XLINKS' MOROCCO-UK POWER PROJECT

Environmental Statement

Volume 4, Appendix 1.1: Greenhouse Gas Assessment Technical Report

Document Number: 6.4.1.1

PINS Reference: EN010164/APP/6.4

APFP Regulations: 5(2)(a)

November 2024

For Issue

Document status					
Version	**Purpose of document**	**Authored by**	**Reviewed by**	**Approved by**	**Review date**
For Issue	Application	RPS	Xlinks 1 Ltd	Xlinks 1 Ltd	November 2024

Prepared by:

RPS

Prepared for:

Xlinks 1 Limited

Contents

Tables

Figures

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 carried out by National Grid Electricity Transmission. This does not form part of the Proposed Development, however, it is considered cumulatively within the Environmental Impact Assessment as it is necessary to facilitate connection to the national grid.
Bipole	A Bipole system is an electrical transmission system that comprises two Direct Current conductors of opposite polarity (one conductor with positive voltage and one with negative voltage).
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.
HVAC Cable Corridors	The proposed corridors (for each Bipole) within which the onshore High Voltage Alternating Current cables would be routed between the Converter Site and the Alverdiscott Substation Site.
HVDC Cables	The High Voltage Direct Current 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 bays 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 UK 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.
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).

Term	Meaning
Proposed Development	The element of the Xlinks' Morocco-UK Power Project within the UK. The Proposed Development covers all works required to construct and operate the offshore cables (from the UK Exclusive Economic Zone to Landfall), Landfall, onshore Direct Current and Alternating Current cables, converter stations, and highways improvements.
Study area	This is an area which is defined for each environmental topic which includes the 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.
The national grid	The 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.
Transition joint bay	A transition joint bay is an underground structure at the landfall area where the offshore cables are jointed to the onshore cables.
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
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DC	Direct Current
DESNZ	Department for Energy Security and Net Zero
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EPD	Environmental Product Declaration
ES	Environmental Statement
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
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
GWh	Gigawatt Hours
km	Kilometres
kg	Kilograms
kWh	Kilowatt hours
m^2	Metres squared
MW	Megawatt
MWh	Megawatt hours
MVA	Megavolt amperes
t	Tonnes

1 GREENHOUSE GAS TECHNICAL REPORT

1.1 Introduction

1.1.1 This document forms Volume 4, Appendix 1.1 of the Environmental Statement (ES) 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 ES presents the 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 ES. 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 Volume 4, Chapter 1: Climate Change of the ES.

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

- the UK's 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 Project, thus connecting the Moroccan generation assets to the national grid (see Volume 1, Chapter 1: Introduction, of the ES 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 and transmission infrastructure, on the global atmospheric mass of CO_2 has been assessed. The cumulative Project includes the following components:

- Generation assets, comprising approximately 7.5 GW solar farm, 4 GW wind farm[1] and 5 GW / 22.5 GWh 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 cumulative assessment also considers the anticipated development at the existing Alverdiscott Substation site (referred to as the 'Alverdiscott Substation Connection Development'), which would include a new 400 kV substation and other extension modification works to be developed by National Grid Electricity Transmission (NGET). Whilst this development will be brought forward by NGET, it would be necessary to facilitate connection to the national grid and thus, has been considered cumulatively.

1.1.8 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 Alverdiscott Substation Connection Development and the wider Project (outside of the UK EEZ). Information relating to the generation assets of the Project has been sourced from Xlinks 1 Limited (the 'Applicant') and Volume 1, Chapter 1: Introduction of the ES.

[1] The installed capacity of the solar farm and wind farm for the Moroccan generation assets has been amended since the submission of the Preliminary Environmental Information Report (PEIR), which were previously 7 GW and 4.5 GW, respectively. The updated values have been utilised within the Greenhouse Gas (GHG) calculations presented in Table 1.14 of this ES Chapter. Such variations in installed capacity have little to no impact on the significance of effect as a result of output of the Project to the national grid (3.6 GW) and cumulative effects assessment.

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 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 and Alverdiscott Substation Connection Development 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, transition joint bays, etc.), in addition to fuel use by vehicle and vessel 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 generation asset and transmission elements of the wider 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 renewable generation, 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.

1.3.12 Land use change includes the loss of land utilised for UK-generated renewable energy (i.e. permitted solar farm development). The associated impact is assessed by calculating the potential loss of GHG emissions savings from UK renewable energy generation. This is considered in **paragraphs 1.6.5** to **1.6.11.**

Cumulative Assessment

Embodied Carbon

1.3.13 The cumulative assessment considers the GHG emissions associated with the construction of the Alverdiscott Substation Connection Development, as well as the rest of the Project outside of the UK EEZ, which both form cumulative schemes to the Proposed Development for this EIA assessment. This follows the approach detailed within **paragraphs 1.3.7** to **1.3.10**.

1.3.14 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

1.3.15 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).

1.3.16 The NREL (2013) study was based on the output of the Dolan & Heath (2012) paper and as such the Dolan & Heath paper 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.

1.3.17 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).

1.3.18 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

1.3.19 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).

1.3.20 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).

1.3.21 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).

1.3.22 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

1.3.23 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.

1.3.24 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

1.3.25 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 A proportion 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 ES).

1.5.2 The Order Limits includes a small area of land at the Converter Site and onshore HVDC Cable Corridor, which is occupied by part of a permitted solar farm development, which is under construction at the time of writing (planning application 1/1057/2021/FULM). Although the Proposed Development only partially covers the permitted solar farm site, it would have potential to displace existing and potential UK-generated renewable energy that is delivered by the solar farm.

1.5.3 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 ES). However, it is unlikely that this land has high soil or vegetation carbon stocks that would be subject to disturbance by construction.

1.5.4 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 252.95 kg CO_2e/MWh (including scope 3 but as generated, i.e., excluding transmission and distribution losses) (DESNZ, 2024).

Future Baseline

1.5.5 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 permitted solar farm application (Planning reference: 1/1057/2021/FULM), which would continue to deliver UK-generated renewable energy that would contribute to the decarbonisation of the grid.

1.5.6 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.

1.5.7 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.

1.5.8 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, 2023a). 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.

1.5.9 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.

1.5.10 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.

1.5.11 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.

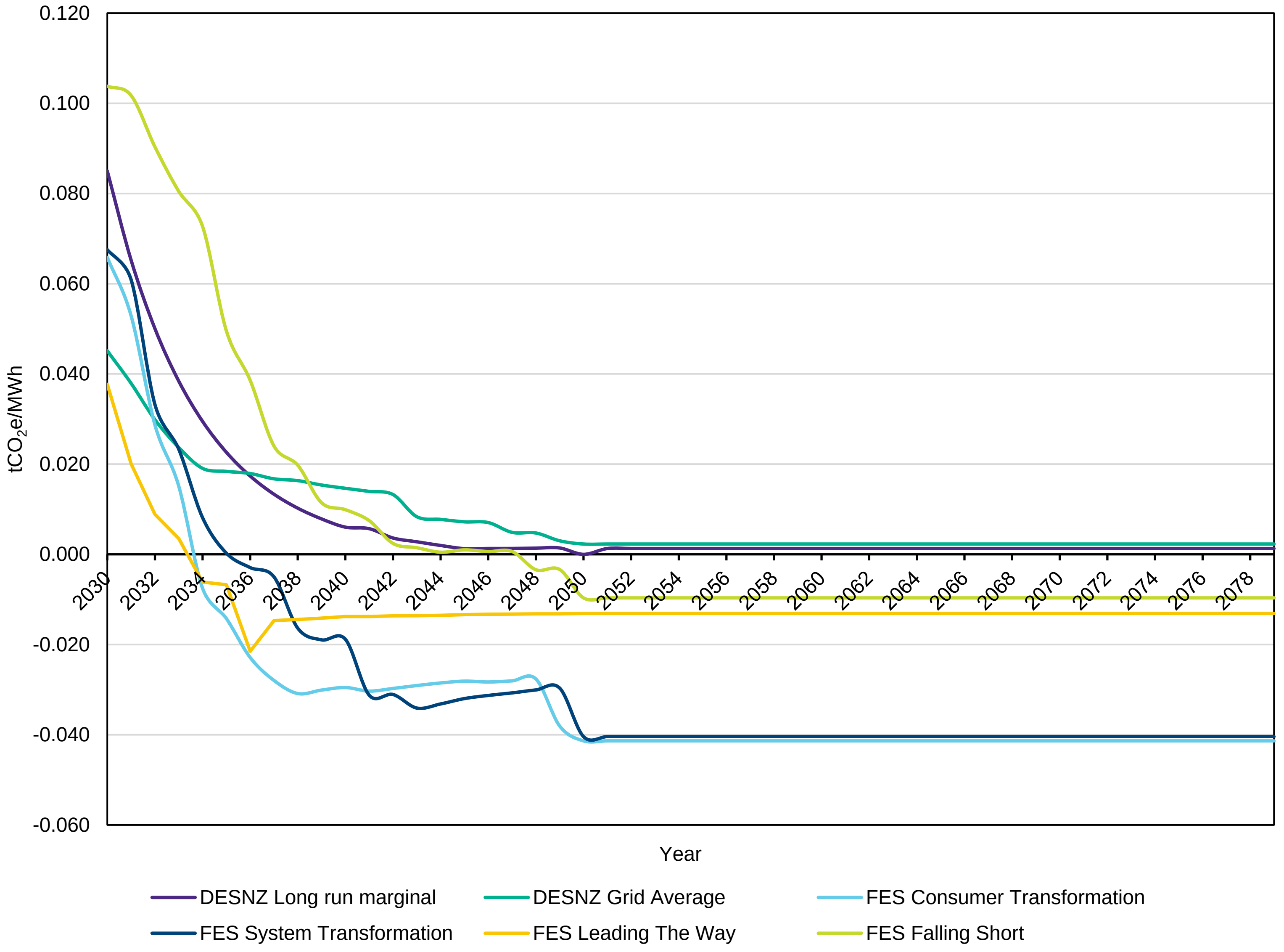

Figure 1.1: DESNZ and FES future grid carbon intensities

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

Year of Full Operation*	Year	DESNZ Long-Run Marginal (tCO_2e/MWh)	DESNZ Grid Average (tCO_2e/MWh)
-2 (commencement of operation for Bipole 1)	2031	0.065	0.038
-1	2032	0.050	0.030
1 (full operation – both Bipole 1 and Bipole 2 commissioned)	2033	0.038	0.024
2	2034	0.029	0.019
3	2035	0.023	0.018
4	2036	0.017	0.018
5	2037	0.013	0.017
6	2038	0.010	0.016
7	2039	0.008	0.015
8	2040	0.006	0.015
9	2041	0.006	0.014
10	2042	0.004	0.013
11	2043	0.003	0.008
12	2044	0.002	0.008
13	2045	0.001	0.007
14	2046	0.001	0.007
15	2047	0.001	0.005
16	2048	0.001	0.005
17	2049	0.001	0.003
18	2050	0.002	0.002
19	2051	0.002	0.002
20	2052	0.002	0.002
21	2053	0.002	0.002
22	2054	0.002	0.002
23	2055	0.002	0.002
24	2056	0.002	0.002
25	2057	0.002	0.002
26	2058	0.002	0.002
27	2059	0.002	0.002
28	2060	0.002	0.002
29	2061	0.002	0.002
30	2062	0.002	0.002
31	2063	0.002	0.002
32	2064	0.002	0.002
33	2065	0.002	0.002
34	2066	0.002	0.002
35	2067	0.002	0.002

Year of Full Operation*	Year	DESNZ Long-Run Marginal (tCO_2e/MWh)	DESNZ Grid Average (tCO_2e/MWh)
36	2068	0.002	0.002
37	2069	0.002	0.002
38	2070	0.002	0.002
39	2071	0.002	0.002
40	2072	0.002	0.002
41	2073	0.002	0.002
42	2074	0.002	0.002
43	2075	0.002	0.002
44	2076	0.002	0.002
45	2077	0.002	0.002
46	2078	0.002	0.002
47	2079	0.002	0.002
48	2080	0.002	0.002
49	2081	0.002	0.002
50	2082	0.002	0.002

*Full operation is expected to commence in 2033 following the connection of both converter stations (Bipole 1 and Bipole 2) to the national grid. Bipole 1 and Bipole 2 are expected to be operational in 2031 and 2033, respectively.

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 ES 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 ES). 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 Order Limits.

1.6.4 The site selection and design process for the Proposed Development has considered areas of woodland and has avoided areas such as Littleham Wood. Whilst Lodge Plantation (situated to the east of the River Torridge) is situated within the Order Limits, trenchless methods would be utilised 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.

1.6.5 However, it has been identified that the permitted solar farm development (Planning reference 1/1057/2021/FULM) is partially situated within the Converter Site and a small section within the onshore HVDC Cable Corridor, which would be required for the construction and operation of the converter stations. This permitted solar farm has a capacity of 36 MW and following construction, would have an operational lifetime of 40 years. The construction of the Proposed Development would require approximately 6 ha of solar panels to be removed, which would equate to 2.5 MW of installed capacity. Therefore, the Proposed Development has the potential to displace existing and potential UK-generated renewable energy.

1.6.6 The magnitude of impact for the displacement of potential UK-generated renewable energy is determined by the quantity of renewable energy output lost and the associated GHG impacts (i.e. loss of potential emissions savings). Firstly, the quantity of renewable energy enabled (over the 40 year lifetime) and fossil fuel generated energy displaced by the solar farm are calculated by the total energy output values for the solar farm (see **Table 1.3**). The associated GHG emissions are determined by the GHG intensity of the enabled and displaced sources of generation.

1.6.7 **Table 1.3** sets out the annual energy input and output values for the permitted solar farm and the parameters by which they are determined.

Table 1.3: Estimated energy flows for the permitted solar farm development

Stage	Value	Unit	Source
Input Parameter – installed capacity	2.5	MW	Volume 1, Chapter 3: Project Description of the ES.
Input Parameter – capacity factor	10.7	%	DESNZ (2023b)
Input Parameter – annual degradation factor	0.8	%	Jordan and Kurtz (2012)
Input Parameter – total hours per annum	8,760	Hours	Assumed operational 24/7
Output Parameter - annual energy output	2,343.30	MWh	Calculated based on the input parameters

1.6.8 A degradation factor for solar farms (0.8%) (Jordan and Kurtz, 2012) was determined and incorporated into the annual output beyond the first year of operation.

1.6.9 The input and output figures for the operation of the permitted solar farm were then calculated against the assumptions stated within the DESNZ long-run marginal (DESNZ, 2023a).

1.6.10 **Table 1.4** displays the annual power output and associated emissions savings that would be lost due to the land use change (e.g. removal of solar panels) over the lifetime of the solar farm.

Table 1.4: Impacts associated with the loss of UK-generated renewable energy

Year	Output (MWh)	DESNZ long-run marginal (tCO_2e/MWh)	Loss of Avoided GHG Emissions (tCO_2e)
2026	2,343.30	0.174	408.04
2027	2,324.55	0.154	358.42
2028	2,305.96	0.133	306.14
2029	2,287.51	0.110	251.02
2030	2,269.21	0.085	192.88
2031	2,251.06	0.065	146.85
2032	2,233.05	0.050	111.80
2033	2,215.18	0.038	85.11
2034	2,197.46	0.029	64.80
2035	2,179.88	0.023	49.33
2036	2,162.44	0.017	37.56
2037	2,145.14	0.013	28.59
2038	2,127.98	0.010	21.77
2039	2,110.96	0.008	16.57
2040	2,094.07	0.006	12.62
2041	2,077.32	0.006	11.81
2042	2,060.70	0.004	7.45
2043	2,044.21	0.003	5.68
2044	2,027.86	0.002	3.98
2045	2,011.64	0.001	2.53
2046	1,995.54	0.001	2.59
2047	1,979.58	0.001	2.58
2048	1,963.74	0.001	2.70
2049	1,948.03	0.001	2.74
2050	1,932.45	0.002	3.86
2051	1,916.99	0.002	3.83
2052	1,901.65	0.002	3.80
2053	1,886.44	0.002	3.77
2054	1,871.35	0.002	3.74
2055	1,856.38	0.002	3.71
2056	1,841.53	0.002	3.68
2057	1,826.79	0.002	3.65
2058	1,812.18	0.002	3.62
2059	1,797.68	0.002	3.60
2060	1,783.30	0.002	3.57
2061	1,769.03	0.002	3.54
2062	1,754.88	0.002	3.51
2063	1,740.84	0.002	3.48
2064	1,726.92	0.002	3.45
		Total	**2,188.37**

1.6.11 Due to the removal of solar panels, there would be a potential loss of 2,188.37 tCO_2e in emissions savings over the lifetime of the solar farm, based on the long run marginal scenario. A sensitivity analysis has been carried out using the current national grid carbon intensity and current estimated intensity from electricity supplied for 'all non-renewable fuels' to understand how this potential loss of emissions saving may vary based on the different future scenarios. A summary is provided in **Table 1.5**, which shows that the potential loss of emissions savings ranges between 2,188.37 (long run marginal) and 33,400.52 tCO_2e ('non-renewable fuels').

Table 1.5: Impacts associated with the loss of UK-generated renewable energy - Sensitivity analysis

	Long run marginal	Current national grid carbon intensity	Non-renewable fuels
Potential loss of emissions savings (tCO_2e)	2,188.37	19,926.09	33,400.52

1.6.12 This figure is reflective of the whole life of the Project, however, it is included as a construction-stage impact, rather than an operation and maintenance impact, as this is when the solar panels would be removed.

1.6.13 Nevertheless, 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).

1.6.14 Throughout the decommissioning process it is anticipated that the existing baseline environment would be restored, with the exception of the solar PV panels. 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

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

1.6.16 The offshore environment consists of sand, mud, rock, coarse sediment, mixed sediment, biogenic reef, and diverse benthic communities. However, it is unlikely that this land has high soil/sediment or vegetation carbon stocks that would be subject to disturbance by construction.

1.6.17 The land use change would be constrained to the 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

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

1.6.19 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.

1.6.20 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

1.6.21 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 1.6**).

Table 1.6: Information required for calculation of major converter plant embodied carbon

Stage	Value	Unit	Source
Input Parameter – Project Output	3,600	MW	Volume 1, Chapter 1: Introduction of the ES
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

1.6.22 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.

1.6.23 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.

Joint Bays and Link Boxes

Joint Bays

1.6.24 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 ES, totalling 9,922 kg of concrete, and scaled by the relevant material intensity factor (0.103 kgCO_2e/kg, (Jones and Hammond, 2019)).

1.6.25 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)).

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

Link Boxes

1.6.27 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 ES. 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).

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

Cabling

Power Cables

1.6.29 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.

1.6.30 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 1.7**, (Jones and Hammond, 2019)) were then scaled by the estimated quantities. Material quantities applied to this calculation are summarised within **Table 1.7** below.

1.6.31 **Table 1.7** 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 ES.

Table 1.7: 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	163,213	415
PVC		3.23	13,184	43
Lead		1.67	328,195	548
Cable Duct (PVC)		3.23	98,811	319
			Total	**2,805**
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	690,836	1,999
			Total	**9,745**
Offshore DC Cables				
Aluminium	370	6.67	14,726,397	98,225
Polyethylene		2.54	17,937,854	41,564
Lead		1.67	17,994,948	30,052
Steel Wire		2.27	49,390,478	112,116
Bitumen		0.33	161,212	53
Polyethylene (Landfall HDD Ducts)	2.11	2.54	449,802	1,143
			Total	**283,152**

1.6.32 As detailed within Volume 1, Chapter 3: Project Description of the ES, 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 1.6.25** above). This resulted in a total embodied carbon of 1,005 tCO_2e associated with onshore cable trenches, including 808 tCO_2e for onshore DC trenches and 197 tCO_2e for onshore AC trenches.

1.6.33 Overall, the total embodied carbon associated with the construction of power cables (including the use of CBS) has been estimated to be 283,152 tCO_2e for offshore DC cables, 3,002 tCO_2e for onshore AC cables and 10,552 tCO_2e for onshore DC cables.

Fibre Optic Cables

1.6.34 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.

1.6.35 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 1.8** below.

1.6.36 Total embodied carbon emissions associated with the construction of fibre optic cables for both the onshore and offshore environment has been estimated to be 2,757 tCO_2e.

Table 1.8: 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	77,264	196
				Total	**466**
Offshore					
Fibre Optic Cable (Medium density polyethylene)	2	370	2.54	902,014	2,291
				Total	**2,291**

Temporary Haul Roads

1.6.37 Material quantities utilised in the construction of temporary haul roads were estimated using dimensions provided within Volume 1, Chapter 3: Project Description of the ES. 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 and Vessel Movements

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

1.6.39 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 ES. 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 (0.25798 kgCO_2e/kWh) (DESNZ, 2024), totalling 118,921 tCO_2e.

1.6.40 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 (0.17726 kgCO_2e/km) (DESNZ, 2024). Resultant emissions associated with the onshore vehicle movements total 9,612 tCO_2e.

Summary

1.6.41 **Table 1.9** summarises the calculated construction phase emissions associated with the Proposed Development, which totals 510,737 tCO_2.

Table 1.9: Construction phase embodied carbon emissions summary

Element	Emissions (tCO_2e)
Converter stations	78,734
Joint Bays and Link Boxes	1,310
Offshore and Onshore Cabling (including fibre optic cables and CBS)	299,462
Temporary Haul Roads	509
Vehicle Movements (including vessels and onshore vehicles)	128,533
Land Use Change (loss of Sonnedix panels)	2,188
Total	**510,737**

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 1.6.16**).

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 1.6.38** to **1.6.40**. Such emissions total 32,409 tCO_2e.

1.7.5 Throughout the Proposed Development lifetime, it is assumed that major plant equipment, such as transformers, will be replaced once for the converter stations. As such, the embodied carbon emissions detailed in **paragraph 1.6.21** have been used to account for the replacement of transformers over the lifetime of the Proposed Development. Total emissions from major converter plant (transformers) over the Proposed Development lifetime were calculated to be 7,884 tCO_2e.

1.7.6 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 5,641 tCO_2e.

Summary

1.7.7 **Table 1.10** summarises the calculated construction phase emissions associated with the Proposed Development, which totals 45,935 tCO_2.

Table 1.10: Operation and maintenance phase embodied carbon emissions summary

Element	Emissions (tCO_2e)
Converter Station – maintenance (e.g. replacement of materials)	7,884
Cable Replacement	5,641
Vehicle Movements (including vessel movements)	32,409
Total	**45,935**

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 65,170 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 transition 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 1.11** provides the total decommissioning phase emissions associated with the Proposed Development, which totals 128,533 tCO_2e.

Table 1.11: Decommissioning phase embodied carbon emissions summary

Element	Emissions (tCO_2e)
Vehicle movements (including vessel and onshore vehicles)	128,533
Total	**128,533**

1.9 Assessment of Cumulative Projects

1.9.1 The following sections detail the methodology used to calculate the GHG emissions associated with the Alverdiscott Substation Connection Development and the cumulative Project.

Alverdiscott Substation Connection Development

1.9.2 Following the methodology detailed within **paragraph 1.6.21**, 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.

1.9.3 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 1.6.23**. A carbon intensity of 545 $kgCO_2e/m^2$ was scaled by the total maximum area of the substation (28,000 m^2), to give an embodied carbon value of 15,260 tCO_2e.

1.9.4 In terms of operation and maintenance, it is assumed that major plant equipment, such as transformers, will be replaced once for the substation within the 50 years lifetime of the Proposed Development. As such, the embodied carbon emissions detailed in **paragraph 1.9.2** have been used to account for the replacement of transformers. Total emissions from major substation plant (transformers) over the Proposed Development lifetime were calculated to be 7,884 tCO_2e.

1.9.5 Total emissions associated with the Alverdiscott Substation Connection Development are presented in **Table 1.12**.

Table 1.12: Total emissions associated with the Alverdiscott Substation Connection Development

Element	Emissions (tCO_2e)
Construction emissions	23,144
Operation and maintenance	7,884
Total	**31,028**

The Moroccan Generation Assets and Transmission Infrastructure

Embodied Carbon

Onshore and Offshore HVDC Cables

1.9.6 The offshore and onshore HVDC Cables outside of the UK EEZ would comprise the same material quantities as 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 1.7**. The total embodied carbon associated with onshore and offshore cables are summarised within **Table 1.13** below.

Table 1.13: 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	762.19[2]	3,520	2,682,899
Offshore Fibre Optic Cables	6.19	3,520	21,797
Onshore HVDC Cables	727.73	150	109,159

1 This has been determined from the Proposed Development calculations in **paragraphs 1.6.29** to **1.6.33** (total embodied carbon was divided by the total distance to get the embodied carbon per km).

2 The embodied carbon per km for the offshore cables excludes the value calculated for the HDD ducting at Landfall (i.e. 282,009 tCO_2e / 370 km = 762.19 tCO_2e).

Converter Stations

1.9.7 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.

1.9.8 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.

1.9.9 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 1.6.23**, 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

1.9.10 As highlighted within **paragraph 1.3.14**, 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.

1.9.11 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 1.14**:

- 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.

1.9.12 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 1.14: 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	7,029,900 (1st year MWh)	31.20	219,333
	290,648,890 (total project MWh)	11.04	3,208,764
	4,742,650 (final year MWh)	5.76	27,318
Wind	12,228,960 (1st year MWh)	9.46	115,686
	423,097,869 (total project MWh)	0.99	418,867
	5,548,165 (final year MWh)	0.55	3,051

1.9.13 In relation to the battery storage, as detailed within **paragraph 1.3.24**, 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.

1.9.14 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 and totalled, which results in an estimated embodied carbon emission in the order of 3,130,000 tCO_2e (see **Table 1.15**).

Table 1.15: 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

1.9.15 The primary purpose of the operational stage of the generation assets (solar, wind and battery storage) is to avoid the need for fossil fuel generation assets and reduce the national grid carbon intensity. The Project would export energy to the national grid that is zero-carbon at the point of generation[2], thereby displacing the marginal generating source that would be providing energy in the absence of the Project.

1.9.16 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 1.16**). The associated GHG emissions are determined by the GHG intensity of the enabled and displaced sources of generation.

1.9.17 **Table 1.6** sets out the annual energy input and output values for the Project and the parameters by which they are determined. The output and associated avoided emissions are based on a modelled energy output (see Figure 1.2), developed by the Applicant. This can be determined based on the following calculation:

Annual energy output = total annual operating hours (8760 hrs) x HVDC system capacity (3,600 MW) x HVDC system capacity factor (80.12%)

Table 1.16: Energy flows from the Project

Parameter	Value	Unit	Source
Input Parameter – HVDC system capacity	3,600	MW	Volume 1, Chapter 1: Introduction of the ES.
Input Parameter – HVDC system capacity factor	80.12*	%	Determined from the Project generation profile provided by the Applicant.
Input Parameter – total annual operating hours	8,760	hours	N/A – assumed continuous operational hours throughout the year.
Output parameter – average annual energy output	25,109,331	MWh	Project generation profile provided by the Applicant.

* This capacity factor has been calculated as an average across all years in which both bipoles would be operational. Therefore, this is an average across the Project lifetime and the annual energy output in this table would be impacted by daily fluctuations in the capacity factor. As such, the assumed energy output used for the assessment, as provided by the Applicant, will differ to the average stated above year on year.

---

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

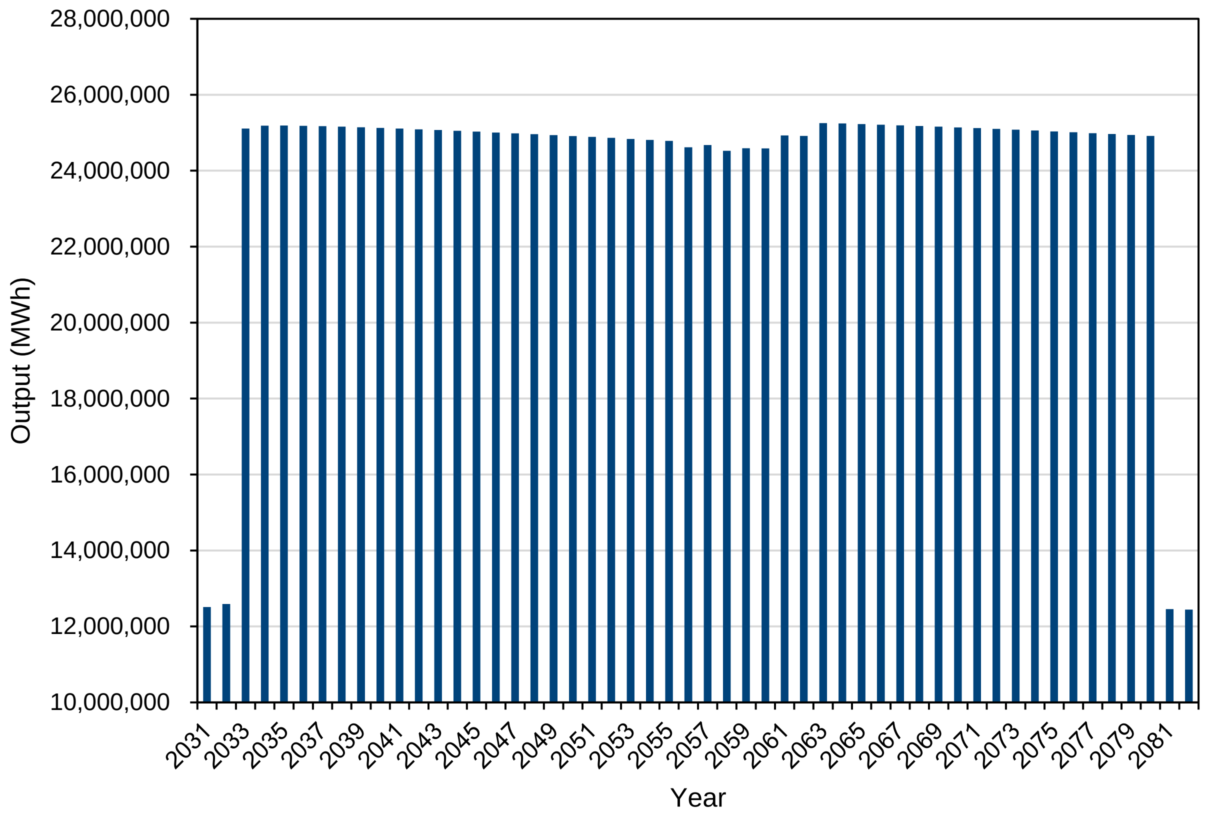

Figure 1.2: Project Generation Forecast

1.9.18 The output parameters 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 Project generation profile takes 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 2033.

1.9.19 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.

1.9.20 It should be noted that 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.

1.9.21 Overall, the avoided emissions resulting from the cumulative Project are reflected in **Table 1.17** below.

1.9.22 **Table 1.17** displays the annual power output and emissions avoidance of the Project when comparing the abated fossil fuel generation using the DESNZ (2023a) long run marginal carbon intensity for the future UK electricity Grid, consistent with years throughout.

Table 1.17: Cumulative Operational Avoided 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)
-2 (commencement of operation for Bipole 1)	2031	12,511,784.10	0.065	816,195.42	816,195
-1	2032	12,590,618.30	0.050	630,339.63	1,446,535
1 (full operation)	2033	25,109,331.12	0.038	964,751.24	2,411,286
2	2034	25,187,481.87	0.029	742,707.14	3,153,993
3	2035	25,190,434.83	0.023	570,060.78	3,724,054
4	2036	25,183,846.10	0.017	437,381.29	4,161,435
5	2037	25,172,855.38	0.013	335,523.75	4,496,959
6	2038	25,159,094.56	0.010	257,358.46	4,754,318
7	2039	25,143,785.86	0.008	197,390.73	4,951,708
8	2040	25,126,954.53	0.006	151,387.00	5,103,095
9	2041	25,109,194.25	0.006	142,722.68	5,245,818
10	2042	25,090,228.04	0.004	90,724.14	5,336,542
11	2043	25,070,401.25	0.003	69,669.85	5,406,212
12	2044	25,049,539.04	0.002	49,141.54	5,455,354
13	2045	25,028,414.95	0.001	31,439.56	5,486,793
14	2046	25,006,023.78	0.001	32,433.97	5,519,227
15	2047	24,983,679.49	0.001	32,514.58	5,551,742
16	2048	24,960,768.19	0.001	34,294.46	5,586,036
17	2049	24,937,351.02	0.001	35,101.61	5,621,138
18	2050	24,913,799.82	0.002	49,827.60	5,670,965
19	2051	24,889,006.15	0.002	49,778.01	5,720,743
20	2052	24,863,676.06	0.002	49,727.35	5,770,471
21	2053	24,837,420.58	0.002	49,674.84	5,820,146
22	2054	24,810,886.65	0.002	49,621.77	5,869,767
23	2055	24,784,104.03	0.002	49,568.21	5,919,336

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	2056	24,615,139.04	0.002	49,230.28	5,968,566
25	2057	24,675,766.64	0.002	49,351.53	6,017,917
26	2058	24,523,052.76	0.002	49,046.11	6,066,964
27	2059	24,592,281.95	0.002	49,184.56	6,116,148
28	2060	24,586,928.41	0.002	49,173.86	6,165,322
29	2061	24,928,767.04	0.002	49,857.53	6,215,179
30	2062	24,915,440.06	0.002	49,830.88	6,265,010
31	2063	25,255,327.76	0.002	50,510.66	6,315,521
32	2064	25,242,875.72	0.002	50,485.75	6,366,007
33	2065	25,228,114.94	0.002	50,456.23	6,416,463
34	2066	25,212,367.59	0.002	50,424.74	6,466,888
35	2067	25,195,592.13	0.002	50,391.18	6,517,279
36	2068	25,178,168.74	0.002	50,356.34	6,567,635
37	2069	25,159,781.57	0.002	50,319.56	6,617,955
38	2070	25,141,213.64	0.002	50,282.43	6,668,237
39	2071	25,121,263.46	0.002	50,242.53	6,718,480
40	2072	25,101,142.89	0.002	50,202.29	6,768,682
41	2073	25,080,103.17	0.002	50,160.21	6,818,842
42	2074	25,058,308.41	0.002	50,116.62	6,868,959
43	2075	25,036,296.05	0.002	50,072.59	6,919,031
44	2076	25,012,929.66	0.002	50,025.86	6,969,057
45	2077	24,989,331.72	0.002	49,978.66	7,019,036
46	2078	24,964,832.48	0.002	49,929.66	7,068,966
47	2079	24,940,161.16	0.002	49,880.32	7,118,846
48	2080	24,915,047.10	0.002	49,830.09	7,168,676
49	2081	12,457,685.85	0.002	24,915.37	7,193,591
50	2082	12,444,904.13	0.002	24,889.81	**7,218,481**

Sensitivity Analysis

1.9.23 The long run marginal figures, which have been used in the above **Table 1.17**, 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.

1.9.24 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**. The whole life avoided emissions sensitivity test data is found in **Table 1.18**.

1.9.25 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 1.18: Whole life avoided emissions sensitivity test

Operating Years	Output (MWh)	DESNZ long-run marginal avoided emissions (tCO_2e/MWh)	Current national grid average avoided emissions (tCO_2e)	DESNZ 'non-renewable fuels' avoided emissions (tCO_2e)
50	1,250,283,504	7,218,481	316,259,212	530,120,206

Summary

1.9.26 **Table 1.19** summarises the net GHG emissions associated with the cumulative Project.

Table 1.19: Cumulative GHG emissions associated with the construction, operation and decommissioning of the Moroccan generation assets and transmission infrastructure

	Avoided Emissions Scenario	Total Embodied Carbon (tCO_2e)	Avoided Emissions (tCO_2e)	Net Emissions (tCO_2e)
Total	DESNZ Long-run marginal avoided emissions	10,033,617	7,218,481	2,815,136
	Current national grid average avoided emissions	10,033,617	316,259,212	-306,225,595

	Avoided Emissions Scenario	Total Embodied Carbon (tCO_2e)	Avoided Emissions (tCO_2e)	Net Emissions (tCO_2e)
	DESNZ 'non-renewable fuels' avoided emissions	10,033,617	530,120,206	-520,086,588

1.10 Net Emissions Summary

1.10.1 **Table 1.20** presents a summary of the lifetime emissions of the Proposed Development, contextualised against the cumulative emissions of the Alverdiscott Substation Connection Development and the cumulative Project. Net emissions are calculated to be between 3,531,368 tCO_2e and -519,370,356 tCO_2e. Note that negative values represent avoided emissions, i.e. emissions that would have occurred without the Project.

Table 1.20: Summary of Net GHG Emissions

Item	Value (tCO_2e)
Proposed Development emissions	
Construction emissions (including land use change)	510,737
Operation and maintenance emissions	45,935
Decommissioning emissions	128,533
Total	**685,204**
Cumulative emissions	
Alverdiscott Substation Connection Development	31,028
Xlinks Morocco-UK Power Project	2,815,136 (long-run marginal) to -520,086,588 (non-renewables mix)
Net Emissions, including cumulative emissions	
Net Emissions	3,531,368 (long-run marginal) to -519,370,356 (non-renewables mix)

1.11 References

ABB (2003) Environmental Product Declaration: Power transformer TrafoStar 500 MVA. Available: https://library.e.abb.com/public/566748ad75116903c1256d630042f1af/Productdeclaration StarTrafo500.pdf. (Accessed: January 2024).

DESNZ and Defra (2023) UK Government GHG Conversion Factors for Company Reporting. Available at: https://www.gov.uk/government/collections/government-conversion-factors-forcompany-reporting (Accessed: January 2024).

British Geological Survey (2024). GeoIndex Onshore Mapping [Online]. Available at: https://mapapps2.bgs.ac.uk/geoindex/home.html?_ga=2.193381613.1780815216.1704292554-643460377.1704292554 (Accessed: January 2024).

DESNZ (2023a). Valuation of Energy Use and Greenhouse Gas: Supplementary guidance to the HM Treasury Green Book. Available at: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal (Accessed: July 2024).

Department for Energy Security and Net Zero (DESNZ) (2023b) Digest of UK Energy Statistics. Load Factors for renewable electricity generation. Department for Business, Energy and Industrial Strategy. Available at: https://www.gov.uk/government/statistics/renewable-sources-of-energy-chapter-6-digest-of-united-kingdom-energy-statistics-dukes (Accessed January 2024).

Dolan, S.L & heath, G.A (2012) Life Cycle Greenhouse Gas Emissions of Utility-Scale Wind Power. Journal of Industrial Ecology. Volume 16 Number S1

Emtelle (2020) Emtelle DI Traditional Cable. Available at: https://www.emtelle.com/solutions-library/di-traditional-cable/ (Accessed January 2024).

IPCC (2013) Climate Change 2013: The Physical Science Basis Available: https://www.ipcc.ch/report/ar5/wg1/ (Accessed January 2024).

National Grid ESO (2023). Future Energy Scenarios. Available: https://www.nationalgrideso.com/future-energy/future-energy-scenarios (Accessed January 2024).

NorthConnect (2018). HVDC Cable Infrastructure – UK Construction Method Statement [Online]. Available at: https://marine.gov.scot/sites/default/files/hvdcca1.pdf (Accessed: December 2023).

NREL (2013) Wind LCA Harmonization Available: https://www.nrel.gov/docs/fy13osti/57131.pdf (Accessed January 2024).

Jordan, D. and Kurtz, R. (2012). Photovoltaic Degradation Rates — An Analytical Review [Online]. Available at: https://www.nrel.gov/docs/fy12osti/51664.pdf (Accessed: January 2024).

RICS (2012) RICS Professional Information, UK Methodology to calculate embodied carbon of materials. Available: https://www.igbc.ie/wp-content/uploads/2015/02/RICS-Methodology_embodied_carbon_materials_final-1st-edition.pdf. (Accessed January 2024).

RICS (2023). Whole Life Carbon Assessment for the Built Environment.

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

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

Nicholson, Scott, David Keyser, Marissa Walter, Greg Avery, and Garvin Heath. (2021). "Chapter 8: Greenhouse Gas Emissions." in The Los Angeles 100% Renewable Energy Study. Golden, CO: National Renewable Energy Laboratory. Available at: https://www.nrel.gov/docs/fy21osti/79444-8.pdf (Accessed: January 2024).