Longfield Solar Farm

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1. Climate Change

1.1 Introduction

1.1.1 This technical appendix to the climate change chapter of the ES has been prepared to present the raw data provided by the Applicant to allow the GHG assessment to be carried out. It will also outline the emissions factors and the methodology applied to carry out the GHG.

1.1.2 Emissions calculations apply the following format:

Activity data x emissions factor = emissions in mass of CO_2e

1.1.3 The information contained in this appendix follows the overall format of the GHG assessment as contained within the climate change chapter. Data is presented as follows:

a. Lifetime electricity generation

b. Components and materials

c. Transport of components and materials to site

d. Other construction activities

e. Land use change, temporary and permanent

f. Operations, including replacement of components

g. Decommissioning and waste disposal

1.2 Lifetime electricity generation

1.2.1 The efficiency of the PV panels to be used on the Scheme is known to progressively degrade over time (Ref 1). They are assumed to degrade by 2% in the first year, then by 0.45% each year thereafter. Table 1 below summarises the annual electricity generation rates likely to be achieved by the Scheme, which has a rated capacity of 375 MW (i.e., with no degradation).

1.2.2 This estimate is likely to be conservative (i.e., the Scheme can be anticipated to generate more than shown in **Table 1**) as projected decreases in summer cloud cover are likely to result in more insolation and higher yields in the future.

Table 1: Annual electricity generation by the Scheme

Year	Estimated capacity of the Scheme in each year (MW)	Anticipated annual generation (MWh/kWp/yr)	Estimated annual generation (MWh)
2026	367.50	970	356,475
2027	365.85	970	354,871
2028	364.20	970	353,274
2029	362.56	970	351,684

Year	Estimated capacity of the Scheme in each year (MW)	Anticipated annual generation (MWh/kWp/yr)	Estimated annual generation (MWh)
2030	360.93	970	350,102
2031	359.31	970	348,526
2032	357.69	970	346,958
2033	356.08	970	345,396
2034	354.48	970	343,842
2035	352.88	970	342,295
2036	351.29	970	340,755
2037	349.71	970	339,221
2038	348.14	970	337,695
2039	346.57	970	336,175
2040	345.01	970	334,662
2041	343.46	970	333,156
2042	341.91	970	331,657
2043	340.38	970	330,165
2044	338.84	970	328,679
2045	337.32	970	327,200
2046	335.80	970	325,727
2047	334.29	970	324,262
2048	332.79	970	322,803
2049	331.29	970	321,350
2050	329.80	970	319,904
2051	328.31	970	318,464
2052	326.84	970	317,031
2053	325.37	970	315,605
2054	323.90	970	314,184
2055	322.44	970	312,770

Year	Estimated capacity of the Scheme in each year (MW)	Anticipated annual generation (MWh/kWp/yr)	Estimated annual generation (MWh)
2056	320.99	970	311,363
2057	319.55	970	309,962
2058	318.11	970	308,567
2059	316.68	970	307,178
2060	315.25	970	305,796
2061	313.84	970	304,420
2062	312.42	970	303,050
2063	311.02	970	301,686
2064	309.62	970	300,329
Total			13,076,218

1.3 Components and materials

1.3.1 Estimated embodied carbon resulting from the manufacture of the PV Panels is derived from an Environmental Product Declaration (EPD) (Ref 2) for a comparable PV Panel.

1.3.2 The preparation of EPDs is controlled by international standards and complying with environmental management systems subject to independent 3rd party verification. Where available, EPDs provide reliable information on embodied carbon alongside other environmental parameters.

1.3.3 The EPD for a PV Panel comparable to the one to be used in the Proposed Development contained the following data:

a. The panels had embodied carbon of 0.00748 kg CO2e for each kilowatt-hour of power generated

b. This data comes from a site in China that generated 2,127,954,734 kWh over a 30 year period, for an annual generation figure of 70,931,824 kWh/yr.

c. The site has a capacity of 60,000 kWp, which indicates an average generation figure of 1,182 kWh per kWp installed.

d. This figure is 1.22 times higher than the 970 kWh/kWp figure anticipated for the DCO Site and provided by the Applicant.

e. Therefore, the embodied carbon value from the EPD must be multiplied by 1.22 times to get an embodied carbon figure of 0.00912 kg CO2e/kWh

1.3.4 The embodied carbon figure for the PV Panels and the estimated lifetime generation figure feed into **Table 2** below, which shows the activity data as provided by the Applicant, relevant emissions factor, and calculated emissions for each component or quantity of materials required to construct the Proposed Development.

Table 2: GHG emissions from the manufacture of components and materials

Component or material	Activity data	Units	Emissions factor, kg CO_2e per unit	Emissions (tCO_2e)
Battery storage (BESS)	1,600	MWh (storage capacity)	8,900 (Ref 3)	142,400
PV Panels	13,076,218	MWh (lifetime generation)	9.12 (Ref 2)	119,207
PV Inverters	450,000	kW	65.31 (Ref 4)	29,390
PV framework (steel)	15,000	tonnes	1,550 (Ref 5)	23,250
PV framework (aluminium	750	tonnes	6,670 (Ref 5)	5,003
BESS Inverters	360,000	kW	65.31 (Ref 4)	23,512
Transformers	380	MVA	10,850 (Ref 9)	4,123
Cables (aluminium)	282	tonnes	6,670 (Ref 5)	1,881
Cables (plastic)	188	tonnes	3,310 (Ref 5)	622
Concrete	6,000	tonnes	103 (Ref 5)	618
Aggregate	15,240	Tonnes	7.5 (Ref 5)	114
Total				350,119

1.4 Transport of components and materials to site

1.4.1 Table 3 below shows activity data, emission factors and emissions for the transportation of each item to site. Factors for sea and road transport are taken from the UK Government's annual emissions factors dataset. (Ref 6)

Table 3: GHG emissions from the transport of components and materials to site

Component or material and mode of transport	Mass in tonnes	Distance in km	Emissions factor, kg CO_2e per tonne.km	Emissions (tCO_2e)
Battery storage; sea	8,000	19,377	0.13	1,965
Battery storage; HGV	8,000	112	0.24	216
PV Panels; sea	25,529	19,377	0.13	6,270
PV Panels; HGV	25,529	112	0.24	688
PV Inverters; sea	720	100	0.13	0.9
PV Inverters; HGV	720	500	0.24	19
PV framework (steel); sea	15,000	100	0.13	3,684
PV framework (steel); HGV	15,000	500	0.24	404
PV framework (aluminium); sea	750	19,377	0.13	184
PV framework (aluminium); HGV	750	112	0.24	20
BESS Inverters; sea	700	100	0.13	0.9
BESS Inverters; HGV	700	112	0.24	19
Transformers; sea	1,185	100	0.13	1.5
Transformers; HGV	1,185	500	0.24	143
Concrete; HGV	6,000	50	0.24	77
Aggregate; HGV	15,240	50	0.24	183

Component or material and mode of transport	Mass in tonnes	Distance in km	Emissions factor, kg CO_2e per tonne.km	Emissions (tCO_2e)
Total				13,938

1.5 Waste disposal

1.5.1 Table 4 below shows the activity data, emission factors and emissions for the disposal of construction waste. Activity data is provided by the Applicant; emissions factors are from the UK Government. (Ref 6) It is assumed that all waste disposal takes place within a 100km radius of the Scheme location.

Table 4: GHG emissions from construction waste disposal

Category	Activity data	Units	Emissions factor kg CO_2e per unit	Emissions (tCO_2e)
Concrete; landfill	150	Tonnes	1.239	0.186
Concrete; recycled	150	Tonnes	0.9891	0.148
Aggregate; landfill	381	Tonnes	1.239	0.472
Aggregate; recycled	381	Tonnes	0.9891	0.377
Steel; recycled	225	Tonnes	0.9891	0.297
Aluminium; recycled	4.5	Tonnes	0.9891	0.0056
Plastic; landfill	78	Tonnes	8.902	0.692
Plastic; recycled	233	Tonnes	21.294	4.967
Paperboard; recycling	3,455	Tonnes	21.294	73.573
Wood; landfill	1,852	Tonnes	828	862.835
Wood; recycling	5,557	Tonnes	21.294	66.566
Waste transport	930,200	Tonne.km	0.24	224.006
Total				1,234.193

1.6 Other construction activities

1.6.1 GHG emissions from worker travel to site are based on estimated worker numbers on site during each month of the construction period as provided by the Applicant. Numbers of workers on site varies between 15 in month 1, rising to a maximum of 500 in months 16 and 17 of the build.

1.6.2 Key assumptions for worker travel are that car sharing takes place, with an average of 1.35 people per vehicle. It is assumed that all workers live within a 30km radius of the site for a 60km daily round trip. Total vehicle distance travelled with these assumptions is 11,113,348 km over the 24 months of the construction period. An emissions factor for an average car of unknown fuel was applied (Ref 6).

1.6.3 Fuel will be consumed on site, both in generators and in plant and machinery. Generators are assumed to consume 16.5 litres per hour, 6 hours a day, 26 days a month for a total of 61,776 litres. Plant and machinery are assumed to consume 5,000 litres per week for a total of 520,000 litres over the 24 month construction period. All fuel is assumed to be gas oil (Ref 6).

1.6.4 Water consumption during the construction period is assumed to be 90 litres per person per day; applying this rate to the data provided by the Applicant gives a total water consumption of 780,060 cubic metres. A composite emissions factor comprising both water supply and wastewater treatment was applied (Ref 6).

1.6.5 **Table 5** below shows the activity data, emission factors and calculated emissions for each element of construction.

Table 5: GHG emissions from other construction activities

Category	Activity data	Units	Emissions factor kg CO_2e per unit	Emissions (tCO_2e)
Worker commuting (total car journeys)	11,113,348	km	0.17148	1,906
Total fuel consumption – Plant	520,000	Litres	2.75857	1,434
Total fuel consumption - generators	61,776	Litres	2.75857	170
Total water consumption	780,060	m^3	0.421	328
Total				3,838

1.7 Land use change

Temporary land use change

1.7.1 Table 6 below summarises the soil and vegetation carbon stored over the design life of the Scheme. A key assumption is that these areas of land will revert to arable land on decommissioning and the end of the Scheme's design life. With the exception of the rewilding scrubland, which will be converted from grassland, each of these areas will be converted from arable land. The additional soil and vegetation carbon stored are shown relative to the values in the previous land use (Ref 7).

Table 6: GHG storage from temporary land use change (design life only)

Land use category	Area (Ha)	Soil carbon stored (tCO_2/Ha)	Vegetation carbon stored (tCO_2/Ha)	Soil + vegetation carbon stored (tCO_2)
Biodiverse grassland	235	108	25	31,235
Natural regeneration grassland	44	108	25	5,793
Lowland meadow	26	108	25	3,444
Conservation field margin	33	108	25	4,447
Rewilding scrubland	9	0	2.2	20
Total				44,939

Permanent land use change

1.7.2 Table 7 below summarises the soil and vegetation carbon assumed to be stored beyond the design life of the Scheme. The working assumption is that new woodland (including woodland edge and woodland strip) and new hedgerows will be retained at the end of the Scheme's design life. Each of the areas in Table 7 will be converted from arable land, and the additional soil and vegetation carbon values are shown relative to that contained in arable land (Ref 7).

Table 7: GHG storage from permanent land use change (beyond design life)

Land use category	Area (Ha)	Soil carbon stored (tCO_2/Ha)	Vegetation carbon stored (tCO_2/Ha)	Soil + vegetation carbon stored (tCO_2)
New woodland	101	108	220	33,191
Natural regeneration woodland edge	23	108	220	7,537

Land use category	Area (Ha)	Soil carbon stored (tCO_2/Ha)	Vegetation carbon stored (tCO_2/Ha)	Soil + vegetation carbon stored (tCO_2)
Native woodland strip	4.3	108	220	1,401
New hedgerows	1.2	108	27	158
Total				42,288

1.8 Operations, including component replacement

Consumption of grid electricity

1.8.1 The single on-site warehouse is estimated to have a continuous electricity demand of 10kW, with this being supplied from the national grid for a total annual demand of 87,600 kWh. Table 8 below shows the annual GHG emissions from the supply of electricity over the design life of the Scheme as the grid is progressively decarbonised (Ref 8).

Table 8: GHG emissions from consumption of on-site electricity demand

Year	Annual consumption of grid electricity (kWh)	Projected grid carbon intensity (kg CO_2e/kWh)	Emissions (tCO_2e)
2026	87,600	0.092	8.09
2027	87,600	0.076	6.70
2028	87,600	0.071	6.19
2029	87,600	0.066	5.80
2030	87,600	0.053	4.60
2031	87,600	0.042	3.64
2032	87,600	0.036	3.15
2033	87,600	0.031	2.73
2034	87,600	0.028	2.48
2035	87,600	0.025	2.21
2036	87,600	0.021	1.83
2037	87,600	0.019	1.63
2038	87,600	0.018	1.59

Year	Annual consumption of grid electricity (kWh)	Projected grid carbon intensity (kg CO_2e/kWh)	Emissions (tCO_2e)
2039	87,600	0.017	1.51
2040	87,600	0.016	1.37
2041	87,600	0.013	1.13
2042	87,600	0.012	1.08
2043	87,600	0.012	1.05
2044	87,600	0.011	0.99
2045	87,600	0.010	0.84
2046	87,600	0.009	0.76
2047	87,600	0.008	0.70
2048	87,600	0.008	0.67
2049	87,600	0.007	0.62
2050	87,600	0.007	0.61
2051	87,600	0.007	0.61
2052	87,600	0.007	0.61
2053	87,600	0.007	0.61
2054	87,600	0.007	0.61
2055	87,600	0.007	0.61
2056	87,600	0.007	0.61
2057	87,600	0.007	0.61
2058	87,600	0.007	0.61
2059	87,600	0.007	0.61
2060	87,600	0.007	0.61
2061	87,600	0.007	0.61
2062	87,600	0.007	0.61
2063	87,600	0.007	0.61
2064	87,600	0.007	0.61

Year	Annual consumption of grid electricity (kWh)	Projected grid carbon intensity (kg CO_2e/kWh)	Emissions (tCO_2e)
Total			71.2

Worker commuting and water use

1.8.2 There are assumed to be 8 members of staff on site each day of the year. It is assumed that they each commute to site each day in their own car and travel a round trip distance of 60km for a total annual commuting distance of 175,200km. A representative emissions factor for an average car of unknown fuel type has been applied to this annual mileage (Ref 6).

1.8.3 Each member of staff on site is assumed to result in the consumption (for drinking, cooking and washing) of 90 litres of water per day, for a total annual water consumption of 262.8 cubic metres. Emissions factors for the supply of water and the treatment of wastewater have been applied to this consumption (Ref 6).

1.8.4 **Table 9** below summarises the GHG emissions resulting from worker commuting and water consumption.

Table 9: GHG emissions from worker commuting and water consumption

Category	Annual activity data	Emissions factor (kg CO_2e/unit)	Annual emissions (tCO_2e)	Lifetime emissions (tCO_2e)
Worker commuting	175,200 km	0.2156	37.8	1,511
Water consumption	262,800 m^3	0.421	0.11	4.43
Total				1,515

Component replacement (including transport)

1.8.5 The Applicant has assumed that over the design life of the Scheme, certain components will need to be replaced one or more times. It is assumed that 5% of transformers, 10% of PV Panels, and 150% of PV inverters, BESS inverters and the cells in the BESS itself will require replacement.

1.8.6 These replacement rates have been applied to the GHG values for the manufacture and transport of these components that were estimated for the construction phase and shown in **Table 2** and **Table 3** above. **Table 10** below summarises the embodied and transport emissions resulting from component replacement.

Table 10: GHG emissions from component replacement

Item	Design life replacement rate	Original embodied emissions (tCO_2e)	Original transport emissions (tCO_2e)	Replacement embodied and transport emissions (tCO_2e)
Transformers	5%	4,123	145	213
PV Panels	10%	119,207	6,958	12,616
BESS Inverter	150%	23,512	20	35,297
PV Inverter	150%	29,390	20	44,216
BESS cells	150%	142,400	2,181	216,871
Total				305,079

1.9 Decommissioning

1.9.1 **Table 11** below summarises the emissions resulting from the disposal of materials at the end of the Scheme's design life. It is assumed that by the end of life of the Scheme, all materials will be recycled with nothing going to landfill by this time. It is likely that by the time the Scheme is decommissioned, the GHG impact from recycling will be lower than currently as the UK complies with net-zero targets.

1.9.2 The emissions factors used in this assessment are taken from the UK Government's conversion factors for company reporting. (Ref 6)

Table 11: GHG emissions from material recycling at the end of life

Category	Mass in tonnes	Waste type	Emissions factor kg CO_2e per unit	Emissions (tCO_2e)
Concrete; recycled	6,000	Construction–concrete	0.989	5.93
Aggregate; recycled	15,240	Construction - aggregate	0.989	15.07
Steel, recycled	15,000	Construction – metals	0.989	14.84
Aluminium; recycled	1,032	Construction – metals	0.989	1.02
Plastic; recycled	188	Plastic	21.294	4.00
Batteries, recycled	8,000	Electrical items – batteries	21.294	170.35

Category	Mass in tonnes	Waste type	Emissions factor kg CO_2e per unit	Emissions (tCO_2e)
Miscellaneous other (WEEE), recycled	28,134	Electrical items – WEEE mixed	21.294	599.09
Total				810.30

1.9.3 The transport of materials for final disposal at the end of life assumes that concrete and aggregate will be disposed of within a 50km ratio, while all other materials will travel no more than 200km for disposal. Transport emissions are very likely to be significantly lower by the Scheme's end of life, so this assessment is inherently conservative as it applies transport factors published by the UK Government for emissions reporting in 2021/22. (Ref 6) **Table 12** summarises emissions from the transport of waste.

Table 12: GHG emissions from the transport of waste at end of life

Category	Mass in tonnes	Distance (km)	Emissions factor kg CO_2e per tonne.km	Emissions (tCO_2e)
Concrete	6,000	50	0.24312	72.94
Aggregate	15,240	50	0.24312	185.26
Steel	15,000	200	0.24312	729.36
Aluminium	1,032	200	0.24312	50.18
Plastic	188	200	0.24312	9.13
Batteries	8,000	200	0.24312	388.99
Miscellaneous other (WEEE)	28,134	200	0.24312	1,367.99
Total				2,803.86

1.9.4 In the absence of any reliable data surrounding the circumstances or impacts of decommissioning the scheme at the end of its design life, it has been decided in discussion with the Applicant to assume that all other decommissioning-related emissions (worker commuting, plant use, water use) will be 50% of the value from the construction phase.

1.10 References

Ref 1 Datasheet for Jinkosolar TR-Bifacial 72M 510-530 Watts.

Ref 2 Environmental Performance Declaration (EPD) for Jolywood JW-HD144N-166 PV Module.

Ref 3 Forbes (2020). Estimating the carbon footprint of utility-scale battery storage.

Ref 4 Rajput & Singh (2017). Reduction in CO2 emission through photovoltaic system: a case study.

Ref 5 Circular Ecology (2019). Inventory of Carbon and Energy.

Ref 6 DEFRA/BEIS (2021) Conversion Factors for Company Reporting

Ref 7 European Commission (2010). Guidelines for the calculation of land carbon stocks for the purpose of Annex V to Directive 2009/28/EC

Ref 8 Department for Business, Energy & Industrial Strategy (BEIS) (2021). Data Tables 1 to 19.

Ref 9 Meta-analysis of multiple Environmental Product Declarations for power transformers; unpublished