British Precast
Drainage Association

Publications from the British Precast Drainage Association (BPDA):

BPDA was formed in 2017 from the integration of the Concrete Pipeline Systems Association (CPSA) and the Box Culvert Association (BCA).

Information published by both CPSA and BCA will be rebranded and replaced as BPDA in due course. New material will be branded BPDA.

All CPSA and BCA web traffic will be redirected to the new BPDA web site at www.precastdrainage.co.uk control your carbon impact.

CPSA Manhole Systems Comparison Report

15th June 2011

carbonclear

www.carbon-clear.com

1. Executive Summary

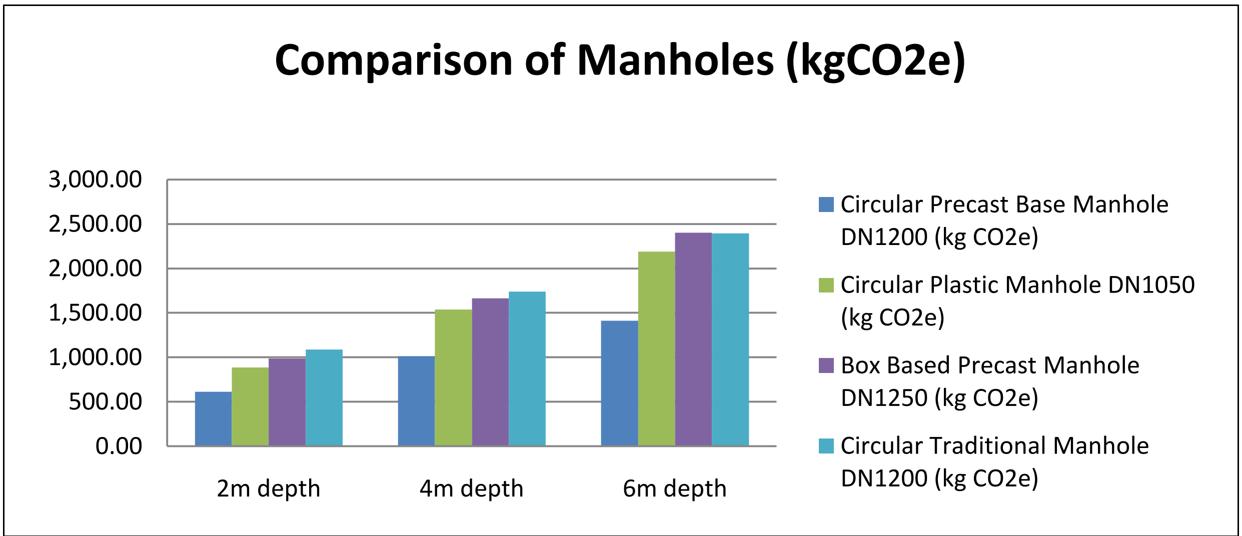
Concrete Pipeline System Association (CPSA) members produce two different types of precast concrete manhole systems: circular manholes with pre-cast bases and traditional circular manholes where the base and surround are constructed at the site of installation. CPSA engaged Carbon Clear to perform a comparison of these two manhole systems with imported precast concrete box based manholes and circular plastic manholes.

CPSA supplied Carbon Clear with estimated Life Cycle Inventory and carbon footprint data for plastic and box based manhole systems available within the UK (see Appendix) and asked for a comparison to be carried out between these four types of manhole systems at DN1200 and DN1050 size or equivalent specification, with installed depths of 2 metres, 4 metres and 6 metres.

Our overall results, based on assumptions and data provided by CPSA, show the following:

- Circular precast base manhole systems perform the best at all depths, resulting in the lowest greenhouse gas emissions.
- At 2 metres of depth, box based precast manholes perform better than circular traditional manholes in resulting CO_2e emissions.
- At 4 metres depth, circular traditional manholes perform marginally better than box based precast manholes on CO_2e emissions.
- At 6 metres of depth, circular traditional manholes perform marginally better than box based precast manholes in terms of resulting CO_2e emissions.
- At 2, 4 and 6 metres of depth, circular plastic manholes perform better than box based and circular traditional manholes. On the other hand they perform worse than circular precast base manholes in terms of resulting CO_2e emissions.

This is demonstrated in the chart below:



2. Introduction

The members of CPSA produce two different types of manholes: circular manholes with precast concrete bases and traditional circular manholes where the base and surround are constructed at the site of installation. CPSA engaged Carbon Clear Ltd to perform a comparison of these two manhole systems with imported precast concrete box based manholes and circular plastic manholes available in the UK market based on their embodied carbon emissions.

CPSA supplied Carbon Clear with information about plastic manhole systems and box based manhole system (produced in Europe by Kijlstra See Appendix) and asked that a comparison be carried out between these four types of manholes systems. CPSA's objectives for this study are to:

- Understand the footprint of their products
- Determine the difference in greenhouse gas emissions between 4 types of manholes
  - Circular manhole with a precast base (precast)
  - Circular manhole with base and surround poured on-site (traditional)
  - Square manhole which is entirely precast (box based) and
  - Circular plastic manhole whose base and surround are constructed on-site
- Be in a position to substantiate claims about the environmental benefits of their products

Previously Carbon Clear was engaged to conduct PAS 2050 carbon partial life cycle assessment for the following elements produced by CPSA members: concrete pipe, concrete manhole ring and cover slab.

Product Comparison and Justification:

ISO 14044, section 4.3.2.7, states that "in a comparative study systems shall be compared using the same functional unit and equivalent methodological considerations, such as performance, system boundary, data quality, allocation procedures, decision rules on evaluating inputs, and outputs and impact assessment". PAS 2050 identifies the same principles (4.2.C).

The following manholes are being compared in this study:

1. **Precast:** Size 1200 mm diameter
2. **Traditional:** Size 1200 mm diameter
3. **Box based** Size 1250 x 1250mm[1]
4. **Plastic:** Size 1050 mm diameter*

All to installed depths of 2m, 4m and 6m

Scope:

This analysis provides a "cradle-to-gate" emissions inventory according to PAS 2050. Inclusions and exclusions are as indicated below:

[1] Listed in Appendix, Section 1

- * This size of manhole is not functionally equivalent to DN1200 manholes but is used in the study as a reference in terms of embodied carbon emissions

Includes (For ALL types of manholes)

- Raw Materials – embodied emissions
- Delivery of Raw Materials to factory
- Concrete manufacturing
- Internal transport
- Gas consumption
- Electricity Use
- Diesel consumption
- Transportation of Goods to Installation site (indirect or so-called pre-combustion emissions)

Excludes (For ALL types of manholes)

- Transport of machinery to site of installation
- Machinery used for installation
- Bedding
- Staff transportation
- End Use
- Disposal

Included in CPSA Product Assessments ONLY

- Waste
- Primary Energy information included in Fuel
- Transport of cement mixer/pourer to site (only for base poured on-site)

Excluded in CPSA Product Assessments ONLY

- Pipe Seals (Joints)

Emissions Factors: Emissions for **traditional and pre-cast manholes** are calculated using standard formulae and expressed as tonnes of carbon dioxide equivalent (CO_2e). Emissions Factors are supplied by:

- UK government – 2009-2010 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting (CPSA)
- Bath University – Inventory of Carbon & Energy, 2011
- BRE Environmental Profile Reports
- CEMBUREAU Environmental Product Declaration report for CEM I
- Energy Consumption Guide – ECG19 (2004)
- Arup in 2009/2010
- UK Building Blackbook
- Paper comparing electric and LPG forklifts (Johnson, 2008)

Emissions for **box based manholes** are calculated from the information and assumptions provided by CPSA (See Appendix).

Emissions for **plastic manholes** are calculated using standard formulae and expressed as tonnes of carbon dioxide equivalent (CO_2e). Emissions Factors are supplied by:

- UK government – 2009-2010 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting
- Bath University – Inventory of Carbon & Energy, 2011
- Eco Profiles of the European Plastic Industry-Polypropylene Injection Moulding 2005
- Eco Profiles of the European Plastic Industry-HDPE. PVC and Polypropylene Life Cycle Analysis

Data:

All data about **precast and traditional manholes** was supplied by CPSA. CPSA's proprietary data about four factories was gathered through a questionnaire that was distributed to the factories. This survey was carried out by CPSA and the results were supplied to Carbon Clear in spreadsheet form and validated to PAS 2050. Information relating to installation processes was also provided by CPSA.

Data about **box based manholes** was taken from the Carbon Footprint Report for Kijlstra Ltd 15th March 2010 http://www.kijlstra.co.uk/downloads/KIJLSDR_carbon_footprint.pdf. The calculations based on the assumptions have been checked and updated in the following report. The calculations in the Appendix are left in the original form supplied by CPSA, whereas updated calculations can be found throughout this report and in relevant excel spreadsheets[2].

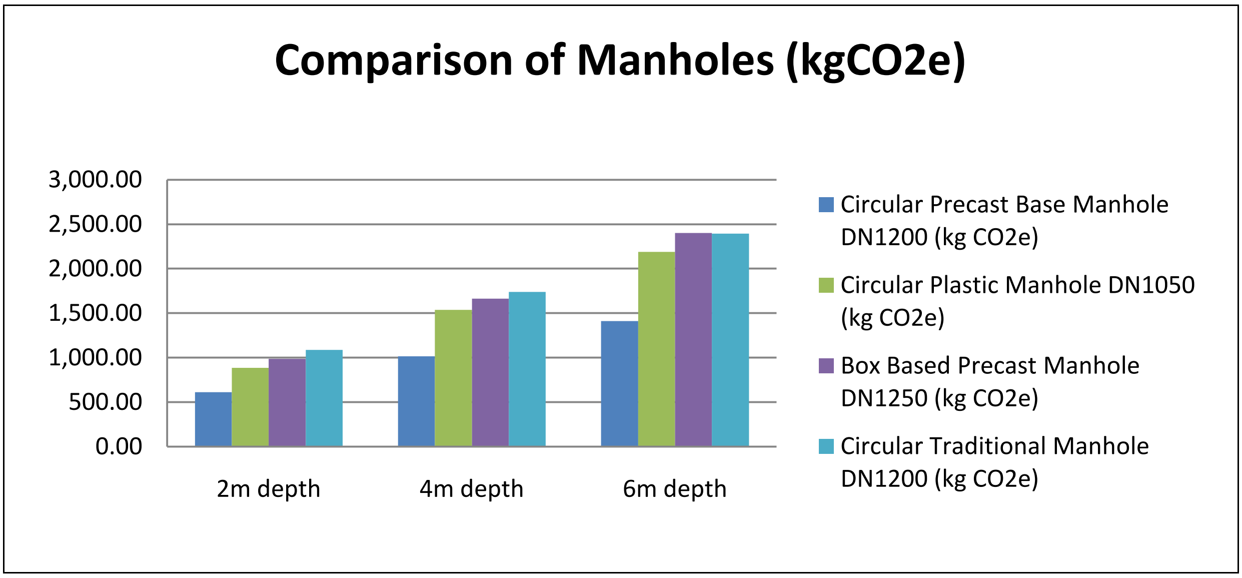
Data about **plastic manholes were** supplied by CPSA and the emissions calculations were made by Carbon Clear.

[2] CPSA Manhole Comparison excel spreadsheet

3 RESULTS AND KEY FINDINGS

The following table and chart illustrate the carbon footprint of all four manhole systems:

Manhole Size	Circular Precast Base Manhole DN1200 (kg CO2e)	Circular Plastic Manhole DN1050 (kg CO2e)	Box Based Precast Manhole DN1250 (kg CO2e)	Circular Traditional Manhole DN1200 (kg CO2e)
2m depth	612.76	885.46	984.94	1,086.20
4m depth	1,013.65	1,536.59	1,662.01	1,739.80
6m depth	1,412.62	2,187.83	2,400.58	2,393.25



4 ANALYSIS

The emissions arising from several processes are taken into consideration:

1. Raw materials and product fabrication
2. Transportation of products to the construction site
3. Installation (only relevant for traditional and plastic Manhole Systems)

Each of these processes will be compared and discussed below.

4.1 RAW MATERIALS:

CPSA members employ two types of cement in the four factories included in this study: CEM I, and CEM II. CEM I consists only of traditional Portland cement and has an emissions factor of 924.5 kg CO_2e per tonne of product, whereas CEM II is a mixture of Portland cement and ash. As a result of the inclusion of ash in the mixture, CEM II has a lower emissions factor of 654.65 kg CO2e/tonne product[3]. Overall, this accounts for a 30% difference in emissions factors, where CEM II is less carbon intensive. CPSA also uses coarse aggregates, crushed concrete, fine aggregates, steel reinforcement, admixtures and water as raw materials. All of these factors, including the embodied emissions arising from excavation and manufacture are taken into consideration in the overall emissions calculations. Emissions arising from transportation of the raw materials to the factories are also included in the calculations.

The information in the Kijlstra Carbon Footprint report describes the raw materials in Kijlstra's products (box based) as cement (Appendix, section 2), aggregates (Appendix, section 4), admixtures (Appendix, section 8), and additional raw materials (Appendix, section 7). Additionally, steel reinforcement and pipe seals are taken into consideration.

The information provided by CPSA defines the raw materials used in plastic manhole as GEN3 ready mix concrete, Polypropylene and Polypropylene Injection Moulding.

Note: Calculation of the carbon footprint of wet concrete used in traditional manhole systems is based on an emission factor established by The Bath University, (Inventory of Carbon & Energy, 2008) – 109 kg CO_2 per tonne.

4.2 PRODUCT FABRICATION:

Circular precast base:

For this type of manhole, CPSA members produce several components of the manhole system at the factory, and then transport them to the installation site. Afterwards, these components are assembled and installed on site. The units created at the factory include manhole rings, cover slabs, and pre-cast bases. Emissions stemming from each of these products are included in the calculations. This includes the electricity and gas emissions from the factories, as well as any internal transportation of the products of materials.

Circular traditional:

Component parts are created at the factories and transported to the site of installation. However; the manhole base and surround are constructed at the site of installation. This process typically requires two days to let the concrete develop

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[3] The ash is a by-product of another process, and emissions associated with its production are attributed in part to that other process.

sufficient strength. The rest of the components that are brought from the factory are then assembled and installed on-site. Emissions resulting from the creation of manhole rings and cover slabs are included in the product creation part of the calculation. The creation of the base and surround are included in the installation phase. These include the electricity and gas emissions from the factories, as well as any internal transportation of the products of materials.

Precast box based:

The manufacturing impact and carbon footprint information relating to box based manhole products was provided to Carbon Clear by CPSA from a publicly available carbon footprint report commissioned by Kijlstra Ltd. Details of the information provided to Carbon Clear by CPSA are included within the appendix of this document.

Circular plastic:

In this manhole system, the plastic shaft is produced at the factory and transported to the site of installation. The concrete base and surround are formed from wet concrete placed at the site of installation. Emissions resulting from the creation of plastic manhole rings and cover slabs are included in the product creation part of the calculation. The creation of the base and surround are included in the installation phase.

In order to come up with a realistic carbon footprint estimate for plastic manhole systems currently used in the UK it will be assumed that 65% of resin used in these plastic manholes is originally produced abroad. The following breakdown for resin is assumed based on the report "PolyOlefins Planning Service: Executive Report, Global Commercial Analysis"[4]:

- 35% of HDPE, PVC, and PP basic resins are assumed to be originally sourced from a UK cracker.
- 16% of HDPE, PVC, and PP basic resins are assumed to be originally sourced from a West European cracker. It is assumed that the resin is imported from a plant in Rosignano, Italy and shipped from La Spezia port to a UK port (say Southampton) and then taken to the Midlands to Leicester.
- 24.5% of HDPE, PVC, and PP basic resins are assumed to be originally sourced from a Middle Eastern cracker. It is assumed that the resin is imported from the Persian Gulf to a UK port (say Dover) and then taken to the Midlands to Leicester.
- 24.5% of HDPE, PVC, and PP basic resins are assumed to be originally sourced from South Asia. IT is assumed that the resin is imported from the main Indian Oil Corp cracker in Haryana 100 km north of Delhi and then imported via the main Visakhapatnam port terminal to be shipped to Dover and then transported by road to Leicester.

[4] http://www.chemsystems.com/about/cs/news/items/POPS09_Executive%20Report.cfm

4.3 Transportation of Products to Site of Installation:

Circular precast base: Calculations include the transportation of individual product components to site in round-trips, where the return trip to the factory is empty. An average distance of 113.5 km was used to calculate the emissions from the transportation of the component products (rings, cover slabs, and pre-cast base)

Circular traditional: Calculations include the transportation of individual product components to site in round-trips, where the return trip to the factory is empty. An average distance of 113.5 km was used to calculate the emissions from the transportation of the component products (rings and cover slabs). In addition, the transportation of the readymix concrete needed to construct the base and surround on site is also included in the calculations (8.3 km).

Precast box based: According to CPSA, box based manholes produced in the Netherlands are transported by land to a sea port. From here they are shipped in a 2,500 tonne carrying vessel. Finally, they are transported by land from the port to the site of installation. Details on the transportation process are given in the Appendix, section 12.

Circular plastic: Calculations include the transportation of individual product components to site in round-trips, where the return trip to the factory is empty. An average distance of 113.5 km was used to calculate the emissions from the transportation of the component products (plastic rings and cover slabs). In addition, the transportation of the wet concrete needed to construct the base and surround on-site are also included in the calculations (8.3 km).

Emissions from transportation of units:

Depth	Pre-cast t CO2e	Box based t CO2e	Traditional t CO2e	Plastic t CO2e
2m	33.97	182.94	22.44	6.11
4m	56.74	317.01	40.25	8.81
6m	77.73	458.98	58.05	11.51

4.4 Installation – Materials Only for Traditional and Plastic:

Emissions arising from installation are only relevant for the traditional manhole and plastic manhole in this report. We are accounting for the wet concrete that is placed at the construction site around the manhole components (surround) as well as for the manhole base. Emissions from machinery used for installation are excluded from the calculations.

5 CONCLUSIONS

The conclusions drawn about the comparative carbon footprints of four types of manholes specification are described below:

In 2, 4 and 6 meter depth variations of the DN 1200 specification, the circular precast base manhole system results in the lowest greenhouse gas emissions. Imported box based manholes result in the highest greenhouse gas emissions at the 4 and 6 metre depth, whereas circular traditional manholes result in marginally higher greenhouse gases than box based manholes at the 2 metre depth. DN1050 plastic manholes in 2, 4 and 6 meter depth variations result in higher greenhouse gases than DN1200 precast base manholes but lower greenhouse gas emissions than DN1200 traditional and LN1250 box based manholes.

Some of the major assumptions used in this project are listed below.

Traditional Manholes:

- When installing the manhole, the surrounding and base concrete is placed around and at the bottom of the manhole
- The amount of concrete used in the base changes based on the depth of the manhole installation
- The distances travelled by trucks carrying readymix concrete are less than the distances travelled by lorries carrying precast manhole bases to the site
- Emissions from granular bedding use remains constant between traditional, box based and circular precast base manhole installations, as they use the same amount and the materials are transported the same assumed distances.

The readymix concrete used by CPSA in their calculations for traditional manholes is based on a blended cement or mixer blend. This has lower embedded carbon emissions than standard CEM I cement to EN 197-1. and for the purpose of this report the standard carbon footprint for readymix GEN 3 concrete is based on data from Bath University Inventory of Carbon and Energy (109 kg CO_2e per tonne).

Circular precast base manholes:

- No surrounding concrete is poured around the manhole on the site of installation
- The manhole base stays the same regardless of the depth of the manhole installation. The amount of concrete used does not vary depending on the depth.
- Lorries carrying precast manhole bases to the site of installation travel from the factories to the site of installation. This is a longer distance than the lorries carrying readymix concrete.
- Emissions from granular bedding use remains constant between traditional, box based and pre-cast manhole installations, as they use the same amount and the materials are transported the same assumed distances.

Box based manholes:

No energy for curing is consumed at the site. The only activities carried out are mixing, casting, handling, storing, testing (for a few samples), and loading.

Plastic manholes:

- When installing the manhole, the surrounding and base concrete is placed around and at the bottom of the manhole
- The amount of concrete used for the base and surround changes based on the depth of the manhole installation
- The distances travelled by trucks carrying ready mixed concrete are less than the distances travelled by lorries carrying plastic rings and cover slabs to the site

The readymix concrete used by CPSA in their calculations for plastic manholes is based on a blended cement or mixer blend. This has lower embedded carbon emissions than standard CEM I cement to EN 197-1. and for the purpose of this report the standard carbon footprint for ready mix GEN 3 concrete is based on data from Bath University Inventory of Carbon and Energy (109 kg CO_2e per tonne).

APPENDIX

[CPSA's estimate for a manhole system manufactured in Europe and imported to the UK by European manufacturer (based on manholes produced by a Dutch manufacturer Kijlstra)]

1. Comparison of DN1200 UK Traditional, DN1200 Precast Base Manhole System and equivalent Imported box-based Manhole Systems

This part of the project should compare UK's traditional concrete manhole and the new precast base systems with any manhole systems imported from abroad. The main sources of manholes imported to the UK are Ireland and mainland Europe. As the vast majority of Irish manhole systems are familiar to the user in the UK it was felt that a direct comparison between Irish and British produced manhole system will not yield new results unknown to the market. It was felt that comparison with a different manhole system such as manhole boxes produced in the
Netherlands and imported may be of greater benefit. Such comparison can answer a few questions and may also test some statements made recently one competitor.

We would therefore like you to compare UK traditional manhole systems with UK manufacturers' newly introduced precast base systems and with a typical manhole box system imported from Europe.

Very little information is available on the carbon footprint of box-based manholes imported to the UK. The only source of information is a publically available report prepared by Kijlstra. This report will be used for the comparison. 1250x1250mm will be the chosen size in accordance with functional equivalence requirements as explained in the main comparison report.

2. Assembling the Functional Unit

Three functional units will be assessed: These are 2, 4, and 6 metre deep 1250x1250mm box-based manholes. Each unit will consist of a base with benching, raiser manhole units (one or more), and a top slab with a 650mm opening.

Manhole Unit	Components	Weight of components (Tonnes)	Total Weight (tonnes)
2m	Base Unit	1.675	5.743
	Raiser manhole	3.236 (1300mm high)	
	Slab	0.832	
4m	Base Unit	2.037 (1000mm high)	9.951
	Raiser manholes	3.541 + 3.541 (1450mm high)	
	Slab	0.832	
6m	Base Unit	2.037 (1000mm high)	14.41
	Raiser manholes	3.847 + 3.847 + 3.847 (1600mm high)	
	Slab	0.832	

3. Sourcing carbon footprint data

Kijlstra's report can be found at the company's UK website (http://www.kijlstra.co.uk/). Values for 1250x1250mm box-based manholes can be taken from that report. However, it was found that the transport criteria might need some amendments in order to use a transport distance to site identical to that of UK manholes (for comparison purposes). Carbon footprint information was used without that study specific transport emissions:

	1250x1250mm, 2 metres deep	1250x1250mm, 4 metres deep	1250x1250mm, 6 metres deep
Total cradle-to-site carbon footprint	948 kg CO_2e	1,590 kg CO_2e	2,295 kg CO_2e
Transport to site emissions	146 kg CO_2e (15.4%)	245 kg CO_2e (15.4%)	353.4 kg CO_2e (15.4%)
Cradle-to-gate emissions	802 kg CO_2e	1,345 kg CO_2e	1,941.6 kg CO_2e

4. Transport Criteria

According to the report published by Kijlstra, 1250x1250mm manholes are produced at Kijlstra's factory at Drachten, north of Amsterdam in the Netherlands. It is believed that three product transport stages are needed to transport a finalized product to a construction site in the UK:

The product is transported from Drachten site to the main port in the Netherlands (Rotterdam's) for shipping to the UK. The overall distance is 212 km. The products are then assumed to be taken to the Port of Felixstowe (which is a 228 km away only), which is one of the largest ports in the UK) and then transported for an average distance of 100 km to a typical UK construction site.

4.1 Land transport to Rotterdam Port:

A maximum load for the truck is assumed to be 20 tonnes (due to shape of units).

For 2m deep unit: 212 x (1.1354 + 0.6858) x 5.743 / 20 = **110.87 kg CO_2e per unit**
For 4m deep unit: 212 x (1.1354 + 0.6858) x 9.952 / 20 = **192.12 kg CO_2e per unit**
For 6 m deep unit: 212 x (1.1354 + 0.6858) x 14.41 / 20 = **278.15 kg CO_2e per unit**

4.2 Sea transport via 2,500 tonnes container vessel

For 2m deep unit 228 x 0.0151 x 5.743 = **19.77 kg CO_2e per unit**
For 4m deep unit 228 x 0.0151 x 9.952 = **34.27 kg CO_2e per unit**
For 6m deep unit 228 x 0.0151 x 14.41 = **49.61 kg CO_2e per unit**

4.3 UK Land Transport to Construction site (100 km distance assumed)

For 2m deep unit 100 x (1.1354 + 0.6858) x 5.743 / 20 = **52.3 kg CO_2e per unit**
For 4m deep unit 100 x (1.1354 + 0.6858) x 9.952 / 20 = **90.62 kg CO_2e per unit**
For 6 m deep unit 100 x (1.1354 + 0.6858) x 14.41 / 20 = **131.22 kg CO_2e per unit**

5. Cradle-to-Site Carbon Footprint

Manhole System	Carbon Footprint (kg CO_2e per unit)
2m deep	985
4m deep	1,662
6m deep	2,400