Strength and Durability for LiFe®

dipra
Ductile Iron Pipe
Research Association

Environmental Product Declaration

This document is an industry average Type III Environmental Product Declaration (EPD) of 10 sizes of Ductile iron pipes used in pressurized water and sewer and gravity sewer applications. Seven manufacturing facilities, owned by three U.S. Ductile iron pipe producers, are included in the study, representing 100% of U.S. production.

Last Revised:
November 2022

General Information

Size (in)	Applications	Description	Standards
6	Pressurized Water	PC 350 Cement Mortar Lined	AWWA C150, AWWA C151
8	Pressurized Water	PC 350 Cement Mortar Lined	AWWA C150, AWWA C151
12	Pressurized Water	PC 350 Cement Mortar Lined	AWWA C150, AWWA C151
16	Pressurized Water	PC 250 Cement Mortar Lined	AWWA C150, AWWA C151
24	Pressurized Water	PC 200 Cement Mortar Lined	AWWA C150, AWWA C151
30	Pressurized Water	PC 150 Cement Mortar Lined	AWWA C150, AWWA C151
36	Pressurized Water	PC 150 Cement Mortar Lined	AWWA C150, AWWA C151
8	Gravity Sewer	PC 350 Cement Mortar Lined	AWWA C150, AWWA C151, ASTM A746
12	Gravity Sewer	PC 350 Cement Mortar Lined	AWWA C150, AWWA C151, ASTM A746
24	Pressurized Sewer	PC 200 Cement Mortar Lined	AWWA C150, AWWA C151

Environmental Product Declaration
Declaration prepared in accordance with ISO 14025, EN-15804, and ASTM International EPD Program Operator rules.

Core Product Category Rule
Norwegian EPD Foundation (2017). NPCR Part A: Construction Products & Services.

Product Category Rule
The Norwegian EPD Foundation. (2018). NPCR 019 v.2.0: Piping systems for use for sewage and storm water (under gravity).

Independent verification of the declaration and data, according to ISO 14025:
___Internal _X_ External

Third-party verifier
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ASTM International
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Declaration Number: EPD-291

Participating Manufacturers and Locations

Seven manufacturing facilities, owned by three U.S. ductile iron producers, are included in the study. Plants are located throughout the U.S.

American Cast Iron Pipe Co.
1501 31st Ave
North Birmingham, AL 35207

McWane Ductile
183 Sitgreaves Street
Phillipsburg, NJ 08865

2266 South Sixth Street
Coshocto, OH 43812

2550 South Industrial Parkway
Provo, Utah 84606

U.S. Pipe
10 Adams Street
Lynchburg, VA 24506

1295 Whipple Road
Union City, CA 94587

2023 Saint Louis Avenue
Bessemer, AL 35020

This EPD is based on a cradle-to-grave life cycle assessment (LCA) of 10 applications of Ductile Pipes used in pressurized water and sewer and gravity sewer applications.

Functional Unit

100 feet of installed pipe over a 100-year lifetime, the assumed reference service life of the product.

Material Content

Each 18' length of pipe contains the following components:

Pipe Size (in)	Ductile Iron (lb)	Cement Lining (lb)	Rubber Gasket (lb)
6	299	2.7	2.3
8	397	3.6	4.4
12	655	5.3	5.5
16	941	10.5	11.5
24	1,549	15.6	21.7
30	2,002	25.8	32.8
36	2,677	30.9	38.9

LCA Study

Product function

The function of the pipe is to transport (via gravity or pressure) a certain volume of liquid or sewage from a source location to a destination location over a period of 100 years.

Product system

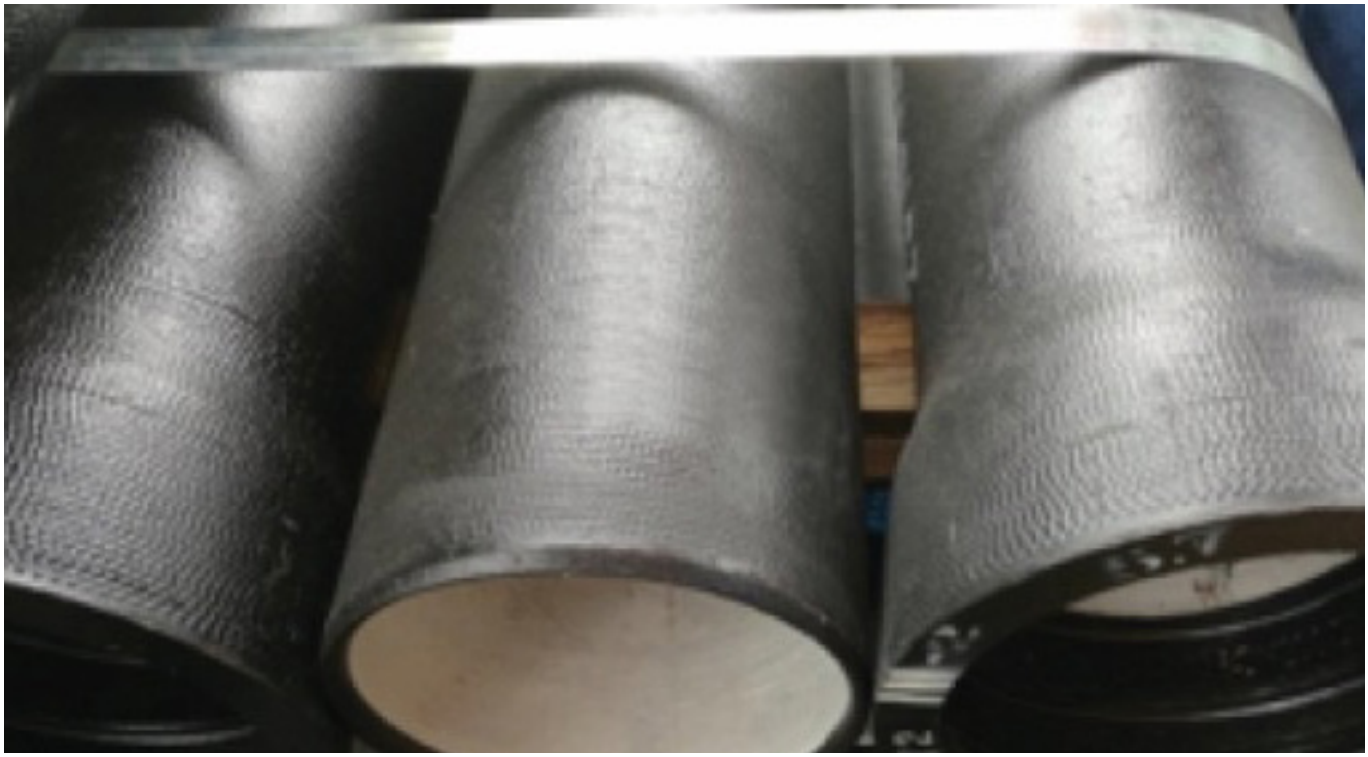
The piping system includes the pipe and gasket. During installation, the gasket is seated into the bell-end of the pipe and the joint is assembled by pushing the plain end into the bell end which compresses the gasket and forms a watertight seal.

Functional unit

The declared unit used in this study is 100 feet (30.48 meters) of installed pipe over a 100-year lifetime, the reference service life.

Calculation rule for averaging data

Average environmental impacts were calculated based on the 2019 weighted average production (in feet) for each product.



System boundary

The study considers the life cycle activities from cradle-to-grave. All life cycle stages (production, installation, use and end-of-life, as displayed in Figure 1) are included.

The following processes are excluded from the study:

- Production, manufacture, and construction of manufacturing capital goods and infrastructure;
- Production and manufacture of production equipment, delivery vehicles, and laboratory equipment;
- Personnel-related activities (travel, furniture, office supplies);
- Energy and water use related to company management and sales activities that may be located either within the factory site or at another location.

Figure 1.
Life-cycle stages and modules included in study

Production Stage				Installation Stage		Use Stage						End-of-Life Stage			
Extraction and upstream production	Transport to factory	Manufacturing	Transport to site	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/Demolition	Transport waste processing or disposal	Waste processing	Disposal of waste
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4

LCA Study

Installation/laying stage

Transportation distance of pipes from production to installation site is based on the weighted average distance each pipe size was transported in 2019 by each plant.

Installation is done in accordance with the AWWA C600 standard. There is no standard depth of bury for water and wastewater pipelines because soil and environmental conditions are site specific. Typically, pressurized water and wastewater lines are buried at the minimum allowable depth while gravity sewers have to maintain a certain grade which can result in a deeper installation depth. For water mains and force mains a depth of bury of four feet was chosen while a depth of bury of 10 feet was chosen for gravity sewers. These are typical depths of bury used across the country but not meant to be representative of all installations. It is not common for pipes to break or be rejected so no waste pipe is included.

TABLE 1
Weighted average transportation distance

Size (in)	Application	Distance Truck (mi)	Distance Train (mi)
6	Pressurized Water	291	400
8	Pressurized Water	302	350
12	Pressurized Water	327	408
16	Pressurized Water	306	454
24	Pressurized Water	360	506
30	Pressurized Water	340	775
36	Pressurized Water	359	549
8	Gravity Sewer	302	350
12	Gravity Sewer	327	408
24	Pressurized Water	360	506

TABLE 2
Installation scenario variables for each pipe

Ductile Iron Pipe Size (in)	Application	Depth of Bury	Trench Type	Trench Volume (m3)	Local Mass Used (tn.sh)	Time to Install 100′ (hr)′	Required Equipment[2]	Fuel Burn per Hour (gal)	Avg. Fuel Burn per Hour (gal)	Total Fuel Consumption (gal)
6	Water Main	4′	Type 1	33.4	73.5	2	Cat 308	0.8-1.5	1.15	2.3
8	Water Main	4′	Type 1	37.0	81.7	2	Cat 308	0.8-1.5	1.15	2.3
12	Water Main	4′	Type 1	44.8	98.7	2	Cat 314	0.9-1.8	1.35	2.7
16	Water Main	4′	Type 2	53.2	117	2	Cat 320	1.3-2.5	1.9	3.8
24	Water Main	4′	Type 2	72.3	159	2	Cat 330	1.4-2.9	2.15	4.3
30	Water Main	4′	Type 2	88.1	194	2	Cat 330	1.4-2.9	2.15	4.3
36	Water Main	4′	Type 2	105.7	233	2	Cat 345	3.8-7.7	5.75	11.5
8	Gravity Sewer	10′	Type 1	83.9	185	6	Cat 345	7.7-11.4	9.55	57.3
12	Gravity Sewer	10′	Type 1	97.4	215	6	Cat 345	7.7-11.4	9.55	57.3
24	Pressure Sewer	4′	Type 2	72.3	159	2	Cat 330	1.4-2.9	2.15	4.3

[1] Time estimates provided by: Garney Construction, 200 Crutchfield Avenue, Nashville, TN 37210

[2] Equipment requirements provided by: Garney Construction, 200 Crutchfield Avenue, Nashville, TN 37210

[3] (Caterpillar, 2015)

Figure 2.
Type 1 trench, flat-bottom[4], loose backfill

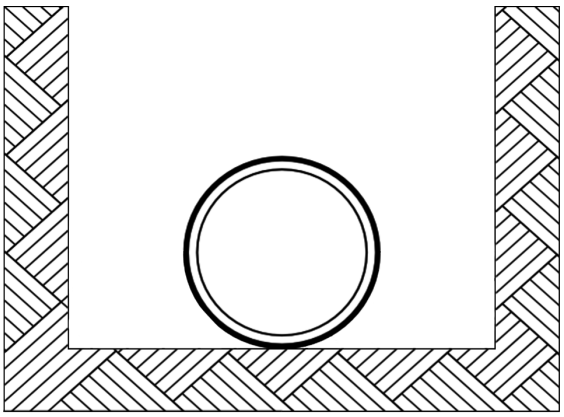
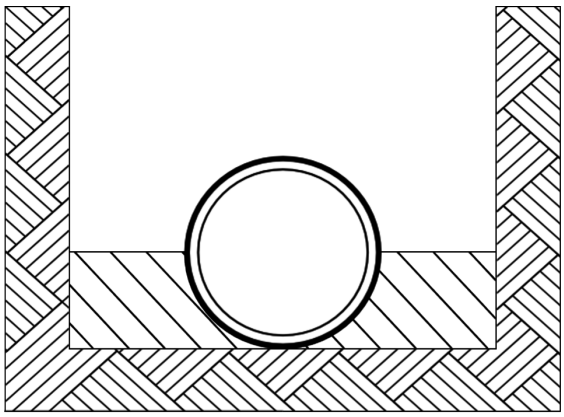


Figure 3.
Type 2 trench, flat-bottom, backfill lightly consolidated to centerline of pipe



Use stage

To calculate the amount of energy required of pumps the friction head loss through 100 feet of pipe was calculated using the Hazen-Williams equation[5]. Calculation details are displayed in Table 3.

TABLE 3
Use stage information

Water								Sewer
Pipe Size	6.00	8.00	12.00	16.00	24.00	30.00	36.00	24.00
Internal Diameter (inches)	6.28	8.43	12.52	16.61	24.95	31.09	37.29	24.95
C Factor	140	140	140	140	140	140	140	140
Pump efficiency	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.50
Velocity (fps)	1.87	1.72	1.69	1.70	1.64	1.65	1.70	2.00
Flow (gpm)	180	300	650	1,150	2,500	3,900	5,800	3,047
Friction Head loss (ft./100 ft.)	0.25	0.17	0.11	0.08	0.05	0.04	0.03	0.07
Annual Pumping Energy (kWh/100 ft.)	**85.70**	**87.65**	**115.81**	**148.75**	**187.76**	**229.27**	**292.36**	**109.84**

It is assumed that replacements or repairs of pipes are not required during the course of 100 years. The American Water Works Association estimates the life of Ductile iron pipe to range from 105-120 years depending on installation location (AWWA).

End of life stage

It is assumed that at end-of-life, pipes are left in ground (a common industry practice).

[4] "Flat-bottom" is defined as undisturbed earth.
[5] (DIPRA, 2016)

Environmental Impacts

Industry average cradle-to-grave impact results per 100 feet (30.48 meters) of installed pipe over a 100-year lifetime are outlined in Tables 4-13.

TABLE 4
Impact results for 6" pressurized cement mortar lined water pipe

Results Categories		Product Stage	Transport	Installation	Use	End-of-Life	Total
Impact Assessment	**Units**	**A1-A3**	**A4**	**A5**	**B1-B6**	**C1-C4**	**A-C**
Global warming potential	kg CO_2-eq.	981.3	55.5	22.6	5,137.5	0	**6,197.0**
Acidification potential	kg SO_2-eq.	4.33	0.79	0.25	22.58	0	**27.96**
Eutrophication potential	kg N-eq.	2.53	0.048	0.020	1.73	0	**4.33**
Photochemical smog formation potential (Smog creation potential)	kg O_3-eq.	53.9	22.1	7.8	256.5	0	**340.3**
Ozone depletion potential	kg CFC11-eq.	2.44 E-04	2.29 E-09	4.78 E-08	1.35 E-04	0	**3.79 E-04**
Total primary energy consumption							
Non-renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	17,406.0	775.3	344.1	96,816.1	0	**115,341.4**
Non-renewable primary resources w/ energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	612.2	0	0.8	5,584.4	0	**6,197.3**
Renewable primary resources with energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Abiotic depletion potential for fossil resources	MJ	16,190.5	775.3	339.1	68,185.8	0	**85,490.7**
Material resources consumption							
Secondary materials	kg	764.5	0	0	0	0	**764.5**
Renewable secondary fuels	MJ	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ	259.6	0	0	0	0	**259.6**
Recovered energy	MJ	0	0	0	0	0	**0**
Net fresh water (inputs minus outputs)	m^3	6.31	0	3.01 E-03	6.81	0	**13.12**
Waste disposed							
Non-hazardous waste disposed	kg	139.9	0	0	0	0	**139.9**
Hazardous waste disposed	kg	1.66	0	0	0	0	**1.66**
Radioactive waste *	kg	0.08	0	0	0.27	0	**0.35**
Other outputs							
Components for reuse	kg	0	0	0	0	0	**0**
Secondary material for recycling	kg	12.39	0	0	0	0	**12.39**
Materials for energy recovery	kg	0	0	0	0	0	**0**
Exported energy	MJ	0	0	0	0	0	**0**

* Radioactive waste comes from the nuclear power that feeds each plant's regional electric grid. The pipe contains no radioactive wastes.

TABLE 5
Impact results for 8" pressurized cement mortar lined water pipe

Results Categories		Product Stage	Transport	Installation	Use	End-of-Life	Total
Impact Assessment	**Units**	**A1-A3**	**A4**	**A5**	**B1-B6**	**C1-C4**	**A-C**
Global warming potential	kg CO_2-eq.	1,334.1	74.5	22.6	5,254.4	0	**6,685.7**
Acidification potential	kg SO_2-eq.	5.82	1.06	0.25	23.09	0	**30.22**
Eutrophication potential	kg N-eq.	3.42	0.064	0.020	1.77	0	**5.27**
Photochemical smog formation potential (Smog creation potential)	kg O_3-eq.	72.8	29.1	7.8	262.3	0	**372.0**
Ozone depletion potential	kg CFC11-eq.	3.35 E-04	3.08 E-09	4.78 E-08	1.38 E-04	0	**4.73 E-04**
Total primary energy consumption							
Non-renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	23,647.3	1,044.8	344.1	99,019.0	0	**124,055.2**
Non-renewable primary resources w/ energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	819.1	0	0.8	5,711.4	0	**6,531.3**
Renewable primary resources with energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Abiotic depletion potential for fossil resources	MJ	21,983.9	1,044.8	339.1	69,737.3	0	**93,105.1**
Material resources consumption							
Secondary materials	kg	1,031.5	0	0	0	0	**1,031.5**
Renewable secondary fuels	MJ	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ	401.6	0	0	0	0	**401.6**
Recovered energy	MJ	0	0	0	0	0	**0**
Net fresh water (inputs minus outputs)	m^3	8.67	0	3.01 E-03	6.96	0	**15.64**
Waste disposed							
Non-hazardous waste disposed	kg	187.3	0	0	0	0	**187.3**
Hazardous waste disposed	kg	2.45	0	0	0	0	**2.45**
Radioactive waste *	kg	0.11	0	0	0.28	0	**0.39**
Other outputs							
Components for reuse	kg	0	0	0	0	0	**0**
Secondary material for recycling	kg	17.03	0	0	0	0	**17.03**
Materials for energy recovery	kg	0	0	0	0	0	**0**
Exported energy	MJ	0	0	0	0	0	**0**

* Radioactive waste comes from the nuclear power that feeds each plant's regional electric grid. The pipe contains no radioactive wastes.

TABLE 6 Impact results for 12" pressurized cement mortar lined water pipe							
Results Categories		**Product Stage**	**Transport**	**Installation**	**Use**	**End-of-Life**	**Total**
Impact Assessment	**Units**	**A1-A3**	**A4**	**A5**	**B1-B6**	**C1-C4**	**A-C**
Global warming potential	kg CO_2-eq.	2,186.2	135.1	26.6	6,942.6	0	**9,290.4**
Acidification potential	kg SO_2-eq.	9.53	1.92	0.29	30.51	0	**42.26**
Eutrophication potential	kg N-eq.	5.52	0.116	0.024	2.33	0	**8.00**
Photochemical smog formation potential (Smog creation potential)	kg O_3-eq.	118.4	53.2	9.2	346.6	0	**527.4**
Ozone depletion potential	kg CFC11-eq.	5.52 E-04	5.59 E-09	5.61 E-08	1.82 E-04	0	**7.35 E-04**
Total primary energy consumption							
Non-renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	38,550.4	1,892.7	403.9	130,831.6	0	**171,678.6**
Non-renewable primary resources w/ energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	1,314.7	0	0.9	7,546.4	0	**8,862.0**
Renewable primary resources with energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Abiotic depletion potential for fossil resources	MJ	35,856.5	1,892.7	398.1	92,142.3	0	**130,289.6**
Material resources consumption							
Secondary materials	kg	1,704.0	0	0	0	0	**1,704.0**
Renewable secondary fuels	MJ	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ	639.3	0	0	0	0	**639.3**
Recovered energy	MJ	0	0	0	0	0	**0**
Net fresh water (inputs minus outputs)	m^3	14.40	0	3.54 E-03	9.20	0	**23.61**
Waste disposed							
Non-hazardous waste disposed	kg	277.8	0	0	0	0	**277.8**
Hazardous waste disposed	kg	4.07	0	0	0	0	**4.07**
Radioactive waste *	kg	0.17	0	0	0.37	0	**0.54**
Other outputs							
Components for reuse	kg	0	0	0	0	0	**0**
Secondary material for recycling	kg	31.77	0	0	0	0	**31.77**
Materials for energy recovery	kg	0	0	0	0	0	**0**
Exported energy	MJ	0	0	0	0	0	**0**

* Radioactive waste comes from the nuclear power that feeds each plant's regional electric grid. The pipe contains no radioactive wastes.

TABLE 7
Impact results for 16" pressurized cement mortar lined water pipe

Results Categories		Product Stage	Transport	Installation	Use	End-of-Life	Total
Impact Assessment	**Units**	**A1-A3**	**A4**	**A5**	**B1-B6**	**C1-C4**	**A-C**
Global warming potential	kg CO_2-eq.	3,107.3	202.5	37.4	8,917.3	0	**12,264.4**
Acidification potential	kg SO_2-eq.	13.56	2.91	0.41	39.19	0	**56.07**
Eutrophication potential	kg N-eq.	8.00	0.176	0.034	3.00	0	**11.20**
Photochemical smog formation potential (Smog creation potential)	kg O_3-eq.	168.2	81.2	13.0	445.1	0	**707.5**
Ozone depletion potential	kg CFC11-eq.	7.94 E-04	8.35 E-09	7.89 E-08	2.34 E-04	0	**1.03 E-03**
Total primary energy consumption							
Non-renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	55,115.9	2,827.6	568.4	168,044.2	0	**226,556.2**
Non-renewable primary resources w/ energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	1,995.7	0	1.3	9,692.8	0	**11,689.8**
Renewable primary resources with energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Abiotic depletion potential for fossil resources	MJ	51,202.6	2,827.6	560.2	118,350.5	0	**172,940.9**
Material resources consumption							
Secondary materials	kg	2,407.5	0	0	0	0	**2,407.5**
Renewable secondary fuels	MJ	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ	900.0	0	0	0	0	**900.0**
Recovered energy	MJ	0	0	0	0	0	**0**
Net fresh water (inputs minus outputs)	m^3	19.81	0	4.98 E-03	11.82	0	**31.63**
Waste disposed							
Non-hazardous waste disposed	kg	485.8	0	0	0	0	**485.8**
Hazardous waste disposed	kg	5.79	0	0	0	0	**5.79**
Radioactive waste *	kg	0.22	0	0	0.47	0	**0.69**
Other outputs							
Components for reuse	kg	0	0	0	0	0	**0**
Secondary material for recycling	kg	32.88	0	0	0	0	**32.88**
Materials for energy recovery	kg	0	0	0	0	0	**0**
Exported energy	MJ	0	0	0	0	0	**0**

* Radioactive waste comes from the nuclear power that feeds each plant's regional electric grid. The pipe contains no radioactive wastes.

TABLE 8
Impact results for 24" pressurized cement mortar lined water pipe

Results Categories		Product Stage	Transport	Installation	Use	End-of-Life	Total
Impact Assessment	**Units**	**A1-A3**	**A4**	**A5**	**B1-B6**	**C1-C4**	**A-C**
Global warming potential	kg CO_2-eq.	5,152.8	384.2	42.3	11,255.8	0	**16,835.1**
Acidification potential	kg SO_2-eq.	22.55	5.50	0.46	49.47	0	**77.99**
Eutrophication potential	kg N-eq.	13.07	0.332	0.038	3.78	0	**17.22**
Photochemical smog formation potential (Smog creation potential)	kg O_3-eq.	280.3	153.0	14.7	561.9	0	**1,009.8**
Ozone depletion potential	kg CFC11-eq.	1.28 E-03	1.59 E-08	8.93 E-08	2.96 E-04	0	**1.58 E-03**
Total primary energy consumption							
Non-renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	91,310.1	5,370.5	643.2	212,114.2	0	**309,438.0**
Non-renewable primary resources w/ energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	3,189.7	0	1.5	12,234.8	0	**15,425.9**
Renewable primary resources with energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Abiotic depletion potential for fossil resources	MJ	84,960.7	5,370.5	633.9	149,388.2	0	**240,353.3**
Material resources consumption							
Secondary materials	kg	4,057.4	0	0	0	0	**4,057.4**
Renewable secondary fuels	MJ	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ	1,054.9	0	0	0	0	**1,054.9**
Recovered energy	MJ	0	0	0	0	0	**0**
Net fresh water (inputs minus outputs)	m^3	31.04	0	5.63 E-03	14.92	0	**45.97**
Waste disposed							
Non-hazardous waste disposed	kg	917.5	0	0	0	0	**917.5**
Hazardous waste disposed	kg	10.66	0	0	0	0	**10.66**
Radioactive waste *	kg	0.37	0	0	0.59	0	**0.97**
Other outputs							
Components for reuse	kg	0	0	0	0	0	**0**
Secondary material for recycling	kg	73.19	0	0	0	0	**73.19**
Materials for energy recovery	kg	0	0	0	0	0	**0**
Exported energy	MJ	0	0	0	0	0	**0**

* Radioactive waste comes from the nuclear power that feeds each plant's regional electric grid. The pipe contains no radioactive wastes.

TABLE 9
Impact results for 30" pressurized cement mortar lined water pipe

Results Categories		Product Stage	Transport	Installation	Use	End-of-Life	Total
Impact Assessment	**Units**	**A1-A3**	**A4**	**A5**	**B1-B6**	**C1-C4**	**A-C**
Global warming potential	kg CO_2-eq.	6,172.4	569.6	42.3	13,744.3	0	**20,528.5**
Acidification potential	kg SO_2-eq.	27.78	8.42	0.46	60.41	0	**97.08**
Eutrophication potential	kg N-eq.	15.94	0.509	0.038	4.62	0	**21.10**
Photochemical smog formation potential (Smog creation potential)	kg O_3-eq.	340.5	240.8	14.7	686.1	0	**1,282.0**
Ozone depletion potential	kg CFC11-eq.	1.52 E-03	2.33 E-08	8.93 E-08	3.61 E-04	0	**1.88 E-03**
Total primary energy consumption							
Non-renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	111,503.7	7,879.4	643.2	259,008.4	0	**379,034.7**
Non-renewable primary resources w/ energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	4,058.1	0	1.5	14,939.6	0	**18,999.2**
Renewable primary resources with energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Abiotic depletion potential for fossil resources	MJ	103,704.5	7,879.4	633.9	182,414.9	0	**294,632.7**
Material resources consumption							
Secondary materials	kg	4,689.0	0	0	0	0	**4,689.0**
Renewable secondary fuels	MJ	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ	269.1	0	0	0	0	**269.1**
Recovered energy	MJ	0	0	0	0	0	**0**
Net fresh water (inputs minus outputs)	m^3	37.30	0	5.63 E-03	18.21	0	**55.52**
Waste disposed							
Non-hazardous waste disposed	kg	1,013.4	0	0	0	0	**1,013.4**
Hazardous waste disposed	kg	1.66	0	0	0	0	**1.66**
Radioactive waste *	kg	0.29	0	0	0.72	0	**1.02**
Other outputs							
Components for reuse	kg	0	0	0	0	0	**0**
Secondary material for recycling	kg	75.04	0	0	0	0	**75.04**
Materials for energy recovery	kg	0	0	0	0	0	**0**
Exported energy	MJ	0	0	0	0	0	**0**

* Radioactive waste comes from the nuclear power that feeds each plant's regional electric grid. The pipe contains no radioactive wastes.

TABLE 10
Impact results for 36" pressurized cement mortar lined water pipe

Results Categories		Product Stage	Transport	Installation	Use	End-of-Life	Total
Impact Assessment	**Units**	**A1-A3**	**A4**	**A5**	**B1-B6**	**C1-C4**	**A-C**
Global warming potential	kg CO_2-eq.	8,911.6	699.5	113.1	17,526.4	0	**27,250.6**
Acidification potential	kg SO_2-eq.	40.29	10.07	1.23	77.03	0	**128.63**
Eutrophication potential	kg N-eq.	23.01	0.609	0.102	5.89	0	**29.61**
Photochemical smog formation potential (Smog creation potential)	kg O_3-eq.	492.3	281.5	39.2	874.9	0	**1,687.8**
Ozone depletion potential	kg CFC11-eq.	2.30 E-03	2.88 E-08	2.39 E-07	4.60 E-04	0	**2.76 E-03**
Total primary energy consumption							
Non-renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	157,962.9	9,761.1	1,720.3	330,281.7	0	**499,726.1**
Non-renewable primary resources w/ energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	5,729.0	0	3.9	19,050.7	0	**24,783.6**
Renewable primary resources with energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Abiotic depletion potential for fossil resources	MJ	146,709.0	9,761.1	1,695.4	232,611.4	0	**390,777.0**
Material resources consumption							
Secondary materials	kg	7,061.9	0	0	0	0	**7,061.9**
Renewable secondary fuels	MJ	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ	1,746.8	0	0	0	0	**1,746.8**
Recovered energy	MJ	0	0	0	0	0	**0**
Net fresh water (inputs minus outputs)	m^3	54.05	0	1.51 E-02	23.22	0	**77.29**
Waste disposed							
Non-hazardous waste disposed	kg	1,356.3	0	0	0	0	**1,356.3**
Hazardous waste disposed	kg	12.57	0	0	0	0	**12.57**
Radioactive waste *	kg	0.54	0	0	0.92	0	**1.46**
Other outputs							
Components for reuse	kg	0	0	0	0	0	**0**
Secondary material for recycling	kg	69.10	0	0	0	0	**69.10**
Materials for energy recovery	kg	0	0	0	0	0	**0**
Exported energy	MJ	0	0	0	0	0	**0**

* Radioactive waste comes from the nuclear power that feeds each plant's regional electric grid. The pipe contains no radioactive wastes.

TABLE 11
Impact results for 8″ gravity cement mortar lined sewer pipe

Results Categories		Product Stage	Transport	Installation	Use	End-of-Life	Total
Impact Assessment	**Units**	**A1-A3**	**A4**	**A5**	**B1-B6**	**C1-C4**	**A-C**
Global warming potential	kg CO_2-eq.	1,334.1	74.5	563.7	0.0	0	**1,972.3**
Acidification potential	kg SO_2-eq.	5.82	1.06	6.15	0.00	0	**13.03**
Eutrophication potential	kg N-eq.	3.42	0.064	0.508	0.00	0	**3.99**
Photochemical smog formation potential (Smog creation potential)	kg O_3-eq.	72.8	29.1	195.3	0.0	0	**297.2**
Ozone depletion potential	kg CFC11-eq.	3.35 E-04	3.08 E-09	1.19 E-06	0.00 E+00	0	**3.36 E-04**
Total primary energy consumption							
Non-renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	23,647.3	1,044.8	8,571.5	0.0	0	**33,263.6**
Non-renewable primary resources w/ energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	819.1	0	19.4	0.0	0	**838.4**
Renewable primary resources with energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Abiotic depletion potential for fossil resources	MJ	21,983.9	1,044.8	8,447.6	0.0	0	**31,476.3**
Material resources consumption							
Secondary materials	kg	1,031.5	0	0	0	0	**1,031.5**
Renewable secondary fuels	MJ	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ	401.6	0	0	0	0	**401.6**
Recovered energy	MJ	0	0	0	0	0	**0**
Net fresh water (inputs minus outputs)	m^3	8.67	0	7.51 E-02	0.00	0	**8.75**
Waste disposed							
Non-hazardous waste disposed	kg	187.3	0	0	0	0	**187.3**
Hazardous waste disposed	kg	2.45	0	0	0	0	**2.45**
Radioactive waste *	kg	0.11	0	0	0.00	0	**0.11**
Other outputs							
Components for reuse	kg	0	0	0	0	0	**0**
Secondary material for recycling	kg	17.03	0	0	0	0	**17.03**
Materials for energy recovery	kg	0	0	0	0	0	**0**
Exported energy	MJ	0	0	0	0	0	**0**

* Radioactive waste comes from the nuclear power that feeds each plant's regional electric grid. The pipe contains no radioactive wastes.

TABLE 12 Impact results for 12" gravity cement mortar lined sewer pipe							
Results Categories		**Product Stage**	**Transport**	**Installation**	**Use**	**End-of-Life**	**Total**
Impact Assessment	**Units**	**A1-A3**	**A4**	**A5**	**B1-B6**	**C1-C4**	**A-C**
Global warming potential	kg CO_2-eq.	2,186.2	135.1	563.7	0.0	0	**2,885.0**
Acidification potential	kg SO_2-eq.	9.53	1.92	6.15	0.00	0	**17.60**
Eutrophication potential	kg N-eq.	5.52	0.116	0.508	0.00	0	**6.15**
Photochemical smog formation potential (Smog creation potential)	kg O_3-eq.	118.4	53.2	195.3	0.0	0	**366.9**
Ozone depletion potential	kg CFC11-eq.	5.52 E-04	5.59 E-09	1.19 E-06	0.00 E+00	0	**5.53 E-04**
Total primary energy consumption							
Non-renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	38,550.4	1,892.7	8,571.5	0.0	0	**49,014.6**
Non-renewable primary resources w/ energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	1,314.7	0	19.4	0.0	0	**1,334.0**
Renewable primary resources with energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Abiotic depletion potential for fossil resources	MJ	35,856.5	1,892.7	8,447.6	0.0	0	**46,196.8**
Material resources consumption							
Secondary materials	kg	1,704.0	0	0	0	0	**1,704.0**
Renewable secondary fuels	MJ	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ	639.3	0	0	0	0	**639.3**
Recovered energy	MJ	0	0	0	0	0	**0**
Net fresh water (inputs minus outputs)	m^3	14.40	0	7.51 E-02	0.00	0	**14.48**
Waste disposed							
Non-hazardous waste disposed	kg	277.8	0	0	0	0	**277.8**
Hazardous waste disposed	kg	4.07	0	0	0	0	**4.07**
Radioactive waste *	kg	0.17	0	0	0.00	0	**0.18**
Other outputs							
Components for reuse	kg	0	0	0	0	0	**0**
Secondary material for recycling	kg	31.77	0	0	0	0	**31.77**
Materials for energy recovery	kg	0	0	0	0	0	**0**
Exported energy	MJ	0	0	0	0	0	**0**

* Radioactive waste comes from the nuclear power that feeds each plant's regional electric grid. The pipe contains no radioactive wastes.

TABLE 13
Impact results for 24" pressurized cement mortar lined sewer pipe

Results Categories		Product Stage	Transport	Installation	Use	End-of-Life	Total
Impact Assessment	**Units**	**A1-A3**	**A4**	**A5**	**B1-B6**	**C1-C4**	**A-C**
Global warming potential	kg CO_2-eq.	5,152.8	384.2	42.3	6,582.3	0	**12,161.6**
Acidification potential	kg SO_2-eq.	22.55	5.50	0.46	28.93	0	**57.45**
Eutrophication potential	kg N-eq.	13.07	0.332	0.038	2.21	0	**15.65**
Photochemical smog formation potential (Smog creation potential)	kg O_3-eq.	280.3	153.0	14.7	328.6	0	**776.5**
Ozone depletion potential	kg CFC11-eq.	1.28 E-03	1.59 E-08	8.93 E-08	1.73 E-04	0	**1.45 E-03**
Total primary energy consumption							
Non-renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	91,310.1	5,370.5	643.2	124,042.1	0	**221,365.9**
Non-renewable primary resources w/ energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Renewable primary resources used as an energy carrier (fuel)	MJ (NCV)	3,189.7	0	1.5	7,154.8	0	**10,345.9**
Renewable primary resources with energy content used as material	MJ (NCV)	0	0	0	0	0	**0**
Abiotic depletion potential for fossil resources	MJ	84,960.7	5,370.5	633.9	87,360.6	0	**178,325.7**
Material resources consumption							
Secondary materials	kg	4,057.4	0	0	0	0	**4,057.4**
Renewable secondary fuels	MJ	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ	1,054.9	0	0	0	0	**1,054.9**
Recovered energy	MJ	0	0	0	0	0	**0**
Net fresh water (inputs minus outputs)	m^3	31.04	0	5.63 E-03	8.72	0	**39.77**
Waste disposed							
Non-hazardous waste disposed	kg	917.5	0	0	0	0	**917.5**
Hazardous waste disposed	kg	10.66	0	0	0	0	**10.66**
Radioactive waste *	kg	0.37	0	0	0.35	0	**0.72**
Other outputs							
Components for reuse	kg	0	0	0	0	0	**0**
Secondary material for recycling	kg	73.19	0	0	0	0	**73.19**
Materials for energy recovery	kg	0	0	0	0	0	**0**
Exported energy	MJ	0	0	0	0	0	**0**

* Radioactive waste comes from the nuclear power that feeds each plant's regional electric grid. The pipe contains no radioactive wastes.

TABLE 14 GWP of A3 Electricity for Each Pipe Size	
Global Warming Potential	
Pipe Size	Quantity (kg CO2-eq.)
6	98.2
8	138.6
12	232.1
16	375.8
24	639.6
30	882.3
36	1173.4

Additional Environmental Information

All materials making up the piping system (ductile iron, cement, coatings, and gaskets) 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. Each material complies with NSF/ANSI 61 standard (NSF International). There are no known hazardous or dangerous substances used in the production of these pipe products, nor are there known toxicity effects that occur in the use of the products.

Biogenic carbon. While there are minor amounts of biogenic material associated with the packaging of the pipes, the emissions associated with its disposition into a landfill after the construction phase are negligible and therefore have not been included in these results.

Emissions due to land use change. Land use change is not significant for any of the systems in this study, so its metric has not been included in this EPD.

Carbonation takes place during mortar production; this process has been accounted for in upstream process modeling.

The DIPRA Environmental Policy Compliance, Protection, Improvement

Our Commitment

The member companies of the Ductile Iron Pipe Research Association will uphold the following principles in all of their business activities through management commitment, employee involvement and allocation of adequate personnel and other resources:

- **Compliance:** We will manage our business activities to meet all governmental laws and regulations as well as internally established environmental, health, and safety requirements. Our goal is 100% compliance, 100% of the time.

- **Protection:** We will conduct our activities in a responsible manner to protect our employees, the public, and the environment by focusing on injury and illness prevention, pollution prevention and minimizing impacts and risks to the environment from our operations.

- **Improvement:** We will continually improve our environmental, health, and safety performance with a primary focus on setting and achieving goals and objectives.

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Abbreviations

CFC11-eq	trichlorofluoromethane equivalents	lb	pounds
CO_2-eq	carbon dioxide equivalents	m^3	cubic meters
ft	feet	mi	miles
fps	feet per second	MJ	megajoules
gal	gallons	MJ (NCV)	megajoules in net calorific value
gpm	gallons per minute	N-eq	nitrogen equivalents
hr	hour	O_3-eq	ozone equivalents
in	inches	SO_2-eq.	sulfur dioxide equivalents
kg	kilograms	tn.sh	short tons
kWh	kilowatt hours		

For more information contact DIPRA or any of its member companies.

Ductile Iron Pipe Research Association

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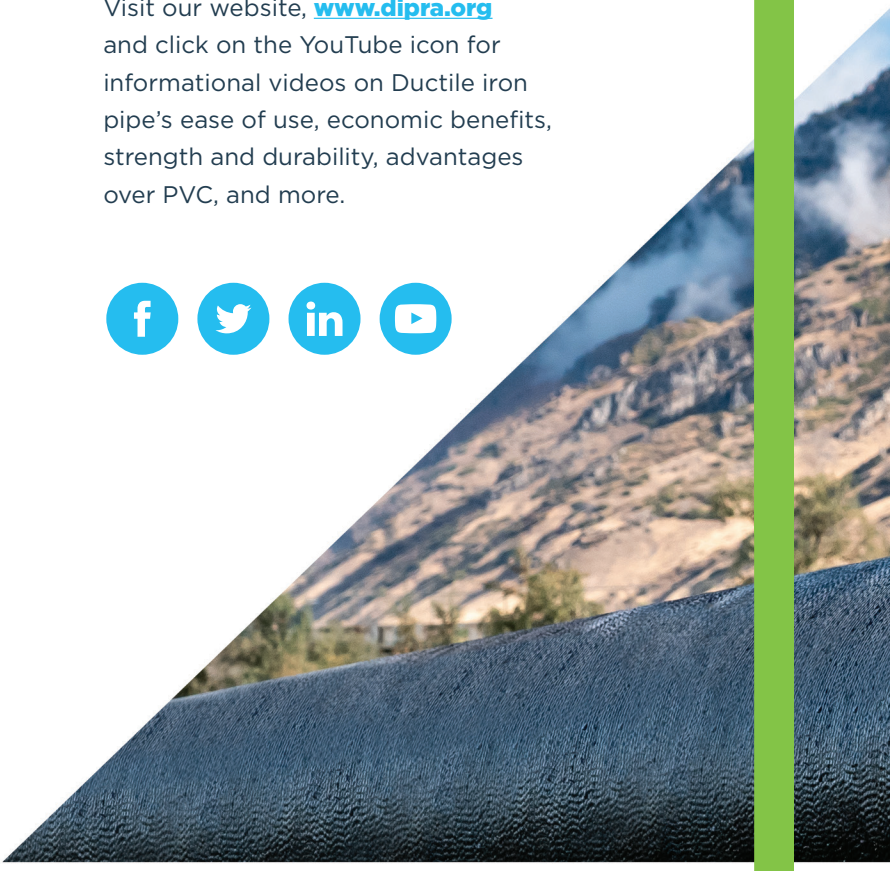

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