Life Cycle Assessment of North American Stormwater Pipe Systems

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Foreword

This technical report was developed and published with the technical help and financial support of the members of the Plastics Pipe Institute (PPI). These members have shown their commitment to developing and improving quality products by assisting standards development organizations in the development of standards, and also by developing design aids and reports to help engineers, code officials, specifying groups, contractors and users.

The purpose of this technical report is to summarize the Life Cycle Assessment (LCA) completed for the Drainage Division by Franklin Associates in 2020. The completed LCA is over 140 pages in length and can be requested in its entirety from PPI. The LCA reviews the impact to the environment of corrugated HDPE pipe made with virgin and recycled materials, reinforced concrete pipe, PVC pipe and aluminized steel pipe over a 100-year service life period. The results demonstrate that corrugated HDPE pipe is the most environmentally sustainable choice for storm drainage pipe material.

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1.0   INTRODUCTION

Plastics Pipe Institute funded a research project titled, "Life Cycle Assessment of North American Municipal Stormwater Pipe Systems," which was performed by Franklin Associates, a division of ERG completed April 2020. The purpose of this technical note is to summarize the scope and methodology of the research program and highlight the results, which are the environmental impacts of high-density polyethylene (HDPE) and alternative stormwater pipe systems.

This information will assist PPI members in communicating the environmental impacts of HDPE pipe systems. It will also provide specifiers, owners, and others with useful information when selecting which technology to employ for stormwater pipe systems.

2.0   LCA METHODOLOGY

Life-cycle assessment (LCA) is an internationally accepted method used to quantify the environmental impact of a product or process over its entire life cycle. LCA can be performed on a simple product (like a pencil), a complex product (like a building), or a process (such as the process for manufacturing a car). Two international standards govern the LCA methods: ISO 14040, *Environmental management—Life cycle assessment—Principles and framework*, and ISO 14044, *Environmental management—Life cycle assessment—Requirements and guidelines*. These standards set minimum requirements for performing an LCA in four main areas:

- Goal and scope definition
- Life-cycle inventory (LCI) analysis
- Life-cycle impact assessment
- Life-cycle interpretation

2.1. Goal and scope definition

During this phase of the LCA, a number of important decisions are made related to the goal and scope of the project. In defining the goal of the study, the following items are established related to the research:

- o the intended application and audience,
- o the reasons for conducting it, and
- o whether the results will be used for comparative assertions.

The goal of the PPI study is to develop baseline data for North American corrugated HDPE pipe used as municipal stormwater drainage pipe. The HDPE pipe systems are compared to alternative material piping systems used for the same applications. The intended use of this study is to inform PPI and its member companies about the environmental profiles of HDPE and alternative stormwater pipe systems.

In the full LCA report, the results are presented by life-cycle stage (for example, pipe production, installation, use, end of life management). However, in this technical note, the results are presented in aggregated form for the full life cycle. The LCA has been conducted following internationally accepted (ISO) standards for LCI methodology. Since PPI is using this report as the basis for public comparative assertions about HDPE pipe systems and alternative pipe systems, a panel peer review of the study is required for conformance with ISO LCA standards.

The scope phase of the LCA establishes such things as the product system studied, the function of the product systems, the functional unit, the system boundary, the allocation procedures, and any assumptions, among other ISO-14044 requirements. For the current LCA, a functional unit of 1000 ft of 24-in.-diameter piping is used with an assumed 100 year length of service.

The following functionally equivalent pipe systems were chosen to be studied in the LCA. Each system is made of a different material, but overall measurements and expected performance are unchanged.

o 24-in. corrugated high-density polyethylene (HDPE) double-wall pipe made with virgin HDPE and having bell and spigot joints with gasket
o 24-in. corrugated HDPE pipe made with 50% post-consumer recycled content, and having bell and spigot joints with gasket
o 24-in. corrugated polyvinyl chloride (PVC) double-wall pipe with PVC bell and spigot joints with gasket
o 24-in. Class III reinforced concrete pipe (RCP) with concrete bell and spigot joints with gasket
o 24-in. aluminum coated type 2 spiral-wound corrugated steel pipe with gasket

Although LCA studies can be performed with a more-limited scope or time scale, the most representative accounting of a product's environmental impact includes all environmental flows over the full life of the product. Thus the full life cycle of the pipe systems—from extracting raw materials from nature, any transformation or manufacturing of these raw materials into a product, the product use, to end-of-life scenarios—was included in this study, which is also called a cradle-to-grave LCA.

Three different end-of-life scenarios were considered: leave-in-place, recycle, and landfill. Only the results of the leave-in-place scenario are presented, which assumes that once the pipes are done with 100 years of service without complications, they will be left in the ground. Results from all three end-of-life scenarios are included in the full LCA, but only the leave-in-place scenario is included in this technical note. There is considerable uncertainty with how products will be handled at the end of their service lives so far in the future. This level of uncertainty is one reason why many manufacturers have avoided full cradle-to-grave LCA studies. The leave-in-place scenario has the fewest assumptions and the least uncertainty given that future technology related to recycling or landfilling is unknown. Thus, because of the significant uncertainty related to circumstances 100 years in the future, the leave-in-place scenario is conservative when estimating the end-of-life impacts for all pipe systems.

2.1.1. Allocation procedures

When raw materials and emissions associated with the manufacturing process cannot be easily attributed to several product outputs from a system, these LCI data must be allocated to the various co-products. There are several methods available to allocate co-products, and in this LCA, mass and enthalpy allocation are used.

Co-product allocations were needed in this LCA due to the multiple useful outputs from some of the "upstream" chemical processes involved in producing the resins used to manufacture plastic pipes and fittings. In this LCA, environmental impacts were assigned to any useful process output that is produced and sold. All scrap co-product was allocated on a mass basis.

For heat or steam co-products or a co-product sold for use as a fuel, the energy amount (Btu or J) of the heat, steam, or fuel was allocated as recovered energy that reduced the net process energy assigned to the resin.

2.1.2. Assumptions

There are a number of assumptions made for any LCA study, which must be presented to put the results in the correct context. It's worth noting that, for comparative assertions, ISO 14044 requires that assumptions related to non-represented industries be conservative. Because this study is a comparative assertion and non-HDPE industries were not involved in the decision-making process for assumptions, the ISO standard requires that the non-represented industries be given the benefit of a decision.

Many of the conservative assumptions made during this study are described in the following:

- **Companies operate in compliance with emissions standards**. If actual industry emissions data are not available, published emissions standards are used as the basis for determining environmental emissions. In reality, exceptions to compliance may occur.
- **Energy and emissions for production of imported crude oil is assumed to be the same as that for U.S. crude oil**. This assumption is followed even though standards and regulations for foreign production can vary significantly from those of the United States.
- **Space-conditioning energy in manufacturing facilities is much less than process energy**. The fuels and power consumed to heat, cool, and light manufacturing establishments are omitted from the calculations. Energy consumed for space conditioning is usually less than one percent of the total energy consumption for the manufacturing process.
- Energy and waste associated with research and development, sales, and administrative personnel or related activities are also small and have been omitted from this study.
- The energy and emissions associated with production of capital equipment, facilities, and infrastructure are not included.
- Miscellaneous materials and additives (catalysts, pigments, or other additives) that total less than one percent by weight of the net process inputs are typically not included. No low-level use of resource-intensive or high-toxicity chemicals or additives was identified for any of the pipe systems; therefore, they are not expected to significantly affect the results.
- Inputs and outputs reported in the data sources used account for any input materials that are converting scrap.
- Transportation to construction site by tractor-trailer for all pipe types.
- **Pipes did not develop cracks that may cause leakage and water contamination**. This analysis did not attempt to quantify rates of cracks and leakage from the stormwater pipe systems evaluated, nor does the analysis address potential human or ecosystem health issues that could result from contamination issues associated with stormwater pipe cracks and leakage.
- **Pipes did not require replacement during the 100-year service life**. While some pipe systems have proven service lives of 100 years, other systems are known to be more susceptible to corrosion or deleterious contaminants.
- The need for high-quality backfill soil was identical for HDPE, PVC, and steel pipe systems, and reinforced concrete pipe used more native soil. This is a conservative assumption, especially for installations beneath pavement or inside the public right-of-way.

2.1.3. Comparative assertion

The LCA study was conducted "as the basis for public comparative assertions about PE pipe systems and alternative pipe systems." ISO 14044 requires an additional level of technical rigor for these types of studies, especially if representatives of the alternative-pipe-system industries are not involved in the development or review process, which was the case in this project.

2.1.4. Peer-review

The full LCA report was reviewed by an external peer-review panel "to ensure the study has been conducted in a manner consistent with ISO 14044 standards, including goal and scope, data acquisition and compilation, key assumptions, and interpretation of results." The peer-review panel adequately fulfilled its duty to perform an unbiased external peer review that was in conformance with the ISO 14044 standard. In addition, the LCA practitioner appropriately responded to the external peer-review comments.

2.2. Life-cycle inventory analysis

Environmental flows are material and energy resources that go into a product, as well as all emissions to air, water, and land that result from its manufacture and use. This phase of an LCA involves handling and tracking data related to materials, water, and energy use, as well as emissions to air, water, and land (typically in the form of waste).

The primary data for this study were provided directly from PPI members that produce virgin and recycled HDPE pipe types. Data for the other industries (PVC, concrete, and steel) were provided from sources such as the 2015 Uni-Bell PVC pipe environmental declaration (EPD), Franklin Associates' United States industry average database, the U.S. LCI Database, and the European ecoinvent database (adapted to represent U.S. conditions where appropriate).

2.3. Life-cycle impact assessment

For the life-cycle impact assessment phase of the LCA, data compiled during the LCI phase is converted into environmental impacts with the use of characterization factors. Computer models are used to assist with the data compilation and assignment of environmental impacts.

For this LCA, the characterization factors from two sources were used to convert LCI data into the following environmental impact categories:

- o Global warming potential (kg CO_2 eq.)
- o Acidification potential (kg SO_2 eq.)
- o Eutrophication potential (kg N eq.)
- o Ozone depletion potential (kg CFC-11 eq.)
- o Smog formation potential (kg O_3 eq.)

For global warming potential (GWP), LCI data are characterized using factors reported by the Intergovernmental Panel on Climate Change (IPCC) with a 100-year time horizon. For the other categories, the U.S. EPA TRACI 2.1 method was used.

Global warming potential (GWP), which is synonymous with potential to cause climate change, is the most-commonly known environmental impact category. It is expressed in terms of mass of carbon-dioxide (CO_2) equivalent, which means that all other greenhouse gas (GHG) emissions are normalized to an equivalent amount of CO_2 emissions. For example, 1 unit of mass of methane is equivalent to approximately 30 units of mass of carbon dioxide related to the effect the gas has on climate change.

Acidification potential is related to chemical compounds that are precursors to acidic rain. These compounds are most often released in fuel combustion, which can occur in manufacturing and transportation of piping. The units are in terms of sulfur dioxide (SO_2), which is the most common precursor to acid rain.

Eutrophication potential refers to the enrichment of bodies of water with minerals and nutrients. Over enrichment can result in reduced oxygen counts in the water, causing damage to the ecosystem, usually through the use of fertilizers and detergents. This is measured in unit mass of nitrogen (N), the primary nourishing compound.

Ozone depletion potential is the measure of a compound's potential to remove protective ozone from the atmosphere, measured in standard units of trichlorofluoromethane, also known as freon-11 (CFC-11).

Smog formation potential measures the amount of harmful, visible ozone that can be created throughout a manufacturing and transportation process. Ozone (O_3) is used as standard units, which can be very harmful to the human body if not in minimal exposure.

2.4. Life-cycle Interpretation

During the last phase of the LCA, results are presented and sensitivity analyses are run. The results often highlight environmental "hot spots," which are materials or processes in the life-cycle of a product that contribute more to its

environmental impact. Sensitivity analyses explain changes in data or in LCA execution caused by a fundamental difference of materials or circumstances.

2.4.1. Results

Oftentimes, data are presented in LCA reports with many decimal places, implying that all digits are significant, which is typically not the case. In fact, most data values can be truncated to two significant figures without any loss of accuracy. Although LCA is a good tool, and arguably the best tool we have, it is not perfect. LCA practitioners understand that there is inherent variability within the data.

When comparing results of different LCAs, the differences in some of the environmental impact categories might be quite small. But a small change in a small number may result in a large percentage shift. Therefore, if results are presented as a percentage, it's important to look at the absolute differences in values, and beware of the coefficient of variation within the data. The percent difference in values among data sets may be smaller than the coefficient of variation among the data, thus the difference is insignificant.

In Table 1, the full life-cycle results are presented for all stormwater pipe systems for the leave-in-place scenario at the end-of-life. Tables 2 and 3 present relative, full life-cycle results for all stormwater pipe systems for the leave-in-place scenario at the end-of-life when compared to the HDPE and HDPE with 50% recycled content pipe system, respectively. Green highlights indicate areas of significant, positive difference, while gray indicates insignificant variance and red indicates significant, negative difference. Significance levels of 10% for energy results and 25% for total solid waste and impact assessment results were used for this study. These values were chosen due to the inherent uncertainty in the data itself, as well as uncertainty imposed in the study due to assumptions made.

Data are presented for the calculated environmental impact categories as well as for selected, measured LCI data categories. The environmental impact categories are global warming potential, acidification potential, eutrophication potential, ozone depletion potential, and smog formation potential. LCI data is presented for total energy demand, total solid waste, and amount of water consumption.

The results show that the HDPE pipe systems performed as well or better than the other stormwater pipe systems in almost all categories. For LCI or environmental impact categories where other stormwater pipe systems perform better than HDPE, additional explanation is provided in the following sections.

Table 1: Results for 24-in.-diameter Stormwater Pipe for Leave in Place at End-of-Life Evaluated with Cut-off Method (results per 1000 feet of pipe for 100 years of service)

Impact category	Unit	HDPE	HDPE with 50% RC	PVC	RCP	Steel
Total Energy Demand	MJ eq.	6.71E+05	4.94E+05	7.59E+05	5.91E+05	6.54E+05
Solid Waste by Weight	kg eq.	7.19E+02	6.37E+02	1.36E+03	3.85E+03	2.65E+03
Water Consumption	L	8.39E+04	7.86E+04	1.25E+05	1.91E+05	1.42E+05
Global Warming Potential	kg CO_2 eq.	2.85E+04	2.49E+04	3.91E+04	5.23E+04	5.17E+04
Acidification Potential	kg SO_2 eq.	1.19E+02	1.12E+02	1.61E+02	2.17E+02	1.81E+02
Eutrophication Potential	kg N eq.	5.36E+00	5.25E+00	8.00E+00	8.00E+00	7.94E+00
Ozone Depletion Potential	kg CFC-11 eq.	1.40E-04	1.29E-04	1.07E-03	2.25E-04	-2.34E-05
Smog Formation Potential	kg O_3 eq.	2.96E+03	2.89E+03	3.42E+03	4.05E+03	3.91E+03

Table 2: Comparative Results with HDPE baseline for 24-in.-diameter Stormwater Pipe for Leave in Place at End-of-Life (results per 1000 feet of pipe for 100 years of service)

Impact category	HDPE	HDPE with 50% RC	PVC	RCP	Steel
Total Energy Demand		-30%	12%	-13%	-2%
Solid Waste by Weight		-12%	62%	137%	115%
Water Consumption		-7%	40%	78%	52%
Global Warming Potential		-13%	32%	59%	58%
Acidification Potential		-6%	30%	58%	41%
Eutrophication Potential		-2%	39%	40%	39%
Ozone Depletion Potential		-8%	154%	47%	-280%
Smog Formation Potential		-2%	14%	31%	28%

Table 3: Comparative Results with HDPE with 50% recycled content baseline for 24-in.-diameter Stormwater Pipe for Leave in Place at End-of-Life (results per 1000 feet of pipe for 100 years of service)

Impact category	HDPE	HDPE with 50% RC	PVC	RCP	Steel
Total Energy Demand	30%		42%	18%	28%
Solid Waste by Weight	12%		72%	143%	122%
Water Consumption	7%		46%	84%	58%
Global Warming Potential	13%		45%	71%	70%
Acidification Potential	6%		36%	64%	47%
Eutrophication Potential	2%		42%	42%	41%
Ozone Depletion Potential	8%		157%	55%	-289%
Smog Formation Potential	2%		17%	33%	30%

2.4.1.1. Global Warming Potential

In the United States, because energy is primarily generated from fossil fuel sources, and global warming potential is primarily associated with carbon dioxide emissions, there is a strong correlation between global warming potential results and non-renewable energy demand. In this study, there is a significant difference in this correlation for the HDPE pipe. This is because the non-renewable energy results for plastic pipe also include the energy content of fossil fuel resources that are used as material feedstocks and not combusted.

The total global warming potential for PVC, reinforced concrete, and corrugated steel pipe systems are greater than that of the HDPE pipe in all end-of-life scenarios. The use of recycled resin reduces results for the 50% recycled content HDPE pipe compared to virgin HDPE pipe, but the differences between the HDPE pipe systems are too small to be considered meaningful.
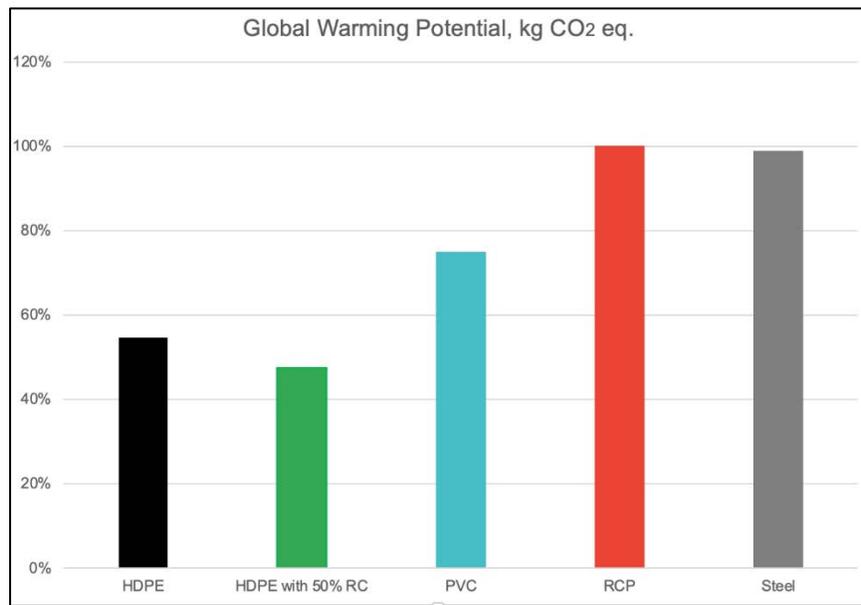
Figure 1: Comparison of relative global warming potential (GWP) for all pipe systems studied normalized to the pipe system with the greatest GWP. For this environmental impact category, the pipe system with the greatest GWP is the reinforced concrete pipe system.

2.4.1.2. Acidification Potential

Like with global warming potential, acidification potential is also closely correlated to non-renewable energy demand. So also like with global warming potential, acidification potential for PVC, reinforced concrete, and corrugated steel pipe systems are greater than that of the HDPE pipe in all end-of-life scenarios.
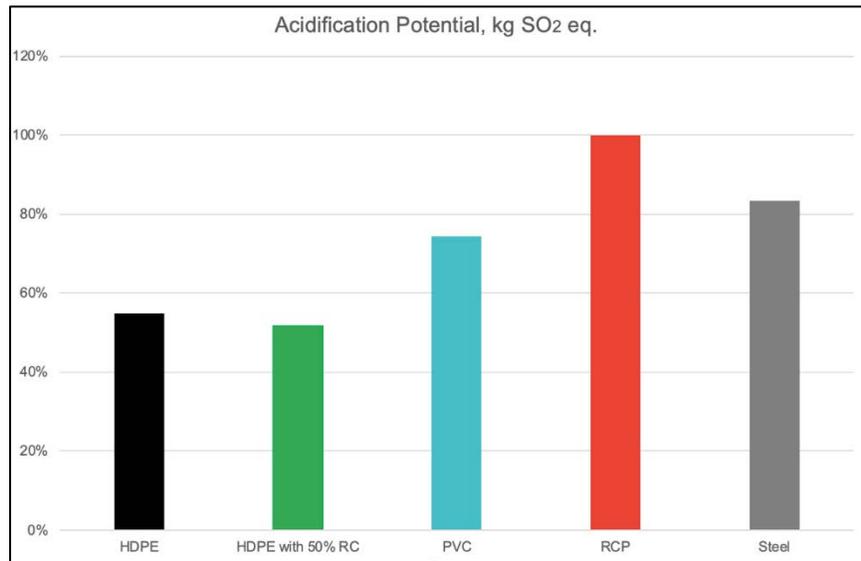
Figure 2: Comparison of relative acidification potential (AP) for all pipe systems studied normalized to the pipe system with the greatest AP. For this environmental impact category, the pipe system with the greatest AP is the reinforced concrete pipe system.

2.4.1.3. Eutrophication Potential

For all end-of-life scenarios, the eutrophication potential of HDPE pipe is less than that for PVC, reinforced concrete, and corrugated steel pipe systems. Eutrophication potential is closely tied to pipe production, installation, and cleaning during the 100 year life, and HDPE pipe systems have much lower eutrophication impacts than the other pipe types for all end-of-life scenarios.
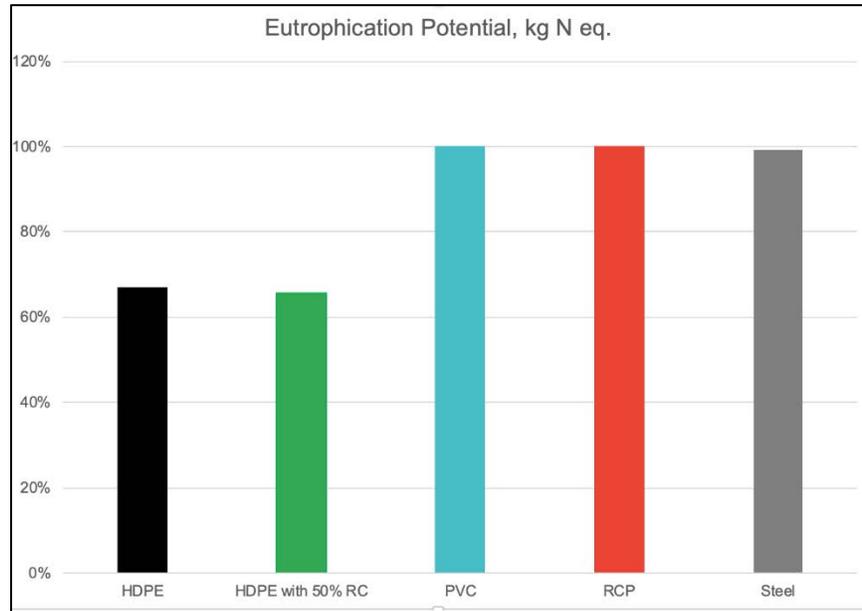
Figure 3: Comparison of relative eutrophication potential (EP) for all pipe systems studied normalized to the pipe system with the greatest EP. For this environmental impact category, the pipe systems with the greatest EP are the PVC and reinforced concrete pipe systems.

2.4.1.4. Ozone Depletion Potential

Steel pipe performed better in the ozone depletion environmental impact category when compared to both systems with HDPE pipe. For HDPE and steel pipe systems, the largest source of pollutants that contribute to ozone depletion potential come from fuel use during installation. For PVC and reinforced concrete pipe systems, pipe production is the greatest contributor to ozone depletion potential.

The primary reason for the better performance of the steel pipe system in this category is due to the background Worldsteel data set used for modeling. In this dataset, there are negative amounts of emissions that contribute to ozone depletion potential. This is due to credits given for avoided production of fuels and chemicals during the production of steel co-products. Thus, the corrugated steel pipe system has lower ozone depletion results compared to all other pipe systems due to the credit given during the pipe-production stage.
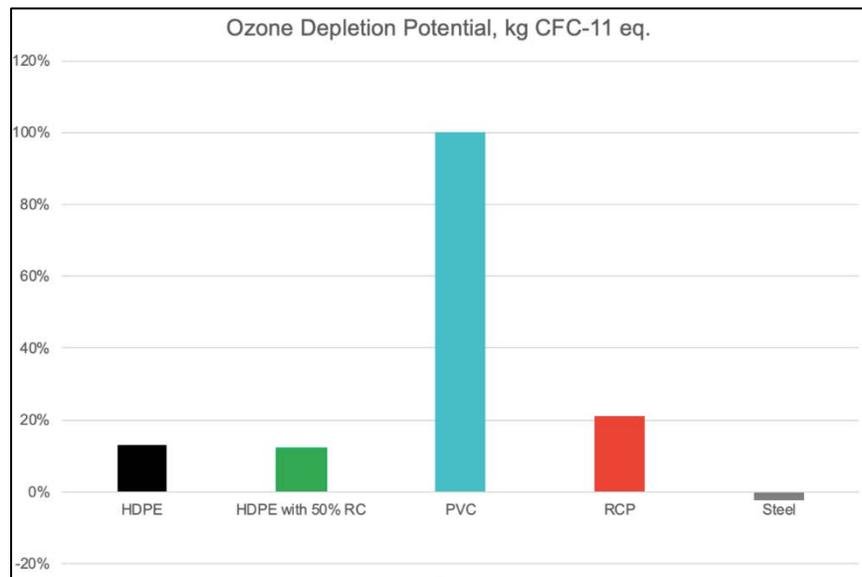
Figure 4: Comparison of relative ozone depletion potential (ODP) for all pipe systems studied normalized to the pipe system with the greatest ODP. For this environmental impact category, the pipe system with the greatest ODP is the PVC pipe system.

2.4.1.5. Smog Formation Potential

Smog formation potential is closely related to the amount of emissions from combustion of diesel fuels, for excavation equipment, trucks, and pipe cleaning equipment, as well as combustion of coal used for process energy and electricity generation. For all end-of-life scenarios, total smog formation potential for HDPE pipe systems are lesser than those for corrugated steel and reinforced concrete pipe systems. Differences in smog formation potential results for HDPE and PVC pipe systems are inconclusive.
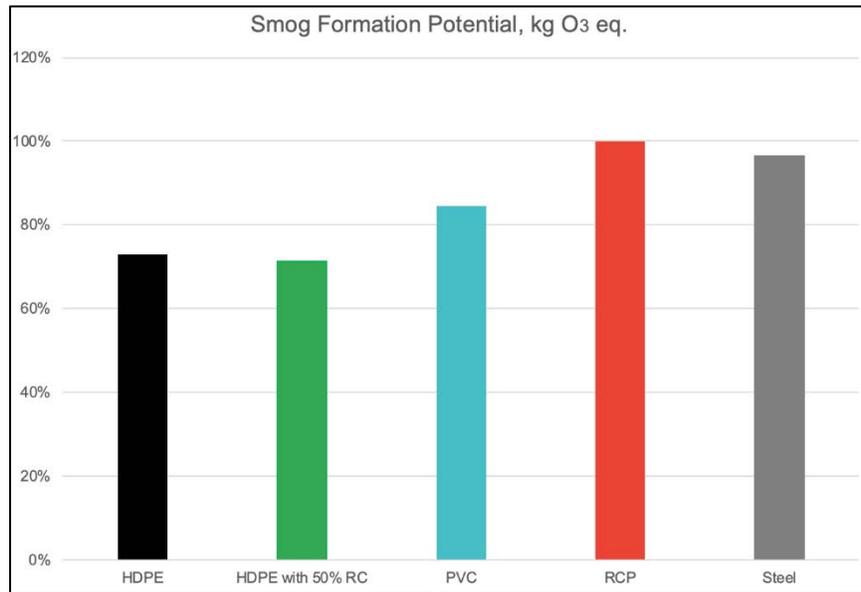
Figure 5: Comparison of relative smog formation potential (SFP) for all pipe systems studied normalized to the pipe system with the greatest SFP. For this environmental impact category, the pipe system with the greatest SFP is the reinforced concrete pipe system.

2.4.1.6. Total Energy Demand

The reinforced concrete pipe performed better than the virgin HDPE pipe system in the total energy demand category. As shown in the following table, pipe production creates the greatest total energy demand for the product system during the life cycle, while pipe installation is the source of the second greatest energy demand.

During the pipe production phase, reinforced concrete pipe requires a lower amount of production energy compared to other systems. This may seem counterintuitive because it is common knowledge that cement is an energy-intensive material to make, but in practice only a small amount of cement by mass is included in concrete. When the energy consumption required in the production of cement is allocated to the percent mass of cement contained in the concrete, while more than 80% of the mass of concrete is made of materials with very little

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production energy (sand, gravel, and aggregate), the energy demand per pound of reinforced concrete pipe is much less than that of other pipe systems. So even though the reinforced concrete pipes are much heavier than the other systems, the total energy demand per 1000 ft of pipe is less than other systems.

Reinforced concrete pipe systems also have installation energy demands that are less than those of virgin HDPE pipe. This is because more native soil can be used as backfill, which results in less energy demand due to bringing in less select fill material and hauling away less native soil. HDPE pipe made with recycled resins show lower energy demands than with virgin HDPE as a result of using less energy reclaiming, reprocessing, and reusing recycled HDPE resins for 50% of the content rather than producing 100% HDPE from virgin materials.
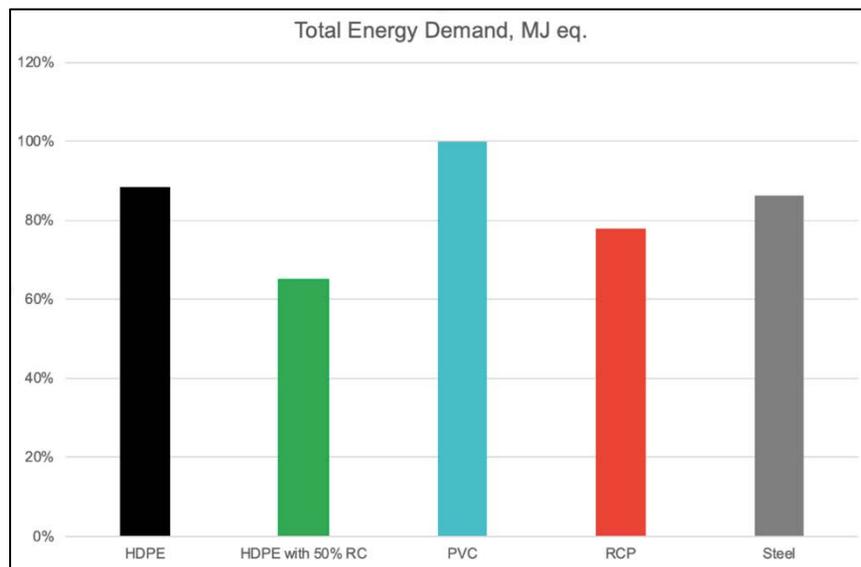
Figure 6: Comparison of relative total energy demand for all pipe systems studied normalized to the pipe system with the greatest total energy demand. For this environmental impact category, the pipe system with the greatest total energy demand is the PVC pipe system.

2.4.1.7. Solid Waste

Solid waste results are strongly influenced by the end-of-life management scenario for the pipe system. The reinforced concrete pipe system generated the greatest amount of solid waste for all end-of-life scenarios evaluated, and the HDPE pipe systems have the least total solid waste for all end-of-life scenarios. Solid waste differences between the virgin and 50% recycled content HDPE pipe systems are not large enough to be considered meaningful.
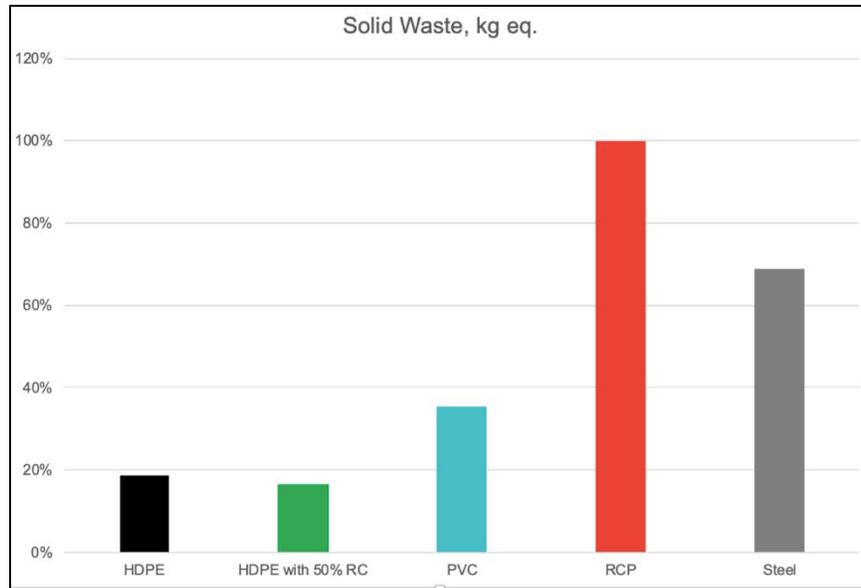
Figure 7: Comparison of relative solid waste for all pipe systems studied normalized to the pipe system that generates the greatest amount of solid waste. For this environmental impact category, the pipe system with the greatest solid waste is the reinforced concrete pipe system.

2.4.1.8. Water Consumption

Water consumption for all pipe systems is associated with the generation of electricity used for process energy, as well as extraction and processing of other process and transportation fuel. The HDPE pipe systems consume less water than all other pipe systems for all end-of-life scenarios. Differences between water consumption of virgin and recycled content HDPE pipe are not large enough to be considered meaningful.
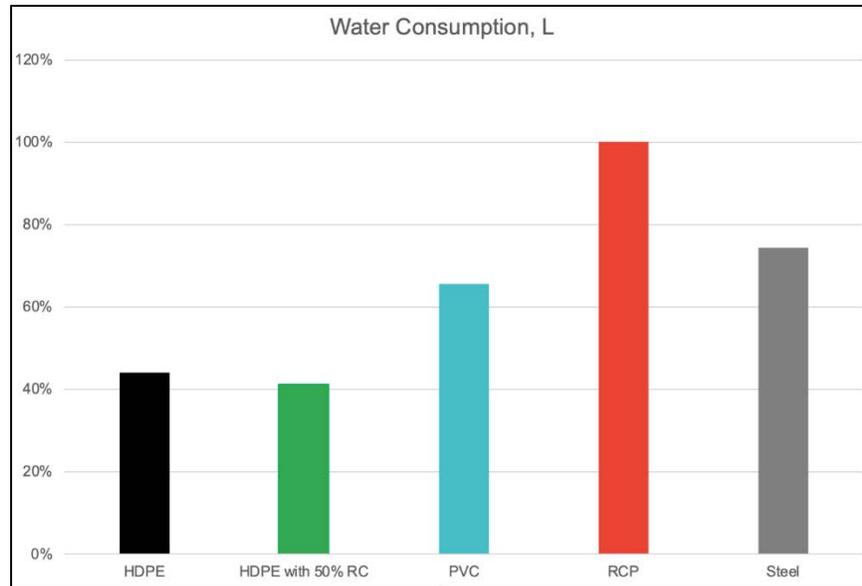
Figure 8: Comparison of relative water consumption for all pipe systems studied normalized to the pipe system with the greatest water consumption. For this environmental impact category, the pipe system with the greatest water consumption is the reinforced concrete pipe system.

2.4.2. Sensitivity Analyses

Sensitivity analyses are used to verify that assumptions made during the LCA do not significantly change the results. For this study, sensitivity analyses were run for three assumptions: those related to pipe weights, steel reinforcement content in the reinforced concrete pipe, and average transportation distances for reinforced concrete pipe.

2.4.2.1. Pipe Weights

A sensitivity analysis is included on pipe weight because there can be weight variations for pipe produced by different manufacturers. For the HDPE pipe, results were run for the highest and lowest pipe weights reported by producers. For other types of pipe, results were run at weights 10% higher than the baseline weight and 10% lower than the baseline weight. Results comparing low weight HDPE pipe with high weight alternative pipe (best case scenario for HDPE) and comparing high weight HDPE pipe with low weight alternative pipe (worst case

scenario for HDPE) were run for all three end-of-life fates for both recycling methodologies.

Overall, the pipe weight sensitivities do not show notable changes in the comparative conclusions for baseline weight pipes. Comparing low weight HDPE pipe with high weight alternative pipes shifts some comparative conclusions from inconclusive to lower for HDPE pipes, and comparing high weight HDPE pipe with low weight alternative pipes generally shifts some comparative results into the inconclusive range rather than showing significant benefits for alternative pipes compared to HDPE pipe. Supporting data tables are presented in the full report.

2.4.2.2. Reinforcing Steel Content of Reinforced Concrete Pipe

The reinforcing steel content of reinforced concrete pipe was modeled based on industry data per metric tonne of pipe from a 2017 study for the Canadian Concrete Pipe & Precast Association (CCPPA). From this report, a 5.2% weighted average of reinforcing steel was calculated for 24-in. diameter reinforced concrete pipe. A 2010 fact sheet from The Wire Reinforcement Institute indicated that steel content values varied between 1.1% and 2.8% of the weight of the reinforced concrete pipe.

If the reinforced concrete pipe is modeled with the lower steel content, only a few comparative conclusions for HDPE and reinforced concrete pipe are affected. For pipe that is left in place, some energy comparisons between 50% recycled content HDPE and reinforced concrete pipe shift from higher for reinforced concrete pipe to inconclusive differences. Some eutrophication and smog comparisons between reinforced concrete pipe and HDPE pipe also shift from higher for reinforced concrete pipe to inconclusive differences. All other comparisons of results are higher for reinforced concrete pipe compared to virgin and recycled HDPE pipe. Results tables for the reinforced concrete pipe steel weight sensitivity analysis are presented in the full report.

2.4.2.3. Transport Distance for Reinforced Concrete Pipe to Installation Site

A distance of 100 miles from manufacturer to installation site was modeled for all pipe types except reinforced concrete pipe. Due to its heavy weight, RCP is generally sourced from local plants, so the transport distance for reinforced concrete pipe was modeled as 50 miles in the baseline results. A sensitivity analysis on a transport distance of 100 miles for reinforced concrete pipe showed no changes in comparative conclusions for HDPE and reinforced concrete pipe systems.