

Environmental Product Declaration

Uni-Bell PVC Pipe Association |

PVC Pressure Pipe: Potable Water, Reclaimed Water, Sewer Force Main

PVC Non-Pressure Pipe: Sanitary Sewer and Storm Sewer Pipe Systems

ENVIRONMENTAL PRODUCT DECLARATION VERIFICATION





POTABLE WATER PIPES, RECLAIMED WATER PIPES, SEWER FORCE MAINS,
GRAVITY SANITARY SEWER AND GRAVITY STORM SEWERS

This document covers PVC pressure pipe for potable water, reclaimed water, and sewer forcemain systems; and PVC non-pressure pipe for storm sewer and sanitary sewer systems. All pipes are made in lengths that are assembled at the job site. Each length has a belled end with a elastomeric gasket such that each pipe length's spigot end fits inside the belled end of the next pipe length.



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Environmental
Product Declaration**
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ENVIRONMENTAL PRODUCT DECLARATION VERIFICATION

EPD Information			
Program Operator		NSF International	
Declaration Holder		Uni-Bell PVC Pipe Association	
Product Potable Water, Gravity Storm Water, and Sanitary Sewer Pipe Systems	Date of Issue May 15, 2015	Period of Validity 5 Years	Declaration Number EPD10047
This EPD was independently verified by NSF International in accordance with ISO 14025:		 Lori Bestervelt LBestervelt@nsf.org	
<input type="checkbox"/> Internal	<input checked="" type="checkbox"/> External		
This life cycle assessment was independently verified by in accordance with ISO 14044 and the reference PCR:		 J. Renée Morin, PRé morin@pre-sustainability.com	
LCA Information			
Basis LCA	Potable Water, Gravity Storm Water, and Sanitary Sewer Pipe Systems, October 18, 2013		
LCA Preparer	James Mellentine, Sustainable Solutions Corporation Cara Watson, Sustainable Solutions Corporation		
This life cycle assessment was critically reviewed in accordance with ISO 14044 by:	Rita Schenck, Ph.D. LCACP (Review Chair), Executive Director, Institute for Environmental Research and Education Nigel Howard, Managing Director, Clarity Environment Charlie He, Associate Vice President, Carollo Engineering		
PCR Information			
Program Operator	The Norwegian EPD Foundation, with Addendum by UL Environment		
Reference PCR	Piping systems for use for sewage and storm water (under gravity), The Norwegian EPD Foundation, with Addendum v2 by UL Environment		
Date of Issue	9/20/2012 (Addendum 6/10/2014)		
PCR review was conducted by:	The Norwegian EPD Foundation PB 5250 Majorstuen, 0303 Oslo		

ENVIRONMENTAL PRODUCT DECLARATION: DETAILED VERSION



Terms and Definitions/ Definition of Product Category

The PVC pipe industry recognizes the benefits of communicating credible, science-based and transparent environmental information about its products. This document provides a baseline for 100 feet of seven different pipe products, used in various applications, to assist with measuring and understanding the environmental impacts of PVC pipe across the life cycle. The seven PVC pipe products examined are used for both pressure applications (potable water pipes, reclaimed water pipes and sewer force mains), and non-pressure applications (gravity sanitary sewer and gravity storm sewers). These products are listed below in Table 1.

Application	Standard	Nominal Diameter	Dimension Ratio/ Pipe Stiffness
Pressure Pipe	AWWA C900 ¹	8 in.	DR18
Pressure Pipe	AWWA C900	8 in.	DR25
Pressure Pipe	AWWA C905 ²	CIOD 24 in.	DR25
Storm Water	ASTM F794 ³ / AASHTO M304 ⁴	24 in. (profile wall)	PS 46
Sanitary Sewer	ASTM F794	8 in. (profile wall)	PS 46
Sanitary Sewer	ASTM D3034 ⁵	8 in. (solid wall)	DR35 (PS 46)
Sanitary Sewer	ASTM F679 ⁶	24 in. (solid wall)	PS 46

Table 1. Products Included in Study

¹ AWWA C900 Standard for Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, 4 in. through 12 in., For Water Transmission and Distribution. 2007.
² AWWA C905 Standard for Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, 14 in. through 48 in., For Water Transmission and Distribution. 2010.
³ ASTM F794 Standard Specification for Poly(Vinyl Chloride) (PVC) Profile Gravity Sewer Pipe and Fittings Based on Controlled Inside Diameter. 2014
⁴ AASHTO M304 Standard Specification for Poly(Vinyl Chloride) (PVC) Profile Wall Drain Pipe and Fittings Based on Controlled Inside Diameter. 2011
⁵ ASTM D3034 Standard Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings. 2014
⁶ ASTM F679 Standard Specification for Poly(Vinyl Chloride) (PVC) Large Diameter Plastic Gravity Sewer Pipe and Fittings. 2013

This study uses data from seven manufacturers and 21 facilities to represent roughly 20% of all PVC pipe product capacity in the United States and Canada. The participating manufacturers are listed in Table 2 and include:

Participating PVC Pipe Manufacturers
Diamond Plastics Corporation
IPEX, Inc.
National Pipe & Plastics Corporation
North American Pipe Corporation
North American Specialty Products
PipeLife JetStream, Inc.
Royal Building Products

Table 2. Participating Manufacturers

The terms defined by the PCR are listed below:

Environmental Product Declaration (EPD): environmental declaration providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information

Functional Unit: the quantified performance of a product system for use as reference unit

Life Cycle Assessment (LCA): compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle

Life Cycle Costing (LCC): investigation and evaluation of economic costs of a product or service from 'cradle' to 'grave'

Product Category Rule (PCR): a set of specific rules, requirements and guidelines for developing Type III environmental declarations for one or more product categories

Pressure Pipe: pipe for pressurized transport of potable water, reclaimed water, or sewage.

Non-Pressure Pipe: pipe for non-pressure transport of sanitary sewage or drainage water.

Piping system function: the function of the pipe is to transport (via gravity or pressure) a certain amount of liquid or sewage from a source location to a destination location



Functional Unit/Reference Service Life

The environmental impacts are reported per functional unit of a product and the functional unit is the basis for comparison in an LCA. For PVC pipe, the functional unit is 100 feet of installed pipe over a 100 year lifetime, as pipe length is a more useful functional unit than weight. To calculate the environmental impacts for 100 meters of installed pipe, multiply these EPD results by 3.28 feet per meter. The pumping energy required to pump water through the pipe during the use stage is considered and reported separately from the rest of the life cycle, since operating conditions can vary.



System Boundaries

The system boundary of this EPD is cradle-to-grave. This project considers the life cycle activities from resource extraction through installation and end-of-life effects. The boundary covers the product, construction process, use, and end of life stages, as seen in Figure 1.

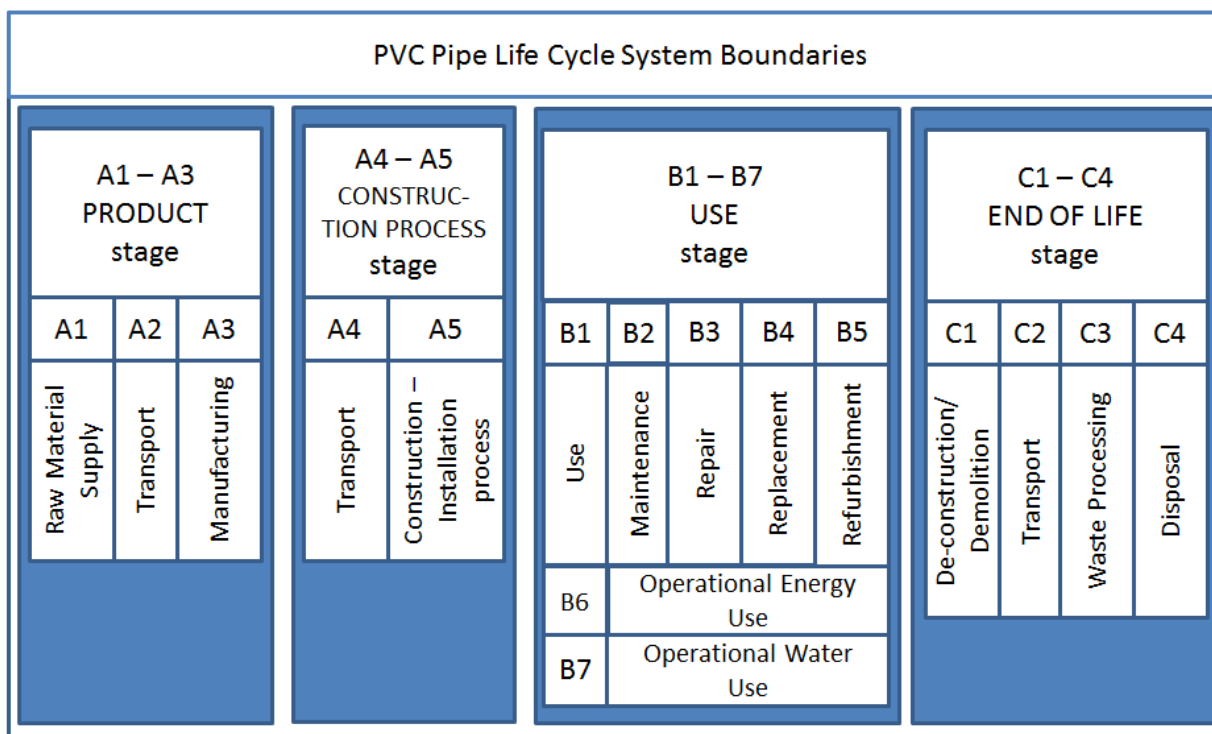


Figure 1. System Boundary

Criteria for the inclusion of inputs and outputs (cut-off)

Processes whose total contribution to the final result, in relation to all considered impact categories, is less than 1% can be neglected. The sum of the neglected processes may not exceed 5% by mass of the considered impact categories. If 5% is exceeded, a documented assumption is admissible.

For Hazardous Substances, as defined by the U.S. Occupational Health and Safety Act, the following requirements apply:

- The Life Cycle Inventory (LCI) of hazardous substances will be included, if the inventory is available.
- If the LCI for a hazardous substance is not available, the substance will appear as an input in the LCI of the product, if its mass represents more than 0.1% of the product composition.
- If the LCI of a hazardous substance is approximated by modeling another substance, documentation will be provided.

This LCA/EPD is in compliance with the cut-off criteria since no known processes were neglected or excluded from this analysis outside of the specific items listed below:

- Construction of capital equipment
- Maintenance of operation and support equipment
- Human labor and employee commute
- Ink for printing pipe label
- Casings for pipe installed under structures
- Fittings
- Shoring, soil compaction during installation of pipe
- Molecularly oriented PVC (PVCO) analysis
- Water consumption analysis



Data Quality Requirements

The data quality requirements are as follows:

Data shall be as current as possible. Data sets used for calculations shall have been updated within the last 10 years for generic data and within the last 5 years for producer specific data; data sets shall be based on 1 year averaged data; deviations shall be justified.

Both primary and secondary LCI and metadata are used throughout the study. All secondary data is taken from literature, previous LCI studies, and life cycle databases. The US LCI database (www.nrel.gov/lci) and the ecoinvent v2.2 database are frequently used in this analysis. The US LCI data are free and publicly available, and thus, offer both a high degree of transparency and an ability to replicate the results of the study; however, there are limitations, as some processes are missing for some of the products available in this LCI database, creating an issue with respect to completeness. If data gaps were identified, data from the ecoinvent v2.2 database were selected for the model. With each ecoinvent process used in this study, the data had already been adapted to US conditions via the SimaPro provider, EarthShift.



Raw Materials Extraction and Origin

PVC pipe compound ingredients are given in the units Parts per Hundred Resin (PHR). This means that for every 100 pounds of resin, the PHR amount should be added to the compound when mixing. This ensures consistency throughout the industry. The industry average PVC pipe formulations are listed in Table 3.

Raw Material	Potable Water (PHR)	Profile Sewer (PHR)	Solid Wall Sewer (PHR)
PVC resin	100	100	100
Heat Stabilizer	0.69	2.26	0.57
Paraffin Wax	1.38	1.65	1.12
Calcium Carbonate	5.51	9.59	17.65
Calcium Stearate	0.72	0.70	0.84
Polyethylene Wax	0.21	0.22	0.15
Titanium Dioxide	0.83	1.03	1.11
Process Aid	-	1.13	-
Impact Modifier	-	5.30	-
Pigments	0.23	0.20	0.30
Total	109.75	122.06	121.74

Table 3. PVC Pipe Product Formulation

The average raw materials transportation distances are listed in Table 4 for each pipe included in the study.

Raw Materials Transportation (km)	8" DR18 C900	8" DR25 C900	24" DR25 C905	24" PS 46 (profile)	8" PS 46 (profile)	8" DR35 PS 46	24" PS 46
Rail	949	1,580	1,376	3,024	1,879	1,298	1,436
Truck	109	97	114	297	94	143	157
Ocean Freighter	35	90	1	200	71	31	18
Total	1,093	1,766	1,491	3,541	2,125	1,472	1,611

Table 4. PVC Pipe Raw Material Average Shipping Distances



Production

The production process begins when the raw materials are blended together, after which the compound flows into an electrically heated extruder. The compound passes through a die at the end of the extruder, where it is formed into a pipe shape. The pipe then moves through a sizing sleeve that provides dimensional accuracy. Solid-wall pipe is then water cooled, cut to length and labeled as the pipe moves to the end of the production line. Profile-wall pipe undergoes additional processing to

form the profile shape. At the end of the production line, the pipe is belled and pressure tested (for pressure rated pipes). The pipe is then packaged and prepared for shipment from the manufacturing facility. The packaging is typically a set of wooden frames that hold the bundle of pipes together. Packaged pipe is loaded onto trucks for shipping.

Transportation of pipes from production site to location is included in the production stage. The final PVC pipes are shipped throughout the United States and Canada. Each participating facility provided average transportation distances for the products investigated in this study. A weighted average was taken for each product in this study as seen in Table 5. All manufacturing facilities ship the PVC pipe via truck.

Final Product Shipping	8" DR18 C900	8" DR25 C900	24" DR25 C905	24" PS 46 (profile)	8" PS 46 (profile)	8" DR35 PS 46	24" PS 46
Truck Shipments (km)	422	775	257	711	967	592	367

Table 5. Weighted Average of Final Product Shipping from Manufacturing Facilities



Installation

Installation of PVC pipe is assumed to be similar to other open-cut pipe installation, requiring the digging and refilling of a trench. The trench depth and time required to dig and re-fill it varies widely per region, soil type, climate, existing infrastructure, equipment operator, local convention, and other factors, so the actual installation time and effort is widely variable. For 8-inch pipe, the trench width used was at least 24 inches. For 24-inch pipe, the trench width should extend at least 36 inches. Typically, a hydraulic digger is used to dig the trench, and a small loader re-fills the trench.

Scenarios:

Two scenarios were identified for this study. The first scenario represents a trench depth of 4 feet for the 8-inch diameter potable water pipe, with an estimated 1.5 hours of machine run time for 100 feet of pipe. The second scenario represents a trench depth of 10 feet for the 24-inch diameter non-pressure pipe, with an estimated 2.5 hours of machine run time for 100 feet of pipe.

Diesel fuel usage rates are estimated to be 8 gallons/hour for the digger⁷ and 2 gallons/hour for the loader⁸. Therefore the 1.5-hour baseline scenario assumes 15 gallons of diesel is required to install 100 feet of pipe. The longer 2.5-hour scenario assumes 36 gallons of diesel is required to install 100 feet of pipe. No shoring was required. Gravel and sand was assumed to be used in the bedding and

⁷ Forum on Heavy Equipment. <http://www.heavyequipmentforums.com/showthread.php?5804-Fuel-Consumption> Accessed March 2013.

⁸ Forum on Forestry Forum. <http://www.forestryforum.com/board/index.php?topic=14063.0>. Accessed March 2013.

haunching of the trench, per the *Handbook of PVC Pipe: Design & Construction* manual. A combined bulk density of 120 lb/ft³ was assumed⁹. Not all pipe installations require bedding, and some installations can use native soil.

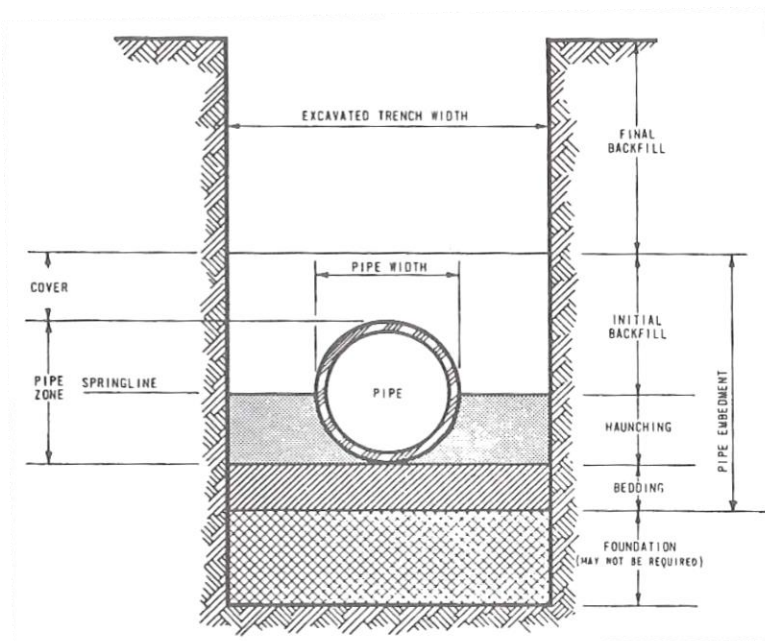


Figure 2. Trench Cross-Section Diagram

Use (100 years)

It is assumed that replacements or repairs of pipes will not be necessary during the course of 100 years. Pumping energy is required to compensate for the friction against the water flow caused from the inner wall of the pipes of pressurized piping systems. To calculate the amount of energy required of the pumps for the friction head from the PVC pipe, the following assumptions were made. Note that 8760 annual operating hours equal 24-hour, 365-day pumping.

Parameter	Value
Water flow velocity in PVC pipe	2 feet/second
Pump efficiency	75%
Operating hours per year	8760
Length of pipe	100 feet
Elevation increase	0 feet
Hazen-Williams Coefficient for PVC	150 ¹⁰

Table 6. Assumptions made for the use of potable water pipe

⁹ SI Metric. Density of Dry Material Table. http://www.simetric.co.uk/si_materials.htm Accessed September 25, 2013.

¹⁰ *Handbook of PVC Pipe: Design and Construction*. Fifth Edition. Uni-Bell. (2012) 9.7.

The friction head loss through 100 feet of pipe was calculated using the Hazen-Williams equation.	8" DR18 AWWA C900	8" DR25 AWWA C900	24" DR25 AWWA C905
Hazen-Williams Coefficient ¹¹	150	150	150
Inside Diameter (inch)	8.04	8.33	23.74
Flow Rate (gpm) at 2ft/s velocity	317	339	2,758
Friction head loss (ft/100 ft of pipe)	0.17	0.14	0.05
Pumping Energy (kWh/yr)	115	98	286

Table 7 – Assumptions for Use Phase Calculations for Constant Velocity of 2 ft per second



End of Life

The study assumes the service life is 100 years and the end-of-life disposition is modeled as left in the ground. The selected service life used in the project reflects the expert opinions of the product manufacturers as well as the AWWARF study and Utah State University study¹² which confirms PVC pipe will last well over 100 years¹³. Infrastructure pipe is generally left in the ground at the end of its service life, and that is the assumption made in this study. Disposal in a municipal landfill is permissible and should be done in accordance with local, state, and federal regulations. However, PVC pipe is 100% recyclable so if the product is removed from the ground after its service life, the preferred disposition is recycling.

¹¹ *Handbook of PVC Pipe: Design and Construction*. Fifth Edition. Uni-Bell. (2012) 9.7.

¹² Folkman, Steven. *PVC Pipe Longevity Report: Affordability & the 100+ Year Benchmark Standard*. Utah State University Buried Structures Laboratory. May 2014.

¹³ Burn, S. et. al., "Long-term Performance Prediction for PVC Pipes," AWWARF Report 91092F, May 2006.

Life Cycle Inventory Analysis

Resources



The use of renewable and non-renewable material sources, primary energy, and water are reported in the tables below.

Resource (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Use of renewable primary energy excluding renewable primary energy resources used as raw materials (MJ)	4.6E+02	0.0E+00	4.0E+01	5.1E+03	0.0E+00	5.6E+03
Use of renewable primary energy resources used as raw materials (MJ)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total use of renewable primary energy resources (MJ)	4.6E+02	0.0E+00	4.0E+01	5.1E+03	0.0E+00	5.6E+03
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials (MJ)	1.3E+04	2.7E+02	3.8E+03	1.1E+05	0.0E+00	1.3E+05
Use of non-renewable primary energy resources used as raw materials (MJ)	9.3E+03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.3E+03
Total use of non-renewable primary energy resources (MJ)	2.3E+04	2.7E+02	3.8E+03	1.1E+05	0.0E+00	1.4E+05
Use of secondary material (kg)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Use of renewable secondary fuels (MJ)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Net use of fresh water (m ³)	1.1E+03	0.0E+00	2.8E+02	1.1E+00	0.0E+00	1.3E+03

Table 8 – 8” DR18 AWWA C900 PVC Pressure Pipe Use of Resources

Resource (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Use of renewable primary energy excluding renewable primary energy resources used as raw materials (MJ)	3.7E+02	0.0E+00	3.5E+01	4.4E+03	0.0E+00	4.8E+03
Use of renewable primary energy resources used as raw materials (MJ)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total use of renewable primary energy resources (MJ)	3.7E+02	0.0E+00	3.5E+01	4.4E+03	0.0E+00	4.8E+03
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials (MJ)	7.8E+03	2.0E+02	3.7E+03	9.6E+04	0.0E+00	1.1E+05
Use of non-renewable primary energy resources used as raw materials (MJ)	7.7E+03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.7E+03
Total use of non-renewable primary energy resources (MJ)	1.5E+04	2.0E+02	3.7E+03	9.6E+04	0.0E+00	1.2E+05
Use of secondary material (kg)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Use of renewable secondary fuels (MJ)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Net use of fresh water (m ³)	1.6E+03	0.0E+00	2.5E+02	9.8E-01	0.0E+00	1.8E+03

Table 9 – 8” DR25 AWWA C900 PVC Pressure Pipe Use of Resources

Resource (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Use of renewable primary energy excluding renewable primary energy resources used as raw materials (MJ)	2.6E+03	0.0E+00	3.7E+01	1.3E+04	0.0E+00	1.5E+04
Use of renewable primary energy resources used as raw materials (MJ)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total use of renewable primary energy resources (MJ)	2.6E+03	0.0E+00	3.7E+01	1.3E+04	0.0E+00	1.5E+04
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials (MJ)	7.8E+04	7.8E+02	7.5E+03	2.8E+05	0.0E+00	3.7E+05
Use of non-renewable primary energy resources used as raw materials (MJ)	5.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.7E+04
Total use of non-renewable primary energy resources (MJ)	1.4E+05	7.8E+02	7.5E+03	2.8E+05	0.0E+00	4.2E+05
Use of secondary material (kg)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Use of renewable secondary fuels (MJ)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Net use of fresh water (m ³)	2.5E+03	0.0E+00	2.6E+02	2.9E+00	0.0E+00	2.8E+03

Table 10 – 24” DR25 AWWA C905 PVC Pressure Pipe Resource Use

Resource (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Use of renewable primary energy excluding renewable primary energy resources used as raw materials (MJ)	2.7E+02	0.0E+00	3.5E+01	0.0E+00	0.0E+00	3.0E+02
Use of renewable primary energy resources used as raw materials (MJ)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total use of renewable primary energy resources (MJ)	2.7E+02	0.0E+00	3.5E+01	0.0E+00	0.0E+00	3.0E+02
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials (MJ)	3.4E+03	8.7E+01	3.7E+03	0.0E+00	0.0E+00	7.2E+03
Use of non-renewable primary energy resources used as raw materials (MJ)	2.3E+03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.3E+03
Total use of non-renewable primary energy resources (MJ)	5.7E+03	8.7E+01	3.7E+03	0.0E+00	0.0E+00	9.5E+03
Use of secondary material (kg)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Use of renewable secondary fuels (MJ)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Net use of fresh water (m ³)	1.2E+04	0.0E+00	2.2E+02	0.0E+00	0.0E+00	1.2E+04

Table 11 – 24” PS 46 ASTM F794/AASHTO M304 Profile-Wall Gravity Sewer PVC Pipe Resource Use

Resource (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Use of renewable primary energy excluding renewable primary energy resources used as raw materials (MJ)	2.5E+03	3.2E+01	0.0E+00	0.0E+00	0.0E+00	2.5E+03
Use of renewable primary energy resources used as raw materials (MJ)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total use of renewable primary energy resources (MJ)	2.5E+03	0.0E+00	3.2E+01	0.0E+00	0.0E+00	2.5E+03
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials (MJ)	4.7E+04	2.8E+02	7.4E+03	0.0E+00	0.0E+00	5.5E+04
Use of non-renewable primary energy resources used as raw materials (MJ)	1.2E+02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E+02
Total use of non-renewable primary energy resources (MJ)	4.7E+04	2.8E+02	7.4E+03	0.0E+00	0.0E+00	5.5E+04
Use of secondary material (kg)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Use of renewable secondary fuels (MJ)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Net use of fresh water (m ³)	1.4E+03	0.0E+00	2.5E+02	0.0E+00	0.0E+00	1.6E+03

Table 12 – 8” PS 46 ASTM F794 Profile-Wall PVC Pipe Resource Use

Resource (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Use of renewable primary energy excluding renewable primary energy resources used as raw materials (MJ)	2.4E+02	3.5E+01	0.0E+00	0.0E+00	0.0E+00	2.8E+02
Use of renewable primary energy resources used as raw materials (MJ)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total use of renewable primary energy resources (MJ)	2.4E+02	0.0E+00	3.5E+01	0.0E+00	0.0E+00	2.8E+02
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials (MJ)	5.7E+03	1.0E+02	3.7E+03	0.0E+00	0.0E+00	9.5E+03
Use of non-renewable primary energy resources used as raw materials (MJ)	4.1E+03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.1E+03
Total use of non-renewable primary energy resources (MJ)	9.8E+03	1.0E+02	3.7E+03	0.0E+00	0.0E+00	1.4E+04
Use of secondary material (kg)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Use of renewable secondary fuels (MJ)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Net use of fresh water (m ³)	8.4E+02	0.0E+00	2.5E+02	0.0E+00	0.0E+00	1.1E+03

Table 13 – 8” DR35 PS46 ASTM D3034 Solid-Wall Sanitary Sewer PVC Pipe Resource Use

Resource (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Use of renewable primary energy excluding renewable primary energy resources used as raw materials (MJ)	2.1E+03	0.0E+00	3.5E+01	0.0E+00	0.0E+00	2.1E+03
Use of renewable primary energy resources used as raw materials (MJ)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total use of renewable primary energy resources (MJ)	2.1E+03	0.0E+00	3.5E+01	0.0E+00	0.0E+00	2.1E+03
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials (MJ)	6.0E+04	6.7E+02	8.4E+03	0.0E+00	0.0E+00	6.9E+04
Use of non-renewable primary energy resources used as raw materials (MJ)	3.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.7E+04
Total use of non-renewable primary energy resources (MJ)	9.7E+04	6.7E+02	8.4E+03	0.0E+00	0.0E+00	1.1E+05
Use of secondary material (kg)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Use of renewable secondary fuels (MJ)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Net use of fresh water (m ³)	4.1E+03	0.0E+00	2.5E+02	0.0E+00	0.0E+00	4.3E+03

Table 14 – 24” PS 46 ASTM F679 Solid-Wall Sanitary Sewer PVC Pipe Resource Use



Waste

The following tables show the amount of waste (hazardous, non-hazardous, and radioactive) in each life cycle stage. Note that this waste is from both foreground and background processes. For example, there is no direct radioactive waste from PVC pipe production – it is from the nuclear electricity production that feeds the regional electric grid where PVC pipe is produced.

Waste (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Hazardous waste (kg)	9.2E-02	0.0E+00	2.2E-03	2.0E-03	0.0E+00	9.6E-02
Non-hazardous waste (kg)	1.6E+01	0.0E+00	2.3E+01	2.7E+00	0.0E+00	4.2E+01
Radioactive waste (kg)	2.3E-03	0.0E+00	2.2E-03	3.6E-03	0.0E+00	8.1E-03

Table 15 – Waste for 100 feet of Installed 8” DR18 AWWA C900 PVC Pressure Pipe

Waste (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Hazardous waste (kg)	5.4E-02	0.0E+00	2.1E-03	1.7E-03	0.0E+00	5.8E-02
Non-hazardous waste (kg)	7.6E+00	0.0E+00	2.2E+01	2.3E+00	0.0E+00	3.1E+01
Radioactive waste (kg)	2.6E-03	0.0E+00	2.0E-03	3.1E-03	0.0E+00	7.7E-03

Table 16 – Waste for 100 feet of Installed 8” DR25 AWWA C900 PVC Pressure Pipe

Waste (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Hazardous waste (kg)	5.2E-01	0.0E+00	2.0E-03	5.0E-03	0.0E+00	5.3E-01
Non-hazardous waste (kg)	7.8E+01	0.0E+00	2.1E+01	6.8E+00	0.0E+00	1.1E+02
Radioactive waste (kg)	9.8E-03	0.0E+00	2.0E-03	8.9E-03	0.0E+00	2.1E-02

Table 17 – Waste for 100 feet of Installed 24” DR25 AWWA C905 PVC Pressure Pipe

Waste (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Hazardous waste (kg)	3.0E-01	0.0E+00	1.9E-03	0.0E+00	0.0E+00	3.0E-01
Non-hazardous waste (kg)	5.2E+01	0.0E+00	2.0E+01	0.0E+00	0.0E+00	7.1E+01
Radioactive waste (kg)	1.9E-02	0.0E+00	1.8E-03	0.0E+00	0.0E+00	2.1E-02

Table 18 – Waste for 100 feet of Installed 24” PS 46 ASTM F794/AASHTO M304 Profile-Wall Gravity Sewer PVC Pipe

Waste (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Hazardous waste (kg)	3.8E-02	0.0E+00	2.1E-03	0.0E+00	0.0E+00	4.0E-02
Non-hazardous waste (kg)	6.8E+00	0.0E+00	2.1E+01	0.0E+00	0.0E+00	2.8E+01
Radioactive waste (kg)	2.1E-03	0.0E+00	2.0E-03	0.0E+00	0.0E+00	4.1E-03

Table 19 – Waste for 100 feet of Installed 8” PS 46 ASTM F794 Profile-Wall PVC Pipe

Waste (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Hazardous waste (kg)	4.0E-02	0.0E+00	2.1E-03	0.0E+00	0.0E+00	4.2E-02
Non-hazardous waste (kg)	6.2E+00	0.0E+00	2.1E+01	0.0E+00	0.0E+00	2.8E+01
Radioactive waste (kg)	1.5E-03	0.0E+00	2.0E-03	0.0E+00	0.0E+00	3.5E-03

Table 20 – Waste for 100 feet of Installed 8” DR35 PS46 ASTM D3034 Solid-Wall Sanitary Sewer PVC Pipe

Waste (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Hazardous waste (kg)	3.6E-01	0.0E+00	2.5E-03	0.0E+00	0.0E+00	3.6E-01
Non-hazardous waste (kg)	5.6E+01	0.0E+00	2.0E+01	0.0E+00	0.0E+00	7.6E+01
Radioactive waste (kg)	9.6E-03	0.0E+00	2.0E-03	0.0E+00	0.0E+00	1.2E-02

Table 21 – Waste for 100 feet of Installed 24” PS 46 ASTM F679 Solid-Wall Sanitary Sewer PVC Pipe



Life Cycle Impact Assessment

The impact categories analyzed for this EPD include: global warming potential, ozone depletion, acidification, eutrophication and smog formation. The TRACI 2 version 4.0 impact assessment methodology was used to calculate the environmental impacts in this LCA.

Pressure Pipe

(unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Ozone Depletion (kg CFC-11 eq)	5.6E-05	7.5E-10	5.4E-06	5.4E-06	0.0E+00	6.2E-05
Global Warming Potential (kg CO ₂ eq)	1.1E+03	2.0E+01	2.5E+02	2.5E+02	0.0E+00	1.4E+03
Smog (kg O ₃ eq)	5.2E+01	3.2E+00	8.5E+01	8.5E+01	0.0E+00	1.4E+02
Acidification (mol H ⁺ eq)	2.8E+02	6.6E+00	1.7E+02	1.7E+02	0.0E+00	4.5E+02
Eutrophication (kg N eq)	3.7E-01	6.6E-03	3.9E-01	3.9E-01	0.0E+00	7.7E-01

Table 22 – 8” DR18 AWWA C900 PVC Pressure Pipe environmental impacts using the TRACI impact methodology

Impact Category (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Ozone Depletion (kg CFC-11 eq)	4.1E-05	5.7E-10	5.2E-06	1.3E-07	0.0E+00	4.6E-05
Global Warming Potential (kg CO ₂ eq)	7.4E+02	1.5E+01	2.5E+02	8.2E+03	0.0E+00	9.2E+03
Smog (kg O ₃ eq)	3.2E+01	2.4E+00	8.5E+01	5.0E+02	0.0E+00	6.2E+02
Acidification (mol H ⁺ eq)	1.6E+02	5.0E+00	1.7E+02	3.7E+03	0.0E+00	4.0E+03
Eutrophication (kg N eq)	2.2E-01	5.0E-03	3.8E-01	9.7E-01	0.0E+00	1.6E+00

Table 23 – 8” DR25 AWWA C900 PVC Pressure Pipe environmental impacts using the TRACI impact methodology

Impact Category (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Ozone Depletion (kg CFC-11 eq)	3.5E-04	2.2E-09	5.0E-06	4.4E-06	0.0E+00	3.6E-04
Global Warming Potential (kg CO ₂ eq)	6.7E+03	5.7E+01	5.1E+02	2.7E+05	0.0E+00	2.8E+05
Smog (kg O ₃ eq)	3.1E+02	9.3E+00	2.0E+02	1.6E+04	0.0E+00	1.7E+04
Acidification (mol H ⁺ eq)	1.6E+03	1.9E+01	3.7E+02	1.2E+05	0.0E+00	1.2E+05
Eutrophication (kg N eq)	2.1E+00	1.9E-02	5.9E-01	3.2E+01	0.0E+00	3.4E+01

Table 24 – 24” DR25 AWWA C905 PVC Pressure Pipe environmental impacts using the TRACI impact methodology

Gravity Sewer Pipe

Impact Category (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Ozone Depletion (kg CFC-11 eq)	1.2E-04	7.8E-10	4.7E-06	0.0E+00	0.0E+00	1.3E-04
Global Warming Potential (kg CO ₂ eq)	2.3E+03	2.1E+01	5.0E+02	0.0E+00	0.0E+00	2.9E+03
Smog (kg O ₃ eq)	1.3E+02	3.4E+00	2.0E+02	0.0E+00	0.0E+00	3.3E+02
Acidification (mol H ⁺ eq)	5.6E+02	6.8E+00	3.7E+02	0.0E+00	0.0E+00	9.3E+02
Eutrophication (kg N eq)	1.5E+00	6.8E-03	5.7E-01	0.0E+00	0.0E+00	2.1E+00

Table 25 – 24” PS 46 ASTM F794/AASHTO M304 Profile-Wall Gravity Sewer PVC Pipe environmental impacts using the TRACI impact methodology

Impact Category (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Ozone Depletion (kg CFC-11 eq)	1.5E-05	2.4E-10	5.2E-06	0.0E+00	0.0E+00	2.0E-05
Global Warming Potential (kg CO ₂ eq)	2.7E+02	6.4E+00	2.5E+02	0.0E+00	0.0E+00	5.3E+02
Smog (kg O ₃ eq)	1.3E+01	1.0E+00	8.5E+01	0.0E+00	0.0E+00	9.9E+01
Acidification (mol H ⁺ eq)	6.0E+01	2.1E+00	1.7E+02	0.0E+00	0.0E+00	2.3E+02
Eutrophication (kg N eq)	1.5E-01	2.1E-03	3.8E-01	0.0E+00	0.0E+00	5.3E-01

Table 26 – 8” PS 46 ASTM F794 Profile-Wall PVC Pipe environmental impacts using the TRACI impact methodology

Impact Category (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Ozone Depletion (kg CFC-11 eq)	2.4E-05	2.9E-10	5.2E-06	0.0E+00	0.0E+00	2.9E-05
Global Warming Potential (kg CO ₂ eq)	4.8E+02	7.5E+00	2.5E+02	0.0E+00	0.0E+00	7.4E+02
Smog (kg O ₃ eq)	2.2E+01	1.2E+00	8.5E+01	0.0E+00	0.0E+00	1.1E+02
Acidification (mol H ⁺ eq)	1.2E+02	2.5E+00	1.7E+02	0.0E+00	0.0E+00	2.8E+02
Eutrophication (kg N eq)	1.6E-01	2.5E-03	3.8E-01	0.0E+00	0.0E+00	5.4E-01

Table 27 – 8” DR35 PS46 ASTM D3034 Solid-Wall Sanitary Sewer PVC Pipe environmental impacts using the TRACI impact methodology

Impact Category (unit per 100 ft pipe for 100 yrs)	Product Stage (A1-A3)	Transport (A4)	Construction - Installation (A5)	Use (B1-B7)	End of Life (C1-C4)	Total
Ozone Depletion (kg CFC-11 eq)	2.4E-04	1.9E-09	1.5E-05	0.0E+00	0.0E+00	2.6E-04
Global Warming Potential (kg CO ₂ eq)	4.8E+03	4.9E+01	5.6E+02	0.0E+00	0.0E+00	5.4E+03
Smog (kg O ₃ eq)	2.2E+02	8.0E+00	2.2E+02	0.0E+00	0.0E+00	4.5E+02
Acidification (mol H ⁺ eq)	1.1E+03	1.6E+01	4.0E+02	0.0E+00	0.0E+00	1.6E+03
Eutrophication (kg N eq)	1.5E+00	1.6E-02	6.5E-01	0.0E+00	0.0E+00	2.2E+00

Table 28 – 24” PS 46 ASTM F679 Solid-Wall Sanitary Sewer PVC Pipe environmental impacts using the TRACI impact methodology



Life Cycle Impact Conclusions

PVC pipe is designed to minimize environmental impacts. Its smooth interior surface minimizes energy consumption for pumping due to reduced frictional forces. Its corrosion resistance enables long-term durability. Studies confirm PVC pipe’s longevity to be in excess of 100 years, which means that it has to be replaced less often, resulting in additional environmental impact reductions.

Based on the results from the life cycle assessment, the use phase is the primary driver of environmental impacts for PVC pipe in pressurized water applications. For non-pressure PVC pipes (and for pressure pipes excluding the use phase), the life cycle impacts are strongly driven by the PVC resin and the installation process.



Additional Environmental Information

The following statements are required by the referenced product category rule. PVC pipe and fittings are resistant to chemicals generally found in water and sewer systems, preventing any leaching or releases to ground and surface water during the use of the piping system. No known chemicals are released internally into the water system. No known toxicity effects occur in the use of the product.



LCA Development

This EPD and corresponding LCA were prepared by Sustainable Solutions Corporation of Royersford, Pennsylvania.



SustainableSolutions
CORPORATION



Comparability

This EPD meets the requirements for comparability with products evaluated in accordance to the guiding PCR document. EPDs from different programs may not be comparable.

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