Outer Dowsing Offshore Wind

Environmental Statement

Chapter 31 Climate Change

Volume 1

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</table>

Table of Contents

Table of Tables

Table of Plates

Table of Figures (Volume 2)

- This chapter has no figures.

Table of Appendices (Volume 3)

- This chapter has no appendices.

Acronyms & Terminology

Abbreviations / Acronyms

Abbreviation / Acronym	Description
AR	Assessment Report
BEIS	Department for Business, Energy and Industrial Strategy
CCC	Climate Change Committee
CCGT	Combined Cycle Gas Turbine
CH_4	Methane
CO_2	Carbon dioxide
CO_2eq	Carbon dioxide equivalent
DESNZ	Department of Energy Security and Net Zero
DCO	Development Consent Order
DNV	Det Norske Veritas
DUKES	Digest of United Kingdom Energy Statistics
ECC	Export Cable Corridor
EIA	Environmental Impact Assessment
EPP	Evidence Plan Process
ES	Environmental Statement
ETG	Expert Technical Group
GBS	Gravity-Based Structure
GHG	Greenhouse Gas
GT R4	GT R4 or GT R4 Limited, the incorporated joint venture development Co.
GW	Gigawatt
GWP	Global Warming Potential
HVAC	Heating, Ventilation, Air Conditioning
IPCC	International Panel on Climate Change
ISO	International Standards Organisation
ktkm	Thousands of tonne-kilometres (units of freight movement)
kWh	Kilowatt-hour (unit of energy)
LCA	Life Cycle Assessment
MS	Microsoft
N_2O	Nitrous oxide
NCV	Net Calorific Value
NPPF	National Planning Policy Framework
NPS	National Policy Statements
NSIP	Nationally Significant Infrastructure Project
ODOW	Outer Dowsing Offshore Wind, trading name of GT R4 Limited
OnSS	Onshore Substation
ORCP	Offshore Reactive Compensation Platform
OSP	Offshore Platform
OSS	Offshore Substation
PEIR	Preliminary Environmental Information Report
SF_6	Sulphur hexafluoride
SoS	Secretary of State
tkm	Tonne-kilometre (unit of freight movement)
UK	United Kingdom
WTG	Wind Turbine Generator

Terminology

Term	Definition
Baseline	The status of the environment at the time of assessment without the development in place.
Cumulative impact	Impacts that result from changes caused by other past, present, or reasonably foreseeable actions together with the Project.
Development Consent Order (DCO)	An order made under the Planning Act 2008 granting development consent for a Nationally Significant Infrastructure Project (NSIP).
Effect	Term used to express the consequence of an impact. The significance of an effect is determined by correlating the magnitude of the impact with the sensitivity of the receptor, in accordance with defined significance criteria.
Environmental Impact Assessment (EIA)	A statutory process by which certain planned projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the EIA Regulations, including the publication of an Environmental Statement (ES).
Environmental Statement (ES)	The suite of documents that detail the processes and results of the EIA.
Evidence Plan	A voluntary process of stakeholder consultation with appropriate Expert Topic Groups (ETGs) that discusses and, where possible, agrees on the detailed approach to the Environmental Impact Assessment (EIA) and information to support Habitats Regulations Assessment (HRA) for those relevant topics included in the process, undertaken during the pre-application period.
Export cables	High voltage cables which transmit power from the Offshore Substations (OSS) to the Onshore Substation (OnSS) via the Offshore Reactive Compensation Platform (ORCP).
Impact	An impact to the receiving environment is defined as any change to its baseline condition, either adverse or beneficial.
Inter-array cables	The cable which connects the wind turbines to each other and to the offshore substation(s).
Landfall	The location at the land-sea interface where the offshore export cables and fibre optic cables will come ashore.
Mitigation	Mitigation measures are commitments made by the Project to reduce and/or eliminate the potential for significant effects to arise as a result of the Project. Mitigation measures can be embedded (part of the project design) or secondarily added to reduce impacts in the case of potentially significant effects.
National Policy Statements (NPS)	A document setting out national policy against which proposals for Nationally Significant Infrastructure Projects (NSIPs) will be assessed and decided upon
Onshore Export Cable Corridor (ECC)	The Onshore Export Cable Corridor (Onshore ECC) is the area within which the export cables running from the landfall to the onshore substation will be situated.
Onshore Infrastructure	The combined name for all onshore infrastructure associated with the Project from landfall to grid connection.

Term	Definition
Onshore Substation (OnSS)	The Project's onshore HVAC substation, containing electrical equipment, control buildings, lightning protection masts, communications masts, access, fencing and other associated equipment, structures, or buildings; to enable connection to the National Grid
Outer Dowsing Offshore Wind (ODOW)	The Project.
The Planning Inspectorate	The agency responsible for operating the planning process for Nationally Significant Infrastructure Projects (NSIPs).
Preliminary Environmental Information Report (PEIR)	The PEIR was written in the style of a draft Environmental Statement (ES) and provided information to support and inform the statutory consultation process during the pre-application phase.
The Project	Outer Dowsing Offshore Wind, an offshore wind generating station together with associated onshore and offshore infrastructure.
Project Design Envelope	A description of the range of possible elements that make up the Project's design options under consideration, as set out in detail in the project description. This envelope is used to define the Project for Environmental Impact Assessment (EIA) purposes when the exact engineering parameters are not yet known. This is also often referred to as the "Rochdale Envelope" approach.
Receptor	A distinct part of the environment on which effects could occur and can be the subject of specific assessments. Examples of receptors include species (or groups) of animals or plants, people (often categorised further such as 'residential' or those using areas for amenity or recreation), watercourses etc.
Transboundary impacts	Transboundary effects arise when impacts from the development within one European Economic Area (EEA) state affects the environment of another EEA state(s)
Wind Turbine Generator (WTG)	A structure comprising a tower, rotor with three blades connected at the hub, nacelle and ancillary electrical and other equipment which may include J-tube(s), transition piece, access and rest platforms, access ladders, boat access systems, corrosion protection systems, fenders and maintenance equipment, helicopter landing facilities and other associated equipment, fixed to a foundation.

Reference Documentation

Reference number	Document title
5.1.3	Consultation Report
6.1.2	Chapter 2 Need, Policy & Legislation
6.1.3	Chapter 3 Project Description
6.1.4	Chapter 4 Site Selection and Alternatives
6.1.6	Chapter 6 Technical Consultation
6.1.24	Chapter 24 Hydrology and Flood Risk
6.3.24.2	Appendix 24.2 Flood Risk Assessment: Onshore ECC
6.3.24.3	Appendix 24.3 Flood Risk Assessment: Onshore Substation/ Operation.

31 Climate Change

31.1 Introduction

1. This chapter of the Environmental Statement (ES) presents the results to date of the Environmental Impact Assessment (EIA) process for the potential impacts of Outer Dowsing Offshore Wind (the Project) on Climate Change.
2. GT R4 Limited (trading as Outer Dowsing Offshore Wind) hereafter referred to as the 'Applicant', is proposing to develop the Project. The Project will be located approximately 54km from the Lincolnshire coastline in the southern North Sea. The Project will include both offshore and onshore infrastructure including an offshore generating station (windfarm), export cables to landfall, onshore cables, and connection to the electricity transmission network, and ancillary and associated development (see Volume 1, Chapter 3: Project Description (document reference 6.1.3) for full details).

31.2 Statutory and Policy Context

3. The need for the Project arises from the United Kingdom's (UK) Government's ambition to deliver 50GW (gigawatt) of renewable energy from offshore wind by 2030.
4. The commitment to offshore wind targets was originally set out in the Offshore Wind Sector Deal agreed between the Government and the offshore wind industry in 2019. Originally targeting 30GW of operating capacity by 2030, this figure was increased to 40GW in the Energy White Paper published in 2020, as part of the plan for the green industrial revolution. It is a key recommendation of the Climate Change Committee (CCC) that offshore wind should become the backbone of the whole UK energy system, growing from 40GW of capacity in 2030 to 100GW or more by 2050. In October 2021, the UK Government has committed to decarbonise the UK's electricity system by 2035.
5. Most recently, the UK Government has outlined an even greater level of ambition in the British Energy Security Strategy (HM Government, 2022), which sets out an ambition to reach 50GW of offshore wind by 2030. As part of this strategy, investing in offshore wind generation has been listed as one of the key points of the UK Government's '10 Point Plan', contributing to a carbon net zero by 2050. The British Energy Security Strategy is anticipated to support 90,000 jobs in offshore wind by 2028, with a goal of accelerating offshore wind deployment, ensuring energy security, and stabilising consumer prices in the longer term.
6. Details regarding the relevant international obligations on climate change and national climate change and energy legislation are set out in Volume 1 Chapter 2: Need, Policy, and Legislative Context (document reference 6.1.2) of the ES. This Chapter identifies legislation guidance, and national and local policy of relevance to the potential impact of and on climate change associated with construction, operation, and decommissioning of the Project.

7. The Planning Act 2008 (as amended) is the primary legislation that established the legal framework for applying for, examining, and determining applications for Nationally Significant Infrastructure Projects (NSIPs). National Policy Statements (NPS) set the framework for decisions by the Secretary of State (SoS) for Energy Security and Net Zero.
8. In November 2023, the government published revised versions of the NPS documents in reflection of the March 2023 consultation on the draft statements. Since publication, the guidance was updated in January 2024 and through this update, it has come into effect. It is expected that the statements will be reviewed every five years, which will ensure that they reflect evolving policy and legislative changes.
9. The new Overarching NPS for Energy EN-1 (DESNZ, 2023) outlines government strategies for developing significant energy infrastructure to ensure energy security, support economic growth, and transition to low-carbon sources, while also emphasising the importance of promoting long-term sustainable development.
10. The NPS EN-1 notes the change in target and focus since the original iteration of EN-1, which had a target of 80% reduction in Greenhouse Gases (GHG) by 2050, by highlighting the more ambitious target to reach Net Zero by 2050.
11. Part 2 of the NPS EN-1 sets out the government policy context for major energy infrastructure. This includes the need to meet legally binding targets to cut GHG emissions, transition to a low-carbon economy and decarbonise the power sector.
12. Paragraph 1.1.2 of the NPS for Renewable Energy Infrastructure (NPS EN-3) underlines the importance of the generation of electricity from renewable sources by stating that electricity generation from renewable sources of energy is an essential element in the Government's development of a low-carbon economy. It stresses that there are ambitious renewable energy targets in place and that a significant increase in generation from large-scale renewable energy infrastructure is necessary.
13. NPS EN-3 paragraph 1.1.2 states that electricity generation from renewable sources of energy is an essential element of the transition to net zero.
14. Paragraph 5.3.4 of the NPS EN-1 also includes the following requirement in relation to GHG assessment:
    - All proposals for energy infrastructure projects should include a GHG assessment as part of their ES. This should include:
        - A whole-life GHG assessment showing construction, operational and decommissioning GHG impacts, including impacts from change in land use;
        - An explanation of the steps that have been taken to drive down the climate change impacts at each of those stages;
        - Measurement of embodied GHG impact from the construction stage;
        - How reduction in energy demand and consumption during operation has been prioritised in comparison with other measures;

- How operational emissions have been reduced as much as possible through the application of the best available techniques for that type of technology;
- Calculation of operational energy consumption and associated carbon emissions;
- Whether and how any residual GHG emissions will be (voluntarily) offset or removed using a recognised framework; and
- Where there are residual emissions, the level of emissions and the impact of those on national and international efforts to limit climate change, both alone and where relevant in combination with other developments at a regional or national level, or sector level, if sectoral targets are developed.

15. The NPS EN-1 outlines several methods of mitigation the Project should consider:
    - Paragraph 5.3.5 states that "A GHG assessment should be used to drive down GHG emissions at every stage of the proposed development and ensure that emissions are minimised as far as possible for the type of technology, taking into account the overall objectives of ensuring our supply of energy always remains secure, reliable, and affordable, as we transition to net zero;
    - Paragraph 5.3.6 states that "Applicants should look for opportunities within the proposed development to embed nature-based or technological solutions to mitigate or offset the emissions of construction and decommissioning", and
    - Paragraph 5.3.7 "Steps taken to minimise and offset emissions should be set out in a GHG Reduction Strategy, secured under the Development Consent Order. The GHG Reduction Strategy should consider the creation and preservation of carbon stores and sinks including through woodland creation, hedgerow creation and restoration, peatland restoration and through other natural habitats.".
16. Paragraph 157 of the National Planning Policy Framework (NPPF) applies a number of core planning principles that are to underpin planning decision-making, including to support the transition to a low-carbon future in a changing climate. Planning should help to shape places in ways that contribute to radial reductions in GHG emissions and support renewable and low-carbon energy and associated infrastructure.
17. The Climate Change Act 2008 sets legally binding targets for reducing emissions of GHG by 2050. The net UK carbon account for 2050 must be at least 100% lower than the 1990 baseline.
18. The UK Carbon Budgets: to support continuous efforts to achieve Net Zero by 2050 under the UK Climate Change Act 2008, a series of sequential carbon budgets have been developed. Each budget provides a five-year statutory cap on total GHG emissions, which should not be exceeded to meet the UK's emission reduction commitments. These legally binding targets are currently available to the 6^{th} carbon budget period (2033-2037) which became legislation under the Carbon Budget Order 2021, and which came into force on 24 June 2021.

19. The UK's Net Zero Strategy: The 2021 Report to Parliament: Progress in Reducing Emissions highlighted that whilst the UK Government has made historic climate promises, it has been too slow to follow these with delivery. Therefore, sustained reductions in emissions will require a strong Net Zero Strategy. The Strategy includes policies and proposals for decarbonising all sectors of the UK economy to meet net zero by 2050.

31.3 Consultation

20. Consultation is a key part of the Development Consent Order (DCO) application process. Consultation regarding Climate Change has been conducted through the Evidence Plan Process (EPP) Expert Technical Group (ETG) meetings, the EIA scoping process (Outer Dowsing Offshore Wind, 2022) and the Preliminary Environmental Information Report (PEIR) process (Outer Dowsing Offshore Wind, 2023). An overview of the Project consultation process is presented within Volume 1, Chapter 6: Technical Consultation (document reference 6.1.6) and wider consultation is presented in the Consultation Report (document reference 5.1).
21. A summary of the key issues raised during consultation to date, specific to Climate Change, is outlined in Table 31.1 below, together with how these issues have been considered in the production of this ES.

Table 31.1 Summary of consultation relating to Climate Change

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
Scoping Opinion (the Planning Inspectorate, 9 September 2022) Comment ID: 3.23.1 Paragraphs 9.2.15 and 9.2.27	Impacts on climate resilience during construction. The Planning Inspectorate disagrees that within 10 years of construction, the impacts from climate change would not lead to a significant effect as impacts to infrastructure would be limited, particularly at coastal locations. This does not take into account extreme weather events both onshore and offshore or impacts on human receptors (e.g., construction workers). It is not clear whether this will be accounted for in the assessment of major accidents and disasters (Scoping Report paragraphs 9.1.46 to 9.1.59). The ES should assess impacts from climate change over the construction period where significant effects are likely to occur and describe and secure any relevant mitigation measures.	The effects of climate change during construction are likely to be limited to the consequences of flooding as a result of extreme weather events. The effects of such flooding events are assessed in Volume 1, Chapter 24: Hydrology and Flood Risk (document reference 6.1.24) and Appendix 24.2 Flood Risk Assessment: Onshore ECC and Appendix 24.3 Flood Risk Assessment: Onshore Substation.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
Scoping Opinion (the Planning Inspectorate, 9 September 2022) Comment ID: 3.23.2 Paragraphs 9.2.19 to 9.2.20	Impacts on climate resilience during decommissioning. The Scoping Report proposed to scope out climate resilience issues during decommissioning on the basis of the 'short period' over which of decommissioning is expected to occur. The Scoping Report contains no information regarding the length of time decommissioning activities would take place; therefore, the Planning Inspectorate does not agree to scope this matter out of the assessment at this stage. The ES should include an assessment of climate resilience during decommissioning, where likely significant effects could occur, and include an appropriate cross-reference to the assessment of climate resilience matters in other relevant aspect chapters, such as Hydrology, Hydrogeology and Flood Risk, and also the proposed major accidents and disasters assessment matrix (Scoping Report paragraphs 9.1.46 to 9.1.59), as appropriate.	The effects of climate change during decommissioning are considered to be no worse than those for construction and are addressed in Chapter 24: Hydrology and Flood Risk (document reference 6.1.24). The potential effects of climate change have been scoped into the flood risk assessments for all elements of the Project.
Scoping Opinion (the Planning Inspectorate, 9 September 2022) Comment ID: 3.23.3 Paragraph 9.2.21	Cumulative impacts from emissions The Planning Inspectorate agrees that the assessment of GHG emissions against the carbon budgets are inherently cumulative and therefore this will be assessed in the Climate Change aspect chapter rather than as a separate element of the cumulative chapter.	This is addressed within Sections 22 to 31.7.
Scoping Opinion (the Planning Inspectorate, 9 September 2022) Comment ID: 3.23.4 Paragraph 9.2.24	Transboundary climate change Effects The Planning Inspectorate agrees that although climate change is a global issue, the assessment will focus on the UK context and relevant targets and budgets. Therefore, the Planning Inspectorate is content to scope out transboundary effects in relation to climate change.	N/A

22. As identified in Chapter 3: Project Description (document reference 6.1.3) and Volume 1, Chapter 4: Site Selection and Consideration of Alternatives (document reference 6.1.4), the Project design envelope has been refined throughout the stages of the Project prior to DCO submission. This process has been reliant on stakeholder consultation feedback.

31.4 Introduction to GHG Assessment

23. Since the Industrial Revolution, humans have accelerated the release of previously stored carbon (in the form of carbon dioxide) and other gases into the atmosphere, where they act to trap heat and cause global warming. Climate change is the term for this long-term rise in average temperatures, which is also associated with changes to global weather patterns.
24. The climate change impacts of a product, process, service, or installation can be determined using a technique known as Life Cycle Assessment (LCA). The International Standards Organisation (ISO), in its series ISO 14040-44, defines LCA to be the "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle", and outlines the four-step method adopted for this analysis. The sections that follow cover each of these steps, in turn, explaining:
    - Setting the system boundary to define the scope of work;
    - Collecting the necessary data for the modelling;
    - Bringing together the flow data and characterisation factors; and
    - Interpreting and reporting the results.
25. The relative contributions that different so-called GHGs make towards climate change are denoted by the global warming potential (GWP) of each gas, relative to the chosen reference gas, carbon dioxide. Because the gases dissipate at different rates in the atmosphere, the GWP of gases varies according to the timeframe of the analysis. Whilst datasets exist for GWP over 20-year to 500-year timeframes, the usual basis for international analysis and reporting is 100-years (GWP100).
26. Within this timeframe, the United Nations Intergovernmental Panel on Climate Change has published a series of Assessment Reports (AR) to provide the latest scientific opinion on the GWP factors that should be used. While we await the results of the sixth report (AR6), the UK government's carbon reporting factors are currently based on AR5 (International Panel on Climate Change (IPCC), 2014), and so the GWP factors used in this report are based on these. Table 31.2 lists the GWP of all of the gases that make a contribution to the total reported, and no significant emissions are thought to be excluded from the calculations.

Table 31.2 GWP100 factors (from AR5) used in this analysis.

Greenhouse gas	GWP100 factor (in kg CO_2eq per kg)
Carbon dioxide (CO_2)	1
Methane (CH_4)	28
Nitrous Oxide (N_2O)	265
Sulphur Hexafluoride (SF_6)	23,500

31.5 Setting the Goal and Scope for Analysis

27. The first step was to agree on the goal and scope for the analysis, defining what would be within the scope of study and what would not. The topics and the decisions agreed are summarised in Table 31.3.

Table 31.3 Scope of Analysis

Topic	Decision
Study goal:	To identify the life cycle climate change impacts of the Project, in comparison with how its electricity might otherwise be generated.
Scenarios:	One scenario was considered, involving the construction, operation, and decommissioning of the Project.
Time:	The Project is expected to operate for at least 35 years. This means that impacts arising from its decommissioning, as well as those from the later years of its operation, are subject to some level of uncertainty. The approach taken to deal with this uncertainty has generally been to assume the worst case. This is explained in more detail in the relevant sections below.
Geography:	The Project will be located off the coast of East England. Accordingly, the study was founded on operations in the UK and included freight impacts to get materials and components to that region from their points of origin, around the globe. As The Project has not concluded any procurement of major components, it is unable to confirm the origins of the main suppliers at this stage.
Functional unit:	This is the basis for the reporting of the results. Initial calculations sought to estimate the lifetime impacts of the Project. For the purposes of comparing these to the alternative means of electricity generation, impacts are reduced to an average carbon intensity of generation, in g CO_2eq/kWh.
Impact criteria:	A full LCA would examine a wide range of environmental impacts. However, for this Climate Change assessment, it is sufficient to focus solely on global warming potential impacts, over 100 years (GWP100).
Data sources:	The data sources used in this study are discussed in the next section.
Life-cycle stages:	An **attributional approach** was deemed appropriate for this study, looking at the Project's complete impacts across its lifetime. A **systems expansion** approach was adopted to account for the benefits of the electricity generated over its lifetime. This was expected to displace UK marginal electricity, expected to continue to be generated by gas for years to come. A sensitivity was also performed against the Government's "all non-renewables" technology mix. The **"cut-off" approach** was adopted to account for the benefits of recycled content and recyclability at the end of life. Simply put, this means that the Project could be credited with the benefits of using secondary rather than virgin raw materials in its inputs but could not take credit for sending materials to be recycled at the end of life (to avoid double-counting).
Platform:	Calculations were performed in Microsoft (MS) Excel®.
GHG absorption:	High-level calculations estimate that less than 1000t of CO_2e sequestration capacity may be lost over the course of the project. This is far smaller than the other impacts calculated in this report, and so, in line with similar assessments undertaken for other

Topic	Decision
	DCO schemes including Hornsea Project Four, Awel-y-Mor and Norfolk Vanguard offshore windfarms. GHG emissions associated with the loss of GHG absorption capacity are not considered in the assessment. There will also be benefits in respect of ecology and biodiversity net gain (for example, through the mass planting of new trees), which are detailed in Volume 1, Chapter 21: Onshore Ecology.

31.6 Data Collection

28. To model the entire climate change burdens of an offshore windfarm before, during and after an assumed 35 years of operation is a challenge, and involves collecting data from across six key stages of the life cycle:
    - Raw Materials;
    - Manufacturing;
    - Installation;
    - Operation;
    - Freight; and
    - End of Life.
29. The rest of this section provides more detail on the data collected for each of the six stages. The primary source of data for the Project was information regarding the planning, design and construction of the wind farm which has also been used to inform the EIA process to date for the Project.

31.6.1 Raw Materials

30. 'Raw Materials' refers to the environmental impacts embedded in the materials of construction of the wind farm (but not their fabrication or installation, which are covered in later stages). The Project provided details of the materials that are expected to be needed for the construction of, for example, the wind turbine generators (WTGs). This information was supported with data provided in a bespoke template, on the amounts of materials expected to be used in the construction. The main components and weights are listed in Table 31.4. For the purposes of undertaking a robust, worst-case analysis, it was assumed that none of these materials would contain recycled content, instead being produced from newly extracted materials.
31. The Project is considering the potential to install four possible WTG foundation types, as discussed in Chapter 3 (Document Reference: 6.1.3). Following initial investigations of the four foundation types, it was found that the quantities of concrete and steel required for jacket/pile foundations and gravity-based structures (GBSs) were considerably greater than for monopile or suction bucket foundations. As such, to ensure a worst-case scenario approach, the assessment has been based on the WTG foundations, either using a 50:50 combination of jacket/pile foundations and GBSs (50:50) or just 100% jacket/pile foundations (100% Jacket).

Table 31.4 Main materials in Project components, and their amounts (indicative values)

Description	Detail	50:50	100% Jacket	Units
WTG Foundation	Steel	194,294	383,475	t
	Cement	418,608	826,200	t
	Concrete	298,627	0	m^3
OSP Foundation	Steel	8,831		t
	Cement	300		t
OSP Topside	Steel	8,636		t
ORCP Foundation	Steel	8,831		t
	Cement	300		t
ORCP Topside	Steel	8,636		t
WTG Tower	Steel	37,558		t
	Aluminium	1,162		t
WTG Blades	Carbon fibre	8,730		t
	Wood	69,840		m^3
WTG Nacelle	Copper	4,029		t
	Other	76,551		t
	Oil & Grease	1		t
Inter-array cables	Aluminium (*)	12,476		t
Interlink cables	Aluminium (*)	5,638		t
Offshore export cables	Copper	22,584		t
	Lead	16,705		t
	Steel	31,495		t
Landfall cables	Copper	67		t
	Lead	33		t
	Steel	109		t
Onshore export cables	Copper	30,413		t
	Lead	22,493		t
	Steel	42,413		t
Onshore Substation	Concrete	11,800		m^3
	Fill	397,320		t
	Fencing	6		t
	Reinforcement	1,400		t
	Chippings	13,944		t
	Drainage	4		t
	Structural Steel	2,800		t
	Cladding	14,200		m^2
	Asphalt	15,400		m^3
	Steel	500		t

Description	Detail	50:50	100% Jacket	Units
Fluids & Gases	Oil & Grease	3,145		t
	Diesel	157		t
	SF6	47		t
	Battery	3,310		t

(*) The cables may be made from aluminium or copper. As the former has about three times the GWP, only aluminium was assumed as the worst-case scenario.

31.6.2 Manufacturing

32. Some of the values in the above section simply cover the production of, for example, a tonne of steel. Further emissions are embedded during the manufacturing of the wind farm components from those materials. From experience, it is not practical to gather actual manufacturing data for all components, and many would make a negligible contribution to the final impacts, but it was deemed appropriate to estimate the manufacturing burdens for some of the materials, as detailed in Table 31.5. The quoted weights were deduced from all of the data described above and, for steel, are presented for the two foundation scenarios described in paragraph 31.

Table 31.5 Materials weights separately assigned manufacturing burdens

Description	Detail	50:50	100% Jacket	Units
Metal working	Aluminium	19,276		t
	Copper	133,644		t
	Lead	39,231		t
	Steel	345,509	534,690	t
Plastic pipe production	Polyethylene	10		t

31.6.3 Installation

33. Installation covers the effort associated with constructing the Project and is primarily related to the transport requirements from the source to the site. For the different aspects of the installation, the typical assumed single-trip distances are presented in Table 31.6.

Table 31.6 Installation travel distances in km

Vessel	Distance (km)
Helicopters	75
Foundations	534
WTGs	158
Cables	845
OSPs	280

34. Estimations were provided of the anticipated numbers of journeys that will be required by a range of vessels, as shown in Table 31.7. Combining these data led to the deduction of the total activities also presented in the table.

Table 31.7 Vessel activities during installation

Vessel	Total Movements	Total Activity	Units
Helicopter	375	96	hr
Cable-burial	32	54,080,000	tkm
Cable-jointing	16	27,040,000	tkm
Cable-laying	42	70,980,000	tkm
Installation	118	99,710,000	tkm
Support	3,662	1,547,195,000	tkm
Transport	793	335,042,500	tkm

35. An estimate of the piling work (energy per blow, strikes per pile, piles per turbine and total number of turbines) that would be necessary to construct the windfarm, led to an estimation of 1,800TJ of energy. This is assumed to be delivered by diesel (with a Net Calorific Value (NCV) of 43GJ/t).

31.6.4 Operation

36. During the operation of the Project, many trips will again be needed to keep the installation in good working order. The anticipated numbers of annual journeys are presented in Table 31.8.

Table 31.8 Vessel activities during operation and maintenance (per year)

Vessel	Total Movements	Total Activity	Units
Helicopter	1,968	531	hr
Transport vessel	1,968	831,480,000	tkm

37. The maintenance work will include regular replacement of various materials, listed in Table 31.9.

Table 31.9 Anticipated materials needed (per infrastructure item per year) during operation.

Material	Turbine	Substation	Units
Grease	2,400	0	l
Hydraulic oil	4,700	0	l
Gear oil	9,500	0	l
Nitrogen	295,600	0	l
Transformer silicon/ester oil	35,500	0	l
Diesel fuel	2,400	47,300	l
SF6	500	11,800	kg
Glycol/Coolants	70,900	0	l

38. It is also anticipated that the Project will consume a relatively low level of grid electricity itself, in order to enable its efficient operation. There is some uncertainty about the level involved, however, the estimate used in these calculations is 5,446 MWh/year.

31.6.5 Freight

39. In addition to the vessel movements already described, the calculations consider the freight that will bring the construction and maintenance materials to the local area, and (at end of life) remove the materials for recycling or disposal. The estimated total additional amounts of freight movements required, in thousands of tonne-kilometres (ktkm) by road and by sea, are presented in Table 31.10, for the two foundation scenarios described in para 31.

Table 31.10 Additional anticipated freight requirements

	Road ktkm		Ship ktkm	
Stage	50:50	100% Jacket	50:50	100% Jacket
Raw Materials	114,273	119,455	14,950,775	17,481,438
Manufacturing	0		0	
Construction	0		0	
Operation	1,500		0	
End of Life	135,903	191,077	0	
Total	**251,677**	**312,032**	**14,950,775**	**17,481,438**

31.6.6 Decommissioning (End of Life)

40. It is difficult to be certain what will happen to the Project's materials at the end of life, simply because this will not occur for at least another 35 years, by which time, the state of available technology may be very different. To a large extent, however, the choice of the "cut-off" approach to accounting for recycled content and recycling means this is less critical.

41. In that accounting framework, the Project could be given credit for any recycled materials used in its lifetime, as these (typically) contain less embedded carbon than the virgin materials they replace. In reality, as described in the Materials section above, it has been assumed that all materials are virgin. At the end of life, the materials are charged with the further burdens of their management, until they reach their final resting place, or are ready to become new materials.

42. For wind turbine infrastructure, this means that the transport elements at the end of life must be included, but once the materials reach the point where they are ready to be recycled, they exit the analysis boundary and are not further considered. Moreover, for the materials that are landfilled, associated emissions should be included, however, it is anticipated that there should be little if anything emissions of the materials whilst in a landfill, so the burden is reduced to the freight impacts previously mentioned above.

31.7 Life Cycle Impact Assessment

43. By bringing all the above information together, and applying appropriate characterisation factors, a first estimation was determined.

31.7.1 Characterisation factors

44. Three sources were used to estimate the unit impacts of the different flows required across the lifetime model of the wind farm, as follows:

- For three factors (as well as some energy unit conversions), it was necessary to use the UK Government's "conversion factors for company reporting of greenhouse gas emissions" (UK Government, 2023). These are themselves based on the Fifth Assessment Report (AR5) from the International Panel on Climate Change (IPCC, 2014);
- For one factor, Circular Ecology's Inventory of Carbon and Energy dataset (Circular Ecology, 2023) was used; and
- All the remaining characterisation factors were taken from the ecoinvent database (2023). To ensure consistency with the UK Government's data, the method used was the same IPCC 2014 data from the AR5 report.

45. This selection of sources for the characterisation factors means that all impacts are reported as emissions of GHGs that contribute to climate change, considered over a 100-year period, relative to the impact of carbon dioxide, so in units of weight of carbon dioxide equivalents.

31.7.2 Climate Change Results

46. Applying the chosen characterisation to the inventory of flows generated during the data collection, and summation by life cycle stage, led to the compilation of the initial results presented in Table 31.11 below.

Table 31.11 Climate change impact (in t CO_2eq (tonnes of Carbon Dioxide Equivalent)) contributions from each life cycle stage

	GWP100a (t CO_2eq)	
Life Cycle Stage	50:50 Foundations	100% Jacket/Pile
Raw Materials	3,357,000	3,987,000
Manufacture	1,289,000	1,676,000
Transport	190,000	224,000
Installation	22,000	22,000
Operation and Freight	362,000	362,000
End of Life	0	0
Total	**5,220,000**	**6,271,000**

47. The results show that the Project's materials (and their manufacture) make the largest contribution to the overall impact. In contrast, despite the large number of vessel movements throughout the lifetime, the impacts from transport are relatively insignificant. Equally, the uncertainty around the levels of electricity consumed by the Project is unlikely to be material, as the operation phase impacts are of the order of a thousand times smaller than materials and manufacturing.

48. Table 31.11 also shows that, of the two foundation scenarios investigated, the first (a 50:50 combination of jacket/pile foundations and gravity-based structures) has a smaller impact than the use of the 100% jacket/pile foundation scenario would.

31.7.3 Carbon Intensity Calculation

49. 5.2Mt CO_2eq is a significant amount of carbon emissions for the Project over its lifetime, but this should be assessed in the context of the electricity it will generate. To determine that, it is necessary to estimate the Load Factor of the installation. This factor is used to convert from the total "design" energy that a wind farm could generate (the product of the rated total turbine power and the number of hours in a year) to the amount of actual electricity that would be generated. It is a factor of availability, system efficiency and wind capture.
50. Three references for plausible load factor values were found through a literature review. The most optimistic comes from the Department for Energy Security and Net Zero (DESNZ), who, for future Contracts for Difference calculations, for new-build windfarms to be delivered in the period 2025-2028, suggest a load factor value of 61.5% for offshore windfarms (DESNZ, 2023).
51. A much more pessimistic load factor of 40.58% for offshore wind is reported by RenewableUK, calculated as a rolling average of the past five years of data from the Digest of UK Energy Statistics (DUKES) from DESNZ (RenewableUK, 2023).
52. A third reference comes from a report by Det Norske Veritas (DNV) for the Department for Business, Energy, and Industrial Strategy (BEIS, 2019[1]), looking at ways to improve offshore wind load factors. This offers a mid-value of 52.9%, with an uncertainty of 6.9%. The three values are presented together schematically below.
53. The plot also includes the figures used for these calculations. It was decided to take the precautionary approach and adopt the most pessimistic load factor (40.58%, from RenewableUK) for the default calculations, but then to look at the consequences if the Project achieved the BEIS mid-value load factor of 52.9%.

[1] Now Department of Energy Security and Net Zero

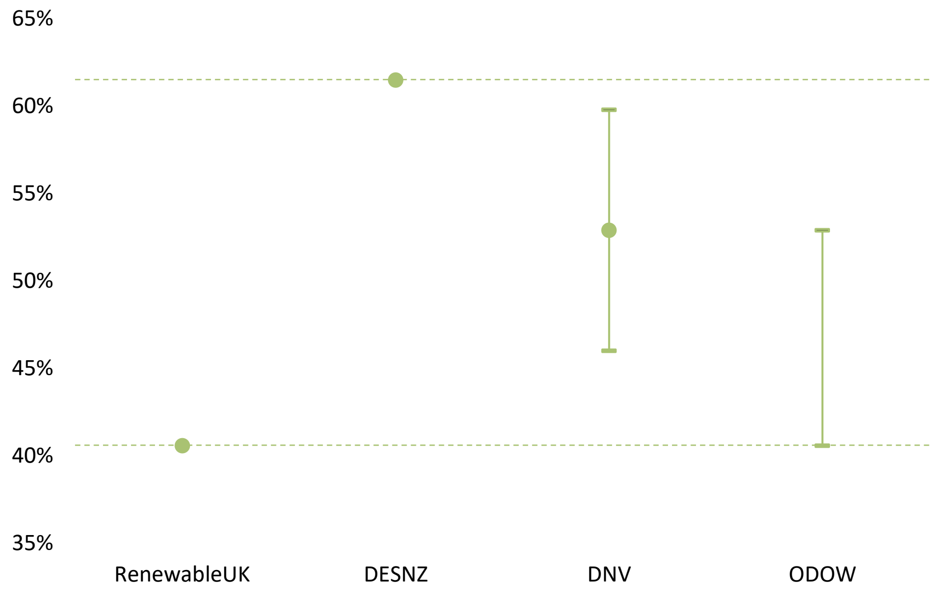

Plate 31.1 Offshore Wind Load Factors from Literature, and for this Project.

54. Applying the load factor of 40.58% to the 1,500MW of installed capacity leads to estimated annual electricity production levels of the order of 5,332GWh/yr. Running at this rate for 35 years, the Project will generate 187,000GWh of electricity over its lifetime. Dividing the aforementioned 5.2Mt CO2eq of carbon emissions (for the 50:50 foundation split) across this electricity generated yields the average carbon intensity of the electricity over the Project's lifetime:

- Project carbon intensity $= \frac{\text{Lifetime carbon emissions}}{\text{Lifetime electricity generated}} = \frac{5{,}220{,}000}{187{,}000} =$ 28.0t/GWh (or g/kWh)

55. The equivalent value for 100% jacket/pile foundations is 33.6g CO_2eq/kWh (Kilowatt-Hour).

31.7.4 Pay Back Period

56. It is common practice to determine the Project's carbon "pay-back" period – that is, how long into the lifetime of the wind farm before the carbon emissions associated with its construction are counter-acted by the lower carbon emissions of the electricity it generates, relative to the source it would be replacing. To perform this calculation, it is necessary to determine how the electricity would otherwise be generated. It is accepted that, when the wind farm comes online, its additional electricity will not replace nuclear or other renewable generating technologies. Rather, it will displace whatever generation technology would have been "the last to be turned on" – not the grid mix, therefore, but the so-called "marginal mix". In the UK, for the foreseeable future, the marginal mix technology is gas, which has a carbon intensity of about

371g/kWh[2]. Alternatively, RenewableUK recommends[3] using the DUKES “all non-renewable fuels” emission factor of 424g/kWh[2].

57. Multiplying these intensities by the 5,332GWh of electricity generated each year reveals that the counterfactual-sourced electricity would be responsible for 1.9Mt CO_2eq (gas) or 2.3Mt CO_2eq (all non-renewables) each year. The cumulative impact of this over the first four years of operation is compared in Plate 31.2 with the total lifetime impact for the Project. As the annotation shows, under the assumptions outlined above, the Project would be expected to achieve carbon payback in about two to three years (and then deliver annual savings for each of the following 33 years of operation).

58. Another way of looking at this is to determine the cumulative GWP emissions from 35 years of the alternative electricity sources. These turn out to be 69 (gas) or 79Mt CO_2eq (all non-renewables), which are between 11 and 15 times the lifetime carbon emissions of the Project, depending on the choice of foundations.

[2] Taken from DUKES 2023 data, Table 5.14.

[3] See https://www.renewableuk.com/page/UKWEDExplained

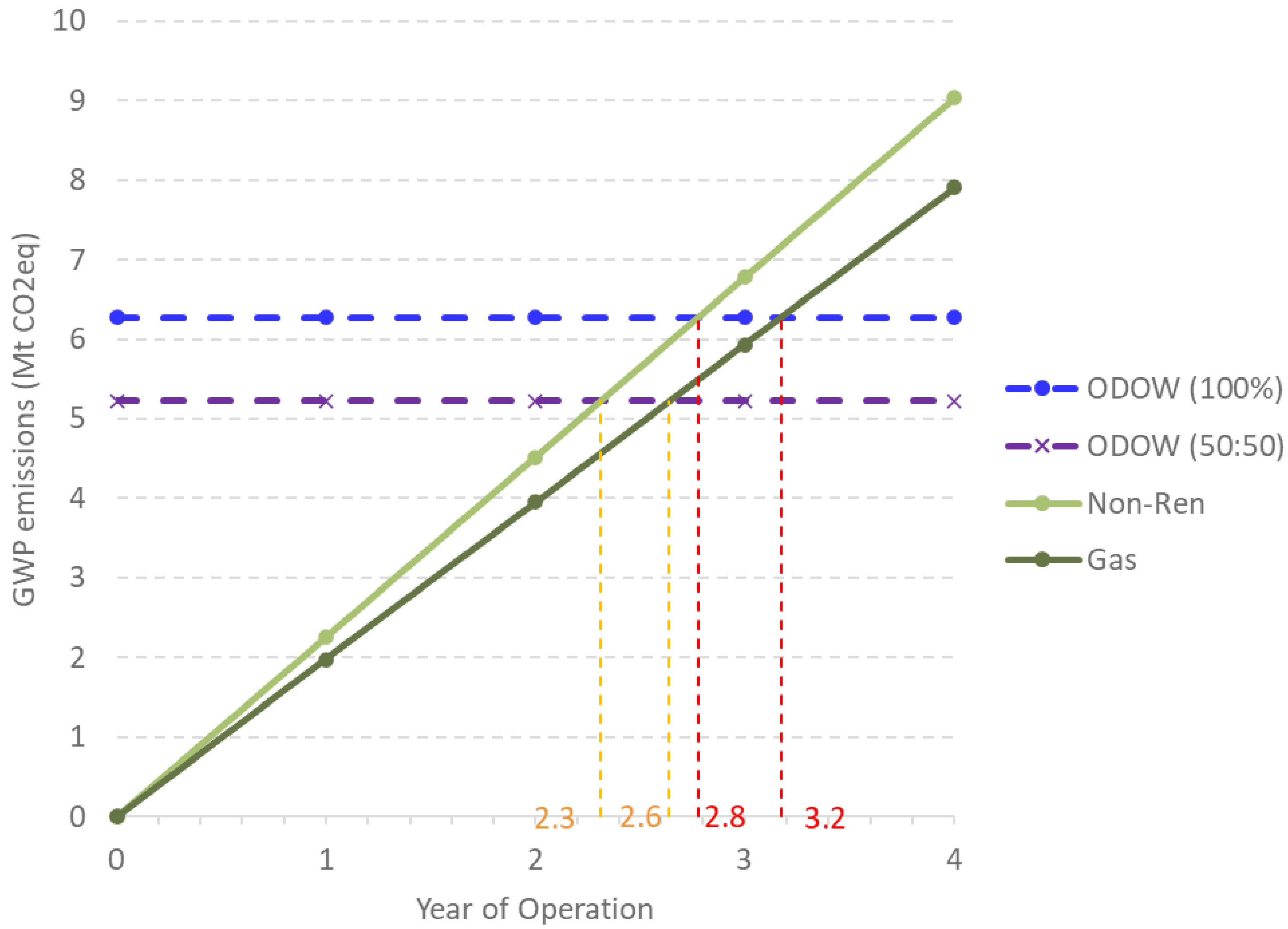

Plate 31.2 Cumulative GWP emissions from Project versus counterfactuals.

31.7.5 Sensitivity Testing

59. As demonstrated in Plate 31.2, it is good practice to explore how the results might depend on important uncertainties or assumptions in the underlying data. In this instance, the results are quite conclusive that the Project is 11-15 times better than the likely counterfactual electricity alternatives. However, it is still instructive to explore how much the values might change, based on changes in the underlying data. In this section, two further checks are performed below.

31.7.5.1 Load Factor and Annual Electricity Production

60. The initial calculations used the most pessimistic load factor assumption (40.58%), from RenewableUK based on the last five years of data. A more optimistic alternative is the mid-value load factor of 52.9% from BEIS/DNV.
61. Moving to this load factor increases the annual electricity production (for the 50:50 foundation scenario) from 5,332GWh to 6,951GWh, dropping the pay-back period from 2.3-2.6 years down to 1.8-2.0 years.
62. Plate 31.1 shows that the 40.58% is at the low end of the likely scale for load factors, but, for sensitivity testing, what if the electricity generated were even lower, say by 10%? This would reduce production to 4,799GWh, and increase the pay-back period to 2.6-2.9 years. This is still far shorter than the Project's anticipated 35-year operating life.
63. The conclusion from these results is that the Project's carbon payback is relatively robust to uncertainties around the exact amount of electricity that will be generated.

31.7.5.2 Construction Burdens

64. As there are some uncertainties about the exact details surrounding the materials to be used for the Project, it was decided to explore how the results would change if the material burdens were double the originally estimated values. In this scenario, the Project would take 4.5-5.1 years to pay back its carbon burden, once again demonstrating the strong carbon benefit of the Project.

31.8 Summary

65. This study has performed an LCA of the Project. The scope considered impacts across the whole life cycle, from the production of the raw materials used to construct the facility, all the way through to the recycling or disposal of those same materials after decommissioning at the end of its lifetime.
66. The GHG emissions across an assumed 35-year lifetime operation are estimated to be 5.2Mt CO_2eq (using a 50:50 combination of jacket/pile and gravity-based structure (GBS) foundations). The Project is expected to produce 5,332GWh of electricity each year, meaning the carbon intensity of the electricity generated will be about 28.0g CO_2eq/kWh.
67. When compared with the alternative of generating the electricity by gas combined cycle gas turbine (CCGT) (with a carbon intensity of 371g CO_2eq/kWh) or "all non-renewables" (424g CO_2eq/kWh), the Project will pay back the embedded emissions in its construction in about two to three years.

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