Sheringham Shoal and Dudgeon Offshore Wind Farm Extension Projects

Environmental Statement

Volume 3

Appendix 4.2 - Greenhouse Gas Footprint Assessment

August 2022
Document Reference: 6.3.4.2
APFP Regulation: 5(2)(a)

Title:	
Sheringham Shoal and Dudgeon Offshore Wind Farm Extension Projects **DCO Application** **Appendix 4.2 Greenhouse Gas Footprint Assessment**	
PINS no.: 6.3.4.2	
Document no.: C282-RH-Z-GA-00114	
Date:	Classification
August 2022	**Final**
Prepared by:	
Royal HaskoningDHV	
Approved by:	Date:
Sarah Chandler, Equinor	August 2022

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Glossary of Acronyms

AC	Alternating Current
BEIS	Department for Business, Energy and Industrial Strategy
CBS	Concrete Bound Sand
CCC	Committee on Climate Change
COP26	26th Annual Conference of Parties
CO_2e	Carbon Dioxide Equivalent
$CO_2e.kWh^{-1}$	Carbon Dioxide Equivalent per Kilowatt-Hour
CTV	Crew Transfer Vessels
DCO	Development Consent Order
DEP	Dudgeon Offshore Wind Farm Extension Project
DfT	Department for Transport
DOW	Dudgeon Offshore Wind Farm
EC	European Commission
EIA	Environmental Impact Assessment
ES	Environmental Statement
EU	European Union
GHG	Greenhouse Gas
GRP	Glass Reinforced Plastic
GW	Gigawatt
GWP	Global Warming Potential
HDD	Horizontal Directional Drilling
HGV	Heavy Goods Vehicle
HVAC	High Voltage Alternating Current
ICE	Inventory of Carbon and Energy
IEMA	Institute of Environmental Management & Assessment
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
kW	Kilowatt
kWh	Kilowatt-hour
LCA	Life Cycle Analysis
MGO	Marine Gas Oil
MW	Megawatts

NRMM	Non-Road Mobile Machinery
O&M	Operation and Maintenance
OSP	Offshore Substation Platform
SEP	Sheringham Shoal Offshore Wind Farm Extension Project
SOV	Service Operation Vessel
SOW	Sheringham Shoal Offshore Wind Farm
UK	United Kingdom
UNFCCC	UN Framework Convention on Climate Change

Glossary of Terms

Carbon Dioxide Equivalent (CO_2e)	Carbon dioxide equivalent is a term for describing different greenhouse gases in a common unit. The unit takes the different global warming potentials of greenhouses gases into account. CO_2e is signifies the amount of CO_2 which would have the equivalent global warming impact.
Cradle-to-factory or cradle to (factory) gate	A term which includes the extraction, manufacture and production of materials to the point at which they leave the factory fate of the final processing location
Dudgeon Offshore Wind Farm Extension Project (DEP)	The Dudgeon Offshore Wind Farm Extension onshore and offshore sites including all onshore and offshore infrastructure.
Global Warming Potential (GWP)	Global Warming Potential of a greenhouse gas (GHG) is a measure of how much heat is trapped by a certain amount of gas in the atmosphere relative to carbon dioxide.
Greenhouse gas (GHG)	A greenhouse gas is a gas that traps heat in the atmosphere and causes the greenhouse effect.
Horizontal directional drilling (HDD) zones	The areas within the onshore cable corridor which would house HDD entry or exit points.
Infield cables	Cables which link the wind turbine generators to the offshore substation platform(s).
Interlink cables	Cables linking two separate project areas. This can be cables linking: 1) DEP South and DEP North 2) DEP South and SEP 3) DEP North and SEP 1 is relevant if DEP is constructed alone or first in a phased development. 2 and 3 are relevant in an integrated construction.
Integrated Grid Option	Transmission infrastructure which serves both extension projects.
Landfall	The point at the coastline at which the offshore export cables are brought onshore and connected to the onshore export cables.

Offshore export cables	The cables which would bring electricity from the offshore substation platform(s) to the landfall. 220 – 230kV.
Offshore substation platform (OSP)	A fixed structure located within the wind farm area, containing electrical equipment to aggregate the power from the wind turbine generators and convert it into a more suitable form for export to shore.
Onshore cable corridor	The area between the landfall and the onshore substation sites, within which the onshore cable circuits will be installed along with other temporary works for construction.
Onshore export cables	The cables which would bring electricity from the landfall to the onshore substation. 220 – 230kV.
Onshore Substation	Compound containing electrical equipment to enable connection to the National Grid.
Sheringham Shoal Offshore Wind Farm Extension Project (SEP)	The Sheringham Shoal Offshore Wind Farm Extension site as well as all onshore and offshore infrastructure.
The Applicant	Equinor New Energy Limited.
Transition joint bay	Connects offshore and onshore export cables at the landfall. The transition joint bay will be located above mean high water.

4.2 GREENHOUSE GAS FOOTPRINT ASSESSMENT

4.2.1 Introduction

1. This report presents an assessment of the greenhouse gas (GHG) footprint of the Sheringham Shoal Offshore Wind Farm Extension Project (SEP) and Dudgeon Offshore Wind Farm Extension Project (DEP).
2. This assessment contains a quantified assessment of GHG emissions over the lifetime of SEP and DEP considering both onshore and offshore components of the development and detailing construction (SEP and DEP built in isolation, sequentially and concurrently), operation and maintenance (O&M) and decommissioning aspects.
3. The GHG footprint for SEP and DEP accounts for four main source groups, which are listed below:
    - Embodied carbon within materials used for the onshore and offshore components of SEP and DEP;
    - Emissions associated with the movement of marine vessels;
    - Emissions associated with the movement of road traffic vehicles; and
    - Emissions from the use of plant and equipment during construction.
4. GHG calculations were derived using available information at the time of the assessment, which included emissions from the sources listed above.
5. During 2021, 54.5% of electricity consumed in the UK was generated by ‘low carbon’ sources such as nuclear, solar, biomass and wind. Approximately 43% of the generation share was from fossil fuels, which primarily comprised gas. Energy consumption in 2021 remained low, down 9% on 2019, but had increased compared to 2020. Energy generation within the UK was 14% lower in 2021 compared to 2020, and was the lowest level in over 50 years. Renewable generation (as a percentage of generation) reached a record 43% in 2020, but dropped slightly to 40% of generation in 2021 due to less favourable weather conditions for renewable generation. However, the UK’s electricity generation landscape continued to evolve towards more renewable alternatives (BEIS, 2022a).
6. The current installed generating capacity of onshore and offshore wind farms is 25.5 gigawatts (GW) – 14.2 GW and 11.3 GW of onshore and offshore capacity respectively (RenewableUK, 2022a). SEP and DEP will each have a maximum export capacity greater than 100 megawatts (MW) and therefore would contribute significantly to the decarbonisation of the UK energy supply.

4.2.1.1 Purpose of Document

7. The purpose of the GHG footprint assessment is to quantify emissions associated with SEP and DEP as a whole (both concurrent and sequential construction) and as separate projects (either SEP or DEP alone) for both the onshore and offshore components. Existing literature was used to place the outcomes of the GHG footprint in the context of the wider offshore wind industry, and to provide a benchmark to verify the outcomes of the assessment.

8. The requirement to consider climate and GHG emissions has resulted from the 2014 amendment to the Environmental Impact Assessment (EIA) Directive (2014/52/EU), and the Infrastructure Planning (EIA) Regulations 2017 ('EIA Regulations'). This includes the requirement to include an estimate of expected emissions and the impact of a project on climate, including consideration of the nature and magnitude of the release of GHGs during construction and operation.

9. Recently published Institute of Environmental Management & Assessment (IEMA) 'Assessing Greenhouse Gas Emissions and Evaluating their Significance' guidance (2022) was used in the discussion and evaluation of the significance of any potential GHG impacts of the SEP and DEP.

4.2.1.1.1 Project Background

10. The Applicant is seeking a Development Consent Order (DCO) for the Sheringham Shoal Offshore Wind Farm Extension Project (SEP) and Dudgeon Offshore Wind Farm Extension Project (DEP) which are extensions to the existing Sheringham Shoal Offshore Wind Farm (SOW) and Dudgeon Offshore Wind Farm (DOW), located in the southern North Sea off the north Norfolk Coast, with the closest point to the coast being 15.8km from SEP and 26.5km from DEP.

11. SEP and DEP would each have maximum export capacity greater than 100 MW. SEP will consist of between 13 and 23 turbines, each having a rated electricity capacity between 15 MW and 26 MW. DEP will consist of between 17 and 30 wind turbines, each having a rated electrical capacity of between 15 MW and 2 6MW. Taken together, there will be between 30 and 53 wind turbines and have the combined potential to generate renewable power for up to 785,000 United Kingdom (UK).

4.2.1.1.2 Key Components of SEP and DEP

4.2.1.1.2.1 Offshore

12. SEP and DEP would comprise the following main offshore components:
- Wind turbines and their associated foundations;
- Offshore substation platform/s (OSP/s) and associated foundation/s; and
- Subsea cables and cable protection – offshore export cables, infield cables and interlink cables.

13. Electricity would flow from the wind turbines via infield (array) cables to offshore substation platform(s). There will be up to two offshore substations with one in SEP and one in DEP, located to optimise the length of the offshore cables. Interlink cables will link the separate SEP and DEP offshore sites. At the offshore substation/s, the generated power will be transformed to a higher alternating current (AC) voltage. The power will be exported through two export cables, in two separate trenches, to a landfall east of Weybourne on the north Norfolk coast. At the landfall the offshore export cables will meet and be joined up with the onshore export cables in a transition joint bay.

4.2.1.1.2.2 Onshore

14. The onshore export cables would then travel approximately 60km inland to a high voltage alternating current (HVAC) onshore substation near to the existing Norwich Main substation. The onshore substation would be constructed to accommodate the connection of both SEP and DEP to the transmission grid.

15. The main onshore components of SEP and DEP include:
    - Landfall including transition joint bay;
    - Up to two ducts installed under the beach at the landfall by Horizontal Directional Drilling (HDD);
    - Onshore cable corridor, including:
        - Onshore export cables laid within open cut trenches or installed in ducts, and associated infrastructure including joint bays and link boxes;
        - Temporary construction access roads and haul roads;
        - Construction compounds; and
        - Trenchless crossings at sensitive features and habitats (e.g. A roads, main rivers and sites designated for nature conservation).
    - Onshore substation, including:
        - Substation operational access road; and
        - Associated earthworks, surface water attenuation and/or landscaping.

16. Further details of the key components of offshore and onshore infrastructure can be found in **Chapter 4 Project Description** of the Environmental Statement (ES) (document reference 6.1.4).

4.2.1.1.3 Scenarios

17. The various construction and operation scenarios are presented in detail in **Chapter 4 Project Description** of the Environmental Statement (ES) (document reference 6.1.4). A summary of these is scenarios are detailed in below.

4.2.1.1.3.1 Construction Scenarios

18. In the event that both SEP and DEP are built, the following principles set out the framework for how SEP and DEP may be constructed:
    - SEP and DEP may be constructed at the same time, or at different times;
    - If built at the same time both SEP and DEP could be constructed in four years;
    - If built at different times, either Project could be built first;
    - If built at different times, each Project would require a four year period of construction;
    - If built at different times, the offset between the start of construction of the first Project, and the start of construction of the second Project may vary from two to four years;

- Taking the above into account, the maximum construction period over which the construction of both Projects could take place is eight years; and
- The earliest construction start date is 2025 and the latest is Q4 2028 assuming DCO award in Q4 2023.

4.2.1.1.3.2 Operation Scenarios

19. Three operation scenarios exist for the Project, these are:
    - Only SEP in operation;
    - Only DEP in operation; and
    - The two Projects operating at the same time, with a gap of two to four years between each Project commencing operation.
20. The operational lifetime of each Project is expected to be 40 years.

4.2.1.1.3.3 Decommissioning Scenarios

21. Decommissioning scenarios are described in detail in **Chapter 4 Project Description** (document reference 6.1.4). Decommissioning arrangements for the onshore elements of SEP and DEP will be agreed through the submission of an onshore decommissioning programme to the relevant planning authority for approval within six months of the permanent cessation of commercial operation (unless otherwise agreed in writing by the relevant planning authority), however for the purpose of this assessment it is assumed that decommissioning of SEP and DEP could be conducted separately, or at the same time.

4.2.1.1.4 Context

22. The construction, O&M and decommissioning of wind farm projects entail the generation of GHG emissions, both from the standpoint of:
    - Embedded carbon and GHGs – the emissions caused by the extraction and refinement of raw materials and their manufacture into the commodities and products that make up the components of the wind turbines and their associated physical infrastructure; and
    - Carbon and other GHG emissions arising from the combustion of fuels and energy used in constructing, operating and maintaining SEP and DEP components over its lifetime and in decommissioning.
23. There are inherent uncertainties associated with carrying out GHG footprint assessments for offshore wind power projects, although the approach to determine emissions from individual source groups (see **Section 4.2.3.2**) is well defined.
24. A report published by the University of Edinburgh in 2015 (Thomson & Harrison, 2015) examined the lifecycle costs and GHG emissions associated with offshore wind energy projects, comparing data gleaned from the analysis of some 18 studies carried out over the period 2009 to 2013 (Thomson & Harrison, 2015). This report provided useful context for the SEP and DEP GHG assessment, and benchmark figures which were used to verify the outcomes of the assessment.

25. **Table 4.2-1** provides a summary of the percentage of total GHG emissions associated with the different phases of a wind farm development as provided within the report (Thomson & Harrison, 2015).

Table 4.2-1:Summary of Offshore Wind Farm GHG Emissions (Thomson & Harris, 2015)

Phase	% of Total GHG Emissions
Manufacture and Installation	78.4
O&M	20.4
Decommissioning	1.2

26. The report highlighted that the greatest proportion of emissions are associated with the manufacture and installation of the wind farm components. Decommissioning accounted for the smallest proportion, only 1.2%, of total life cycle GHG emissions. A more detailed breakdown of emissions is given in the Thomson & Harris (2015) report for an offshore wind farm with steel foundations (as is SEP and DEP). This is reproduced in **Table 4.2-2**.

Table 4.2-2: Further Detailed Breakdown of GHG Emissions (Thomson & Harris, 2015)

Component or Phase	% of Total GHG Emissions
Foundations	34.7
Turbines	23.8
Cables & transformers	19.8
Maintenance shipping	14.3
Spare parts	3.7
Maintenance helicopter	2.4
Dismantling and disposal	1.2

27. Of the components or phases listed in **Table 4.2-2**, GHG emissions associated with foundation fabrication and installation accounted for the largest proportion of emissions (34.7%), followed by manufacture and installation of the turbines (23.8%) and the cables and transformers (19.8%). GHG emissions from shipping movements during maintenance operations over the operational lifetime of the wind farm contributed 14.3%[1].

28. This may appear to be unexpectedly high, but the vessel movements contribution is associated with a 20-year operational lifespan of the wind farms considered in the studies. Emissions derived from spare parts (3.7%), helicopter movements (2.4%) and dismantling and disposal (1.2%) are all small, in comparison.

[1] Shipping GHG emissions associated with installation of the wind farm components are included within the first three categories in **Table 4.2-2**.

29. Additional analysis of the data extracted from the 18 technical studies expressed the GHG emissions as grammes (g) of carbon dioxide equivalent (CO_2e) per kilowatt-hour (kWh) of electricity generated. These were found to vary quite widely, between approximately 5 and 33 g carbon dioxide equivalent per kilowatt-hour ($CO_2e.kWh^{-1}$). There was no clear relationship between the metrics and either turbine rating (in MW) or capacity factor.

30. A further study in 2012 (Dolan & Heath, 2012), amassed the results of over 200 studies of carbon emissions from wind power and attempted to "harmonise" the results to use only the most robust and reliable data and to align methodological inconsistences. The harmonised results of this study revealed that the range in GHG emissions per kWh of electricity generated varied between approximately 7 and 23 g $CO_2e.kWh^{-1}$, with a mean value of around 12 g $CO_2e.kWh^{-1}$.

31. It is acknowledged that the Dolan & Heath study is 10 years old and there have been a number of developments in the offshore wind sector since the analysis was undertaken. The methodological approach to the study is still considered to be robust, and results provide a useful benchmark for the carbon intensity figures determined for SEP and DEP.

32. To place these metrics into context, comparable values for electricity generation by gas are around 371 g $CO_2e.kWh^{-1}$ (30.9 times that of offshore wind) and, for coal, approximately 985 g $CO2e.kWh^{-1}$ (82.1 times that of offshore wind) (BEIS, 2020).

33. Although robust and fit for purpose, this report should not be taken to be a comprehensive, detailed Life Cycle Analysis (LCA) of SEP and DEP. The reason that this report does not take the form of a detailed LCA is, because it is not possible to fully define the supply chain for the project and undertake the relevant detailed assessments at this stage in the project. Therefore, assumptions and simplifications to the methodology were made in certain areas and a precautionary approach was adopted for the assessment to allow for this. These assumptions and simplifications are referred to at the relevant point in **Section 4.2.3.3**.

4.2.2 Legislative Background

34. In the Intergovernmental Panel on Climate Change (IPCC)'s most recent synthesis Report (IPCC, 2014) on the science of climate change, it was reported that *"it is extremely likely [i.e. 95-100% likelihood] that human influence has been the dominant cause of the observed warming since the mid-20th century*" (IPCC, 2014), and that the observed temperature rises over this period and those predicted in the future are anticipated to give rise to deleterious effects across the globe arising from temperature rises, changes to the global water cycle, changes to ocean temperatures, changes to sea level and changes to the global carbon cycle.

35. On 12 December 2015, the UK along with 195 other parties signed the 'Paris Agreement', a legally binding international treaty on climate change committing all parties to the goal of limiting global warming to well below 2 degrees Celsius (^{o}C), preferably to 1.5^{o}C, compared to pre-industrial levels. The Agreement requires all parties to submit plans to reduce their emission (along with other climate action) every 5-years, starting in 2020.

36. In December 2020, the UK set a Sixth Carbon Budget, recommending a reduction in UK GHG emissions of 78% by 2035 relative to a 1990 baseline (a 63% reduction from 2019) (CCC, 2020). This target has been set in line with the UK commitments in relation to the Paris Agreement and with the goal of achieving a target of reaching net zero GHG emissions by 2050 compared to the 1990 baseline, which has since been enshrined in to law. As part of this budget, the role of the offshore wind sector and the construction industry are both the focus of action to contribute to meeting these targets.

37. COP26 was held by the UK Government between 31 October and 13 November 2021 in Glasgow, Scotland and was the 26^{th} annual conference of parties (hence ‘COP26’) meeting to the UN Framework Convention on Climate Change (UNFCCC). The four specific objectives that were aimed to be achieved for COP26 were (UK Parliament, 2022):

- Securing global net zero by mid-century and keep $1.5^{o}C$ within reach by:
  - Accelerating the phase-out of coal
  - Curtailing deforestation
  - Speeding up the switch to electric vehicles
  - Encouraging investment in renewables
- Adapt to protect communities and natural habitats
- Mobilise at least $100 billion in climate finance per year
- Work together to deliver the Paris Rulebook and accelerate action to tackle the climate crisis through.

38. For the first time, nations have been called upon to ‘phase down’ unabated coal power and inefficient subsidies for fossil fuels (UNFCCC, 2022). The main headlines of COP26 were the (1) signing of the Glasgow Climate Pact, which is a series of decisions and resolutions that build on the Paris accord setting out what needs to be done to tackle climate change but does not specify what each country must do and is not legally binding, and (2) agreeing the Paris Rulebook, which gives guidelines on how the Paris Agreement is delivered. Agreements in the finalised Rulebook include an enhanced transparency framework for the reporting of emissions, common timeframes for emissions reduction targets and mechanisms and standards for international carbon markets (UK Parliament, 2022).

39. Recently published IEMA ‘Assessing Greenhouse Gas Emissions and Evaluating their Significance’ guidance (2022) was used for the evaluation and significance of GHG emissions from SEP and DEP. This guidance is a revision of the first iteration of the guidance released in 2017 (IEMA, 2017).

40. The 2022 IEMA guidance presents guidelines for undertaking GHG assessments and to distinguish different levels of significance. The guidance does not update the IEMA’s position that all emissions contribute to climate change, however it now provides relative significance descriptions to assist assessments specifically in the EIA context (detailed further in **Section 4.2.3.3**).

4.2.3 Methodology

4.2.3.1 Approach

41. In this assessment the term 'GHG' or 'carbon' encompasses CO_2 and the six other gases as referenced in the Kyoto Protocol. These are methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PRCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3)[2]. Where practicable, the results in this assessment are expressed in CO_2e, which recognises that different gases have notably different global warming potentials (GWP)[3].

42. Emissions were quantified for the construction, operational and decommissioning phases of SEP and DEP to determine GHG emissions. GHG emissions per kWh of energy generated by SEP and DEP were also calculated.

43. The system boundary of the GHG footprint includes material extraction and manufacturing, transport and installation, O&M and end of life and decommissioning. A schematic diagram of the SEP and DEP boundary is provided in **Figure 4.2-1**

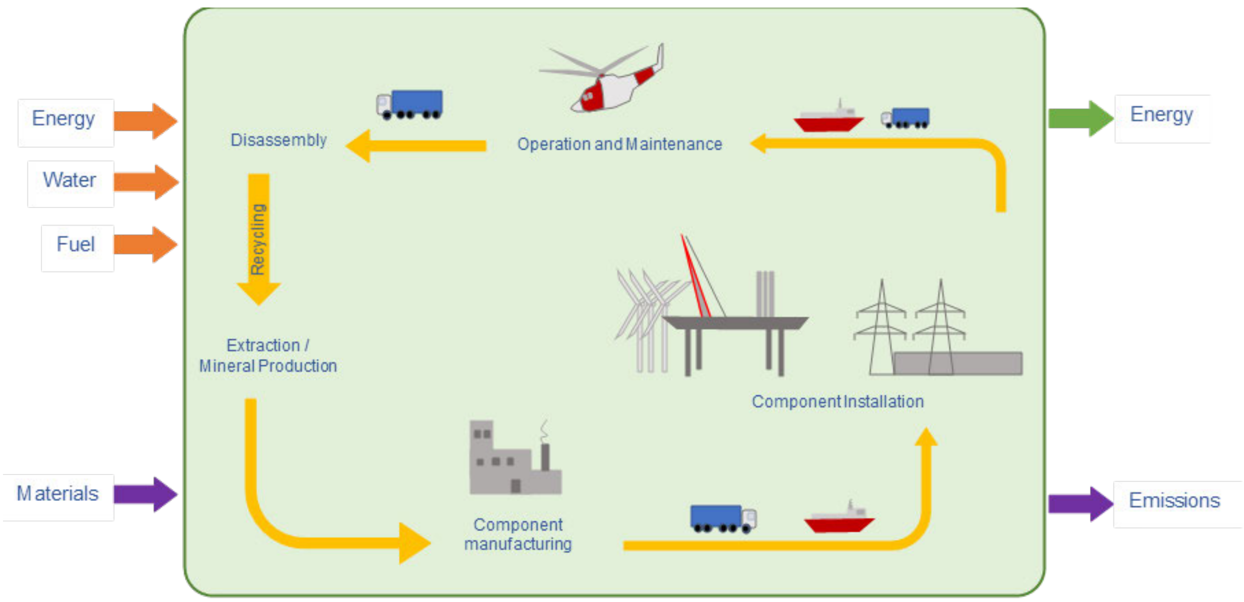

Figure 4.2-1 System Boundary for SEP and DEP GHG Assessment

[2] NF_3 was incorporated in the second Kyoto Protocol compliance period in 2012.

[3] Global Warming Potential (GWP) of a GHG is a measure of how much heat is trapped by a certain amount of gas in the atmosphere relative to carbon dioxide.

4.2.3.2 Emission Calculations

44. GHG emissions for SEP and DEP were quantified for SEP and/or DEP in isolation as well as the concurrent and sequential build scenarios for SEP and DEP. The emission sources were categorised into four main source groups, as detailed in **Table 4.2-3**.

Table 4.2-3: Emission Source Groups Considered in the Assessment

Source ID	Source Name	Definition	Project Sources
1	Embodied emissions in materials (offshore and onshore)	Embodied emissions within materials comprise GHGs released throughout the supply chain, and includes the extraction of materials from the ground, transport, manufacturing, assembly and its end-of-life profile.	Embodied emissions were quantified for the main construction materials to be used for the onshore and offshore components of SEP and DEP. The components that were considered included the main infrastructure associated with SEP and DEP, such as foundations, wind turbines, cables (onshore and offshore), offshore electrical platforms and the onshore project substation. The requirement for spare (or replacement) parts during operation is not known at this stage, therefore the likely composition of emissions in terms of the overall footprint of SEP and DEP was obtained from existing literature.
2	Marine vessels (offshore)	GHG emissions are released in exhaust gases from the combustion of fossil fuels on marine vessels.	Emissions were calculated associated with the movement of marine vessels for the offshore component of SEP and DEP. Vessels associated with installation of foundations, wind turbines and cables, as well as supply and support, accommodation and commissioning vessels were also quantified. Marine vessel movements during the O&M phase were also quantified.
3	Road traffic vehicles (onshore)	Emissions associated with the movement of road vehicles.	Emissions were calculated associated with the movement of Heavy Goods Vehicles (HGVs) during construction, the staff travel during construction and operation.
4	Plant and equipment (onshore)	Emissions are released from Non-Road Mobile Machinery (NRMM) as a result of fuel combustion.	Emissions were calculated from the use of NRMM during construction of the onshore component SEP and DEP. This included the landfall, trenchless crossing, cable installation, main onshore compound and substation works.

45. Activities that will take place during the decommissioning phase are unknown at this stage. Emissions from decommissioning were therefore derived from previous studies (Thomson & Harrison, 2015), which quantified them to be approximately 1.2% of the a typical offshore wind farm carbon footprint.

46. As detailed in **Section 4.2.1.1.1**, numerous options for construction of SEP and DEP have been assessed. For the purposes of the GHG footprint assessment, emissions were calculated for SEP and DEP built in isolation, sequentially and concurrently.

47. The approach to quantifying GHG emissions for each of the source groups detailed in **Table 4.2-3** are provided in the sections below. Further details with respect to the origin of the values used within the GHG assessment are provided in **Annex A**.

4.2.3.2.1 Embodied Emissions in Materials

48. Emissions of 'cradle to (factory) gate', a term which includes the extraction, manufacture and production of materials to the point at which they leave the factory gate of the final processing location, were calculated for SEP and DEP. GHG emissions were derived from quantities or volumes of known materials that will be used in construction, including the following infrastructure:

- The key offshore components of both SEP and DEP comprise:
    - Wind turbines;
    - Offshore substation platform(s) (OSP);
    - Foundation structures for wind turbines and OSP(s);
    - Infield cables;
    - Interlink cables; and
    - Export cables from the wind farm site/s to the landfall.
- The key onshore components comprise:
    - Landfall and associated transition joint bay(s);
    - Onshore export cables installed underground from the landfall to the onshore substation and associated joint bays and link boxes;
    - Onshore substation and onward 400 kilovolt (kV) connection to the existing Norwich Main substation;
    - Trenchless crossing zones (e.g. Horizontal Directional Drilling (HDD));
    - Construction and operational accesses; and
    - Construction compounds.

49. To provide a precautionary assessment, it was assumed that there will be no reduction in the emissions intensity during abstraction and manufacturing of materials up until and during the construction phase of SEP and DEP (earliest pre-construction could commence under any scenario is anticipated to be 2024 and the latest is 2028). The quantities of each type of construction material to be used on site were obtained from the SEP and DEP design team, and the relevant emission factors sources from the Inventory of Carbon and Energy (ICE) database (Jones & Hammond, 2019) where possible. Alternative sources for emission factors were used for more specific components to wind farms (i.e. infield and interlink cables), which are detailed in **Annex A**. Precautionary assumptions were adopted with respect to material quantities to be used for each component of SEP and DEP which include contingency allowing for the worst-case scenario (e.g. maximum number of the largest sized wind turbines) of the design envelope to be accounted for.

50. There are many possible foundation types currently available to support offshore wind turbines and/or offshore platforms. Emissions were quantified for the monopile foundation type in the GHG footprint assessment, as these are the foundation type with the highest level of GHG emissions from the information available at the time of assessment and therefore represent a worst-case scenario.

51. The emission factors from the ICE database are ‘cradle-to-factory’ and, therefore do not include the transportation of materials to site. Emissions associated with the movement of materials to the site were quantified from the road traffic vehicle and marine vessel source groups, detailed in **Sections 4.2.3.2.2** and **4.2.3.2.3** respectively. The road traffic vehicle source group also included emissions associated with the removal of excavated materials from the site.

4.2.3.2.2 Marine Vessels

52. Marine vessels will be used to bring materials and components to the SEP and DEP offshore sites, install infrastructure (foundations, wind turbines, substations and cables), provide crew accommodation and support during construction, commissioning and O&M.

53. Topside infrastructure will be installed by crane and lifting vessels, which will travel to the site from ports in Europe. GHG emissions associated with the transport of vessels to the site, and during the installation process were quantified.

54. Marine vessels will also be used to transport scour protection material (i.e. quarried rock), which is likely to be sourced from Norway, however, GHG emissions associated with these deliveries were not able to be quantified as the level of information about deliveries is not known at this stage of the DCO Application.

55. Marine vessel information was provided by the design team for SEP and DEP to derive estimated fuel consumption during construction and operation. Emission factors for marine gas oil (MGO), in kg $CO_2e.kWh^{-1}$ were obtained from the Department for Business, Energy and Industrial Strategy (BEIS) (BEIS, 2022b). For some construction processes, the vessel likely to be used during installation was already known, therefore fuel consumption figures were calculated by multiplying the engine size of the vessels by activity hours on site (accounting for average engine load factors). Where the vessel to be used was unknown, engine sizes for representative vessels were obtained to determine fuel consumption.

56. The installation vessels for offshore wind projects are specialised for the implementation of components such as wind turbines and substations. Such vessels include crane lifting equipment and other plant and machinery that are required during the installation process. It was assumed that this specialised equipment is also powered by MGO, and this was also included within the fuel consumption calculations.

57. GHG emissions from dredging activities during construction of SEP and DEP have not been included in the assessment, as this level of information about dredging activities is not known at this stage of the DCO application.

58. Emissions were also quantified from the O&M phase over the anticipated life span of SEP and DEP (currently anticipated to be 40-years). This included the use of Crew Transfer Vessels (CTV) (as a worst-case, as daughter craft may be used instead) and Lift Vessels. A Service Operation Vessel (SOV) will also operate during the O&M phase. This vessel is already utilised for the full year for the neighbouring SOW and DOW, and will undertake the O&M tasks for SEP and DEP within its current schedule. Therefore, the movement of the SOV for SEP and DEP is not considered to be an net addition to existing GHG emissions. Survey vessels and cable repair vessel movements during the O&M phase were not available at the time of the assessment, however, are anticipated to have a negligible contribution to GHG emissions due to the infrequent nature of these O&M activities.

59. Some elements of the data used to calculate GHG emissions from marine vessels are confidential at this stage due to commercial sensitivities, therefore a detailed breakdown of information used to derive GHG emissions from this source is unavailable.

4.2.3.2.3 Road Traffic Vehicles

60. Road traffic vehicle movements associated with the construction and O&M phases of SEP and DEP will result in the release of GHG emissions.

61. GHG emissions were calculated from total kilometres travelled by HGVs and staff transport to and from the construction sites, and also during the O&M phase.

62. The total distance travelled for the entirety of construction was provided by the Transport Consultants for the project. To provide a conservative assessment, the fleet make up (in terms of fuel and Euro standards) for the earliest year of construction (2025) was used in the assessment for employee travel. It was also assumed that employees would travel in private cars (referred to as Light Vehicles). The forecasted 2025 fleet composition (i.e. proportion of diesel, petrol and electric cars) was obtained from the Department for Transport (DfT) WebTAG data v1.17 (DfT, 2021). In the absence of suitable empirical data, it was assumed that the fleet composition of HGVs did not change over the temporal scope of the assessment to provide a precautionary approach.

63. Emission factors for each vehicle type considered in the assessment were obtained from BEIS (2022b), in kg CO_2e per km travelled. To provide a precautionary assessment, it was assumed that there were no fuel efficiency improvements or reduction in emissions over the project period for each mode of transport in the assessment.

64. Distances travelled for all scenarios were calculated for HGVs and employee movements according to the following methodology:

- **General:**
  - Vehicle movements were collated by the Transport Consultants for SEP and DEP from ES **Chapter 24 Traffic and Transport** (document reference 6.1.24).

  - In order to present a proportionate assessment, the ES **Chapter 24 Traffic and Transport** (document reference 6.1.24) does not present a separate assessment of the SEP and DEP sequential scenario. Therefore, for this assessment it was assumed the number of vehicle movements for the sequential scenario would be twice the in isolation scenario.

- **HGV movements:**
  - The ES **Chapter 24 Traffic and Transport** (document reference 6.1.24) identifies that bulk materials such as concrete and stone aggregate would make up the majority of the total HGV trips for SEP and/or DEP and that a viable source for bulk materials would be the ports local to SEP and DEP. King's Lynn Port to the west and Lowestoft/Great Yarmouth Ports to the east are considered to be the most likely source for most materials.
  - The distances from the ports have been calculated to each of the project infrastructure destination sites for each stage of construction (this approach is considered to represent a worst-case scenario noting that deliveries from local suppliers would reduce the distance travelled).
  - The ES **Chapter 24 Traffic and Transport** (document reference 6.1.24) utilises a gravity model approach to determine the proportion of HGV trips that could originate from each port.
  - The total HGV movements were multiplied by the portion of HGV traffic from each port and the calculated distances. This provides the total HGV distance travelled in km.

- **Light Vehicle movements:**
  - The ES **Chapter 24 Traffic and Transport** (document reference 6.1.24) adopted a conservative approach that assumes all construction employees travel by single occupancy vehicles, i.e. no reduction to light vehicle movements has been applied to account for employees using public transport, car-sharing etc;
  - The distribution of light vehicles presented in the ES **Chapter 24 Traffic and Transport** (document reference 6.1.24) has been informed by a review of the distribution of local and in-migrant labour. 30% of the labour is assumed to be drawn from the local area and 70% would be non-local (referred to an in-migrant).
  - The ES **Chapter 24 Traffic and Transport** (document reference 6.1.24) outlines that origin of in-migrant labour is based upon the number of bed spaces within local hotels, whilst the distribution of local labour is informed by census data.
  - Distances between the employee origins and the project infrastructure destination sites for each stage of construction have been calculated.
  - The total light vehicle movements were multiplied by calculated distances. This provides the total light vehicle distance travelled in km.

65. GHG emissions from road traffic vehicles during construction were calculated for the different scenarios (i.e. SEP/DEP alone, SEP and DEP sequential and SEP and DEP concurrent) separately.

66. During the operational phase of SEP and DEP, traffic movements would be limited to those generated by the daily operation and periodic maintenance at the onshore substation and at link boxes along the onshore cable corridor. It was therefore assumed that there would be two traffic movements (i.e. one visit) per week during the 35-year lifespan of the operational phase of SEP and DEP. This visit was assumed to a 40 km round-trip, i.e. 20 km each way.

4.2.3.2.4 Plant and Equipment

67. Fuel consumption associated with the operation of NRMM for the onshore components of SEP and DEP were calculated based on the estimated use of each item of plant and equipment, with representative engine sizes derived from manufacturer specifications. Construction plant and equipment for each work area, along with their anticipated duration and programme, were provided by the design team for SEP and DEP, which includes earth moving equipment, cranes and specialist equipment such as cable pulling machinery and piling rigs.

68. The anticipated fuel demand over the duration of construction was calculated and the emission factor for gas oil consumption was obtained from BEIS (2022b) to derive GHG emissions.

69. The following assumptions were adopted in the assessment:

- Plant and equipment would operate throughout the consented working hours for the project (66 hours), with the exception of concrete pouring activities at the onshore substation and HDD works along the onshore cable corridor and landfall, which are proposed to have the option to be undertaken 24 hours a day. On-time factors were applied for each plant and equipment, and are consistent with those used in ES **Appendix 23.3 Construction Noise Assessment** (document reference 6.3.23.3);
- Construction plant and equipment were all assumed to use diesel to provide a conservative assessment; and
- Engine sizes for plant and equipment were obtained for NRMM typically required during construction activities, and from manufacturer specifications. It was assumed that engines operated at a load factor of 75%.

70. GHG emissions from plant and equipment were calculated for the different scenarios (i.e. SEP/DEP alone, SEP and DEP sequential and SEP and DEP concurrent) separately.

4.2.3.3 Baseline Scenario

71. To help determine the significance and contextualise the outcomes of the assessment (detailed in **Section 4.2.3.4**), consideration of a baseline or 'without development' scenario is required. The UK electricity grid is made up from a number of different energy sources, including gas, nuclear, onshore and offshore wind, coal, bioenergy, solar and hydroelectric.

72. The growth of renewable energy is key to the UK's Energy Strategy and net zero target, and a transition away from electricity generated by fossil fuels. Gas is the most common form of new plant in terms of fossil fuel combustion (BEIS, 2020), and it is assumed that electricity produced by fossil fuels is displaced as part of the transition towards renewable energy generation. Therefore, to evaluate the impact of SEP and DEP, it was assumed that electricity produced by gas is displaced by SEP and DEP (0.371 kg/kWh). This is more robust than the approach adopted by Renewable UK, which uses a factor for "all non-renewable fuels" in the latest calendar year, which is unlikely to be representative of the energy mix when SEP and DEP commences operations.

4.2.3.4 Assessment Significance

73. The IEMA guidance (2022) provides an updated approach to determine significance of GHG assessments in EIA, and recognises *"when evaluating significance, all new GHG emissions contribute to a negative environmental impact; however, some projects will replace existing development or baseline activity that has a higher GHG profile. The significance of a project's emissions should therefore be based on its net impact over its life time, which may be positive, negative or negligible".*

74. In addition, the guidance states *"the crux of significance is not whether a project emits GHG emissions, nor even the magnitude of GHG emissions alone, but whether it contributes to reducing GHG emissions relative to a comparable baseline consistent with a trajectory towards net zero by 2050".*

75. The significance and contextualisation of a GHG assessment can be evaluated in a number of ways depending on the context and sector in which the project operates. This could include a comparison of the change in GHG emissions from a project to sector, local or national carbon budgets, sector specific policy goals or relevant performance standards.

76. The IEMA guidance (2022) describes five levels of significance which were used as significant criteria for the assessment, and are presented below in **Table 4.2-4**.

Table 4.2-4 Assessment Significance Criteria

Significance	Description
Major adverse	The project's GHG impacts are not mitigated or are only compliant with do-minimum standards set through regulation, and do not provide further reductions required by existing local and national policy for projects of this type. A project with major adverse effects is locking in emissions and does not make a meaningful contribution to the UK's trajectory towards net zero.
Moderate adverse	The project's GHG impacts are partially mitigated and may partially meet the applicable existing and emerging policy requirements but would not fully contribute to decarbonisation in line with local and national policy goals for projects of this type. A project with moderate adverse effects falls short of fully contributing to the UK's trajectory towards net zero.
Minor adverse	The project's GHG impacts would be fully consistent with applicable existing and emerging policy requirements and good practice design standards for projects of this type. A project with minor adverse effects is fully in line with measures necessary to achieve the UK's trajectory towards net zero.

Significance	Description
Negligible	The project's GHG impacts would be reduced through measures that go well beyond existing and emerging policy and design standards for projects of this type, such that radical decarbonisation or net zero is achieved well before 2050. A project with negligible effects provides GHG performance that is well 'ahead of the curve' for the trajectory towards net zero and has minimal residual emissions.
Beneficial	The project's net GHG impacts are below zero and it causes a reduction in atmospheric GHG concentration, whether directly or indirectly, compared to the without-project baseline. A project with beneficial effects substantially exceeds net zero requirements with a positive climate impact.

4.2.3.5 Limitations

77. The key limitations of the assessment, and how they have been addressed, are listed in **Table 4.2-5**.

Table 4.2-5: Key Limitations of the GHG Assessment

ID	Limitation	Action Taken
1	Quantities for all materials to be used during construction were not available at the time of the assessment.	Quantities of the main and most GHG intensive materials were included in the assessment. Furthermore, precautionary assumptions were adopted for quantities of known materials (i.e. using the maximum quantity), particularly for quantities of concrete, scour protection, gravel, etc.
2	Lack of emission factors for future year activities, such as fuel consumption and material extraction.	The most recent available emissions factors were used in the assessment to provide a precautionary assessment.
3	The origin port of some of the marine vessels was not known at the time of the assessment, which affects how far the vessels have to travel to the site, and subsequently the amount of emissions released.	As the majority of emissions will be released from vessels whilst at the site during installation, changes to the transit time for marine vessels will have a limited effect in terms of the overall GHG footprint. However, the most likely origin ports known at the time of the assessment were used to derive GHG emissions during vessel transit. It has been assumed that for O&M activities, the origin port will be Great Yarmouth.
4	Expected operational requirements of construction plant and equipment for the onshore components were not known at the time of the assessment.	An on-time correction factor was applied to all listed plant and equipment for construction of each component, which align with assessments undertaken in the ES (i.e. the noise assessment in **Chapter 23 Noise and Vibration** (document reference 6.1.23) and **Appendix 23.3** (document reference 6.3.23.3)).
5	Specific nature and composition of some materials, such as the type of concrete or steel to be used, was unknown which may affect the carbon intensity of the material.	If there was variation across different compositions of the same material, the 'General' option was chosen, if available, or the median value if not.
6	Duration O&M marine vessels remain on site	The duration O&M marine vessels would visit the site during O&M activities is not known for all vessel types, therefore it was assumed to be four 7 day periods (i.e. 28 days) per year for the lift vessel over the 40-year O&M period. No information is currently available on the cable repair or survey vessel movements during O&M, therefore these have not been included in the GHG footprint.

ID	Limitation	Action Taken
		SOV vessel emissions are considered to be part of the baseline as SEP and DEP will be using the existing SOV contracted for Dudgeon and Scira. SEP and DEP O&M tasks will be performed within the current sailing schedule, therefore there will be no new movements for the SOV. Two CTV scenarios are currently under consideration, so the worst-case scenario, where two new CTVs will be used for O&M requirements of SEP and DEP, has been included in the GHG footprint.

4.2.4 Results

78. GHG emissions associated with each source group listed in **Table 4.2-3** is provided for all scenarios considered in **Table 4.2-6** and **Table 4.2-7**.

Table 4.2-6: GHG Emissions Associated with each of the Source Groups Considered in the Assessment for SEP and DEP alone

Source Group	SEP alone		DEP alone	
	GHG Emissions (Tonnes CO_2e)	Percentage of GHG Footprint	GHG Emissions (Tonnes CO_2e)	Percentage of GHG Footprint
Construction – embodied emissions in materials (offshore and onshore)	498,062	72%	623,502	76%
Construction – marine vessels (offshore)	61,979	9%	71,280	9%
Construction – road traffic vehicles (onshore)	12,163	2%	12,163	1%
Construction – plant and equipment (onshore)	41,558	6%	41,558	5%
O&M (40-year period)	65,279	10%	65,279	8%
Decommissioning	8,149	1%	9,765	1%
Total	**687,190**		**823,547**	

Table 4.2-7: GHG Emissions Associated with each of the Source Groups Considered in the Assessment for SEP and DEP (Concurrent and Sequential)

Source Group	SEP and DEP			
	Concurrent		Sequential	
	GHG Emissions (Tonnes CO_2e)	Percentage of GHG Footprint	GHG Emissions (Tonnes CO_2e)	Percentage of GHG Footprint
Construction – embodied emissions in materials (offshore and onshore)	1,080,755	78%	1,121,564	76%
Construction – marine vessels (offshore)	106,625	8%	106,625	7%
Construction – road traffic vehicles (onshore)	15,022	1%	24,326	2%
Construction – plant and equipment (onshore)	43,468	3%	79,023	5%
O&M (40-year period)	130,545	9%	130,545	9%
Decommissioning	16,517	1%	17,545	1%
Total	**1,421,672**		**1,479,629**	

79. The results presented in **Table 4.2-6** and **Table 4.2-7** highlight that embodied emissions associated with extraction and manufacture processed within materials used on the SEP and DEP forms the largest component of the GHG footprint.

4.2.5 Discussion

80. The results presented in **Section 4.2.4** show that the GHG footprint for SEP and DEP is as follows over the project lifetime (approximately 4-years construction for the single and concurrent scenario, up to 8-years construction for the sequential scenario and an operational lifetime of 40-years):

- SEP alone: 687,190 tonnes CO_2e.
- DEP alone: 823,547 tonnes CO_2e.
- SEP and DEP concurrent: 1,392,933 tonnes CO_2e.
- SEP and DEP sequential: 1,479,629 tonnes CO_2e.

81. The GHG intensity of SEP and DEP was determined by dividing these figures above by the anticipated energy produced over the lifespan of SEP and DEP.

82. The approach to estimating the amount of energy produced by SEP and DEP was derived from the approach advocated by RenewableUK (2022b), where the installed capacity (maximum: 338 MW for SEP alone, 448 MW for DEP alone and 786 MW for SEP and DEP) is multiplied by the hours in the year and by the appropriate average load or capacity factor for SEP and DEP. For new build offshore projects, BEIS advises that the load factor is 63.1% (BEIS, 2021).

83. The energy generated and GHG intensity of electricity produced by SEP and DEP is presented in **Table 4.2-8**.

Table 4.2-8: Energy generated and GHG intensity of electricity produced by SEP and DEP Scenarios

Scenario	GHG Emissions (Tonnes CO_2e)	Annual energy generated (GWh/p.a.)	Energy generated over 40-year lifespan (GW)	GHG intensity of electricity produced (g $CO_2e.kWh^{-1}$)
SEP alone	687,190	1,868	74,733	9.2
DEP alone	823,547	2,476	99,054	8.3
SEP and DEP (Concurrent)	1,421,672	4,345	173,786	8.0
SEP and DEP (Sequential)	1,479,629			8.5

84. When compared with other offshore wind farm life cycle studies (Thomson & Harrison, 2015; Dolan & Heath, 2012), the GHG intensity of the SEP and DEP scenarios is in the mid-range for offshore wind projects.

85. The estimated GHG footprint of SEP and DEP, which includes emissions from all components of the project including the extraction of materials, construction, operation and decommissioning, ranges from 0.69 to 1.48 million tonnes of CO_2e, depending on the scenario brought forward (see **Table 4.2-6** and **Table 4.2-7**).

86. To estimate the 'GHG payback' of SEP and DEP, it was assumed that electricity produced by gas is displaced (0.371 kg/kWh), as gas is the most common form of new plant in terms of fossil fuel combustion (BEIS, 2020).

87. The GHG payback of SEP and DEP, assuming that electricity produced by gas is displaced in less than a maximum of 1 year from the point when SEP and DEP start to produce electricity to the UK grid.

4.2.5.1 Significance

88. The SEP and DEP are predicted to result in a reduction in atmospheric GHG concentration compared to the without-project baseline (i.e. electricity produced by gas), and will provide a renewable source of electricity which beneficially contributes to the UK's goal of achieving net zero emissions by 2050. It is therefore considered that SEP and DEP would have a **beneficial** effect to reducing GHG emissions, when compared to a relevant baseline scenario.

4.2.6 Summary

89. A GHG assessment was carried out for SEP and DEP to determine emissions that will arise from construction, operation and decommissioning activities. The assessment considered emissions from the extraction and manufacture of materials, marine vessel and road traffic movements, and the use of plant and equipment.

90. GHG emissions from construction, operation and decommissioning of the SEP or DEP in isolation are predicted to be 0.69 and 0.82 million tonnes of CO_2e, respectively. Both SEP and DEP concurrently scenarios are anticipated to release 1.39 – 1.48 million tonnes CO_2e, depending on whether the projects are concurrent or sequential. The largest GHG contribution to SEP and DEP is embodied emissions within materials to be used during construction, particularly in the offshore components of the project.

91. The GHG intensity of energy produced by SEP and DEP project anticipated to range between 8.9 to 10.2 g CO_2e/kWh depending on the scenario constructed. This is around the midrange of previous studies for offshore wind farms and therefore the GHG payback of emissions is likely to be less than 1.1 years from when SEP and DEP start to produce electricity for the UK grid.

92. Given the Project leads to a reduction in atmospheric GHG concentration compared to the without-project baseline, it is considered that SEP and DEP would have a **beneficial** effect on GHG emissions and assist the UK's trajectory towards net zero in 2050.

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Annex A: GHG Emissions Calculation

A1 – Embodied Emissions in Materials

1. The emission factors used in the GHG assessment for embodied emissions in materials are presented in **Table 1-1**.

Table 1-1: Emission Factors for Embodied GHG in Materials

Material	Emission Factor ($kgCO_2e.kg^{-1}$, unless otherwise stated)	Source	Notes
Aggregate and Sand: Sand	0.00747	ICE Database V3.0 November 2019 (Jones & Hammond, 2019)	General UK, mixture of land won, marine, secondary and recycled, bulk, loose
Aggregate and Sand: Concrete Bound Sand (CBS) Proxy	0.12003		Mortar (1:6 cement : sand mix)
Cement and mortar: Cement	0.83211		General (UK average)
Cement and mortar: Grout	0.62		Cement; Grout
Concrete	0.10336		General concrete
Soil	0.024		General (rammed soil)
Steel (average)	2.47		Average of embodied CO_2e steel values provided in ICE Database
Steel, electrogalvanized steel	3.03		N/A
Steel, hot-dip galvanized steel	2.76		N/A
Steel, Cold Rolled Coil	2.53		N/A
Steel, Hot Rolled Coil	2.28		N/A
Stone/Gravel	0.079		Stone (general)
Glass reinforced plastic (GRP) - Fibreglass (Fibreglass Proxy)	8.1		CO_2 only
Plastic: PVC Pipe	3.23		N/A
Aggregate: clay (Bentonite proxy)	0.39321		Assumed clay to be representative of bentonite, as bentonite is *"an absorbent swelling clay"*
Plaster: Gypsum	0.13		General

Material	Emission Factor ($kgCO_2e.kg^{-1}$, unless otherwise stated)	Source	Notes
RC 32/30 (reinforced concrete walls)	0.149		Assumed 360 kg cementitious content per m^3 concrete. Possible uses: structural purposes, in site floors, walls, superstructure
Concrete block (high density concrete block – cellular (140 mm))	1.98		N/A
Lightweight wall	35.45 (kg $CO_2e.m^{-2}$)		Assumed 150 mm thickness wall
Flooring	3.19		Assumed vinyl flooring
Copper (Cu) (cables)	2.71	Cableizer (2021)	N/A
XLPE (cables)	1.93		N/A
Semiconductor (cables – proxy) (paper)	1.49		N/A
PE sheath (cables)	2.54		N/A
Lead (Pb) (cables)	1.67		N/A
Armouring (cables)	1.46		N/A
PP yarn (cables)	3.69		CO_2 only
PE filler (cables)	2.54		N/A
Water	0.149 (kg $CO_2e.m^{-3}$)	BEIS Conversation Factors (2022b)	N/A
Waste soil (recycled closed loop)	0.00098		N/A
Waste soil (landfill)	0.01758		N/A

A2 – Road Traffic Vehicles

2. The methodology used to derive total distance travelled by HGVs and employees in private cars is detailed in **Section 4.2.3.2.3**. The travel distances used in the assessment for each of the scenarios are presented in **Table 1-2**.

Table 1-2: Distances Travelled by HGVs and Employees during Construction

Scenario	HGVs (km Travelled) for duration of construction	Employees – Car (km Travelled) for duration of construction
SEP or DEP alone	13,545,809	3,940,625
SEP and DEP (concurrent construction)	16,585,534	5,610,990
SEP and DEP (sequential construction)	13,545,809 + 13,545,809 = 27,091,618 (assumed that the sequential distance travelled would be twice that of SEP or DEP alone, in lieu of other information)	3,940,625 + 3,940,625 = 7,881,249 (assumed that the sequential distance travelled would be twice that of SEP or DEP alone, in lieu of other information)

3. The proportion of diesel, petrol and electric cars in the UK fleet for earliest year of construction (2025) were obtained from the DfT (2021) to determine a representative emission factor associated with employee travel. The fleet composition used in the assessment, and emission factors associated with each vehicle type are provided in **Table 1-3**. Emission factors for each vehicle type were obtained from BEIS (2022b).

Table 1-3: Car Fleet Composition and Emission Factors used in the GHG Assessment

Earliest Year of Construction	Fleet composition (DfT, 2021)			Vehicle emission factor ($kg\ CO_2e.km^{-1}$) (BEIS, 2022b)			Emission Factor Used in the Assessment ($kg\ CO_2e.km^{-1}$)
	Diesel	Petrol	Electric	Diesel	Petrol	Electric*	
2025	53.2%	41.4%	5.4%	0.171	0.17	0.068	0.165
*Assumed to be plug-in hybrid electric vehicle, as battery electric vehicle has 0 CO_2e emissions in the 2022 BEIS dataset.							

4. It was assumed that all HGVs used on SEP and DEP were diesel powered. The emission factor for HGV movements (50% laden) was obtained from BEIS (2022b) and was 0.850 $kg\ CO_2e.km^{-1}$.

A3 – Plant and Equipment

5. Plant and equipment used for the construction of SEP and DEP is provided below in **Table 1-4** for each work area association with the onshore component of the projects. The information provided in **Table 1-4** represents the number of plant and equipment that could be present for each activity at any one time. The duration these plant and equipment were used was dependent on the construction programme of each of the different scenarios (i.e. SEP/DEP alone, SEP and DEP (concurrent/sequential)).

6. Multiple operative vehicles will be present for each of the work areas. At this stage in the Project, it is not known how many will be needed for the construction of each work area. Therefore it was assumed 10 vehicles were present at each work area, and these vehicles would a travel an average of 5 km per day.

Table 1-4: Plant and Equipment Requirements (at any one time) for each Component

Name	No.	kW	On-Time Correction	Equipment
Substation Civils *Assumed duration:* *SEP or DEP Alone = 28 months* *SEP and DEP (Concurrent) = 31 months* *SEP and DEP (Sequential) = 2x 28 months*				
Hydraulic hammer piling rig	1	470	35%	Casagrande Piling Driving with Hydraulic Hammer
Tracked excavator 40t	4	240	85%	40-tonne DX380LC-7
Low loader 23t	2	206	85%	CAT Medium wheeled loader 996M
Tele handler 10t	1	107	85%	Merlo P 120.10 HM

Name	No.	kW	On-Time Correction	Equipment
Hiab wagon	2	302	85%	Truck-mounted crane
Tractor and Trailer	1	211	85%	Fendt 800 Vario tractor
Tipper Wagons	2	206	85%	BLAZO X28 Tipper Truck BS6
Compacting Roller	1	150	85%	Bomag BW 226 BVC-5
Ride on Roller	1	15.6	85%	Single-cylinder road roller
Wacker Plate	1	2.1	85%	Forward Plate Compactor
Dumpers	1	34.8	85%	Small Dumper (Thwaites 444, 4.5t)
Dozer	2	158	85%	D6 Dozers (Dozer (Med))
Cement Mixer Truck*	1	247	80%	Concrete truckmixer
Truck Mounted Concrete Pump*	1	372	85%	Concrete pump
Generator	2	110	85%	Construction diesel generator
Cable Duct Installation (per work front) *Assumed up to 4 weeks per 1 km section (i.e. 60 sections), twice for the sequential scenario*				
Tracked excavator 40t	2	240	85%	40-tonne DX380LC-7
Low loader 23t	1	206	85%	CAT Medium wheeled loader 996M
Tele handler 10t	1	107	85%	Merlo P 120.10 HM
Hiab wagon	1	302	85%	Truck-mounted crane
Dozer	1	158	85%	D6 Dozers (Dozer (Med))
Generator	1	110	85%	Construction diesel generator
Tractor and Trailer	1	211	85%	Fendt 800 Vario tractor
Wacker Plater	1	2.1	85%	Forward Plate Compactor
Pump	1	1.7	85%	Centrifugal water pump
Cable Pull (per location) *At landfall, assumed for duration of landfall cable pull, i.e. 2 months for SEP or DEP in isolation, 4 months for SEP and DEP concurrently and 2x 2 months for SEP and DEP sequentially.* *Along cable corridor, assumed 2 days per joint bay (60 joint bays for SEP or DEP alone, 120 for SEP and DEP).*				
Tracked excavator 40t	2	240	85%	40-tonne DX380LC-7
Low loader 23t	1	206	85%	CAT Medium wheeled loader 996M
Tele handler 10t	1	107	85%	Merlo P 120.10 HM
Hiab wagon	1	302	85%	Truck-mounted crane
Cable winch	1	19.1	85%	5 Te LV-HV Power Cable Pulling Winch (Twin Capstan)
Compressor	1	105	85%	Deutz Diesel-engine
Generator	1	110	85%	Construction diesel generator
Tractor and Trailer	1	211	85%	Fendt 800 Vario tractor

Name	No.	kW	On-Time Correction	Equipment
Cable Rollers	1	0.75	85%	Geared Motor Drive Unit, assumed to be powered by the Drive Unit (SEW Eurodrive)
Trenchless Crossings (per location) *At landfall, assumed for duration of landfall HDD, i.e. 4 months for SEP or DEP in isolation, 5 months for SEP and DEP concurrently and 2x 4 months for SEP and DEP sequentially.* *Assumed up 4-6 weeks on average per crossings and approximately 72 crossings (this occurs twice in the sequential scenario).* *Assumed Weybourne Woods and River Wensum trenchless crossings to be of 12 week duration each.*				
Tracked excavator 40t*	2	240	85%	40-tonne DX380LC-7
Low loader 23t*	1	206	85%	CAT Medium wheeled loader 996M
Tele handler 10t*	1	107	85%	Merlo P 120.10 HM
Hiab wagon*	1	302	85%	Truck-mounted crane
Drilling rig*	1	390	100%	Drilling rig (Liebherr LB36-410)
Mixing tank*	1	247	100%	Concrete truckmixer
Circulation pump*	1	1.7	85%	Centrifugal water pump
Generator*	1	110	85%	Construction diesel generator
Tractor and Trailer*	1	211	85%	Fendt 800 Vario tractor
Butt Fusion Jointing Machine Cabin & Generator*	1	8.6	85%	Diesel Kohler/Lombardini Welding System
Installation of Temporary Access Tracks *Assumed (conservatively) 36 weeks in total (twice this for the sequential scenario)*				
Tracked excavator 40t	2	240	85%	40-tonne DX380LC-7
Low loader 23t	1	206	85%	CAT Medium wheeled loader 996M
Tele handler 10t	1	107	85%	Merlo P 120.10 HM
Hiab wagon	1	302	85%	MAN 26.414 6x4 + HIAB 225 manual 2002 Truck-mounted crane
Dozer	1	158	85%	D6 Dozers (Dozer (Med))
Asphalt spreader	1	129	85%	Asphalt pavers (CAT AP655)
Asphalt roller	1	137	85%	Road roller (CAT CB54)
Establishing Temporary Work Areas/Small Compounds *Assumed main compound will take 2 months to construct and secondary compounds will take 2 months (total) to construct (conservative) (this would occur twice in the sequential scenario)*				
Tracked excavator 40t	2	240	85%	40-tonne DX380LC-7
Low loader 23t	1	206	85%	CAT Medium wheeled loader 996M
Tele handler 10t	1	107	85%	Merlo P 120.10 HM
Hiab wagon	1	302	85%	Truck-mounted crane
Onshore Main Compound				

Name	No.	kW	On-Time Correction	Equipment
Assumed operational for full duration of onshore construction works, i.e. 31 months for SEP or DEP in isolation, 34 months for SEP and DEP concurrently and 2x 31 months for SEP and DEP sequentially				
Tipper wagon 29t*	2	206	85%	BLAZO X 28 TIPPER TRUCK BS6
Tracked excavator 40t	2	240	85%	40-tonne DX380LC-7
Low loader 23t*	2	206	85%	CAT Medium wheeled loader 996M
Tele handler 10t*	1	107	85%	Merlo P 120.10 HM
Hiab wagon	1	302	85%	Truck-mounted crane
Mobile telescopic crane*	1	107	85%	Merlo P 120.10 HM
Generator*	1	110	85%	Construction diesel generator
Batching Plant*	1	100	85%	Mobile Concrete Batching Plant (MCM40/60)
*Assumed operational 24/7 for duration of time specified for the scenario and work type.				

7. For the purposes of the assessment, it was assumed that plant and equipment operated using gas oil as fuel, which has an emission factor of 0.257 kg $CO_2e.kWh^{-1}$ (BEIS, 2022b).

8. All plant were assumed to operate at an average load factor of 0.75 and a 66-hour working week, with the exception of concrete pouring activities at the onshore substation and HDD works along the onshore cable corridor and landfall location, which are proposed to have the option to be undertaken 24 hours a day. On-time factors were applied for each plant and equipment, consistent with those used in ES **Appendix 23.3 Construction Noise Assessment** (document reference 6.3.23.3), are detailed in **Table 1-4**.