2e/m^2) and scaling by the total footprint to give a value of 71,559 tCO_2e.

Generation Assets

1.9.6 As highlighted within **paragraph 1.3.13**, there is high variability in the published GHG figures relating to the LCA of renewable energy generation such as solar panels, wind turbines and battery storage. As a result, the embodied carbon associated with the generation assets has been estimated using embodied carbon intensities, derived from the analysis and harmonisation of literature by various studies. These industry benchmarks used for solar, wind and battery storage should capture the GHG emissions associated with the associated AC cabling and substations.

1.9.7 For both the wind and solar generation assets, the relevant LCA stage intensity was multiplied by the operational energy output of the project elements (generation assets) during the different phases of the Proposed Development, as detailed below and within **Table 1.10**:

- Construction Phase: The construction stage intensity was multiplied by the operational energy output in the first year of operation.
- Operation and Maintenance Phase: The operation and maintenance stage intensity was multiplied by the total operation energy output over the lifetime.
- Decommissioning Phase: The decommissioning stage intensity was multiplied by the operational energy output in the final year of operation.

1.9.8 When calculating the total operational energy output over the Project lifetime, relevant degradation factors were utilised, to account for loss of output over time, for both the wind assets (1.6%, (Staffell and Green, 2014)) and solar assets (0.8% (Jordan and Kurtz, 2012)).

Table 1.10: Summary of embodied carbon for generation assets - wind and solar

Project Element	Input	LCA stage intensity (kg CO_2e/MWh)	GHG Emission (tCO_2e)
Solar	6,561,240 (1st year MWh)	31.20	204,711
	271,272,298 (total project MWh)	11.04	2,994,846
	4,426,473 (final year MWh)	5.76	25,496

Project Element	Input	LCA stage intensity (kg CO_2e/MWh)	GHG Emission (tCO_2e)
Wind	13,757,580 (1st year MWh)	9.46	130,147
	475,985,102 (total project MWh)	0.99	471,225
	6,241,685,327 (final year MWh)	0.55	3,433

1.9.9 In relation to the battery storage, as detailed within **paragraph 1.3.23**, the intensity benchmark for battery storage excludes operation as there would be no further material emissions beyond what is accounted for within the construction and decommissioning intensities.

1.9.10 The GHG emissions factors (527,000 kgCO_2e/MW and 99,000 kgCO_2e/MW) were multiplied by the installed storage capacity (5,000 MW) of the battery storage component of the generation assets, which results in an estimated embodied carbon emission in the order of 3,130,000 tCO_2e (see **Table 1.11**).

Table 1.11: Summary of embodied carbon for generation assets - battery storage

Project Element	Input	LCA stage intensity (kgCO_2e/MW)	GHG Emission (tCO_2e)
Battery Storage	5,000 MW (storage capacity)	527,000	2,635,000
		99,000	495,000

Avoided Emissions

1.9.11 The primary purpose of the operational stage of the generation assets (solar, wind and battery storage) are to avoid the need for fossil fuel generation assets and reduce the national grid carbon intensity. The Project would export energy to the GB national grid that is zero-carbon at the point of generation[1], thereby displacing the marginal generating source that would be providing energy in the absence of the Project.

1.9.12 The magnitude of impact of the Project is determined by the quantity of renewable energy use it enables by avoiding curtailment, the quantity of fossil fuel generation it displaces, and the associated GHG impacts of both. The quantity of renewable energy enabled and fossil fuel generated energy displaced is determined by the total annual energy input and output values for the Project (see **Table 1.12**). The associated GHG emissions are determined by the GHG intensity of the enabled and displaced sources of generation.

1.9.13 **Table 1.12** sets out the annual energy input and output values for the Project and the parameters by which they are determined.

Table 1.12: Energy flows from the Project

Parameter	Value	Unit	Source
Input Parameter – imported power to GB national grid (Bipole 1)	1,800	MW	Volume 1, Chapter 1: Introduction of the PEIR.

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[1] i.e., not including the embodied carbon emissions associated with the construction of the cumulative Project discussed in the construction effects section.

Parameter	Value	Unit	Source
Input Parameter – imported power to GB national grid (Bipole 2)	1,800	MW	Volume 1, Chapter 1: Introduction of the PEIR.
Input Parameter – degradation factor	1.6	%	Staffell and Green (2014).
Input Parameter – total annual operating hours	8,760	hours	N/A – assumed continuous operational hours throughout the year.
Output parameter – annual energy output (Bipole 1)	15,768,000	MWh	N/A – determined from the imported power and operating hours.
Output parameter – annual energy output (Bipole 2)	15,768,000	MWh	N/A – determined from the imported power and operating hours.

1.9.14 Degradation factors for both wind farms (1.6%) (Staffell and Green, 2014) and solar farms (0.8%) (Jordan and Kurtz, 2012) were determined, as the generation assets of the Project includes both solar and wind. As a conservative approach, the greatest degradation factor of 1.6% was incorporated into the annual output beyond the first year of operation.

1.9.15 The input and output figures for the operational stage of the Project are then calculated against the assumptions stated within the DESNZ long-run marginal. This allows for a direct presentation of the cumulative GHG emissions avoided throughout the operational lifetime of the Project and therefore, how the Project contributes towards reaching net zero targets. The calculations take into account the delayed commissioning of the Bipole 2 and thus, the associated operational output. The operational energy output of the Bipole 2 is included onwards from 2032.

1.9.16 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, the 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 moves towards its 2050 net zero carbon target, the marginal source of electricity generation will likely become a combination of renewables (predominantly solar and wind) and storage. Therefore, from circa 2040 onwards, comparing the Project’s GHG impacts with the marginal source of generation is akin to comparing it with itself and has limited value.

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

1.9.18 Overall, the avoided emissions resulting from the cumulative Project are reflected in **Table 1.13** below.

1.9.19 As detailed in **paragraph 1.9.14**, an assumed degradation factor of 1.6% (Staffell and Green, 2014) has been incorporated into the annual output beyond the first year of operation.

1.9.20 **Table 1.13** displays the annual power output and emissions avoidance of the Project when comparing the abated fossil fuel generation using the DESNZ (2023) long run marginal carbon intensity for the future UK electricity Grid, consistent with years throughout.

Table 1.13: Cumulative Operational GHG Impacts

Year of Operation	Year	Output (MWh)	DESNZ long-run marginal (tCO_2e/MWh)	Avoided GHG Emissions (tCO_2e)	Cumulative Avoided GHG Emissions (tCO_2e)
1 (Bipole 1 commissioned)	2030	15,768,000	0.085	1,340,280	1,340,280
2	2031	15,515,712	0.065	1,008,521	2,348,801
3 (Bipole 2 commissioned)	2032	31,035,461	0.05	1,551,773	3,900,574
4	2033	30,538,893	0.038	1,160,478	5,061,052
5	2034	30,050,271	0.029	871,458	5,932,510
6	2035	29,569,467	0.023	680,098	6,612,608
7	2036	29,096,355	0.017	494,638	7,107,246
8	2037	28,630,813	0.013	372,201	7,479,446
9	2038	28,172,720	0.01	281,727	7,761,174
10	2039	27,721,957	0.008	221,776	7,982,949
11	2040	27,278,406	0.006	163,670	8,146,620
12	2041	26,841,951	0.006	161,052	8,307,671
13	2042	26,412,480	0.004	105,650	8,413,321
14	2043	25,989,880	0.003	77,970	8,491,291
15	2044	25,574,042	0.002	51,148	8,542,439
16	2045	25,164,857	0.001	25,165	8,567,604
17	2046	24,762,220	0.001	24,762	8,592,366
18	2047	24,366,024	0.001	24,366	8,616,732
19	2048	23,976,168	0.001	23,976	8,640,708
20	2049	23,592,549	0.001	23,593	8,664,301
21	2050	23,215,068	0.001	23,215	8,687,516
22	2051	22,843,627	0.002	45,687	8,733,203
23	2052	22,478,129	0.002	44,956	8,778,160

Year of Operation	Year	Output (MWh)	DESNZ long-run marginal (tCO_2e/MWh)	Avoided GHG Emissions (tCO_2e)	Cumulative Avoided GHG Emissions (tCO_2e)
24	2053	22,118,479	0.002	44,237	8,822,396
25	2054	21,764,584	0.002	43,529	8,865,926
26	2055	21,416,350	0.002	42,833	8,908,758
27	2056	21,073,689	0.002	42,147	8,950,906
28	2057	20,736,510	0.002	41,473	8,992,379
29	2058	20,404,725	0.002	40,809	9,033,188
30	2059	20,078,250	0.002	40,156	9,073,345
31	2060	19,756,998	0.002	39,514	9,112,859
32	2061	19,440,886	0.002	38,882	9,151,740
33	2062	19,129,832	0.002	38,260	9,190,000
34	2063	18,823,754	0.002	37,648	9,227,648
35	2064	18,522,574	0.002	37,045	9,264,693
36	2065	18,226,213	0.002	36,452	9,301,145
37	2066	17,934,594	0.002	35,869	9,337,014
38	2067	17,647,640	0.002	35,295	9,372,310
39	2068	17,365,278	0.002	34,731	9,407,040
40	2069	17,087,433	0.002	34,175	9,441,215
41	2070	16,814,035	0.002	33,628	9,474,843
42	2071	16,545,010	0.002	33,090	9,507,933
43	2072	16,280,290	0.002	32,561	9,540,494
44	2073	16,019,805	0.002	32,040	9,572,533
45	2074	15,763,488	0.002	31,527	9,604,060
46	2075	15,511,273	0.002	31,023	9,635,083
47	2076	15,263,092	0.002	30,526	9,665,609
48	2077	15,018,883	0.002	30,038	9,695,647
49	2078	14,778,581	0.002	29,557	9,725,204
50	2079	14,542,123	0.002	29,084	9,754,288

Sensitivity Analysis

1.9.21 The long run marginal figures, which have been used in the above **Table 1.13**, are dynamic and show year-on-year decarbonisation of 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. However, the long run marginal figures are projections and cannot be taken with absolute certainty. Furthermore, the long-run marginal includes assumed abatement of fossil fuel generation sources within the UK electricity Grid. As such it is likely that the true value of the avoided emissions displaced as a result of the Project's contribution to the UK electricity Grid would be higher than that of avoided emissions detailed above.

1.9.22 As such, a sensitivity analysis has been carried out using the current UK electricity Grid carbon intensity and current estimated intensity from electricity supplied for 'all non-renewable fuels' as detailed in **section 1.5**.

1.9.23 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. As such, the long run marginal provides a conservative quantification of avoided emissions for the purpose of this assessment.

Table 1.14: Whole life avoided emissions sensitivity test

Operating Years	Output (MWh)	DESNZ long-run marginal avoided emissions (tCO_2e/MWh)	Current UK Grid average avoided emissions (tCO_2e)	DESNZ 'non-renewable fuels' avoided emissions (tCO_2e)
50	1,076,659,419	9,754,288	272,366,840	477,865,852

Summary

1.9.24 **Table 1.15** summarises the net GHG emissions associated with the cumulative Project.

Table 1.15: Cumulative GHG emissions associated with the construction, operation and decommissioning of the Moroccan generation assets

	Avoided Emissions Scenario	Total Embodied Carbon (tCO_2e)	Avoided Emissions (tCO_2e)	Net Emissions (tCO_2e)
Total	DESNZ Long-run marginal avoided emissions	10,143,026	9,754,288	388,737
	Current UK Grid average avoided emissions	10,143,026	272,366,840	-262,223,814
	DESNZ 'non-renewable fuels' avoided emissions	10,143,026	477,865,852	-467,722,826

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