RWE

Tween Bridge Solar Farm

Environmental Statement
Appendix 14.3: GHG Footprint Methodology

Planning Act 2008
Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

APFP Regulation 5(2)(a)

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Appendices

Tween Bridge Solar Farm

Chapter 14: Air Quality and Greenhouse Gases Appendices

For RWE Renewables UK Solar and Storage Ltd

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14.3 GHG Footprint Methodology

Introduction

14.3.1 This Section sets out the methodology for calculating the baseline Greenhouse Gas (GHG) footprint, and GHG footprint for the Scheme. It covers the following GHG emissions sources:

- existing site: agricultural emissions from arable land use;
- construction phase: embodied GHG emissions in materials used in the construction of the Scheme, construction transport and construction site emissions;
- operational phase: operational transport emissions and repair, maintenance and replacement; and
- energy intensity.

14.3.2 The GHG footprint has been calculated for the lifetime of the Scheme, which includes a 54-month construction period (assumed to commence in 2028) and then a 40-year operational period from 2029 onwards (with full Scheme completion in 2032).

14.3.3 Details of the methodology to calculate the GHG emissions from each of the emission sources included in the GHG footprint is provided in the following sections.

Baseline Emissions

14.3.4 The existing baseline GHG emissions within the Order Limits, are established by taking account the total emissions from current land use such as agricultural activities.

14.3.5 A summary of the data used for the calculation of the current GHG emissions from the Order Limits resulting from agricultural activities is shown in Table 14.3.1. The GHG factor for agricultural land use has been taken from Natural England[12].

Table 14.3.1: Existing Order Limits Data

Land Use	Total Site Area (ha)	GHG Emissions Factor ($kgCO_2e/ha$)	Lifetime GHG Emissions (tonnes CO_2e)[a]
Agricultural land	1,831	0.29	21,240

[a] Value rounded to nearest whole number.

Construction Phase

Embodied GHG Emissions in Materials used in the Construction of the Scheme

14.3.6 Embodied carbon emissions from the construction phase of the Scheme have been estimated based on data and information provided by the Applicant, including:

[12] Natural England (2021) Carbon storage and sequestration by habitat: a review of the evidence (second edition).

- quantities (mass and/or volume) of key materials such as steel for solar PV modules and mounting structures, and concrete for hard standing;
- dimensions of key structures on site including battery containers;
- numbers, sizes, weights, dimensions for key components of the solar and BESS systems including PV panels, inverters, transformers, switchgear, battery cells and HVAC systems; and
- lengths, type and specifications of cabling to be used throughout the Scheme.

14.3.7 These input data have been processed and combined with embodied carbon emissions factors from a number of sources to model the embodied carbon emissions.

14.3.8 A summary of the sources and assumptions used in the calculation of embodied carbon emissions is presented in Table 14.3.2.

Table 14.3.2: Sources and Assumptions of Emissions Factors for Embodied Carbon

Component	GHG Emissions Factors Source and Assumptions
Solar Array	
PV Modules	GHG emissions factor of 0.0081 kgCO_2e/kWh calculated using an Environmental Performance Declaration (EPD) for Jolywood JW-HD156N-158.75 monocrystalline solar panels (manufactured in China)[13].
PV Frames & Mounting Structures	GHG emission factor for electro galvanised steel obtained from ICE 3.0 database[14].
Cabling	Material composition of cables assumed from the Lifecycle Carbon Impact Assessment of the Respond Project Report[15]. GHG emission factors for aluminium, copper, and plastics (XLPE and MDPE) obtained from ICE 3.0[14] and ICE 2.0 databases[16].
HV Infrastructure	
Inverters	EPD CO_2e intensity calculated using and Environmental Environmental Performance Declaration (EPD) for Sungrow central power inverter[17].
Transformers	Typical material composition of transformers obtained from lifecycle analysis of power transformers[18] and emissions factors for steel, copper and insulating paper taken from ICE 2.0[16] and 3.0[14].
Switchgear	GHG intensity of switchgear converters assumed from the Lifecycle Carbon Impact Assessment of the Respond Project Report[15].

[13] Environmental Performance Declaration (2020) Jolywood N-type Bifacial Double Glass PV Modules, valid to Nov 2025: https://pvsky.pl/wp-content/uploads/2021/12/Jolywood-JW-HD144N-445-470W-Raport-EPD.pdf
[14] University of Bath (2019) Inventory of Carbon and Energy (ICE) Version 3.0.
[15] FuturoFirma (2018) Lifecycle Carbon Impact Assessment of the Respond Project: https://www.enwl.co.uk/globalassets/innovation/respond/respond-key-documents/carbon-impact-assessment-final-report.pdf
[16] University of Bath (2013) Inventory of Carbon and Energy (ICE) Version 2.0.
[17] Environmental Performance Declaration (2024) EPD Sungrow central power inverter: https://en.sungrowpower.com/Downloads
[18] Hong Guo, Yuting Gao, Junhao Li (2022) The greenhouse gas emissions of power transformers based on life cycle analysis. Energy Reports Volume 8, Supplement 15, Pages 413-419.

BESS	
Battery Cells	GHG emissions factor of 172kgCO_2e/kWh calculated using an Environmental Performance Declaration (EPD) for Huawei battery cells[19].
Battery Containers	GHG emissions calculated based on size of structures using GHG emissions factors obtained from RICS guidance for specialist buildings/structures[20].
HVAC Systems	GHG emissions factor for HVAC systems obtained from embodied carbon in HVAC system lifecycle analysis and applied to total area of all battery containers[21].
Concrete/hard standing	GHG emissions factor for general UK concrete obtained from ICE database[14,16].

14.3.9 The resultant embodied carbon emissions are provided in Table 14.3.3.

Table 14.3.3: Embodied Carbon Emissions (tonnes CO_2e)

Component	Embodied Carbon (tonnes CO_2e)[a]	% of Total
PV Panels	359,092	60.2%
PV Framework	26,708	4.5%
Cabling	62,283	10.4%
HV Infrastructure (PCS) (Inverters, Transformers and Switchgear)	31,260	5.2%
BESS (Batteries, Containers, HVAC)	73,598	12.3%
Substations	37,714	6.3%
Concrete/hard standing	5,801	1.0%
Total	**596,457**	**100%**

[a] All values rounded to nearest whole number.

Construction Transport

14.3.10 The transport movements generated by the Scheme during the construction phase have been provided by the project transport consultant. The transport movements included vehicle movements associated with the delivery of goods and materials, and movement of construction site workers by private van and minibus.

[19] Environmental Performance Declaration (2022) Huawei Digital Power Technologies battery modules valid to Sep 2027: https://www.epditaly.it/wp-content/uploads/2016/12/EPD_Huawei_2022-Battery-Modules.pdf
[20] RICS (2012) Methodology for the calculation of embodied carbon in materials. 1st edition.
[21] Rodriguez Droguett, B (2019) Embodied Carbon of Heating, Ventilation, Air Conditioning and Refrigerants (HVAC+R) Systems. University of Washington.

14.3.11 GHG factors for construction transport have been obtained from DESNZ[22] for 2025. The factors for 2025 have been applied to the construction traffic in 2028-2032, which ignores any potential decarbonisation in the interim period and is therefore conservative.

14.3.12 For construction transport of materials, articulated HGVs are assumed to travel 120km and rigid HGVs are assumed to travel 80km. In the absence of trip distance data, distances have been based on the RICS guidance[23]. Construction transport data for the Scheme provided total HGV movement numbers and it was assumed that 50% of the HGVs would be articulated and 50% rigid.

14.3.13 It has been assumed that due to lower vehicle loading to move materials around the site, the tractor and trailer movements will be 150% of the external HGV deliveries. On-site external tractors and trailer movements are assumed to travel 10km per trip. These movements are contained within the Order Limits.

14.3.14 For construction site staff, an average travel distance of 20km has been used, which encompasses Doncaster. Staff are assumed to travel to the site either by staff minibus or private car.

14.3.15 It is expected that many of the products and materials used within the Scheme will be manufactured abroad and shipped to the UK for installation. GHG emissions associated with the international shipping of these goods has therefore been accounted for in the GHG footprint. It is likely that the PV modules, cables, inverters, transformers and the BESS will be manufactured in China. The GHG factors for a container ship has been taken from DESNZ GHG conversion factors[22].

14.3.16 A summary of the data used for the calculation of construction transport GHG emissions is shown in Table 14.3.4 to Table 14.3.6.

Table 14.3.4: Construction Vehicles Data and Emissions

Vehicle Type	Number of Movements	Distance Travelled (km)	GHG Emissions Factor ($kgCO_2e/km$)	GHG Emissions (tonnes CO_2e)[a]
HGV (Artic)	40,378	4,845,360	0.929	4,499
HGV (Rigid)	40,378	3,230,240	0.838	2,705
LDV	89,926	4,496,310	0.256	1,149
On-site tractor/trailer	256,023	2,560,233	0.838	2,144

[a] All values rounded to nearest whole number.

Table 14.3.5: Construction Staff Transport Data and Emissions

Vehicle Type	Number of Two-Way Movements	Distance Travelled (km)	GHG Emissions Factor ($kgCO_2e/km$)	GHG Emissions (tonnes CO_2e)[a]
Minibus	54,513	1,090,253	0.16725	182
Private car	132,354	2,647,080	0.25561	677

[22] DESNZ (2025) Greenhouse gas reporting: conversion factors 2025.
[23] RICS (2023) Whole life carbon assessment for the built environment, 2nd edition.

[a] All values rounded to nearest whole number.

Table 14.3.6: Construction Shipping Data and Emissions

Vehicle Type	Item	Mass (T) [a]	Total (T) [b]	Shipping Distance (km)	GHG Emissions Factor (kg CO_2 per tonne.km)	GHG Emissions (tonnes CO_2e)
Container Ship	PV panels	77,212	123,934	18,520	0.01612	36,999
	Cables	13,750				
	Inverters	9,106				
	Transformers	1,616				
	BESS	10,982				

[a] Values rounded to nearest whole number.

[b] Includes 10% uplift for packaging and uncertainty.

14.3.17 The estimated construction phase transport emissions are 48,356tonnes CO_2e.

Construction Site Emissions

14.3.18 Emissions from diesel consumed by construction site plant and machinery has been estimated based on data from the Applicant in relation to the types of machinery to be used for the construction works. A detailed plan of plant requirements for each of the phases of the work has been obtained from the Applicant.

14.3.19 Fuel consumption for each machine/plant has been obtained from data in the European Environment Agency/EMEP emissions inventory guidebook. The data provides fuel consumption per hour.

14.3.20 Emissions factors for diesel fuel consumption have been obtained from DESNZ GHG conversion factors[22].

14.3.21 Construction site emissions are estimated using the following assumptions:

- Numbers of each machine/plant have been estimated based on the construction programme, discussion with the project team and experience from other large scale solar developments;
- Scheme operating hours and the 54-month duration of each work phases have been based on those described in **ES Chapter 2 Scheme Description [Document Reference 6.1.2]**;
- Each machine/plant operates for 50% of available site hours on average; and
- Average engine loading during operation is 50% of full load/power.

14.3.22 The estimate construction phase emissions from site plant and machinery are 17,076tonnes CO_2e.

Operational Phase (including Maintenance)

Operational Transport

14.3.23 The applicant has advised that it is likely that the operational transport movements will be limited to one round trip journey per month with an average travel distance of 20km per round trip.

14.3.24 The operational transport data and assumptions used in the assessment is shown in Table 14.3.7. A 2025 GHG emissions factor has been used for the whole lifetime of the Scheme as a conservative assumption as this does not account for any decarbonisation of road traffic over this period.

Table 14.3.7: Transport Data, Assumptions and Emissions

Parameter	Value	Unit	Notes
Number of Trips	2	Per month	From the Applicant.
Type of Vehicle	LDV		Project team discussion
Average Travel Distance	10	km	10km each way.
GHG Factor (2025)	0.256	$kgCO_2e/km$	DESNZ GHG conversion factors[22].
Annual GHG	0.1	tonnes CO_2e	
Lifetime GHG (40 Years)	2.5		

Repair, Maintenance and Replacement

14.3.25 Repair, maintenance and replacement of the Scheme over its 40-year operational lifetime is predominated by the embodied carbon associated with parts and products used for repairs, maintenance and replacements.

14.3.26 In order to be conservative, the assessment has used the same embodied carbon emissions factors and intensities as used in the calculation of embodied carbon emissions described above. This is conservative as it ignores the potential future decarbonisation of the mining, processing and manufacturing sectors.

14.3.27 The data and assumptions used in the calculation of emissions from repair, maintenance and replacement at provided in Table 14.3.8.

Table 14.3.8: Operational Repair, Maintenance and Replacement Assumptions, Data and Emissions

Component	Number of Replacements during Lifetime	Lifetime Carbon (tonnes CO_2e)[a]
Solar Array		
Solar PV Modules	0.1	35,909
PV Framework & Mounting Structures	0.1	2,671
Cables	0.1	6,228

HV Infrastructure		
Inverters	0.1	2,605
Transformers	0.1	516
Switchgear	0.1	4
BESS		
Battery Cells	1	68,957
HVAC Systems	1	978
Substations		
Substation Infrastructure	0.1	3,771
Concrete/hard standing	0.1	580
Total		**122,221**

[a] All values rounded to nearest whole number.

Energy Intensity/Offset

14.3.28 The calculation of the lifecycle energy intensity of the Scheme is calculated using the total lifecycle carbon emissions and the total expected lifetime electricity export. To calculate the lifetime electricity exported, the annual (opening year) value has been extrapolated over 40 years, assuming a PV panel degradation rate of 0.45% per annum over the lifetime.

14.3.29 The Scheme will be built out over 54 months and it is expected that the generation of electricity will be phased in from 2029 but not reach full capacity of 1,260,000 MWh until 2032. As such, it has been assumed that in 2029, 315,000MWh will be generated, with a further 315,000MWh each year to 2032, from which the Scheme will operate at full capacity. These numbers have been adjusted for 0.45% degradation from 2029, which slightly reduces the expected export capacity from 2032 onwards.

14.3.30 A summary of the energy intensity calculation is provided in Table 14.3.9.

Table 14.3.9: Energy Intensity Calculation

Parameter	Year	Value	Unit
Total Annual Electricity Export	2029	315,000,000	MWh
	2030	628,582,500	MWh
	2031	940,753,879	MWh
	2032	1,250,083,879	MWh
	2033-2069	1,250,083,879 less annual degradation	MWh
Annual Degradation Rate		0.45	%
Total Lifetime (40-year) Electricity Export		48,233,678,771	kWh
Total Lifetime GHG Emissions		784,112	tonnes CO_2e
Lifecycle Carbon Intensity		16.26	gCO_2e/kWh

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