MONA OFFSHORE WIND PROJECT

Environmental Statement

Volume 8, Annex 2.1: Greenhouse gas assessment technical report

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Image of an offshore wind farm

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Glossary

Term	Meaning
Future grid average	Projection of how clean the future UK Grid electricity is likely to be based on current policies. It refers to how many grams of carbon dioxide (CO_2) are released to produce a kilowatt hour (kWh) of electricity.
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 and generation sources 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
ALC	Agricultural Land Classification
BECCS	Bioenergy with Carbon Capture Storage
CCC	Climate Change Committee
CSP	Concentrating solar panels
CTVs	Crew Transfer Vessels
DESNZ	Department for Energy Security and Net Zero
DUKES	Digest of UK Energy Statistics
EIA	Environmental Impact Assessment
EPD	Environmental Product Declaration
FES	Future Energy Scenario
GHG	Greenhouse Gas
GWP	Global Warming Potential
HGV	Heavy Goods Vehicles
HVAC	High Voltage Alternating Current
IEA	International Energy Agency
IPPC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
MDS	Maximum Design Scenario
PD	Project Description
UNFCCC	United Nations Framework Convention on Climate Change

Units

Unit	Description
CO_2e	Carbon dioxide equivalent
g	Grams
GW	Gigawatts
kg	Kilograms
km	Kilometres
MVA	Megavolt amperes
MW	Megawatts
MWh	Megawatt Hours
t	Tonnes

1 Greenhouse gas assessment technical report

1.1 Introduction

1.1.1.1 This greenhouse gas (GHG) technical report sets out the methodology and calculations of the GHG emissions for the Mona Offshore Wind Project. These calculations inform the assessment of the climate change impacts in volume 4: chapter 2 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 Mona Offshore Wind Project. 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 volume 4: chapter 2 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. 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 (UNFCCC).

1.2.1.2 The annex scope considers the generation and transmission elements of the Mona Offshore Wind Project 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 for both generation and transmission assets
- Transport emissions both onshore and offshore
- Avoided emissions associated with the abatement of required fossil fuel generators and their associated emissions related with the UK Grid electricity.

1.3 Methodology

1.3.1 Overview

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 Mona Offshore Wind Project have been informed via the following source:

- 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 to construct, operate, maintain and decommission 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.

1.3.1.3 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 Mona Offshore Wind Project. These emissions shall not be separated out by defined scopes (Scopes 1, 2 or 3) in the assessment.

1.3.1.4 Due to the nature of the Mona Offshore Wind Project, i.e. exporting generated electricity to the grid, its gross GHG emissions total is dominated by avoided emissions. The avoided emissions are those that would have occurred as a result of the predicted UK Grid carbon intensity without the Project.

1.3.1.5 The assessment has considered: (a) the GHG emissions arising from the Mona Offshore Wind Project, (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 Mona Offshore Wind Project is required in order to quantify its net contribution to climate change and as such the magnitude of change owing to the Mona Offshore Wind Project.

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 (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)
- operations and maintenance (B1-B5)

- decommissioning (C1-C4).

1.3.2.2 As the Mona Offshore Wind Project is currently in its early stages of design, data relating to metrics for site specific design details including chosen manufacturer of wind turbines, substation design etc. is currently unavailable.

1.3.2.3 Therefore, emissions resulting from the manufacturing and construction of the wind turbines, cabling, onshore substation and associated site infrastructure (onshore and offshore) 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 Defra, 2023).

1.3.2.4 Methodology specific to each element comprising the Mona Offshore Wind Project is detailed within section 1.6.2 below.

1.3.3 Land use change

1.3.3.1 The calculation of climate change effects as a result of land use change considers the impact of the Mona Offshore Wind Project 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 also considers the GHG emissions that would not be generated (i.e. avoided) during the operation of the Mona Offshore Wind Project during the future baseline (see section 1.5.2).

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 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 Mona Offshore Wind Project.

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 Mona Offshore Wind Project. Government projections consistent with national carbon budget commitments have been used in the assessment.

1.4.1.3 The specific turbine technology and design of associated infrastructure (including substations etc.) that would be used by the Mona Offshore Wind Project have 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 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. Such emissions are likely to present a conservative maximum design scenario.

1.5 Baseline Environment

1.5.1 Current baseline

1.5.1.1 The current baseline for the onshore elements primarily comprises agricultural land. This land has been identified as Grades 3a and 3b (within Volume 7: Annex 7.1: Published soil and agricultural land classification data of the Environmental Statement of the Environmental Statement), however, this land does not have high soil or vegetation carbon stocks (e.g. peat) that would be subject to disturbance by construction.

1.5.1.2 When considering the current baseline for the offshore elements the baseline consists of various subtidal habitats of stony reef, subtidal course, mixed sediments and diverse benthic communities.

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

1.5.2 Future baseline

1.5.2.1 The future baseline GHG emissions for existing land-use without the Mona Offshore Wind Project are expected to remain similar to the current baseline.

1.5.2.2 The future baseline for electricity generation that would be displaced by the Mona Offshore Wind 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 Mona Offshore Wind Project, 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.

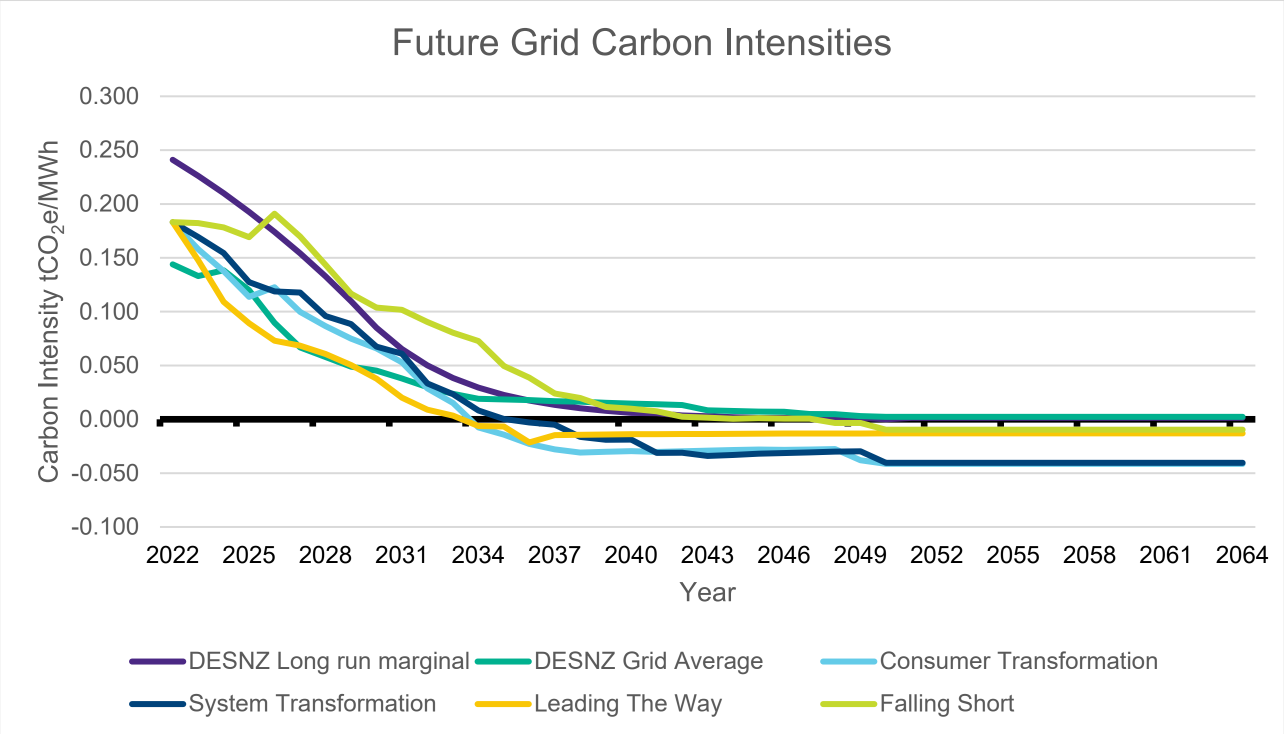
1.5.2.4 DESNZ publishes projections of the carbon intensity of long-run marginal electricity generation and supply that would be affected by small (on a national scale) sustained changes in generation or demand (DESNZ, 2023a). DESNZ's projections over the operating lifetime of the Mona Offshore Wind Project

(2030 to 2065) are used to estimate the potential emissions as a result of the Project.

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, 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.

Figure 1.1: DESNZ and FES future grid carbon intensities.



1.5.2.7 As can be seen from 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 and Storage (BECCS). It has been assumed that the Mona Offshore Wind 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 1.1 lists the DESNZ grid-average and marginal factors for the 35 years of the Mona Offshore Wind Project's operation.

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

Year of Operation	Year	DESNZ Long-Run Marginal (tCO_2e/MWh)	DESNZ Grid Average (tCO_2e/MWh)
33	2062	0.002	0.002
34	2063	0.002	0.002
35	2064	0.002	0.002

1.6 Assessment of Construction Effects

1.6.1 Land use change

1.6.1.1 The infrastructure components of the Mona Offshore Wind Project that will alter the onshore and offshore land use comprise:

- Mona Array Area: This is where the wind turbines, Offshore Substation Platforms (OSPs), foundations (for both wind turbines and OSPs), inter-array cables, interconnector cables and offshore export cables will be located.
- Mona Offshore Cable Corridor and Access Areas: The corridor located between the Mona Array Area and the landfall up to Mean High Water Springs (MHWS), in which the offshore export cables will be located and in which the intertidal access areas are located.
- Mona Onshore Development Area: The area in which the landfall, onshore cable corridor, onshore substation, mitigation areas, temporary construction facilities (such as access roads and construction compounds), and the connection to National Grid infrastructure will be located.
- Onshore Substation: This is where the new substation will be located, containing the components for transforming the power supplied from the offshore wind farm up to 400 kV.
- Mona 400 kV Grid Connection Cable Corridor: The corridor from the onshore substation to the National Grid substation.

Onshore

1.6.1.2 Volume 3, Chapter 6: Land use and recreation and Volume 7, Annex 7.1: Published soil and agricultural land classification of the Environmental Statement outline the baseline conditions for the onshore components and any subsequent effects of the Mona Offshore Wind Project on land use.

1.6.1.3 Volume 7, Annex 7.1 highlights areas of woodland located near Gwrych Castle that fall into the Mona Onshore Development Area and may be of value in relation to carbon storage, however the Mona Offshore Wind Project is to drill under the woodland and not disturb the carbon storage. The annex does not identity any further areas of value due to the nature of the baseline environment as predominantly agricultural farmland. Furthermore, no soil or woodland of high carbon storage value has been identified at the onshore substation location.

Offshore

1.6.1.4 The offshore land use change would be constrained to the Mona Array Area and Offshore Cable Corridor and would not directly impact any carbon stores. The land use would be affected throughout the construction and operations and maintenance phases of the development. However, through the decommissioning process it is anticipated that the existing baseline environment would be restored or improved (i.e. where structures will be left in situ and could provide biodiversity benefit). As no carbon stores are directly affected by the Mona Offshore Wind Project and the habitat is anticipated to return back to its pre-development habitat (or improved as described above) after decommissioning the change concerning the carbon storage value of the land use would be minimal.

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 Mona Offshore Wind Project. Each section groups relevant elements of the Mona Offshore Wind Project 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 Mona Offshore Wind Project 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 substations and it is often the stage where the majority of embodied carbon is emitted.

Wind turbines, offshore substation platforms, cabling

1.6.2.4 The construction stage emissions associated with the following elements of the Mona Offshore Wind Project have been calculated using approximate material quantities, and relevant material emission factors:

- Wind turbines (including foundations),
- offshore substation platforms (OSP),
- cables (including all inter-array, interconnector, offshore export, onshore export, and 400 kV grid connection cables), and
- scour and cable protection.

1.6.2.5 Table 1.2 summarises the material quantities input and relevant material emission intensities sourced from the Inventory of Carbon and Energy (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	15,469	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	21,016	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	1,717,500	m^3	0.007	Aggregates and sand, ICE Database

Mona Onshore and Offshore Substations

1.6.2.6 There is limited information concerning the substations and few published LCAs from which to calculate associated embodied carbon emissions. 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, as transformers are among the major substation plant components and have a relatively high materials and carbon intensity.

1.6.2.7 The LCA (ABB, 2003) listed a manufacturing GWP of 2,190 $kgCO_2e$ per MW. This was scaled by the Mona Offshore Wind Project 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. The same calculation was carried out for the onshore substation plant (consisting of 3 x 850 MVA power transformers) resulting in an additional 5,585 tCO_2e.

1.6.2.8 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 onshore substation buildings.

1.6.2.9 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 substations (14,400 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 7,848 tCO_2e.

Joint Bays and Transition Joint Bays

1.6.2.10 Material quantities associated with the construction of joint bays were estimated based on best practice dimensions (National Grid, 2015), totalling 12,720,000 kg of concrete, and scaled by the relevant material intensity factor 0.103 $kgCO_2e/kg$ (Jones and Hammond, 2019). Total emissions are estimated at 1,310 tCO_2e.

Vehicle Movements

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

1.6.2.12 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 consistent with those listed within 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 five possible ports as detailed in Volume 8: Annex 3.1 of the ES. This value was then scaled by the emission factor for marine gas oil (0.258 $kgCO_2e/kWh$) (DESNZ and Defra, 2023), totalling 54,945 tCO_2e.

1.6.2.13 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 (as detailed within Volume 1: Chapter 3: Project Description of the Environmental Statement) and assumed distance from a potential helicopter base, 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.

1.6.2.14 Heavy Goods Vehicle (HGV) movements and personnel vehicle movements associated with the construction of the onshore export cables and onshore substation were scaled by an assumed average distance of travel (300 km for HGVs, in line with RICS whole life carbon guidance (2017), and 50 km for personnel) and an emissions factor for fully laden diesel HGVs (0.98496 $kgCO_2e/km$) and medium petrol car (0.19819 $kgCO_2e/km$) (DESNZ and Defra, 2023). Resultant emissions associated with the onshore vehicle movements total 70,551 tCO_2e.

1.6.3 Summary

1.6.3.1 Table 1.3 summarises the calculated construction stage emissions associated with the Mona Offshore Wind Project, which totals 2,040,818 tCO_2e.

Table 1.3: Construction stage embodied carbon emissions summary

Item	Value	Unit
Offshore Infrastructure		
Wind turbines (blades and tower)	591,343	tCO_2e
Wind turbines (foundations)	1,067,040	tCO_2e
OSP (topsides)	49,400	tCO_2e
OSP (foundations)	59,280	tCO_2e
Inter-array cables	20,617	tCO_2e
Interconnector cables	9,516	tCO_2e
Offshore export cables	22,838	tCO_2e
Scour protection	63,809	tCO_2e
Onshore Infrastructure		
Onshore export cables	11,419	tCO_2e
400 kV grid connection cables	1,142	tCO_2e
Joint bays and Transition Joint Bays	1,310	tCO_2e
Combined Offshore and Onshore		
Onshore Substations and associated plant	16,718	tCO_2e
Transport	126,387	tCO_2e
Total	2,040,818	tCO_2e

1.7 Assessment of operations and maintenance effects

1.7.1 Land use 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 Mona Offshore Wind 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 Mona Offshore Wind Project (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 Mona Offshore Wind Project and the parameters by which they are determined.

Table 1.4: Energy flows from Mona Offshore Wind Project.

Parameter	Value	Unit	Source
Input parameter - rated power	1,500	MW	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 a year
Output parameter - annual energy output	4,585,860	MWh	Calculation multipling the MW rated power by hours

1.7.2.3 The input and output figures for the operational stage of the Mona Offshore Wind Project are then calculated against the assumptions stated within the DESNZ long-run marginal, published by the National Grid. This allows for a direct presentation of the cumulative GHG emissions avoided throughout the operational lifetime of the Mona Offshore Wind Project and therefore, how the Project contributes towards reaching net zero targets.

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

1.7.2.5 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 Mona Offshore Wind Project with the DESNZ long-run marginal or grid-average source.

1.7.2.6 Table 1.5 displays the annual power output and emissions avoidance of the Mona Offshore Wind Project when comparing the abated fossil fuel generation using the DESNZ (2023a) long run marginal carbon intensity for the future UK Grid.

Table 1.5: Operational GHG impacts.

Year of Operation	Year	Output (MWh)	DESNZlong-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
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

Year of Operation	Year	Output (MWh)	DESNZlong-run marginal (tCO_2e/MWh)	Avoided GHG emissions (tCO_2e)	Cumulative GHG emissions (tCO_2e)
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

Sensitivity Analysis

1.7.2.7 The long run marginal figures, which have been used in Table 1.5, are dynamic and show year-on-year decarbonisation of UK Grid electricity 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 Grid electricity. As such it is likely that the true value of the avoided emissions displaced as a result of the Mona Offshore Wind Project's contribution to the UK Grid electricity would be higher than that of avoided emissions detailed above.

1.7.2.8 As such, a sensitivity analysis has been carried out using the current UK Grid carbon intensity (252.974 $kgCO_2e$/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. The inputs and results of the sensitivity analysis have been tabulated below in Table 1.6.

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

Table 1.6: Whole life avoided emissions sensitivity test.

Operating years	Output (MWh)	DESNZ long-run marginal avoided emissions (tCO_2e)	Current UK Grid average avoided emissions (tCO_2e)	DESNZ 'non-renewable fuels' avoided emissions (tCO_2e)
35	123,638,148	2,404,980	31,277,273	52,422,575

1.7.2.10 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.

1.7.3 Fuel and energy consumption operations and maintenance activities

1.7.3.1 The primary purpose of the operational stage of a wind farm is to avoid the need for fossil fuel generation assets and reduce the national grid carbon intensity. Emissions during the operational phase of the Mona Offshore Wind Project refers to activities contributing to the high-level management of the asset such as remote monitoring, environmental monitoring, electricity sales, etc. Maintenance accounts for by far the largest portion 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.

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

1.7.3.3 Emissions associated with the proposed maintenance vessel, helicopter, HGV and personnel vehicle movements follow the methodology detailed in paragraph 1.6.2.9. Such emissions total 41,762 tCO_2e.

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

1.7.3.5 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. It has been assumed there would be no need for replacement of major components at the onshore substation, and as such, this has not been included within the GHG emissions calculations. Although a replacement would have emissions associated with this activity it is not anticipated that this would alter the assessment of effects for the operations and maintenance stage. As such, the embodied carbon emissions detailed in paragraph 1.6.2.9 have been scaled by a factor of three. Total emissions from major substation plant (transformers) over the Project lifetime were calculated to be 9,855 tCO_2e.

1.7.3.6 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 48 km long. The subtidal export cable will require two repairs every 5 years per export cable, with a maximum of 4 km of cable replaced during each repair event. The intertidal export cable will require a maximum of 1.6 km of cable replaced every 5 years (total for all four export cables). Emissions associated with the replacement of such cables were calculated using the methodology detailed at paragraph 1.6.2.4. Total emissions from cable replacement over the Project lifetime were calculated to be 55,489 tCO_2e.

1.7.3.7 There would be indirect increases in emissions attributed to deviation of ferry and cargo vessels as a result of the Mona Offshore Wind Project. This has indirect emissions increases that require consideration. The Navigation and Risk Assessment (NRA) (Volume 6: Annex 7.1 of the Environmental Statement) and the shipping and navigation chapter (Volume 2: Chapter 7 of the Environmental Statement) have conducted navigation simulations to establish the impact and consequential route deviation for existing routes as a result of the Mona Offshore Wind Farm.

1.7.3.8 Based on information from the NRA (Volume 6: Annex 7.1 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 NRA (Volume 6: Annex 7.1 of the Environmental Statement) and manufacturer's information regarding 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	Stena LIV_BEL_W (TSS)	Seatruck HEY_DUB	IOMSPC LIV-DOUG	Cargo Routes
Approximate annual crossings (2022)	1,098	392	606	30	798
Baseline distance (nm)	113.3	115.2	109.3	61.2	579.8
Deviated distance (nm)	114.4	117.3	109.4	65.7	592
Maximum additional distance nm (per journey)	1.1	2.1	0.1	4.5	12.2
Maximum additional distance km (per journey)	2.04	3.89	0.19	8.33	22.59
Uplift in baseline distance (%)	0.97%	1.82%	0.09%	7.35%	2.10%
Total per annum (km)	2,236.85	1,524.57	112.23	250.02	2,623.17
Passenger capacity	927	927	0	850	N/A
Car capacity*	480 (120 cars)	480 (120 Cars)	480 (120 Cars)	800 (200 cars)	N/A
Assumed Average Cargo Weight (tonnes)	N/A	N/A	N/A	N/A	25,000

1.7.3.9 Emissions associated with the route deviations as a result of the Mona Offshore Wind Farm used national carbon intensities (DESNZ & Defra, 2023) to estimate the GHG impact. This included:

- average ferry: foot passenger (0.01871 kgCO_2e/passenger/km) and car passenger (0.12933 kgCO_2e/passenger/km); and
- average general cargo (0.01321 kgCO_2e/tonne/km)

1.7.3.10 Emissions associated with the route deviation result in 335.55 tCO_2e for ferry vessels in normal and adverse conditions, in addition to, 866.48 tCO_2e for cargo vessels per annum. No assumptions concerning decarbonisation of fleet or variations in annual crossings have been included.

1.7.4 Decommissioning

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

1.7.4.2 The components of the wind turbines are considered to be highly recyclable. When disposing of wind turbines, recycling is the preferred solution. This not only prevents the materials from being sent to landfills, but also reduces the need for the extraction of primary materials. Material which cannot be recycled might be used for incineration or energy from waste. It is considered the same approach can be applied to any cables retrieved during decommissioning. Cables and other infrastructure left in situ during decommissioning will not result in additional emissions during this phase. As such, emissions associated with the disposal of materials at the end of their lifetime is considered to be immaterial and may even result in future avoided emissions. This impact is not assessed further.

1.7.4.3 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 126,387 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 Mona Offshore Wind Project, this is likely to present a conservative maximum design scenario.

1.8 References

ABB (2003) Environmental Product Declaration: Power transformer TrafoStar 500 MVA. Available: https://library.e.abb.com/public/566748ad75116903c1256d630042f1af/ProductdeclarationStarTrafo500.pdf. Accessed December 2023

Committee on Climate Change (2020) The Sixth Carbon Budget: The UK's path to Net Zero. Available: https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf. Accessed December 2023

Crown Estates, 2021, Offshore Wind Leasing Round 4, Delivering a low carbon future. Available:

https://assets.ctfassets.net/nv65su7t80y5/1biBQHUvwdn5c9nB73cPfL/432022ec970c104b82ee2721e3c15862/guide-to-offshore-wind-leasing-round-4.pdf Accessed December 2023

Department for Business, Energy and Industrial Strategy (2019) Contracts For Difference Scheme For Renewable Electricity Generation Allocation Round 3: Allocation Framework, 2019 Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/799074/Allocation_Round_3_Allocation_Framework__2019.pdf Accessed December 2023

Department for Business, Energy and Industrial Strategy (2021) Contracts for Difference Scheme for renewable electricity generation Allocation Round 4: Allocation Framework, 2021. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1035899/cfd-allocation-round-4-allocation-framework.pdf Accessed December 2023

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

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

Department for Energy Security & Net Zero, and Department for Environment, Food & Rural Affairs (2023) UK Government GHG Conversion Factors for Company Reporting. Available at: https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting Accessed December 2023

HM Government (2021) Net Zero Strategy: Build Back Greener. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1033990/net-zero-strategy-beis.pdf Accessed December 2023

IPCC (2013) Climate Change 2013: The Physical Science Basis Available: https://www.ipcc.ch/report/ar5/wg1/ Accessed December 2023

Jones and Hammond (2019) Inventory of Carbon and Energy (ICE) Database. Available: https://circularecology.com/embodied-carbon-footprint-database.html. Accessed December 2023

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

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 December 2023

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 December 2023

WRI and WBSCD (2004) A Corporate Accounting and Reporting Standard Available: https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf Accessed December 2023