# MORGAN OFFSHORE WIND PROJECT: GENERATION ASSETS

## Environmental Statement

### Volume 4, Annex 12.1: Technical greenhouse gas assessment

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# Glossary

| Term | Definition |
|---|---|
| Bioenergy with Carbon Capture Storage (BECCS) | BECCS involves capturing and permanently storing carbon dioxide ($CO_2$) from processes where biomass (Organic matter, such as plants) is converted into fuels or directly burned to generate energy. Because plants absorb $CO_2$ as they grow, this is a way of removing $CO_2$ from the atmosphere. |
| Life Cycle Assessment | The systematic analysis of the potential environmental impacts of products or services during their entire life cycle. |
| Marginal generation source | Accounts for sustained changes in energy consumption for the purposes of cost-benefit analysis, including policy appraisal. |
| UK Grid Carbon Intensity | Carbon intensity is a measure of how clean UK Grid electricity is. It refers to how many grams of carbon dioxide ($CO_2$) are released to produce a kilowatt hour (kWh) of electricity. |

# Acronyms

| Acronym | Description |
|---|---|
| BECCS | Bioenergy with Carbon Capture Storage |
| BEIS | Department for Business, Energy and Industrial Strategy |
| DEFRA | Department for Environment, Food and Rural Affairs |
| DESNZ | Department for Energy Security and Net Zero |
| EPD | Environmental Product Declaration |
| FES | Future Energy Scenario |
| GHG | Greenhouse Gas |
| GWP | Global Warming Potential |
| ICE | Inventory of Carbon & Energy |
| LCA | Life Cycle Assessment |
| MDS | Maximum Design Scenario |
| OSPs | Offshore Substation Platforms |
| UNFCCC | United Nations Framework Convention on Climate Change |
| WBCSD | World Business Council for Sustainable Development |
| WRI | World Resources Institute |

# Units

| Unit | Description |
|---|---|
| $CO_2$ | carbon dioxide |
| $CO_2e$ | carbon dioxide equivalent |
| km | Kilometres |
| $m^2$ | Metres squared |
| $m^3$ | Metres cubed |
| kg | Kilograms |
| kWh | Kilowatt Hours |
| MW | Megawatts |
| MWh | Megawatt Hours |
| kVA | Kilovolt ampere |
| MVA | Megavolt ampere |
| g | Grams |
| t | Tonnes |
| knots/hr | Knots per hour |
| % | Percentage |

# 1 Technical greenhouse gas assessment

## 1.1 Introduction

1.1.1.1 This greenhouse gas (GHG) assessment technical report sets out the methodology and calculations of the GHG emissions for the Morgan Offshore Wind Project: Generation Assets (hereafter referred to as the Morgan Generation Assets). These calculations inform the assessment of the climate change impacts in Volume 4, Chapter 12: Climate change of the Environmental Statement. This annex should be read in conjunction with the chapter as supporting information.

1.1.1.2 GHG emissions have been estimated by applying published emissions factors to activities in the baseline and to those required for the Morgan Generation Assets. The emissions 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 Annex presents the technical calculations which relate to the potential magnitude of impact as assessed within the climate change chapter of the Environmental Statement (Volume 2, Chapter 12: Climate change of the Environmental Statement).

## 1.2 Scope

1.2.1.1 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. The GWPs typically used are the 100-year factors in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (IPCC, 2013) or as otherwise defined for national reporting under the United Nations Framework Convention on Climate Change (UNFCCC).

1.2.1.2 The scope of this annex relates to the Morgan Generation Assets during the construction, operations and maintenance phase, and decommissioning. Key emissions sources included in the assessment are:

- Land use (seabed) change
- Embodied carbon emissions in materials (wind turbine generators, Offshore Substation Platforms (OSPs), inter-array and inter-connector cabling)
- Offshore transport emissions
- Avoided emissions associated with the abatement of required fossil fuel generators and their associated emissions related with the UK electricity grid. Emissions presented as part of the generation asset to be realised at point of grid connection as part of the Morgan and Morecambe Offshore Wind Farms: Transmission Assets project, which is being taken forward through a separate Development Consent Order (DCO) application
- Decommissioning of Morgan Generation Assets.

## 1.3 Methodology

### 1.3.1 Approach

1.3.1.1 Published benchmarks have been used to establish the baseline of current and future grid-average carbon intensity. Baseline information for this, as well as other relevant activities for the Morgan Generation Assets have been informed via the following sources:

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

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

- 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). Downstream use of products and services sold to customers would also be captured under Scope 3 emissions.

1.3.1.3 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 Morgan Generation Assets. These emissions are not separated out by defined scopes (scopes 1, 2 or 3) in the assessment.

1.3.1.4 Due to the nature of the Morgan Generation Assets (i.e. which results in generated electricity being exported to the grid via the Transmission Assets) its gross GHG emissions total is dominated by avoided scope 2 emissions. The avoided scope 2 emissions are those that would have occurred as a result of the predicted UK Grid Carbon Intensity without the Morgan Generation Assets.

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

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

### 1.3.2 Embodied carbon

1.3.2.1 A Life Cycle Assessment (LCA) comprises an evaluation of the inputs, outputs and potential environmental impacts that occur throughout the lifecycle of a particular project, in this case an offshore wind farm, encompassing either a cradle-to-gate 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)
- Operations and maintenance (B1-B5)

- Decommissioning (C1-C4).

1.3.2.2 As the Morgan Generation Assets is currently in its early stages of design, data relating to specific metrics for site specific design details including chosen manufacturer of wind turbines and OSP design is currently unavailable.

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

- Environmental Product Declaration Power transformer TrafoStar 500 MVA (ABB, 2003)
- RICS Professional Information, UK Methodology to calculate embodied carbon of materials RICS (2012)
- Inventory of Carbon & Energy (ICE) database (Jones and Hammond, 2019)
- UK Government GHG Conversion Factors for Company Reporting (DESNZ and Department for Environment, Food & Rural Affairs (Defra), 2023).

1.3.2.4 Methodology specific to each element comprising the Morgan Generation Assets is detailed within section 1.6.2 below.

### 1.3.3 Land use (seabed) change

1.3.3.1 The calculation of climate change effects as a result of land use (seabed) change considers the impact of the Morgan Generation Assets on carbon sinks that may be required for temporary and permanent land take.

### 1.3.4 Operational avoided emissions

1.3.4.1 The assessment would also consider the GHG emissions that would not be generated (i.e. avoided) during the operation of the Morgan Generation Assets during the future baseline (see section 1.7.2.7).

## 1.4 Assumptions and limitations

1.4.1.1 The majority of the 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 UKs 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 Morgan Generation Assets.

1.4.1.2 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 Morgan Generation Assets. Government projections consistent with national carbon budget commitments have been used in the assessment. It should be noted that latest government projections include an increase in renewable energy generation, like Morgan Generation Assets, consistent with the Governments current drive for a large and rapid influx of renewable energy into the UK electricity grid.

1.4.1.3 The specific wind turbine technology and design of associated infrastructure that would be used by the Morgan Generation Assets have not yet been specified. Thus, there is a degree of uncertainty regarding all project-stages GHG emissions resulting from the manufacturing and construction of wind turbines and infrastructure. The assessment seeks to limit the impact this might have by using Maximum Design Scenario (MDS) material quantities, in the calculation of construction stage emissions. The MDS when considering the impact of and from climate change relates to the largest amount of sea bed area take and the largest amount of material including, greatest number of wind turbines (including foundations), longest cable route and largest OSP area (including foundations). This approach would combine scenarios, however, would represent the maximum design scenario as a conservative approach for the assessment of potential impacts.

## 1.5 Baseline environment

### 1.5.1 Current baseline

1.5.1.1 With regard to GHG emissions, the current baseline is the offshore sea surface, water column and seabed uses for the Morgan Array Area, including inter-array and interconnector cables, which is to be temporarily displaced. Carbon sequestration rates in marine habitats are usually lower than those of terrestrial habitats. Subtidal sediments recorded across the Morgan benthic subtidal ecology study area ranged from muddy sandy gravel to gravelly muddy sand with most samples classified as gravelly muddy sand in the Morgan Array Area. The baseline consists of various subtidal habitats including subtidal sand and muddy sand sediments to subtidal course and mixed sediments with diverse benthic communities (see Volume 4, Annex 2.1: Benthic subtidal ecology technical report of the Environmental Statement).

1.5.1.2 With regards to the current baseline concerning the UK electricity grid at the time of writing, the conversion factor for companies reporting UK Electricity generation carbon intensity resides at 252.97 kg$CO_2$e/MWh including scope 3 but as-generated (i.e. excluding transmission and distribution losses) (DESNZ and Defra, 2023).

### 1.5.2 Future baseline

1.5.2.1 The future baseline GHG emissions for existing land-use (seabed) without the Morgan Generation Assets are expected to remain similar to the current baseline identified above (section 1.5.1).

1.5.2.2 The future baseline for electricity generation that would be displaced by the Morgan Generation Assets 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 Morgan Generation Assets, compared to other generation sources available; this will be influenced by commercial factors and National Grid’s needs.

1.5.2.3 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.

1.5.2.4 DESNZ (formerly Department for Business, Energy and Industrial Strategy (BEIS)) publishes projections of the carbon intensity of long-run marginal electricity generation and supply that would be affected by small (on a national scale) sustained changes in generation or demand (DESNZ, 2023b). DESNZ projections over the operating lifetime of the Morgan Generation Assets (2030 to 2065) are used to estimate the potential emissions as a result of the Morgan Generation Assets.

1.5.2.5 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.

1.5.2.6 National Grid publishes 'Future Energy Scenario' (FES) projections (National Grid ESO, 2023) of grid-average carbon intensity under several possible evolutions of the UK energy market. These are: 'Falling Short' – slowest decarbonisation with minimal behaviour change; 'System Transformation' – Hydrogen heat network, limited consumer behaviour change whit flexibility in supply; 'Consumer Transformation' – Good consumer behaviour change, electrified heating, higher efficiency; and 'Leading the Way' – Fastest decarbonisation, significant lifestyle and behaviour change, mix of hydrogen and electrified heating.

1.5.2.7 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.

1.5.2.8 As can be seen in Figure 1.1, all of the FES grid-average carbon intensity projections achieve net negative values due to the sequestration of biogenic $CO_2$, via Bioenergy with Carbon Capture Storage (BECCS). It has been assumed that the Morgan Generation Assets 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.

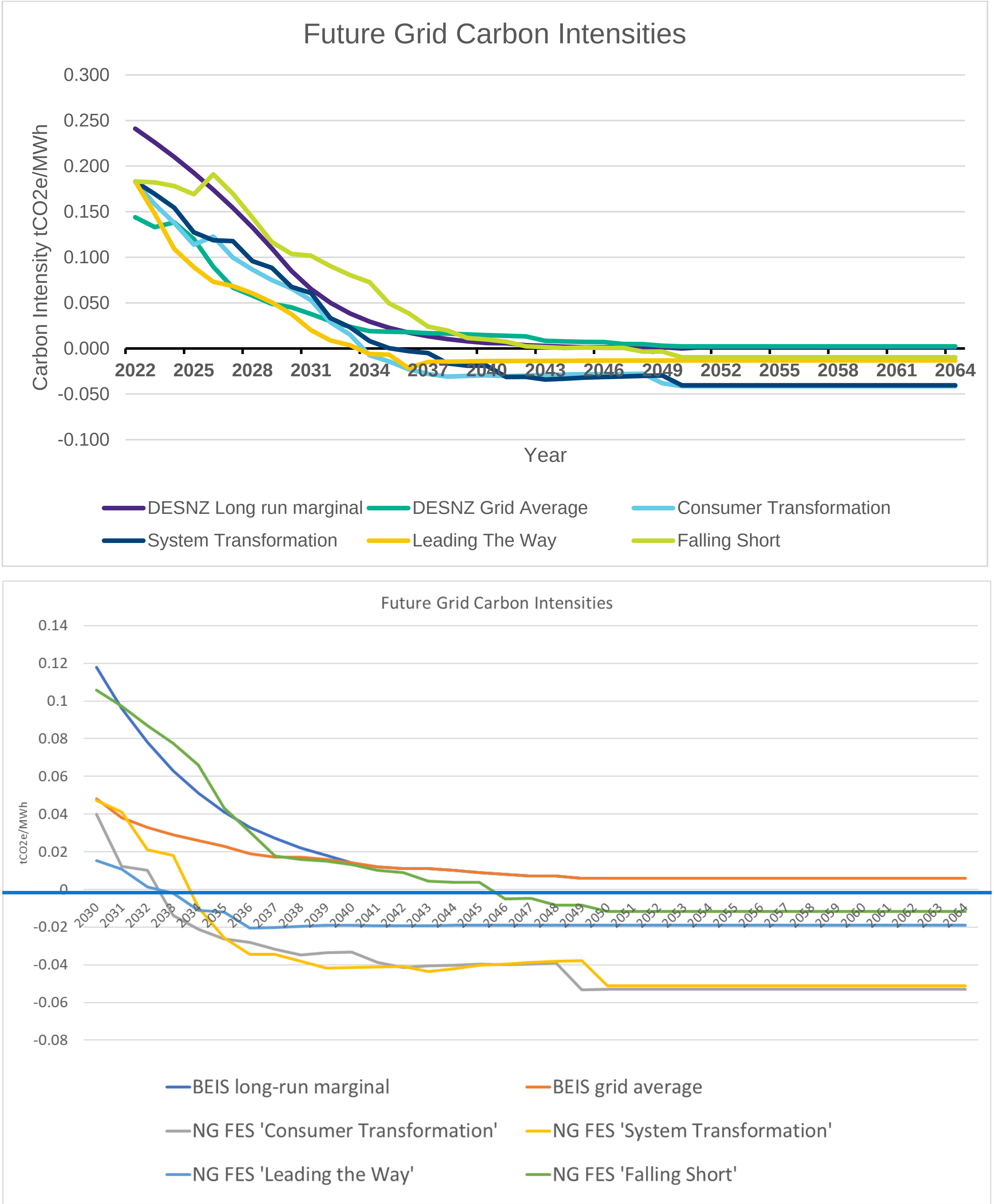


**Figure 1.1: DESNZ and FES future grid carbon intensities.**

1.5.2.9 Table 1.1 lists the DESNZ grid-average and marginal factors for the 35 years of the Morgan Generation Assets operations and maintenance phase.

**Table 1.1: DESNZ grid average and long-run marginal grid carbon intensities.**

| Year of Operation | Year | DESNZ long-run marginal ($tCO_2e/MWh$) | DESNZ grid average ($tCO_2e/MWh$) |
|---|---|---|---|
| 1 | 2030 | 0.091 | 0.045 |
| 2 | 2031 | 0.076 | 0.038 |
| 3 | 2032 | 0.063 | 0.03 |
| 4 | 2033 | 0.053 | 0.024 |
| 5 | 2034 | 0.044 | 0.019 |
| 6 | 2035 | 0.037 | 0.018 |
| 7 | 2036 | 0.03 | 0.018 |
| 8 | 2037 | 0.025 | 0.017 |
| 9 | 2038 | 0.021 | 0.016 |
| 10 | 2039 | 0.018 | 0.015 |
| 11 | 2040 | 0.015 | 0.015 |
| 12 | 2041 | 0.014 | 0.014 |
| 13 | 2042 | 0.013 | 0.013 |
| 14 | 2043 | 0.008 | 0.008 |
| 15 | 2044 | 0.008 | 0.008 |
| 16 | 2045 | 0.007 | 0.007 |
| 17 | 2046 | 0.007 | 0.007 |
| 18 | 2047 | 0.005 | 0.005 |
| 19 | 2048 | 0.005 | 0.005 |
| 20 | 2049 | 0.003 | 0.003 |
| 21 | 2050 | 0.002 | 0.002 |
| 22 | 2051 | 0.002 | 0.002 |
| 23 | 2052 | 0.002 | 0.002 |
| 24 | 2053 | 0.002 | 0.002 |
| 25 | 2054 | 0.002 | 0.002 |
| 26 | 2055 | 0.002 | 0.002 |
| 27 | 2056 | 0.002 | 0.002 |
| 28 | 2057 | 0.002 | 0.002 |
| 29 | 2058 | 0.002 | 0.002 |
| 30 | 2059 | 0.002 | 0.002 |
| 31 | 2060 | 0.002 | 0.002 |
| 32 | 2061 | 0.002 | 0.002 |
| 33 | 2062 | 0.002 | 0.002 |
| 34 | 2063 | 0.002 | 0.002 |

| Year of Operation | Year | DESNZ long-run marginal ($tCO_2e/MWh$) | DESNZ grid average ($tCO_2e/MWh$) |
|---|---|---|---|
| 35 | 2064 | 0.002 | 0.002 |

## 1.6 Assessment of construction effects

### 1.6.1 Land use (seabed) change

1.6.1.1 The infrastructure components of the Morgan Generation Assets that will alter the seabed use comprise:

- Wind turbines and associated components (foundations)
- OSPs
- Inter-array cables
- Interconnector cables
- Scour protection and cable protection.

1.6.1.2 The seabed use change would be constrained to the Morgan Array Area and would not directly impact any carbon stores. The seabed would be affected throughout the construction, operations and maintenance phases of the Morgan Generation Assets. As no carbon stores are directly affected by the Morgan Generation Assets and the habitat is anticipated to return back to its pre-development habitat after decommissioning the magnitude of impact is therefore, considered to be negligible.

### 1.6.2 Embodied carbon

1.6.2.1 The following sections detail the methodology used to calculate the construction stage emissions associated with the Morgan Generation Assets. Each section groups relevant elements of the Morgan Generation Assets by methodology used to calculate resultant emissions.

1.6.2.2 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) have been analysed.

1.6.2.3 The materials involved in the offshore components of the Morgan Generation Assets are the initial elements to consider within the cradle-to-grave approach towards completing this LCA. Emissions are derived from the raw material production required to manufacture the wind turbine generators, foundations, cables and OSPs and it is often the stage where the majority of embodied carbon is emitted.

#### Wind turbines, offshore substation platforms and cabling

1.6.2.1 The construction stage emissions associated with the following elements of the Morgan Generation Assets have been calculated using approximate material quantities, and relevant material emission factors:

- Wind turbines (including foundations)
- (OSPs (including foundations)
- Inter-array and inter-connector cabling

- Scour and cable protection.

1.6.2.2 Table 1.2 summarises the material quantities input based on the project description (Volume 1, Chapter 3: Project description of the Environmental Statement) and relevant material emission intensities sourced from the ICE database (Jones and Hammond, 2019).

**Table 1.2: Material quantities and emission factors for embodied carbon.**

| Item | Material | Quantity | Unit | Emissions factor ($kgCO_2e/kg$) | Source |
|---|---|---|---|---|---|
| Wind turbine blades and towers | Steel | 1,756 | tonnes per tower | 2.47 | Steel (average), ICE Database |
| | Glass reinforced plastic | 75 | tonnes per blade | 8.10 | Glass reinforced plastic, ICE Database |
| Wind turbine foundations | Steel | 4,500 | tonnes per wind turbine | 2.47 | Steel (average), ICE Database |
| | Scour protection | 25,029 | $m^3$ per wind turbine | 0.007 | Aggregates and sand, ICE Database |
| OSP topside | Steel | 4,000 | tonnes per OSP | 2.47 | Steel (average), ICE Database |
| OSP foundations | Steel | 6,000 | tonnes per OSP | 2.47 | Steel (average), ICE Database |
| | Scour protection | 56,252 | $m^3$ | 0.007 | Aggregates and sand, ICE Database |
| Cables | Copper | 17 | kg per metre | 2.71 | Copper, ICE Database |
| | Lead | 10.4 | kg per metre | 1.67 | Lead, ICE Database |
| | Scour protection | 637,500 | $m^3$ | 0.007 | Aggregates and sand, ICE Database |

## Offshore substation platforms

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

1.6.2.4 The LCA (ABB, 2003) listed a manufacturing GWP of 2,190 $kgCO_2e$ per MW. This was scaled by the current estimated Morgan Generation Assets output capacity of 1,500 MW to give an estimated embodied emission value of 3,285 $tCO_2e$. This value includes lifecycle stages A1-A3.

1.6.2.5 At this stage of design, materials estimates have some uncertainty in terms of the amounts and in the grouping into the main categories of material rather than it being possible to specify all products to be used in the final, detailed design. As a means of comparison, a published benchmark (RICS, 2012) has therefore also been used to estimate possible emissions from the substation buildings.

1.6.2.6 The benchmark data is expressed in $kgCO_2e/m^2$ of floorspace as an intensity which is applied against the total floor area for all four OSPs (11,700 $m^2$). When using the RICS intensity for other industrial/utilities/specialist uses (545 $kgCO_2e/m^2$) with the substation floor area, it results in an estimated embodied carbon emission of 6,377 $tCO_2e$.

### Vessel and helicopter movements

1.6.2.7 Indicative vessel and helicopter movements were used to calculate emissions associated with their activities during the construction phase.

1.6.2.8 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 activity hours informed by vessel speed and distance from port (vessel information was sourced from specifications of likely vessel types (Volume 1, Chapter 3: Project description of the Environmental Statement). A distance of 100 km (one way) was assumed as a conservative estimate based on the possible port locations as detailed in Volume 4, Annex 13.1: Socio-economics technical impact report of the Environmental Statement. This value was then scaled by the emission factor for marine gas oil (0.258 $kgCO_2e/kWh$) (DESNZ and Defra, 2023), totalling 52,827 $tCO_2e$.

1.6.2.9 Helicopter movements and their associated emissions were calculated by determining the anticipated fuel consumption, informed by their predicted movements. An indicative number of return trips and assumed distance (100 km) from a potential helicopter base (Volume 1, Chapter 3: Project description of the Environmental Statement), alongside average fuel consumption (430 kg/hr) and fuel economy data (145 knots/hr) (obtained from manufacturers specifications) were used to estimate fuel consumption. Emission factors for aviation turbine fuel (2.54 $kgCO_2e/l$) (DESNZ and Defra, 2023) were then scaled by the fuel consumption to give associated emissions, totalling 892 $tCO_2e$.

## 1.6.3 Summary

1.6.3.1 Table 1.3 summarises the calculated construction stage emissions associated with the Morgan Generation Assets, which totals 1,927,~~452~~ 897 $tCO_2e$.

**Table 1.3: Construction stage embodied carbon emissions summary.**

| Item | Value | Unit |
|---|---|---|
| Wind turbines (blades and tower) | 591,343 | tCO2e |
| Wind turbines (foundations) | 1,067,040 | tCO2e |
| OSP (topsides) | 49,400 | tCO2e |
| OSP (foundations) | 59,280 | tCO2e |
| Inter-array cables | 24,741 | tCO2e |
| Interconnector cables | 11,419 | tCO2e |
| Scour and cable protection | ~~60,849~~61,295 | tCO2e |
| Substations (transformers) | 9,662 | tCO2e |
| Vessel and helicopter | 53,718 | tCO2e |
| **Total** | **1,927,~~452~~897** | **tCO2e** |

# 1.7 Assessment of operational effects

## 1.7.1 Land use (seabed) change

1.7.1.1 Considered with construction stage impacts see section 1.6.1.

## 1.7.2 Avoided emissions

1.7.2.1 The magnitude of impact of the Morgan Generation Assets is determined by the quantity of renewable energy use it enables by avoiding curtailment, the quantity of peaking plant generation it displaces, and the associated GHG impacts of both. The quantity of renewable energy enabled and peaking plant energy displaced is determined by the total annual energy input and output values for the Morgan Generation Assets (see Table 1.4). The associated GHG emissions are determined by the GHG intensity of the enabled and displaced sources of generation.

1.7.2.2 Table 1.4 sets out the annual energy input and output values for the Morgan Generation Assets and the parameters by which they are determined.

**Table 1.4: Energy flows from Morgan Generation Assets.**

| Parameter | Value | Unit | Source |
|---|---|---|---|
| Input parameter - rated power (based on current estimates) | 1,500 | MW | P Assumed export capacity in line with Crown Estates Round 4 leasing requirements (Crown Estates, 2021) |
| Input parameter – capacity factor | 34.9 | % | DESNZ (2023b) |
| Input parameter – degradation factor | 1.6 | % | Staffell and Green (2014) |
| Input parameter – total annual operating hours | 8,760 | hrs | Total number of hours in year |
| Output parameter - annual energy output | 4,585,860 | MWh | Calculation of MW multiplied by total hours |

1.7.2.3 The input and output figures for the operations and maintenance phase of the Morgan Generation Assets are then calculated against the assumptions stated within the FES, published by the National Grid. This allows for a direct presentation of the cumulative GHG emissions avoided throughout the operational lifetime of the Morgan Generation Assets and therefore, how the Morgan Generation Assets contributes towards reaching net zero targets.

1.7.2.4 The marginal emissions factor for the UK electricity grid is used to estimate the change in UK electricity sector emissions associated with policies that lead to sustained marginal changes in the consumption of electricity.

1.7.2.5 The marginal electricity source displaced may in practice vary from moment to moment depending on the operation of the capacity market (i.e. led by commercial considerations and National Grid's needs at any given time). For the purpose of this assessment, longer-term trends (annual averages) have been used as it is not possible to predict shorter-term variations with confidence. It should be noted that as the UK moves towards its 2050 net zero carbon target, the primary source of electricity generation in the marginal emissions scenario will likely become a combination of renewables (predominately solar and wind) and storage. Therefore, from circa 2040 onwards, comparing the Morgan Generation Assets' GHG impacts with the marginal emissions factor source of generation is akin to comparing it with itself and has limited value.

1.7.2.6 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 Morgan Generation Assets with the DESNZ long-run marginal or grid-average source.

1.7.2.7 Table 1.5 displays the annual power output and emissions avoidance of the Morgan Generation Assets when comparing the abated fossil fuel generation using the DESNZ (2023b) long run marginal carbon intensity for the future UK Grid.

**Table 1.5: Operational GHG impacts.**

| Year of Operation | Year | Output (MWh) | DESNZ long-run marginal ($tCO_2e$/MWh) | Avoided GHG emissions ($tCO_2e$) | Cumulative GHG emissions ($tCO_2e$) |
|---|---|---|---|---|---|
| 1 | 2030 | 4,585,860 | 0.091 | 417,313 | 417,313 |
| 2 | 2031 | 4,512,486 | 0.076 | 342,949 | 760,262 |
| 3 | 2032 | 4,440,286 | 0.063 | 279,738 | 1,040,000 |
| 4 | 2033 | 4,369,242 | 0.053 | 231,570 | 1,271,570 |
| 5 | 2034 | 4,299,334 | 0.044 | 189,171 | 1,460,741 |
| 6 | 2035 | 4,230,545 | 0.037 | 156,530 | 1,617,271 |
| 7 | 2036 | 4,162,856 | 0.03 | 124,886 | 1,742,157 |
| 8 | 2037 | 4,096,250 | 0.025 | 102,406 | 1,844,563 |
| 9 | 2038 | 4,030,710 | 0.021 | 84,645 | 1,929,208 |
| 10 | 2039 | 3,966,219 | 0.018 | 71,392 | 2,000,600 |
| 11 | 2040 | 3,902,759 | 0.015 | 58,541 | 2,059,141 |
| 12 | 2041 | 3,840,315 | 0.014 | 53,764 | 2,112,906 |
| 13 | 2042 | 3,778,870 | 0.013 | 49,125 | 2,162,031 |
| 14 | 2043 | 3,718,408 | 0.008 | 29,747 | 2,191,778 |
| 15 | 2044 | 3,658,914 | 0.008 | 29,271 | 2,221,049 |
| 16 | 2045 | 3,600,371 | 0.007 | 25,203 | 2,246,252 |
| 17 | 2046 | 3,542,765 | 0.007 | 24,799 | 2,271,051 |
| 18 | 2047 | 3,486,081 | 0.005 | 17,430 | 2,288,482 |
| 19 | 2048 | 3,430,304 | 0.005 | 17,152 | 2,305,633 |
| 20 | 2049 | 3,375,419 | 0.003 | 10,126 | 2,315,760 |
| 21 | 2050 | 3,321,412 | 0.002 | 6,643 | 2,322,402 |
| 22 | 2051 | 3,268,269 | 0.002 | 6,537 | 2,328,939 |
| 23 | 2052 | 3,215,977 | 0.002 | 6,432 | 2,335,371 |
| 24 | 2053 | 3,164,522 | 0.002 | 6,329 | 2,341,700 |
| 25 | 2054 | 3,113,889 | 0.002 | 6,228 | 2,347,928 |
| 26 | 2055 | 3,064,067 | 0.002 | 6,128 | 2,354,056 |
| 27 | 2056 | 3,015,042 | 0.002 | 6,030 | 2,360,086 |
| 28 | 2057 | 2,966,801 | 0.002 | 5,934 | 2,366,020 |

| Year of Operation | Year | Output (MWh) | DESNZ long-run marginal ($tCO_2e/MWh$) | Avoided GHG emissions ($tCO_2e$) | Cumulative GHG emissions ($tCO_2e$) |
|---|---|---|---|---|---|
| 29 | 2058 | 2,919,332 | 0.002 | 5,839 | 2,371,858 |
| 30 | 2059 | 2,872,623 | 0.002 | 5,745 | 2,377,603 |
| 31 | 2060 | 2,826,661 | 0.002 | 5,653 | 2,383,257 |
| 32 | 2061 | 2,781,435 | 0.002 | 5,563 | 2,388,820 |
| 33 | 2062 | 2,736,932 | 0.002 | 5,474 | 2,394,293 |
| 34 | 2063 | 2,693,141 | 0.002 | 5,386 | 2,399,680 |
| 35 | 2064 | 2,650,050 | 0.002 | 5,300 | 2,404,980 |

### 1.7.3 Sensitivity analysis

1.7.3.1 The long run marginal figures, which have been used in Table 1.5, 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 Morgan Generation Assets' contribution to the UK electricity Grid would be higher than that of avoided emissions detailed above.

1.7.3.2 As such, a sensitivity analysis has been carried out using the current UK electricity Grid carbon intensity (252.974 kgCO2e/MWh) and current estimated intensity from electricity supplied for 'all non-renewable fuels' (424 $kgCO_2e/MWh$) (intensity currently provisional) as detailed in section 1.5.1.

1.7.3.3 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.

1.7.3.4 Table 1.6 details the potential avoided emissions for the assessment scenario (DESNZ long run marginal) and two alternative scenarios as part of the sensitivity analysis (Current UK electricity grid average as of 2023, and DESNZ 'non-renewable fuels intensity as of 2023). These Are presented for the entire assumed life time of 35 years for the purpose of the GHG calculations (whole life).

**Table 1.6: Whole life avoided emissions sensitivity test.**

| Operating years | Output (MWh) | DESNZ long-run marginal avoided emissions (tCO2e) | Current UK Grid average avoided emissions (tCO2e) | DESNZ 'non-renewable fuels' avoided emissions (tCO2e) |
|---|---|---|---|---|
| 35 | 123,638,148 | 2,404,980 | 31,277,273 | 53,411,680 |

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

### 1.7.4 Fuel and energy consumption operations and maintenance activities

1.7.4.1 The primary purpose of the operations and maintenance phase of a wind farm is to create low carbon electricity. Emissions during the operations phase of the Morgan Generation Assets refers to activities contributing to the high-level management of the asset such as remote monitoring, environmental monitoring, electricity sales, etc. Maintenance accounts for the largest portion and can be divided into preventative maintenance and corrective maintenance:

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

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

1.7.4.3 Emissions associated with the proposed maintenance vessels and helicopter movements follow the methodology detailed in paragraph 1.6.2.6. Such emissions total 18,212 $tCO_2e$.

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

1.7.4.5 Throughout the project's lifetime it is assumed that major plant equipment, such as transformers, will be replaced no more than three times over the lifetime of each OSP. As such, the embodied carbon emissions detailed in paragraph 1.6.2.6 have been scaled up by a factor of three. Total emissions from major offshore substation platforms (transformers) over the project lifetime were calculated to be 9,855 $tCO_2e$.

1.7.4.6 It is anticipated that the inter-array cables will undergo one repair event every three years. Should the cable require replacement, the longest length to be replaced would be 10 km. Similarly, the interconnector cables will undergo three repairs every ten years, with the longest length of cable to be replaced 58.9 km long. Emissions associated with the replacement of such cables were calculated using the methodology detailed at paragraph 1.6.2.1. Total emissions from cable replacement over the project lifetime were calculated to be ~~41,102~~47,192 $tCO_2e$.

1.7.4.7 There would be indirect increases in emissions attributed to deviation of ferry and cargo vessels as a result of the Morgan Generation Assets. This has indirect emissions increases that require consideration. The Navigation Risk Assessment (NRA) (Volume 4, Annex 7.1: Navigational Risk Assessment of the Environmental Statement) and the Shipping and navigation chapter (Volume 2, Chapter 7: Shipping and navigation of the Environmental Statement) include details on navigation simulations which were undertaken as part of the assessment to establish the impact and consequential route deviation for existing routes as a result of the Morgan Generation Assets.

1.7.4.8 Based on information from the NRA (Volume 4: Annex 7.1: Navigational Risk Assessment of the Environmental Statement) a number of ferry (Stena Line, Seatruck and Isle of Man Steam Packet Company (IoMSPC)) and cargo routes would be affected. The following information (Table 1.7) has been used to estimate the likely indirect GHG impact as a result of route deviation. The information has been sourced from the NRA and manufacturer's information regarding individual vessels.

**Table 1.7: Vessel route deviation information.**

* Assumes four passengers per car. This might result in double counting with passenger number, however, is a conservative assumption.

| Parameter | Stena LIV-BEL-W | IOMSPC LIV-DOUG | IoMSPC HEY-DOUG | Seatruck HEY-WAR | IoMSPC HEY-DOUG | Stena LIV-BEL-E | Stena HEY-BEL | Cargo Routes |
|---|---|---|---|---|---|---|---|---|
| Approximate annual crossings (2022) | 1,451 | 593 | 390 | 1,099 | 20 | 10 | 52 | 140 |
| Baseline distance (nm) | 46.80 | 56.90 | 113.90 | 100.20 | 50.10 | 11 | 106.90 | 474.10 |
| Deviated distance (nm) | 47.30 | 57.10 | 117.40 | 100.80 | 55.80 | 134.40 | 123.20 | 483.70 |
| Maximum additional distance nm (per journey) | 0.50 | 0.20 | 3.50 | 0.60 | 5.70 | 20.40 | 16.30 | 9.60 |
| Maximum additional distance km (per journey) | 1.07% | 0.35% | 3.07% | 0.60% | 11.38% | 17.89% | 15.25% | 2.02% |
| Uplift in baseline distance (%) | 0.93 | 0.37 | 6.48 | 1.11 | 10.56 | 37.78 | 30.19 | 17.78 |
| Total per annum (km) | 1,343.63 | 219.65 | 2,527.98 | 1,221.21 | 211.13 | 377.81 | 1,569.76 | 2,489 |
| Passenger capacity | 927 | 850 | 666 | - | 666 | 927 | 927 | N/A |
| Car capacity* | 480 | 800 | 1,100 | 480 | 1,100 | 480 | 480 | N/A |
| Assumed Average Cargo Weight (tonnes) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 25,000 |

1.7.4.9 National carbon intensities (DESNZ & Defra, 2023) were used to estimate the GHG emissions associated with the route deviations as a result of the Morgan Generation Assets. This included:

- Average ferry: foot passenger (0.01871 $kgCO_2e$/passenger/km) and car passenger (0.12933 $kgCO_2e$/passenger/km)
- Average general cargo (0.01321 $kgCO_2e$/tonne/km).

1.7.4.10 Emissions associated with the route deviations result in 593.38 $tCO_2e$ for ferry vessels in normal and adverse conditions, in addition to, 84.79 $tCO_2e$ for cargo vessels per annum. No assumptions concerning decarbonisation of fleet or variations in annual crossings have been included.

### 1.7.5 Decommissioning

1.7.5.1 The majority of emissions during this phase relate to the use of plant/equipment for Morgan Generation Assets decommissioning, disassembly, transportation to a waste site, and ultimate disposal and/or recycling of the equipment and other site materials. The components of the wind turbines are considered to be currently or at end of life for generation assets (35 years) recyclable. When disposing of wind turbines, recycling is the preferred solution in line with the waste hierarchy (reduce, reuse, recycle, recover). 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.

1.7.5.2 In the absence of detailed information regarding offshore transport movements during the decommissioning phase, it has been assumed that such emissions equal those associated with the construction phase, totalling 53,7198 $tCO_2e$. Given carbon emissions associated with use of plant/equipment and fuel is expected to have achieved good levels of decarbonisation at the decommissioning phase of the Morgan Generation Assets, this is likely to present a conservative maximum emission scenario.

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