Lound PFA Extraction Chapter 15 Climate Change:

Appendix 15.1: GHG Technical Methodology and Data

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1 Introduction

1.1 This appendix sets out the methodology for the calculating the Greenhouse Gas (GHG) footprint for the Proposed Development. It covers the following GHG emissions sources:

- Construction: embodied carbon, construction transport and site activities; and
- Operation: site maintenance and restoration; material transport; staff travel, and operational fuel consumption.

1.2 The GHG footprint has been calculated for each year, from the start of the construction in 2023, out to 2044, which is the anticipated year of completion of the Pulverised Fuel Ash (PFA)_ extraction and site restoration (consistent with phasing programme presented in Chapter 5, Table 5.1). It is acknowledged that operation of the Site may extend beyond the phasing programme (up to 25 years), to account for the possibility of a gradual increase to full production in the early years of the Proposed Development, however this would not materially affect this assessment. It is also assumed that construction of the Main Processing Site would take place in 2023.

1.3 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.

2 Construction

Embodied Carbon

2.1 Emissions from construction of the Proposed Development have been estimated using data from a number of sources. The buildings, structures and assets included in the calculation of embodied carbon are:

- materials storage buildings;
- 6 x portacabin offices;
- weighbridge and wheel wash;
- 4 x PFA silos;
- Combined Heat and Power plant;
- 2 x gas storage tanks;
- gas pipelines;
- 10 x PFA drying modules;
- 40 x PFA filtration cyclone units;
- PFA conveyors;
- roadways;
- 1.5 Ha of concrete pads/hardstanding in processing areas (i.e. Processing Areas 1-3_; and
- site plant (3 x excavators, 2 x loaders and 2 x tippers).

2.2 Areas of the Site selected for processing and car parking have existing hardstanding which would be retained. Embodied carbon emissions calculations therefore exclude hardstanding and car parking, as these are already in place.

2.3 For each of the buildings, structures and assets, embodied carbon has been estimated based either on building areas, or mass of materials and primary material types provided by the design team. GHG emissions factors have been obtained from RICS, University of Bath ICE 3.0 or other published resources where appropriate.

2.4 A summary of the data used for the calculation of GHG emissions from embodied carbon is presented in Table 1.

Table 1: GHG Emissions Data for Embodied Carbon

Building/ Structure	Area (m^2)	Mass (kg)	Primary Materials	Embodied Carbon Factor ($kgCO_2e$/ unit)	Source of Emissions Factor	Embodied Carbon (TCO_2e)
Materials Storage Building	2,000			545 [a]	RICS[1]	1,090
6 x Portacabin Offices	178			545 [a]		97
Weighbridges	60			545 [a]		33
4 x PFA Silos	560			545 [a]		305
CHP Plant		50,000	Steel and Aluminium	4.85 [b]	ICE 3.0[2]	243
2 x Gas Storage Tanks	59			545 [a]	RICS[1]	32
Gas Pipeline		4,896	Steel	3.02 [c]	ICE 3.0[2]	15
10 x Drying Modules	68			545 [a]	RICS[1]	37
40 x Filtration Cyclones		303,200	Steel and Aluminium	4.85 [b]	ICE 3.0[2]	1,471
Conveyors		185,000	Steel and Aluminium	4.85 [b]	ICE 3.0[2]	897
Roadways	1,780		Bitumen and Aggregates	84.5 [d]	UKRI/ DCarbon8[3]	150
Concrete Pads		5,400,000	Concrete	0.103 [e]	ICE 3.0[2]	556
Site Machinery		210,000		3.73 [f]	LowCVP[4]	783
					TOTAL	**5,709**
					TOTAL +25% Uplift	**7,136**

[a] RICS factor for specialist used applied.

[b] Hybrid factor from ICE 3.0 assuming 50% steel and 50% aluminium.

[c] Factor for steel pipework from ICE 3.0.

[d] GHG factor from DCarbon8 report is 591.5 kgCO2e/km road. Factor calculated assuming 7 m road width (i.e., 7,000 m^2 per km).

[e] Factor for general UK concrete from ICE 3.0.

[f] Low Carbon Vehicle Partnership report estimates 5.6 TCO_2e per standard gasoline vehicle. Based on estimated passenger vehicle weight of 1.5 T, this is equal to 3.73 TCO_2e/T.

[1] RICS (2012) Methodology to calculate embodied carbon of materials. First edition.

[2] University of Bath (2019) Inventory of Carbon and Energy (ICE) version 3.0.

[3] UKRI/DCarbon8 (2022) Measuring Road Infrastructure Carbon: A 'critical' in transport's journey to net zero.

[4] Low Carbon Vehicle Partnership (2018) Lifecycle emissions from cars.

2.5 Due to the complexity of embodied materials and respective carbon intensities of many of the components of the compounds and processing areas, the calculated embodied carbon has been uplifted by 25% to account for uncertainty. This is intended to provide a conservative estimate of the embodied carbon from construction materials and ensure a robust assessment.

2.6 Total emissions from embodied carbon during construction are 7,136 tonnes CO_2e.

Construction Transport

2.7 The Project Transport Consultants have provided information on the estimated number of HGVs and construction staff cars accessing the site each working day during construction works. These are combined with assumptions on the average travel distance of these vehicles, and GHG emissions factors from DfT data to calculate the GHG emissions from construction transport.

2.8 The main/initial construction phase is assumed to cover the construction of the main compounds and processing areas and predicted to be completed within a 12-month period from 2023. Emissions from vehicles supporting ongoing construction (e.g., conveyors for latter phases) are covered in the operational transport emissions calculations.

2.9 A summary of the construction transport data, assumptions and GHG emissions factors is provided in Table 2.

Table 2: GHG Emissions Data for Construction Transport

Parameter	Value	Units	Comment
Construction HGVs per Day	20	Number of movements	Data provided by the project Transport Consultant, Arcus Consulting.
Construction Staff Cars per Day	30	Number of movements	
Average HGV Travel Distance	175	km	Assumes 50% local (within 50 km) and 50% national (within 300 km).
Average Construction Staff Travel Distance	30.15	km	Assumes 75% local (within 15 miles) and 25% regional (within 30 miles).
Total Annual HGV Distance Laden	486,500	km	Assumes 50% of the HGV movements are laden vehicles arriving at the site. Based on 278 working days per year.
Total Annual HGV Distance Unladen	486,500	km	Assumes 50% of the HGV movements are unladen vehicles returning to their point of origin. Based on 278 working days per year.
Total Annual Staff Travel Distance	251,451	km	Based on 278 working days per year.
GHG Factor Laden HGV	0.984	$kgCO_2e/km$	Emissions factors derived from DfT WebTAG databook[5].
GHG Factor Unladen HGV	0.699	$kgCO_2e/km$	
GHG Factor Staff Car	0.148	$kgCO_2e/km$	
GHG Emissions HGV	819	TCO_2e	Total of laden and unladen journeys.
GHG Emissions Staff Car	37	TCO_2e	
GHG Emissions Total	**856**	**TCO_2e**	

2.10 Total emissions from construction transport are 856 tonnes CO_2e.

[5] DfT (2022) Guidance TAG data book. May 2022 v1.18.

3 Operation

Site Maintenance and Restoration

3.1 Emissions from site maintenance and restoration are the embodied carbon associated with the replacement and repair of site buildings and structures over the Proposed Development's lifetime, and the embodied carbon from imported backfill material (clay) used for site restoration.

3.2 A summary of the calculation of embodied GHG emissions from site maintenance and restoration is presented in Table 3.

Table 3: GHG Emissions Data for Site Maintenance and Restoration

Item	Description	Assumption	GHG Emissions (TCO_2e)	Comments
Restoration Engineering	Clay for restoration	440,000 tonnes clay	3,286.8	Based on ICE 3.0[2] aggregates factor of 0.00747 $kgCO_2e/kg$.
Materials Storage Building	Ongoing repairs	62% of embodied	675.8	Conservative estimate of embodied carbon based on RICS whole life carbon guidance[6] for warehouse (i.e., simple construction).
6 x Portacabin Offices	Ongoing repairs	62% of embodied	60.1	
Weighbridges	Ongoing repairs	62% of embodied	20.3	
4 x PFA Silos	Ongoing repairs	62% of embodied	189.2	
Gas Pipeline	Ongoing repairs	62% of embodied	9.2	
10 x Drying Modules	Ongoing repairs	62% of embodied	23.0	
Conveyors	Ongoing repairs	62% of embodied	556.3	
CHP Plant	Replacement	One replacement	242.5	Conservative assumption that units will need one replacement during the lifetime of the Proposed Development.
Gas Storage Tanks	Replacement	One replacement	32.2	
Filtration Cyclones	Replacement	One replacement	1470.5	
Roadways	Ongoing repairs	Resurface twice (surface dressing)	4.7	Estimate of road maintenance derived from UKRI/DCarbon8 report = 2.614 $kgCO_2e/m^2$ [3].
Site Machinery	Replacement	One replacement	783	Assumption.
		TOTAL LIFETIME	**7,354**	
		TOTAL ANNUAL	**350**	Assuming 21-year operation.

[6] RICS (2017) Whole Life Carbon Assessment for the Built Environment.

3.3 It has been assumed that concrete pads and hard standing would require little repair or replacement during the Proposed Development's lifetime and as such embodied emissions are assumed to be zero.

3.4 Total emissions from site maintenance and restoration would be 350 tonnes CO_2e in 2024 and 7,354 tonnes CO_2e over the lifetime of the Proposed Development.

Materials Transport

3.5 Emissions from materials transport predominantly relate to the export of PFA, as well as the import of materials including natural gas for the CHP, diesel fuel for site plant and clay material for site restoration.

3.6 Data on the number of movements of HGVs during operation to export PFA and import materials have been provided by the Project Transport Consultant. For PFA export, the GHG emissions are calculated assuming an expected annual tonnage of approximately 300,000 tonnes.

3.7 For PFA export, GHG emissions are calculated based on tonne.km travelled (i.e., distance hauled per tonne of material). For material imports and the return journey of empty HGVs, GHG emissions are calculated based on vehicle kms travelled for laden HGVs (material imports) and unladen HGVs (vehicle return journeys). The main input data for the calculation of GHG emissions from materials transport is shown in Table 4.

Table 4: GHG Input Data for Operational Materials Transport

Parameter	Value	Units	Comment
PFA extraction/export	307,476	tpa	Approximately 6,457,000 tonnes over lifetime of the project as defined in Table 5.1 of Chapter 5 Project Description.
PFA loads per annum	10,677	Loads	Calculated on the basis of 30 T per load.
Materials import loads per annum	3,336	Loads	Based on 12 loads per working day, and 278 working days per year.
Delivery distance per load	80.4	km	50 miles. Applies to both PFA export and restoration clay import.
Annual PFA export	24,721,086	tonne.km	PFA extraction x delivery distance
Annual materials import	268,214	km	Material imports loads x delivery distance
Return vehicle travel	1,092,251	km	(PFA loads per annum + materials import loads per annum) x delivery distance

3.8 GHG emissions factors have been derived from the DfT's WebTAG databook, which takes account of year-on-year decarbonisation of HGVs through fuel efficiency improvements but does not account for the expected introduction of zero-emission HGVs in the coming 20 years.

As such the emissions factors used in the assessment are likely to be conservative. The emissions factors used and calculated GHG emissions are presented in Table 5.

Table 5: GHG Factors and Emissions for Materials Transport

Year	GHG Emissions Factors			GHG Emissions (TCO_2e)			
	Laden HGV		Unladen HGV	PFA Export	Materials Import	Return Vehicles	TOTAL
	PFA Export ($kgCO_2e$/ tonne.km)	Materials Import ($kgCO_2e$/ km)	Return Vehicles ($kgCO_2e$/ km)				
2024	0.0595	0.9786	0.6952	1,471	262	759	2,493
2025	0.0584	0.9604	0.6822	1,444	258	745	2,447
2026	0.0573	0.9426	0.6696	1,417	253	731	2,401
2027	0.0563	0.9259	0.6577	1,392	248	718	2,359
2028	0.0554	0.9107	0.6469	1,369	244	707	2,320
2029	0.0545	0.8968	0.6370	1,348	241	696	2,284
2030	0.0528	0.8678	0.6165	1,305	233	673	2,211
2031	0.0511	0.8407	0.5972	1,264	225	652	2,142
2032	0.0496	0.8159	0.5796	1,227	219	633	2,079
2033	0.0483	0.7942	0.5641	1,194	213	616	2,023
2034	0.0471	0.7747	0.5503	1,165	208	601	1,974
2035	0.0461	0.7587	0.5389	1,141	203	589	1,933
2036	0.0454	0.7461	0.5300	1,122	200	579	1,901
2037	0.0448	0.7360	0.5228	1,107	197	571	1,875
2038	0.0443	0.7283	0.5174	1,095	195	565	1,855
2039	0.0439	0.7224	0.5132	1,086	194	561	1,840
2040	0.0437	0.7181	0.5101	1,080	193	557	1,829
2041	0.0435	0.7150	0.5079	1,075	192	555	1,821
2042	0.0433	0.7126	0.5062	1,071	191	553	1,815
2043	0.0432	0.7107	0.5049	1,069	191	551	1,811
2044	0.0431	0.7093	0.5039	1,066	190	550	1,807
			TOTAL LIFETIME	**25,506**	**4,550**	**13,163**	**43,220**

3.9 Total emissions from materials transport are 2,493 tonnes CO_2e in 2024 and 43,220 tonnes CO_2e over the lifetime of the Proposed Development.

Operational Employee Travel

3.10 Emissions from employee travel are related to emissions from the vehicles used by site employees to travel to and from the Proposed Development for work.

3.11 Due to the rural location of the Proposed Development, it has been assumed that all employees would travel by private car. This is a worst-case assumption as it results in higher emissions than may otherwise occur if some employees travel via car share or active travel such as cycling.

3.12 Data on the number of employee vehicle movements to and from the Proposed Development each day have been provided by the Project Transport Consultant.

3.13 It has been assumed that 75% of the employees would live locally and travel on average 15 miles (24.12 km) to and from the site to work. The remaining 25% of employees are assumed to live regionally and travel on average 30 miles (48.24 km) to and from the site to work.

3.14 The input data and assumptions for the calculation of GHG emissions from operational employee travel are shown in Table 6.

Table 6: GHG Input Data for Operational Employee Travel

Parameter	Value	Units	Comment
Operational employees	20	No.	Full time
Local employees	75	%	Assumption based on discussions with the applicant and project team.
Regional employees	25	%	
Local employee travel distance	24.12	km	On average (15 miles)
Regional employee travel distance	48.24	km	On average (30 miles)
Employee journeys per day	40	No.	One journey to and from the site per working day.
Working days per year	278	No.	5.5 days per week minus bank holidays, consistent with the Transport Assessment.
Local employees annual travel distance	201,161	km	75% of journeys per day x working days per year x local travel distance.
Regional employees annual travel distance	134,107	km	25% of journeys per day x working days per year x regional travel distance.

3.15 GHG emissions factors have been derived from the DfT's WebTAG databook, which takes account of year-on-year decarbonisation of passenger cars through fuel efficiency improvements and uptake of electric vehicles.

3.16 The emissions factors and calculated GHG emissions from employee travel during operation are provided in Table 7.

Table 7: GHG Factors and Emissions for Operational Employee Travel

Year	GHG Emissions Factor ($kgCO_2e/km$)	GHG Emissions (TCO_2e)		
		Local Employees (<24.12 km)	Regional Employees (<48.24 km)	TOTAL
2024	0.1444	29	19	48
2025	0.1403	28	19	47
2026	0.1361	27	18	46
2027	0.1319	27	18	44
2028	0.1277	26	17	43
2029	0.1235	25	17	41
2030	0.1177	24	16	39
2031	0.1120	23	15	38
2032	0.1067	21	14	36
2033	0.1017	20	14	34
2034	0.0971	20	13	33
2035	0.0929	19	12	31
2036	0.0891	18	12	30
2037	0.0856	17	11	29
2038	0.0825	17	11	28
2039	0.0798	16	11	27
2040	0.0770	15	10	26
2041	0.0742	15	10	25
2042	0.0721	15	10	24
2043	0.0703	14	9	24
2044	0.0685	14	9	23
	TOTAL LIFETIME	**429**	**286**	**714**

3.17 Total emissions from operational employee travel are 48 tonnes CO_2e in 2024 and 714 tonnes CO_2e over the lifetime of the Proposed Development.

Operational Fuel Consumption

3.18 Emissions from operational fuel consumption relate to the use of natural gas in the CHP plant used to provide heat to the PFA drying process as well as generate electricity for the Site, and diesel used in site plant such as excavators and loaders.

3.19 The natural gas consumption of the CHP plant used to provide heat to the PFA dryers (and electricity to the Site) has been provided by the technology supplier for the drying system.

3.20 GHG factors for natural gas consumption have been obtained from BEIS data. To provide a worst-case assessment, no decarbonisation of natural gas has been assumed during the lifetime of the Proposed Development. The calculation of GHG emissions from natural gas consumption is provided in Table 8.

Table 8: GHG Input Data and Emissions from Operational Natural Gas Consumption

Parameter	Value	Units	Comment
Natural gas consumption rate	47	kW/tonne	Gas consumption per tonne of PFA dried, provided by technology supplier.
Annual natural gas consumption	15,040,000	kWh	Based on drying 320,000 tonnes of PFA per annum.
GHG Factor Natural Gas	0.18254	$kgCO_2e/kWh$	From BEIS[7]
Annual GHG Emissions	2,745	TCO_2e	
Lifetime GHG Emissions	57,653	TCO_2e	2024 to 2044

3.21 Emissions from natural gas consumption are 2,745 tonnes CO_2e in 2024 and 57,653 tonnes CO_2e over the lifetime of the Proposed Development.

3.22 The diesel consumption of site machinery and plant has been based on data provided by the applicant on the number and type of machinery to be used during operation. It is proposed to use excavators, loaders and tippers to extract, transport and load the PFA into the dryers and road vehicles for export.

3.23 GHG factors for diesel consumption have been obtained from BEIS data. To provide a worst-case assessment, no decarbonisation of diesel has been assumed during the lifetime of the Proposed Development (i.e., it is assumed that the plant will not be replaced at any point with low or zero emission alternatives). The calculation of GHG emissions from diesel consumption is provided in Table 9.

[7] BEIS (2022) Greenhouse Gas Reporting: Conversion Factors 2022.

Table 9: GHG Input Data and Emissions from Operational Diesel Consumption

Parameter	Excavators	Loaders	Tippers	Comment
Number of plant	3	2	2	Applicant estimate
Engine size	400 kW	400 kW	300 kW	Assumption based on typical Caterpillar/Volvo/ JCB machines.
Average engine load	50 %			Conservative assumption for whole working day assuming periods of idle and periods in drive.
Fuel Flow	250 g/kWh			EEA/EMEP Emissions Inventory[8]
	50 kg/h	50 kg/h	37.5 kg/h	Engine size x fuel flow x engine load
Daily Operating Hours	11 hours			Assumes 92% usage during site working hours (7am – 7pm).
Annual Fuel Use	458.7 T	305.8 T	229.4 T	Fuel flow x operating hours x number of plant x 278 working days per year.
GHG Factor Diesel	3032.89 $kgCO_2e/T$			From BEIS[7]
Annual GHG Emissions	1,391	927	696	TCO_2e
	3,014			
Lifetime GHG Emissions	29,215	19,477	14,607	
	63,299			

3.24 Emissions from diesel consumption are 3,014 tonnes CO_2e in 2024 and 63,299 tonnes CO_2e over the lifetime of the Proposed Development.

3.25 Total emissions from operational fuel consumption (natural gas and diesel) are 5,760 tonnes CO_2e in 2024 and 120,952 tonnes CO_2e over the lifetime of the Proposed Development.

GHG Footprint Summary

3.26 A summary of the Proposed Development's GHG footprint is provided in Table 10. The footprint shows a worst-case annual year (2024, assuming all construction and full production operating emissions) and the lifetime of the Proposed Development.

[8] EEA/EMEP (2019) Air pollutant emissions inventory guidebook 2019. Part 1.A.4 Non-Road Mobile Machinery.

Table 10: Summary of Proposed Development GHG Emissions

Source	GHG Emissions (TCO_2e)	
	Annual (2024)	Lifetime (2024-2044)
Embodied Carbon	7,136	7,136
Construction transport	856	856
Site Maintenance and Restoration	350	7,354
Materials Transport	2,493	43,220
Operational Employee Travel	48	714
Operational Fuel Consumption	5,760	120,952
Total	**16,644**	**180,233**

3.27 Total annual (2024) emissions would be 16,644 tonnes CO_2e and lifetime emissions total 180,233 tonnes CO_2e.

4 GHG Benefits of PFA Use

4.1 The GHG benefits of the use of PFA relate to the equivalent emissions released from the production of Portland Cement, for which it is intended the PFA produced by Project Development would be a direct replacement.

4.2 The calculation of GHG benefits used in the GHG assessment within the climate change chapter assumes that 95% of the extracted PFA would be used as Portland Cement replacement in cementitious applications. It is assumed that the remaining 5% would be used in non-cementitious applications, for which the GHG benefits of PFA vs virgin materials would be relatively small as opposed to savings vs Portland Cement, so has not been quantified.

4.3 A sensitivity test has also been carried out to demonstrate the GHG savings as a result of 100% of the extracted PFA being used in cementitious applications, which is the aspiration of the project applicant.

4.4 To calculate the equivalent GHG emissions from Portland Cement production, the GHG emissions factor for UK average Portland Cement has been obtained from a verified Environmental Product Declaration for the product published by the Mineral Products Association. The EPD is the latest available (dated April 2022) and valid to April 2027.

4.5 A summary of the GHG benefits of use of the extracted PFA, assuming both 95% use in cementitious applications (as used in the climate change chapter) and 100% use in cementitious applications is provided in

4.6 Table 11.

Table 11: GHG Benefits from PFA Use

Parameter	Value	Units	Comment
PFA extracted per year	307,476	tpa	
GHG intensity Portland Cement	812.3	TCO_2e/T	Verified EPD for UK Portland Cement[9]
Annual GHG from PFA production	16,644	TCO_2e	See Table 10.
Lifetime GHG from PFA production	180,233	TCO_2e	
95% of PFA used for Cementitious Applications			
Portland Cement replaced	292,102	tpa	Assume 95% of extracted PFA used for cementitious applications
Annual GHG from Portland Cement production	237,275	TCO_2e	Portland Cement replaced x GHG intensity
Lifetime GHG from Portland Cement production	4,982,770	TCO_2e	Annual GHG x 21 years production
Annual GHG Benefit	-220,631	TCO_2e	GHG from PFA production minus GHG from Portland Cement production.
Lifetime GHG Benefit	-4,802,537	TCO_2e	
100% of PFA used for Cementitious Applications			
Portland Cement replaced	307,476	tpa	Assume 100% of extracted PFA used for cementitious applications
Annual GHG from Portland Cement production	249,763	TCO_2e	Portland Cement replaced x GHG intensity
Lifetime GHG from Portland Cement production	5,245,021	TCO_2e	Annual GHG x 21 years production
Annual GHG Benefit	-233,119	TCO_2e	GHG from PFA production minus GHG from Portland Cement production.
Lifetime GHG Benefit	-5,064,788	TCO_2e	

4.7 Overall, assuming 95% use within cementitious applications the use of the PFA has the potential to save -220,631 tonnes CO_2e per annum, equivalent to up to -4,802,537 tonnes CO_2e over the lifetime of the Proposed Development.

4.8 Assuming the applicant's aspiration for 100% of the PFA to be used within cementitious applications, the use of the PFA has the potential to save -249,763 tonnes CO_2e per annum, equivalent to up to -5,064,788 tonnes CO_2e over the lifetime of the Proposed Development.

[9] EPD (2022) Environmental Performance Declaration, UK Average Portland Cement for Mineral Products Association: https://epd-portal-api.azurewebsites.net/api/v1/EPDLibrary/Files/d3b7186b-96ec-4d67-dd14-08da1c754aa8/Data