Comparative LCAs of QuickStream Poo Pit Maintenance Shaft and Concrete Manhole

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CleanMetrics Corp.

4804 NW Bethany Blvd.

Suite I-2, #108

Portland, OR 97229

USA

www.cleanmetrics.com

Contents

Executive Summary 3
1. Introduction 5
2. Standards and Methods 5
3. Goal and Scope Definition 5
4. System Description and Activity Data 6
5. Life-cycle Data and Methodology 7
  5.1 Life-cycle Inventory Data 7
  5.2 Methodology Considerations 7
6. Inventory Analysis and Impact Assessment 8
  6.1 Life Cycle Impact Assessment 8
  6.2 Life Cycle Comparison of the Two Products 10
7. Interpretation and Conclusion 11

Executive Summary

This report details the **cradle-to-grave life-cycle assessments (LCAs)** of the **Poo Pit sewer maintenance shafts** and an analogous product, a reinforced **concrete manhole**. The impact categories of interest are embodied carbon (climate change), embodied energy and embodied water. The LCAs are based on standards, and use the best-available secondary life-cycle inventory (LCI) data for materials, transport, energy and waste disposal. QuickStream provided the activity data which quantifies the manufacturing process and supply chain for both products.

The system boundary for the LCAs is are cradle to grave, with water infiltration and inflow in the use phase considered separately, for minimal (.008L/s), low (.08L/s) and high (.8L/s) rates. The functional unit is one maintenance shaft or manhole. The comparison between the two products is on the basis of one sewer access point used for 100 years. Table E1 below summarizes the life cycle impact assessment results for the two products. Table E2 compares them on a lifecycle basis, a 100-year basis, and lastly, on the basis that accounts for rainwater infiltration through the concrete manhole.

On the basis of providing a sewer access point for a 100-year period, for any significant degree of rainwater infiltration through the concrete manhole (i.e., 0.08 L/s/manhole or higher), the carbon footprint of a Poo Pit maintenance shaft is less than 1% of the footprint associated with concrete manholes. In other words, the Poo Pit shaft is at least 137 times more carbon efficient than concrete manholes under those conditions. These results demonstrate that the Poo Pit maintenance shaft is a climate-friendly infrastructure solution.

Table E1: Life-cycle impact assessment summary (without rainwater infiltration)

Poo Pit Maintenance Shaft	Carbon (kg CO2e)	Energy (MJ)	Water (L)
Energy use (fuel, electricity)	73.39	966.80	0
Processing	9.42	156.44	0
Inflows (materials, goods, services)	41.87	1,360.72	151.58
Transport	5.31	68.55	0
Waste disposal	0	0	0
Total	129.99	2,552.52	151.58

Concrete Manhole	Carbon (kg CO2e)	Energy (MJ)	Water (L)
Energy use (fuel, electricity)	260.99	3,463.65	0
Processing	0.33	10.36	0
Inflows (materials, goods, services)	1,232.87	8,033.69	960.04
Transport	187.95	2,443.85	0
Waste disposal	107.69	(173.45)	0
Total	1,789.83	13,778.09	960.04

Table E2: Life-cycle carbon footprint comparison of the two products (including rainwater infiltration)

Comparison Basis	Poo Pit (Kg/CO2e)	Concrete Manhole (Kg CO2e)	Poo Pit Carbon Emissions as % of Concrete Emissions	Concrete Emissions as Multiple of Poo Pit Emissions
Product lifecycle basis	130	1,790	7.26%	13.8
100-year basis	130	3,580	3.63%	27.5
100-year basis + minimal rainwater infiltration	130	5,006	2.60%	38.5
100-year basis + low rainwater infiltration	130	17,839	0.73%	137.2
100-year basis + high rainwater infiltration	130	146,170	0.09%	1124.5

1. Introduction

This report details the cradle-to-grave life-cycle assessments (LCAs), undertaken by CleanMetrics, of the Poo Pit sewer maintenance shafts and an analogous product, a reinforced concrete manhole. The impact categories of interest are embodied carbon (climate change), embodied energy and embodied water[1]. The LCAs are based on standards, and use the best-available secondary life-cycle inventory (LCI) data for materials, energy and waste disposal. QuickStream provided the activity data which quantifies the manufacturing process and supply chain for both products.

2. Standards and Methods

The LCAs are guided by the following international standards: ISO 14040/14044; PAS 2050; and GHG Protocol Product Standard. CarbonScope is used to conduct the LCAs for the purpose of quantifying and comparing the carbon, energy and water footprints for the two products. The analysis leverages the CarbonScopeData life-cycle inventory (LCI) database.

3. Goal and Scope Definition

This study considers two interchangeable products – the Poo Pit sewer maintenance shaft (Figure 1) and the reinforced concrete manhole (Figure 2) – both which are used to provide sewer access points.

The **product system** in each case consists of the manufacture of one maintenance shaft or manhole, and the supply chains used to source the necessary components and other materials that are consumed in the manufacture. This includes the transportation to the install site and a disposal site at the end of life. The system includes all raw material and component production, energy production, water production, solid waste disposal, wastewater treatment, production and assembly of finished products, incoming transportation and transportation to the installation site. This analysis includes end-of-life disposal but ignores installation energy.

The **system boundary** is cradle-to-grave, starting from the extraction of raw materials and ending with the disposal of the maintenance shaft or the manhole after its useful life. The use phase, consisting of water infiltration and inflow, is included in this study. Product maintenance during the use phase is not included.

The **functional unit** for the LCAs is one maintenance shaft or manhole. The comparison between the two products is on the basis of one sewer access point used for 100 years.

The three life-cycle impact categories or footprints of interest in this LCA study are:

- **Embodied carbon** = carbon dioxide equivalent (CO2e) emissions reflecting the major greenhouse gas emissions (generally carbon dioxide, methane and nitrous oxide) and quantifying the climate change impact, in units of Kg of CO2e
- **Embodied energy** = primary energy combusted + feedstock energy, in units of MJ
- **Embodied water** = water consumption, in units of Liters

[1] The terms "embodied carbon" and "carbon footprint" are synonymous and refer to the climate change impact. Similarly, the terms "embodied water" and "water footprint" are synonymous.

4. System Description and Activity Data

Figures 1 and 2 illustrate the two product systems, including the system boundaries and an inventory of inputs and outputs. The activity data provided by QuickStream (with gaps filled in by CleanMetrics) for both products includes:

- Components and materials used in the production, including materials consumed.
- Transport of components and materials to the final assembly location.
- Energy and water used in the final assembly and packaging.
- Any waste generated in the manufacturing and final assembly.
- Waste generated at the end of life.
- Water infiltration rates for the concrete manhole in the use phase.

The Poo Pit maintenance shaft has a useful lifetime of about 100 years, while the concrete manhole lasts about 50 years.

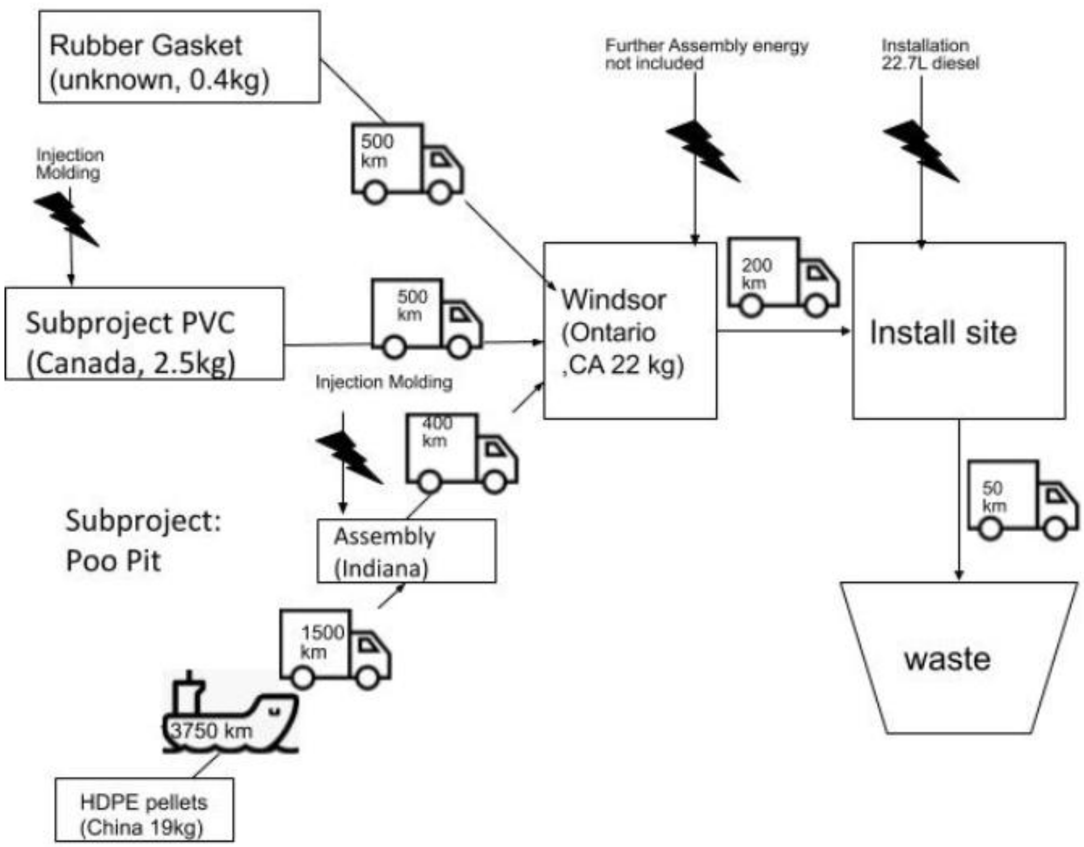

Figure 1 Life cycle inventory and system boundary for a Poo Pit maintenance shaft

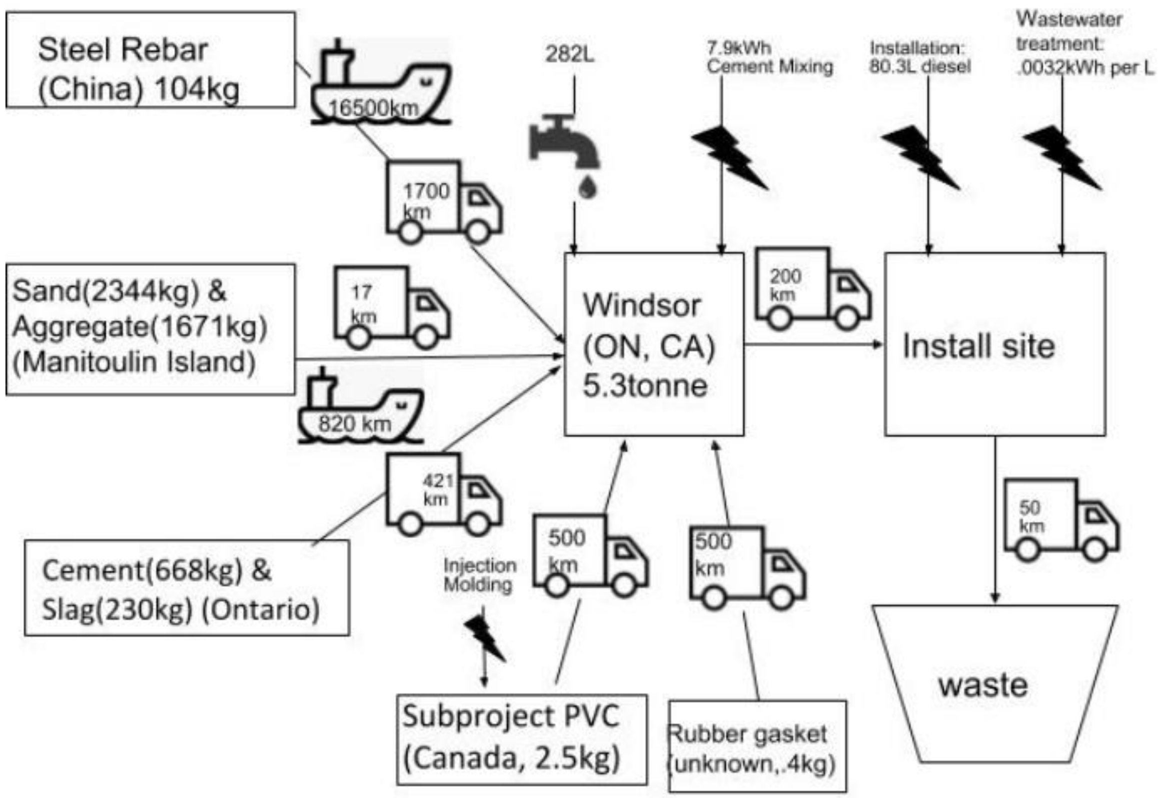

Figure 2 Life cycle inventory and system boundary for a concrete manhole

5. Life-cycle Data and Methodology

5.1 Life-cycle Inventory Data

The analysis leverages the CleanMetrics CarbonScopeData life-cycle inventory (LCI) database. CarbonScopeData is one of the largest and most comprehensive LCI databases in North America. LCAs generally necessitate the use of secondary data from an LCI database since material/component suppliers do not usually provide any specific data regarding their internal manufacturing processes. Secondary data for a specific material or manufacturing process generally represents a typical process, a similar process or an average of similar processes. Sometimes multiple data points for specific materials exist, and we have used our best judgment to choose the most suitable data points.

5.2 Methodology Considerations

We list here several important methodology considerations that we apply to LCA studies in general:

1. Use of placeholders/substitutions for missing data, and the use of sensitivity analysis to verify that the placeholders do not materially change the final results.
2. Use of hybrid modeling (process LCI combined with selective use of EEIO LCI) when data is missing or is of low quality in the process LCI database.

3. Avoidance of cutoffs (i.e., completely omitting some inputs due to lack of data - this is a last resort for many LCAs) by using placeholders and hybrid modeling.
4. Recycling of waste as an output as well as use of recycled materials as inputs are both handled using the "recycled content" method.
5. Allocation of environmental burdens to co-products will be based on the economic values of the co-products. Mass-based allocation is generally avoided.
6. Production of capital goods is excluded from the product life-cycle impacts.
7. Time-based modeling of carbon storage and carbon releases follows the PAS 2050 standard.

The following placeholders and modeling decisions apply specifically to the product systems in this study:

1. Both products are assumed to have final assembly occur in Windsor, Ontario.
2. The exact location for sourcing the PVC fittings and rubber gaskets are unknown, thus placeholders of 500 km are used.
3. While processing energy has been assigned to the injection molding for all plastic components used in both products and the cement mixing for the concrete manhole, other processing has been ignored: curing of the concrete, assembly of the parts.
4. Installation energy is estimated by QuickStream in terms of diesel used for the excavators as well as dump trucks to haul debris from and backfill to the install site, assuming half hour trips are required. More remote install sites will have different energy usage.
5. A representative (200 km) journey to an installation is assumed so that we can explore the ramifications of expanding this journey.
6. End-of life-disposal is assumed to occur a short (50 km) distance from the installation site for both products.

6. Inventory Analysis and Impact Assessment

The inventory analysis step constructs a model of the entire cradle to grave system, combining processes such as the manufacture of the components and materials used for production, transportation, energy use, and waste disposal. This step generally combines the LCI data for all the individual processes and generates an aggregated table of emissions and resource uses (collectively known as environmental flows) for the full product system. The impact assessment step converts these environmental flows into contributions to the relevant impact categories. This conversion, known as characterization, generates the final life-cycle impact figures for the categories of interest. The LCI database used in this study merges these two steps and provides data for the impact categories directly.

6.1 Life Cycle Impact Assessment

For the purposes of this study, the impact categories of interest are embodied carbon, embodied energy and embodied water as defined in Section 2. Tables 1 and 2 list the detailed impact assessment results (itemized by individual processes) for the two products. All of the significant materials and all of the energy sources have been mapped to the best available secondary data from the LCI database and other sources as listed in the table. Additional details are available in the spreadsheets delivered along with this report.

Table 1 Life-cycle impact assessment results for a Poo Pit maintenance shaft

Model Name	Process Type	Process	Quant	Unit	Carbon	Energy	Water
Poo-Pit-ChinaIndiana:HubProcessing	Material/Process	Processed material or product	19.05	kg	0	0	0
PVC-fittings:HubProcessing	Material/Process	Processed material or product	2.5	kg	0	0	0
Poo-Pit-ChinaIndiana:PooPit-body-spigot	Material/Process (cradle-to-gate)	High Density Polyethylene (HDPE), granulate, at plant,	19.05	kg	34.10	1,178.38	35.07
PVC-fittings:MaterialIn	Material/Process (cradle-to-gate)	Polyvinyl Chloride, from emulsion process (E-PVC), at	2.5	kg	6.34	136.58	116.51
Poo-Pit-ChinaIndiana:HubProcessing	Material/Process (unit process)	Plastic injection moulding	1		9.09	146.09	0
PVC-fittings:HubProcessing	Material/Process (unit process)	Plastic injection moulding	1		0.33	10.36	0
Poo-Pit-ChinaIndiana:PooPit-body-spigot	Transport	Ocean, large bulk carrier	13750	km	2.15	27.14	0
Poo-Pit-ChinaIndiana:Indiana-to-Windsor	Transport	Semi-trailer truck	400	km	0.57	7.53	0
Poo-Pit-ChinaIndiana:PooPit-body-spigot	Transport	Semi-trailer truck	1500	km	2.15	28.23	0
ProductUse	Energy-UsePhase	Diesel	22.7	L	73.39	966.80	0
gasket-placeholder	Material/Process (cradle-to-gate)	Rubber, general	0.45	kg	1.43	45.77	0
EndOfLifeDisposal	Solid Waste	Plastics (Landfill, Anerobic)	22	kg	0	0	0
EndOfLifeDisposal	Transport	Semi-trailer truck	50	km	0.08	1.09	0
Transport-to-Installation	Transport	Semi-trailer truck	200	km	0.33	4.35	0
gasket-placeholder	Transport	Semi-trailer truck	500	km	0.02	0.22	0
			total		**129.99**	**2,552.52**	**151.58**

Table 2 Life-cycle impact assessment results for a concrete manhole

Model Name	Process Type	Process	Quanti	Ui	Carbon	Energy	Water
PVC-	Material/Process	Processed material or product	2.5	kg	0	0	0
PVC-fittings:MaterialIn	Material/Process (cradle-to-gate)	Polyvinyl Chloride, from emulsion process (E-PVC), at plant, Europe	2.5	kg	6.34	136.58	116.51
PVC-	Material/Process (unit process)	Plastic injection moulding	1		0.33	10.36	0
Hub	Energy	Electricity (grid mix) - grid: Canada	7.9	KWh	1.39	43.64	0
install-and-	Energy-UsePhase	Diesel	80.3	L	259.60	3,420.01	0
Stone-and-Sand	Material/Process (cradle-to-gate)	Aggregate, general	1671	kg	8.36	167.10	0
Cement-and-slag	Material/Process (cradle-to-gate)	Portland cement, at plant	668	kg	910.35	3,363.17	561.53
rubbergasket	Material/Process (cradle-to-gate)	Rubber, general	0.4	kg	1.27	40.68	0
Stone-and-Sand	Material/Process (cradle-to-gate)	Sand, general	2344	kg	11.72	234.40	0
Cement-and-slag	Material/Process (cradle-to-gate)	Slag (GGBS)	230	kg	16.10	305.90	0
Rebar	Material/Process (cradle-to-gate)	Steel, bar and rod, virgin	104	kg	278.72	3,785.60	0
water	Material/Process (cradle-to-gate)	Water, agricultural, USA	282	kg	0.02	0.26	282.00
EndOfLifeDisposal	Solid Waste	Other (Landfill, Anerobic)	5301.9	kg	107.69	(173.45)	0
Rebar	Transport	Ocean, large bulk carrier	16500	km	14.05	177.79	0
Stone-and-Sand	Transport	Ocean, large bulk carrier	820	km	26.96	341.10	0
EndOfLifeDisposal	Transport	Semi-trailer truck	50	km	19.99	261.85	0
Transport-to-	Transport	Semi-trailer truck	200	km	79.95	1,047.41	0
Rebar	Transport	Semi-trailer truck	1700	km	13.33	174.64	0
Stone-and-Sand	Transport	Semi-trailer truck	17	km	5.15	67.42	0
Cement-and-slag	Transport	Semi-trailer truck	421	km	28.50	373.43	0
rubbergasket	Transport	Semi-trailer truck	500	km	0.02	0.20	0
			Total		**1,789.83**	**13,778.09**	**960.04**

Table 3 summarizes life-cycle impact assessment results for the two products and shows the contributions of each process category to each of the three impact categories.

Table 3 Life-cycle impact assessment summary for both products (without rainwater infiltration)

Poo Pit Maintenance Shaft	Carbon (kg CO2e)	Energy (MJ)	Water (L)
Energy use (fuel, electricity)	73.39	966.80	0
Processing	9.42	156.44	0
Inflows (materials, goods, services)	41.87	1,360.72	151.58
Transport	5.31	68.55	0
Waste disposal	0	0	0
Total	129.99	2,552.52	151.58
Concrete Manhole	**Carbon (kg CO2e)**	**Energy (MJ)**	**Water (L)**
Energy use (fuel, electricity)	260.99	3,463.65	0
Processing	0.33	10.36	0
Inflows (materials, goods, services)	1,232.87	8,033.69	960.04
Transport	187.95	2,443.85	0
Waste disposal	107.69	(173.45)	0
Total	1,789.83	13,778.09	960.04

Rainwater infiltration will occur with concrete manholes but not with the Poo Pit maintenance shaft. The exact amount of infiltration is dependent on many factors, and QuickStream has referenced studies that suggest it may be as high as 0.8L/s. To be conservative, we consider a range of infiltration rates including lower rates (0.08L/s and .008L/s) since some areas will have lower precipitation than others. CarbonScope's reference for the energy required in treating 1 liter of wastewater is 0.0032 kWh, leading to the development of Table 4.

Table 4: Energy required for wastewater treatment and resultant emissions for different infiltration rates

Rainwater infiltration rate (L/sec)		Rainwater infiltration rate (L/day)	Wastewater treatment energy (kWh/day)	GHG emissions (Kg CO2e/day) from wastewater treatment	Additional GHG emissions (Kg CO2e) over 100 yrs
minimal	0.008	691	0.22118	0.0390390	1,426
low	0.08	6912	2.21184	0.39038976	14,259
high	0.8	69120	22.12	3.9038976	142,590

6.2 Life Cycle Comparison of the Two Products

As shown in Table 5, the Poo Pit shaft generates about 7% of the lifecycle carbon emissions that a comparable concrete manhole generates. If compared on the basis of providing a sewer access point for a 100-year period, two units of the concrete manhole will be required (since each unit has a useful lifetime of 50 years) while just one unit of the Poo Pit will be sufficient. On a 100-year basis, the Poo Pit shaft generates less than 4% of the carbon emissions that the concrete manhole would generate. Accounting for the rainwater infiltration that occurs with concrete manholes but not Poo Pits further increases the vast emissions gap between these two products.

Table 5 Life-cycle carbon footprint comparison of the two products

Comparison Basis	Poo Pit (Kg/CO2e)	Concrete Manhole (Kg CO2e)	Poo Pit Carbon Emissions as % of Concrete Emissions	Concrete Emissions as Multiple of Poo Pit Emissions
Product lifecycle basis	130	1,790	7.26%	13.8
100-year basis	130	3,580	3.63%	27.5
100-year basis + minimal rainwater infiltration	130	5,006	2.60%	38.5
100-year basis + low rainwater infiltration	130	17,839	0.73%	137.2
100-year basis + high rainwater infiltration	130	146,170	0.09%	1124.5

7. Interpretation and Conclusion

The key takeaways and recommendations from the life-cycle impact assessment results follow:

- Poo Pit maintenance shafts have much lower production and transport impacts than their concrete counterparts due to the major differences in weight and the carbon/energy-intensive materials (primarily cement and steel) used in the concrete manholes. The Poo Pit shafts do not suffer from water infiltration and exhibit a large advantage over concrete manholes in the use phase as well.

- The primary carbon impact from the Poo Pit shaft is due to the installation process and the HDPE body, with minimal contributions from the other components and transport. Thus, the uncertainty associated with any other assumptions made is negligible and the results can be considered to be of high certainty.

- **On the basis of providing a sewer access point for a 100-year period, for any significant degree of rainwater infiltration through the concrete manhole (i.e., 0.08 L/s/manhole or higher), the carbon footprint of a Poo Pit maintenance shaft is less than 1% of the footprint associated with concrete manholes. In other words, the Poo Pit shaft is at least 137 times more carbon efficient than concrete manholes under those conditions. These results demonstrate that the Poo Pit maintenance shaft is a climate-friendly infrastructure solution.**

- Given the large disparity in life-cycle carbon emissions between Poo Pit maintenance shafts and their concrete counterparts, the focus of QuickStream should not be on improving their sourcing process to make it more carbon and energy efficient but on expanding their business as quickly as possible to win bids for providing Poo Pit shafts in lieu of their much more environmentally detrimental concrete counterparts.

- As climate change increasingly becomes the deciding factor in many government decisions, particularly around critical infrastructure development and maintenance, this study shows that assessing the climate impacts of alternate components and materials could become an important part of lowering the carbon footprint of the built environment. Products such as the Poo Pit can play a significant role in this process.