Frodsham Solar

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Appendix 5-1: GHG Assessment

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Appendix 5-1: GHG Assessment

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Document approval

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Contents

1 Introduction

This appendix has been written in support of **ES Vol 1 Chapter 5: Climate Change [EN010153/DR/6.1]**. This appendix details the inputs and assumptions within the calculation of GHG emissions associated with the Proposed Development.

This GHG Assessment has been based on the design of the Proposed Development as described in **ES Vol 1 Chapter 2: The Proposed Development [EN010153/DR/6.1].** For the purposes of the assessment, it has been assumed central inverters will be used on-site rather than string inverters. This is a more conservative assumption as more raw materials are required for central inverters and therefore, there will be greater embodied GHG emissions.

The GHG emissions scoped into the assessment are summarised in **Table 5-7** of **ES Vol 1 Chapter 5: Climate Change [EN010153/DR/6.1]**.

2 Assumptions and Inputs

2.1 Construction Phase (2027-2029)

It has been assumed that the construction of the Proposed Development would commence the beginning of 2027 and last for a period of 2.5 years.

2.1.1 Raw material extraction and manufacturing of products required for the Proposed Development and transportation of raw materials to the place of manufacturing

Embodied GHG emissions associated with raw material extraction and manufacturing of products required for the Proposed Development and transportation of raw materials to the place of manufacturing can make up a significant contribution to the GHG emissions associated with the Proposed Development. Manufacturers are increasingly carbon footprinting their products and reporting the embodied GHG emissions associated with their product. At this stage the exact manufacture of the equipment is not known. However, candidate equipment has been provided by the Applicant for the basis of this assessment.

Table 1 and Table 2 outline the candidate equipment and any assumptions that have been made in relation to the embodied GHG emissions associated with the equipment and materials needed to construct the Proposed Development.

Table 1: Source of equipment and materials

Equipment	Source
Solar PV modules	Candidate solar PV module is 720Wp bifacial.
Power Conversion Unit (PCU)	Candidate PCU is a combined unit containing a central inverter and transformer for the solar PV modules. It is assumed total weight of PCU is made up of steel and applied ICE database emission factor for electrogalvanised steel.
Mounting structure	Candidate mounting structure holds 28 solar PV modules. Assumed total weight of candidate mounting structure is made up of steel and applied ICE database emission factor for engineering steel. The candidate mounting structure has been amended to reflect the proposed piling depth of 5 m throughout the Site. This is a very conservative assumption as piles are unlikely to go to depths of 5 m across the whole Site. Additionally, the candidate mounting structure has been amended to reflect the height of the solar PV modules. The height of the mounting structure will be 2 m on the eastern fields of the Solar Array Development Area (east of Brooks Furlong) as parts of the fields are within Flood Zone 3. The height of the mounting structure will be 0.8 m on the western fields of the Solar Array Development Area.
Cables	There are four types of candidate cables at the Site: • DC String cables; • MV cable; • 132 kV cable; and

Equipment	Source
	• Earthing cable.
Batteries	Swedish Environmental Research Institute paper (2019), associated with the manufacture of lithium-ion batteries. Range of 59-119 kg CO_2e/kWh, with a mid-point of 89 CO_2e/kWh. Applied the mid-point given the age of the paper and pushes from industry to reduce the GHG intensity of the manufacturing process.
Power Conversion Station (PCS)	Candidate PCS is a combined transformer station and power conversion station for the BESS. Assumed total weight of PCS is made up of steel and applied ICE database emission factor for electrogalvanised steel.
Aggregates	Weight of aggregates multiplied by the density of gravel and multiplied by the emission factor for "aggregates and sand from secondary resources, bulk, loose" from the ICE database.
Concrete	ICE database emission factor for general concrete.
Stabilisation material – lime/cement	Lime/cement is required for stabilisation of the soil for the NBBMA works. It has been conservatively assumed that cement is to be used because it is a more GHG intensive material than lime. ICE database emission factor for general cement.
Fencing	Weight of a candidate fence and applied the ICE database emission factor for electrogalvanised steel.

Table 2: Equipment weight assumptions

Equipment	Unit	Value	Source
PCU	t	36	Candidate transformer
PCS	t	36	Candidate transformer
Solar PV module	kg	38	Candidate bifacial module
Battery	t	23	Candidate battery
Average mounting structure	kg	20	Candidate mounting structure
DC string cables	kg/km	470	Candidate DC String cables
MV cable	kg/km	5,600	Candidate MV cable
132 kV cable	kg/km	11,400	Candidate 132 kV cable
Earthing cable	kg/km	2,400	Candidate earthing cable
Fencing	kg/100 m	75	Candidate fencing

Table 3 sets out the quantity of equipment and materials assumed to be required to construct the Proposed Development.

Table 3: Equipment and materials required to construct the Proposed Development

Equipment	Unit	Value
DC string cables	km	2,940
MV cable	km	68
132 kV cable	km	10
Earthing cable	km	34

Equipment	Unit	Value
Number of solar PV modules	-	288,600
Number of solar PV mounting structures[1]	-	10,307
Number of PCU	-	49
Number of PCS	-	23
Number of batteries	-	184
Aggregates	t	34,880
Fencing	km	14
Concrete	m^3	3,523
Cement for NBBMA	t	1,000

2.1.2 Transportation of manufactured equipment and materials to the Proposed Development

To calculate the GHG emissions associated with the transportation of manufactured equipment and materials to the Proposed Development, the total weight equipment / material, and the distance to the Proposed Development has been calculated. The GHG emissions have been calculated by applying the appropriate emission factors from Department of Energy Security and Net Zero (DESNZ). Where appropriate well-to-tank (WTT) emission factors have also be applied.

The following assumptions have been used for the place of manufacture for equipment and source of materials.

Table 4: Place of manufacture of equipment, source of material

Equipment / material	Source
Cables	Europe – assumed central Poland
Solar PV modules	China – assumed central China
Solar PV mounting structure	China – assumed central China
PCU	China – assumed central China
PCS	China – assumed central China
Batteries	China – assumed central China

The following assumptions have been used for the transportation of equipment and materials from their source of manufacture.

Table 5: Transportation assumptions

Equipment / material	Leg 1		Leg 2		Leg 3	
	Route	Method	Route	Method	Route	Method
Solar PV modules	Central China to Shanghai	HGV	Shanghai to Felixstowe	Cargo	Felixstowe to Site	HGV

[1] Assumed each mounting structure can hold 28 solar PV modules.

Equipment / material	Leg 1		Leg 2		Leg 3	
	Route	Method	Route	Method	Route	Method
Solar PV mounting structure	Central Poland to Rotterdam	HGV	Rotterdam to Felixstowe	Cargo	Felixstowe to Site	HGV
Cables	Central Poland to Rotterdam	HGV	Rotterdam to Felixstowe	Cargo	Felixstowe to Site	HGV
Battery	Central China to Shanghai	HGV	Shanghai to Felixstowe	Cargo	Felixstowe to Site	HGV
PCU	Central China to Shanghai	HGV	Shanghai to Felixstowe	Cargo	Felixstowe to Site	HGV
PCS	Central China to Shanghai	HGV	Shanghai to Felixstowe	Cargo	Felixstowe to Site	HGV

The weight of each equipment / material has been multiplied by the distance of the leg and the sum of the appropriate DESNZ emission factor and DESNZ WTT emission factor for that leg[2].

The following assumptions relating to the distances travelled have been applied.

Table 6: Distance travelled

Parameter	Unit	Value	Source
Central China to Shanghai	km	1,000	Google maps
Central Poland to Rotterdam	km	1,000	Google maps
Shanghai to Felixstowe	km	22,052	Ports.com, Port of Shanghai to Port of Felixstowe
Rotterdam to Felixstowe	km	248	Ports.com, Port of Rotterdam to Port of Felixstowe
Felixstowe to Site	km	400	Google maps

2.1.3 Transportation of construction materials (where not included in the product-stage embodied GHG emissions)

To calculate the GHG emissions associated with the transportation of construction materials to the Proposed Development, the total weight construction material, and the distance to the Proposed Development has been calculated. The GHG emissions have been calculated by applying the appropriate emission factors from Department of Energy Security and Net Zero (DESNZ). Where appropriate WTT emission factors have also be applied.

The following assumptions have been used for the source of the construction materials:

[2] Greenhouse gas reporting: conversion factors 2024, average car, unknown fuel

Table 7: Place of manufacture of equipment, source of material

Equipment / material	Source
Aggregate	UK – assumed local to Proposed Development – Aggregate Industries Contracting Wigan
Concrete	UK – assumed local to Proposed Development – Heidelberg Materials Cement Padeswood

The following assumptions have been used for the transportation of the construction materials from their source to the Site.

Table 8: Transportation assumptions

Equipment / material	Leg 1	
	Route	Method
Concrete	Heidelberg Materials Cement Padeswood to Site	HGV
Aggregate	Aggregate Industries Contracting Wigan to Site	HGV

The weight of each equipment / material has been multiplied by the distance of the leg and the sum of the appropriate DESNZ emission factor and DESNZ WTT emission factor for that leg[2].

The following assumptions relating to the distances travelled have been applied.

Table 9: Distance travelled

Parameter	Unit	Value	Source
Aggregate Industries Contracting Wigan to Site	km	60	Google maps
Heidelberg Materials Cement Padeswood to Site	km	60	Google maps

2.1.4 On-Site construction activities

The GHG emissions associated with the on-site plant vehicles and generators required for construction have been calculated from the expected diesel fuel use and applying the appropriate DESNZ emission factor (including WTT emission factor)[3].

Table 10: Energy usage from on-site plant vehicles and generators for construction

Equipment	Unit	Value
Diesel usage required for construction	L	208,000

[3] Greenhouse gas reporting: conversion factors 2024, diesel emission factor WTT

The GHG emissions associated with the on-site plant vehicles and generators required for the NBBMA creation works have also been calculated from the expected diesel fuel use and applying the appropriate DESNZ emission factor (including WTT emission factor)[4].

Table 11: Energy usage from on-site plant vehicles and generators for NBBMA works

Equipment	Unit	Value
Diesel usage required for NBBMA works	L	507,800

2.1.5 Travel of construction workers

The GHG emissions associated with the travel of construction workers has been calculated using the number of construction workers on-site per month as set out by the Applicant. Given the source of workers is unknown, a reasonable conservative assumption that a worker would travel 50 km to the site (and then return) has been made. This has conservatively assumed each worker would work five days a week and travel to site in pairs, as per the Transport Assessment. The DESNZ emission factor for average car emission factor (unknown fuel) and the DESNZ WTT average car emission factor (unknown fuel) have been applied.

Table 12: construction workers distance travelled

Parameter	Unit	Value	Source
Distance to work	km	50	Assumption, unknown location of workers assumed 50 km each way

2.1.6 Loss of peat

Peat lenses are known to be present across the Site and loss of peat would result in a loss of a carbon store, resulting in a net increase in GHG emissions. As mentioned within the **ES Vol 1 Chapter 10: Ground Conditions [EN010153/DR/6.1]**, peat has been found within the western half of the Site, at depths of circa 12m.bgl to circa 17m.bgl. In 2024 ground investigations to a depth of 5m were undertaken across the eastern half of the Site. The investigation did not identify any peat. Therefore, it is considered unlikely that the peat lenses will be disturbed, and it is unlikely that there would be any GHG emissions associated with loss of peat.

If peat is found during further site investigation, additional measures would be considered to prevent impacts on peat such as trenchless or shallow cable routing or re-routing to avoid peat areas. This is set out in the **oCEMP [EN010153/DR/7.5]** and secured via the Requirements in Schedule 2 of the draft DCO.

2.1.7 Energy consumption from the provision of clean water and treatment of wastewater

The GHG emissions associated with the energy consumption from the provision of clean water has been calculated by taking the sum of the water used for cleaning the solar PV modules and wheel washing and the water requiring treatment during construction and applying the DESNZ water supply emission factor.

[4] Greenhouse gas reporting: conversion factors 2024, diesel emission factor WTT

The GHG emissions associated with the energy consumption from the treatment of wastewater has been calculated by taking the water requiring treatment during construction and applying the DESNZ water treatment emission factor.

Table 13: Water usage

Parameter	Unit	Value
Water used in construction, including solar PV module cleaning, wheel washing etc.	Million litres per annum	0.39
Water requiring treatment	Million litres per annum	1.03

2.2 Operation Phase (2029-2069)

It has been assumed that the Proposed Development would be commissioned in Q3 2029 and operate for 40 years.

2.2.1 Energy consumption from the provision of clean water and treatment of wastewater

The GHG emissions associated with the energy consumption from the provision of clean water has been calculated by taking the sum of the water used for cleaning the solar PV modules and the water required for the welfare facilities during operation and applying the DESNZ water supply emission factor.

The GHG emissions associated with the energy consumption from the treatment of wastewater has been calculated by taking the water requiring treatment during operation and applying the DESNZ water treatment emission factor.

Table 14: Water usage

Parameter	Unit	Value
Water used on site for cleaning of solar PV modules etc	Million litres per annum	0.216
Water requiring treatment	Million litres per annum	0.068

2.2.2 Leakage of GHGs

Sulphur hexafluoride (SF_6) is one of the seven GHGs identified by the Kyoto Protocol which has an extremely high Global Warming Potential (GWP) of 23,900 for the 100-year time horizon. While SF_6 is a potential source of GHG emissions over the lifetime of the Proposed Development (i.e. derived from certain electric items such as gas-insulated switchgear and gas-insulated transformers during production, operation through leakage, and dismantling), it is difficult to quantify fugitive emissions from the leakage of SF_6 as there is insufficient research data available. Additionally, manufacturers are now increasingly able to offer SF_6-free components, and those that do continue to use SF_6 are sealed-for-life with extremely low leakage rates. For this reason, it is assumed that emissions of SF_6 from the Proposed Development will be minimal and not material to this GHG assessment.

2.2.3 Energy generated

During operation of the Proposed Development, there are no GHG emissions associated with the energy generated. The electricity generated by the Proposed Development will be exported to the national grid, offsetting more carbon intensive methods of energy generation. The following table sets out the assumptions used to calculate the energy generated.

Table 15: Energy generated

Parameter	Unit	Value
DC capacity	MW	207.7
AC capacity	MW	147
Capacity factor	%	10.9%
First year degradation	%	0.25%
Degradation after first year	%	0.50%
Parasitic load	kW	15

2.2.4 Energy consumption, material and waste generation from ongoing maintenance on-site

The life expectancy of the equipment as shown in Table 16 has been factored into the calculation of the GHG emissions during the operational phase. For example, as the solar PV modules, PCUs, and PCSs have a life expectancy of 20 years, it has been assumed they will be replaced once at year 20 and as the batteries have a life expectancy of 10 years, it has been assumed they will be replace three times at year 10, 20, and 30. The equipment with a life expectancy over 40 years would not require replacement during the operational lifetime of the Proposed Development. The emissions include those associated with the manufacture of the equipment, transport to the Proposed Development, and disposal and transport of waste materials (i.e. the swapped equipment) and the emissions have been allocated to the year that each piece of equipment will be replaced. It has been assumed the operational vehicle movements around the Site will be minimal.

Table 16: Life expectancy of equipment

Equipment	Life expectancy (years)
Cables	40+
Solar PV modules	20
Solar PV mounting structure	40+
PCU	20
PCS	20
Batteries	10
Aggregate	40+
Fencing	40+
Concrete	40+

Additionally, the failure rate as shown in Table 17 of the solar PV modules, PCUs, PCSs and batteries have been factored into the calculation of the GHG emissions during the operational phase. For example, as the solar PV modules and PCUs, have a failure rate of 10%, it has been assumed 10% of all the solar PV modules and PCUs on-site will require replacement over the lifetime of the Proposed Development. The GHG emissions associated with failure include the manufacture of the equipment, transport to the Proposed Development, and disposal and transport of waste materials (i.e. the swapped equipment) and the emissions have been spread over the operational lifetime of the Proposed Development. It has been assumed the operational vehicle movements around the Site will be minimal.

Table 17: Failure rate of equipment

Equipment	Failure rate (%)
Solar PV modules	10
PCU	10
PCS	50
Batteries	50

2.2.5 Travel of workers during operation

The GHG emissions associated with the travel of workers during operation has been calculated assuming 10 full-time jobs have been created from the operation of the Proposed Development. Given the source of workers is unknown, a reasonable conservative assumption that a worker would travel 50 km to the site (and then return) has been made. This has conservatively assumed each worker would work five days a week and travel to site alone. The DESNZ emission factor for average car emission factor (unknown fuel) and the DESNZ WTT average car emission factor (unknown fuel) have been applied.

Table 18: construction workers distance travelled

Parameter	Unit	Value	Source
Distance to work	km	50	Assumption, unknown location of workers assumed 50 km each way

2.3 Decommissioning Phase (2069-2071)

It has been assumed that the Proposed Development would be decommissioned in Q3 2069, and decommissioning would take two years. It has been assumed that 50% of the equipment and materials used to construct the Proposed Development would be sent to landfill and 50% would be sent to a licenced recycling centre.

2.3.1 On-site decommissioning activities

The GHG emissions associated with the on-site plant vehicles and generators during the decommissioning period has been assumed to be the same as construction.

2.3.2 Transportation and disposal of waste materials

To calculate the GHG emissions associated with the transportation of waste materials, the following assumptions have been applied.

Table 19: Distance to licenced disposal / recycling centre

Parameter	Unit	Value	Source
Distance to licenced landfill	km	100	Assumption, unknown location conservative assumption

Parameter	Unit	Value	Source
Distance to licenced recycling centre	km	100	Assumption, unknown location conservative assumption

The weight of equipment / material to be disposed of has been determined and the DESNZ emission factor for HGV (all diesel) emission factor and the DESNZ WTT HGV (all diesel) emission factor have been applied.

To calculate the GHG emissions associated with the disposal / recycling of waste materials, the DESNZ emission factors have been applied.

2.3.3 Travel for workers during decommissioning

The GHG emissions associated with the travel of workers has been assumed to be the same as construction.

2.3.4 Energy consumption from the provision of clean water and treatment of wastewater

The GHG emissions associated with the energy consumption from the provision of clean water and treatment of wastewater during the decommissioning period has been assumed to be the same as construction.

3 Results

The total GHG emissions over the lifetime of the Proposed Development are summarised in the following table.

Table 20: GHG emissions over the lifetime of the Proposed Development

Parameter	Unit	Value
Construction Phase		
1. Embodied emission associated with raw material extraction and manufacturing of products required for the Proposed Development and transportation of raw materials to the place of manufacturing	tCO_2e	154,225
2. Transportation of manufactured equipment and materials to the Proposed Development	tCO_2e	10,002
3. Transportation of construction materials (where not included in the product-stage embodied GHG emissions)	tCO_2e	500
4. On-Site construction activities	tCO_2e	2,352
5. Travel of construction workers	tCO_2e	334
6. Loss of peat	tCO_2e	-
7. Energy consumption from the provision of clean water and treatment of wastewater during construction	tCO_2e	1.03
Total Construction Phase	**tCO_2e**	**167,414**
Operational Phase		
1. Energy consumption from the provision of clean water and treatment of wastewater	tCO_2e	2.24
2. Leakage of GHGs	tCO_2e	-
3. Energy generated	tCO_2e	-
4. Energy consumption, material and waste generation from ongoing maintenance and replacements on-site	tCO_2e	234,001
5. Travel of workers during operation	tCO_2e	1,097
Total Operational Phase	**tCO_2e**	**235,100**
Decommissioning Phase		
1. On-Site decommissioning activities	tCO_2e	683
2. Transportation and disposal of waste materials	tCO_2e	1,358
3. Travel for workers during decommissioning	tCO_2e	334
4. Energy consumption from the provision of clean water and treatment of wastewater	tCO_2e	1.03
Total Decommissioning Phase	**tCO_2e**	**2,377**
Total emissions	**tCO_2e**	**404,891**

As shown, using the conservative assumptions the total emissions over the lifetime of the Proposed Development are **404,891 tCO_2e**.

4 Emission Factors

Table 21: Energy source emission factors from the Fuel Mix Disclosure Table

Parameter	Unit	Value
Coal	g/kWh	1,046
Natural gas	g/kWh	375
Nuclear	g/kWh	-
Renewables	g/kWh	-
Other	g/kWh	877
Overall average	g/kWh	171

Source: DESNZ, 2024, Fuel Mix Disclosure Table

Table 22: Material emission factors from the Inventory of Carbon and Energy Database

Material	Unit	Value
Aggregates and sand, from secondary resources, bulk, loose	$kgCO_2e/kg$	0.0633
Concrete (general)	$kgCO_2e/kg$	0.103
Steel, engineering steel	$kgCO_2e/kg$	1.64
Steel, electrogalvanised	$kgCO_2e/kg$	2.71
Cement - General (UK Average)	$kgCO_2e/kg$	0.812

Source: Circular Ecology, 2024, Inventory of Carbon and Energy V4.0

Table 23: DESNZ conversion factors for company reporting of greenhouse gas emissions

Parameter	Unit	Value
HGV (all diesel) articulated (>33t) (100% laden)	$kgCO_2e$/tonne.km	0.058
HGV (all diesel) all HGV (100% laden)	$kgCO_2e$/tonne.km	0.072
Cargo ship general cargo (average)	$kgCO_2e$/tonne.km	0.013
Cargo ship container (average)	$kgCO_2e$/tonne.km	0.016
Open loop recycling of electrical items (WEEE-mixed)	$kgCO_2$/tonne	6.411
Landfill of electrical items (WEEE - mixed)	$kgCO_2$/tonne	8.884
Open loop recycling of batteries	$kgCO_2$/tonne	6.411
Landfill of batteries	$kgCO_2$/tonne	8.884
Open loop recycling of aggregates	$kgCO_2$/tonne	0.985
Landfill of aggregates	$kgCO_2$/tonne	1.234
Open loop recycling of concrete	$kgCO_2$/tonne	0.985
Landfill of concrete	$kgCO_2$/tonne	1.234
Open loop recycling of scrap metal	$kgCO_2$/tonne	6.411
Landfill of scrap metal	$kgCO_2$/tonne	8.884
Diesel (100% mineral diesel)	$kgCO_2$/L	2.662
Water supply	$kgCO_2e$/million litres	153

Parameter	Unit	Value
Water treatment	$kgCO_2e$/million litres	186
Average car emission factor (unknown fuel)	$kgCO_2e$/km	0.167
WTT diesel (100% mineral diesel)	$kgCO_2$/L	0.624
WTT HGV (all diesel) all HGV (100% laden)	$kgCO_2e$/tonne.km	0.018
WTT cargo ship general cargo (average)	$kgCO_2e$/tonne.km	0.003
WTT cargo ship container (average)	$kgCO_2e$/tonne.km	0.004
WTT cars (average car) unknown	$kgCO_2e$/km	0.044

Source: DESNZ, 2024, Government conversion factors for company reporting of greenhouse gas emissions

Table 24: Conversion factors

Parameter	Unit	Value	Source
Density of gravel	kg/m^3	2,200	Standard assumption
Density of concrete	kg/m^3	2,400	Standard assumption

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