PIPA

INFRASTRUCTURE PIPE COMPARISON

Report for Plastics Industry Pipe Association of Australia Limited (PIPA)

JUNE 2025

REPORT FOR

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REVISION	REVISION DETAILS	AUTHOR	APPROVED BY	DATE APPROVED
Draft to client	1.0	Roanna Jones and Sazal Kundu	Sazal Kundu	10 May 2024
Draft after client re-view	2.0	Roanna Jones and Sazal Kundu	Sazal Kundu	15 July 2024
Draft after client re-view	3.0	Roanna Jones and Sazal Kundu	Sazal Kundu	20 August 2024
Draft after client re-view	4.0	Roanna Jones and Sazal Kundu	Sazal Kundu	13 September 2024
Draft after client re-view	5.0	Roanna Jones and Sazal Kundu	Sazal Kundu	19 September 2024
Final Report	6.0	Layla Valinoti	Cindy Bray	25 February 2025

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EXECUTIVE SUMMARY

The collective and urgent need to improve sustainable outcomes in all areas of our lives means assessing the systems and engineered products we rely on each day. As plastic pipes, fittings and systems play a vital role in many industries and are essential for the delivery and function of our everyday services and utilities across Australia, understanding their impact is especially important. The Plastics Industry Pipe Association of Australia (PIPA) has been collaborating with members, industry professionals and global counterparts since 1999 to develop best practice guidelines for the manufacture, installation and use of plastic pipeline systems. Future-focused values help advance the use of plastic pipes and fittings as long-life sustainable infrastructure.

PIPA is committed to providing a more sustainable solution through plastic pipes and fittings by measuring the impact across the whole life cycle, from manufacturing to use and disposal. As an efficient, safe and robust solution, plastic pipes have demonstrated superior sustainability performance and advantages when compared to ductile iron cement lined (DICL) pipes.

To better understand the advantages of plastic pipes and how they can contribute to a more sustainable future, PIPA engaged Edge Impact to carry out a Life Cycle Assessment (LCA) comparing plastic pipes to DICL pipes. By using third-party published data, our goal is to provide a credible and accessible comparative report for stakeholders to assist them in selecting pipe solutions for their civil infrastructure projects.

The scope of this comparative study includes cradle-to-gate with transport to site (modules A1-A4) in accordance with General Programme Instructions (GPI) v3.01 for the EPD Australasia System and EN 15804+A2 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products. Infrastructure pipes including Polyethylene (PE) (125 mm and 355 mm), Polyvinyl chloride M and O type (PVC-M, PVC-O) (100 mm and 300 mm) and Ductile Iron Cement Lined (DICL) (100 mm and 300 mm) were included in this study. The diameters of the PE pipes assessed in this study were larger to achieve functional equivalency to the DICL and PVC pipes, as the sizes of PE pipes are larger in application to match the internal bore size of DICL and PVC pipes. The declared unit is 1 m of pipe, assuming all pipe materials have the same service life and last the life of the asset (100 years).

The summary of this study are as follows:

- The plastic pipes considered in this study were produced from 100% virgin materials. By comparison, the DICL pipes used 40% recycled ductile iron. The inclusion of recycled content in the DICL pipes helped to reduce their environmental footprint.
- The assessed PE pipes had larger nominal diameters (125 mm and 355 mm) than the PVC and DICL pipes (100 mm and 300 mm), to reflect the larger diameter required in application to achieve functional equivalency. The nominal size of PE pipes is based on the outer diameter and is selected to align with the internal diameters of the PVC and DICL pipes. The results group all pipes according to the functional equivalency diameters of DN100 and DN300.
- Data for the DICL pipes was obtained from Saint-Gobain EPDs, developed in Europe. The location of the EPD is particularly significant for radioactive waste, as countries use varying

amounts of nuclear power. Australia primarily imports ductile iron pipes from India and China[1], both with significant nuclear power capacities of 55 and 22 operational reactors respectively, and a further 68 and 20 reactors under construction or planned[2]. The current nuclear facilities in China and India are comparable to Europe, with France, for example, having 56 operable reactors[3].

- Of the 13 impact categories compared, DN100 plastic pipes (PVC and PE) performed better in 9 categories, including global warming potential (GWP), acidification potential, eutrophication – freshwater, eutrophication – marine, eutrophication – terrestrial, photochemical ozone creation potential, use of net freshwater (FW), non-hazardous waste disposed, and radioactive waste disposed/stored.
- DN100 plastic pipes performed worse than DICL pipes in the hazardous waste disposed category.
- The ozone depletion potential of plastic pipes and DICL pipes at DN100 was found to be similar.
- Abiotic depletion potential (metals and minerals) and abiotic depletion potential (fossil fuels) have high levels of uncertainty due to the estimation of extractable reserves. As a result, the relative advantages of plastic pipes compared to DICL pipes at DN100 may be diminished in these categories. At DN300, it wasn't possible to conclusively state that plastic or DICL pipes were better than the other for these impact categories.
- At DN300, plastic pipes performed better in five categories including GWP, eutrophication – freshwater, photochemical ozone creation potential, use of net freshwater and radioactive waste disposed/stored.
- DN300 plastic pipes performed worse than DICL pipes in the hazardous waste disposal category.
- The DN300 plastic and DICL pipes had similar outcomes in the remaining five environmental impact categories of acidification potential, eutrophication – marine, eutrophication – terrestrial, ozone depletion potential and non-hazardous waste disposed.
- The relative environmental outcomes of the assessed pipes changed for several environmental impact categories, depending on the nominal diameter of the pipes.
- According to the Green Star Buildings Submission Guidelines[4], the weighting factor[5] for GWP and FW use is 25% each. The Infrastructure Sustainability Council (ISC) uses weighting for their material calculator with a GWP factor of 47.5%[6].
- As the DICL pipes weight per metre is higher compared to plastic pipes, the GWP for plastic pipes transport is expected to be lower than DICL pipes. There was insufficient Australian DICL data to draw reliable comparisons between the module A4 impacts of DICL pipes and plastic pipes.

The conclusions of this study are as follows:

- A comparative LCA study for plastic infrastructure pipes and DICL infrastructure pipes was successfully carried out for 13 midpoint impact indicators, prioritised by the Building Research Establishment (BRE)[7].
- The GWP and FW impact categories are considered most important when using an LCA for the built environment in Australia, and plastic pipes have lower impact than DICL pipes for these categories at DN100 and DN300.
- High radioactive waste generated in the production of DICL pipes is likely due to the use of nuclear energy to generate electricity in Europe.

The comparisons in this report are based on third-party EPD results. The referenced EPDs were developed in accordance with EN 15804+A2 and are aligned with ISO 14040 and ISO 14044. The comparative assertions in this report have not undergone the additional third-party review specified in ISO 14044. Accordingly, the results and interpretations should be regarded as indicative and interpreted with caution. The findings are based on the available data and the assumptions stated in the referenced EPDs.

1 Volza (2024) Ductile Iron Pipes In Imports in Australia - Market Size & Demand based on Import Trade Data, https://www.volza.com/p/ductile-iron-pipes-in/import/import-in-australia/
2 World Nuclear Association (2024) Asia's Nuclear Energy Growth, https://world-nuclear.org/information-library/country-profiles/others/asias-nuclear-energy-growth
3 World Nuclear Association (2024) Nuclear Power in France, https://world-nuclear.org/information-library/country-profiles/countries-a-f/france
4 Green Star Buildings Submission Guidelines, Version 1: Revision B, 10 December 2021
5 Normalisation and weighting are often used in comparative LCA to get a single environmental performance score. When the environmental impact values of a product are normalised with annual impacts caused by one citizen, the mathematical process is known as normalisation. The normalised values are then weighted to get a single environmental impact score. The weighting factors are determined based on the importance of environmental indicators. The EPD results were not transformed to single score in this report. This is because the EN 15804 + A2 complaint EPDs results are not available for normalisation and weighting.
6 ISCA (2018) ISv2.0 Materials Calculator Guideline, https://d3n8a8pro7vhmx.cloudfront.net/themes/5a72941f5ee54d4c43000000/attachments/original/1533001335/2018-02-21_ISCA_Materials_Guideline_Version_2.0_Rev_0.pdf?1533001335
7 Abbe, O. and Hamilton, L., (2017) BRE Global Environmental Weighting for Construction Products using Selected Parameters from EN 15804. BRE Global Ltd.: Hertfordshire, UK.

- The results show lower levels of radioactive waste for plastic pipes. This impact category is of lower concern in Australia as the radioactive waste values indicate its presence in the overseas supply chain. In the case of polypropylene and polyethylene pipes, nuclear energy-based electricity used to produce resins is the primary source of radioactive waste. The background LCA data used for resin productions indicates that nuclear energy-based electricity produced in China, Canada, Europe and the United States are the sources of radioactive waste values of plastic resin productions.
- The ozone depletion potential of PVC-O and PVC-M pipes is higher compared to PE or DICL pipes.

From this study, PIPA can build communications on the following basis:

- At the product stage (A1-A3), plastic pipes (PE and PVC) have demonstrated life cycle advantages in the highest priority environmental categories in Australia, including GWP and FW.
- The GWP to produce plastic pipes is lower compared to DICL pipes for both DN100 and DN300.
- The net fresh water used to produce plastic pipes is lower compared to DICL pipes for both DN100 and DN300.

However, from this study, PIPA can't say the following:

- Plastic pipes have, in general, superior environmental performance over DICL pipes.
- There's less waste generation in the production of plastic pipes compared to DICL pipes.
- There's less depletion of non-renewable resources (fossil and mineral resources) in the production of plastic pipes compared to DICL pipes.
- This study was conducted with the best available third-party technical environmental data and may be challenging to communicate to non-specialist or non-technical audiences and decision-makers. To make a simplified comparison, there's an option to calculate and present aggregated environmental impact (e.g. eco-points). Although both ISC and Green Star have versions of eco-points, they're defined using the old EPD standard (EN 15804 + A1), which isn't yet compatible with EPDs produced using the current standard (EN 15804 + A2).

1. INTRODUCTION

Plastic pipes play a critical role in many industries, including domestic infrastructure, civil construction, agriculture, mining and gas. They're robust and can have a service life of over 100 years, made from materials engineered to be recycled, safe and reliable.

With a growing number of comparable environmental impact data published for construction products in Australia and internationally, Environmental Product Declarations (EPDs) and other Life Cycle Assessment (LCA) based inventories are the main sources of product-based environmental data. However, there's a general lack of understanding amongst decision-makers on how to use this information in the form of credible and accessible guidelines.

PIPA is working to support Australia's broader community of users who benefit from using plastic pipes. This includes making it easier to access information that helps decision-makers and authorities select pipe solutions for their civil infrastructure projects.

Table 1 shows the characteristics of the infrastructure pipes selected for this comparative study. Larger PE pipe diameters were assessed to achieve functional equivalency of the pipes per metre, as PE pipe diameters are larger in application to match the internal bore size of PVC and DICL pipes. Results showing DN100 and DN300 refer to DN100 and 300 equivalents, with the actual diameters of PE pipe listed in Table 1.

Table 1 – Characteristics of selected pipes for the study

MATERIAL TYPE	DIAMETER	KG/M	INFORMATION SOURCE
Polyethylene (PE 100)	125	4.18	(Vinidex, Environmental Product Declaration Polyethylene Pipes, 2022)
	355	33.5	(Vinidex, Environmental Product Declaration Polyethylene Pipes, 2022)
Ductile Iron Cement Lined Pipes (DICL) PN35	100	17.28 (DI: 13.13; CML: 3.95; Other: ≈0.2)[8]	(Saint-Gobain, Environmental Product Declaration Pipe System Natural DN100, 2022)*
Ductile Iron Cement Lined Pipes (DICL) PN20	300	58.46 (DI: 45.77; CML: 12.09; Other: ≈0.6)[5]	(Saint-Gobain, Environmental Product Declaration Pipe System Natural DN300, 2022)
Modified PVC (PVC-M) PN16	100	3.07	(Iplex, Environmental Product Declaration PVC Pressure Pipes, 2022)
	300	24.4	(Iplex, Environmental Product Declaration PVC Pressure Pipes, 2022)
Bi-axially oriented PVC (PVC-O) PN16 MRS450	100	2.04	(Iplex, Environmental Product Declaration PVC Pressure Pipes, 2022)
	300	16.31	(Iplex, Environmental Product Declaration PVC Pressure Pipes, 2022)

* *The weight per metre was adjusted to align with the AS/NZS 2280 Standard. A correction factor was applied to environmental indicators in the Saint-Gobain EPD, as described in section 2: Goal and Scope.*

2. GOAL AND SCOPE

PIPA intends to demonstrate the data-driven sustainability performance of plastic pipes. The goal of this study is to develop a comparative life cycle assessment (LCA) based on third-party published data, providing easy access to information for authorities and other key decision-makers when selecting drainage pipe solutions. Furthermore, PIPA aims to demonstrate its leadership and commitment to sustainability through the design and communication of this LCA study. The final audience of this report includes the government, contractors, builders, designers and architects.

The scope of this comparative study includes the cradle-to-installation modules (A1-A5) in accordance with General Programme Instructions (GPI) v3.01 for the EPD Australasia System and EN 15804+A2 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products. The modules are:

The product stage system, which is comprised of:

- A1 – raw material supply
- A2 – transport of raw materials to the manufacturing site
- A3 – manufacturing

The transport component of construction, which is comprised of

- A4 – transport from manufacturing to the construction site

The infrastructure pressure pipes and sizes included in this comparison are as follows:

- Polyethylene (PE 100) (125 mm and 355 mm)
- Ductile Iron Cement Lined Pipes (DICL) PN35 (100 mm)
- Ductile Iron Cement Lined Pipes (DICL) PN20 (300 mm)
- Modified PVC (PVC-M) PN16 (100 mm and 300 mm)
- Bi-axially oriented PVC (PVC-O) PN16 MRS450 (100 mm and 300 mm)

Based on prioritisation developed by the Building Research Establishment (BRE)[9], the following 13 impact categories were used for the product stage (A1-A3) comparison of plastic and DICL infrastructure pipes:

1. Total global warming potential
2. Ozone depletion
3. Acidification
4. Eutrophication – aquatic freshwater
5. Eutrophication – aquatic marine
6. Eutrophication – terrestrial
7. Photochemical ozone formation
8. Abiotic depletion (metals and minerals)
9. Abiotic depletion (fossil resources)
10. Use of net freshwater
11. Hazardous waste
12. Non-hazardous waste
13. Radioactive waste

In addition, the indicator of GWP-total was used to evaluate the impact of downstream transport (A4).

Environmental data for the product stage (A1–A3) and downstream transport (A4) were sourced from Vinidex, Iplex and Saint-Gobain EPDs that conformed to EN 15804+A2 (Saint-Gobain, Environmental Product Declaration Pipe System Natural DN300, 2022; Saint-Gobain, Environmental Product Declaration Pipe System Natural DN100, 2022; Vinidex, Environmental Product Declaration Polyethylene Pipes, 2022; Iplex, Environmental Product Declaration PVC Pressure Pipes, 2022).

When used in Australia, DICL pipes are defined in the AS/NZS 2280 Standard and have a mean outside diameter based on imperial sizing. In contrast, the DICL pipes assessed with the Saint-Gobain EPD are defined by the European Standard EN 545 and based on metric measurements.

They also have other differences in key dimensions, including nominal wall thickness of the ductile iron component and cement mortar lining. As a result, there are slight differences in the amounts of ductile iron and cement mortar lining required to make a DICL pipe to AS/NZS 2280 versus EN 545 Standards, for the same nominal diameter.

To leverage the Saint-Gobain EPDs for DN100 and DN300 DICL pipes manufactured in Europe and provide an accurate comparison between AS/NZS 2280 DICL pipes and the equivalent PE and PVC pipes, a correction factor was applied to the environmental indicators. The correction factor, listed in Appendix A, introduces a small amount of uncertainty to the results, which should be considered when interpreting them.

9 Abbe, O. and Hamilton, L., (2017) BRE Global Environmental Weighting for Construction Products using Selected Parameters from EN 15804. BRE Global Ltd.: Hertfordshire, UK.

3. DECLARED UNIT AND MEASUREMENT OF COMPARISON

The declared unit is 1 metre of pipe, assuming all pipe materials have the same diameter and service life, and last for the life of the asset (100 years). The comparison was performed using information from published EPDs and LCA databases such as ecoinvent and AusLCI on the SimaPro software platform. The characterisation factors used to analyse background LCA data are consistent with EN 15804+A2 midpoint impact categories.

4. EPD PROCESS DIAGRAM AND BOUNDARIES

Figure 1, Figure 2 and Figure 3 show the lifecycle of Vinidex PE pipes, Saint-Gobain DICL pipes and Iplex PVC pipes, respectively. The dotted lines figures represent the system boundary (A1-A4) considered in this study, which identifies the aspects that lie inside or beyond the scope of the study and determines what to measure in the next steps.

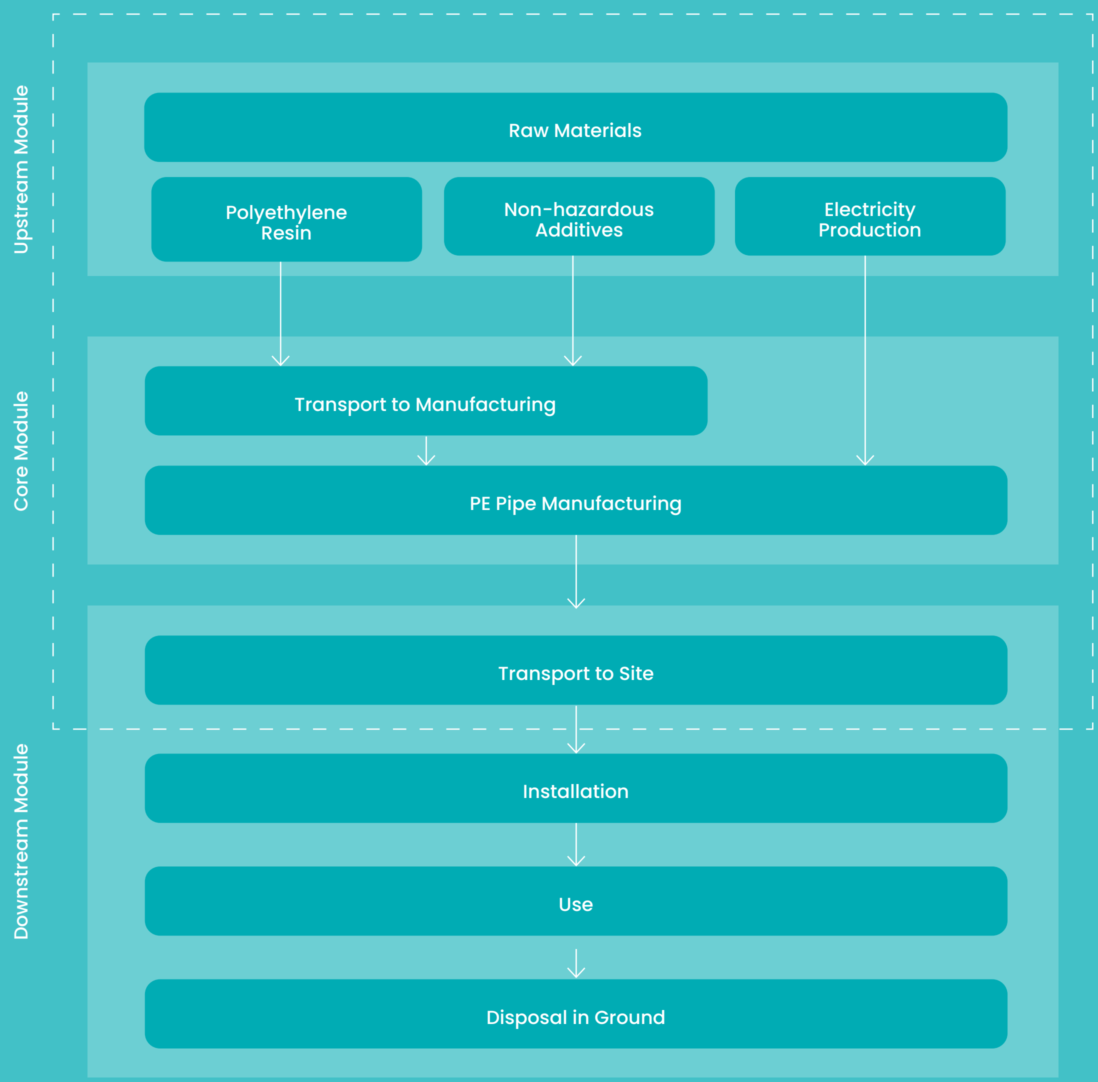

Figure 1: Product system diagram for PE Pipe (Vinidex, Polyethylene Pipes EPD, 2022)

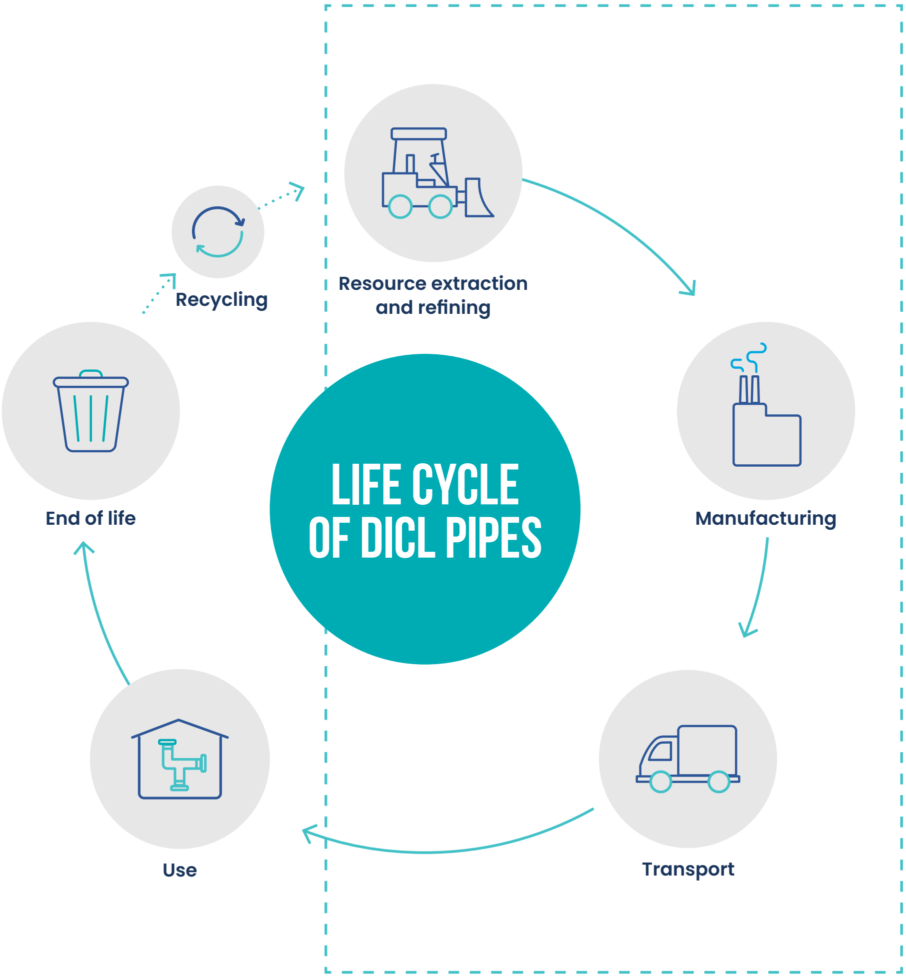

Figure 2: Life cycle diagram for DICL pipes (Saint-Gobain, Environmental Product Declaration Pipe System Natural DN100, 2022; Saint-Gobain, Environmental Product Declaration Pipe System Natural DN300, 2022)

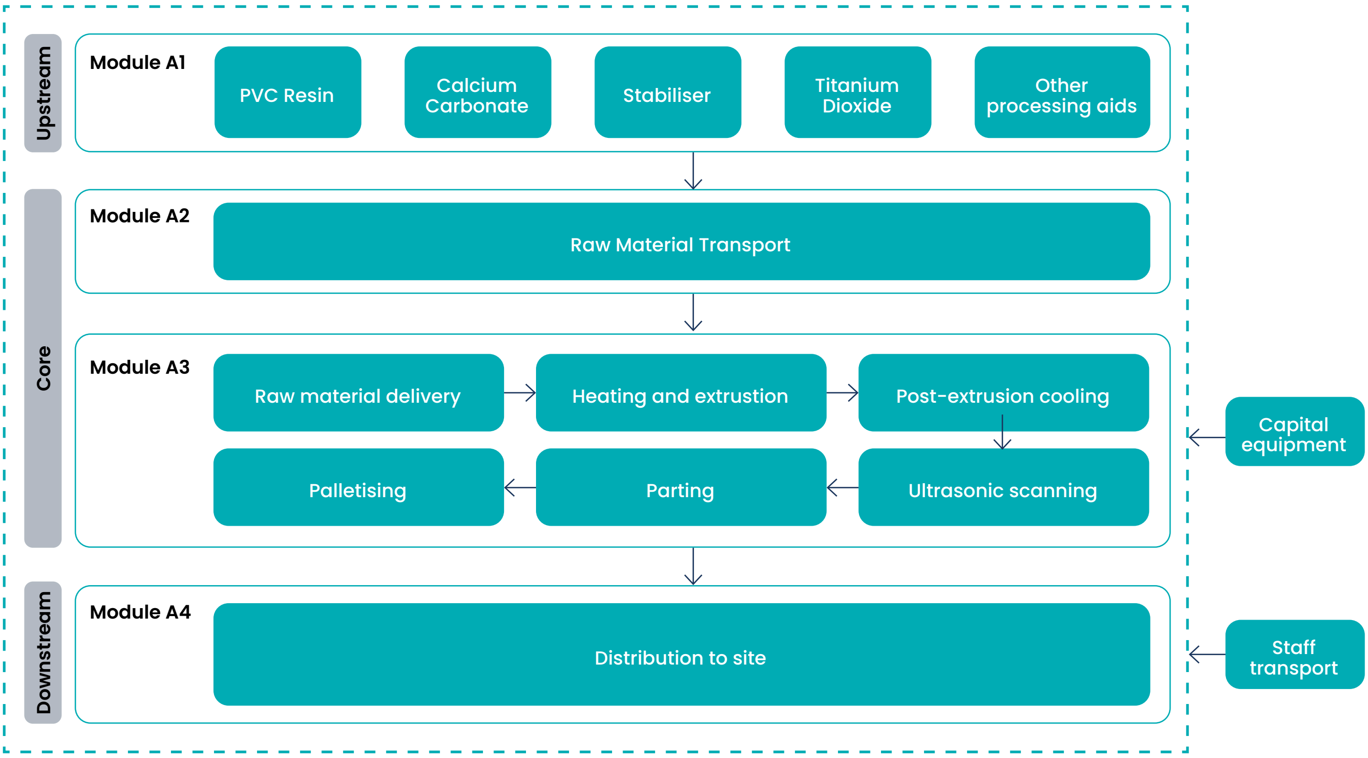

Figure 3: Product system diagram for PVC pipes (Iplex, Environmental Product Declaration PVC Pressure Pipes, 2022).

5. METHODOLOGY

The impact categories and indicators used in this comparative study are from the EPD standard EN15804+A2. According to a survey comprising 60 responses from expert and non-expert groups, Building Research Establishment (BRE)[10] decided on 13 EPD impacts and indicators to prioritise, shown in the table on the next page.

As the BRE study was based on the EN 15804+A1 standard of EPDs and the latest EPDs are based on the EN 15804+A2 standard, the following 13 indicators (Table 2) were chosen in this comparative study.

It should be noted that the results of abiotic depletion potentials (both resource and elements) have a high level of uncertainties. These originate from the uncertainties on the estimation of extractable reserves. In the case of abiotic depletion potential – metals and minerals, there are additional uncertainties in the scattered concentrations of elements (L. van Oers; A. de Koning; J.B. Guinée; G. Huppes, 2002).

Abiotic resource depletion is a highly debated impact category because there's no universally accepted method to derive characterisation factors. This uncertainty arises from several factors, including resource reserves depending on future technologies for extraction, differing and valid definitions of depletion, and methods for quantifying depletion based on assumptions about future resource availability, demand, and technology[11].

A breakdown of product stage (modules A1-A3) impacts was conducted to determine the impacts associated with key material components of the pipes, with environmental data for components of PE and PVC pipes acquired from the associated EPD data.

As the Saint-Gobain EPDs for DICL pipes didn't provide individual component data, assumptions were made to perform a breakdown analysis. It also wasn't reliable to acquire third party environmental impact data associated with ductile iron, due to many factors affecting environmental outcomes, including proportion of recycled content, source of the iron, and manufacturing location.

As a result, impacts associated with zinc[12], the ethylene propylene diene monomer (EPDM)[13] gasket and the cement mortar lining were calculated using data from SimaPro and a cement mortar EPD (Readymix Industries, 2022), with an assumption that the remaining impacts are associated with ductile iron. The proportion of zinc and EPDM at DN100 and 300 is between 0-1% of the pipe mass (Table 4), and was assumed to be 0.2 and 0.6 kg/m at DN100 and 300, respectively, as per Appendix A. As third-party data was incorporated to interpret the Saint-Gobain data, the DICL breakdowns are intended to be representative of general impacts and should be interpreted with caution.

10 Abbe, O. and Hamilton, L., 2017. BRE Global Environmental Weighting for Construction Products using Selected Parameters from EN 15804. BRE Global Ltd.: Hertfordshire, UK.
11 Van Oers L, Guinée J. The Abiotic Depletion Potential: Background, Updates, and Future. Resources. 2016; 5(1):16. https://doi.org/10.3390/resources5010016
12 Simapro process Zinc coat, pieces {RoW}, zinc coating, pieces (of project Ecoinvent 3).
13 Simapro process Synthetic rubber {RoW}, synthetic rubber production (of project Ecoinvent 3).

Table 2 – Life cycle impact, resource and waste assessment categories, measurements and methods in accordance with EN 15804+A2

IMPACT CATEGORY	ABBREVIATION	MEASUREMENT UNIT	ASSESSMENT METHOD AND IMPLEMENTATION
Total global warming potential	GWP - Total	kg CO_2 equivalents (GWP100)	Baseline model of 100 years of the IPCC based on IPCC 2013
Acidification potential	AP	mol H^+ eq.	Accumulated Exceedance, Seppälä et al. 2006, Posch et al., 2008
Eutrophication – aquatic freshwater	EP - freshwater	kg P equivalent	EUTREND model, Struijs et al., 2009b, as implemented in ReCiPe
Eutrophication – aquatic marine	EP - marine	kg N equivalent	EUTREND model, Struijs et al., 2009b, as implemented in ReCiPe
Eutrophication – terrestrial	EP - terrestrial	mol N equivalent	Accumulated Exceedance, Seppälä et al. 2006, Posch et al.
Photochemical ozone creation potential	POCP	kg NMVOC equivalents	LOTOS-EUROS, Van Zelm et al., 2008, as applied in ReCiPe
Abiotic depletion potential (metals and minerals)*	ADPE	kg Sb equivalents	CML (v4.1)
Abiotic depletion potential (fossil fuels)*	ADPF	MJ net calorific value	CML (v4.1)
Ozone depletion potential	ODP	kg CFC 11 equivalents	Steady-state ODPs, WMO 2014
Use of net fresh water	FW	m^3	ReCiPe 2016
Hazardous waste disposed	HWD	kg	EDIP 2003 (v1.05)
Non-hazardous waste disposed	NHWD	kg	EDIP 2003 (v1.05)[14]
Radioactive waste disposed/stored[15]	RWD	kg	EDIP 2003 (v1.05)

* *Disclaimer – The results of these environmental impact indicators shall be used with care as the uncertainties on these results are high or as there's limited experience with the indicator.*

14 Calculated as sum of Bulk waste and Slags/ash.

15 Radioactive waste is a concern for the countries/regions where electricity is produced from nuclear power plants. This impact category is of low concern in Australia as the radioactive waste values in the LCA of Australian products indicate its presence in overseas supply chain. In the case of polypropylene and polyethylene pipes, nuclear energy-based electricity used in the production of resins is the primary source of radioactive waste. The background Global LCA data, used for resin productions, indicates that nuclear energy-based electricity produced in China, the USA, Canada and Europe are the sources of radioactive waste values of plastic resin productions. However, it should be noted that both PP and PE resins aren't sourced from these countries.

6. PRODUCT INFORMATION

This section presents information related to the products considered for this study. The following tables provide detailed information about the materials used to produce pipes. Recycled plastic wasn't considered in the manufacturing stage, as most plastic pipes are made with thermoplastics. This means they're 100% recyclable and have a service life of 100 years. However, due to their long life, there's a limited amount of suitable recycled material available to use in the manufacturing stage. The DICL pipes were manufactured with 40% recycled ductile iron content, as detailed in the EPDs[16].

Table 3 – Material components of PE pipes (Vinidex, Polyethylene Pipes EPD, 2022)

FEED MIX	MASS (%)
Polyethylene polymer	96 – 98
Carbon black	2 – 3
Proprietary additives	0 – 1

Table 4 | Material components of DICL pipes, based on Saint-Gobain EPD data corrected to better represent Australian Standards (Appendix A) (Saint-Gobain, Environmental Product Declaration Pipe System Natural DN100, 2022; Saint-Gobain, Environmental Product Declaration Pipe System Natural DN300, 2022)

FEED MIX INGREDIENT	MASS (%)	
	DN100	**DN300**
Ductile iron	76.0	78.3
Blast furnace cement mortar	22.9	20.7
BioZinalium	0 – 1	0 – 1
Gasket / EPDM	0 – 1	0 – 1

16 Saint-Gobain 100 mm and 300 mm DICL pipe EPDs reported that the ductile iron product component contains 40% recycled content. Australian metals recycling rates are high (87%) (The Department of Climate Change, Energy, the Environment and Water, 2023). DICL pipes with a higher proportion of recycled material may have better environmental outcomes.

Table 5 – Material components of PVC pipes (Iplex, Environmental Product Declaration PVC Pressure Pipes, 2022)

FEED MIX COMPONENT	MASS (%)	
	PVC-M	**PVC-O**
PVC resin	88.77	93.33
Filler	1.33	1.87
Organic stabiliser	3.20	3.36
Titanium dioxide white	1.33	1.40
Processing aid	0.67	0
Chlorinated polyethylene (CPE)	4.66	0
Pigment	0.04	0.05

7. RESULTS AND INTERPRETATIONS

This section presents the principal findings of the comparative infrastructure pipes LCA study. The comparison of results in the Product Stage (modules A1-A3) are presented in section 7.1. After discussing product stage indicators, a comparison of all indicators is summarised, and a brief conclusion is drawn. A breakdown of impacts is provided for DN100 and DN300 plastic and DICL pipes. The GWP total of the downstream transportation stage (module A4) is presented in section 7.2.

The Vinidex PE and Iplex PVC EPD results for product stage and downstream transportation were translated from per kg product/primary ingredients to per metre of pipe. As stated in the respective EPDs, the weights per metre of PE, PVC-M and PVC-O pipes were 4.18, 3.07 and 2.04 kg/m at DN100 and 33.50, 24.40 and 16.31 kg/m and DN300. This conversion allows for the differences of environmental impacts between plastic pipes and DICL pipes in the application stage to be observed. Environmental impacts for Saint-Gobain DICL pipes were reported on a per metre basis in the EPDs.

7.1. PRODUCT STAGE (MODULES A1-A3)

7.1.1. Total global warming potential

Global warming potential (GWP) values are used to compare the climate change effects of greenhouse gases (GHG). The GWP values represent how much heat GHG can trap in the atmosphere and contribute to climate change. The GWP indicator includes GHG emissions from three sources:

1. fossil fuels;
2. bio-based resources; and
3. land use change.

The GWP values are calculated as carbon dioxide equivalents (CO_2-eq). Usually, a 100-year gas residence time in the atmosphere is accounted for in the calculation of GWP values.

As can be seen from Figure 4, plastic drainage pipes have a lower carbon footprint compared to ductile iron infrastructure pipes.

For DN100, PE, PVC-M and PVC-O pipes emit 13, 10 and 7 kg CO_2 eq. per metre pipe, respectively, while DICL emits 37 kg CO_2 eq. per metre pipe. For DN300, PE, PVC-M and PVC-O pipes emit 103 and 81 and 53 kg CO_2 eq. per metre pipe, respectively, while DICL emits 126 kg CO_2 eq. per metre pipe.

For DN100, DICL pipes have the highest impact with 5.6 times greater GWP impacts compared to the PVC-O, the pipe with lowest impact. However, as DICL represents an increase in impact of 2.4 times compared to PVC-O, this difference isn't as large when considering DN300.

To give some perspective on these numbers, let's consider driving a car for a shopping trip. According to data available on the National Transport Commission (NTC) website, passenger cars and SUVs emit 146.5 g/km[17]. If a shopper needs to drive their car for a total of 10 kilometres for a trip, the shopper emits 1.47 kg CO_2 eq. If we consider their shopping behaviour, the production of 1m DN100 PVC-O pipe is equivalent to 4.5 shopping trips, and the production of 1m DICL pipe is equivalent to 25 shopping trips.

GWP-total breakdown

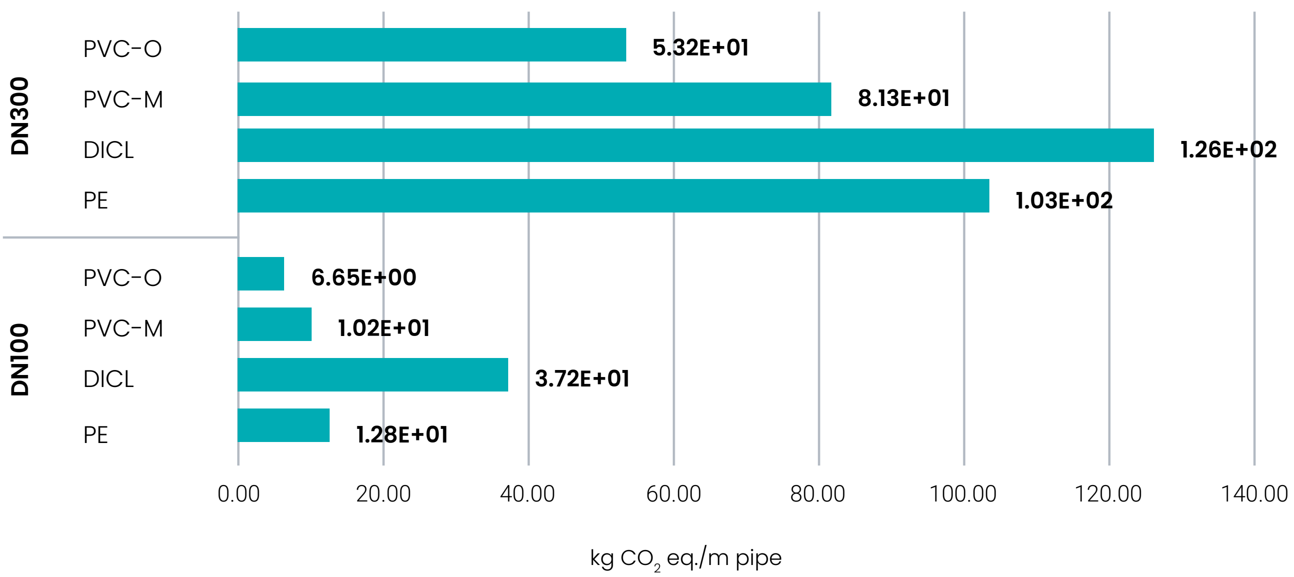

Figure 4: GWP-total comparison of plastic pipes with DICL pipes

17 National Transport Commission (2021) Light Vehicle emissions intensity in Australia, https://www.ntc.gov.au/sites/default/files/assets/files/Carbon%20Dioxide%20Emissions%20Intensity%20for%20New%20Australian%20Light%20Vehicles%202021.pdf

For DICL pipes, the impacts at DN100 and DN300 do not scale linearly according to weight, as they did for PE and PVC pipes. This is because separate EPDs were required for the DICL pipes at DN100 and DN300, where PE and PVC pipe data scaled on a per kilogram basis. According to the Saint-Gobain EPD data for DICL pipes, the weight per metre of pipe doesn't scale uniformly with its diameter. For example, as the diameter scales at a factor of 3, the weight per metre scales at a factor of 3.8. The percentage of ductile iron by pipe weight also increases from 78.8% at DN100 to 82.6% at DN300, so the DICL results change significantly across multiple impact factors at DN100 and DN300 when compared to the PE and PVC results, which scaled predictably.

The breakdowns of product stage GWP-total values for DICL, PE and PVC pipes are presented in Figure 5, Figure 6 and Figure 7. As a small portion of GWP-total contributions for DICL pipes originate from the cement lining, zinc and gasket, the ductile iron component was estimated to contribute the largest proportion of GWP-total impacts. As described in Methodology, the breakdown results of Saint-Gobain should be interpreted with caution due to uncertainty over a lack of available data. For plastic pipes, most GWP-total contributions originate from resin production (PVC/PE resin), with the remainder from environmental impacts associated with the production of additives, upstream transport, manufacturing energy and waste.

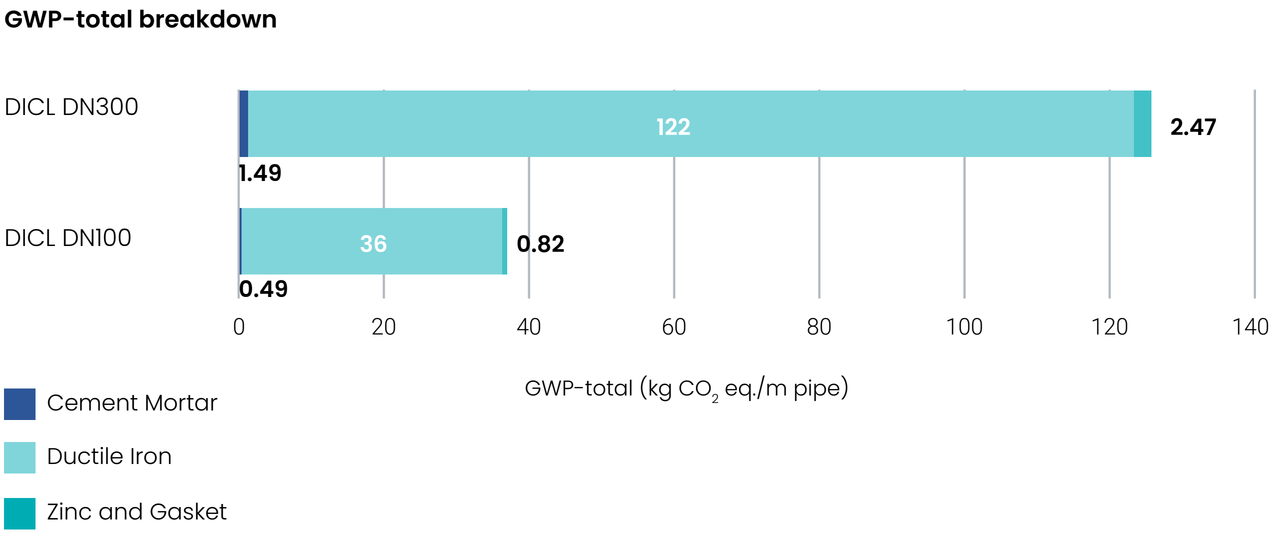

Figure 5: The breakdown of GWP-total of DICL pipes

GWP-total breakdown DN100

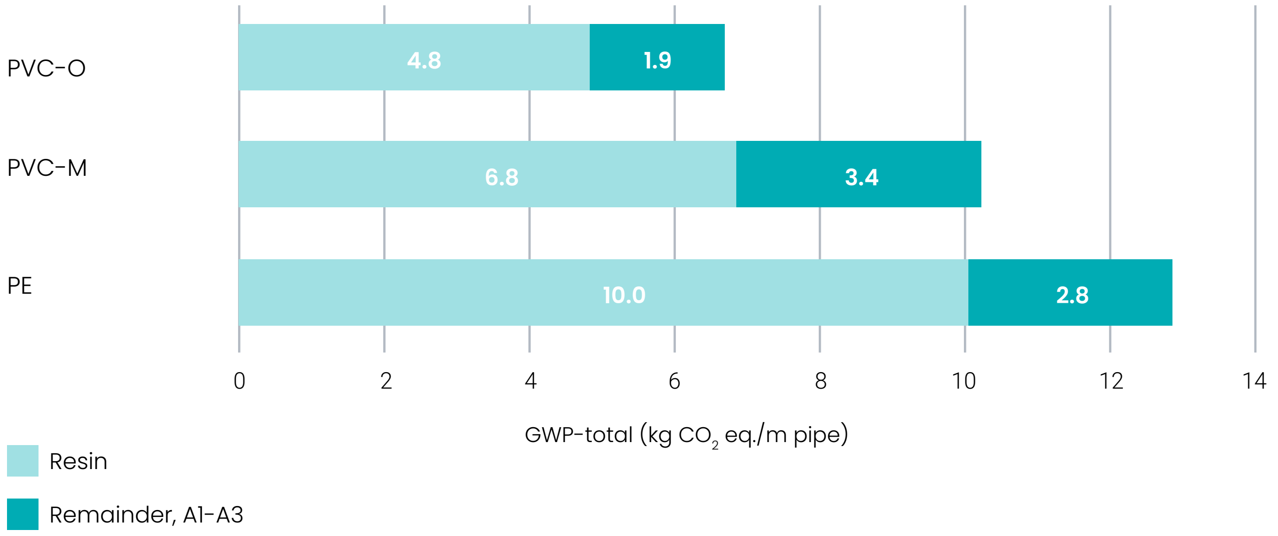

Figure 6: The breakdown of GWP-total of plastic pipes for the size of DN100

GWP-total breakdown DN300

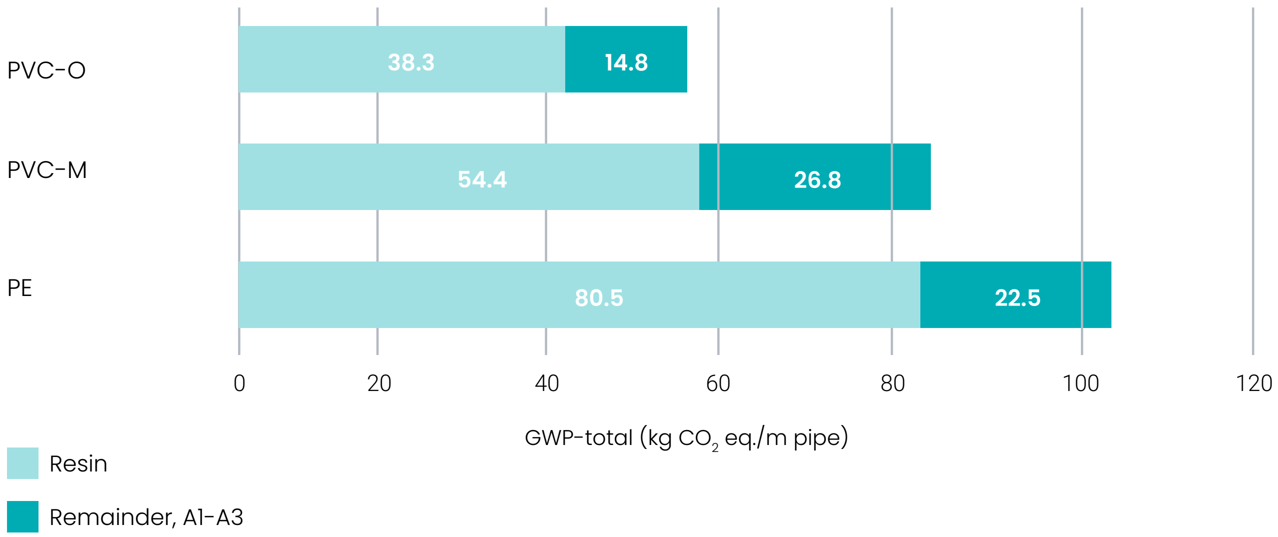

Figure 7: The breakdown of GWP-total of plastic pipes for the size of DN300

7.1.2. Ozone depletion potential (ODP)

The ozone layer sits in the upper atmosphere (the stratosphere) of our planet. Anthropogenic release of chlorinated and brominated chemicals, such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and halons (often termed as ozone depleting substances or ODS) to the atmosphere causes damage to the ozone layer. While the use of many ODS has been restricted or phased out via the establishment of the Montreal Protocol[18], there are existing refrigeration systems and insulation foams that release ODS to the atmosphere. The ozone depletion potential (ODP) indicator measures the release of chlorinated and brominated chemicals equivalent to CFC-11 (trichlorofluoromethane).

Figure 8 shows ODP comparison of plastic pipes and DICL pipes. The production of PVC-M and PVC-O pipes has significantly higher ODP compared to DICL and PE pipes in both diameters. In 2019, the total Australian ODP-weighted emissions of ODS controlled by the Montreal Protocol accounted for 1.1 kilo tonnes[19]. This equates to 0.04 ODP weighted emissions per capita in that year. Using these 2019 results as a benchmark, the ODP values of DN100 and DN300 plastic pipes are significantly lower than that of yearly ODP-weighted emissions per capita.

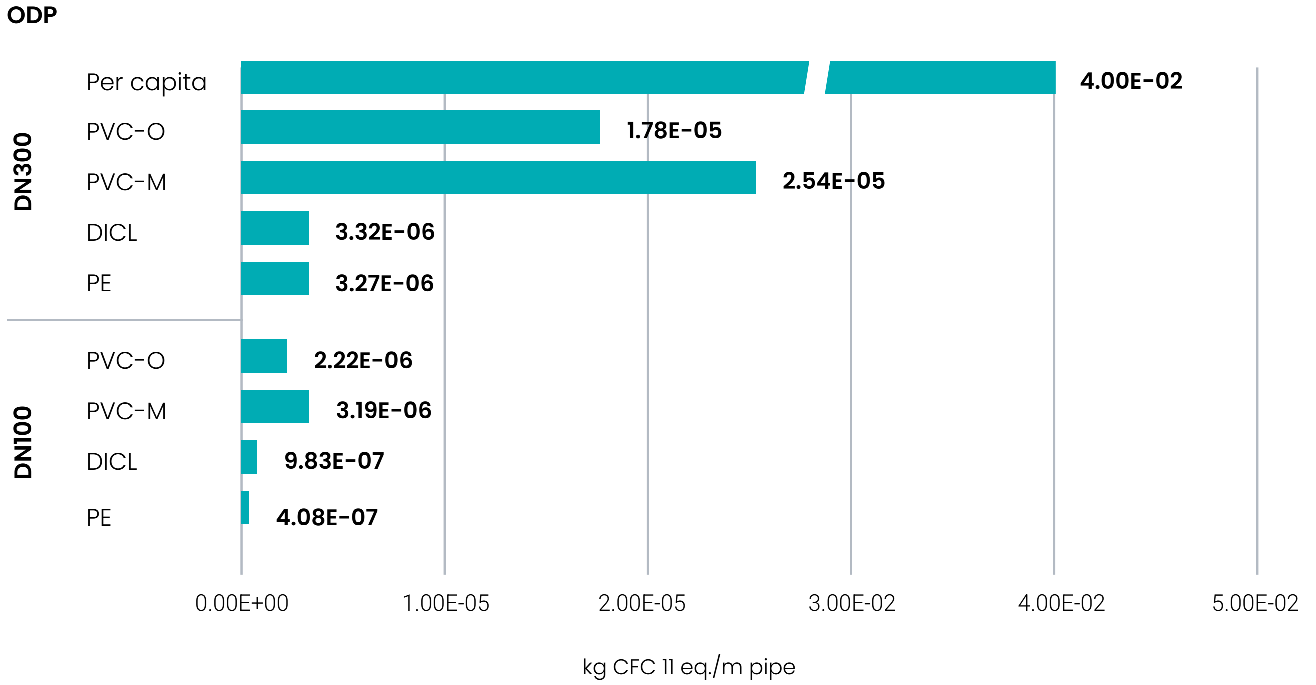

Figure 8: ODP comparison of plastic pipes with DICL pipes with Australian ODP per capita emissions in 2019.

18 United Nations (2024) The Montreal Protocol, https://www.unep.org/ozonaction/who-we-are/about-montreal-protocol

19 Dunse, B., Derek, N., Fraser, P. and Krummel, P., 2021. Australian and Global Emissions of Ozone Depleting Substances, Report prepared for the Australian Government Department of Agriculture, Water and the Environment. Tech. Rep., CSIRO Oceans and Atmosphere, Melbourne, Australia, iii, 57 pp., https://www.agriculture. gov.au/sites/default/files/documents/australian-global-emissions-ozone-depleting-substances.pdf (last access: 06 June 2023).

Figure 9, Figure 10 and Figure 11 show the breakdown of ODP for the product stage of plastic and ductile iron pipes. For DICL pipes, the ductile iron component had the greatest impact on the ODP. For plastic pipes, the majority of ODP originates from resin production. Further analysis shows that the electricity used in the production of PE resins has the highest ODP contribution to the resin's impact. While the use of grid electricity is outside of the plastic pipe industry's control, this finding suggests that using renewable energy can reduce its environmental impact. Relative to the other pipes, PVC had a large ODP, largely due to the use of polyvinyl chloride as a resin material during module A1.

Finding the root source of ODS in the LCA background database can be difficult. While the Montreal Protocol restricts the production and use of ODS, some may be produced and leaked during the manufacture of other important chemicals, creating an ODP impact in the production chain[20].

ODP breakdown

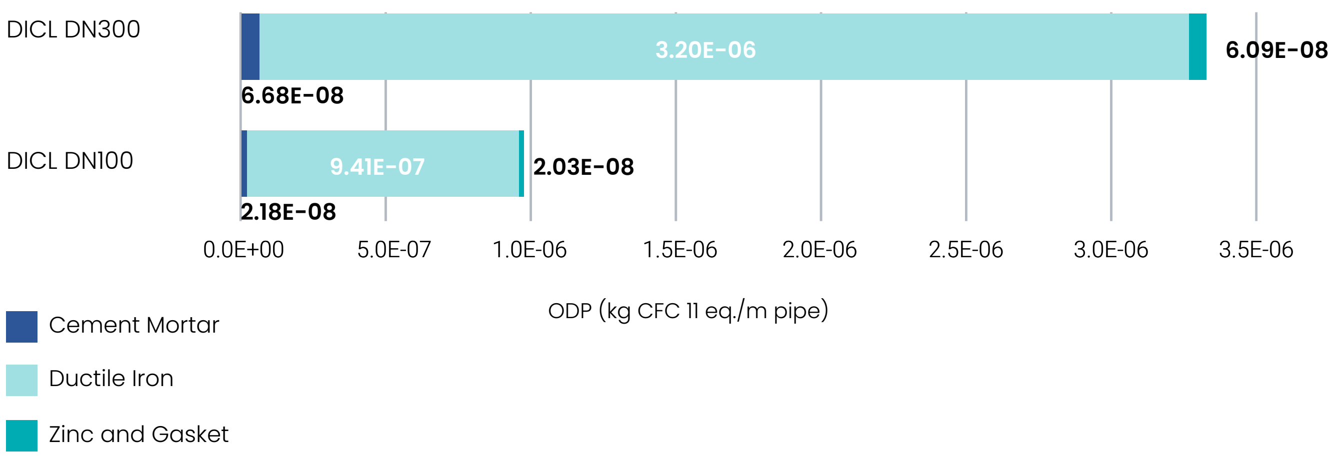

Figure 9: The breakdown of ODP of DICL pipes

20 Western, L., Laube, J., (2023) Countries agreed to ban ozone-depleting chemicals in the 1980s – but we found five CFCs increasing to record levels in the atmosphere, https://theconversation.com/countries-agreed-to-ban-ozone-depleting-chemicals-in-the-1980s-but-we-found-five-cfcs-increasing-to-record-levels-in-the-atmosphere-202925

ODP-total breakdown DN100

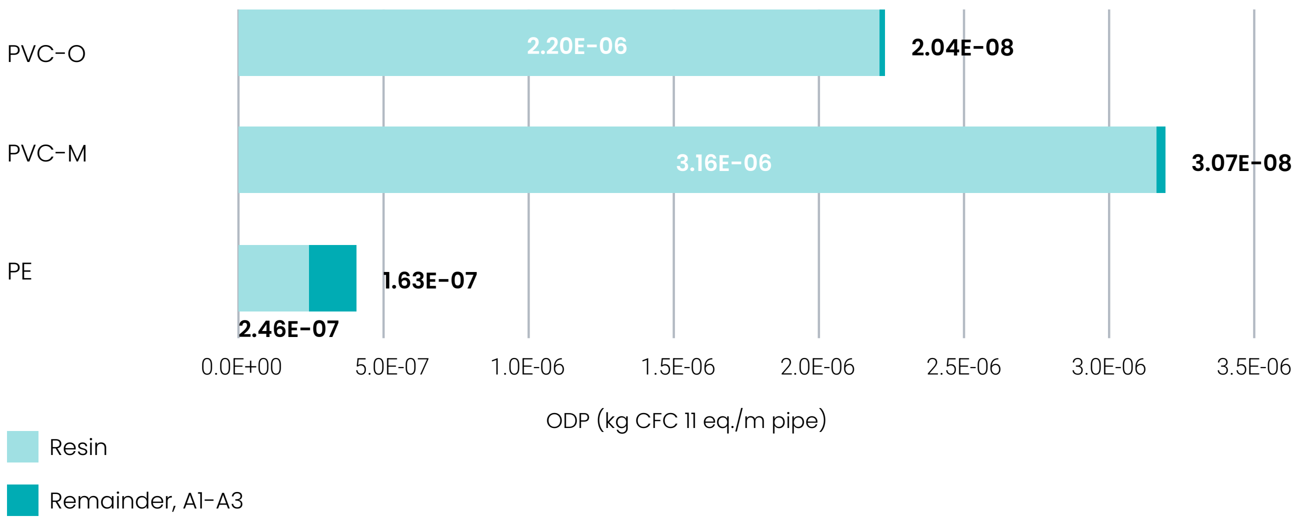

Figure 10: The breakdown of ODP of plastic pipes for the size of DN100

ODP-total breakdown DN300

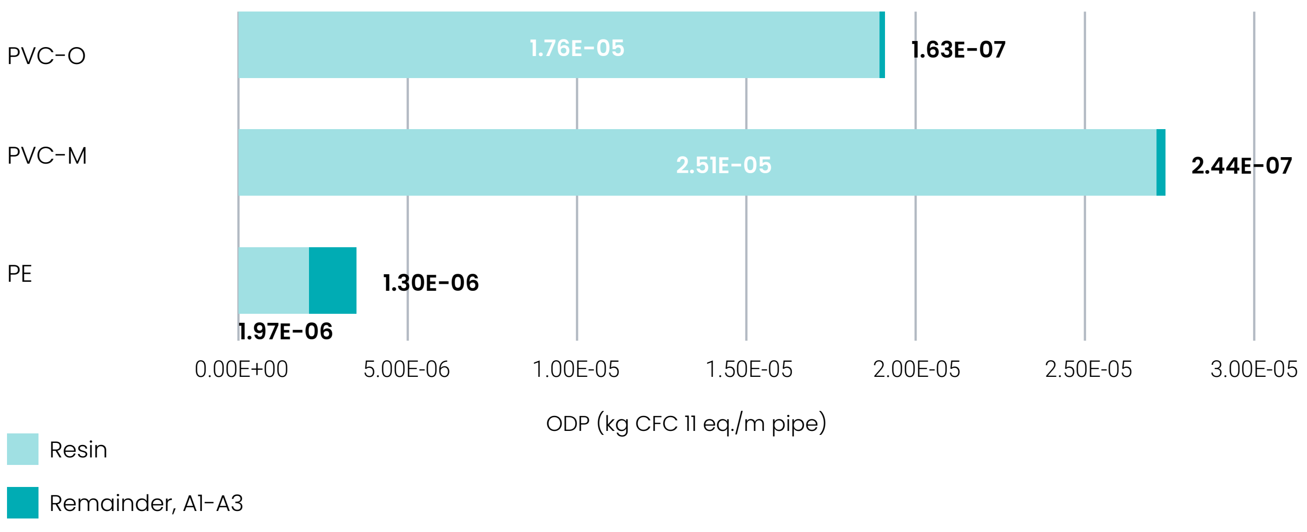

Figure 11: The breakdown of ODP of plastic pipes for the size of DN300

7.1.3. Acidification

The acidification indicator measures the potential acidification of soils and water due to the release of acid gases, including nitrogen oxides and sulphur oxides. The well-known source of these gases' emissions is the combustion of fossil fuels. When these acid gases react with water in the atmosphere, they form an acid that decreases the pH value of rainwater and fog. Depending on the concentration of acid in the rainwater and fog, the damage to ecosystems varies.

For DN300, the acidification potential (AP) of the PVC-M and PE plastic pipes exceeded the impacts of DICL and PVC-O pipes (Figure 12). In contrast, DN100 DICL pipes had the largest AP impacts compared to plastic pipes. At both diameters, PVC-O pipes had the lowest AP impact.

Figure 13, Figure 14 and Figure 15 show the breakdown of acidification for the product stage of the pipes. In the case of DICL pipes, the iron component contributed the most to acidification potential. For plastic pipes, plastic resin production is the primary source of acidification potential.

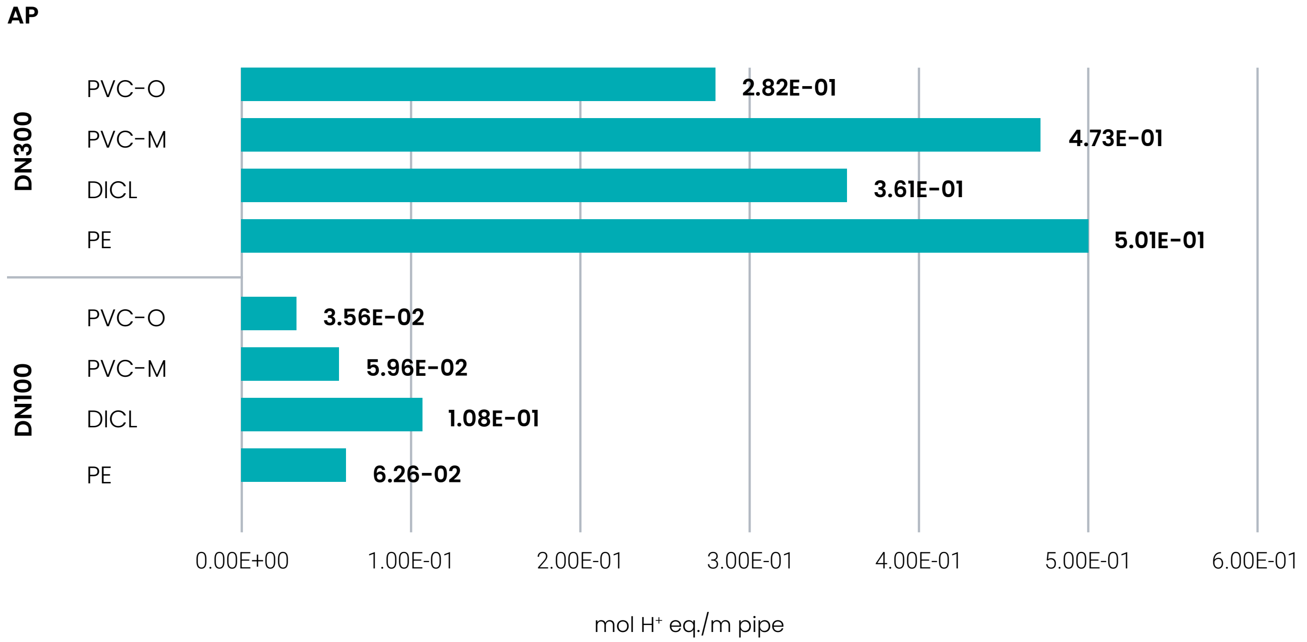

Figure 12: Acidification comparison of plastic pipes with DICL pipes

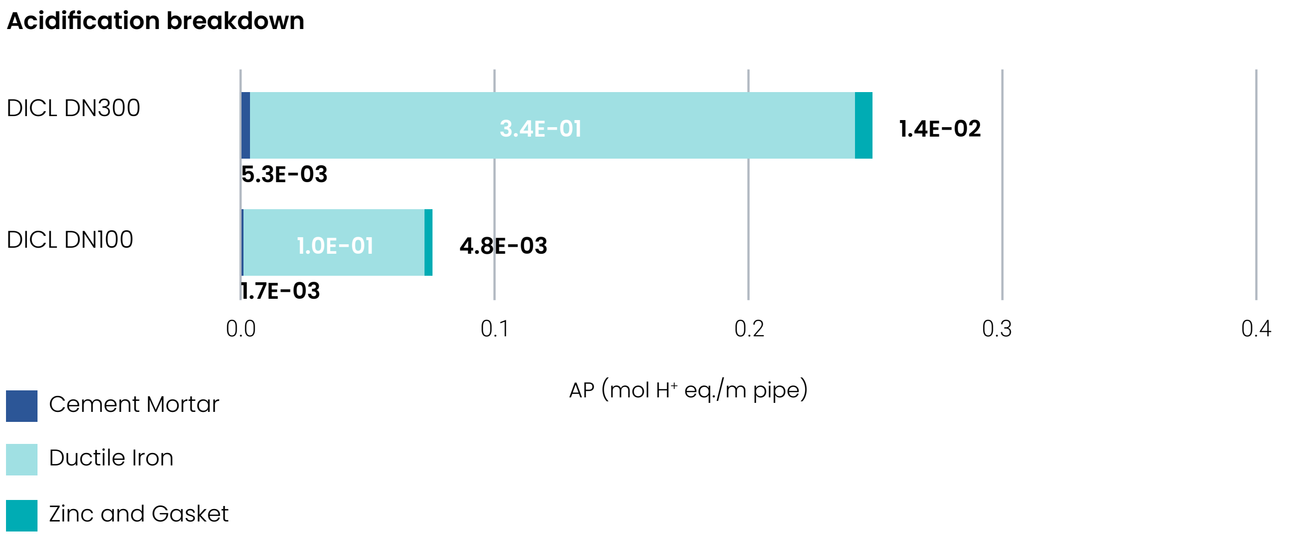

Figure 13: The breakdown of acidification of DICL pipes

Acidification breakdown DN100

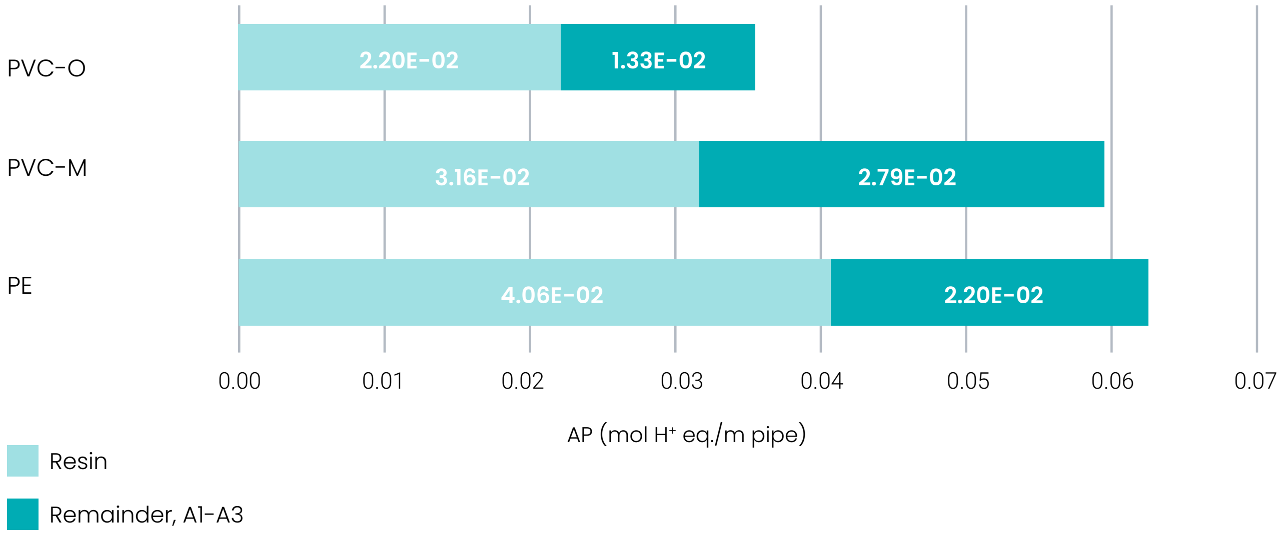

Figure 14: The breakdown of acidification of plastic pipes for the size of DN100

Acidification breakdown DN300

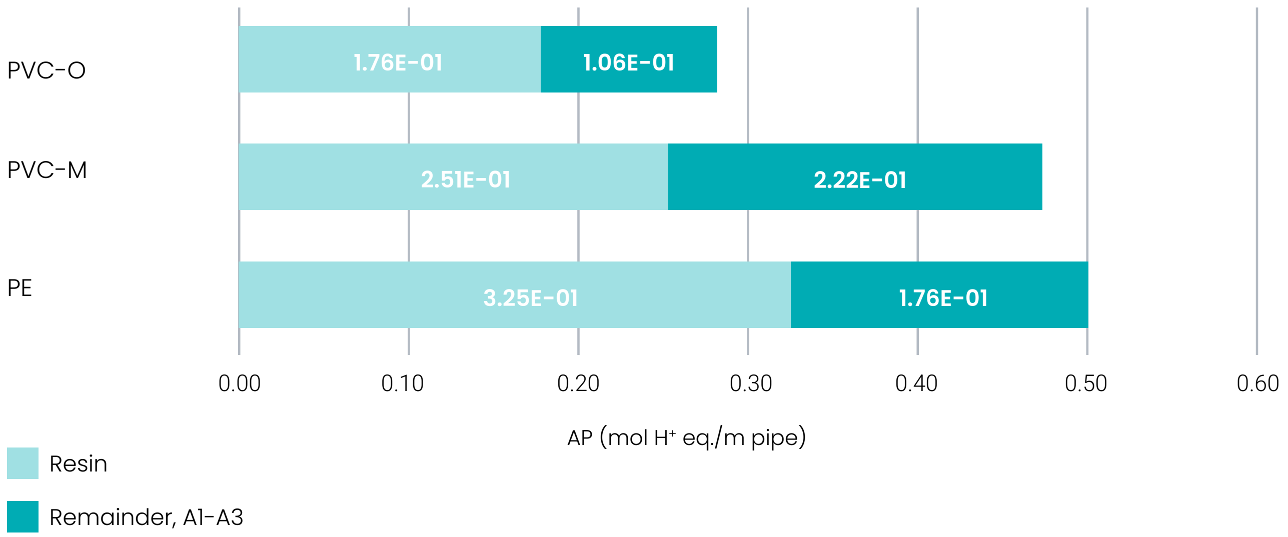

Figure 14: The breakdown of acidification of plastic pipes for the size of DN100

7.1.4. Eutrophication potential (EP) – aquatic freshwater

The discharge of plant nutrients, such as nitrates and phosphates, into freshwater bodies impacts the ecosystem. The nutrient enrichment in water bodies leads to excessive growth of algae, resulting in a reduction of oxygen within the water. This makes it difficult for aquatic organisms to survive. Species that survive only in low-nutrient environments in water can die due to eutrophication. Common sources of nitrates and phosphates include the production of nitrogen oxides from the combustion of fossil fuels and biomass, and the use of nitrogen and phosphorous based fertilisers in agricultural lands.

Figure 16 compares the freshwater eutrophication of plastic pipes and DICL pipes. As demonstrated, plastic pipes generate approximately 80% less EP emissions for DN100, compared to DICL. At DN300, this decreases to 51-65%. Figure 17 shows the breakdown of freshwater eutrophication for DICL pipes, with iron having the largest impact on EP-freshwater in this case. For plastic pipes (Figure 18 and Figure 19) demonstrate most of the freshwater eutrophication originates from plastic resin production.

According to EF 3.0 normalisation software (November 2019)[21], the freshwater eutrophication per capita (global average) per year is 1.607 kg P eq. The freshwater eutrophication values of plastic pipes and DICL pipes was compared to this benchmark in Figure 16.

EP-freshwater

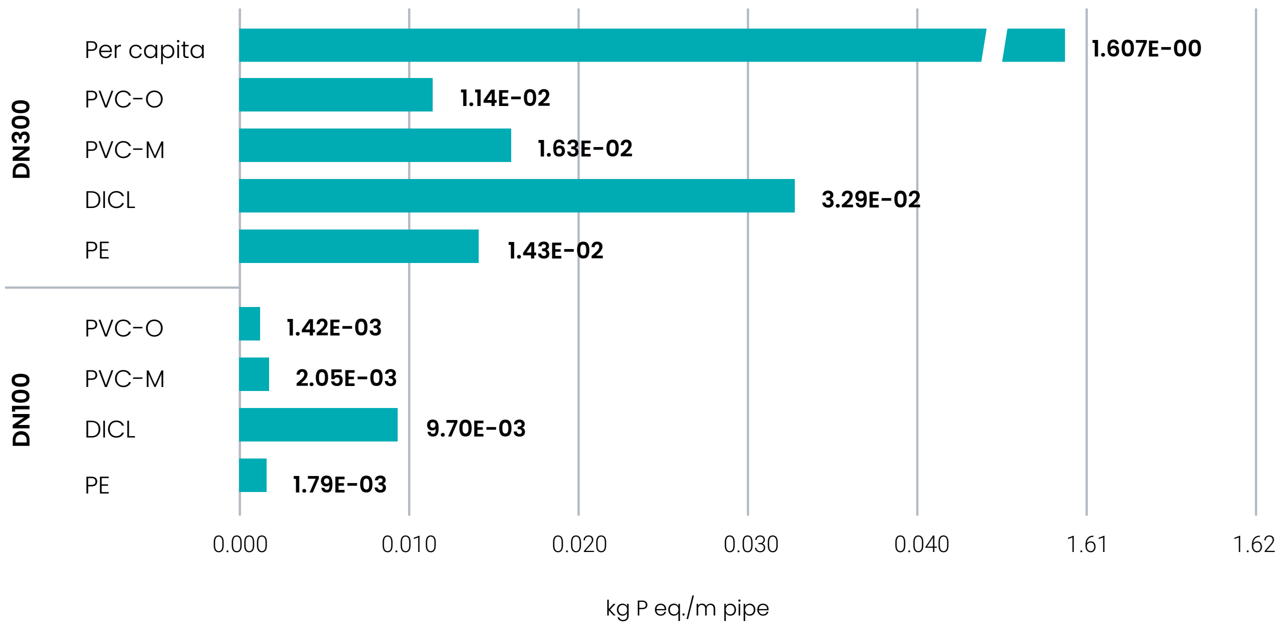

Figure 16: Eutrophication (aquatic freshwater) comparison of plastic pipes with DICL pipes

21 European Commission (2019) EF 3.0 normalisation values, https://eplca.jrc.ec.europa.eu/LCDN/EF_archive.xhtml

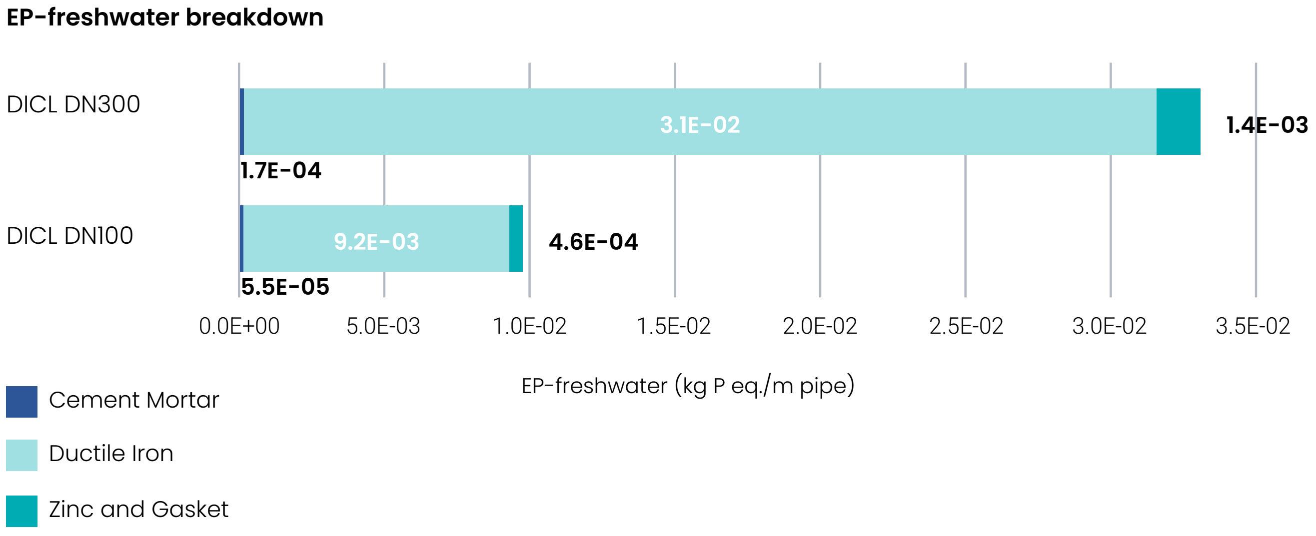

Figure 17: The breakdown of Eutrophication (aquatic freshwater) of DICL pipes

EP-freshwater breakdown DN100

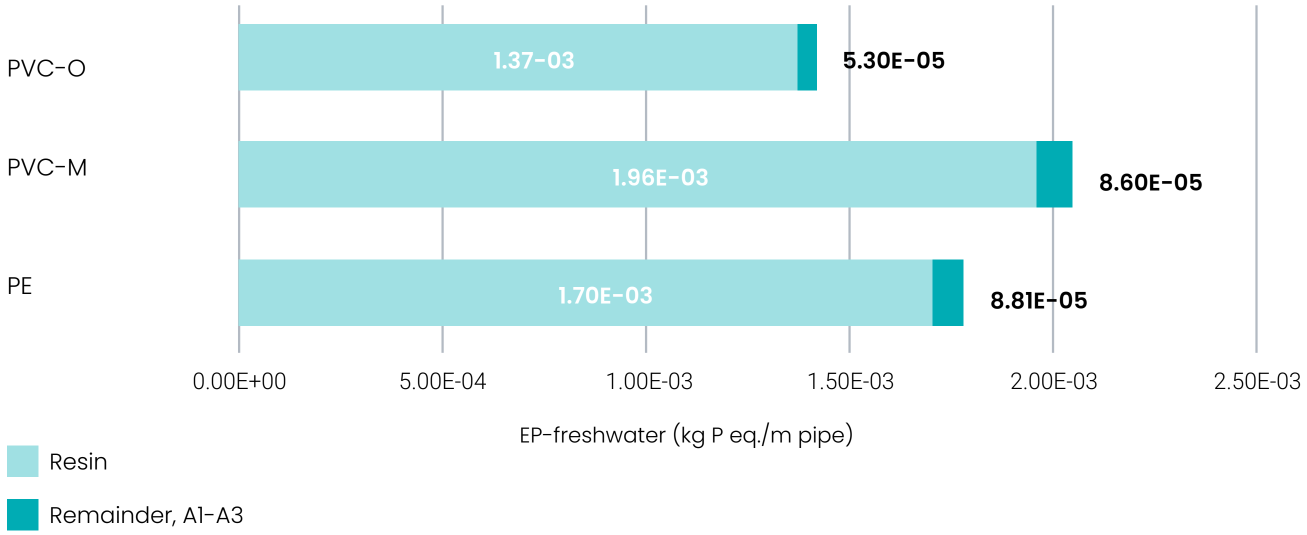

Figure 18: The breakdown of Eutrophication (aquatic freshwater) of plastic pipes for the size of DN100

EP-freshwater breakdown DN300

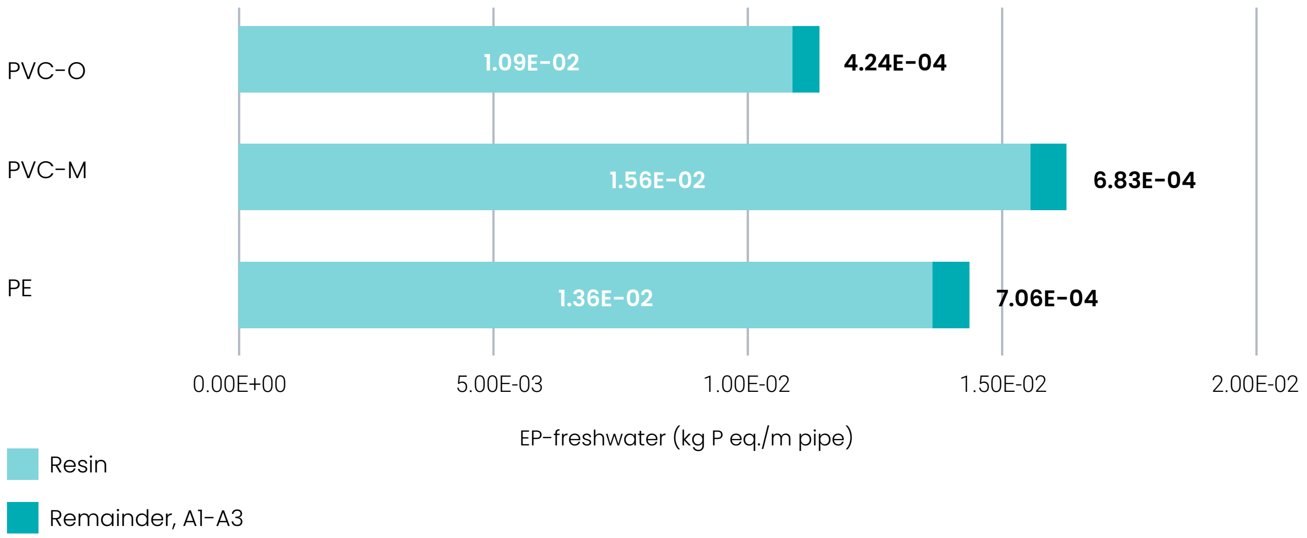

Figure 18: The breakdown of Eutrophication (aquatic freshwater) of plastic pipes for the size of DN300

7.1.5. Eutrophication – aquatic marine

The runoff and leaching of nitrates and phosphates from soil to riverine or marine systems, alongside atmospheric deposition, increases nutrient levels in marine waters. The phytoplankton growth and the anoxia developed due to marine eutrophication cause disturbances to marine ecosystems. These effects are noticeable in many coastal regions of the world, including most parts of the Gulf of Finland, the Gulf of Riga, the Baltic Proper and south-western parts of the Baltic Sea[22].

The marine eutrophication of plastic pipes is lower than that of DICL pipes at DN100, but at DN300 the EP-aquatic marine impacts of PE pipes exceed the impacts of DICL pipes (Figure 20). The breakdowns of marine eutrophication for DN300 are given in Figure 21, Figure 22 and Figure 23. In Figure 21, it's demonstrated that iron causes the most marine eutrophication compared to cement, zinc or gasket impacts.

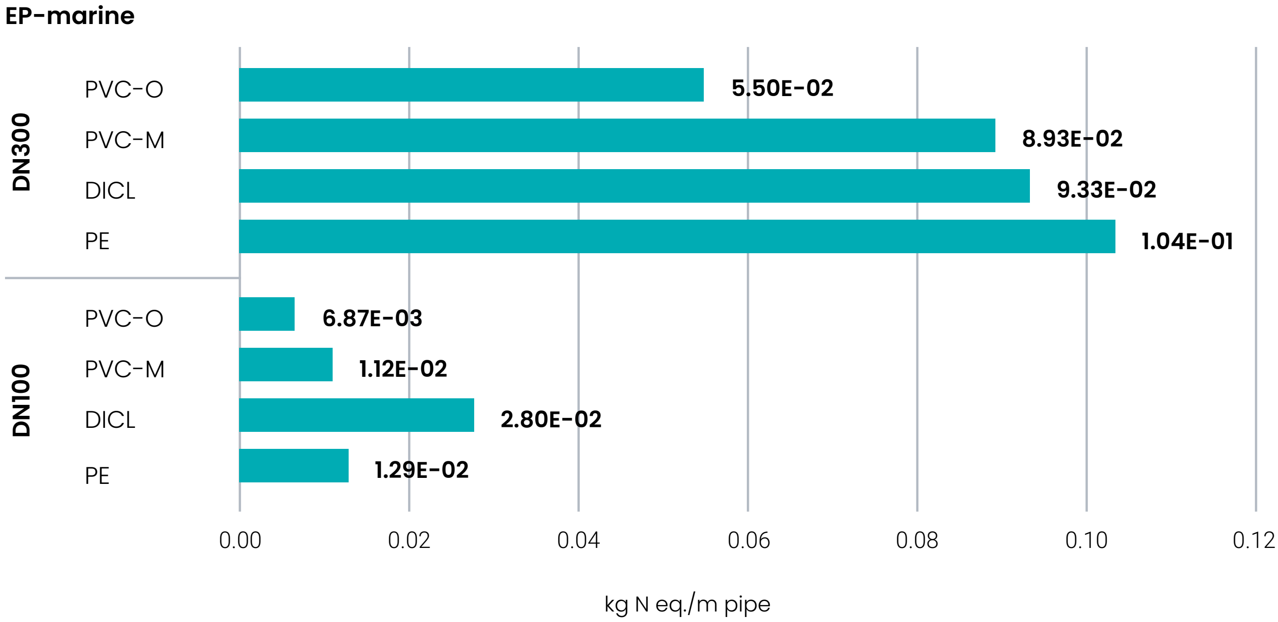

Figure 20: Eutrophication (aquatic marine) comparison of plastic pipes with DICL pipes

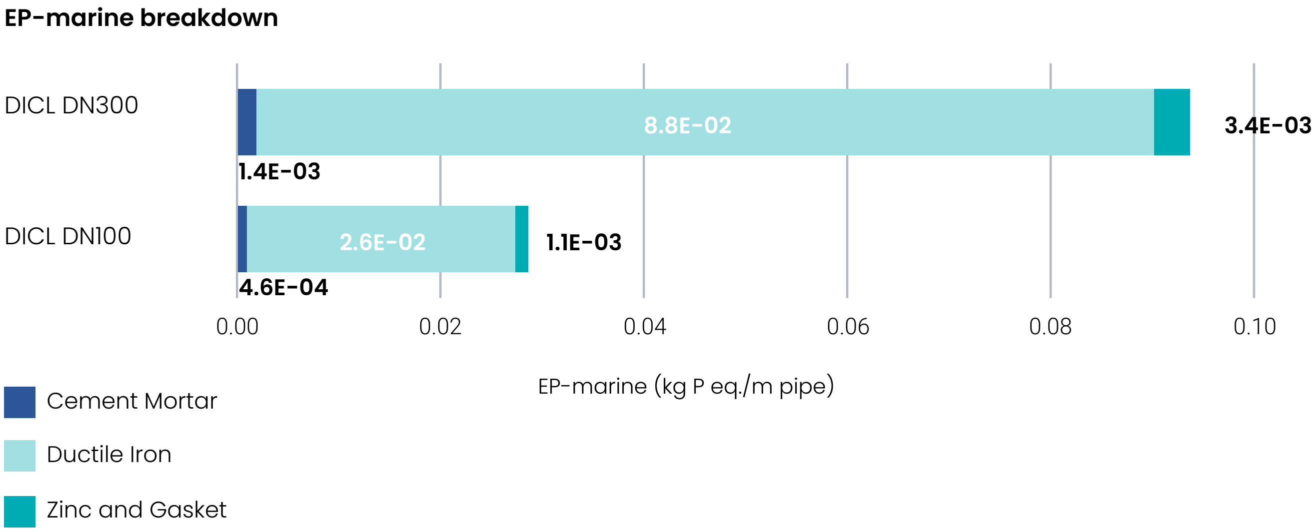

Figure 21: The breakdown of Eutrophication (aquatic marine) of DICL pipes

22 Coastal Wiki (2022) Eutrophication in coastal environments, https://www.coastalwiki.org/introduced/Eutrophication_in_coastal_environments#:~:text=Causes %20of%20eutrophication,-Anthropogenic%20nutrient%20enrichment&text=Atmospheric%20deposition%20in%20the%20sea,areas%20 without%20much%20human%20activities.

EP-marine breakdown DN100

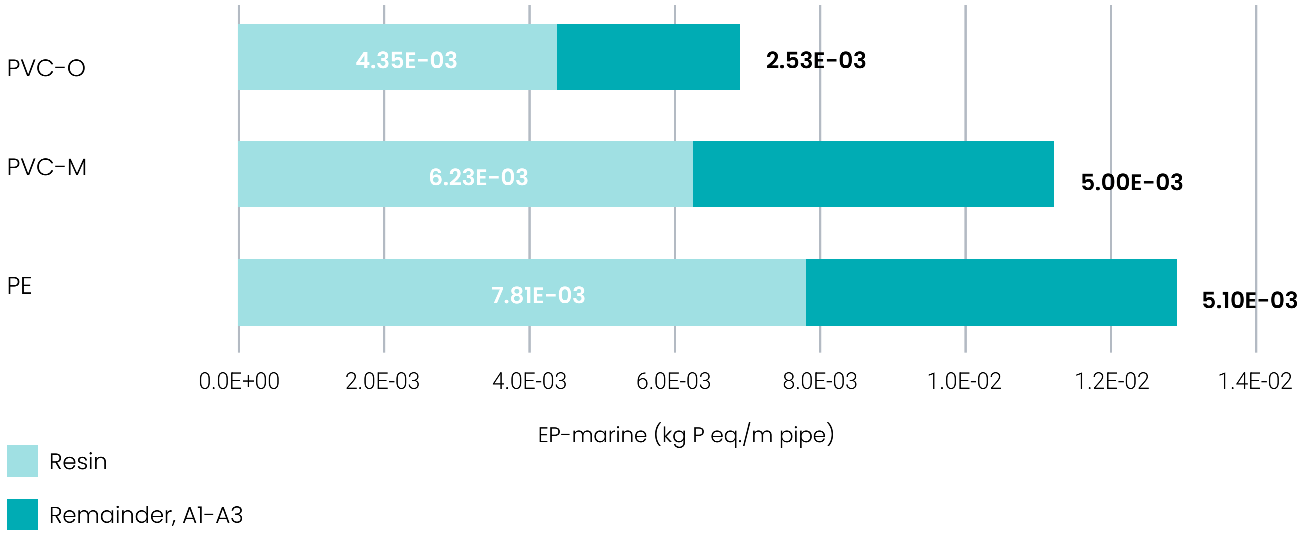

Figure 22: The breakdown of Eutrophication (aquatic marine) of plastic pipes for the size of DN100

EP-marine breakdown DN300

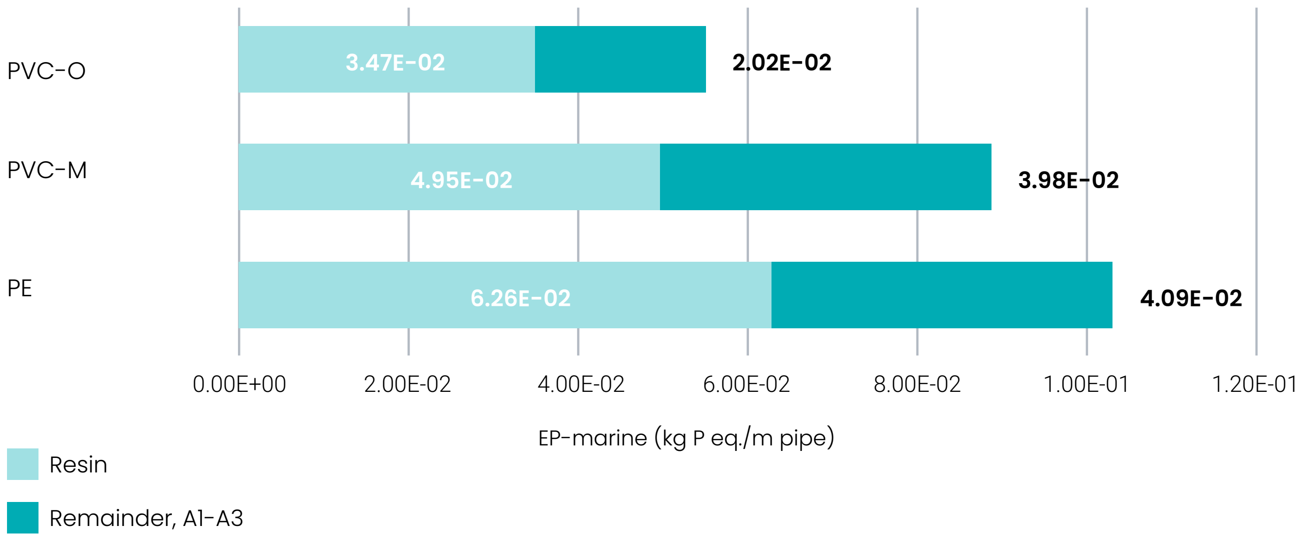

Figure 23: The breakdown of Eutrophication (aquatic marine) of plastic pipes for the size of DN300

7.1.6. Eutrophication – terrestrial

This indicator measures the eutrophication of terrestrial ecosystems due to airborne nitrogen deposition. The airborne nitrogen oxides and ammonia emissions originating from air pollution can lead to airborne nitrogen deposition in ecosystems. Excessive atmospheric nitrogen loads can result in the increased growth of species, including in sensitive terrestrial ecosystems such as grassland. Consequently, the habitat structure and function can be impacted[23].

The trend of terrestrial eutrophication is similar to marine eutrophication. As shown in Figure 24, plastic pipes have lower terrestrial eutrophication compared to DICL pipes at DN100, but PE pipes exceed the impacts of the other pipes at DN300. The breakdown shows that the use of ductile iron causes significant terrestrial eutrophication and plastic resin causes significant impacts for plastic pipe production (Figure 25, Figure 26 and Figure 27).

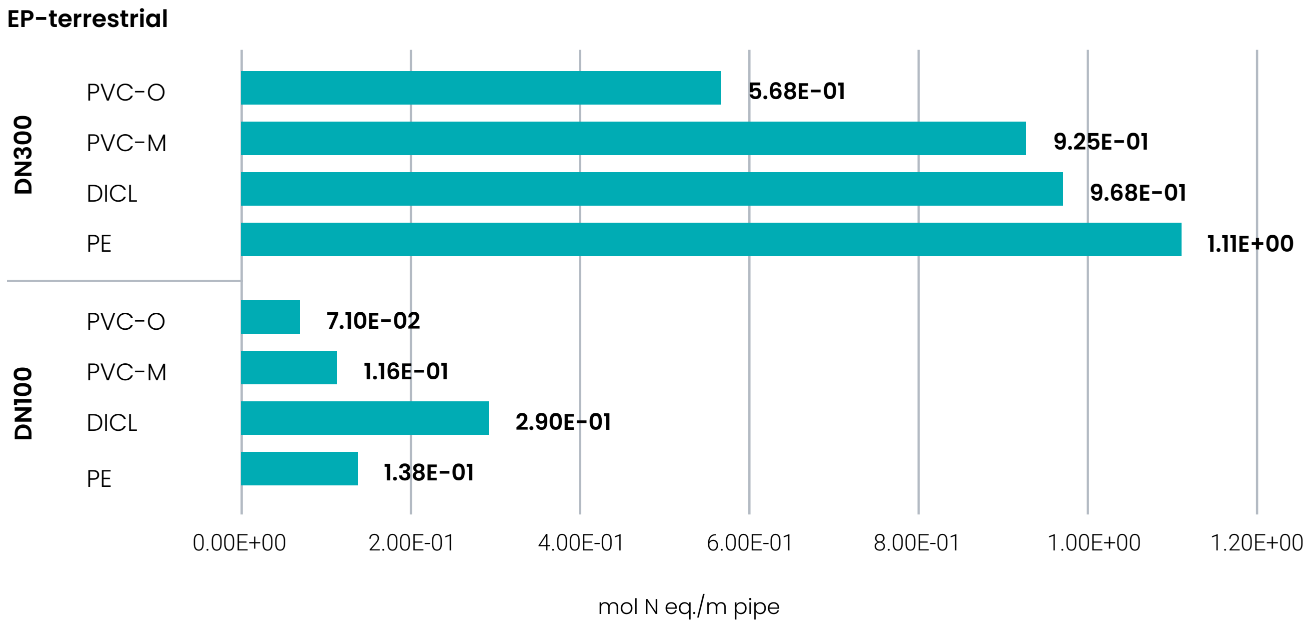

Figure 24: Eutrophication (terrestrial) comparison of plastic pipes with DICL pipes

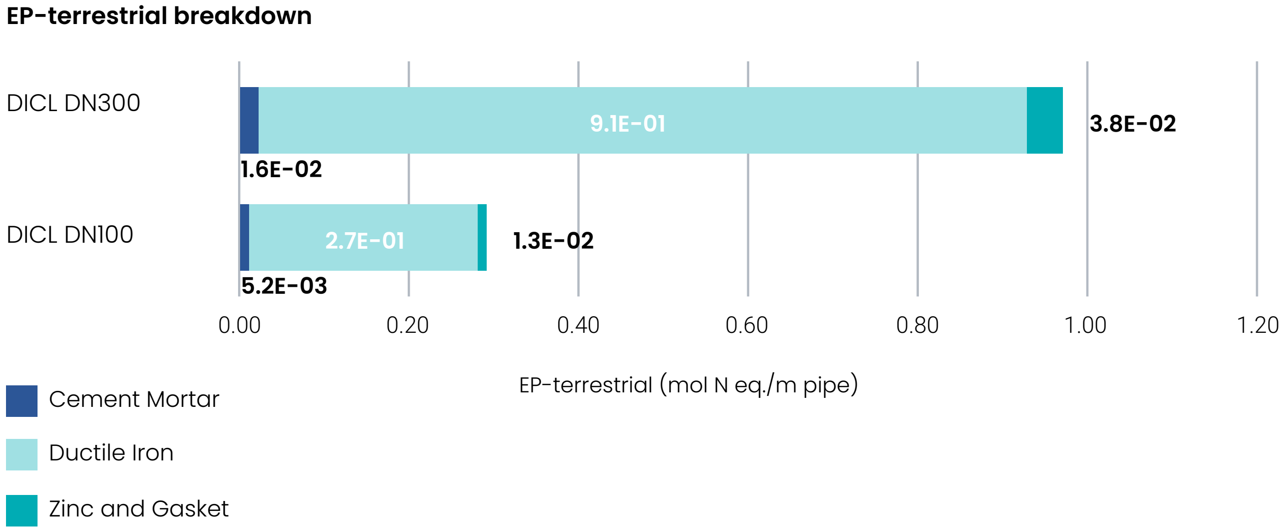

Figure 25: The breakdown of Eutrophication (terrestrial) of DICL pipes

23 European Environment Agency (2021) Eutrophication of terrestrial ecosystems due to air pollution, https://www.eea.europa.eu/airs/2018/natural-capital/eutrophication-of-terrestrial-ecosystems

EP-terrestrial breakdown DN100

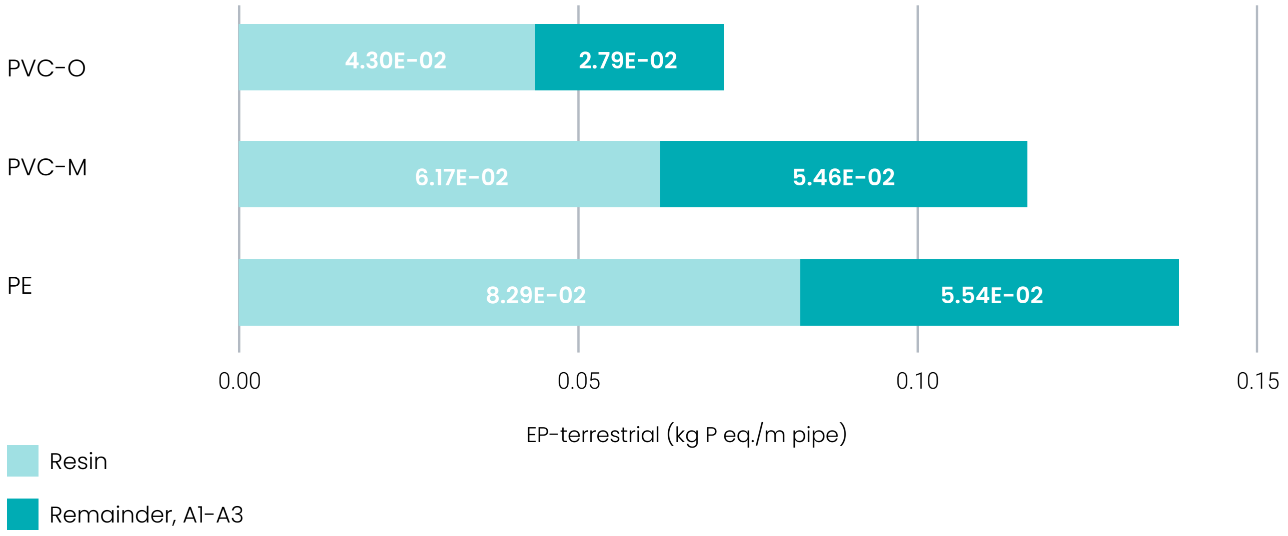

Figure 26: The breakdown of Eutrophication (terrestrial) of plastic pipes for the size of DN100

EP-terrestrial breakdown DN300

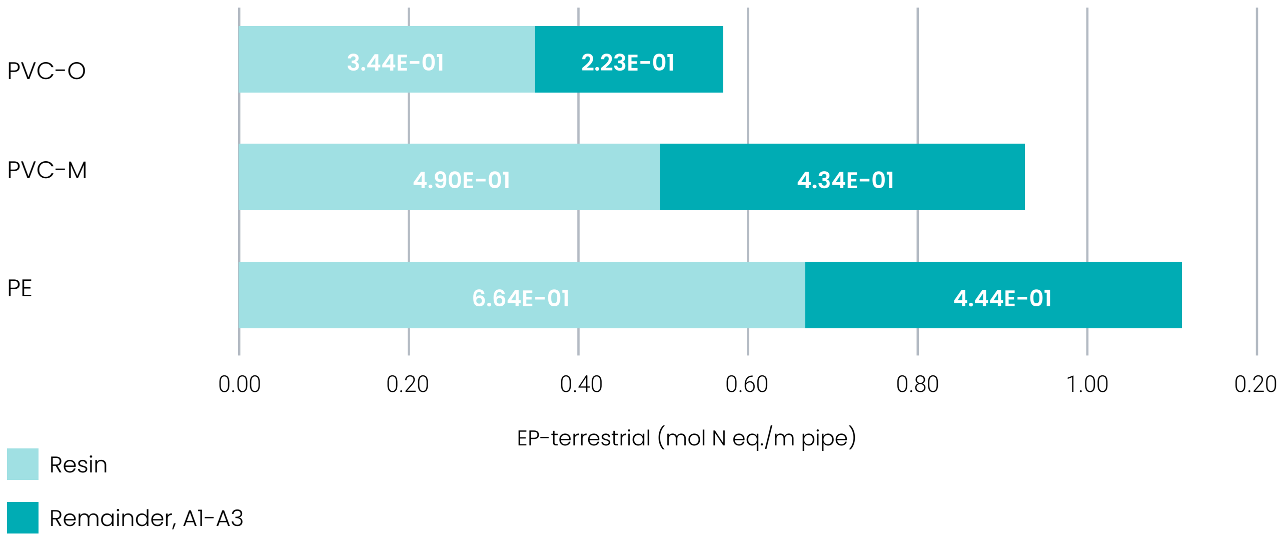

Figure 27: The breakdown of Eutrophication (terrestrial) of plastic pipes for the size of DN300

7.1.7. Photochemical ozone formation potential (POCP)

This indicator measures undesired ozone formation in the lower atmosphere (troposphere). While stratospheric ozone protects us against ultraviolet (UV) light, tropospheric ozone formation impacts our ecosystem, including crop damage and the development of respiratory issues such as asthma.

In the presence of sunlight, ozone can be created in the troposphere where chemicals such as nitrogen oxides (NOx) and volatile organic compounds (VOCs) are present. This indicator is often referred to as 'summer smog'. Chemical factories usually produce NOx and VOCs by burning fossil fuels[24]. In addition, energy production from biofuels, fossil fuels and biomass also produce NOx and VOCs.

Figure 28 compares photochemical ozone formation between plastic and DICL pipes, showing it's lower in plastic pipes than DICL pipes for both DN100 and DN300. Figure 29 demonstrates that the use of ductile iron in DICL pipes is primarily responsible for the photochemical ozone formation. For plastic pipes, plastic resins are responsible, shown in Figure 30 and Figure 31.

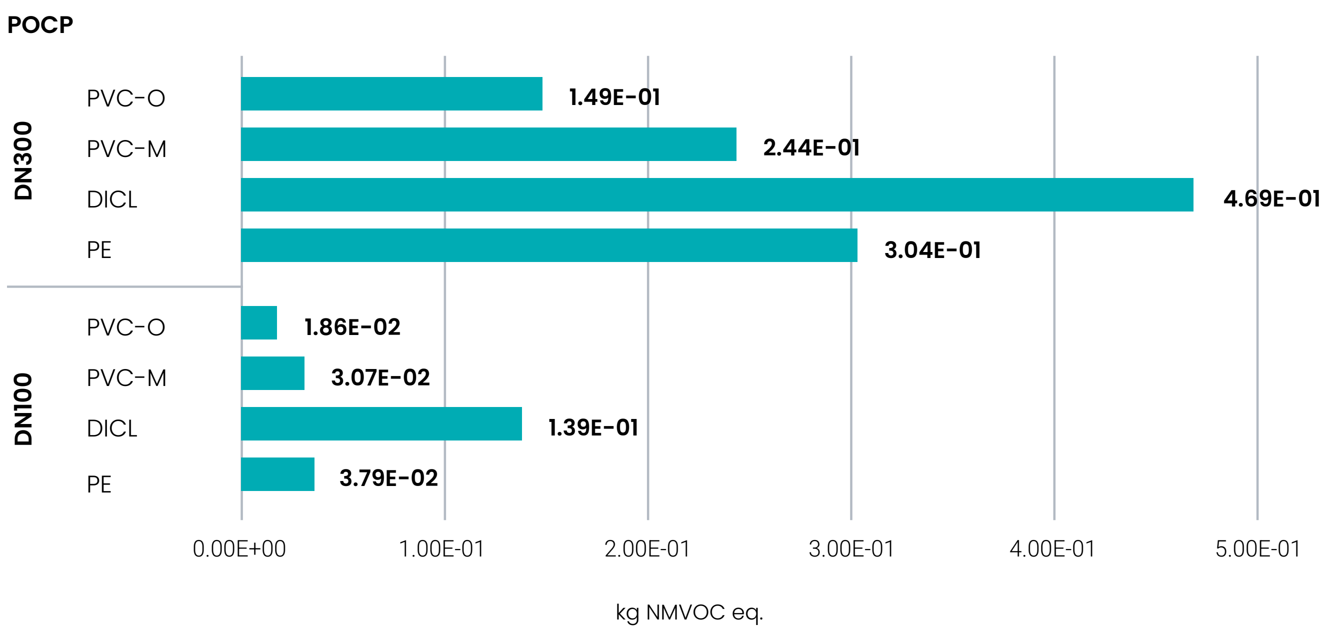

Figure 28: Photochemical ozone formation comparison of plastic pipes with DICL pipes

24 Environmental Protection Agency (2024), Sources of Hydrocarbon and NOx Emissions in New England, https://www3.epa.gov/region1/airquality/piechart.html

POCP breakdown

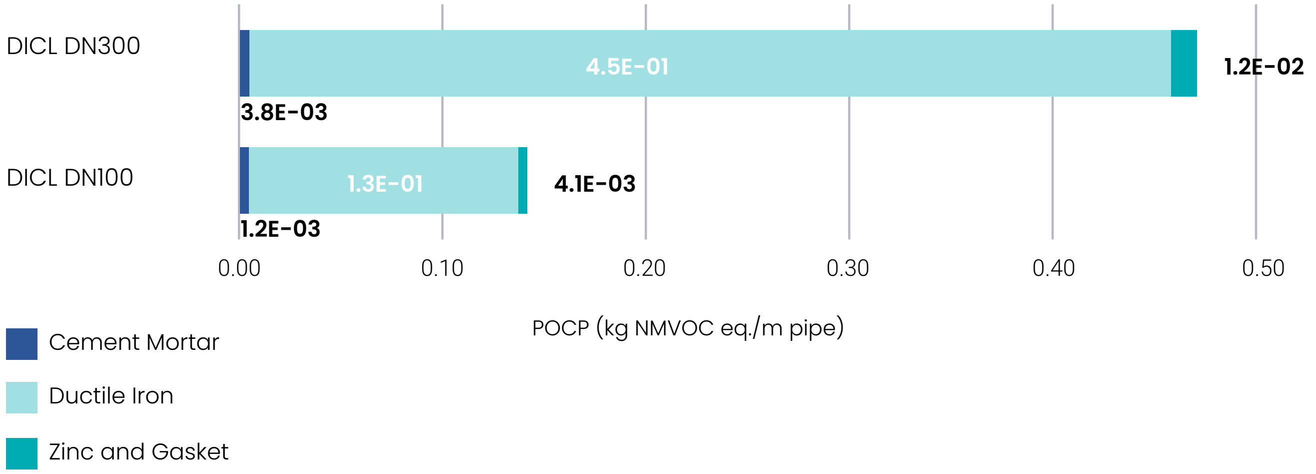

Figure 29: The breakdown of photochemical ozone formation of DICL pipes

POCP breakdown DN100

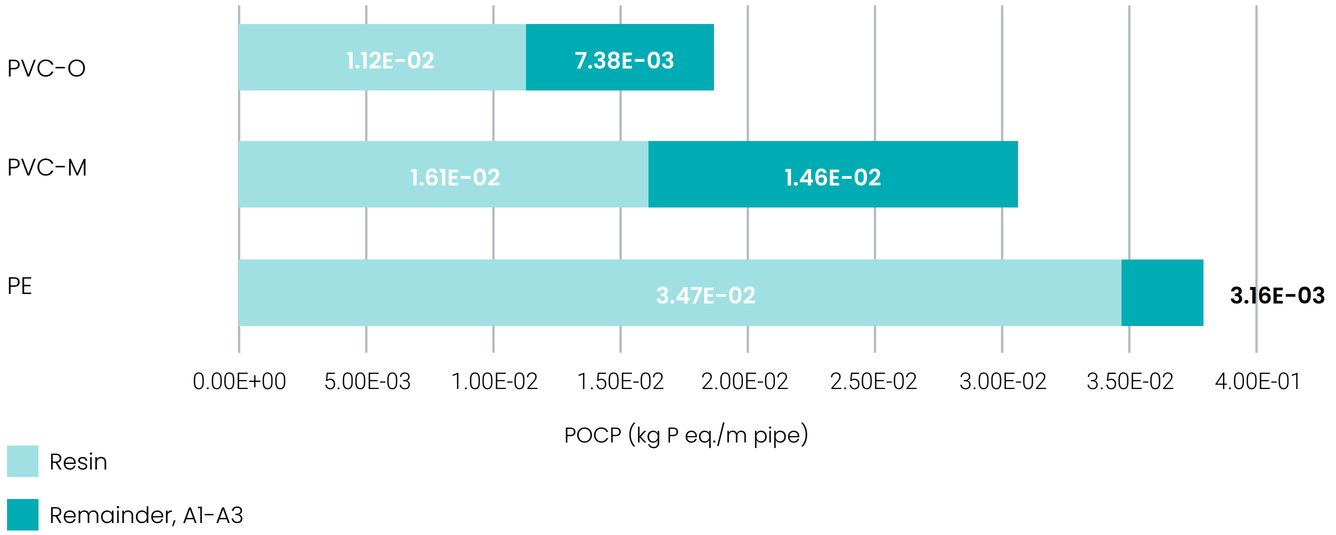

Figure 30: The breakdown of photochemical ozone formation of plastic pipes for the size of DN100

POCP breakdown DN300

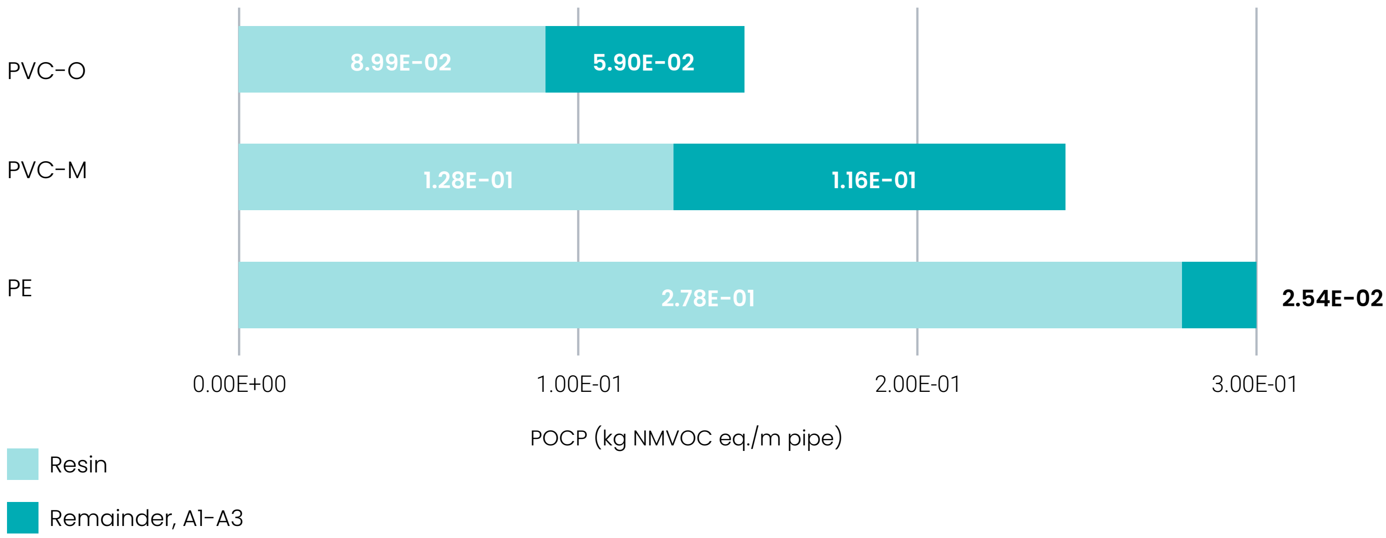

Figure 31: The breakdown of photochemical ozone formation of plastic pipes for the size of DN300

7.1.8. Abiotic depletion potential (metals and minerals)

Our planet has a finite storage of abiotic materials such as aggregates, metal ores and minerals. Due to the continual extraction of these materials, they'll become unavailable for use by future generations. The abiotic depletion potential (metals and minerals) indicator measures the extraction of these abiotic materials and addresses their scarcity.

For DICL pipes, the abiotic depletion of materials is higher than plastic pipes at DN100, but at DN300, the impacts of plastic pipes exceed them (Figure 32). The production of plastic resin is a major contributor (Figure 34) (Figure 35).The detailed analysis shows that the construction of chemical factories for production is primarily responsible, as this requires cement, aggregate and metals.

For DICL pipes (Figure 33), cement production was insignificant to the abiotic depletion of metals and minerals. Due to a high level of uncertainty from third-party data, it wasn't possible to separate ADP-metals and minerals impacts associated with zinc or gaskets. Their cumulative ADP-metals and minerals exceeded the Saint-Gobain impact estimates, which can occur when applying third-party data due to differences in scope and assumptions made.

Due to the high level of uncertainty in the results, originating from the estimation of extractable reserves, they should be interpreted cautiously. In the case of abiotic depletion potential – metals and minerals, uncertainties also originate from the scattered concentrations of elements (L. van Oers; A. de Koning; J.B. Guinée; G. Huppes, 2002).

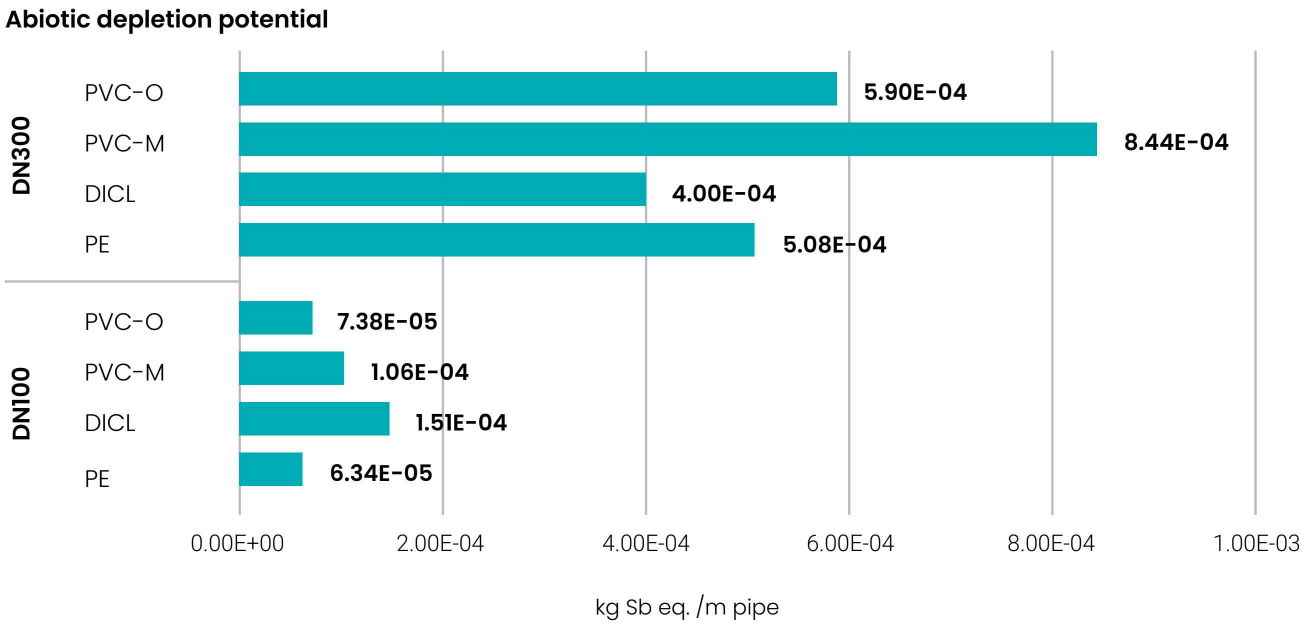

Figure 32: Abiotic depletion potential (metals and minerals) comparison of plastic pipes with DICL pipes

Abiotic depletion potential breakdown

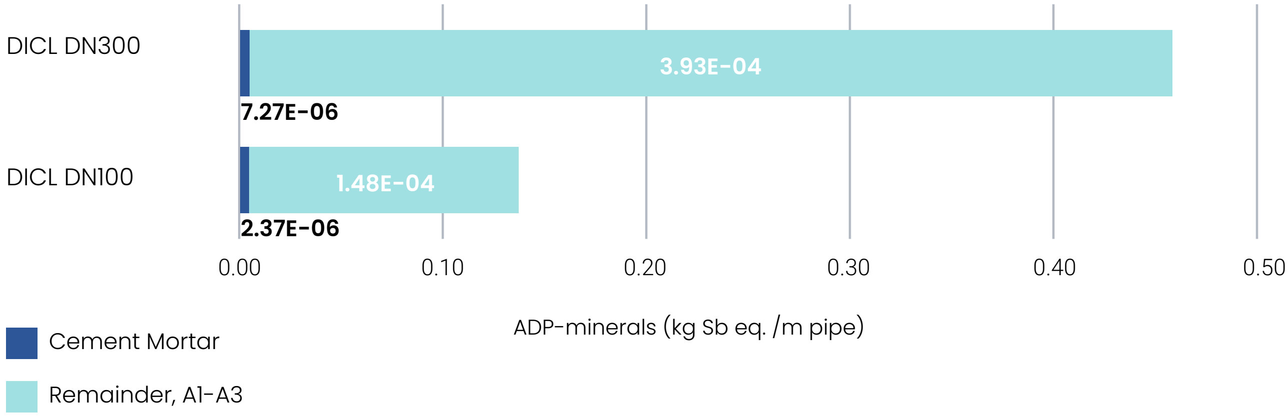

Figure 33: The breakdown of abiotic depletion potential (metals and minerals) of DICL pipes

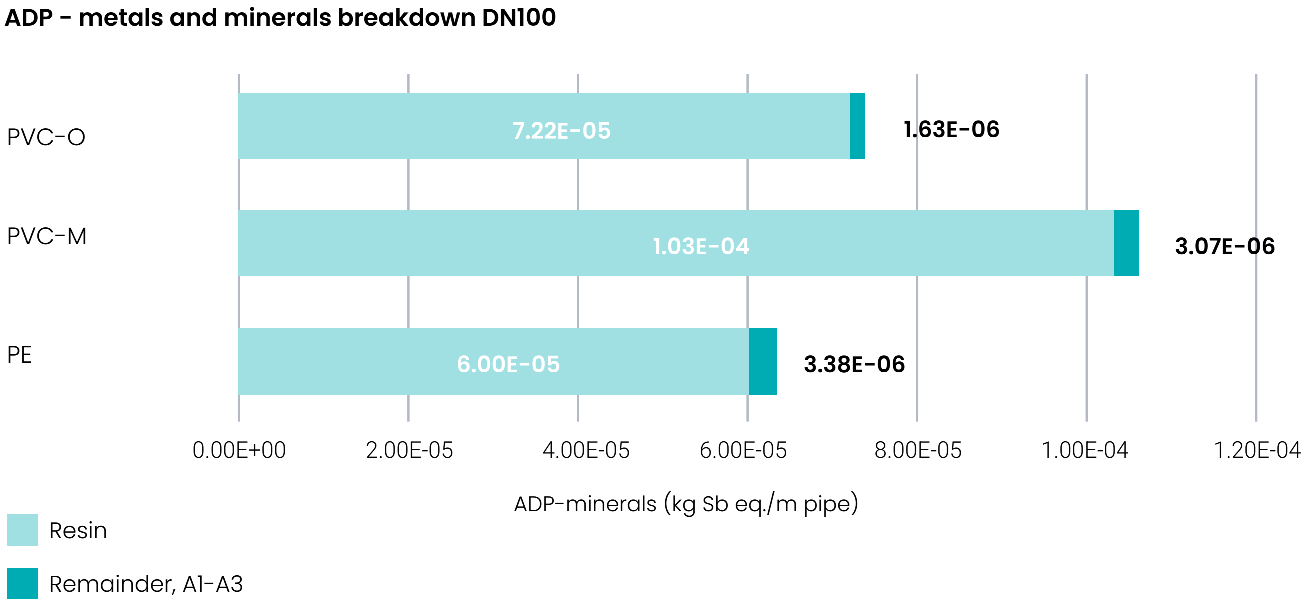

Figure 34: The breakdown of abiotic depletion potential (metals and minerals) of plastic pipes for the size of DN100

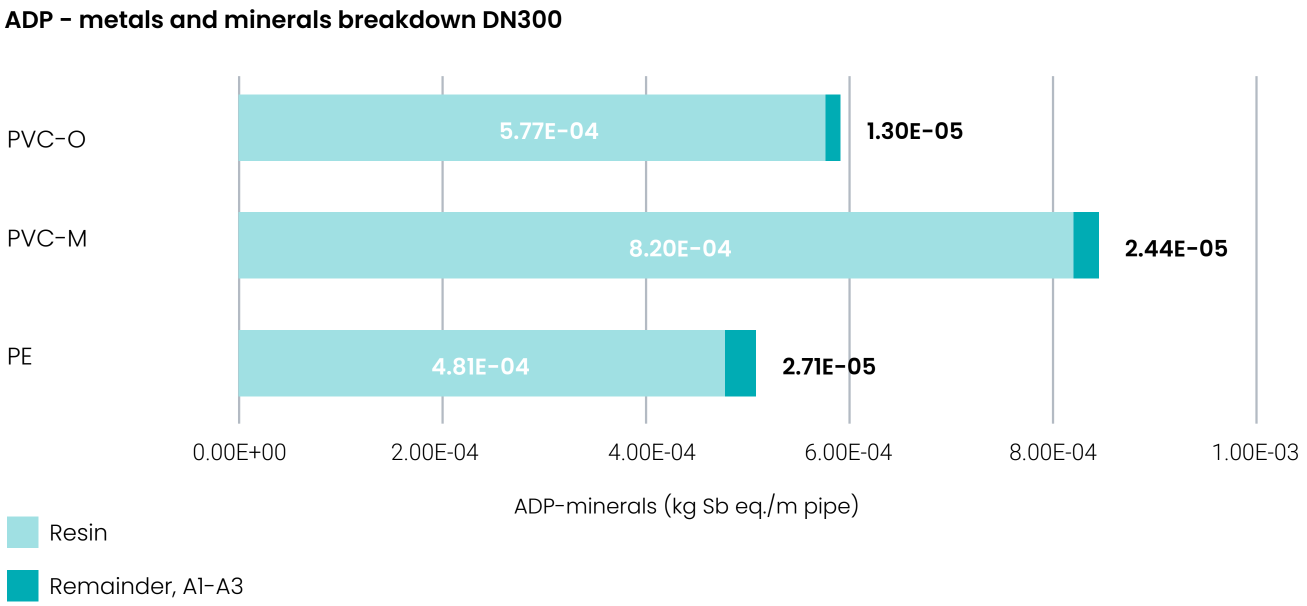

Figure 35: The breakdown of abiotic depletion potential (metals and minerals) of plastic pipes for the size of DN300

7.1.9. Abiotic depletion potential (fossil resources)

Fossil fuels are raw materials used to manufacture commodities like plastics and synthetic rubber. Although renewable energy is emerging, we still rely on fossil fuels in the energy sector. The continual use of fossil fuels, which are finite resources, makes them unavailable for future generations. The indicator abiotic depletion potential (fossil resources) or ADP fossil measures the extraction of fossil resources and addresses the scarcity of them.

Figure 36 shows that the abiotic depletion potential for fossil resources is lowest for PVC pipes at DN100 and DN300. DICL pipes have the greatest impacts at DN100 and PE pipes have a significantly greater impact at DN300. Figure 37, Figure 38 and Figure 39 show the breakdown of ADP-fossil for the product stage of the pipes. For plastic pipes, resin production is a primary contributor to abiotic potentials for fossil resources. A deeper analysis shows that the production of monomers, such as ethylene in the case of polyethylene, consumes significant abiotic fossil resources. For DICL pipes, ductile iron production requires the majority of abiotic fossil resources, relative to the other A1-A3 impacts.

Similar to abiotic depletion potentials (metals and minerals), there's a high level of uncertainties in the abiotic depletion potentials (fossil resources) results, due to the estimation of extractable reserves.

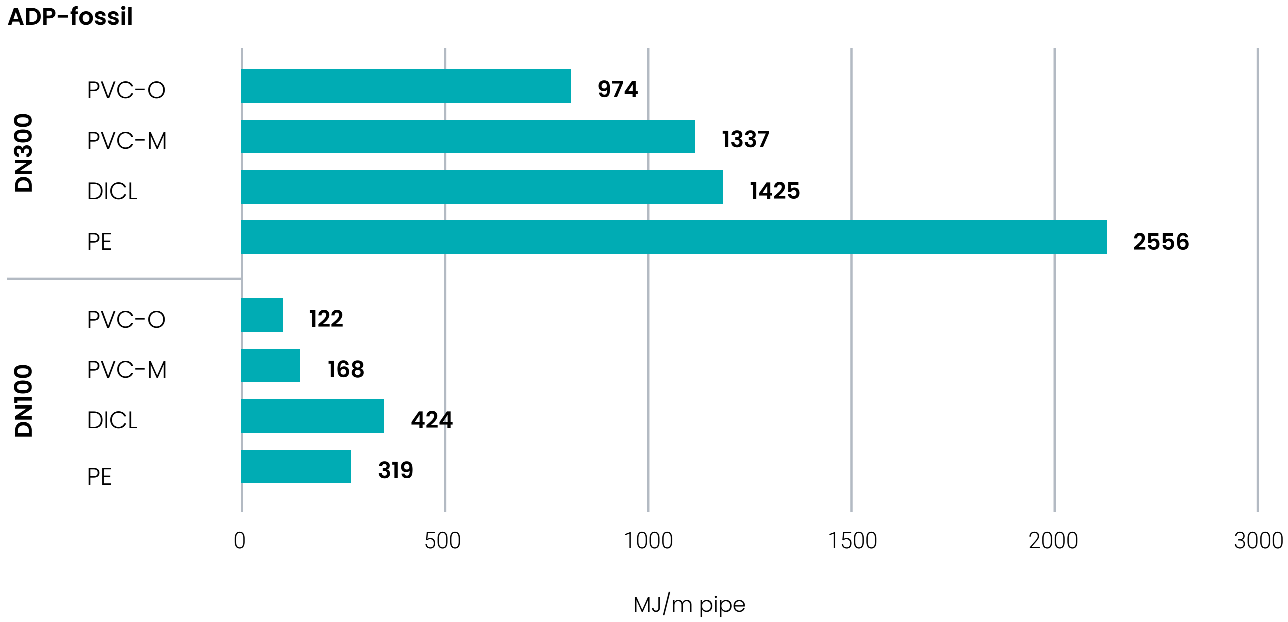

Figure 36: Abiotic depletion potential (fossil resources) comparison of plastic pipes with DICL pipes

ADP-fossil breakdown

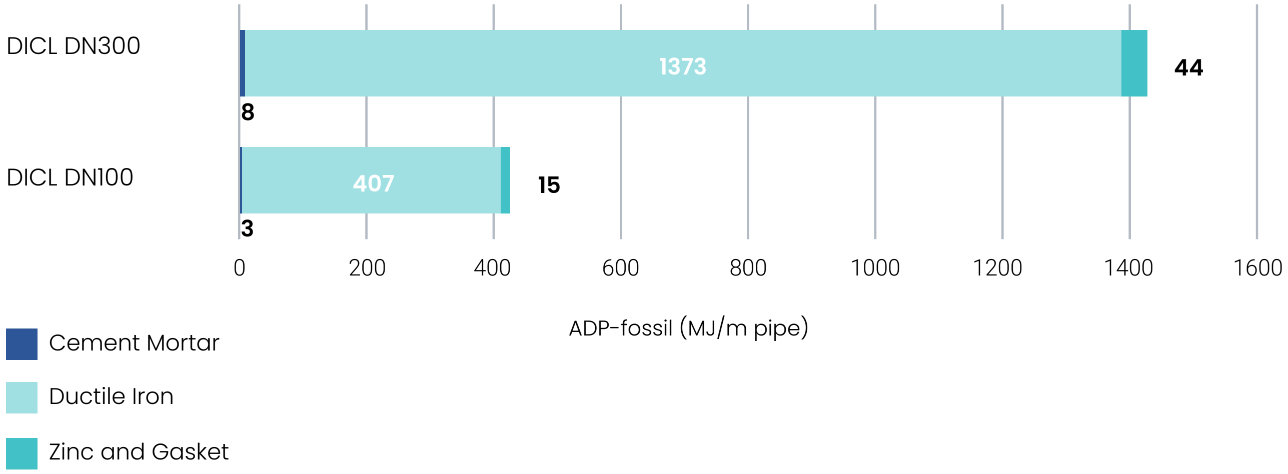

Figure 37: The breakdown of abiotic depletion potential (fossil resources) of DICL pipes

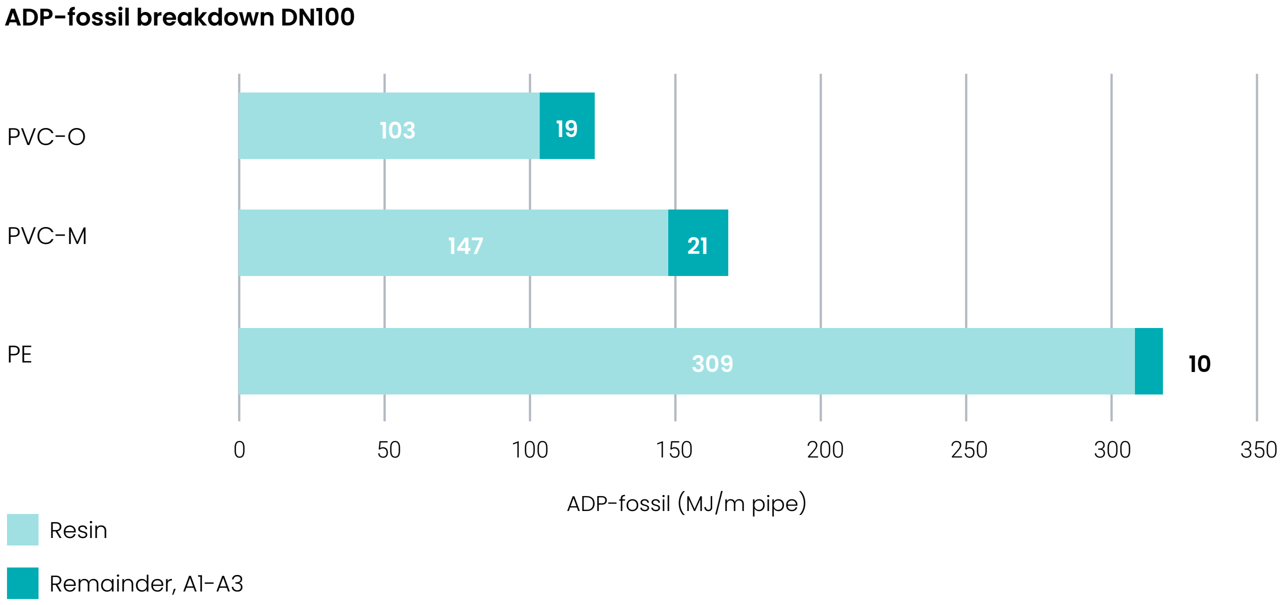

Figure 38: The breakdown of abiotic depletion potential (fossil resources) of plastic pipes for the size of DN100

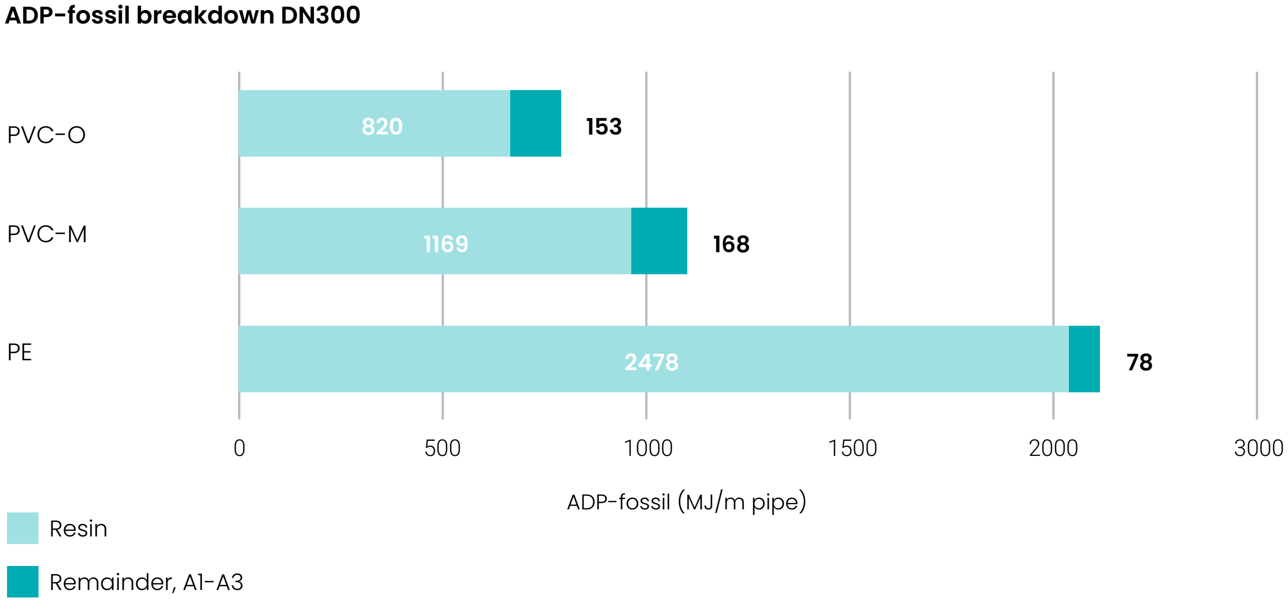

Figure 39: The breakdown of abiotic depletion potential (fossil resources) of plastic pipes for the size of DN300

7.1.10. Use of net freshwater

This indicator models the reduction of freshwater availability to ecosystems. The removal of water from water bodies such as rivers, lakes, reservoirs and aquifers can disrupt ecosystems. Water withdrawn from these sources may be evaporated, transformed into products or transferred to other watersheds or seas.

For DN100, the production of DICL pipes uses approximately triple the net freshwater of plastic pipes (Figure 40). However, at DN300, the differences in impacts between plastic and DICL pipes aren't as significant. The breakdown of DICL pipes in Figure 41 shows that iron production requires the most freshwater, but cement, zinc and gaskets also have a sizeable freshwater impact. For plastic pipes, plastic resin production contributes significantly to freshwater use, demonstrated in Figure 42 and Figure 43.

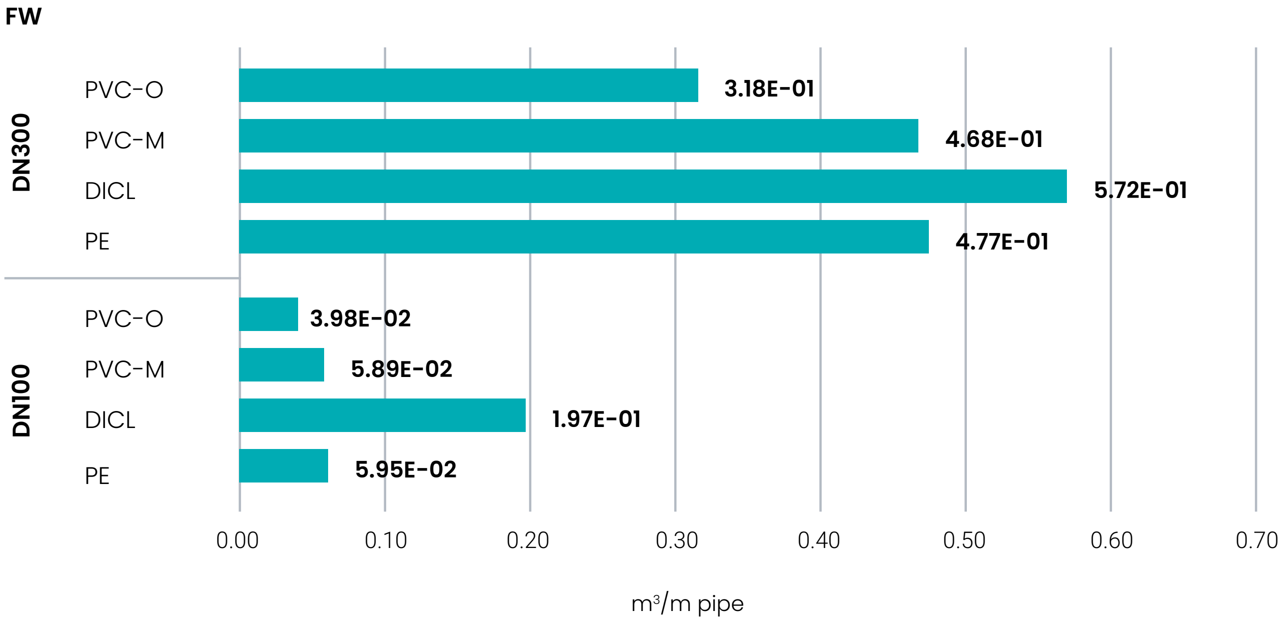

Figure 40: Use of net freshwater comparison of plastic pipes with DICL pipes

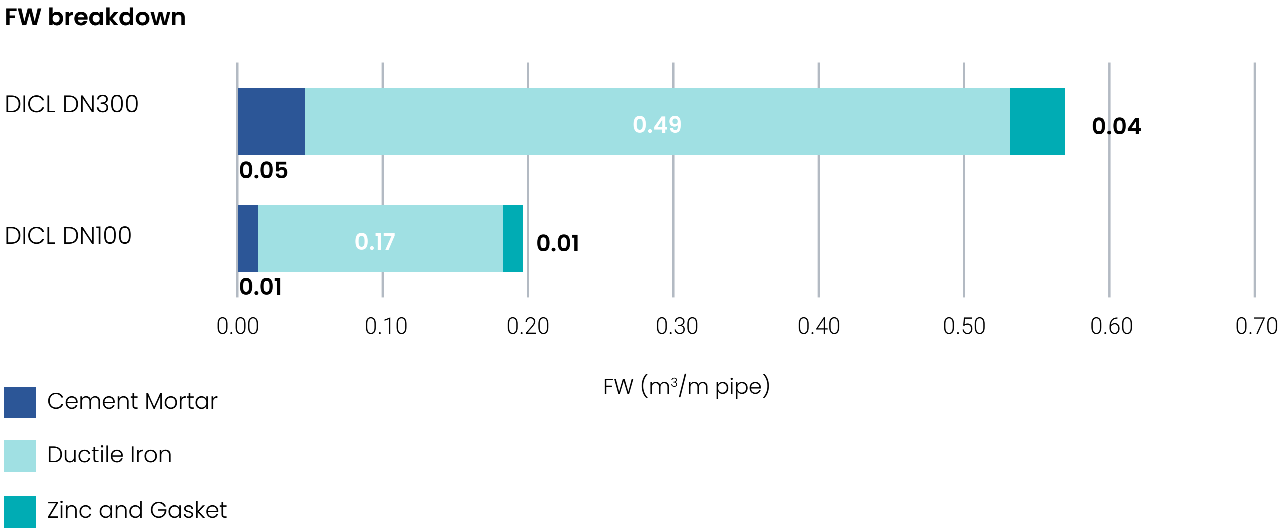

Figure 41: The breakdown of use of net freshwater of DICL pipes

FW breakdown DN100

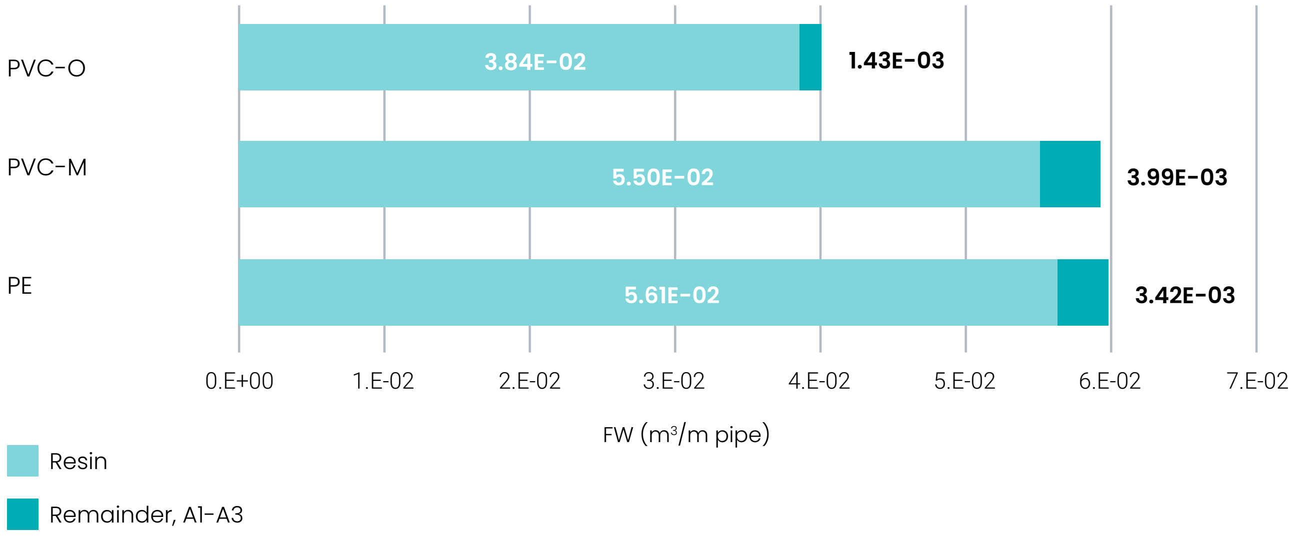

Figure 42: The breakdown of use of net freshwater of plastic pipes for the size of DN100

FW breakdown DN300

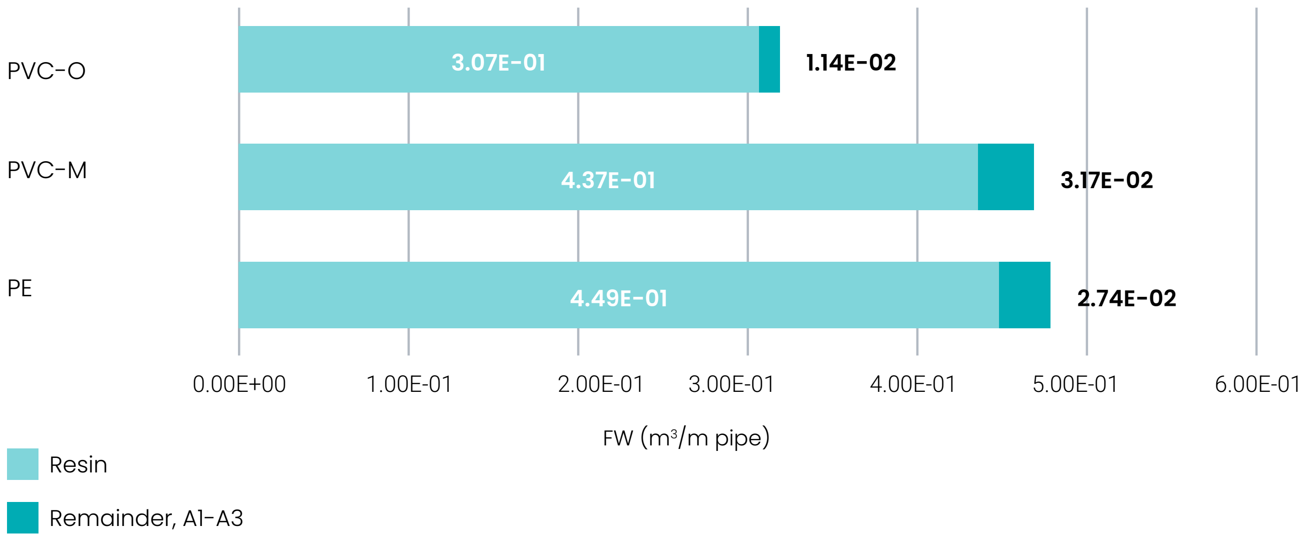

Figure 43: The breakdown of use of net freshwater of plastic pipes for the size of DN300

7.1.11. Hazardous waste disposed

Hazardous waste can cause serious harm to ecosystems, and the waste generated in the production of a product requires special treatment. The value of the indicator hazardous waste disposed (HWD) represents the amount of hazardous waste that needs to be disposed of. However, the method of disposal depends on the local guidelines. For example, the European Union follows a waste framework directive[25]. In Australia, every state and territory has its own waste disposal guidelines. In New South Wales, the EPA provides waste disposal guidelines[26].

Figure 44 shows that the HWD values to produce plastic pipes are significantly higher than DICL pipes for DN100 and DN300. The breakdowns of HWD for the product stage of the pipes are presented in Figure 45, Figure 46 and Figure 47 with Figure 46 and Figure 47 specifically showing that plastic resins contribute to significant hazardous wastes. Hazardous waste generated in the production of plastic resins include spent catalyst, solvent (e.g., hexane) and other chemicals (Abbasi & Kamalan, 2018).

A detailed breakdown of DICL HWD impacts wasn't possible due to high level of uncertainty from the third-party data for zinc and gaskets, as these exceeded the Saint-Gobain HWD impacts values (Figure 45). This is possibly due to the small values of the HWD impacts in the Saint-Gobain EPD study and variations in assumptions and scopes compared to the third-party data.

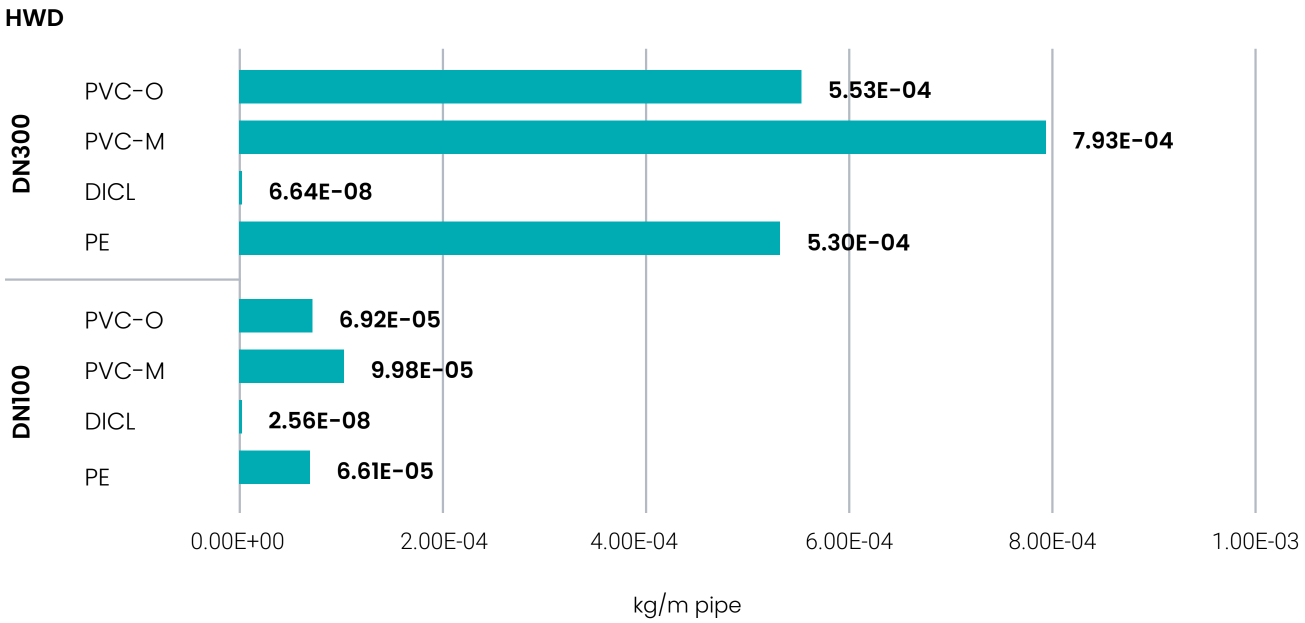

Figure 44: Hazardous waste disposed comparison of plastic pipes with DICL pipes

25 European Commission (2023) Waste framework directive, https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en

26 NSW Environmental Protection Agency (2023) Waste classification guidelines, https://www.epa.nsw.gov.au/your-environment/waste/classifying-waste/waste-classification-guidelines

HWD breakdown

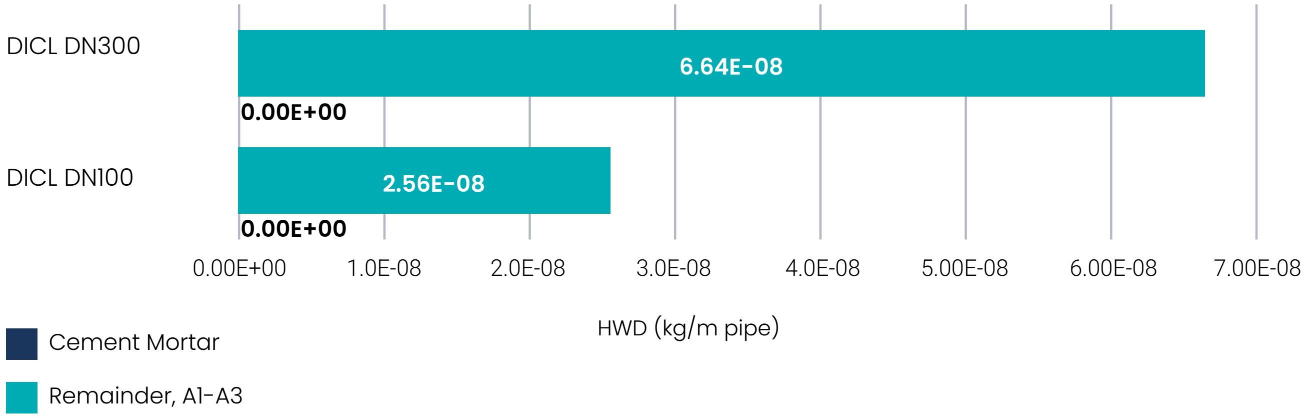

Figure 45: The breakdown of hazardous waste disposed of DICL pipes

HWD breakdown DN100

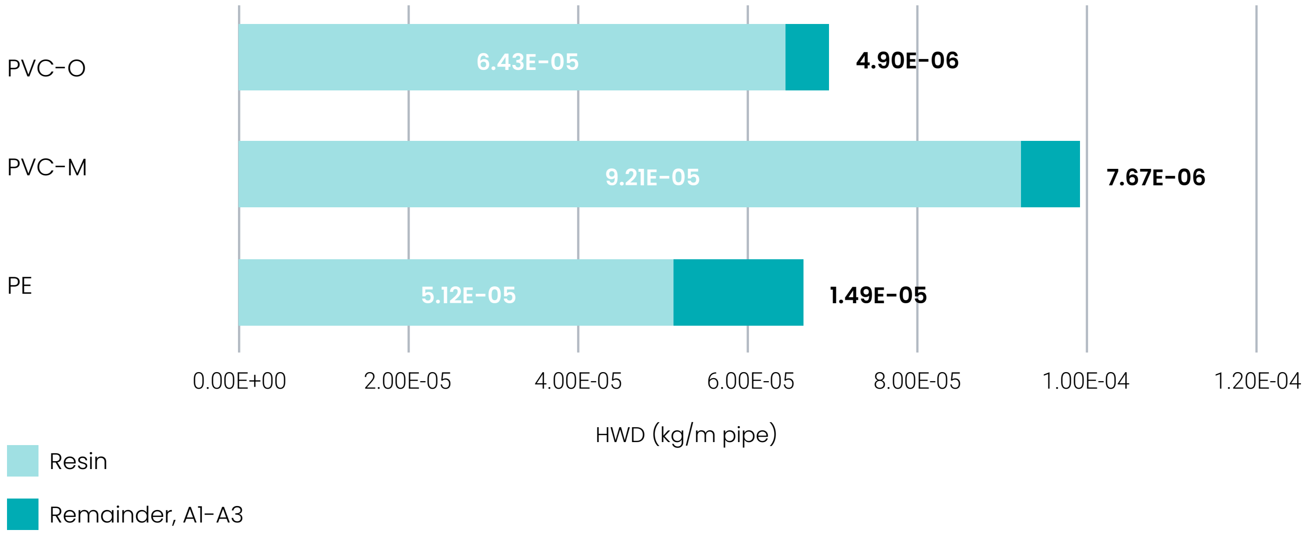

Figure 46: The breakdown of hazardous waste disposed of plastic pipes for the size of DN100

HWD breakdown DN300

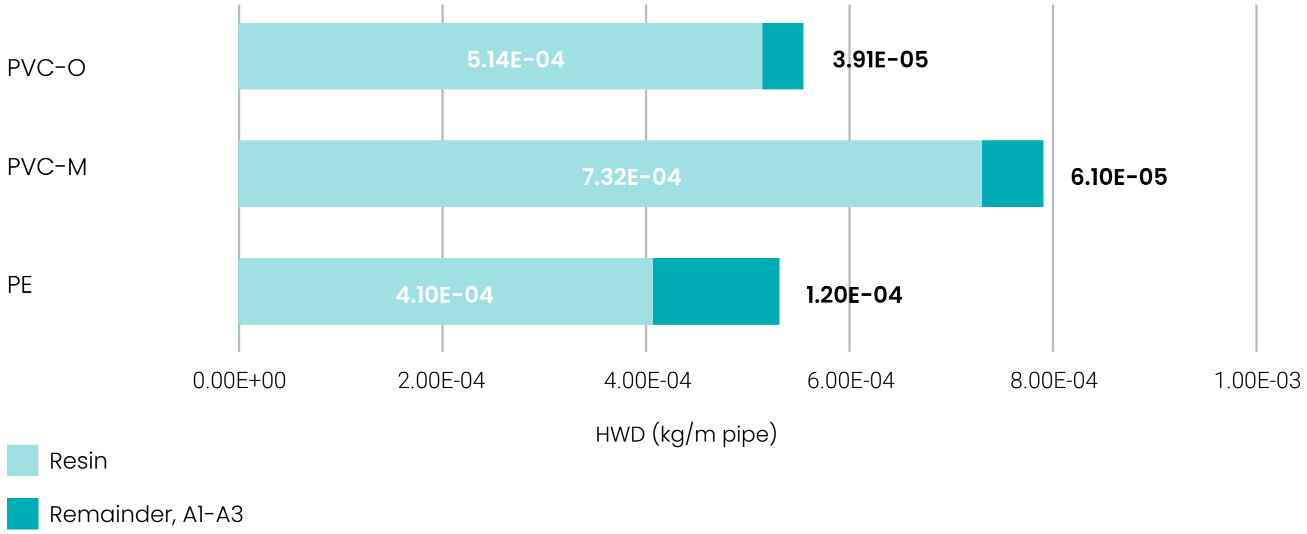

Figure 47: The breakdown of hazardous waste disposed of plastic pipes for the size of DN300

7.1.12. Non-hazardous waste disposed (NHWD)

The non-hazardous waste disposed (NHWD) indicator measures the quantity of non-hazardous waste produced and disposed of during the manufacture of a product. The value of NHWD represents the amount of non-hazardous waste that needs to be disposed of. However, the method of disposal depends on the local guidelines. For example, the EU follows their waste framework directive. In Australia, every state and territory has its own waste disposal guidelines. In NSW, the EPA provides waste disposal guidelines[27].

The non-hazardous waste production during the manufacture of DICL pipes exceeds plastic pipes at DN100, but at DN300, it's similar for all pipes (Figure 48). Figure 49, Figure 50 and Figure 51 show the breakdown of NHWD for the product stage of the pipes. For DICL pipes, ductile iron production is a major contributor to non-hazardous waste, including used containers, paper bags, wooden pallets, anthracite, used ion-exchange resins and cooling tower packing (Abbasi & Kamalan, 2018).

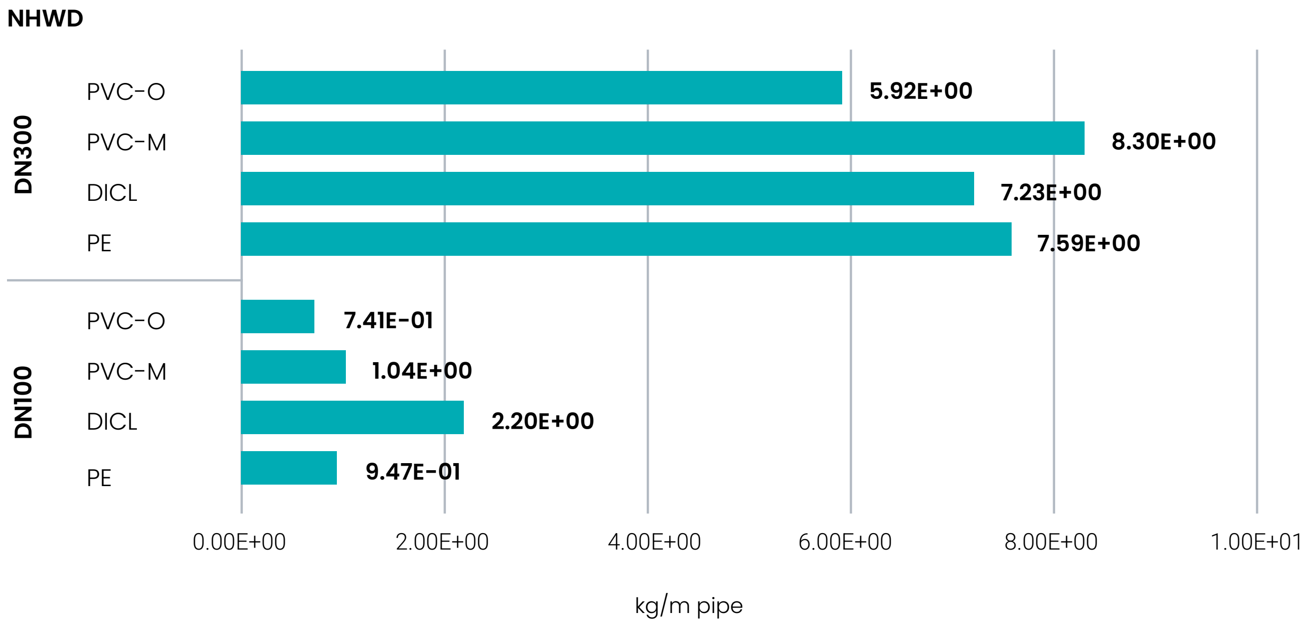

Figure 48: Non-hazardous waste disposed comparison of plastic pipes with DICL pipes

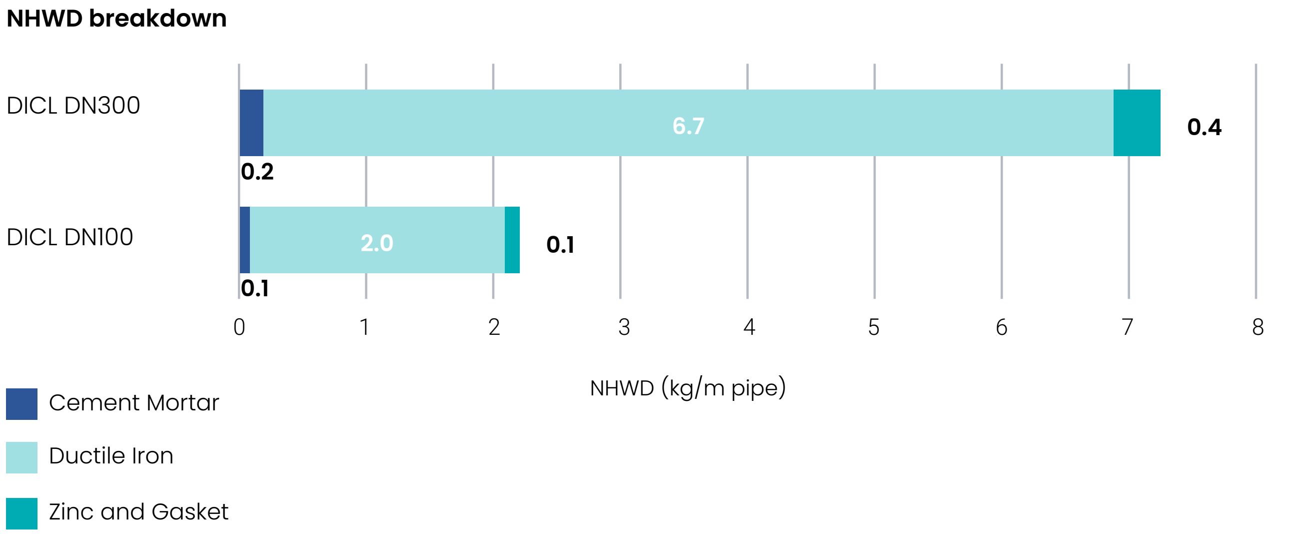

Figure 49: The breakdown of non-hazardous waste disposed of DICL pipes

27 NSW Environmental Protection Agency (2023) Waste classification guidelines, https://www.epa.nsw.gov.au/your-environment/waste/classifying-waste/waste-classification-guidelines

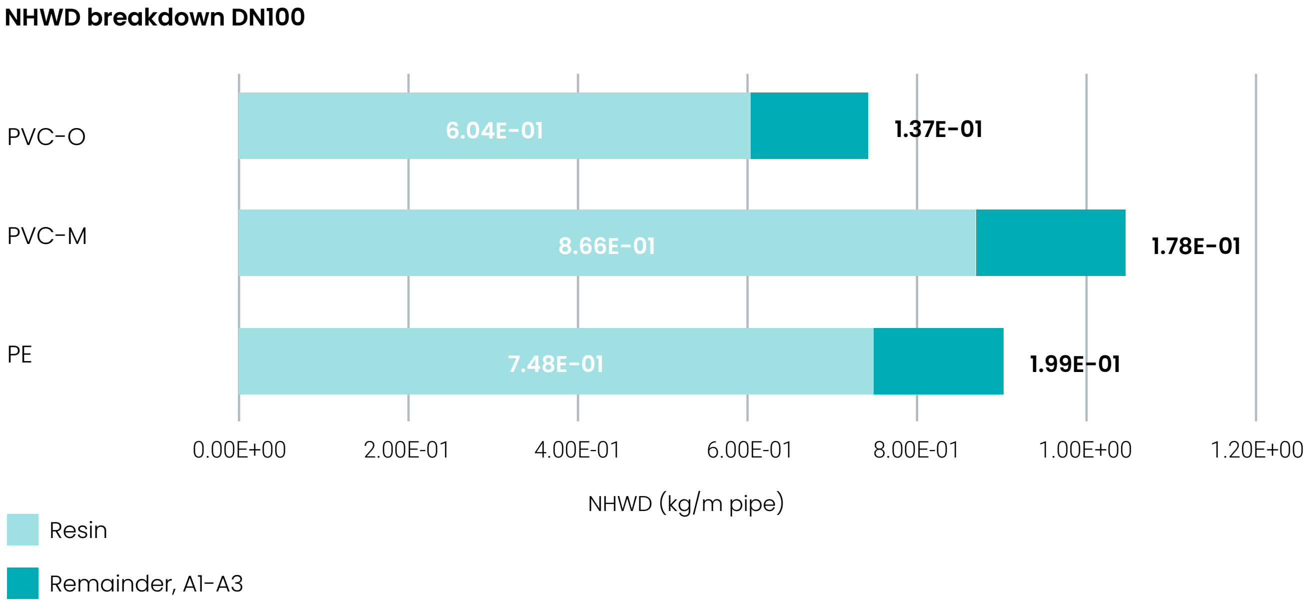

Figure 50: The breakdown of non-hazardous waste disposed of plastic pipes for the size of DN100

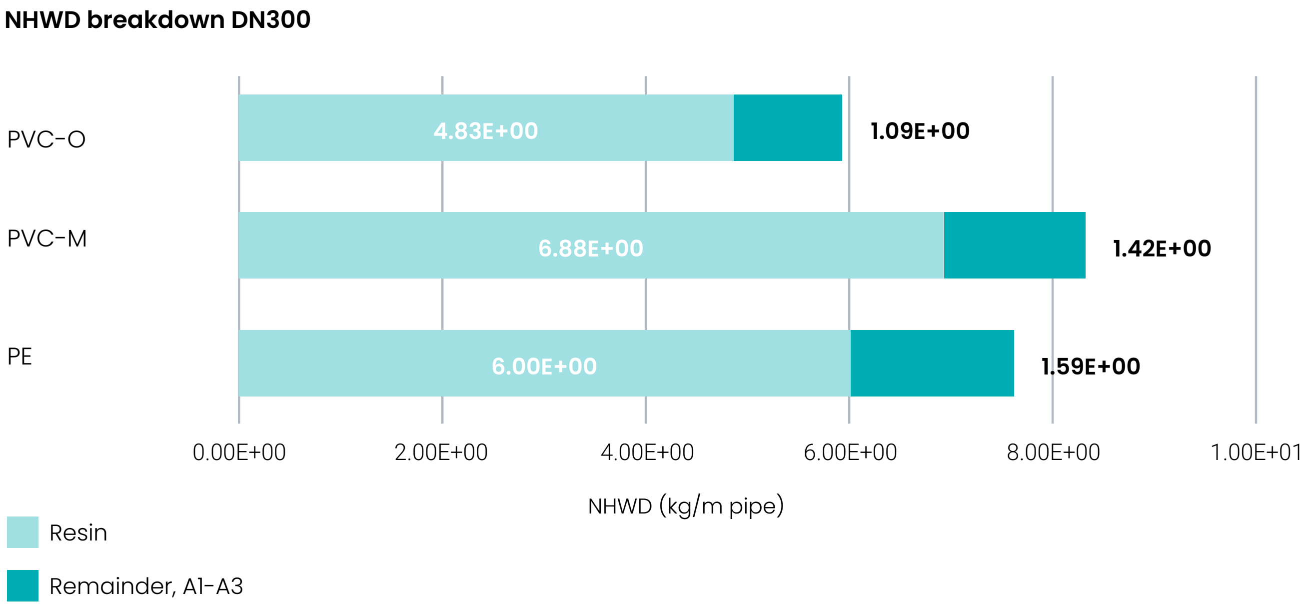

Figure 51: The breakdown of non-hazardous waste disposed of plastic pipes for the size of DN300

7.1.13. Radioactive waste disposed

Radiation poisoning by radioactive materials can cause serious damage to ecosystems. One major source of radioactive waste is nuclear power plants. The spent fuel from nuclear power plants can be highly radioactive requiring more than a few thousand years of safe storage. The 'radioactive waste disposed' (RWD) indicator measures the quantity of radioactive waste produced and disposed of during the manufacture of a product.

This impact category is of lower concern in Australia as the radioactive waste values indicate its presence in the overseas supply chain. In polypropylene and polyethylene pipes, nuclear energy-based electricity used to produce resins is the primary source of radioactive waste. The background LCA data used for resin productions indicates that nuclear energy-based electricity produced in China, the USA, Canada and Europe are the sources of radioactive waste values of plastic resin productions. If resins are purchased outside these geographic areas, it's likely that the RWD values may not be accurately reflected.

As the Saint-Gobain DICL pipe EPDs are based in Europe, radioactive waste will likely be more significant, as indicated in the results. Australia primarily imports ductile iron pipes from India and China[28], both with significant nuclear power capacities of 55 and 22 operational reactors respectively, and a further 68 and 20 reactors under construction or planned[29]. The current nuclear facilities in China and India are comparable to Europe, with France, for example, having 56 operable reactors[30].

Figure 52 shows that the radioactive waste generated during the production of PVC pipes and PE pipes is very similar, while DICL pipes contribute significantly to radioactive waste. For example, radioactive waste associated with DICL pipes was approximately 90 and 40 times greater than PE at DN100 and 300, respectively. The breakdowns of RWD for the product stage of the pipes is presented in Figure 53, Figure 54 and Figure 55.

For DICL pipes, the radioactive waste is most likely produced during the extraction and production of ductile iron (Figure 53). Plastic resin production contributes almost entirely to the radioactive waste associated with PVC pipes and significantly to PE pipes (Figure 54). The remainder (A1-A3) component of PE pipe includes the production of carbon black, pipe manufacturing energy, and wastes, with most radioactive waste caused by the production of carbon black.

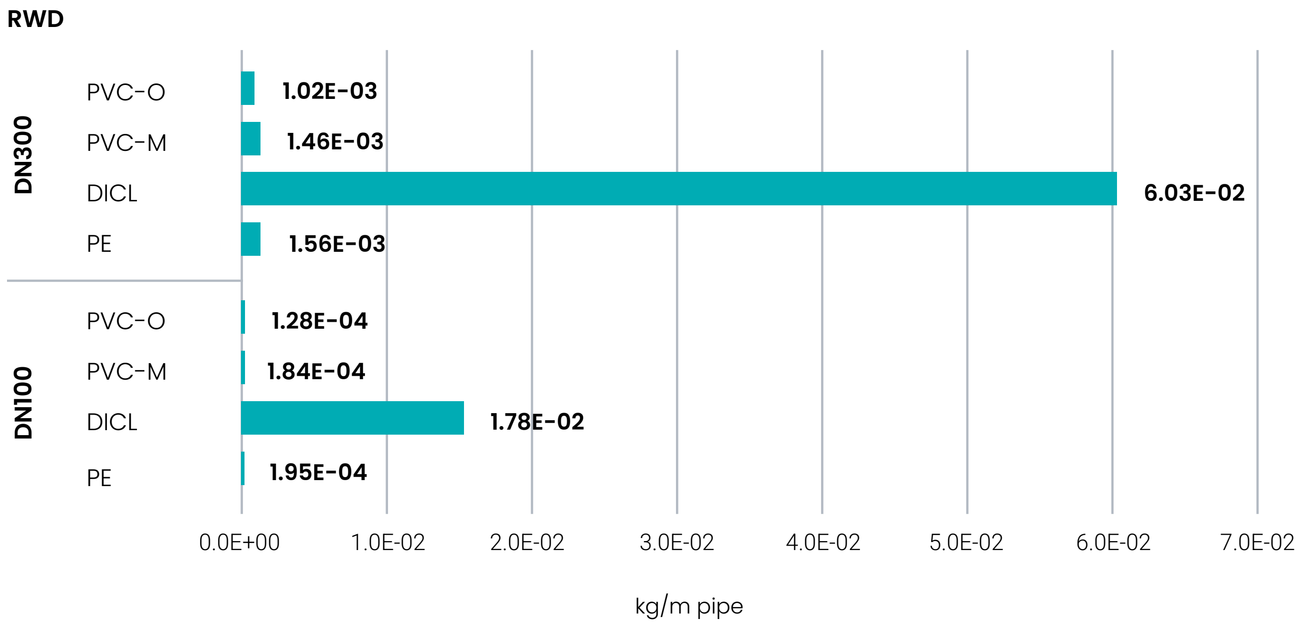

Figure 52: Radioactive waste disposed comparison of plastic pipes with DICL pipes

28 Volza (2024) Ductile Iron Pipes In Imports in Australia - Market Size & Demand based on Import Trade Data, https://www.volza.com/p/ductile-iron-pipes-in/import/import-in-australia/
29 World Nuclear Association (2024) Asia's Nuclear Energy Growth, https://world-nuclear.org/information-library/country-profiles/others/asias-nuclear-energy-growth
30 World Nuclear Association (2024) Nuclear Power in France, https://world-nuclear.org/information-library/country-profiles/countries-a-f/france

RWD breakdown

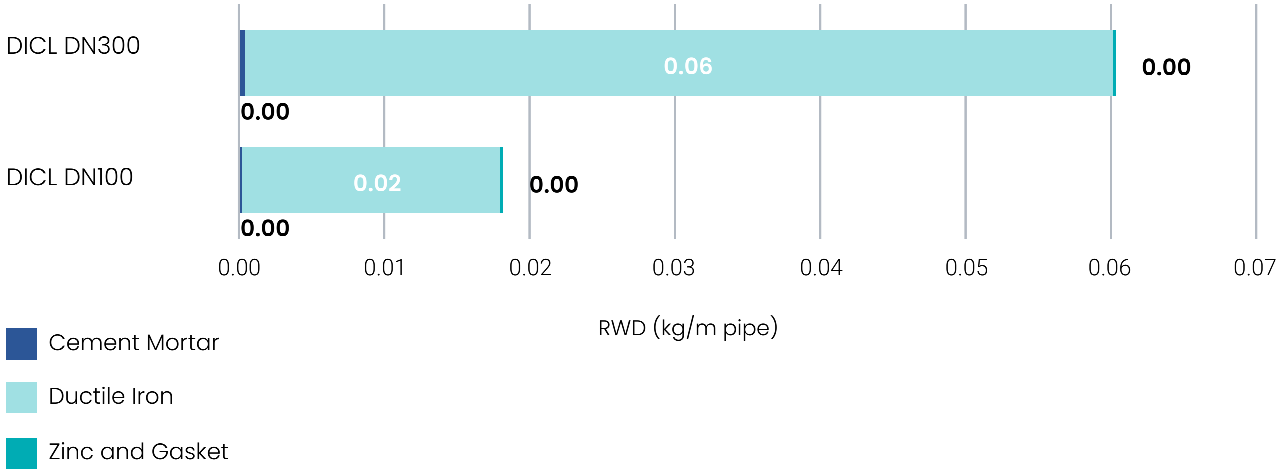

Figure 53: The breakdown of radioactive waste disposed of DICL pipes

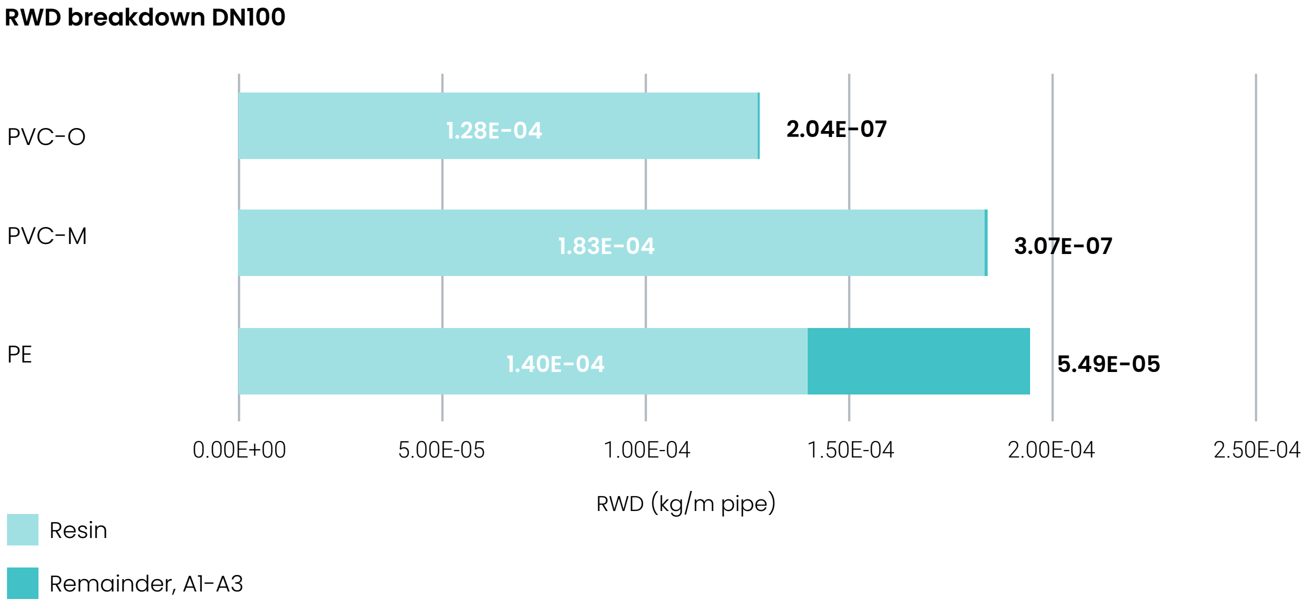

Figure 54: The breakdown of radioactive waste disposed of plastic pipes for the size of DN100

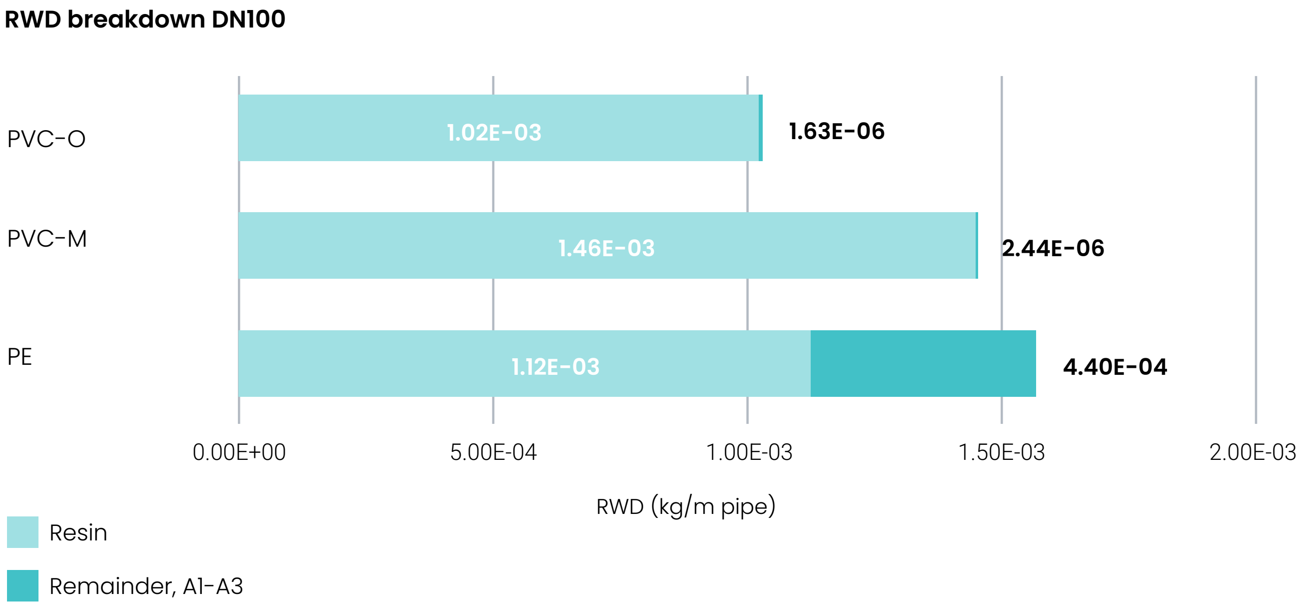

Figure 55: The breakdown of radioactive waste disposed of plastic pipes for the size of DN300

7.1.14. Summarised comparison of all indicators reported

The results presented between 7.1.1 and 7.1.13 are summarised in Table 6, showing plastic pipes perform well in most indicators at DN100. However, at DN300, the performance of plastic and DICL pipes is mixed. For many indicators, the better performing pipe may be apparent at DN100 but inconclusive for DN300, mostly because the DICL pipes don't scale linearly according to weight, as they do for PE and PVC pipes. This is reflected in the fact that separate EDPs were required for the DICL pipes at DN100 and DN300, whereas PE and PVC pipe data scaled on a per kilogram basis.

Based on the Saint-Gobain EPD data for DICL pipes, the weight per metre of pipe doesn't scale uniformly with diameter. For example, as the diameter scales at a factor of 3, the weight per metre scales at a factor of 3.8. The percentage of ductile iron by pipe weight also increases from 78.8% at DN100 to 82.6% at DN300. As a result, the DICL results changed significantly across multiple impact factors at DN100 and DN300, compared to the PE and PVC results which scaled predictably. To align with Australian Standards, correction factors were applied to the Saint-Gobain EPD data, which may also contribute to the differences between DN100 and DN300 pipes.

Table 6: Comparison of midpoint selected indicators for plastic and DICL pipes for DN100 and DN300

IMPACT CATEGORY	ABBREVIATION	DN100		DN300	
		PLASTIC PIPES	DICL PIPES	PLASTIC PIPES	DICL PIPES
Total global warming potential	GWP - Total	↑	↓	↑	↓
Acidification potential	AP	↑	↓	—	—
Eutrophication – aquatic freshwater	EP - freshwater	↑	↓	↑	↓
Eutrophication – aquatic marine	EP - marine	↑	↓	—	—
Eutrophication – terrestrial	EP – terrestrial	↑	↓	—	—
Photochemical ozone creation potential	POCP	↑	↓	↑	↓
Abiotic depletion potential (metals and minerals)*	ADPE	—	—	—	—
Abiotic depletion potential (fossil fuels)*	ADPF	—	—	—	—
Ozone depletion potential	ODP	—	—	—	—
Use of net fresh water	FW	↑	↓	↑	↓
Hazardous waste disposed	HWD	↓	↑	↓	↑
Non-hazardous waste disposed	NHWD	↑	↓	—	—
Radioactive waste disposed/stored	RWD	↑	↓	↑	↓

↑ **performing better** ↓ **performing worse** — **inconclusive**

* Abiotic depletion potential (metals and minerals) and abiotic depletion potential (fossil fuels) have a high level of uncertainty, originating from the uncertainties on the estimation of extractable reserves. It cannot be conclusively stated that one type of pipe is better than the other for the abiotic depletion impact categories.

The comparison presented in Table 6 shows that plastic pipes perform well in both GWP and FW environmental impact categories for DN100 and DN300. According to the Green Star Buildings Submission Guidelines[31], the weighting factor for GWP and FW is 25% each[32]. The Infrastructure Sustainability Council (ISC) uses weighting for their material calculator with a GWP factor of 47.5%, however, a water related indicator isn't included[33].

ISC also concluded that the most significant environmental concerns are conveyed through GWP and FW parameters with weighting factors of 24.1 and 15.2, respectively[34]. They also noted that the ranking of leading issues hasn't changed since their previous assessment in 2008. The comparison shows that plastic pipes have a demonstrable advantage in the environmental categories of highest priority. However, this apparent advantage of plastic pipes compared to DICL pipes is more pronounced at DN100 than DN300.

31 Green Star Buildings Submission Guidelines, Version 1: Revision B, 10 December 2021

32 Normalisation and weighting are often used in comparative LCA to get a single environmental performance score. When the environmental impact values of a product are normalised with annual impacts caused by one citizen, the mathematical process is known as normalisation. The normalised values are then weighted to get a single environmental impact score. The weighting factors are determined based on the importance of environmental indicators. The EPD results were not transformed to single score in this report. This is because the EN 15804 + A2 complaint EPDs results are not available for normalisation and weighting.

33 ISCA (2018) ISv2.0 Materials Calculator Guideline, https://d3n8a8pro7vhmx.cloudfront.net/themes/5a72941f5ee54d4c43000000/attachments/original/1533001335/2018-02-21_ISCA_Materials_Guideline_Version_2.0_Rev_0.pdf?1533001335

34 Abbe, O. and Hamilton, L., (2017) BRE Global Environmental Weighting for Construction Products using Selected Parameters from EN 15804. BRE Global Ltd.: Hertfordshire, UK.

7.2. DOWNSTREAM TRANSPORT (MODULE A4)

Downstream transport refers to product distribution and transportation from the manufacturing plant to the building site. Many factors can affect the results of downstream transport, including the weight of the product, transport load, transport type and transport distance. It's difficult to compare module A4 between EPDs, as the A4 impacts were calculated using different assumptions and circumstances. Most notably, the DICL A4 impacts were calculated in an overseas context.

It's expected that for an equivalent trip, plastic pipes would have lower environmental impacts for downstream transport compared to DICL pipes, due to their weight (Table 1). The lightweight nature of plastic pipes generally reduces fuel consumption and emissions associated with transport. As a point of reference, the A4 GWP total impacts of PE were 0.164 and 1.31 kg CO_2eq per metre of pipe, at sizes of DN100 and 300, respectively (Vinidex, Environmental Product Declaration Polyethylene Pipes, 2022).

Australia imports the majority of DICL pipes from China and India[35], resulting in large transport distances that significantly increase the module A4 impacts compared to local manufacturing. Although international shipping freight has lower emissions on a per-tonne basis compared to road travel[36], the large distances travelled when importing DICL pipes from China and India, plus the in-country road transport, adds significantly to the module A4 environmental impacts. Alternatively, an Australian company importing DICL pipes from overseas incorporates these in the product stage as module A2 raw material transport impacts. In both cases, international freight negatively impacts the life cycle impacts of the DICL pipes.

35 Volza (2024) Ductile Iron Pipes In Imports in Australia - Market Size & Demand based on Import Trade Data, https://www.volza.com/p/ductile-iron-pipes-in/import/import-in-australia/
36 Rouvia (2023) The environmental impact of freight transport, https://rouvia.com/blog/environmental-impact-freight-transportation

8. CONCLUSIONS

This report compares plastic infrastructure pipes of three materials (PE, PVC-M, PVC-O) with DICL pipes. The data for this comparison was primarily sourced from published EPDs (Vinidex PE pipes EPD, Iplex PVC EPD and Saint-Gobain DICL pipes EPDs).

Thirteen impact indicators from EPD results were compared, and these were selected based on prioritisation developed by BRE[37]. They include climate change, ozone depletion, acidification, eutrophication (aquatic freshwater), eutrophication (aquatic marine), eutrophication (terrestrial), photochemical ozone formation, abiotic depletion (metals and minerals), abiotic depletion (fossil resources), use of net freshwater, hazardous waste, non-hazardous waste and radioactive waste. As there are many nuclear power plants in Europe, radioactive waste is of particular concern, so it's important to consider the European context of the Saint-Gobain EPDs. However, this impact category may be of low concern in Australia as the radioactive waste values in the LCA of Australian products indicate its presence in overseas supply chains.

The summary of this study is as follows:

- The plastic pipes considered in this study were produced from 100% virgin materials. The DICL pipes used 40% recycled ductile iron. The inclusion of recycled content in the DICL pipes may help to reduce their environmental footprint.
- The assessed PE pipes had larger nominal diameters (125 mm and 355 mm) than the PVC and DICL pipes (100 mm and 300 mm), to reflect the larger diameter required in application and achieve functional equivalency. The nominal size of PE pipes is based on the outer diameter and was selected to align with the internal diameters of the PVC and DICL pipes. The results group the pipes according to the functional equivalency diameters of DN100 and DN300.
- Data for the DICL pipes was obtained from Saint-Gobain EPDs, developed in Europe. The location of the EPD is particularly significant for radioactive waste, as countries use varying amounts of nuclear power. Australia primarily imports ductile iron pipes from India and China[38], both with significant nuclear power capacities of 55 and 22 operational reactors, respectively, and a further 68 and 20 reactors under construction or planned[39]. This number of nuclear facilities is comparable to Europe, with France, for example, having 56 operable reactors[40].
- Of the 13 impact categories, DN100 plastic pipes (PVC and PE) performed better in 9 categories, including global warming potential (GWP), acidification potential, eutrophication – freshwater, eutrophication – marine, eutrophication – terrestrial, photochemical ozone creation potential, use of net freshwater, non-hazardous waste disposed, and radioactive waste disposed/stored.
- DN100 plastic pipes performed poorer than DICL pipes in the category of hazardous waste disposed.
- Ozone depletion potential of plastic pipes and DICL pipes at DN100 was found to be similar.
- Abiotic depletion potential (metals and minerals) and abiotic depletion potential (fossil fuels) have high levels of uncertainty, due to the

37 Abbe, O. and Hamilton, L., (2017) BRE Global Environmental Weighting for Construction Products using Selected Parameters from EN 15804. BRE Global Ltd.: Hertfordshire, UK.
38 Volza (2024) Ductile Iron Pipes In Imports in Australia - Market Size & Demand based on Import Trade Data, https://www.volza.com/p/ductile-iron-pipes-in/import/import-in-australia/
39 World Nuclear Association (2024) Asia's Nuclear Energy Growth, https://world-nuclear.org/information-library/country-profiles/others/asias-nuclear-energy-growth
40 World Nuclear Association (2024) Nuclear power in France, https://world-nuclear.org/information-library/country-profiles/countries-a-f/france

estimation of extractable reserves. As a result, the advantages of plastic pipes over DICL pipes at DN100 may be diminished in these categories. Similarly, at DN300, it wasn't possible to conclusively state that plastic or DICL pipes were better in these impact categories.

- At DN300, plastic pipes performed better in five categories including GWP, eutrophication – freshwater, photochemical ozone creation potential, use of net freshwater and radioactive waste disposed/stored.
- Plastic DN300 pipes performed worse in hazardous waste disposal.
- The DN300 plastic and DICL pipes had similar outcomes in the remaining five environmental impact categories of acidification potential, eutrophication – marine, eutrophication – terrestrial, ozone depletion potential and non-hazardous waste disposed.
- The relative environmental outcomes of the assessed pipes changed for several environmental impact categories, depending on nominal diameter of the pipes.
- According to the Green Star Buildings Submission Guidelines[41], the weighting factor for GWP and freshwater use is 25% each[42]. The Infrastructure Sustainability Council (ISC) uses weighting for their material calculator with a GWP factor of 47.5%[43]. For DN100 and DN300, plastic pipes performed better in both GWP and use of net freshwater (FW) impact categories compared to DICL pipes.
- As the weights of DICL pipes per metre are higher than plastic pipes, the GWP for plastic pipes transport is expected to be lower than DICL pipes. However, there was insufficient Australian DICL data to draw reliable comparisons between the A4 impacts of DICL pipes and plastic pipes.

The conclusions of this study are as follows:

- The GWP and FW impact categories are considered most important when using an LCA for the built environment in Australia, and plastic pipes have lower impact than DICL pipes for these categories at DN100 and DN300.
- High radioactive waste generated in the production of DICL pipes is likely due to the use of nuclear energy to generate electricity in Europe.
- The results show lower levels of radioactive waste for plastic pipes. This impact category is of lower concern in Australia as the radioactive waste values indicate its presence in the overseas supply chain. In the case of polypropylene and polyethylene pipes, nuclear energy-based electricity used to produce resins is the primary source of radioactive waste. The background LCA data used for resin productions indicates that nuclear energy-based electricity produced in China, Canada, Europe and the United States are the sources of radioactive waste values of plastic resin productions.
- The ozone depletion potential of PVC-O and PVC-M pipes is higher compared to PE or DICL pipes.

From this study, PIPA can build communications on the following basis:

- At the product stage (A1-A3), plastic pipes (PE and PVC) have demonstrated life cycle advantages in the highest priority environmental categories in Australia, including GWP and FW.
- The GWP to produce plastic pipes is lower compared to DICL pipes for both DN100 and DN300.
- The net fresh water used to produce plastic pipes is lower compared to DICL pipes for both DN100 and DN300.

However, from this study, PIPA can't say the following:

- Plastic pipes have, in general, superior environmental performance over DICL pipes.
- There's less waste generation in the production of plastic pipes compared to DICL pipes.
- There's less depletion of non-renewable resources (fossil and mineral resources) in the production of plastic pipes compared to DICL pipes.

This study was conducted with the best available third-party technical environmental data and may be challenging to communicate to non-specialist or non-technical audiences and decision-makers. To make a simplified comparison, there's an option to calculate and present aggregated environmental impact (e.g. eco-points). Although both ISC and Green Star have versions of eco-points, they're defined using the old EPD standard (EN 15804 + A1), which isn't yet compatible with EPDs produced using the current standard (EN 15804 + A2).

41 Green Star Buildings Submission Guidelines, Version 1: Revision B, 10 December 2021

42 Normalisation and weighting are often used in comparative LCA to get a single environmental performance score. When the environmental impact values of a product are normalised with annual impacts caused by one citizen, the mathematical process is known as normalisation. The normalised values are then weighted to get a single environmental impact score. The weighting factors are determined based on the importance of environmental indicators. The EPD results were not transformed to single score in this report. This is because the EN 15804 + A2 complaint EPDs results are not available for normalisation and weighting.

43 ISCA (2018) ISv2.0 Materials Calculator Guideline, https://d3n8a8pro7vhmx.cloudfront.net/themes/5a72941f5ee54d4c43000000/attachments/original/1533001335/2018-02-21_ISCA_Materials_Guideline_Version_2.0_Rev_0.pdf?1533001335

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APPENDIX A:

CORRECTION FACTORS[44] TO ADJUST THE EUROPEAN SAINT-GOBAIN EPD RESULTS TO CLOSER REPRESENT AUSTRALIAN STANDARDS.

Table A1: Data sourced from Saint-Gobain EPD for DICL pipes (Saint-Gobain, Environmental Product Declaration Pipe System Natural DN100, 2022; Saint-Gobain, Environmental Product Declaration Pipe System Natural DN300, 2022).

DN (NOMINAL)	DUCTILE IRON - EN545:2010 (CLASS 40)						CEMENT MORTAR LINING (CML) - ORDINARY PORTLAND CEMENT					OTHER COMPONENTS			TOTAL WEIGHT (KG/M)
	Mean OD (mm)	Min wall thickness (mm)	Nominal wall thickness (mm)	Nominal ID DI only (mm)	kg/m (DI metal only)	% of DI metal vs. total kg/m	Min wall thickness (mm)	Nominal wall thickness (mm)	Nominal ID CL (mm)	kg/m (CML)	% of CML vs. total kg/m	Zinc Coating (kg/m)	EPDM Ring (kg/m)	Zinc coating plus EPDM ring (kg/m)	
100	118	3	4.4	109.2	11.5	78.8%	2.5	4	101.2	3.1	21.2%	< 1	< 1	0.2	14.6
300	326	4.6	6.2	313.6	45.6	82.0%	2.5	4	305.6	9.1	16.4%	< 1	< 1	0.6	55.6

Table A2: Correction factors, provided by PIPA, to adjust the Saint-Gobain data and provide a more representative result within the Australian context.

44 Use of a correction factor in this instance introduces a small amount of uncertainty, which should be considered when interpreting the results.

DN (NOMINAL)	DUCTILE IRON - DI SERIES 2 (AU) - AS/NZS 2280 (PN35)							CEMENT MORTAR LINING (CML) - ORDINARY PORTLAND CEMENT						OTHER COMPONENTS			TOTAL WEIGHT (KG/M)	CORRECTION FACTOR (WEIGHT AVERAGE) [45]
	Mean OD (mm)	Min wall thickness (mm)	Nominal wall thickness (mm)	Nominal ID DI only (mm)	kg/m (DI metal only)[46]	Correction factor (DI metal)	% of DI metal vs. total kg/m	Min wall thickness (mm)	Nominal wall thickness (mm)	Nominal ID CL (mm)	kg/m (CML)[47]	Correction factor (CML)[48]	% of CML vs. total kg/m	Zinc Coating (kg/m)	EPDM Ring (kg/m)	Zinc coating plus EPDM ring (kg/m)		
100	122	3.5	4.9	112.2	13.13	1.14	76.0%	3.5	5	102.2	3.95	1.27	22.9%	< 1	< 1	0.2	17.28	1.16
300	345	4.3	5.9	333.2	45.77	1.00	78.3%	3.5	5	323.2	12.09	1.33	20.7%	< 1	< 1	0.6	58.46	1.06

45 Weight average correction factor of the whole pipe (for each DN): correction factor for DI × % of DI + correction factor for CML × % of CML
46 Weights per metre provided by PIPA.
47 Correction factor for DI calculated by dividing the AS/NZS 2280 kg/m of DI by the kg/m of DI from the Saint-Gobain data, for the equivalent DN.
48 Correction factor for CML calculated by dividing the AS/NZS 2280 kg/m of CML by the kg/m of CML from the Saint-Gobain data, for the equivalent DN.

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