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CONCRETE PIPELINE SYSTEMS ASSOCIATION

PAS 2050 – Partial Lifecycle Assessment

Cradle-to-Gate Analysis for Concrete Pipeline, Manhole Ring and Cover Slab

23rd November 2010

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Concrete Pipeline Systems Association

PAS 2050 – Partial Lifecycle Assessment

Cradle-to-Gate Analysis for Concrete Pipeline, Manhole Ring and Cover Slab

Report for

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TABLE OF CONTENTS

Executive Summary ... 6
1 **Introduction** ... 8
1.1 Background ... 8
1.2 Defining the Lifecycle Assessment (PAS 2050: Sec 4.5) ... 9
1.3 Methods ... 9
1.3.1 Cut-Off Rules (PAS 2050: Sec 6.3, Sec 3.33) ... 9
1.3.2 Gases Emitted ... 9
1.3.3 Functional Unit (PAS 2050: Sec 5.8) ... 10
2 **Data – Collection and Sources** ... 10
2.1 Factories Considered (Population and Sample) ... 11
2.2 Primary Data ... 12
2.3 Secondary Data / Conversion Factors' Sources ... 13
3 **Product Boundary** ... 15
3.1 System Boundary Definition (PAS 2050: Sec 5.3) ... 15
3.1.1 System Boundary Inclusion ... 17
3.1.2 System Boundary Exclusions ... 19
3.2 Emission Allocation Rules ... 20
3.2.1 Allocation for Co-products ... 20
3.2.2 Impacts' Allocation Due to Secondary Products Input / Recycled Content ... 21
3.2.3 Impacts' Allocation for Industrial Waste ... 21
3.3 Stored Carbon in Crushed Concrete ... 22
4 **Carbon Footprint Calculation** ... 22
4.1 Emission Factors ... 22
4.2 Background: Nature of a Concrete Product Mix ... 22
4.3 Aggregates Impact Assessment ... 23
4.4 Cement Impact Assessment ... 23
4.5 Reinforcement Steel Impact Assessment ... 24
4.6 Water Impact Assessment ... 24
4.7 Admixtures' Impact Assessment ... 25
4.8 Raw Materials' Transportation Impact Assessment ... 25
4.9 Fuels Impact Assessment ... 26
4.10 Factory Operations (Sub-Unit Processes) Impact Assessment ... 26
4.10.1 Concrete Mixers Impact Assessment ... 27
4.10.2 Allocation of Steel Reinforcement Impacts ... 28
4.10.3 Concrete Casting/Vibrating Impact Assessment ... 28
4.10.4 Concrete Products Curing Impact Assessment ... 28
4.10.5 Cranes and Mobile Plant Emissions Impact Assessment ... 29
4.10.6 External/ Internal Lighting and Office Activities Impact Assessment ... 29
4.11 Site Operations Impact Assessment ... 30
4.11.1 Transport of Concrete Pipeline Units to Site ... 30
5 **Results of Cradle-to- Construction Site Analysis** ... 31
6 **Data Quality Requirements** ... 32
6.1 Precision & Completeness ... 32
6.2 Consistency and Reproducibility ... 32
6.3 Representativeness ... 33
7 **Claim of Conformity** ... 34

LIST OF FIGURES

1.1 Gasses emitted from the production of concrete products in this study
1.2 concrete pipes, manhole rings, and cover slabs: average weights (Across all 4 factories)
2.2 Plain concrete Cradle-to-gate Greenhouse gas emissions.
2.3 Carbon Clear's results: Percent of emissions arising from processes contributing to the creation of precast concrete products (average from 4 factories)
3.1 Product systems and unit processes identified.
3.2 Product systems and unit processes identified.
3.3 Sub-unit processes identified in pipeline product factories and main fuels causing GHG emissions.
4.1 Maximum load of individual products (one of the following: concrete pipes, manhole rings, and/or cover slabs) transported by a +30 tonne truck in one return journey.
5.1. Emissions arising from the production of the product (excluding transportation to site of installation).
5.2. Overall emissions of the product including production *and* transportation to site of installation.
7.1 Carbon Clear's results: Amount of emissions arising from processes contributing to the creation of precast concrete products (average from 4 factories)
7.2 Emissions per tonne of product arising from production processes within each production facility
8.1. Overall emissions of the product including production and transportation to site of installation.

Executive Summary

Overview

This report was originally written by Concrete Pipeline Systems Association (CPSA) and has been updated and verified by Carbon Clear to be PAS 2050 compliant. It examines the carbon footprint of three co-products within concrete pipeline systems: concrete pipe, concrete manhole ring and concrete cover slab.

A list of the amendments that have been made to this report by Carbon Clear to achieve PAS 2050 compliance can be found in section 1.1 on the Background of the project.

CPSA's objectives of this carbon management project are:

- To verify the emissions of their co-product as specified in this report
- Make this report PAS 2050 compliant
- Be able to communicate the results of this report to third parties.

Key Information

Scope:	This is **a partial business-to-business lifecycle assessment**, also known as Cradle-to-Gate, which includes emissions stemming from all processes beginning with the extraction and production of raw resources and ending with the transportation of the final product to the site of installation.
Co-Products Examined:	Concrete manhole rings, concrete cover slabs and concrete pipes.
PAS 2050 Compliance:	Carbon Clear has completed an analysis of the sections missing or needing to be updated to be PAS 2050 compliant. These have been amended throughout the document.

Results and Key Findings

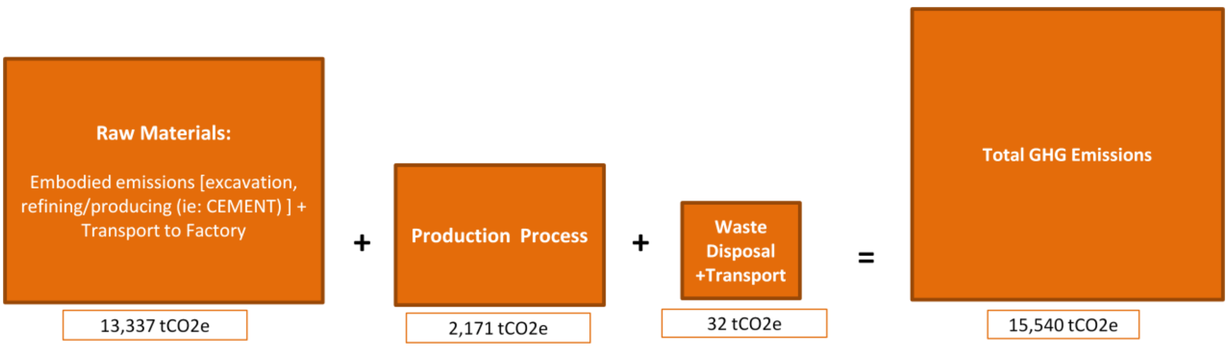
The final footprint emissions for the concrete manhole co-products examined in this study depend on the weight. The ranges are as follows:

- **Manhole rings** range from **82.48 – 541.66 kg CO_2e per meter of depth**;
- **Cover slabs** range between **0.168 – 0.170 kg CO_2e per kg**; and
- **Pipes** range between **17.77 – 592.07 kg CO_2e per meter.**

A breakdown by size of the overall emissions arising from the three manhole co-products are in the following table. The first column indicates the diameter of pipes in millimetres. For example, DN 225 indicates a manhole with a diameter of 225 millimetres. Each of the products examined in this report are selected to match the size of pipe they will be used with. For this reason they are classified by the diameter of the pipes, as seen in the first column.

Size of Pipe (mm)	Concrete Pipes kgCO2e (per metre)	Manhole Rings kgCO2e (per metre depth)	Cover Slabs kgCO2e (per kg)
DN225	17.77	N/A	N/A
DN300	27.13	N/A	N/A
DN450	44.55	N/A	N/A
DN600	76.41	N/A	N/A
DN750	112.76	N/A	N/A
DN900	138.87	82.48	0.168
DN1050	185.21	107.63	0.168
DN1200	236.19	138.76	0.172
DN1350	290.05	166.49	0.170
DN1500	361.21	202.63	0.169
DN1800	482.14	275.67	0.169
DN2100	592.07	338.72	0.175
DN2400	N/A	430.58	0.172
DN2700	N/A	541.66	0.170

Carbon Clear has identified the primary sources of emissions within the production process. A breakdown of the primary emissions can be seen in the following chart.



A further breakdown of the processes comprising each of these major sources of emissions can be found in section 3, Product Boundary.

Carbon Clear has verified all the calculations made by CPSA. With the amendments listed in Section 1.1, Background, made in accordance with PAS 2050, Carbon Clear Limited is pleased to make the full verification statement as follows:

Verification (PAS 2050: 10.3.3)
Greenhouse gas emissions calculated by Concrete Pipeline Systems Association in accordance with PAS 2050, Carbon Clear Limited declared.

1 Introduction

1.1 Background

Carbon Clear is working with the Concrete Pipeline Systems Association (CPSA) to evaluate the lifecycle emissions associated with their concrete pipes, concrete manhole ring units, and concrete cover slabs. In order to report the embedded greenhouse gases (GHG) emissions of their products, and so that they can be compared with the embodied emissions of other similar products, CPSA decided to use the British Standards Institute (BSI) PAS 2050 methodology which assesses the lifecycle GHG emissions of goods and services.

This report is the partial PAS 2050 Business-to-Business Lifecycle Assessment (LCA) for concrete pipes, concrete manhole ring units, and concrete cover slabs. It is a result of a thorough review of CPSA's initial findings and a gap analysis to bring CPSA's report up to PAS 2050 standards. CPSA's report was used as a base and Carbon Clear amended and added sections as needed to make it PAS 2050 compliant. CPSA's original report was extensive and fairly compliant with PAS 2050 to begin with. In order to ensure total compliance with a partial PAS 2050 LCA, Carbon Clear added or amended the following sections in this report:

Area Changed	Description of Change Made
Functional Unit	With CPSA's permission, the functional units were defined in this report not as an entire manhole, but as the three co-products required to make a manhole. These co-product units were defined as: • 1 metre depth of manhole ring • 1 linear metre of pipeline • 1 kg of cover slab.
Defining total percentage of emissions	For verification purposes, Carbon Clear determined that 99% of total emissions were included in the scope. This is now expressly stated in the study
Showing calculations for omitted emissions	For verification purposes, Carbon Clear received the calculations of emissions omitted and determined that they are, in fact, less than 1% of the scope and can therefore be emitted according to PAS 2050.
Defining Primary Gases Emitted	PAS 2050 requires that all gasses emitted that are listed in Annex A of the PAS 2050 be included in the scope. For this reason, the primary gasses emitted by the production of concrete are listed in the report.
Transportation Emission Factor Update	The emissions factors used for emissions from transportation were updated. This includes transportation of raw materials, internal transportation and transportation of the products to the site of installation. These numbers were updated with Defra / DECC 2010 emission factors, since they include emissions created by pre-combustion. The Defra 2010 emission factors are considered more accurate than the pre-combustion factors used by CPSA previously.
Fuel Combustion Emission Factor Update	The emission factor used for fuel combustion was updated. Like transport emission factors, it was decided to use Defra / DECC 2010 emission factors, since they include the emissions created by pre-combustion. The Defra 2010 emission factors are considered more accurate than the pre-combustion factors used by CPSA previously.
Raw Material Calculation Update	The calculations of the raw materials were updated. The correct sources had been used, the calculations simply needed minor corrections.

All data evaluated and used for calculations was from the calendar year of 2009.

1.2 Defining the Lifecycle Assessment (PAS 2050: Sec 4.5)

CPSA has chosen to conduct a Cradle-to-Gate, partial business-to business lifecycle assessment. In this assessment, emissions are included from raw materials through the production of the units and to the point where the units are transported to the site of installation. This does not, however, include emissions arising from installation, maintenance / service / end use, or disposal. In the case that this PAS 2050 will be communicated to third parties, the fact that it is a partial assessment must be clearly communicated.

Only emissions resulting from a single event release (production) will be calculated, and we will not consider the emissions emitted or absorbed over the full 100-year assessment period. The reasons for this are twofold:

1. CPSA does not need to carry out a full LCA of their product for the needs of their buyers, contractors, association members, etc.
2. There are many factors that complicate the end-use and end-of-life stages of the products, making it difficult for a consistent and complete analysis.

1.3 Methods

The data was collected from four main precast concrete pipeline products' factories producing over 70% of concrete pipeline products in the UK in 2009. These four factories are referred to in the data as CPM, F P McCann, Milton, and Stanton Bonna.

1.3.1 Cut-Off Rules (PAS 2050: Sec 6.3, Sec 3.33)

The emissions covered in the report represent 99% of the emissions produced in the Cradle-to-Gate fabrication of manhole rings, cover slabs, and concrete pipes. Only 1% of total emissions have been excluded, as they came from sources which were immaterial to the LCA due to their minute contribution to the overall footprint. PAS 2050 specifies that any emissions contributing less than 1% of total emissions may be excluded, up to 5% of total emissions. According to these qualifications, CPSA has a very comprehensive view of their emissions included in this LCA at 99%. The numbers in this report have been scaled up to represent 100% of the emissions in accordance with PAS 2050's requirements. Carbon Clear checked the calculations to verify that less than 1% of total emissions was excluded. Further detail about exclusions from the footprint can be found in section 3.1.2 "System Boundary Exclusions".

1.3.2 Gases Emitted

The primary gasses emitted through the production of concrete pipes, manhole rings and concrete slabs are in the chart below. When the term CO2 equivalent, or CO2e, is used, it includes all of the following gasses:

Gas	Global Warming Potential
Carbon Dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous Oxide (N_2O)	310

Table 1.1 Gasses emitted from the production of concrete products in this study

1.3.3 Functional Unit (PAS 2050: Sec 5.8)

The functional units used in this report are as follows:

- 1 linear metre of pipeline
- 1 metre depth of manhole ring
- 1 kg of cover slab.

Table 1.2 below shows the average weight from all four factories of the functional units defined. The type of concrete products listed in the table below are all the products that are included in this study.

Size of Pipe (mm)	Concrete Pipes (t per metre)	Manhole Rings (t per metre depth)	Cover Slabs (t per unit)
DN225	0.1165	N/A	N/A
DN300	0.1744	N/A	N/A
DN450	0.2859	N/A	N/A
DN600	0.4893	N/A	N/A
DN750	0.6797	N/A	N/A
DN900	0.8003	0.5150	0.2070
DN1050	1.0821	0.6810	0.2833
DN1200	1.3968	0.8798	0.3993
DN1350	1.8032	1.0683	0.6160
DN1500	2.1147	1.2835	0.8635
DN1800	2.8669	1.7338	1.3520
DN2100	3.5207	2.1288	1.9538
DN2400	N/A	2.6958	2.5508
DN2700	N/A	3.4053	3.4820

Table 1.2 Concrete pipes, manhole rings, and cover slabs: average weights (across all 4 factories)

2 Data – Collection and Sources

Section 7.2 of PAS 2050 specifies what type of data should be used in order to meet the data quality requirements of the lifecycle analysis. In accordance with these specifications, a combination of primary and secondary data was collected and used to help with the assembly of the Life Cycle Inventory of the study and Impact Assessment calculation.

2.1 Factories Considered (Population and Sample)

The study covered four of the main concrete pipeline factories in the UK. The combined total production of concrete pipeline products from the factories considered was 374,061 tonnes of concrete pipes, manhole rings and cover/reducing slabs. According to CPSA, this is approximately 70% of the UK's total production of concrete pipes in 2009, manhole rings and other cover slabs. The sample of factories was therefore considered to be fairly representative of the UK's population of concrete pipeline production facilities. These include:

- **F P McCann Factory, Ellistown:** This factory produces reinforced and unreinforced pipes, gullies, manhole rings, cover slabs and manhole special products.
- **Stanton Bonna, Stanton:** This factory produces reinforced and unreinforced pipes, manhole rings & cover slabs, railway sleepers, one-off precast units and GRP drainage products.
- **CPM Group, Frome:** This factory produces a range of precast products including reinforced/unreinforced pipes, gullies, manhole rings, cover slabs, boundary walls, and other one-off precast products.
- **Milton Pipes, Sittingbourne, Kent:** This factory produces manhole rings and cover slabs, DIC boxes, wall units, gullies, caisson rings, filter tiles, QMB barriers, smaller bespoke precast units.

All these companies regularly provide statistical data to CPSA. With the knowledge of processes and yield from each plant, it is possible to determine what proportion of emissions should be allocated to each factory for their production processes.

According to CPSA, in 2009 the total number of concrete pipe units (2.5 metre long each) manufactured was around 176,559 units. This is around 441.4 kilometres of pipeline. The total number of manholes manufactured was around 138,051 units. For concrete pipes and manholes only, (excluding cover rings) production at the four factories (see Section 3.1) is around 72.4% of total tonnage production in 2009 (a total of 340,949 tonnes of concrete pipes and manhole rings). A breakdown was developed based on the tonnage proportions (between 2009 total production and factory specific production) for each company. A breakdown was also developed for the number of units produced by each company in 2009. This breakdown helped in estimating energy and emissions associated with specific activities at factories, as seen in the table below.

Precaster 1 (units manufactured)	Precaster 2 (units manufactured)	Precaster 3 (units manufactured)	Precaster 4 (units manufactured)
109,582	**86,466**	**136,913**	**103,308**

Table 2.1 Estimated total number of units manufactured by the four factories in 2009.

2.2 Primary Data

Data to support a LCA is usually drawn from a combination of primary and secondary sources. PAS 2050 offers requirements for primary data use: Clause 7.3 notes that "*the primary activity data requirement shall apply to the emissions arising from those processes owned, operated or controlled by the first upstream supplier that does contribute 10% or more to the upstream GHG emissions of the product or input*".

A number of precast concrete product studies (with similar product systems) were examined by CPSA to identify the first upstream supply with 10% or more contribution to a cradle-to-gate GHG footprint of concrete pipeline products. The following table identifies the results of CPSA's studies.

	Swedish Hollowcore EPD (2000)	Vares & Hakkinen (1998)	German pipe Study (Specht & Lorenz, 2010)
Cement production	82.46%	79%	**84.82%**
Transport to factory	1.26%	3%	**unknown (included with other impacts)**
Precast factory	12.9%	8%	**7.82%**
Other impacts	**3.38%**	**10%**	**7.36%**

Table 2.2 Plain concrete Cradle-to-gate Greenhouse gas emissions.

CPSA's study shows a breakdown of the main sources of emissions from their production processes. Carbon Clear conducted a similar breakdown of main sources of emissions using the data provided by the four factories included in the study. The results of Carbon Clear's analysis can be seen in the following pie chart.

Primary data from precast concrete manufacturers has been acquired by CPSA for this study. Primary data will also be used for transportation to the site of installation based on the tonne-km of transportation vehicles.

Carbon Clear's results are seen in figure 2.3 below.

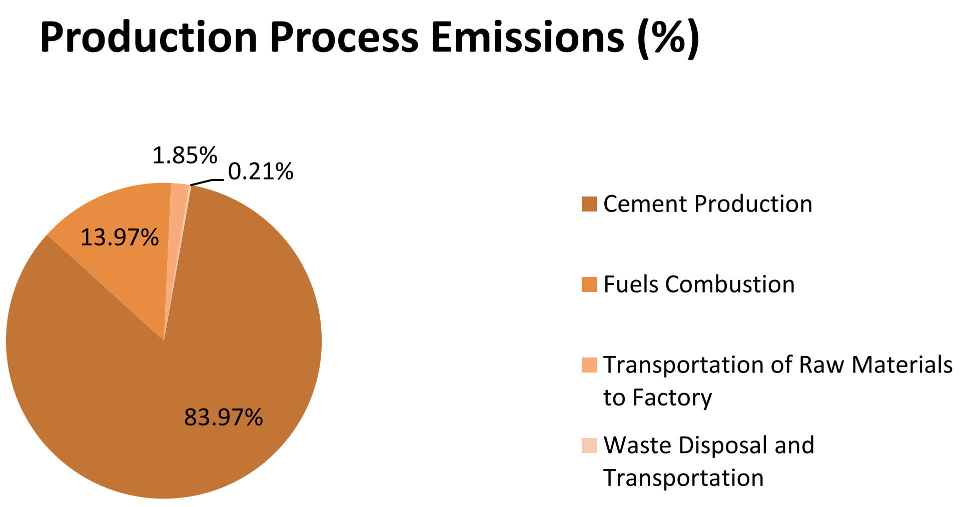


Table 2.3 Carbon Clear's results: Percent of emissions arising from processes contributing to the creation of precast concrete products (average from 4 factories)

In order to comply with PAS 2050, primary data was collected from the four factories in the form of a questionnaire created and distributed by CPSA in December 2009. The questionnaires were filled out and returned in January and February 2010. Additional information and explanations were received by CPSA following the questionnaire period in March and April 2010.

The data in the questionnaire includes the following:

- Information on the total production (pipeline products and otherwise) of the factories throughout 2009[1].
- Detailed fuel consumption throughout 2009.
- Raw materials consumption information throughout 2009.
- Waste generation information throughout 2009.
- Average transport distances (and number of journeys) for raw materials and ancillary materials used in production throughout 2009.

Additional information required after the questionnaire included issues such as the fate of waste steel removed from production sites and additional questions to enable the mass balance of inputs to and outputs from the product system. Information used to enable allocation and breakdown of emissions between different co-products was also collected after the official questionnaire.

2.3 Secondary Data / Conversion Factors' Sources

Secondary data was used from a number of sources to complement the study's inventory and enable a proper breakdown for impact emissions. These sources are assessed in **Chapter 6** in terms of relevance, quality, and representativeness. Sources included the following:

- **2009 and 2010 Guidelines to Defra / DECC's GHG Conversion Factors:** Defra publishes up-to-date national conversion factors to be used for calculating GHG emissions associated with a variety of processes, including combustion and the use of fuels. These conversion, or emission factors, are multiplied by primary data on fuel consumption (collected using the questionnaire) to calculate total fuel consumption GHG emissions at precast pipeline factories. The guideline was also used for a number of other conversion factors, including:

    a) GHG emission conversion factor for water company use
    b) GHG conversion factors for waste handling and treatment (landfill, disposal, etc)
    c) GHG Conversion factors for transport using different vehicles and carrying different loads (2010 – includes indirect emissions: fuel extraction, transportation, distribution)
    d) GHG Conversion factors for fuel combustion and electricity use (2010 – includes indirect emissions: fuel extraction, transportation, distribution).

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[1] The data covered in the questionnaire is for one year (2009) only. This is in accordance with clause 7.6 of PAS 2050 which states that "Where a product is made available on a continuing basis, the assessment of GHG emissions shall cover at least one year." This is also in accordance with ISO 14044 example at Annex A (A4) for a data collection sheet.

- **BRE Environmental Profile Reports:** A number of Environmental Profile reports (EPDs from LCA results) from BRE studies were used to identify the cradle-to-gate carbon footprint of certain raw materials used in the production of concrete pipeline products. These include fly ash and aggregates.

- **CEMBUREAU Environmental Product Declaration Report for CEM I and ISO 14040/PAS 2050 accredited value for CEM I as reported by the UK manufacturer CEMEX:** Due to the lack of any generic UK cradle-to-gate GWP figure for Portland cement (CEM I), figures from Europe (via Cembureau) and the UK manufacturer (CEMEX) were used for the study.

- **Source of office electricity and water data:** Office general annual energy consumption rates were taken from The Carbon Trust's 2003 Energy Consumption Guide. The source of mains water's carbon footprint is Defra's 2009 Conversion factors guide.

- **The Concrete Centre's embodied carbon for commercial, schools and hospital buildings:** This study was carried out by Arup in 2009/2010. It was used as the main source to quote an international carbon footprint of recycled steel used in reinforcement.

- **ICE Database (Bath University):** Used for a number of carbon footprint embodied impacts including recycled reinforcement steel and quicklime.

- **UK Building Blackbook:** This publication (by Franklin + Andrews) is a capital cost and embodied CO_2 Guide. It was used to estimate the GHG emissions of most site based activities such as excavation, backfilling and trench supporting.

- **Paper comparing electric and LPG forklifts (Johnson, 2008):** This is a paper at the April Issue of Energy Policy which was used to assess the viability of international transport data and calculations[2].

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[2] Johnson, E (2008) Disagreement over carbon footprints: A comparison of electric and LPG forklifts. *Energy Policy, Volume 36, Issue 4*, April 2008, Pages 1569-1573

3 Product Boundary

3.1 System Boundary Definition (PAS 2050: Sec 5.3)

The product system for the concrete products considered in this study shall include all different life cycle unit processes from cradle-to-gate. A number of inputs and outputs to the product system are identified including electricity use, combustion processes, operations of the general factory and office premises, operations of production, storage, waste from production by-products, and transportation to the installation site.

The following process map was created by CPSA as a visual representation of the processes included in the footprint LCA. However, it should be noted that the map includes the entire lifecycle, whereas the calculations exclude installation at the site. Therefore, emissions arising from bedding, trench box, excavation, and backfilling are not included in the cradle-to-site LCA.

Figure 2.4 demonstrates the **entire** processes in the production and installation of manhole rings, cover slabs and pipes:

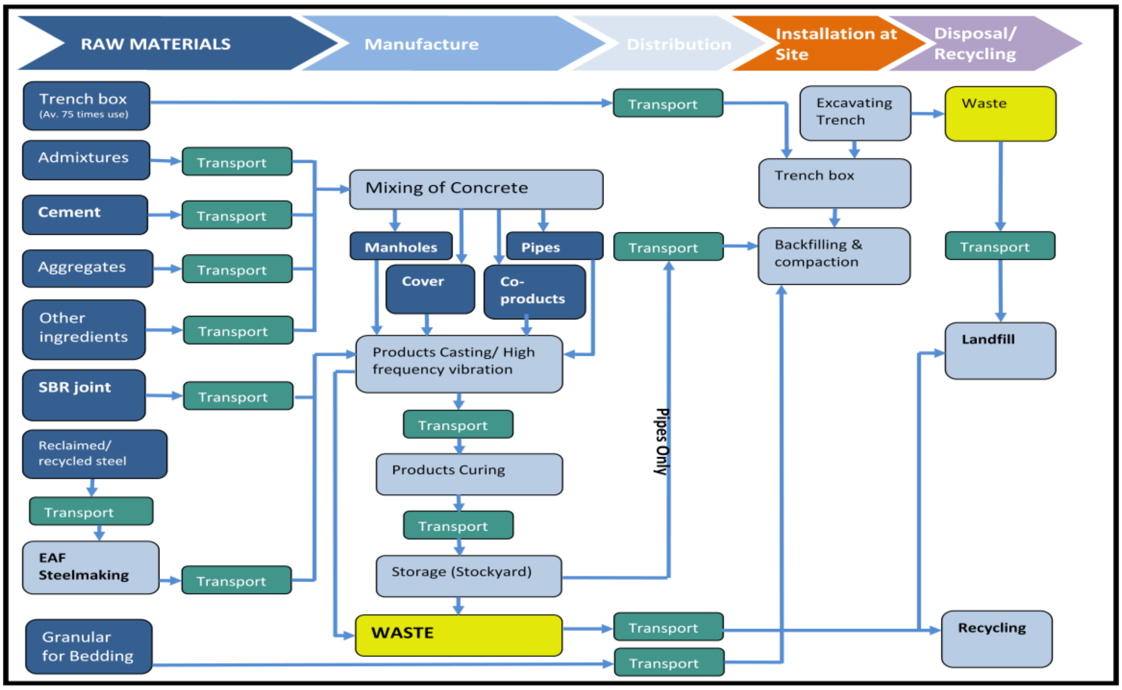


Figure 3.1 Product systems and unit processes identified.

Figure 3.1 identifies 38 processes associated with the production of concrete pipes, manhole rings and cover slabs. There are also a number of sub processes identified within the "pipe factory" unit process.

However, since not all of these processes are included in the calculations, we are also providing a process map which details *only* the processes included in the calculations. The following process map in Figure 3.2 details the processes included in the calculations from raw material excavation and transportation, through production of the pipes, manhole rings and concrete slabs, and ends at the transportation of the concrete products to the site of installation.

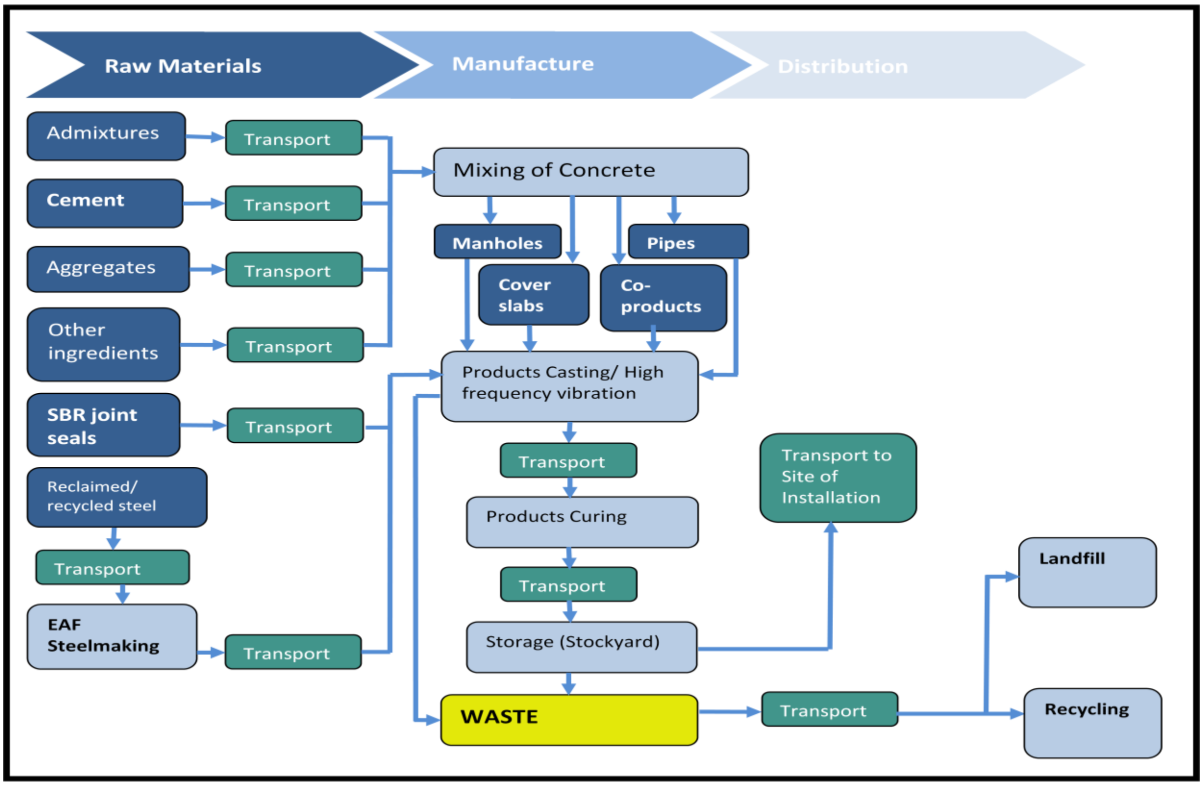
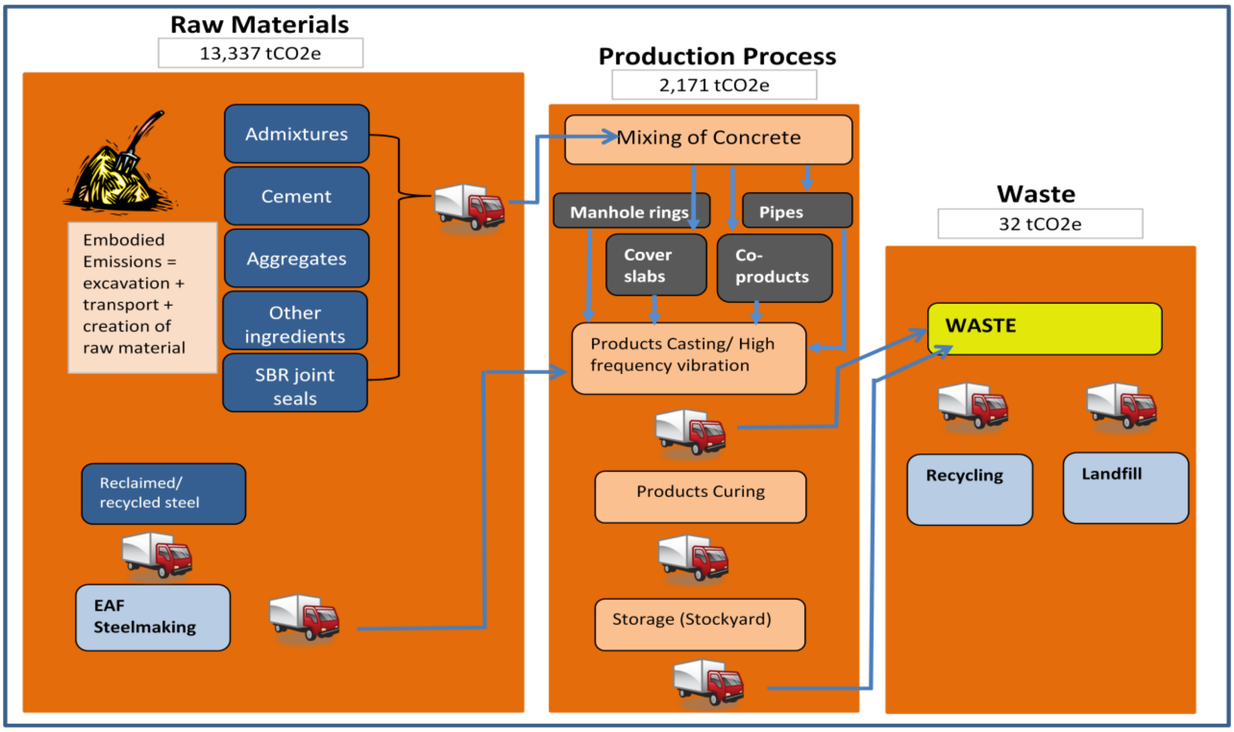


Figure 3.2 Product systems and unit processes identified.

This study examines the consecutive and interlinked unit processes from the point at which raw materials are excavated and transported to the factory, to the transportation of the finished products to the site of installation.

The largest sources of emissions were identified from these processes and shown below.



The largest source of emissions is from the extraction and creation of the raw materials, totalling **13,337 tonnes of CO2e**. This is primarily due to the carbon-intensive process used for the creation of cement, which is one of the primary ingredients of concrete. The actual production of the products uses the second largest amount of energy, but at **2,171 tonnes of CO2e** is significantly less than the raw materials phase. Finally, emissions arising from processes associated with waste are the smallest, producing **32 tonnes of CO2e.**

3.1.1 System Boundary Inclusion

This product system includes a number of consecutive unit processes. Several energy flows have been identified for this product system. The flows directly considered for the unit processes within that product system will mainly be "product flows" identified and imported from other studies. These include the following:

1. Inputs (Raw Materials)
    - Ad-mixtures
    - Cement
    - Aggregates
    - Joint seals and manhole steps.
2. Transportation of Raw Materials to Factory
3. Energy Use
4. Factory and Office Space
    - Water use
    - Factory consumables production and transport.
5. Production of Product / Operations
    - Production Process.

6. Transportation of Waste to landfill or recycling facility
7. Waste and Recycling
    - Landfill
    - Recycling.
8. Transportation of final product to installation site.

Inputs (Raw Materials) & Transportation to Factory

- **Aggregates production:** These include all impacts associated with the extraction and processing of aggregates used in the production of concrete. These include impacts associated with electricity use, fuel use, and use of explosives. The impacts associated with the production of capital equipment used at the quarry are not included.
- **Cement production:** These include all impacts associated with the extraction of cement ingredients (such as limestone), clinker production milling, and all other unit processes associated with the production of cement. Fuel and electricity consumption within cement factories are included, so is internal transport. Impacts associated with calcination are also included. No impacts from the production of capital equipments at cement factories are included.
- **Admixture production:** These include all the cradle-to-gate impacts associated with the production of admixtures.
- **Production of joint seals and manhole steps:** These include all the cradle-to-gate production impacts of producing seals and steps.

Transportation of Raw Materials to Factory

- **Aggregates transport:** In the case of marine aggregates the impacts associated with shipping to land are included. The impacts associated with transport of aggregates from the quarries to the factories are also included.
- **Cement transport:** Cement transport to the concrete pipeline factory is included in the calculations.
- **Admixture transport:** Transport to the precast pipe factories is included.
- **Joint seals and manhole steps transport:** Transport to pipeline product factories is included.

Energy and Water Use – Factory and Office Space

- **Water Use:** Only impacts associated with metered water are included. Borehole water will be considered as an elementary flow with zero GHG emissions. Only impacts associated with fuel (for pumps) will be considered.
- **Factory consumables production and transport:** All impacts associated with production and sourcing fuels, hydraulic oil, release oil, and lubricants are included.

Energy Use – Production of Product / Operations

- **Production Process:** Impacts associated with use of fuel and electricity to produce concrete products are included (for mixing, casting, curing, internal transport, etc). These also include emissions associated with fuels used by mobile plant and emissions associated with the offices in the business. However, impacts associated with any office departments working with other factories (within the same company) or *head-office* activities are not incorporated directly to the system boundary. As noted above, there are a number of sub-unit processes that can be identified. It may not be possible to identify the exact emissions associated with each sub unit process.

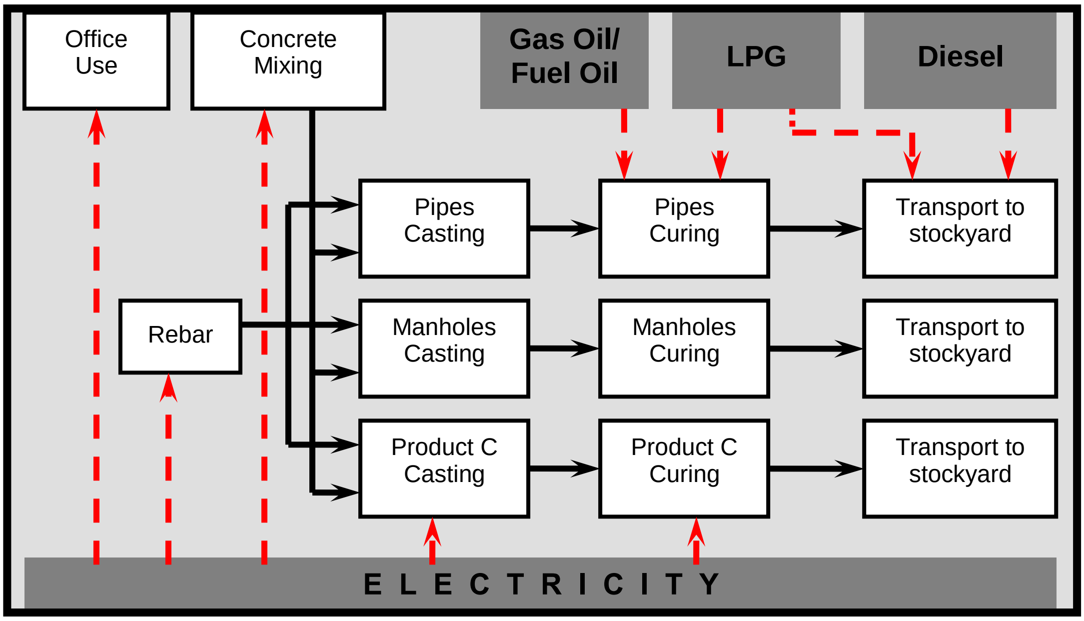


Figure 3.3 Sub-unit processes identified in pipeline product factories and main fuels causing GHG emissions.

Transportation of Waste

- **Waste Transport:** The transportation of waste at all stages of the lifecycle process is accounted for in the boundary scope.

Waste and Recycling

- **Landfill:** Impacts associated with waste disposal, landfill and transport from site are included within the product system boundary. However, impacts associated with further treatment for the purpose of recycling will be allocated to the subsequent product system as explained by Annex D of PAS 2050.
- **Recycling:** While some waste products are recycled, the amounts of recycled waste are negligible (less than 1%). For this reason, the emissions arising from recycling are not included in the calculations.

Transportation of Final Product to Installation Site

- **Transport to Installation:** In order to have a complete business-to-business, or cradle to gate, PAS 2050, transportation to the site of installation is included in the product boundary.

3.1.2 System Boundary Exclusions

As described in the Methods section of this paper under Cut-Off Rules, PAS 2050 identifies a cut-off materiality threshold of 1% of total GHG emissions.

A number of insignificant emissions associated with some consumables, ancillary products on site and waste were cut-off and excluded from the study. It is thought that the impacts of these on the overall carbon footprint is below 1%. Impacts cut off included the following:

a) **Impacts of "minor" factory and site consumables:** A number of consumables associated with production (sanding paper, release agents, etc) were ignored. The GHG emissions associated with these consumables are well below 1%. The main GHG contributing consumables (such as fossil fuel, specific types of hydraulic oil, etc) were all accounted for in the study.

Factory	Emissions (kg CO2e)
Milton	47.45
Stanton Bonna	110.28
CPM Group	59.34
F P McCann	119.18
TOTAL	336.25

The total emissions from factory and site consumables equal less than 1% of the total emissions released through the production of concrete products (pipes, cover slabs and manhole rings).

b) **Transport of workers commuting to precast pipeline factory every day:** PAS 2050 does not require that this information be included in the lifecycle footprint of a product.

c) **Steps in manhole rings:** CPSA chose to exclude this information for two reasons:

1) The impacts from the steps used in manhole rings will have a negligible impact on the overall footprint.
2) Some clients and end users prefer to use their own steps or ladders. Therefore, not all manholes produced by CPSA will have steps included in the end product.

d) **Waste recycling:** CPSA chose to exclude this information as the amount of waste that they recycle is negligible. Carbon Clear also believes the impacts from the amount of waste they recycle will have a negligible impact on the overall footprint.

3.2 Emission Allocation Rules

Concrete pipes, manholes rings and cover slabs are produced at factories where other products (such as road gullies, boundary walls, railway sleepers, and box culverts) are manufactured. This applies to the majority of factories considered in this study. Moreover, all factories produce some secondary by-products such as waste reinforcement wire and some crushed concrete. It is therefore necessary to set some allocation rules to deal with shared impacts.

Section 8 of PAS 2050 provides guidance on how emissions should be allocated in situations such as the one described in the paragraph above. The following sections detail the ways CPSA and Carbon Clear have followed the instructions in PAS 2050 regarding emission allocation.

3.2.1 Allocation for Co-products

PAS 2050, section 8.1.1 identifies two primary decision-making steps for allocation of impacts (in this case GHG emissions) between different co-products. For the purpose of this study, we will use the first method specified, where the unit processes will be divided and allocated in to sub-processes. The input and output data will be collected relating to each of these sub processes.

3.2.2 Impacts' Allocation Due to Secondary Products Input / Recycled Content

It should be noted that all precast concrete pipeline manufacturers in the UK use cement replacements such as Pulverised Fuel Ash (PFA)[3] to reduce the amount of Portland cement (mainly CEM I) and increase sulphate resistance qualities of their products. Some factories considered in this study use PFA. Moreover, all steel used for reinforcement of concrete pipeline products (and co-products) is recycled steel at its "second life" stage. This will have an impact on the product system considered as:

a) PFA will not be treated as an elementary flow with zero emission as it will be allocated a portion of the preceding product system (coal-fired power plant) emissions depending on its amount and economic value compared to generated electricity. GHG emissions associated with its collection, storage and handling will also be included into the product system boundary.
b) Recycled steel used for reinforcement will be allocated some GHG emissions from any processes associated with its recycling and preparation for reuse.

Impacts directly associated with the preceding product system will not be included for any product unless it had a value at its *previous-life* waste state.

3.2.3 Impacts' Allocation for Industrial Waste

Industrial waste generated by the product system is dealt with as follows:

a) Where the industrial waste has an economic value even prior to recycling then specific GHG emissions (allocated in accordance with economic value compared to final product) will need to be deducted from the product system and re-allocated to the industrial waste and its subsequent product system use.
b) Where the industrial waste has no economic value then impacts and emissions associated with its removal from site and disposal (if sent to landfill) will be included into the pipeline products' system boundary.
c) Where the industrial waste has no economic value but is recycled and reused in a subsequent product system then all emissions prior to recycling (e.g. transport off-site) will be allocated to the pipeline products' system boundaries and all emissions associated with recycling will be allocated to the subsequent product system (new life).

It should be noted that some concrete industrial waste is reused again in the product (as recycled content). This concrete industrial waste is kept crushed on site for two or three years prior to being reused. The emissions associated with collecting that waste and placing it in the dedicated concrete rubble area is allocated to the preceding product system (from two or three years ago). The emissions

[3] A by-product from coal-fired power plants.

associated with crushing that concrete waste is allocated to the subsequent product system. The carbon absorption benefits and credit associated with keeping the concrete rubble exposed to air for two or three years are not included in the product boundary at any point.

3.3 Stored Carbon in Crushed Concrete

Some factories store recycled crushed concrete to be used in product creation. This concrete is the result of failed product tested pipes, manhole covers, etc. which are crushed once every six months. The crushed concrete remains stored for 2-3 years and is reused in new product creation. Although concrete absorbs CO2 when it is exposed to air, this study has **not** included the uptake of CO2 in its lifecycle assessment.

4 Carbon Footprint Calculation

After the identification of the system boundary and the preparation of the inventory, the next steps are the classification, characterisation and quantification of the impact being assessed. PAS 2050 requires that the impact of each co-product and sub unit process be identified. Mass allocation for all products is not allowed by the PAS 2050. In order to identify the impact of each sub unit, secondary information drawn from reputable sources such as DEFRA and Bath University, is used in order to calculate the emission coefficients and breakdown the impacts associated with production by co-product. CPSA's expertise in the field is also drawn on to sense-check the data provided by each of the sources.

4.1 Emission Factors

When reporting the emissions arising from the processes associated with the creation of concrete pipes, cover slabs and manhole rings, the final units are reported in kilograms of CO_2-equivalents per functional unit. The reason for using CO_2-equivalents (CO2e), rather than just CO_2 is that carbon dioxide (CO_2) is only one of a group of atmospheric gases able to absorb and emit infrared radiation – known as greenhouse gases. CO_2-equivalent is therefore a metric used to compare the relative global warming potential of different greenhouse gases. For example, methane is 21 times more potent than CO_2 -making 1 tonne of methane equal to 21 tCO_2e.

4.2 Background: Nature of a Concrete Product Mix

Concrete is made by mixing a number of ingredients including fine aggregates, coarse aggregates, cement, admixtures, and water. Concrete mixes usually differ in accordance with the functions and applications of a specific concrete product, BS 8500 (the UK specification standard for concrete) identifies a number of designations for concrete, each with a specific water/cement ratio and each with a specific minimum cement content.

Precast concrete products are made in factory conditions and then transported to site. This usually adds additional requirements (in addition to strength or durability). For example, a precast concrete product is required to cure and strengthen in a relatively shorter period of time compared to in-situ concrete in order to be removed as quickly as possible from the production line and placed in the stockyard or transported to site. This example is associated with all precast concrete products manufactured in a mass production environment with a relatively lower level of customisation and one-off production. This is usually the case for all products manufactured at the four factories under consideration.

According to CPSA, information collected from the four factories indicates that the concrete mix does not experience considerable changes or modifications from one pipeline product to another. All the main products (over 90% of production) employ similar amounts of CEM I content and similar (in most cases) types and sources of aggregates. This means that the carbon footprint of cement used (CEM I, fly ash, or pre-blended options such as CEM II or Phoenix cement) should be similar. Emissions associated with using and transporting aggregates and impacts of mixing and casting at these factories should also be similar as all these products employ identical technology mix, time and geographical coverage.

It is therefore considered, for the purposes of this study, that all co-products within these factories are manufactured using the same concrete mix.

4.3 Aggregates Impact Assessment

All the impacts associated with the processing and sourcing of different types of aggregates from its elementary flow status (from cradle-to-gate) is included within the boundary of this study. As explained in Section 2.3 secondary data is used.

The carbon footprint for all types of aggregates is between 6.5 to 8 kg CO_2/tonne of product, as reported in the BRE Environmental Profile report for generic coarse/fine aggregates. In order to be conservative, and to simplify the calculation process, the carbon footprint will be taken as 8 kg CO_2e per tonne of generic aggregates.

This data meets the quality requirements stipulated by PAS 2050 for secondary data including technology mix, time and geographical coverage as the data is from the aggregates industry generic official environmental profile.

4.4 Cement Impact Assessment

All the impacts associated with the processing and sourcing of different types of cements from its elementary flow status (from cradle-to-gate) are included within the boundary of this study.

Secondary data was used for the impact calculations of processing and sourcing cement. The following sources were used for this purpose:

a) The carbon footprint of CEM I is **899** kg CO_2e/tonne of product as found at Cembureau's Environmental Product Declaration (EPD) report for 2008 for CEM I. This is currently the only publically available generic ISO 14044 certified carbon footprint in Europe for CEM I cement. In the UK, there are no accepted conversion factors for cement. The only ISO 14040/PAS 2050 accredited value for *CEM I* in the UK is **950** kg CO_2e/tonne of product, as reported by UK manufacturer Cemex. This is by far the most comprehensive and complete carbon footprint of CEM I in the UK. However, there is no information that this is equal to the UK's average as it might be lower or higher. The carbon footprint used for CEM I will therefore be an average of these two reported values: **924.5 kgCO_2e/tonne of CEM I**.

b) The carbon footprint for Pulverised Fly Ash is **25 kg CO_2e/tonne of product** as found at BRE's generic Environmental Profile for PFA and UKQAA.

c) It is understood from member companies that all their pre-blended CEM II mixes will employ a 30% PFA content and 70% CEM I. Due to the lack of any ISO 14044 GWP results for pre-blended cement the 30:70 breakdown is employed to identify a GWP for pre-blended cement. The carbon footprint for pre-blended and CEM II cement is therefore taken as **654.65 kg CO_2e/tonne of product**.

All data used meets the quality requirements set up by PAS 2050 for secondary data including technology mix, time and geographical coverage.

4.5 Reinforcement Steel Impact Assessment

All the impacts associated with the processing and sourcing of different types of reinforcement steel (as reinforcement coil, prefabricated reinforcement or wire) from its elementary flow status (from cradle-to-gate) is included within the boundary of this study. It is understood from the pipe manufacturers that all reinforcement steel used in their products is of recycled origin.

The carbon footprint for all reinforcement steel used is taken as **495 kg CO_2/tonne of product**. This figure is the average of two main values for the carbon footprint of reinforced steel. The following sources were used to determine this average for reinforcement steel:

- A carbon footprint of **570 kg CO_2/tonne of product** as reported by the "*Embodied Carbon Study of Commercial Hospital and School buildings*" report, conducted by Arup for MPA, for locally recovered and recycled steel using the Electric Arc Furnace (EAF) methodology.
- An embodied carbon figure of **420 kg CO_2/tonne of bar & rod** as quoted by Bath University's Inventory of Carbon and Energy.

4.6 Water Impact Assessment

The factories considered have two main sources of water used in production and in the product mix. These are (1) from water companies, and (2) from boreholes. All impacts associated with the processing, treatment, and sourcing of water is included within the boundary of this study.

As noted earlier, water sourced from boreholes is considered as an elementary flow and the only emissions associated with it will be from any pumps used at site. These are already being accounted for within factory energy consumption. The carbon footprint for company water supply is **0.276 kg CO_2 eq./m^3 of water** as identified by Defra / DECC's 2009 Guideline for GHG Conversion Factors for Company Reporting.
This data meets the quality requirements set up by PAS 2050 for secondary data.

4.7 Admixtures' Impact Assessment

All the impacts associated with the processing and sourcing of different types of admixtures from its elementary flow status (from cradle-to-gate) is included within the boundary of this study. All these admixtures conform to EN 934. These include plasticizers, super-plasticizers, accelerators, and some air-entraining admixtures. As noted in Chapter 2.3 secondary information can be used for these impacts.

The European Federation of Concrete Admixture Associations (EFCA) has developed generic EPDs for all these types of concrete admixtures in 2005/06. The carbon footprints for the admixtures are as follows:

Admixture	kg CO_2e/tonne
super-plasticizers	745
plasticizers	225
air entraining admixtures	99
accelerators	1250
Average	579.75

Carbon Clear used the average of these numbers to calculate the emissions stemming from admixtures. An average number was used as no detailed breakdown of the proportion of different admixtures was provided. Additionally the contribution of admixtures is very small, thus not affecting the calculations dramatically if an average is used. The average number used for calculations is **579.75 kg CO2e**.

This data meets the quality requirements set up by PAS 2050 for secondary data.

4.8 Raw Materials' Transportation Impact Assessment

All calculations associated with transportation are based on primary data with the consideration of empty return journeys. The number of deliveries and distances from raw material production depot to factories were considered and the following formula is used:

[Number of deliveries reported for raw material x distance return journey (km)] X (Defra's GHG conversion factor for specific lorry used 100% laden + Defra's GHG conversion factor for specific lorry used 0% laden)

Where data is not available on the number of raw material deliveries, the following formula is used:

{[Total raw material (tonnes) / net load for lorry used (tonnes)[4]] x distance return journey (km)} X (Defra's GHG conversion factor for specific lorry used 100% laden + Defra's GHG conversion factor for specific lorry used 0% laden)

[4] Based on DETR Transport Statistics 1996 – cited by Addendum to BRE Methodology for Environmental Profiles of Construction Materials, Components and Buildings, BRE (2000).

Where travel distances for raw materials are unknown, these distances are estimated using existing data regarding other members' average distances. The amount of fuel associated with the lorries considered (travelling the distances reported) was estimated from the Defra / DECC's 2009 Guideline for GHG Conversion Factors for Company Reporting, converted into tonnes of fuel. Defra's 2009 guidelines were employed by CPSA. Carbon Clear decided to verify these emission factors using Defra's 2009 Guidelines, consistent with CPSA's calculations.

In order to give a more complete picture of the emissions associated with raw material delivery, Carbon Clear also decided to update the calculations to include the emissions from pre-combustion using Defra / DECC's 2010 Guidelines for indirect emissions.

4.9 Fuels Impact Assessment

All the impacts associated with the processing and sourcing of different types of fossil fuels (from cradle-to-gate) are included within the boundary of this study. These include gas oil, fuel oil, diesel, natural gas, coal, and LPG. Electricity is also included.

The amount of fuel used in these factories (already available from the Life Cycle Inventory) was multiplied by the Defra / DECC's 2010 Guideline pre-combustion factors and added to the final carbon footprint.

4.10 Factory Operations (Sub-Unit Processes) Impact Assessment

PAS 2050 requires this stage of the study to be based on primary data. This unit process incorporates a number of sub-unit processes detailed and described in Figures 2.2 and 2.3. As noted earlier, concrete pipeline products are not the only products manufactured at the precast factories considered. It is therefore important to offer some information on the proper measures to break down and manage impacts associated with the sub-unit processes in order to avoid any distortions caused by allocation based on market price.

All GHG emissions associated with main factory production operations are caused by fuel and energy use.

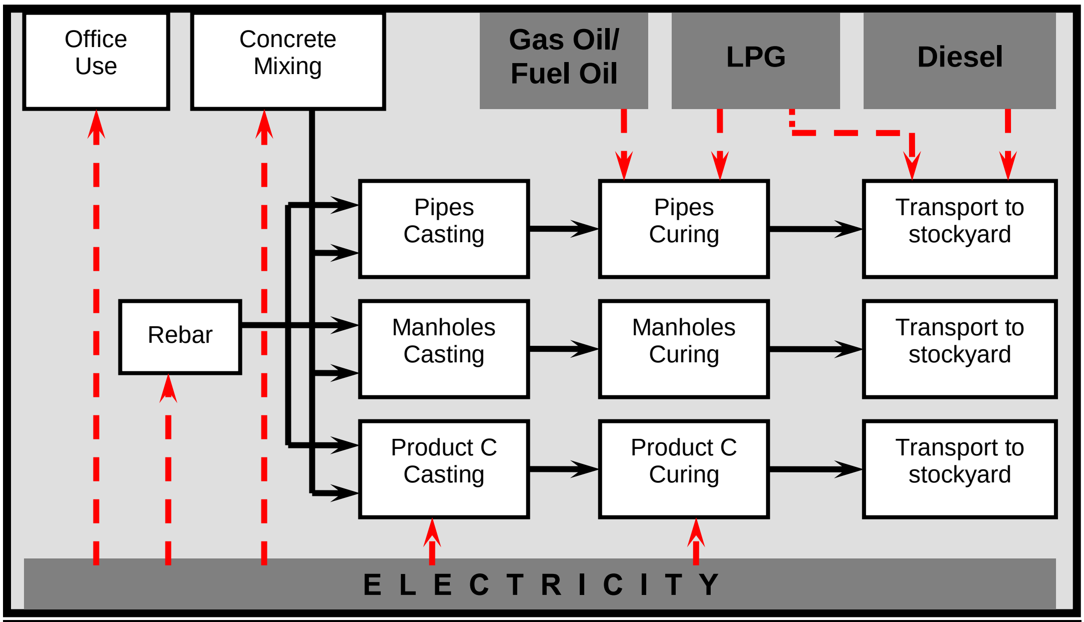
Each of the sub-unit processes is examined and the emissions are broken down in a manner that accounts for a product's method of production, fuel consumption patterns and product handling. There are six main activities that can be identified:

a) **Concrete mixing:** The main source of energy used for this is electricity.
b) **Reinforcement rebar:** The main source of energy used is electricity but the contribution of steel to the final product carbon footprint is incorporated at this stage.
c) **Concrete Casting and Vibrating:** The main sources of energy used are electricity and fuel oil.
d) **Concrete Curing:** The main source of energy used is fuel oil, gas oil, LPG, or natural gas.
e) **Concrete internal transport:** The main source of energy used is diesel and gas oil.

Handling Emissions Associated with Electricity Consumption

Electricity is associated with a wide range of activities throughout the factories. As the measurement unit of concrete and products handled in almost all electricity-powered activities is based on mass or volume (rather than number of units produced), electricity consumption will be more linked to tonnage of production and will be allocated in accordance to that measure of production. This is not a straightforward physical allocation exercise as CPSA used knowledge of production operations to identify how electricity impacts should be allocated to each co-product.

The diagram showing sub-unit processes is repeated below to aid understanding of the way emissions from electricity consumption are broken down in the various factory processes. Further details about the impacts associated with the sub-unit processes can be found in sections 4.10.1 through 4.10.6.



(Repeated Figure 3.3) Sub-unit processes identified in pipeline product factories and main fuels causing GHG emissions.

4.10.1 Concrete Mixers Impact Assessment

Batching of concrete does not usually consume a considerable amount of energy. CPSA's assessment shows that Flower & Sanjayan's (2007) report GHG emissions to be around 0.0033 t CO_2/m^3 from concrete batching in Australia. This is no more than 1.375 kg CO_2e/t. In a study conducted by the American Precast Concrete Association (PCA)[5] it was found that the energy consumption associated with concrete mixing is no more than 1.721 KWh/t – using Defra's conversion factors for electricity this will be associated with no more than 0.936 kg CO_2e/t.

[5] Report No (SN2137a). This report was also published at World Cement April 1997.

As the product considered (concrete mix) is not handled in a specific shape or a uniformed product manner other than 'tonnage' all batching impacts will be allocated / broken down between co-products and product variations on a weight basis based on an average of the two figures mentioned above: **1.155 kg CO_2e per tonne of concrete mixed**.

4.10.2 Allocation of Steel Reinforcement Impacts

The rebar process is usually carried out by an electrically powered machine . The exact energy consumption of that machine is not quantified but is thought to be very low. The most important impact at this unit process is the introduction of reinforcement steel coil / caging / wire to the process. This sub unit-process determines how the GHG impacts associated with reinforcement is allocated.

In regards to the breakdown of emissions associated with the operation of the machine and reinforcement caging, the main function that can be correlated to GHG emissions associated with the machine operation is the amount of reinforcement caging performed. The amount of caging work is linked to the volume of units to be reinforced. Reinforcement machines' energy emissions are therefore broken down in accordance with the volume of each of the co-products being reinforced. As the density of concrete is constant, rebar operations' impacts can be broken down between co-products based on mass.

Additional GHG emissions associated with the carbon footprint for reinforcement steel is then added to that co-product's inventory in accordance with the amount of reinforcement used for each product. Emissions considered for reinforcement steel are detailed in Section 4.5.

4.10.3 Concrete Casting/Vibrating Impact Assessment

The main source of energy used in casting and vibrating concrete pipeline products is electricity. It was not possible to identify the main factors and characteristics that affect concrete casting and vibration intensity from one product to another. Moreover, it was not possible to separate energy associated with casting and vibration from curing. As casting and vibrating are apparently activities that can be affected by the amount of concrete used per unit – it is believed that mass/volume should be considered as the main function for breakdown of impacts from casting/vibrating. It was therefore decided to break down impacts associated with each casted/vibrated co-product based on the total mass of that product. It should be noted that this is the more appropriate breakdown method to use (compared to basic market price allocation).

4.10.4 Concrete Products Curing Impact Assessment

Curing is thought to be the main energy-intensive activity at concrete pipeline product factories. After casting all units are placed in chambers or concealed sections of production halls and subjected to heat to help it cure and gain strength. The process of curing is mainly associated with the mass of the products being cured and the weight/volume of products, rather than shape or surface exposure to heat and hydration. It was therefore decided to break down impacts associated with each product cured based on the total mass of that product. As noted above this should not violate PAS 2050 requirements as this is the most appropriate and accurate means to break down energy impacts associated with accelerated curing.

4.10.5 **Cranes and Mobile Plant Emissions Impact Assessment**

Two of the four companies taking part in this study offered input inventory information in regards to fossil fuel used for mobile plant (forklift trucks). The other two companies offered combined information for fossil fuel used for mobile plants as well as heating/curing.

Emissions associated with the use of mobile plants at factories were cited from Johnson's (2008) comparison of electric and LPG forklifts. The average energy consumption rate (per hour) considered for mobile plant is **2.3 to 3.26 Kg of LPG/h** (based on two different sources cited by Johnson). When correlated to the fossil fuel mobile plant available from the two companies who already submitted data[6] (and using their number of units manufactured information as estimated for this study) it was found that each unit will be internally transported/handled for an average period of 15-17 minutes to 20-24 minutes (including empty journeys for the fork lift). The average of internal transport energy consumption for the two companies with information is therefore taken and this average is used for the other two member companies. The GHG impacts were calculated by CPSA using Defra's 2009 conversion factors and were validated by Carbon Clear. To ensure completeness, Carbon Clear added in indirect emissions arising from fuel pre-combustion based on Defra / DECC's 2010 Guidelines. The GHG impacts are then allocated to the number of units produced (all units despite weight, mass, or shape get the same GHG impact).

The number of units is calculated using a combination of industry statistics (based on pipe and manhole size ranges) submitted previously to CPSA (see table 2.1).

4.10.6 **External/ Internal Lighting and Office Activities Impact Assessment**

GHG emissions at a concrete pipeline factory are not associated with direct production and product handling activities only. There are a number of activities that would trigger carbon dioxide (and other greenhouse gas) emissions. These include external/internal lighting and office activities:

- **Office activities:** GHG emissions at office buildings are associated with different energy-consuming activities such as use of hot water, use of building heating, use of internal lighting, and operation of office equipment. The average energy consumption for office buildings based on Carbon Trust's 2003 Energy Consumption Guide is around **358 KWh/m^2 p.a**. At least in three of these factories some of the office activities are more associated with the parent companies than factories' management and specific factories' production sales/ marketing. The energy consumption (and GHG emissions) associated with these activities will need to be excluded from the study – it is assumed that only half the activities at these offices are associated with the production at these factories and all GHG emissions associated with that 50% is deducted from the GHG inventory.
- **Production Halls Internal Lighting:** The energy consumed on internal lighting of the main production halls at the factories will be broken down in accordance with the tonnage in production (total mass). This is mainly because tonnage was found to be the most appropriate breakdown methodology for all indoor activities in factories and will therefore offer a more accurate breakdown mechanism for lighting emissions per production.

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[6] It was assumed that a mobile plant using gas oil/diesel will have the same energy efficiency (KWh) as a LPG fuelled mobile plant.

4.11 Site Operations Impact Assessment

A number of unit processes were considered as part of the post production stages of the study, up to the delivery at the installation site. Calculation and impact assessment of GHG emissions associated with these unit processes are described below.

4.11.1 Transport of Concrete Pipeline Units to Site

All calculations associated with this stage were based on primary data with the consideration of an empty return journey.

An average distance reported by three factories was considered. The average distance for all deliveries in 2009 was 113.5 kilometres.

Defra's 2010 conversion factors were used to include the emissions arising from scope 3 indirect (pre-combustion) emissions. In order to determine the emissions arising from transport of the products to the site of installation, the following formula was employed:

{[Total number of pipeline products per lorry load (tonnes)] x 113.5 (km)}
X (Defra's 2010 GHG conversion factor for specific lorry used 100% laden + Defra's GHG conversion factor for specific lorry used 0% laden)

In order to analyse the impact of transportation to the site of installation, CSPA calculated the maximum load of each separate concrete product in one trip to the site of installation. Carbon Clear verified these calculations and is including the table below to detail the maximum load transportation information. The results of this calculation are detailed in Table 4.1 below:

Size of Pipe (mm)	Pipes (Maximum Load in meters)	Manhole Rings (Maximum Load in meters of depth)	Cover Slabs (Maximum Load number of Units)
DN225	175	N/A	N/A
DN300	165	N/A	N/A
DN450	100	N/A	N/A
DN600	56.25	N/A	N/A
DN750	41.25	N/A	N/A
DN900	35	38	106
DN1050	25	34	73
DN1200	20	26	52
DN1350	15	22	35
DN1500	12.5	16	23
DN1800	10	12	16
DN2100	7.5	10	10
DN2400	N/A	8	8
DN2700	N/A	8	6

Table 4.1 Maximum load of individual products (one of the following: concrete pipes, manhole rings, and/or cover slabs) transported by a +30 tonne truck in one return journey.

5 Results of Cradle-to- Construction Site Analysis

This chapter describes the GHG emission results for the study expressed in kg CO_2e. The first two tables shown below detail the overall emissions arising from the production of each type of concrete product (cover slabs, pipes and manhole rings).

Table 5.1 details the emissions arising from cradle-to-gate production of the products, not including emissions arising from transportation to the site of installation.

Table 5.2 includes the emissions stemming from cradle-to-gate production *and* transportation to the site of installation.

The calculations for transportation are based on one metre of concrete pipeline products (expressed in kg CO_2e). As noted in section 4.11.1 113.5 km was used as an average distance for the transportation of the end product to the site of installation. Round trip journeys were included; however, the return trip was based on the vehicles being empty.

Carbon Clear recommends that figures from Table 5.2 be used in the final PAS 2050 assessment for reporting and third-party communication purposes.

Size of Pipe (mm)	Concrete Pipes kgCO2e (per metre)	Manhole Rings kgCO2e (per metre depth)	Cover Slabs kgCO2e (per kg)
DN225	16.36	N/A	N/A
DN300	25.63	N/A	N/A
DN450	42.07	N/A	N/A
DN600	72.00	N/A	N/A
DN750	106.75	N/A	N/A
DN900	131.79	75.96	0.156
DN1050	175.30	100.35	0.156
DN1200	223.80	129.24	0.160
DN1350	273.54	155.23	0.159
DN1500	341.40	187.15	0.157
DN1800	457.37	255.03	0.158
DN2100	559.04	313.95	0.162
DN2400	N/A	399.61	0.160
DN2700	N/A	510.70	0.158

Figure 5.1. Emissions arising from the production of the product (excluding transportation to site of installation).

Size of Pipe (mm)	Concrete Pipes kgCO2e (per metre)	Manhole Rings kgCO2e (per metre depth)	Cover Slabs kgCO2e (per kg)
DN225	17.77	N/A	N/A
DN300	27.13	N/A	N/A
DN450	44.55	N/A	N/A
DN600	76.41	N/A	N/A
DN750	112.76	N/A	N/A
DN900	138.87	82.48	0.168
DN1050	185.21	107.63	0.168
DN1200	236.19	138.76	0.172
DN1350	290.05	166.49	0.170
DN1500	361.21	202.63	0.169
DN1800	482.14	275.67	0.169
DN2100	592.07	338.72	0.175
DN2400	N/A	430.58	0.172
DN2700	N/A	541.66	0.170

Figure 5.2. Overall emissions of the product including production *and* transportation to site of installation.

6 Data Quality Requirements

ISO 14044 identifies a number of quality requirements for data used in LCA. PAS 2050 recognises these quality requirements and sets a number of rules (Section 7.2) on how these should be considered in a study.

6.1 Precision & Completeness

ISO 14044, Clause 4.5.3.2, refers to the importance of conducting a completeness check as part of the overall evaluation of the study. A completeness check was conducted by CPSA for the cradle-to-gate main inventory and no missing or incomplete information associated with the Goal and Scope of the study was found to be affecting the study's accuracy by over 1%.

6.2 Consistency and Reproducibility

Consistency is referred to in ISO 14044 and PAS 2050 as qualitative assessment of whether the selection of data is carried out uniformly in the various components of the analysis. The information offered and LCI inventory information was cross checked a number of times and any inconsistencies in specific factory information were either verified with the manufacturer or ruled out.

The results of the study are reproducible. The only elements kept undisclosed to the public are specific production and material consumption information at different factories. Apart from this, all the inputs required to reproduce the study are publically available and all information on the methodology is available in the report and its associated calculation spreadsheets.

6.3 Representativeness

All aspects of temporal, geographical and technological coverage and representativeness of data were adhered to in the study:

- **Time related coverage:** All primary data used for the study was collected from factories as reported in 2009. The sources of secondary information range from 2004 to 2010.
- **Geographical coverage:** The vast majority of information used is from a UK source. Some of the cement data is for Western Europe and some of the steel carbon data may be from global sources.
- **Technology mix:** All secondary information was sourced from studies specifically addressing concrete (and its production ingredients). Some assumptions were made for general waste mix and end-of-life treatment (based on national average), lining of concrete pipes[7], and trench excavations.

[7] Although this part of the study is only informative and is not part of the current LCA remit.

Conclusions

This report is the partial PAS 2050 Business-to-Business Lifecycle Assessment (LCA) for concrete pipes, concrete manhole ring units, and concrete cover slabs. It is a result of a thorough review of CPSA's initial findings and a gap analysis to bring CPSA's report up to PAS 2050 standards. CPSA's report was used as a base and Carbon Clear amended and added sections as needed to make it PAS 2050 compliant.

In this assessment, emissions are included from raw materials through the production of the units and to the point where the units are transported to the site of installation. This does not, however, include emissions arising from installation, maintenance / service / end use, or disposal. In the case that this PAS 2050 will be communicated to third parties, the fact that it is a partial assessment must be clearly communicated. The following table presents overall results of the carbon footprint calculations for all three products per functional unit:

Size of Pipe (mm)	Concrete Pipes kgCO2e (per metre)	Manhole Rings kgCO2e (per metre depth)	Cover Slabs kgCO2e (per kg)
DN225	17.77	N/A	N/A
DN300	27.13	N/A	N/A
DN450	44.55	N/A	N/A
DN600	76.41	N/A	N/A
DN750	112.76	N/A	N/A
DN900	138.87	82.48	0.168
DN1050	185.21	107.63	0.168
DN1200	236.19	138.76	0.172
DN1350	290.05	166.49	0.170
DN1500	361.21	202.63	0.169
DN1800	482.14	275.67	0.169
DN2100	592.07	338.72	0.175
DN2400	N/A	430.58	0.172
DN2700	N/A	541.66	0.170

Figure 8.1. Overall emissions of the product including production and transportation to site of installation.

7 Claim of Conformity

Carbon Clear has verified all the calculations made by CPSA. With the amendments listed in Attachment 1, made in accordance with the PAS 2050, Carbon Clear Limited is pleased to make the full verification statement as follows:

Verification (PAS 2050: 10.3.3)

Greenhouse gas emission calculated by Concrete Pipeline Systems Association are in accordance with PAS 2050, Carbon Clear Limited declared.