Acorn Bioenergy: Carbon Calculation for Construction and operation of an anaerobic digestion facility, associated infrastructure and new access road, connecting pipeline and covered digestate lagoons (SCC/0045/23SE)

6 January, 2025

1. Overview.

As part of its materials for the planning application SCC/0045/23SE, the Applicant submitted a '**Planning Statement**', dated April 2023, which included the following information (on page 3):

"In comparison with standard UK grid emissions, the biomethane produced by the AD facility would have an equivalent saving of 31,320 tonnes of CO_2 each year, equivalent to taking nearly 21,000 cars off the road."

The value for CO_2-equivalent savings of 31,320 tonnes per annum above was calculated using the "Actual Value" method of calculating lifecycle carbon dioxide-equivalent emissions for biomethane as set out within The Renewable Heat Incentive (RHI) Scheme Regulations 2018 Schedule 3 and accounting for the "avoided emissions" from using biomethane as a replacement for standard UK grid gas (i.e., natural gas).

As this development will operate in accordance with the RHI scheme – specifically the Non-Domestic Renewable Heat Incentive (NDRHI) – having already received approval for this scheme through the Applicant Acorn Bioenergy Limited, this was considered the most suitable method of calculating emissions for a biomethane anaerobic digestion site, and this remains the case.

The NDRHI legislation sets the standard for emissions reporting to be in line with Part C of the Renewable Energy Directive I (RED I). The RED I methodology has been the industry standard for reporting carbon emissions for biomethane anaerobic digestion in the UK with 173 producers registered under the scheme (Ofgem, 2024).

For full clarity, it is not in dispute that the RED I methodology is and remains the most relevant UK industry standard for assessing the life cycle carbon emissions of the anaerobic digestion plant proposed in this development.

The current document has been prepared to provide further detail on the carbon dioxide equivalent (CO_2e) emissions associated not only with the **operational phase** of the development as provided in the Planning Statement – which was calculated in line with the Renewable Energy Directive (RED I) methodology as described above – but also to provide values for the embodied emissions associated the **pre-operational** and **post-operational phases** of the development (i.e., areas that are out of the scope of the Renewable Energy Directive (RED I) methodology). A comparison with standard UK grid gas emissions has been included to show the additional emissions saving that will be provided by the replacement of grid gas with biomethane.

This results in a full 'Cradle-to-Grave' analysis of the lifecycle carbon emissions of this development.

The methodology presented here therefore extends the scope of the reporting over and above that utilised within the Anaerobic Digestion industry through existing national requirements under the NDRHI scheme. Furthermore, neither this project nor the Applicant is subject to the requirements of the UK Emissions Trading Scheme or SECR.

2. Scope of this Carbon Calculation.

The diagram below, taken from BS EN 15978: 2011, provides a reference point for clarifying what items will be assessed in this Carbon Calculation. This is a widely used methodology for analysing embodied emissions in built structures in the UK.

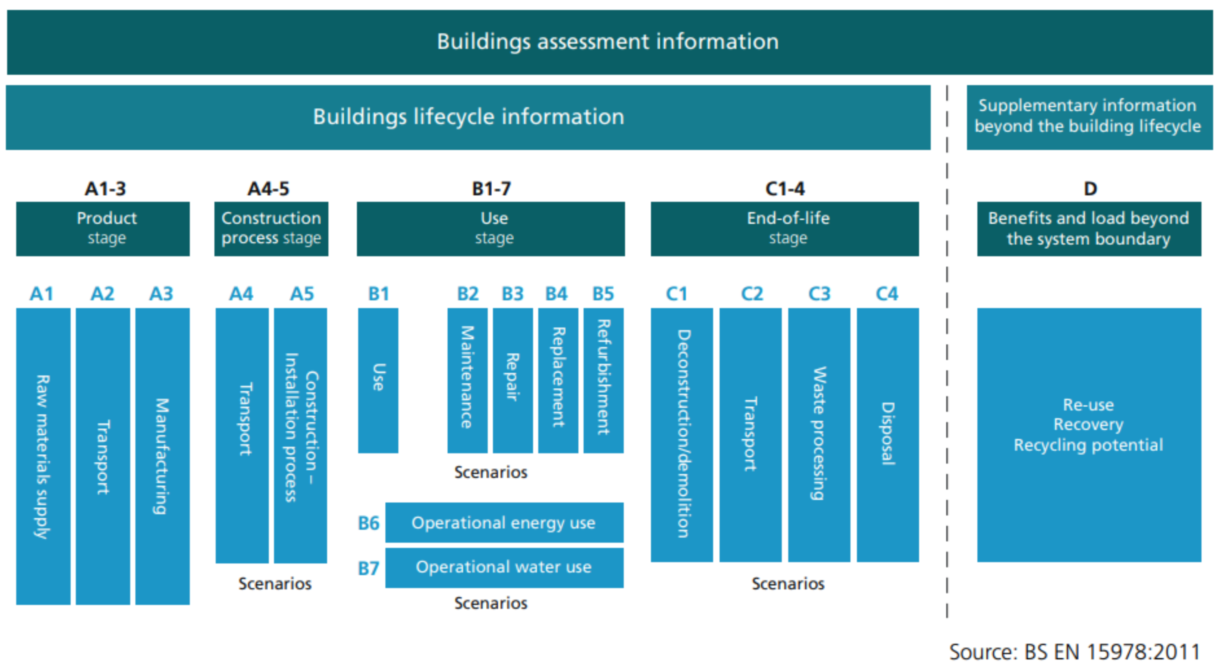

Figure 1: Reference point for supplementary 'Cradle to gate' and 'End of life' calculations provided in this Addendum

The definitions of 'Product' (A1-A3), 'Construction' (A4-A5), and 'End-of-life' (C1-C4) emissions as shown in Figure 1 align well with the proposed structure of this Addendum.

The '**Use**' stage (i.e., **Stages B1-B7**) has already been fully assessed as part of the Planning Statement, using the more suitable RED I methodology. This is covered in **Section 3**.

Stages A1-A5 can be considered as the '**Cradle-to-gate**' and '**Construction**' emissions associated with the pre-operational phase of the development – including emissions associated with the manufacturing and transportation to site of machinery and equipment, materials and activities associated with civil works and installation/commissioning, associated transport movements, and so forth. Such emissions are specifically excluded from the scope of the RED I methodology but have been considered in this Carbon Calculation. This is covered in **Section 4**.

Stages C1-C4 are '**End-of-life**' emissions associated with the post-operational phase of the development – including emissions associated with the decommissioning of machinery and equipment, transportation to end of waste facilities, waste processing and disposal, demolition of on-site civil works and returning of the site to its original state, etc. Again, these emissions are specifically excluded from the scope of the RED I methodology but have been considered in this Carbon Calculation. This is covered in **Section 5**.

Stage D has been excluded from this analysis, for the sake of brevity, although it should be noted Acorn's intention is to re-use and re-cycle materials as far as possible. As mentioned in our analysis below, this indirectly informs the assumption emissions for Stages C3 & C4.

3. 'Use' emissions associated with this development

The carbon calculation during the 'Use' stage (i.e., when the development is in operation) is based on the same method used to calculate the value in the Planning Statement: using the "Actual Value" method of calculating lifecycle carbon dioxide-equivalent emissions for biomethane as set out within The Renewable Heat Incentive (RHI) Scheme Regulations 2018 Schedule 3 and accounting for the "avoided emissions" from using biomethane as a replacement for standard UK grid gas (i.e., natural gas).

The Planning Statement (April 2023) stated that "*In comparison with standard UK grid emissions, the biomethane produced by the AD facility would have an equivalent saving of 31,320 tonnes of CO_2 each year.*"

However, as 20 months have passed since the time of the original planning application, we have updated the calculation for this section using the latest updated values for UK grid emissions factors, emissions factors for other items, feedstock methane yields, etc.

The latest calculation shows that biomethane produced by the AD facility would have an equivalent saving of 30,885 tonnes of CO_2e each year in comparison with standard UK grid emissions. This is the sum of the following values:

- 7,002 tonnes of CO_2e savings from biomethane injected (including 14,018 tonnes of carbon capture)[1]
- 23,883 tonnes of avoided emissions of CO_2e that would have been emitted by standard UK grid gas

The "avoided emissions" from the use of biomethane as a replacement for standard UK grid gas have been calculated using GHG Protocol methodology as the basis – specifically the "attributional" approach to calculating comparative product greenhouse gas impacts as set out in the working paper 'Estimating and Reporting the Comparative Impacts of Products' (World Resources Institute, 2019)[2].

[1] Carbon intensity of biomethane is calculated in accordance with the UK Government's Non-Domestic Renewable Heat Incentive guidance, which uses RED I methodology as its basis: see https://www.ofgem.gov.uk/publications/non-domestic-rhi-main-guidance

[2] https://ghgprotocol.org/sites/default/files/2023-03/18_WP_Comparative-Emissions_final.pdf

The emissions factor for 'standard UK grid gas' is based on the value for 'natural gas (Gross CV)' in the UK Government Department for Energy Security & Net Zero's 'Greenhouse Gas Reporting: Conversion Factors 2024'[3]. In line with the "attributional" approach described above, it is considered appropriate to use the sum of the Scope 1 emissions factor (0.1829kgCO_2e/kWh) and the Scope 3 emissions factor (0.0302kgCO_2e/kWh). However, for completeness the Scope 3 emissions factor has been amended to include any emissions that will take place as a result of transmission of the biomethane through the gas grid, as this is the most likely method of transmission to the end user. As there is no UK Government emissions factor for this element, we have applied the latest value from the European Commission which is equivalent to 0.001kgCO_2e per kWh[4]. This reduces the avoided emissions from Scope 3 to 0.0292kgCO_2e per kWh. The total avoided emissions value is therefore 0.2121 kg for every kWh of natural gas that is replaced by biomethane, resulting in 23,883,443 kg of avoided emissions (i.e., 23,883 tonnes).

When combined with the 7,002 tonnes of CO_2e savings from biomethane injected, this means that in comparison with standard UK grid emissions, the biomethane produced by the AD facility would have an equivalent saving of 30,885 tonnes of CO_2 each year. This is a difference of 1% when compared with the value of 31,320 tonnes in the Planning Statement, which is insignificant. The latest value of 30,885 tonnes of annual CO_2e savings will be used during the rest of this document, to keep the calculation up to date.

There are also significant additional benefits that have not been taken into account in this calculation. For instance, emissions savings from soil carbon accumulation via improved agricultural management are anticipated to deliver significant additional carbon savings but are currently counted as zero. Therefore, the carbon savings methodology is considered somewhat conservative in its current form.

4. 'Cradle to gate' and 'Construction' emissions.

This analysis has been based on the submitted site layout and equipment inventory included in the planning application ref: SCC/0045/23SE. This is therefore an accurate and representative view of the materials and equipment that will ultimately be used in the Proposed Development, as (if consented) this Project will need to be undertaken in accordance with the approved plans.

Furthermore, this assessment is informed by anaerobic digestion plants of a comparable size and design which Acorn Bioenergy is developing in Winchester and Northampton[5], for which planning

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[3] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2024

[4] See https://www.iscc-system.org/updates/26-august-2024/ for an explanation of the application of emissions factor for gas grid losses. The value of 0.001 kgCO_2e per kWh is based on the latest value of 0.01 g CH_4/MJ, multiplied by the global warming potential for methane of 28 as per the Implementing Regulation (EU) 2022/996 (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32022R0996), and converted from MJ into kWh (standard conversion) = 0.01 * 28 * 3.6 / 1000 = 0.001

[5] WNS/2022/2402/EIA | Construction and operation of an Anaerobic Digestion facility associated infrastructure and landscape planting. https://wnc.planning-register.co.uk/Planning/Display/WNS/2022/2402/EIA#undefined

permission has already been secured, and where the construction phases are well progressed. These provide a useful up-to-date point of reference.

A bill of all materials and equipment to be used in the Proposed Development has been prepared. This has been broken down as far as possible on an item-by-item basis. A dry weight for every item has been provided by Acorn's engineering & procurement teams, based on information provided directly from the relevant supplier of materials / equipment. Where necessary, this has then been converted into tonnes, for consistency, with the relevant conversion factor provided for clarity.

The application of 'Cradle-to-gate' emissions factors from the UK Government's '2024 Government Gas Conversion Factors for company reporting'[6] is considered the most suitable source of emissions factors to calculate the embodied emissions associated with the '**Product stage**' as defined in Figure 1 above.

The 'Primary material production' value has been used in all cases, to take the most conservative (i.e., most rigorous) approach. As explained in the 'Methodology Paper for Conversion factors Final Report' (p.117)[7]: "*For primary materials, these factors cover the extraction, primary processing, manufacture and transportation of materials to the point of sale.*" This is therefore an excellent fit for providing the embodied emissions associated with Items A1-A3 in the diagram shown in Figure 1 above, and results in emissions of **5,764 tonnes CO_2e for Stages A1, A2, A3.**

A 20% contingency has been applied to cover any further emissions associated with the '**Construction Process Stage**' (Items A4-A5 in the methodology shown in Figure 1 above). As above, the accuracy of estimated emissions here is informed by data that Acorn has gathered at sites already in development (Winchester and Northampton), and the application of a 20% contingency factor here is considered conservative (i.e., as thorough as possible) based on the emissions incurred at these sites. For example, emissions in the transport (Stage A4) and construction-installation process (Stage A5) for the Winchester project for the period from December 2023 to August 2024 were quantified as 37 tonnes CO_2e, and up to the point of full operations in April 2025 are projected to be 127 tonnes CO_2e in total. This is significantly less than the value based on 20% contingency factor that is assumed here and the value of **1,153 tonnes CO_2e for Stage A4 & A5** included in this document is therefore considered thorough and rigorous.

The total 'Cradle-to-Gate' and 'Construction' stage emissions are therefore 6,917 tonnes CO_2e, as shown in Figure 2 below:

[6] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2024

[7] https://assets.publishing.service.gov.uk/media/66a9fe4ca3c2a28abb50da4a/2024-greenhouse-gas-conversion-factors-methodology.pdf

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6 January, 2025

	Quantity (initial unit)	Initial Unit	Conversion Factor from Initial Unit into tonnes	Conversion factor reference (if applicable)	Number of each item included in development	Final Quantity Units	Final Units	Relevant Material from 'UK Government GHG Conversion Factors 2024, 'Material use' tab	Relevant GHG intensity in kgCO2e from 'UK Government GHG Conversion Factors 2024, 'Material use' tab	Embodied GHG tonnes CO2e	Source for GHG intensity
Embodied Emissions in 'Product Stage'											
Site Floor Area											
Asphalt	360	m3	2.4	Red Stag	1	864.0	tonnes	Asphalt	39.21249	**34**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Asphalt'
Concrete	1883	m3	2.4	Cemex	1	4519.2	tonnes	Concrete	118.75127	**537**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Concrete'
Steel reinforcement	70000	kg	0.001		1	70.0	tonnes	Metals	3815.78473	**267**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Aggregates	3515	m3	1.5	Gabion Stone	1	5272.5	tonnes	Aggregates	7.75127	**41**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Aggregates'
Bund Floor Area											
Aggregates	2315	m3	2.1	Gabion Stone	1	4861.5	tonnes	Aggregates	7.75127	**38**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Aggregates'
Steel reinforcement	100000	kg	0.001		1	100.0	tonnes	Metals	3815.78473	**382**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Concrete	1855	m3	2.4	Cemex	1	4452.0	tonnes	Concrete	118.75127	**529**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Concrete'
Buildings											
Steel frame	125	tonnes	1		1	125.0	tonnes	Metals	3815.78473	**477**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Steel reinforcement	90000	kg	0.001		1	90.0	tonnes	Metals	3815.78473	**343**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Concrete	1024	m3	2.4		1	2457.6	tonnes	Concrete	118.75127	**292**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Concrete'
Skin	26607	kg	0.001		1	26.6	tonnes	Metals	3815.78473	**102**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Clamps											
Ark concrete panels	600	m3	2.4	Cemex	1	1440.0	tonnes	Concrete	118.75127	**171**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Concrete'
Asphalt	1495	m3	2.4	Red Stag	1	3588.0	tonnes	Asphalt	39.21249	**141**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Asphalt'
Aggregates	4105	m3	1.5	Gabion Stone	1	6157.5	tonnes	Aggregates	7.75127	**48**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Aggregates'
Primary AD Equipment											
AD equipment (Pipework)	36000	kg	0.001		1	36.0	tonnes	Metals	3815.78473	**137**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Digester tanks	2803	m3	2.4	Cemex	1	6727.2	tonnes	Concrete	118.75127	**799**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Concrete'
Concrete bases	470	m3	2.4	Cemex	1	1128.0	tonnes	Concrete	118.75127	**134**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Concrete'
Imported stone bases	208	m3	1.5	Gabion Stone	1	312.0	tonnes	Aggregates	7.75127	**2**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Aggregates'
Feeder (Primary digester)	17.35	tonnes	1		2	34.7	tonnes	Metals	3815.78473	**132**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Feeder (Manure)	10	tonnes	1		1	10.0	tonnes	Metals	3815.78473	**38**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Extruders	5.5	tonnes	1		2	11.0	tonnes	Metals	3815.78473	**42**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Leachate/water tanks	2.5	tonnes	1		2	5.0	tonnes	Metals	3815.78473	**19**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Odour Treatment											
Ammonia Scrubber	1	tonnes	1		1	1.0	tonnes	Metals	3814.78473	**4**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
UV treatment	0.45	tonnes	1		1	0.5	tonnes	Metals	3815.78473	**2**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Carbon filter	6.1	tonnes	1		1	6.1	tonnes	Metals	3815.78473	**23**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Process Fan	0.3	tonnes	1		1	0.3	tonnes	Metals	3815.78473	**1**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Ballast Cabinet	0.3	tonnes	1		1	0.3	tonnes	Metals	3816.78473	**1**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Combined Heat & Power											
CHP (within container)	30	tonnes	1		2	60.0	tonnes	Metals	3815.78473	**229**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Tech cooler	2	tonnes	1		2	4.0	tonnes	Metals	3815.78473	**15**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Flue gas pipe	0.95	tonnes	1		2	1.9	tonnes	Metals	3815.78473	**7**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Flue Gas silencer	1.5	tonnes	1		2	3.0	tonnes	Metals	3815.78473	**11**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Chimney pipe	0.2	tonnes	1		2	0.4	tonnes	Metals	3815.78473	**2**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Flue Gas Pipe Lower	0.6	tonnes	1		2	1.2	tonnes	Metals	3815.78473	**5**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Ladder	0.6	tonnes	1		2	1.2	tonnes	Metals	3815.78473	**5**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Flue Gas Exchanger	1.5	tonnes	1		2	3.0	tonnes	Metals	3815.78473	**11**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Railings	0.9	tonnes	1		2	1.8	tonnes	Metals	3815.78473	**7**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Gas Trains	0.2	tonnes	1		2	0.4	tonnes	Metals	3815.78473	**2**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Biogas Upgrader											
Biogas Cooling Skid (mainly pipework & a blower)	5.5	tonnes	1		1	5.5	tonnes	Metals	3815.78473	**21**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Filtration (MDPE vessels, minimal pipework, activiated carbon is build of weight)	18	tonnes	1		1	18.0	tonnes	HDPE	3270	**59**	https://www.climatiq.io/data/emission-factor/35414e39-0c00-489d-b408-103bd961fdcf
Chiller (this is wet weight, i.e. including fluid)	2.5	tonnes	1		1	2.5	tonnes	Metals	3815.78473	**10**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Biogas Upgrading Container (membranes included)	13	tonnes	1		1	13.0	tonnes	Metals	3815.78473	**50**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Biogas Compressor (assume full steel)	25	tonnes	1		1	25.0	tonnes	Metals	3815.78473	**95**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
CO2 Upgrader											
Carbon Filter (loaded weight with carbon)	2.5	tonnes	1		1	2.5	tonnes	HDPE	3270	**8**	https://www.climatiq.io/data/emission-factor/35414e39-0c00-489d-b408-103bd961fdcf
Compressor	15.25	tonnes	1		1	15.3	tonnes	Metals	3815.78473	**58**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Main Container	15	tonnes	1		1	15.0	tonnes	Metals	3815.78473	**57**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
CO2 Tanks (50m3 x2, 68.8 loaded weight)	68.6	tonnes	1		1	68.6	tonnes	Metals	3815.78473	**262**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Carboscan	1.95	tonnes	1		2	3.9	tonnes	Metals	3816.78473	**15**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
CNG Equipment											
Buffer Tank	1	tonnes	1		1	1.0	tonnes	Metals	3815.78473	**4**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Gas Compressor 1	8.12	tonnes	1		1	8.1	tonnes	Metals	3815.78473	**31**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Gas Compressor 2	8.12	tonnes	1		1	8.1	tonnes	Metals	3815.78473	**31**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Gas Storage Bank	6.355	tonnes	1		1	6.4	tonnes	Metals	3815.78473	**24**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Chiller & hEx	0.25	tonnes	1		1	0.3	tonnes	Metals	3815.78473	**1**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
FIlling Post 1	0.1	tonnes	1		1	0.1	tonnes	Metals	3815.78473	**0**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
FIlling Post 2	0.1	tonnes	1		1	0.1	tonnes	Metals	3815.78473	**0**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Filling Post 3	0.1	tonnes	1		1	0.1	tonnes	Metals	3815.78473	**0**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Control Room	2.4	tonnes	1		1	2.4	tonnes	Metals	3815.78473	**9**	UK Government GHG Conversion Factors 2024, 'Material use' tab, kg CO2e per tonne primary material production for 'Metals'
Total emissions in 'Product Stage' tonnes CO2e										**5764**	
Embodied Emissions in 'Construction Process Stage'								**20% of 'Product Stage' emissions**			
Total emissions in 'Construction Process Stage' tonnes CO2e										**1153**	
Total 'Cradle to Gate' emissions in tonnes CO2e										**6917**	

Figure 2: Breakdown of 'Cradle to Gate' and 'Construction' emissions by item

4. 'End-of-life' emissions associated with this development.

Based on the scope outlined in Section 2 above, the 'End-of-life' emissions are classified as 'Stage C' emissions and are broken down further into four separate elements: Deconstruction/Demolition, Transport, Waste processing and Disposal.

In relation to 'Stage C' emissions, the 'BSRIA Guide on the Inventory of Carbon and Energy (ICE)'[8] notes that: "*There is no single universally acceptable method which is, in part, why the subject is so widely debated and methods regularly contested*" (p.117). 'National Planning Framework 4 Research Project: Lifecycle Greenhouse Gas Emissions of NPF4 Proposed National Developments Assessment Findings' in Appendix B also acknowledges the difficulty in this stage and provides the following statement in relation to the methodology adopted by them when looking at the lifecycle stages of a development:

'Finally, the assessment has made assumptions around decommissioning. It is acknowledged that there is a high degree of uncertainty over the decommissioning phase of development, and that different assumptions will apply to different development types and locations. This includes the approach to infrastructure removal or the level of site restoration at the end of the development's lifespan. Where appropriate, restoration to the equivalent of green field condition has been assumed to allow comparison across the NDs. It is acknowledged that future use of a site may be lower or higher intensity in the future.'

Unlike the 'Cradle-to-gate' emissions assigned to 'Stage A,' there is no UK government or even commonly agreed methodology in place that can be used to quantity end-of-life emissions. Therefore, the approach taken has been to assess each of the four elements separately as follows, using the most appropriate methodology in each case.

A 2010 report by the UK Government's Department for Business Innovation and Skills found that 0.4% of emissions in the construction industry were as a result of Refurb and Demolition, therefore the impact of this stage of the project on the overall project must be considered very low.[9]

a. Deconstruction/demolition

According to relevant studies[10,11] the specific carbon emissions generated by manual and mechanical processes used for building demolition or deconstruction (based on a representative site with area of 15,489m^2) are 4.67 kg/m^2 or 3.66 kg/m^2, respectively, as shown in Figure 3 below.

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[8] https://greenbuildingencyclopaedia.uk/wp-content/uploads/2014/07/Full-BSRIA-ICE-guide.pdf

[9] 'Estimating the amount of CO2 emissions that the construction industry can influence - Supporting material for the Low Carbon Construction IGT Report' - Autumn 2010 (publishing.service.gov.uk)

[10] Carbon Emission Reduction Evaluation of End-of-Life Buildings Based on Multiple Recycling Strategies (Lei, Yang, Yan, Tang, Dong; 2023) https://www.researchgate.net/publication/375483712_Carbon_Emission_Reduction_Evaluation_of_End-of-Life_Buildings_Based_on_Multiple_Recycling_Strategies

[11] Quéheille, E.; Ventura, A.; Saiyouri, N.; Taillandier, F. A Life Cycle Assessment model of End-of-life scenarios for building deconstruction and waste management. J. Clean. Prod. 2022,339, 130694.

	Employee × Day	Artificial Carbon Emission Factor (kgCO2-e/Employee × Day) [44]	Artificial Carbon Emissions (kgCO2-e)	Mechanical Energy Consumption (Diesel, L)	Diesel Carbon Emission Factor (kgCO2-e/L) [45]	Mechanical Carbon Emissions (kgCO2-e)	Total Carbon Emissions (kgCO2-e)	Carbon Emissions per Building Area (kgCO2-e/m2)
Demolition	419	4.16	1743.04	18,675	3.178	70,591.5	72,334.54	4.67
Deconstruction	588	4.16	2446.08	17,066	3.178	54,235.748	56,681.82	3.66

Figure 3: Carbon emissions associated with demolition and deconstruction (from Lei, Yang, Yan, Tang, Dong; 2023)

Based on the total site buildable area of 54,664m^2 for the Proposed Development (excluding greenspace as assumed this remains), and assuming full demolition of the site (the most thorough assumption), hence 4.67 kgCO_2e/m^2, this results in emissions of **255 tonnes of CO_2e for Stage C1**.

b. Transport

The following average transport distances are assumed, based on the studies cited in 4.a above, for consistency.

Process	Transport Distance
Storage sites for reuse materials	30
Recycling/remanufacturing plants (e.g., cement, concrete, sand)	30
Recycling/remanufacturing (e.g., other materials)	50
Landfill sites	30

Figure 4: Representative transport distances (from Lei, Yang, Yan, Tang, Dong; 2023)

The following table uses the emissions factor for a >33t articulated HGV (diesel, average laden) from the UK Government's '2024 Government Gas Conversion Factors for company reporting', assuming 20 tonnes per load transported from site to point of use and then return to site:

Material type	**Weight of material used in development** tonnes	**Round trip from site to point of use and back** km	**Emissions factor** kgCO_2e/km	**Emissions factor** kgCO_2e/(t•km)	**Emissions** tonnes CO_2e
Aggregates	16,604	60	0.9125	0.0456	45.45
Concrete	20,724	60	0.9125	0.0456	56.73
Asphalt	4,452	60	0.9125	0.0456	12.19
Metals	769	100	0.9125	0.0456	3.51
HDPE	21	100	0.9125	0.0456	0.09
Total	**42,569**				**117.97**

Figure 5: Carbon emissions associated with transport of items in Figure 2 above

The transport emissions are therefore **118 tonnes of CO_2e for Stage C2**.

c. **Waste processing**, and **d. Disposal**

This represents Stages C3 & C4. To set the context for the 'end-of-life' emissions associated with the materials in this project, we must first consider the 'Cradle-to-gate' emissions factors used in Stage A. All emissions factors used were for 'virgin materials', hence the possibility to recycle the materials at the end of their life has not been considered.

It is an important part of Acorn's plan for this development that materials will be recycled and reused as far as possible. Therefore, the next step is to examine the feasibility of recycling or reusing the materials used in the Proposed Development.

For concrete, aggregates, and asphalt, (and subject to approval as part of a Decommissioning Plan anticipated to be required under planning condition in the event permission is granted) these will be crushed and regraded on site, and the associated CO_2e emissions have already been considered as part of Stage C1. As noted in Arup's report on 'Embodied Carbon of Concrete'[12] emissions: "*Global figures on the waste and disposal of concrete are not readily available and are expected to be highly variable from country to country as well as from region to region. Many different factors contribute to these variations such as local laws and regulations for landfilling of demolition waste and the access to virgin aggregates. Often there are incentives or penalties and therefore there may be increased interest in recycling concrete as aggregate, rather than letting the material go to landfill. High recycling rates are reported in the Netherlands, UK and Japan"* (page 11). This expectation of "*high recycling rates…in the UK*" is backed up by UK government figures which show that in 2020, the UK generated 59.1 million tonnes of non-hazardous C&D waste, of which 54.8 million tonnes was recovered. This represents a recovery rate of 92.6%[13].

Metals from cladding, pipework, building skins, machinery, etc., will be recycled off-site. According to the Eurofer survey of EU member states to quantify the percentage of steel that is recovered from a typical building demolition site[14], 92% of steel was recycled and 4% reused, with only 4% lost. The use of steel in this study is considered representative of the use of metals in this development, the overwhelming majority of which will be able to be recycled or reused.

Product	% Reused	% Recycled	% Lost
Heavy structural sections/tubes	7	93	0
Rebar (in concrete superstructures)	0	98	2
Rebar (in concrete sub-structure or foundations)	2	95	2
Steel piles (sheet and bearing)	12	73	15
Light structural steel	4	94	2
Profile steel cladding (roof/facade)	9	90	1
Internal light steel (e.g. plaster profiles, door frames)	0	95	5
Other (e.g. stainless steel)	1	98	1
Average (across all products)	**4**	**92**	**4**

Figure 6: Summary of reuse and recycling rate from 2012 Eurofer survey

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[12] Arup, 'Buildings & Infrastructure Priority Actions for Sustainability', June 2023: https://www.istructe.org/IStructE/media/Public/Resources/ARUP-Embodied-carbon-concrete_1.pdf

[13] UK Government, Statistics on Waste, June 2023: https://www.gov.uk/government/statistics/uk-waste-data/uk-statistics-on-waste

[14] https://www.steelconstruction.info/The_recycling_and_reuse_survey#Definitions_of_recycling_and_reuse_rates

The 'BSRIA / ICE Embodied Carbon Guide'[15] goes further to propose an approach where future carbon savings from recycling materials may be counted in the whole life carbon analysis as an emissions *saving*. See for instance the explanation from page 122 below:

> 1. **Cradle-to-site (or gate):** The first transparent result should be the cradle-to-site (or cradle-to-gate) burden. This gives a better indicator for the energy and carbon burden on the present climate
> 2. **Operation:** The energy/carbon to operate the product system should be clearly reported
> 3. **End of life:** The last transparent result should estimate the end of life benefit - i.e. the substitution method can be applied to estimate the future benefits of recyclability (taking care not to double count recycling benefits). This should also include an estimate of when the benefit would be expected (in how many years time).

Therefore, it is concluded that:

1) The overwhelming majority of materials used in the Proposed Development will be recycled and/or reused.
2) The emissions associated with processing these materials to a state where they can be recycled have already been accounted for in Stage C1, and the emissions associated with transporting the materials to the point of reuse / recycling have been accounted for in Stage C2.
3) Recycling / reuse will result in net emissions savings when compared with the use of virgin materials, as per ICE Embodied Carbon methodology.

For the sake of a simple estimate of emissions for **Stages C3 & C4**, emissions for these stages are therefore counted here as **net zero**, although it is noted that it would be defensible to claim additional emissions savings here.

5. Summary

The annual net emissions savings of the development during its operational phase (Stage B) are 30,885 tonnes of CO_2e.

The embodied emissions associated with Stage A and Stage C are 7,290 tonnes of CO_2e.

This results in total 'Cradle to Grave' net emissions savings of 764,835 tonnes CO_2e over a 25-year assumed project lifetime.

These findings are summarised in the table below:

[15] https://greenbuildingencyclopaedia.uk/wp-content/uploads/2014/07/Full-BSRIA-ICE-guide.pdf

Stage	Description of stage	Analysis provided	CO2e emissions
A	Cradle-to-gate, Construction	This Document	6917
B	Use stage	Planning Statement, updated using latest emissions factors, etc.	-30,885 annually -772,125 over 25Y lifespan
C	End-of-life	This Document	373
D	Benefits beyond system boundary	Not included (though would provide additional savings)	N/A
	Total emissions 'Cradle to Grave'		**- 764,835**

Figure 6: Total CO_2e emissions at every stage of the lifecycle

Assuming a 25-year plant lifespan with operation of the facility, the annual emissions embodied in the site and equipment are therefore equivalent to 292 tonnes CO_2e per annum.

On an annualised basis, this results in the annual net emissions saving changing from the value of 30,885 tonnes of CO_2e to an updated value of 30,593 tonnes of CO_2e. This is a difference of less than 1%, and this updated value now takes into account all Cradle-to-Grave emissions as well as using the latest updated emissions factors.

6. Conclusion.

For the Proposed Development, the expansion of the scope of analysis to include emissions associated with the stages prior to operations (Stage A) and following end of operations (Stage C) of the facility, has resulted in the identification of 7,290 tonnes of CO_2e emissions that were not included in the scope of the already submitted Carbon Calculation.

When compared with the latest annual emissions savings value of 30,885 tonnes of CO_2e when the Proposed Development is operational (Stage B) this means that the facility will achieve net zero payback after three months of full operations.

Over the full lifetime of this Proposed Development, the expansion of the scope of analysis, and the use of the latest updated emissions factors in the calculation of CO_2e emissions associated with the operational stage, reduces the overall emissions savings associated with this development by 2%, and this is therefore not significant or material.

If consented, over a 25-year period the Proposed Development will deliver total 'Cradle-to-Grave' emissions savings of 764,835 tonnes of CO_2e.