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Volume 7F Intertidal and Combined Assessments Appendices

Appendix 4-1 Greenhouse Gases

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OCEAN WINDS

Volume 7F Appendix 4-1 Greenhouse Gases

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Acronyms and Abbreviations

BNG	Biodiversity Net Gain
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DE	Design Envelope
DEFRA	Department for Environment Food and Rural Affairs
DESNZ	Department for Energy and Net Zero
DUKES	Digest of UK Energy Statistics
EIAR	Environmental Impact Assessment Report
EPD	Environmental Product Declaration
GHG	Greenhouse Gas
GW	Gigawatts
GWh	Gigawatt hours
HGV	Heavy goods vehicles
IC	Inorganic carbon
ICE	Inventory of Carbon and Energy
$kgCO_2e$	Kilograms of carbon dioxide equivalent
Kg/m^3	Kilograms per cubic meter
km	Kilometers
kW	Kilowatts
kWh	Kilowatt hours
m^2	Metres squared
mm^2	Millimetre squared

MW	MegaWatt
NVC	National Vegetation Classification
OC	Organic carbon
OfTI	Offshore Transmission Infrastructure
OnTI	Onshore Transmission Infrastructure
PPP	Planning Permission in Principle
RICS	Royal Institute of Chartered Surveyors
RLB	Red Line Boundary
tCO_2e	Tonnes of carbon dioxide equivalent
tC/ha	Tonnes of carbon per hectare
WRAP	Waste and Resources Action Programme

1 Introduction

1.1.1.1 This appendix provides the assumptions and limitations associated with the Proposed Development Greenhouse Gas (GHG) emissions assessment. This appendix should be read in conjunction with Volume 6, Chapter 4: Greenhouse Gases.

1.1.1.2 The GHG emissions assessment is based on the description of the Proposed Development provided within Volume 1, Chapter 3: Proposed Development Description (Offshore) and Volume 1, Chapter 4: Proposed Development Description (Onshore) of the Environmental Impact Assessment Report (EIAR).

1.1.1.3 This appendix has been separated between the Proposed Development (Offshore) and Proposed Development (Onshore) assessments. The assumptions and limitations of these assessments are divided between construction and operation. This is due to the differing construction and operational requirements for both the Proposed Development (Offshore) and Proposed Development (Onshore) elements of the Proposed Development.

1.1.1.4 Table 1-1 provides a summary of the lifecycle stages included and excluded within the Proposed Development (Offshore) assessment and Table 1-2 provides a summary of the lifecycle stages included and excluded in the Proposed Development (Onshore) assessment.

Table 1-1: GHG emission assessment Proposed Development (Offshore) lifecycle stage inclusions and exclusions

Lifecycle ref	Lifecycle Stage[i]	Assessment Inclusion/ Exclusion	Justification
A0	Pre-construction	Excluded	GHG emissions from preliminary studies and works are largely office-based and are assumed to be insignificant.
A1-3	Product Stage	Included	Embodied GHG emissions associated with the required construction materials.
A4	Construction Transport	Included	GHG emissions associated with transportation of construction materials to and from the Proposed Development (Offshore).
A5	Construction Processes	Included	GHG emissions associated with energy and fuel usage and construction waste.
B1-8	In Use Stage	Included	GHG emissions for assumed operation included as a benchmark of A1-5 calculations.

[i] Lifecycle stages provided within RICS (RICS, 2023) guidance, Figure 2: Buildings and infrastructure life cycle stages and information modules.

Lifecycle ref	Lifecycle Stage[i]	Assessment Inclusion/ Exclusion	Justification
C1	Deconstruction and demolition	Included	GHG emissions associated with the decommission and deconstruction of the Proposed Development (Offshore).
C2	Deconstruction Transport	Included	GHG emissions associated with the transportation of decommissioned materials.
C3	Deconstruction Waste processing	Included	GHG emissions associated with the processing of decommissioned materials.
C4	Deconstruction Disposal	Included	GHG emissions associated with the disposal of decommissioned materials.

Table 1-2: GHG emission assessment Proposed Development (Onshore) lifecycle stage inclusions and exclusions

Lifecycle ref	Lifecycle Stage	Assessment Inclusion/ Exclusion	Justification
A0	Pre-construction	Excluded	GHG emissions from preliminary studies and works are largely office-based and are assumed to be insignificant.
A1-3	Product Stage	Included	Embodied GHG emissions associated with the required construction materials.
A4	Construction Transport	Included	GHG emissions associated with transportation of construction materials to and from the Proposed Development (Onshore).
A5	Construction Processes	Included	GHG emissions associated with energy and fuel usage and construction waste.
B1	Use stage	Excluded	GHG emissions from use not expected to be significant.
B2	Maintenance	Included	GHG emissions associated with transport to site to carry out annual inspections.
B3	Repair	Included	GHG emissions associated with transport to site to carry out repairs and embodied emissions associated with the required materials.
B4	Replacement	Excluded	GHG emissions associated with replacement assumed to be minimal within the study period.
B5	Refurbishment	Excluded	GHG emissions associated with refurbishment assumed to be minimal within the study period.
B6	Operational Energy Use	Excluded	GHG emissions associated with operational energy assumed to be minimal.

Lifecycle ref	Lifecycle Stage	Assessment Inclusion/ Exclusion	Justification
B7	Operational Water Use	Excluded	GHG emissions associated with operational water consumption assumed to be minimal.
B8	User Utilisation of Infrastructure	Excluded	There are no user utilisation emissions within the Red Line Boundary (RLB).
C1	Deconstruction and demolition	Included	GHG emissions associated with the decommissioning, deconstruction of the Proposed Development (Onshore).
C2	Deconstruction Transport	Included	GHG emissions associated with the transportation of decommissioned materials.
C3	Deconstruction Waste processing	Included	GHG emissions associated with the processing of decommissioned materials.
C4	Deconstruction Disposal	Included	GHG emissions associated with the disposal of decommissioned materials.

1.1.1.5 In addition to the lifecycle stages in Table 1-1 and Table 1-2 above for both the Proposed Development (Onshore) and Proposed Development (Offshore) assessments, benefits and loads beyond the system boundary[ii] are also included within the assessment as follows:

- GHG emissions associated with blue (marine) carbon, further details are provided in Section 2.4 Blue Carbon Assessment.
- GHG emissions associated with land use change, further details are provided in Section 3.4 Ongoing Land Use GHG emissions and Sequestered Carbon Assessment.
- The avoided GHG emissions associated with the renewable energy generation, further details are provided in Section 2.2.2 Benefits Arising from the Proposed Development (Offshore).

1.1.1.6 The assessment has been undertaken following the Rochdale Envelope approach to consider realistic worst case assumptions for the Proposed Development design. At time of assessment, the detailed design information for the Proposed Development is not available.

[ii] As defined by RICS (2023) guidance, the system boundary "defines the unit processes to be included in the assessment model". For the Proposed Development, the system boundary is defined as the study area, which for the GHG emissions assessment is defined as the Offshore Transmission Infrastructure (OfTI) and Onshore Transmission Infrastructure (OnTI) Red Line Boundary (RLB).

2 Proposed Development (Offshore) Assessment

2.1 Proposed Development (Offshore) Construction Assessment

2.1.1.1 Materials used for the construction of the Proposed Development (Offshore) were provided by Caledonia Offshore Wind Farm Limited (the Applicant) within a Design Envelope (DE). Assumptions were made to provide indicative quantities within the DE, however these may be subject to change during detailed design.

2.1.1.2 Standard carbon factors for materials were obtained from the Inventory of Carbon and Energy (ICE) database (ICE, 2019[1]) which provides estimates of the cradle-to-factory gate carbon factors[iii] for a range of typical construction materials. In some cases, it has been necessary to draw on benchmark information. Conservative assumptions have been made, where relevant, to provide a reasonable worst-case scenario. This has allowed for a precautionary approach to assessment.

2.1.2 Construction Phase: Materials

2.1.2.1 Construction materials and associated emission factors for the Proposed Development (Offshore) infrastructure are presented in Table 2-1.

Table 2-1: Construction materials and carbon factors for the Proposed Development (Offshore) infrastructure

Material type	Material use	Carbon emissions factor	Carbon factor source
Steel	Wind Turbine Generator tower, Nacelle steel, Nacelle generator structural steel, monopile foundations, jacket foundations, pin piles, semi-submersible foundation substructure and anchors, mooring line chain, tension leg platform substructure and anchor	2.46 kilogram of carbon dioxide equivalent ($kgCO_2e$)/ kilogram (kg)	Steel, plate, ICE V3.0[1]
Secondary steel	Semi-submersible foundation substructure secondary steel	1.30 $kgCO_2e$/kg	Steel, plate, ICE V3.0[1] – with 85% recycled content
Steel spiral strand wire	Mooring line	2.27 $kgCO_2e$/kg	Steel, Wire Rod, ICE V3.0[1]

[iii] An assessment of a partial product life cycle from resource extraction (cradle) to the factory gate (before it is transported to the consumer).

Material type	Material use	Carbon emissions factor	Carbon factor source
Iron	Nacelle generator iron	2.03 $kgCO_2e/kg$	Iron, ICE V2.0[2]
Copper	Nacelle generator copper	2.71 $kgCO_2e/kg$	Copper, ICE V2.0[2]
Magnet	Magnetic materials in generator within Nacelle	27.60 $kgCO_2e/kg$	Jin et al (2016)[3]
Fibre glass	Wind turbine blades	419,402.00 $kgCO_2e$/per single blade[iv]	Nixon-Pearson et al (2022)[4]
Grout	Monopile high strength grout, jacket pin piles high strength grout, jacket pin piles cementitious grout, jacket with suction caissons high strength grout, semi-submersible high strength grout to anchors, tension leg platform grout	1.81 $kgCO_2e/kg$	Cement-General, ICE V3.0[1]
Granite	Armour stone, scour protection	0.08 $kgCO_2e/kg$	General Stone, ICE V3.0[1]
Polyester fibre	Mooring line polyester fibre rope	21.33 $kgCO_2e/kg$	WRAP (2012)[5]
Heating, Ventilation and Air Conditioning Multicore cable	Interconnector cables, Inter-Array Cables, Offshore Export Cables	15.75 $kgCO_2e/m$ @ 500 millimetre squared (mm^2) Copper conductor cross sectional area	Cableizer (2018)[6]

2.1.3 Construction Phase: Transportation of Materials

2.1.3.1 Transport types and distance assumptions from the Royal Institute of Chartered Surveyors (RICS, 2023[7]) guidance was used to calculate the road and sea transport GHG emissions for the materials to the Proposed Development (Offshore). It has been assumed that materials will be sourced from Europe or internationally. In addition, a 50km uplift of travel by sea has been included for all materials for the distance to the Proposed Development (Offshore) Array Area. The carbon factors for average container ship and rigid Heavy Goods Vehicles (HGV) were sourced from Department of Energy Security and Net Zero (DESNZ) and Department of Environment Food and Rural Affairs (DEFRA, 2023[8]). These are presented in Table 2-2.

[iv] Figure given for a single blade of a 15 MegaWatt (MW) wind turbine generator.

Table 2-2: Construction material carbon factors for transport to the Proposed Development (Offshore)

Sourcing Location	Journey	Distance	Transport type	Carbon factor ($kgCO_2e$/ tonne.km)
Global	To international port	500 kilomtre (km) - Road	HGV	0.12
	To local port	10,000km - Sea	Average container ship	0.02
	To Array Area	50km - Sea	Average container ship	0.02
Europe	To European port	100km - Road	HGV	0.12
	To local port	1,500km - Sea	Average container ship	0.02
	To Array Area	50km - Sea	Average container ship	0.02
Note: Emission factors are to two decimal places.				

2.1.4 Construction and Installation Process

2.1.4.1 A benchmark of 40% of the calculated A1-3 product stage emissions has been used as an appropriate uplift to estimate GHG emissions from the construction and installation process of the Proposed Development (Offshore) (A5 emissions), in line with projects of similar industry as well as assumed construction activities. This benchmark includes an allowance for the GHG emissions associated with construction activities and construction waste associated with the Proposed Development (Offshore).

2.1.5 Construction Worker Transport

2.1.5.1 At the current stage of design development, the numbers of construction workers are currently unknown. The GHG emissions from worker transport are likely to be negligible in the context of the other construction emissions and therefore have been excluded from this assessment.

2.2 Proposed Development (Offshore) Operational Assessment

2.2.1 Operation and Maintenance

2.2.1.1 Due to the nature of the Proposed Development (Offshore), operational GHG emissions offshore are expected to be minimal considering the whole life carbon approach for the assessment. Operational phase GHG emissions are expected to arise from maintenance, repairs, and replacement and mostly arise from fuel usage of operation and maintenance vessels.

2.2.1.2 As design information for the operational phase of the Proposed Development (Offshore) is limited, a benchmark percentage uplift for the Proposed Development (Offshore) has been included to account for GHG emissions in this phase. Using other offshore wind farm developments, a 7.3% uplift of A1-5 emissions is included for operations and maintenance of the Proposed Development (Offshore) (Ørsted, 2020[9]).

2.2.2 Benefits Arising from the Proposed Development (Offshore)

2.2.2.1 The purpose of the Proposed Development (Offshore) is to generate large amounts of renewable energy. The Proposed Development (Offshore) (Caledonia North and Caledonia South), the capacity of the Proposed Development (Offshore) is likely to be up to 2 gigawatts (GW). When estimating the displaced energy generation and resultant emissions avoided by the generation of renewable electricity, the following elements associated with the Proposed Development (Offshore) should be considered:

- Whole life emissions of the Proposed Development (Offshore);
- Anticipated energy generation of the Proposed Development (Offshore);
- Operational lifetime of the Proposed Development (Offshore);
- Anticipated load factors for offshore wind projects; and
- Consideration of the carbon intensity of energy generation displaced by the Proposed Development (Offshore).

2.2.2.2 Load factors are defined as "the ratio of how much electricity was generated as a proportion of the total generating capacity" (DESNZ, 2023[10]) and are heavily influenced by weather conditions, for Wind Farm developments predominantly wind speeds. Drawing from the Digest of UK Energy Statistics (DUKES) on renewable energy sources (DESNZ, 2023[11]), the most recent (2022) long term average load factor for offshore wind is 39.5%.

2.2.2.3 The benefits beyond the boundary[ii] elements required in energy generation and displaced energy generation calculations associated with the Proposed Development (Offshore) are presented in Table 2-3.

Table 2-3: Elements required for the avoided emissions calculations for the Proposed Development (Offshore)

Element	Value	Source
Possible maximum Proposed Development (Offshore) capacity	2.1-2.35 GW	DE for Caledonia North and South
Proposed Development (Offshore) operational phase	35 years	DE for Caledonia North and South
Long-term average load factor for offshore wind	39.50%	DESNZ, 2023[11]
GHG emissions intensity of energy generation in 2030 (first year of operation)	85.00 tCO_2/GWh	Generation Based Long-run Marginal Electricity emissions factors to 2100[12]

2.2.2.4 The carbon benefits that accrue from the generation of renewable electricity are challenging to quantify. The UK grid is set to decarbonise over time, and as average grid intensity decreases then the marginal carbon benefit of each unit of renewable energy similarly decreases. A simple arithmetic evaluation of carbon benefits, therefore, shows decreasing benefit each year over time – although that benefit is wholly reliant on projects such as the Proposed Development (Offshore) and the Proposed Development (Onshore) coming on-line to support that decarbonisation trend. Accurately estimating the benefit of wind generated renewables, relative to the wider grid intensity of electricity, is also challenging given the uncertainty in the rate at which the grid will decarbonise (and that in practice the carbon benefit of renewables fluctuates considerably day-to-day depending on levels of generation from other sources). The contextualisation exercise has taken the approach of fixing the carbon benefit per unit of exported electricity at the level expected in the first year of operation. This provides a somewhat optimistic approach to estimating whole-life carbon benefits from the Proposed Development, but also reflects that project such as the Proposed Development are integral to delivering a decarbonised electricity grid. The numerical analysis is intended only to support the contextualisation exercise and, given uncertainties in future grid decarbonisation, should not be relied upon in isolation from the wider contextualisation exercise.

2.2.2.5 Using the elements within Table 2-3, along with the whole life carbon results for the Proposed Development (Offshore), the total benefits beyond the boundary and calculated avoided emissions per year are 617,650 – 692,651 tonnes of carbon dioxide equivalent (tCO_2e) for the Proposed Development's 35 year operational phase. Based on the assumption that the Proposed

Development provides a benefit equivalent to the grid intensity in the year of opening, then the indicative carbon payback associated with the Proposed Development (Offshore) is that avoided generation GHG emissions will balance embodied GHG emissions after approximately 9 to 10 years[v]. Again it should be noted that this calculation has been carried out to support the contextualisation exercise and should not be relied upon in isolation from the wider assessment.

2.2.2.6 The carbon payback methodology set out above is limited in that it only compares electricity generated by the Proposed Development to the equivalent electricity available via the national grid (at the carbon intensity of the opening year of the Proposed Development). By doing so it does not take full account of the carbon benefits that accrue from the provision of renewable energy as part of an increased and extensive electricity supply system that offers a diversity of generation sources, with the carbon and resilience benefits these offer. In practice, low carbon electricity will not only contribute to a decarbonised grid, but will also support the electrification of activities that currently rely on fossil fuel use (such as heating homes and fuelling cars). The limited comparison of generated electricity against equivalent grid intensity (as set out above) ignores the fact that a national process of electrification seeks to displace fossil fuel use. In practice, the energy use from transport, heating and industrial processes that the Proposed Development (and other) renewable energy projects displace may well be significantly more carbon intense than the national grid at that point in time, in which case the carbon payback of the Proposed Development will be much reduced.

2.3 Proposed Development (Offshore) End of Life Assessment

2.3.1 Deconstruction, transport, processing and disposal

2.3.1.1 The End-of-Life scenario for the Proposed Development (Offshore) is based on the assumed deconstruction, transport of waste, waste processing and disposal of waste. This scenario provides an allowance for the GHG emissions at the end of the study period of the assessment.

2.3.1.2 The GHG emissions associated with the deconstruction are assumed to be 50% of the GHG emissions calculated at construction (A5). This assumes a standard practice of demolition, assuming minimal attempt at deconstruction and recovery, as per the whole life carbon assessment for the built environment 2nd edition (RICS, 2023[7]).

[v] Should Caledonia North only be taken forward, the payback period using the same assumptions would be approximately 8 years. Should Caledonia South only be taken forward, the payback period using the same assumptions would be approximately 11 years.

2.3.1.3 The transport of deconstructed materials and waste at end of life has been assumed to be the same emissions as those calculated for the transport of construction materials (A4).

2.3.1.4 The GHG emissions for the end of life waste processing and disposal of materials have been calculated using RICS guidance (RICS, 2023[7]) default waste processing rates per material type and (DESNZ & DEFRA, 2023[8]) emission conversion factors per material type and waste route.

2.4 Blue Carbon Assessment

2.4.1.1 Blue carbon is an emerging area of assessment and relates to the carbon stored in marine and coastal environments. It includes all the ocean plants, such as seagrass and kelp, and sedimentary stores. It is essential to global carbon stocks; an estimated 83% of the global carbon cycle is circulated through the world's oceans (Blue Carbon Initiative, no date[13]).

2.4.1.2 In the context of the Proposed Development (Offshore), the primary concern for the blue carbon assessment is the disturbance of seabed sediment during construction. This sediment is a store of Organic Carbon (OC) and Inorganic Carbon (IC), and disturbances from the installation of foundations and cables can transform them from stores and sinks into sources of carbon, with the resuspension of sediment allowing for the rapid consumption of previously buried OC through remineralization and release as carbon dioxide (CO_2) emissions. IC within seabed sediments is not affected by resuspension in the same way. This is because IC, in forms such as carbonate ions, are not typically digested by marine microbes during suspension in the water column, however, in acidic water environments the risk to IC would be greater. As such, this assessment does not consider the loss of IC from resuspension of sediments.

2.4.1.3 In addition, due to a low presence of kelp and seagrass habitats expected to be affected by the Proposed Development (Offshore), OC and sequestration potential lost from kelp and seagrass are excluded from this assessment as they are not likely to be significant.

2.4.1.4 The blue carbon assessment utilises the data presented in the Sedimentary Carbon Stocks of the United Kingdom's Exclusive Economic Zone (Smeaton et al, 2021[14]). From a sample of 931 points across the Array Area, a mean OC density of 3.33 kilograms per cubic metre (kg/m^3) and IC density of 20.02 kg/m^3 was derived.

2.4.1.5 Volumes of construction related spoil (in m^3) were taken from the DE to calculate a total volume of disturbed sediment. To this, the organic carbon densities were applied to give total OC and IC mass per constructed asset, to be totalled for a worst-case scenario.

2.4.1.6 It is assumed that only OC is remineralized and released as CO_2, at a rate of 22.5% (Heinatz and Scheffold, 2023[15]); the rest is redeposited. This remineralised OC value is converted to CO_2 for a total value of released CO_2.

2.4.1.7 As well as being a store of OC, seabed sediments also act as a sink of OC, sequestering carbon at a rate of 57.1 (± 10.9) g OC m^{-2} yr^{-1} (grams of organic carbon per unit area per year) (Cunningham and Hunt, 2023[16]). This assessment calculates the total area of seabed sediments covered by newly installed infrastructure (mortality footprint) in m^2 and multiplies by the sequestration rate to find the subsequent loss of sequestration potential.

$$Area \times Sequestration\ rate = lost\ sequestration$$

2.4.1.8 This ongoing loss of sequestration totals -97.15 to -110.19 tCO_2e yr^{-1}, <0.1% of emissions from the Proposed Development (Offshore) over its lifetime (modules A1-D, not including avoided emissions from renewable energy generation).

2.4.1.9 Limitations of this approach include:

- The source of OC and IC densities is the Marine Sedimentary Carbon Stocks of the United Kingdom's Exclusive Economic Zone[14]. The mapping accounts for the top 10cm of sediments only. The assumption made is that carbon densities in these locations are uniform through deeper sediments;
- The assessment uses an average of all samples of the OC and IC densities for the Array Area, due to the potential for change in the final positions of infrastructure across the Array Area. At the time of assessment, exact locations for all foundations were not known; and
- Research into the remineralisation rate of suspended sediments is still developing and the rate could be higher or lower than 22.5% for this OfTI RLB. The final reporting will consider sensitivity of this value.

3 Proposed Development (Onshore) Assessment

3.1 Proposed Development (Onshore) Construction Assessment

3.1.1.1 Materials used for the construction of the Proposed Development (Offshore) were provided by Caledonia Offshore Wind Farm Limited (the Applicant) within a DE. Assumptions were made to provide indicative quantities within the DE, however these may be subject to change during detailed design

3.1.1.2 Indicative quantities for materials used for the construction of the Proposed Development (Onshore) were provided in the DE provided by the Applicant.

3.1.1.3 Typical carbon factors for materials were obtained from the ICE database (ICE, 2019[1]) which provides estimates of the cradle-to-factory gate carbon factors[vi] for a range of typical construction materials. In some cases, it has been necessary to draw on benchmark information and make conservative assumptions to provide a reasonable worst-case scenario for the particular item or factor to allow for a precautionary approach to assessment.

3.1.2 Construction Phase: Materials

3.1.2.1 Construction materials and associated emission factors for the Proposed Development (Onshore) infrastructure are presented in Table 3-1.

Table 3-1: Construction materials and carbon factors for the materials used for the Proposed Development (Onshore)

Material type	Material use	Carbon emissions factor	Carbon factor source
Aggregate	Imported earthworks material, compounds, access roads, imported stone for cable joint bays, cable trenching sand, imported gravel	0.01 $kgCO_2e/kg$	Aggregates and Sand - Typical UK Mix, ICE V3.0[1]
Asphalt	Onshore Substation Site roads and car park	15.20 $kgCO_2e/kg$	Asphalt - 5% Bitumen Binder, ICE V3.0[1]
Cable	Onshore Cable Export Cable	71,700.00 $kgCO_2e/km$	Hellenic Cables EPD, 2021[17]

[vi] An assessment of a partial product life cycle from resource extraction (cradle) to the factory gate (before it is transported to the consumer).

Material type	Material use	Carbon emissions factor	Carbon factor source
Concrete	Transition joint bays, Onshore Substations construction	0.10 $kgCO_2e/kg$	Concrete - General, ICE V3.0[1]
Plastic	Horizontal Directional Drilling cable ducts	32.00 $kgCO_2e/kg$	Polypropylene, 30mm diameter plastic pipework, ICE V3.0[1]
	Terram geotextile to export cable	0.28 $kgCO_2e$/ metres squared (m^2)	Non-woven polypropylene geotextile, Don & Low EPD, 2024[18]
Steel	Onshore Substations fencing	11.00 $kgCO_2e/kg$	Steel/wire/chain fence, ICE V3.0[1]
	Onshore Substations construction reinforcement	1.27 $kgCO_2e/kg$	Engineering Steel, ICE V3.0[1]
Note: Emission factors are to two decimal places.			

3.1.2.2 Environmental Product Declarations (EPD) for the proposed electrical equipment were not available at time of assessment due to the limited detail available within the DE. For the Onshore Substations, due to the limited information available at time of assessment, a benchmark of 545 $kgCO_2e/m^2$ for large industrial/factory units from Figure 6 of the RICS methodology to calculate the embodied carbon of materials (RICS, 2012[19]) has been used. It is understood that further details, including EPDs, for the proposed electrical equipment will be available at detailed design stage.

3.1.3 Construction Phase Materials Transportation

3.1.3.1 Transport types and distances from the RICS guidance (RICS, 2023)[7] was used to calculate the road transport GHG emissions for the materials associated with the Proposed Development (Onshore). It has been assumed that all materials will be sourced from the UK. The carbon factor for average rigid HGV was sourced from DESNZ (2023[8]). These are presented in Table 3-2.

Table 3-2: Construction material carbon factors for transport to the Proposed Development (Onshore)

RICS category for travel	Distance	Transport type	Carbon factor ($kgCO_2e$/ tonne.km)
Locally manufactured – mixed concrete	20km - Road	HGV – 50% laden	0.12
Locally manufactured	50km - Road	HGV – 50% laden	0.12
Regionally manufactured	80km - Road	HGV – 50% laden	0.12
Nationally manufactured	120km - Road	HGV – 50% laden	0.12
Note: Emission factors are to two decimal places.			

3.1.4 Construction and Installation Process

3.1.4.1 A benchmark of 30% of the calculated A1-3 product stage emissions has been used as an appropriate uplift to estimate GHG emissions from the construction and installation process of the Proposed Development (Onshore) (A5 emissions), in line with similar projects as well as assumed onshore construction activities. This benchmark includes an allowance for the GHG emissions associated with construction activities and construction waste associated with the Proposed Development (Onshore).

3.1.5 Construction Worker Transport

3.1.5.1 At the current stage of development, the numbers of construction workers are currently unknown. The GHG emissions from worker transport are likely to be negligible in the context of the other construction emissions and therefore have been excluded from this assessment.

3.2 Proposed Development (Onshore) Operational Assessment

3.2.1.1 The assessment of the Proposed Development (Onshore) operational emissions is based on the description of the Proposed Development information provided by the client team in Volume 1, Chapter 4: Proposed Development Description (Onshore) of the EIAR. Due to the nature of the Proposed Development (Onshore), operational phase GHG emissions are expected to be minimal, with operational phase GHG emissions, relevant to the Proposed Development (Onshore) elements, expected to arise from maintenance and repairs.

3.2.2 Operation and Maintenance

3.2.2.1 The Proposed Development (Onshore) is unlikely to have considerable GHG emissions arising from the maintenance, repair and replacement.

3.2.2.2 During operation it is assumed that there will be maintenance requirements such as annual inspections. The GHG emissions associated with these maintenance activities have been included as a 1% allowance of Embodied Carbon (A1-5) calculated emissions, as per the whole life carbon assessment for the built environment 2nd edition (RICS, 2023[7]).

3.2.2.3 An allowance for the assumed repairs during the Proposed Development (Onshore) assets life span have been included as 25% of maintenance (B2) emissions, assuming all items as relevant, and 10% of product stage emissions (A1-3) associated with Onshore Substations equipment as per the whole life carbon assessment for the built environment 2nd edition (RICS, 2023[7]).

3.2.2.4 Significant replacements of the Proposed Development (Onshore) are not anticipated within the 35-year operational phase.

3.3 Proposed Development (Onshore) End of Life Assessment

3.3.1 Deconstruction, transport, processing and disposal

3.3.1.1 The End-of-Life scenario for the Proposed Development (Onshore) is based on the assumed deconstruction, transport of waste, waste processing and disposal of waste. This scenario provides an allowance for the GHG emissions at the end of the study period of the assessment.

3.3.1.2 The GHG emissions associated with the deconstruction of the Proposed Development (Onshore) are assumed to be 50% of the GHG emissions calculated at construction (A5). This assumes that the recovery of the majority of materials is prioritised and promoted, as per the whole life carbon assessment for the built environment 2nd edition (RICS, 2023[7]).

3.3.1.3 The transport of deconstructed materials and waste at end of life has been assumed to be the same emissions as those calculated for the transport of construction materials (A4).

3.3.1.4 The GHG emissions for the end of life waste processing and disposal of materials have been calculated using default waste processing rates per material type within the RICS guidance (2023[7])and DESNZ and DEFRA, (2023[8]) emission conversion factors per material type and waste route.

3.4 Ongoing Land Use GHG emissions and Sequestered Carbon Assessment

3.4.1.1 Habitat areas were provided for the OnTI RLB as per the Biodiversity Net Gain (BNG) calculations within Volume 7E, Appendix 3-1: Biodiversity Enhancement Report. The carbon sequestration factors used in the quantification of land use change are based upon the Natural England 2022 (Natural England, 2022[20]) paper and their supporting assumptions and limitations. Table 3-3 sets out the habitat type, area and carbon factors used to determine the carbon sequestration potential estimates.

Table 3-3: Carbon flux factors used to quantify the carbon sequestration potential for habitat types within the OnTI RLB.

Natural England habitat type	Carbon flux factors	Unit
Arable land use	0.29	$tCO_2e/ha/yr$
Hedgerows	-1.99	$tCO_2e/ha/yr$
Intertidal sediments	-1.98	$tCO_2e/ha/yr$
Mixed native broadleaved woodland (30 years)	-14.5	$tCO_2e/ha/yr$
Arable reversion to low input grassland	-1.59	$tCO_2e/ha/yr$
Intensive grassland on deep peat soils	24.87	$tCO_2e/ha/yr$
Ponds	6.69	$tCO_2e/ha/yr$

Natural England habitat type	Carbon flux factors	Unit
Drainage ditches	1.34	$tCO_2e/ha/yr$
Reedbeds	20.00	$tCO_2e/ha/yr$
Note: Where carbon flux factors are positive, these values are GHG emissions released to the atmosphere from the habitat types. Where carbon flux factors are negative this is sequestration from the atmosphere back into the vegetation or soil by the ecosystem.		

3.4.1.2 The following assumptions and limitations apply to considerations of carbon in habitats:

- Carbon sequestration potential lost due to the loss or change of habitat and soils has been calculated using the BNG baseline scenario and the BNG habitat creation scenario;
- The carbon values used assume a 30-year-old age profile, meaning that the loss of habitats older than 30-years old may result in an underestimation of the carbon stock lost;
- The values given to habitat mitigation measures assume the habitats reach maturity within the lifetime of the development, including restoration of carbon stocks in soils, reach equilibrium (i.e. there is no further sequestration of carbon) and the habitat is in a healthy state. This could result in an overestimation of carbon stocks should there be any impact on the establishment, maturation or health of the habitats restored or created as part of mitigation for the Proposed Development (Onshore);
- The assessment data sources used for carbon sequestration factors focus on the carbon sequestration of the identified habitat. This includes when possible, carbon dioxide, and dissolved and particulate organic carbon and therefore in some cases may not fully account for the potential release of other GHGs, such as methane. This assessment assumes all carbon stored within the soil is oxidised and converted to carbon dioxide. In reality, it is possible that some carbon could be converted to methane, a more potent greenhouse gas. As a result, the GHG emissions from soil disturbance may be underestimated, however given the benchmarks available within the Natural England papers, this remains the most robust identified methodology for assessment of carbon in habitats;
- Similarly, no allowance has been made for any nitrous oxide released during land use change which may also lead to an underestimation of GHG from land use change; and

- Proposed Development (Onshore) habitat types have been mapped to the habitat types for which carbon sequestration potential is available in the Natural England source papers. Mapping has been carried out based on professional judgment, following a qualitative review of similarity from the available information on habitat types and an assessment of the closest match.

3.5 Peat Soil Carbon Assessment

3.5.1.1 In the southern section of the OnTI RLB, near the Onshore Substation Site, there is an area of habitat classed under the Carbon and Peatland 2016 map (Scotland's Soils, 2023[21]) as Class 1[vii] and Class 5[viii] peat. Following further national vegetation classification (NVC) surveys and peat probing, mapped areas of Class 1 peat were found to be heavily modified and not considered to align with NatureScot's 'Priority Peatland Habitat' (NatureScot, 2023[22]). These surveys did, however, find that the mapped Class 1 area is consistent with the definition for Class 5 peat where there are no peatland habitats, but there are carbon rich peat soils. Further details on the NVC surveys can be found in Volume 5, Chapter 3: Terrestrial Ecology and Biodiversity. Further information on the peat probing survey can be found in Volume 7E, Appendix 7-2: Peat Survey Reports.

3.5.1.2 At this stage the Proposed Development (Onshore) is submitting a Planning Permission in Principle (PPP) application for the OnTI with the final Onshore Export Cable Route to be defined at detailed design stage, following further technical studies. Therefore, the volume of peat that may be disturbed is not known at this stage as the Onshore Export Cable Route may cross, or may avoid, areas of carbon rich peat soils within the OnTI RLB.

3.5.1.3 Aligning with the Outline Peatland Management Plan (OPMP) (Application Document 7), where possible, the detailed design of the Proposed Development (Onshore) will avoid peatland areas. However, precautionary analysis of the scale of peat containing soils has been undertaken to determine the potential GHG emissions impact. This is based on the following assumptions:

- The identified area of Class 5 peat within the southern OnTI RLB is the only area of peat soils with potential to be disturbed confirmed through peat probing;

[vii] Class 1 peat is defined as "Nationally important carbon-rich soils, deep peat and priority peatland habitat. Areas likely to be of high conservation value." (Scotland's Soil, 2023[21])
[viii] Class 5 peat is defined as "Soil information takes precedence over vegetation data. No peatland habitat recorded. May also include areas of bare soil. Soils are carbon-rich and deep peat." (Scotland's Soil, 2023[21])

- There are additional areas within the OnTI RLB identified on the Carbon and Peatland 2016 map as Class 3[ix] peat; the vegetation confirmed as part of the NVC surveys was not consistent with peatland habitats, and the peat probing conducted in this area found no carbon rich peat soils. Further information on the peat probing survey can be found in Volume 7E, Appendix 7-2: Peat Survey Reports;
- The Onshore Export Cable Route dimensions, used to determine the volume of peat to be disturbed are estimated as: 400m length, 4m width, 1.5m depth. These dimensions are taken from the maps within Volume 7E, Appendix 7-2: Peat Survey Reports, and design freeze information relating to Onshore Export Cable Route excavation dimensions;
- It is assumed, as a worst-case scenario, that the eventual Onshore Export Cable Route requires excavation within the area of Class 5 peat soils (a conservative assumption given the OPMP seeks to avoid this) and said peat will be removed and therefore will release carbon emissions[x]; and
- Carbon factors for peat containing soil types are used to assess the impact of this Class 5 peat soil removal. The carbon factor used in this assessment of peat impact is taken from Natural England 2022 paper (Natural England, 2022[20]), and it has been assumed that the most appropriate soil type representing the identified peat area is the category "Intensive grassland on deep peat soils" (which includes consideration of peat soils depths to 200cm)[xi,23]. This assumption is based on the arable nature of the landscape and evidence of cutting as outlined in Volume 7E, Appendix 7-2: Peat Survey Reports.

3.5.1.4 The quantification of land use change GHG emissions impacts produces results expressed as mass of carbon (not carbon dioxide). In order to align with the wider GHG quantification it is assumed that all emissions are released in the form of CO_2. Conversion of mass of carbon to an equivalent mass of CO_2 is calculated based on the ratio (by mass) of the molecular weight of CO_2 to the atomic mass of carbon (this ratio is 44/12). Therefore calculated carbon mass has been multiplied by 44/12 to provide an equivalent mass of CO2.

[ix] Class 3 peat is defined as "dominant vegetation cover is not priority peatland habitat but is associated with wet and acidic type. Occasional peatland habitats can be found. Most soils are carbon-rich soils, with some areas of deep peat." (Scotland's Soil, 2023[21])
[x] If removed, the peat soils will be reinstated as part of the construction process and therefore the GHG emissions impact of waste transfer, processing and disposal of this excavated volume is considered to be zero.
[xi] Other factors and assessment tools are available to calculate GHG emissions impact from peat, such as the Scottish Government Energy and Climate Change Directorate's Carbon Calculator for Wind Farms on Scottish Peatlands (Energy and Climate Change Directorate, 2022[23]), however these require further detailed peat probing and design details than are available at this time of assessment. Therefore, the Natural England carbon factor has been used as an appropriate equivalent that is consistent with the land use assessment.

3.5.1.5 The carbon factor used in the quantification of peat soil released carbon emissions is based upon the Natural England (2022[20]) carbon storage factors. The assumed area due to be excavated for the cable trenching is multiplied by the factor in Table 3-4 to estimate the GHG emissions associated with peat disturbance.

Table 3-4: Carbon storage factors used to quantify the carbon stored by habitat type within the OnTI RLB.

Habitat type	Carbon storage factor	Unit
Intensive grassland on deep peat soils (200cm soil depth)	1980	tC/ha
Note: The carbon storage factor, also called carbon stock, is the assumed total carbon held within the soil by the habitat type.		

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