edge environment

# LCA of Australian Pipe

26 March 2009

For: PIPA

Nigel Howard

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## Acknowledgements

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Abstract

The PVC products industries have suffered from a vigorous campaign of opposition to the use of PVC from environmental groups resulting in widespread belief that PVC is inherently damaging to the environment and to human health.

LCA studies internationally and collated in the US, have shown that PVC products are typically no better or worse than the alternatives across a wide range of environmental and health risk assessments. An earlier study conducted by Edge Environment has shown that the conclusions from this international and US work are valid in Australia and that in the case of pipe, Australian PVC pipe is typically advantageous environmentally.

This project follows on from this earlier work and takes the investigation to a new level by conducting an LCA of 100mm PVC pipe from the 2 largest Australian producers, Vinidex and Iplex and drawing comparisons with data for competing pipe products estimated from the Australian SimaPro LCA dataset.

This study shows that per tonne impact assessments of PVC pipe appear to be highly representative of a full range of PVC pipe production and sizes. This enables a highly representative generic average Life Cycle Inventory to be compiled for Australian PVC pipe that can be used to contribute to the AusLCI or BPIC/ICIP projects.

The principal findings for Drain / Waste / Vent (DWV) pipe are that:

- Copper pipe has the highest environmental impacts of all alternatives and would not be recommended on environmental grounds.
- Ductile iron pipe is second worst and would not be recommended on environmental grounds.
- Of the plastics pipes, foamed core PVC was the best, PE pipe was next best overlapping in performance with the worst case for foamed core PVC, solid wall PVC was next with ABS pipe as the worst of the plastics pipe alternatives, but still considerably better than the metal pipe alternatives..

The principal findings for pressure pipe are that:

- PVC-o pipe was substantially the best performer with PE next best followed by different grades of PVC solid-walled pipe.
- The polymeric pipes all outperformed the Cement Lined Ductile Iron pipe at the 100mm pipe size evaluated (this may be a limitation of this study for larger pressure pipe applications).

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# LCA of Australian Pipe

## 1. Background

The PVC products industries have suffered from a vigorous campaign of opposition to the use of PVC from environmental groups resulting in widespread belief that PVC is inherently damaging to the environment and to human health.

LCA studies internationally and collated in the US, have shown that PVC products are typically no better or worse than the alternatives across a wide range of environmental and health risk assessments. An earlier study conducted by Edge Environment has shown that the conclusions from this international and US work are valid in Australia and that in the case of pipe, Australian PVC pipe is typically advantageous environmentally.

This project follows on from this earlier work and takes the investigation to a new level by conducting an LCA of DN100 PVC pipe from the 2 largest Australian producers, Vinidex and Iplex and drawing comparisons with data for competing pipe products estimated from the Australian SimaPro LCA dataset. DN100 pipes were chosen for both the pressure and non pressure comparison as they represent the largest volume of PVC pipe manufactured for these applications in Australia (in the case of PE pressure pipe DN110 was used as the closest available comparable size).

By publishing comprehensive LCA data about PVC pipe and alternatives PIPA hope to change perceptions about the environmental credentials of PVC pipe with key stakeholders and influencers.

## 2. Objective

To determine the environmental profile of generic PVC pipe for different applications in Australia and compare and benchmark its performance against the main available alternatives.

## 3. Methodology

The LCA methodology adopted is compliant to ISO14044 and the emerging methodology guidelines form the Australian Life Cycle Inventory project (AusLCI) and the specific guidelines being developed for the building products sector under the BPIC/ICIP project. The main tasks were:

1. Identification of Products/Archetypes, Goal, Scope and Functional Unit
2. Questionnaire to Gather PIPA Member Product Data
3. Literature Survey to Locate Data for Competing Products – ABS, Cast iron, Ductile Iron, PE, Copper
4. Preliminary SimaPro Modelling of the Data
5. Preliminary Impact Assessment and Ecopoint Modelling
6. Sensitivity Analysis to identify Vulnerable/Crucial Data
7. Confirmation/Refinement of Vulnerable/Crucial Data
8. Draft Report and seek Comment from PIPA Members and other Stakeholders
9. Finalise Draft and Present to Stakeholders

# 4. Goal, Scope and Functional Unit

## 4.1 Goal:

To understand the life cycle impacts of Australian PVC pipe production and compare this with alternatives for the different variants of 100mm drain waste vent pipe and 100mm pressure pipe.

## 4.2 Scope

Cradle to Gate for the product comparisons but providing a basis for extending the study cradle to grave (i.e. through the use phase to disposal) or even cradle to cradle since all post-consumer UPVC waste arising can be used, especially in the foamed fore of foamed core PVC pipe

## 4.3 Functional Unit

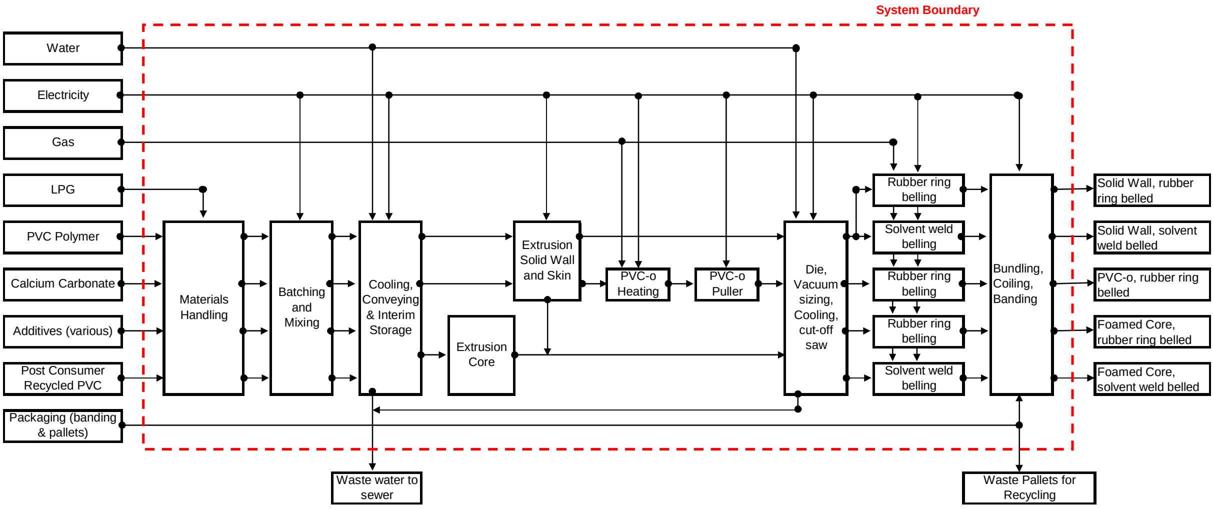
1 m length of DN100 pipe assuming all pipe materials have the same service life and last the life of the building (100 years). 2 classes of pipe to be assessed – Drain Waste Vent (DWV) Pipe and Pressure Pipe.

The different alternatives studied are as follows:

| | Material | Description | Actual OD mm | Wall Thickness | Weight kg/m | Info Source |
|---|---|---|---|---|---|---|
| Drain, Waste, Vent Pipe | **PVC** | DN100 Australian solid wall | 110 | | 1.6 | AS1260, Vinidex |
| | | DN100 Australian Sandwich Construction (foam core) | 110 | | 1.2 | AS1260, Vinidex |
| | **ABS** | DN100 Australian ABS Imperial PN9-12 | 114 | 6.8 | 2.44 | AS3518, Tyco Product Catalogue |
| | | DN100 Australian ABS Imperial PN9 | 114 | 5.3 | 1.92 | AS3518, Tyco Product Catalogue |
| | | DN100 Australian ABS Imperial Class C 9 Bar (PN9) | 114 | 6.7 | 2.32 | Philmac Catalogue |
| | | DN100 Australian ABS Metric PN10 | 110 | 6.6 | 2.27 | AS3518, George Fischer Pipelines |
| | **Cast Iron** | DN100 Australian | 112 | 6 | 8.4 | Crevet Catalogue |
| | **PE** | DN100 PE DWV | 110 | | 1.35 | Geberit brochure , Vinidex |
| | **Copper** | DN100 Type A | 101.6 | | 5.68 | AS1432, Crane Copper Catalogue |
| | | DN100 Type B | 101.6 | | 4.58 | AS1432, Crane Copper Catalogue |
| | | DN100 Type D | 101.6 | | 3.44 | AS1432, Crane Copper Catalogue |
| Pressure Pipe | **PVC** | DN100 Australian solid wall | 121 | | 4.4 | AS1477, Vinidex |
| | | PVC-o | 121 | | 1.7 | AS4441, Vinidex |
| | **Ductile Iron** | DN100 Pressure Pipe (Cement Lined) | | | 17.8 | AS2280, Tyco Catalogue (mortar 5mm) |
| | **PE** | PE100 DN110 PN16 Pressure Pipe | | 10.5 | 3.12 | AS4129, Iplex Catalogue - closest size to DN100 Series 2 |

# 5. Process Diagram and Boundary

The generic process diagram for PVC pipe production is as follows and the system boundary in red defines the scope of the assessment. The inventory results measure all of the inputs, outputs, product quantities, wastes and emissions that cross the system boundary:




NB the process diagramused in practice was considerably more detailed than shown here

# 6. Results

The results of this study show that per tonne assessments of PVC pipe appear to be highly representative of a full range of PVC pipe production and sizes. This arises because the dominant impacts are from electricity use to extrude the pipe and the quantity of electricity used is almost directly proportional to the mass of polymer extruded. This enables a highly representative generic average Life Cycle Inventory (Gate to Gate) to be compiled for Australian PVC pipe that can be used to contribute to the AusLCI or BPIC/ICIP projects. The inventory results per tonne of PVC pipe production that may be offered to the AusLCI and BPIC/ICIP projects are as follows:

## 6.1 Australian Generic PVC Pipe Inventory Results

### Inputs

| Inventory of PVC Pipe Production per tonne of pipe | Inputs Electricity kWh | LPG dm3 | Water m3 | PVC Resin tonnes | Calcium Carbonate tonnes | Titanium Dioxide tonnes | Non-toxic Stabiliser tonnes | Organic Waxes tonnes | Process Aids tonnes | Azodicarb-onamide tonnes | Organic Pigment tonnes | On-site Recyclate tonnes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Solid Wall | | | | | | | | | | | | |
| Standard Range Low | 293 | 2.16 | 0.15 | 0.78 | 0.02 | 0.008 | 0.021 | 0.0006 | - 0.005 | - | 0.00002 | 0.001 |
| Average | 380 | 2.38 | 0.19 | 0.83 | 0.08 | 0.011 | 0.022 | 0.0026 | 0.021 | - | 0.00011 | 0.032 |
| Standard Range High | 467 | 2.60 | 0.24 | 0.87 | 0.15 | 0.013 | 0.023 | 0.0047 | 0.047 | - | 0.00019 | 0.062 |
| Standard Deviation | 87 | 0.22 | 0.05 | 0.05 | 0.06 | 0.003 | 0.001 | 0.0021 | 0.026 | - | 0.00008 | 0.031 |
| Foamed Core | | | | | | | | | | | | |
| Standard Range Low | 222 | 1.03 | 0.09 | 0.32 | 0.03 | 0.003 | 0.009 | - 0.0014 | - 0.009 | 0.00017 | 0.00002 | - 0.001 |
| Average | 337 | 1.73 | 0.15 | 0.58 | 0.07 | 0.008 | 0.015 | 0.0011 | 0.008 | 0.00029 | 0.00008 | 0.016 |
| Standard Range High | 452 | 2.44 | 0.22 | 0.84 | 0.10 | 0.012 | 0.022 | 0.0037 | 0.025 | 0.00040 | 0.00015 | 0.033 |
| Standard Deviation | 115 | 0.71 | 0.06 | 0.26 | 0.03 | 0.004 | 0.007 | 0.0025 | 0.017 | 0.00012 | 0.00007 | 0.017 |

### Outputs

| Inventory of PVC Pipe Production per tonne of pipe | Outputs PVC Pipe tonnes | Solid PVC Waste tonnes | Solid Waste Palet tonnes | Solid Waste Other tonnes | Liquid Effluent m3 |
|---|---|---|---|---|---|
| Solid Wall | | | | | |
| Standard Range Low | 1.00 | - | - | - | 0.09 |
| Average | 1.00 | - | - | - | 0.11 |
| Standard Range High | 1.00 | - | - | - | 0.14 |
| Standard Deviation | 1.00 | - | - | - | 0.03 |
| Foamed Core | | | | | |
| Standard Range Low | 1.00 | - | - | - | 0.05 |
| Average | 1.00 | - | - | - | 0.09 |
| Standard Range High | 1.00 | - | - | - | 0.13 |
| Standard Deviation | 1.00 | - | - | - | 0.04 |

**The outputs from the production processes are nil because all PVC waste arising gets recycled back into product. Packaging waste is minimised and internally recycled (pallets are refurbished on-site)**

## 6.2 Cradle to Gate Results

In order to move from the inventory (Gate to Gate) results to full Cradle to Gate results, all of the upstream data for all of the inputs and downstream data for the waste processing have to be included. This was done by entering the inventory data into SimaPro and linking all of the inputs and outputs to the appropriate data sources for the different materials, resources, energy sources and waste disposal routes.

The results can be expressed in a variety of ways:

- Cradle to gate inventory
- Characterised inventory
- Characterised and normalised inventory
- Characterised, normalised and weighted results.

Each of these approaches has been followed in this report and these are described below and detailed in the appendices. It is the weighted results that provide the best platform for decision making. The weighted results take account of a wide range of stakeholder views about the priorities of concern for different environmental impacts. These provide the best basis for valid comparisons. The weightings adopted are adapted from those used to weight Green Star Credits.

1 ***Cradle to gate inventory*** (thousands of data items) which has little practical value for decision-making

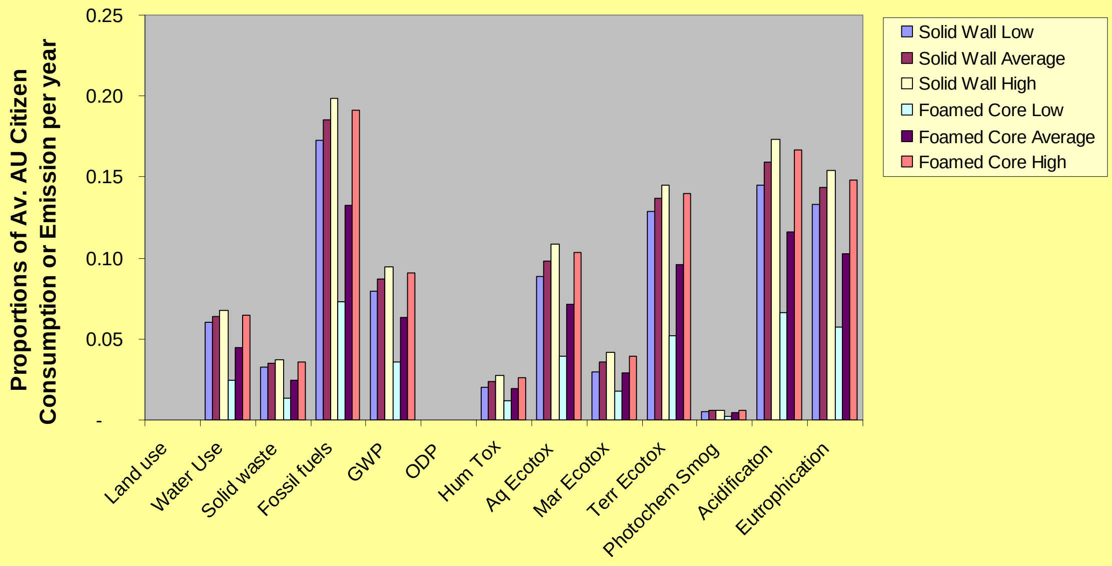
2 ***Characterised inventory*** against key impact categories which classifies each inventory item for the environmental impacts that it contributes to and multiplies the quantity consumed or emitted by relevant potency factors (characterisation factors) to bring all of the contributions of an impact to a common unit. The Characterised impacts may now be summed to a total value for that impact. The impact categories used and units of measurement are as follows:

| | |
|---|---|
| Land use | Ha a |
| Water Use | KL H2O |
| Solid waste | kg |
| Fossil fuels | MJ surplus |
| Global warming (GWP100) | kg CO2 eq. |
| Ozone layer depletion (ODP) | kg CFC-11 eq |
| Human toxicity | kg 1,4-DB eq |
| Fresh water aquatic ecotox. | kg 1,4-DB eq |
| Marine aquatic ecotoxicity | kg 1,4-DB eq |
| Terrestrial ecotoxicity | kg 1,4-DB eq |
| Photochemical oxidation | kg C2H2 |
| Acidification | kg SO2 eq |
| Eutrophication | kg PO4--- eq |

Characterised results for these 13 impact categories allow a comparison between alternatives for any particular issues – for example a carbon footprint or water use comparison or toxicity comparison. However, the characterised results are not suitable for reaching a final decision because there is no consideration of the relative importance of the different impact categories and they are all expressed in different units.

3 ***Characterised and Normalised*** inventory - Normalsation relates all of the characterised results to a common unit of activity like the per capita average impacts of an Australian citizen. This stage eliminates the different units between the different impact categories so that they are all expressed as a proportion of an average citizens impacts for a year. Making the quantities dimensionless ratios is the first step to weighted impacts. Normalised results themselves can be interesting for revealing the extent to which different alternatives contribute to the different impacts in Australia. Figure 1 shows how 1 tonne of each of the PVC pipe variants contributes to the different impact categories,. This fingerprint of impacts is characteristic of an LCA dominated by electricity consumption.

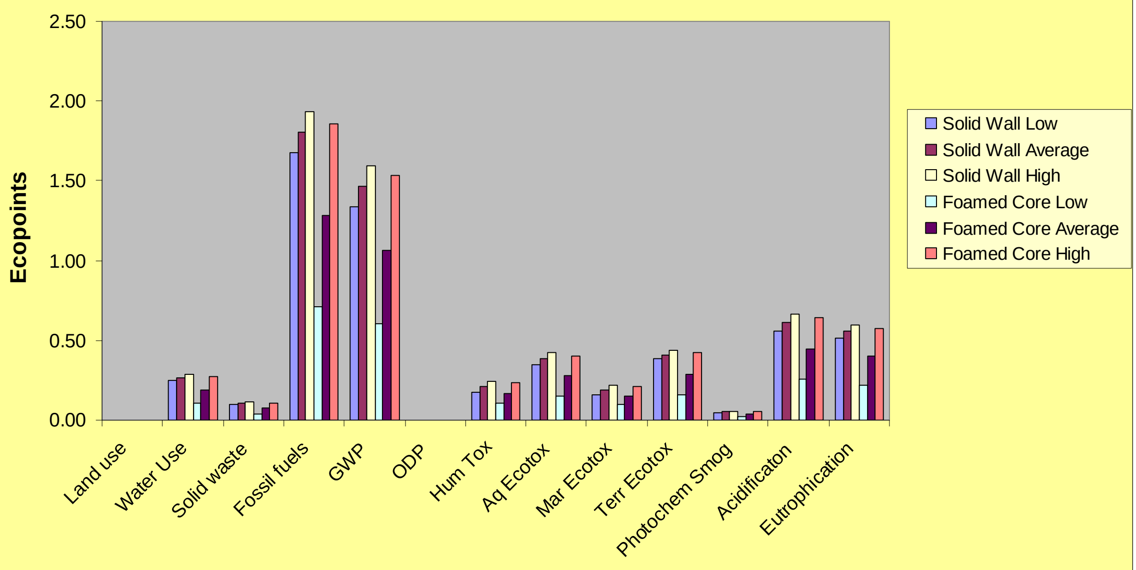
**Figure 1 - Characterised and Normalised Impacts**
**1 tonne of PVC Pipe**




## 4 **Characterised, Normalised and Weighted** Results

Weighting assigns a consensus based judgement of the relative importance of different issues and allows the impacts to be summed across impact categories to a final index of environmental impact or an Ecopoint. The weightings adopted are adapted from those used to weight Green Star Credits. Figure 9 shows that for the weighted results climate change (expressed as Global Warming Potential) is now the key issue.

**Figure 2 - Characterised, Normalised & Weighted Impacts**
**1 tonne of Pipe**



## 6.3 Ecopoint Comparison of All Pipes

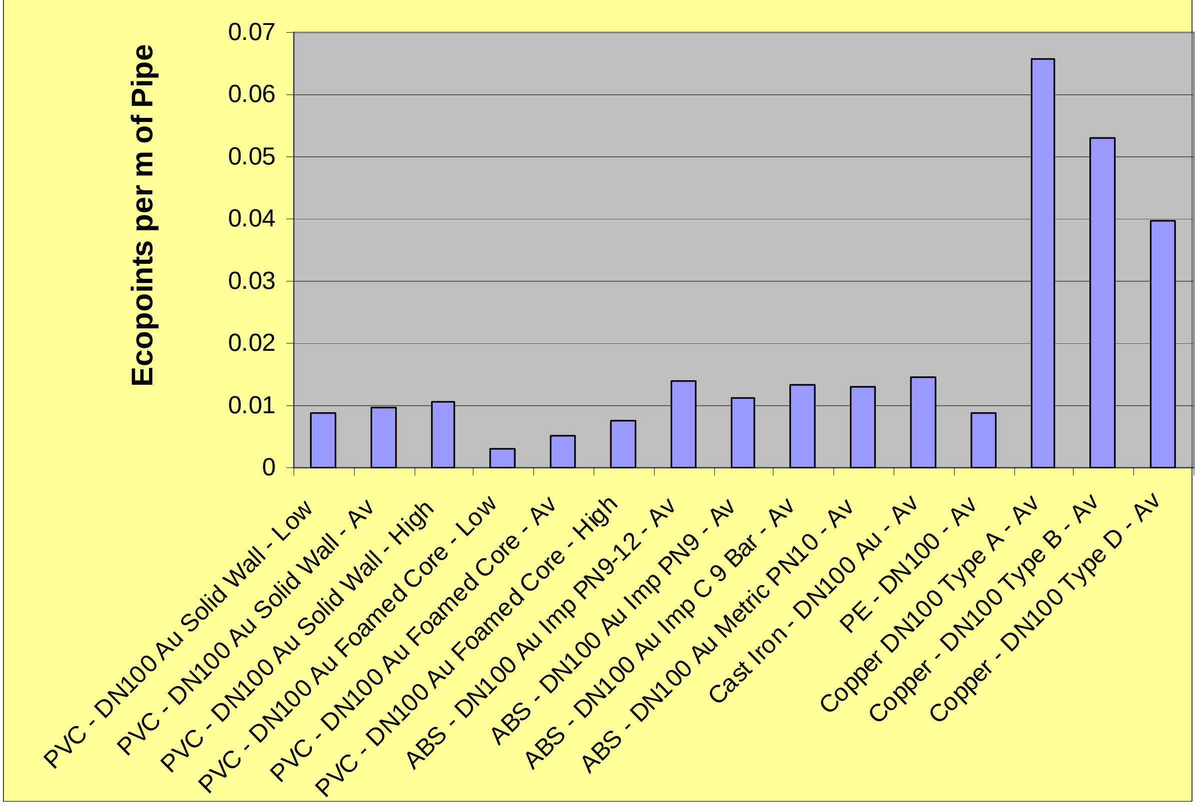
The principal findings for Drain / Waste / Vent (DWV) pipe are that:

- Copper pipe has the highest environmental impacts of all alternatives and would not be recommended on environmental grounds (Figure 3).
- Ductile iron pipe is second worst and comparable to the worst of the ABS pipe alternatives (Figure 4).
- Of the plastics pipes, foamed core PVC was the best, PE pipe was next best and similar to the best of the solid walled PVC pipe with ABS pipe as the worst of the plastics pipe alternatives (Figure 4).

The principal findings for pressure pipe (Figure 5) are that:

- PVC-o pipe was substantially the best performer with PE next best followed by different grades of PVC solid-walled pipe overlapping performance with cement lined ductile iron.
- At larger diameters than the 100mm pipe size evaluated, the cement lined ductile iron pipe may perform relatively better.

**Figure 3 - Ecopoints per m of 100mm DWV Pipe**



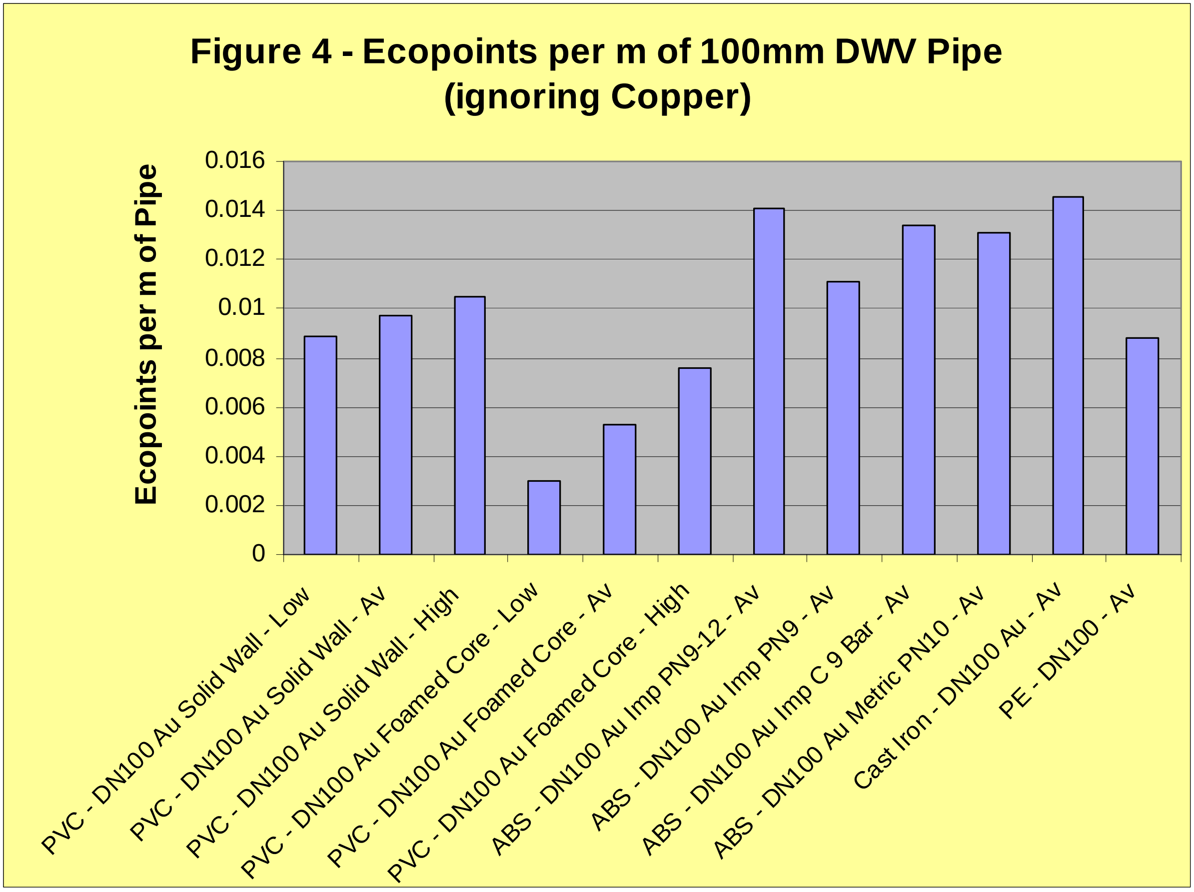


Figure 4 - Ecopoints per m of 100mm DWV Pipe
(ignoring Copper)
Ecopoints per m of Pipe
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
PVC - DN100 Au Solid Wall - Low
PVC - DN100 Au Solid Wall - Av
PVC - DN100 Au Solid Wall - High
PVC - DN100 Au Foamed Core - Low
PVC - DN100 Au Foamed Core - Av
PVC - DN100 Au Foamed Core - High
ABS - DN100 Au Imp PN9-12 - Av
ABS - DN100 Au Imp PN9 - Av
ABS - DN100 Au Imp C 9 Bar - Av
ABS - DN100 Au Metric PN10 - Av
Cast Iron - DN100 Au - Av
PE - DN100 - Av

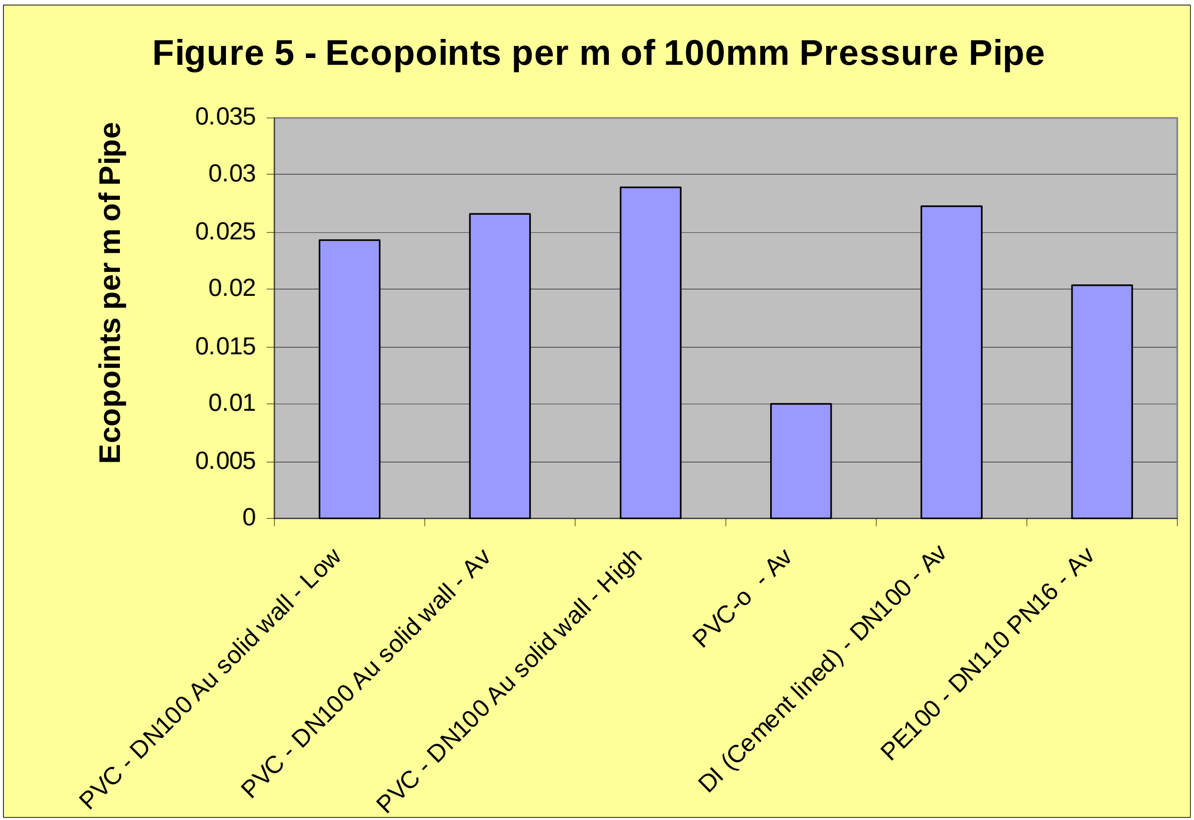


Figure 5 - Ecopoints per m of 100mm Pressure Pipe
Ecopoints per m of Pipe
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
PVC - DN100 Au solid wall - Low
PVC - DN100 Au solid wall - Av
PVC - DN100 Au solid wall - High
PVC-o - Av
DI (Cement lined) - DN100 - Av
PE100 - DN110 PN16 - Av

# 7. Conclusions

Reliable life cycle inventory data have been compiled for generic Australian PVC pipe production – these could be used to contribute to the AusLCI or BPIC/ICIP projects.

There appear to be a wide variety of grades of pipe and dimensions, but per tonne of pipe figures appear to be highly representative of a full range of PVC pipe production. In other words, the per tonne figures can be used with data on pipe mass per unit length to reliably predict life cycle inventory data for a wide range of pipe products.

Comparing with alternatives for DWV:

- Copper pipe has the highest environmental impacts of all alternatives and would not be recommended for DWV applications. Cast iron was next worst, comparative to the worst (ABS) of the plastics pipes.
- The plastics pipes showed a ranking in environmental performance from foamed core PVC best followed by PE followed by solid walled PVC followed by ABS.

Comparing with alternatives for Pressure Pipe:

- Polymeric pipe typically outperforms metal pipe for the 100mm pipe evaluated (this result may not be true for large diameter pressure pipe applications).
- PVC-o pipe performed very significantly better environmentally than all of the alternatives, with PE pipe next best and the different grades of solid walled PVC next, the worst of the solid walled PVC alternatives being equivalent to cement lined ductile iron.

# 8. References


**European Commission** - consortium led by PE Europe GmbH *Life Cycle Assessment of PVC and of Principal Competing Materials* (2004)

**US Green Building Council (USGBC)**, , Altschuler, K. Horst, S., Malin, N., Norris, G. and Nishioka, Y. *Assessment of the Technical Basis for a PVC Related Materials Credit for LEED*, (2007) http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1633

**BRANZ on behalf of PIPA and the NSW DECC** *Adaptation of the USGBC TSAC Report for Relevance to Australian DWV Pipe* (2008)

**Geberit Building Drainage Systems** *Life Cycle Assessment Drainage pipes for buildings*, (2004) http://www.geberit.com/Geberit/Inet/com/wcmscome.nsf/files/usr-nac-LCA_Leaflet_Drainage.pdf/$file/LCA_Leaflet_Drainage.pdf

**Geberit Building Drainage Systems** *Life Cycle Assessment Supply pipes for buildings*, (2004) http://www.geberit.com/Geberit/Inet/com/wcmscome.nsf/files/usr-nac-LCA_Leaflet_Supply.pdf/$file/LCA_Leaflet_Supply.pdf

# APPENDIX.A LCA of Australian Pipe – Detailed Methodology

This project has been conducted in parallel with the BPIC/ICIP project and the AusLCI project. Both projects are establishing a "Level Playing Field" methodology for the application of LCI and LCA in Australia. The BPIC/ICIP project is focussed on building and construction materials and is deriving its methodology from a cross sectoral working group with representation from all of the major building and construction material trade associations (represented by BPIC). The BPIC/ICIP project is intended to contribute to the AusLCI project which will harmonise methodology across all sectors.

Both the BPIC/ICIP and AusLCI projects are in progress. Consequently, the methodology adopted has been in accordance with the latest progress and versions of the BPIC/ICIP methodology guidelines. Although in draft, it is not expected that any further anticipated changes to the guidelines will have any significant impact on these results. The remaining issues over which consensus is being established relate to recyclable materials and recycled products and these currently play a small part in the life cycle assessment of Australian PVC pipe because the quantities of material arising are still small compared to the quantities that the industry is capable of recycling. Into the future this may become a bigger issue, but by then the guidelines will be finalised. For this reason, these results provide a conservative assessment of recyclability and recycled content for current PVC pipe production in Australia.

The main tasks were as follows:

***Task 1: Identification of Products/Archetypes and the Functional Unit***
Facilitation of a meeting on 11 February 2008 with PIPA, Vinidex and Iplex to discuss the goal and scope of the study and hence determine appropriate functional units as the basis for comparing different pipe systems

***Task 2: Questionnaire to Gather PIPA Member Product Data***
Design of a process diagramn and spreadsheet to compile life cycle inventory (LCI) data from Vinidex and Iplex. The spreadsheet was designed to gather data that could also be aggregated and submitted to the AusLCI project (providing an efficient process for the industry's engagement in this project also).

***Task 3: Literature Survey to Locate Data for Competing Products – ABS, Cast iron, PE, Copper and FRC***
Literature survey and internet survey search and search of the available LCA data for Australia and internationally to identify equivalent Life Cycle data for plumbing and rainwater competing products – ABS, Cast Iron, PE, FRC and Copper. As appropriate, adapt this data to consistent methodology to that used to compile the industry's own data.

***Task 4: Preliminary SimaPro Modelling of Data***
Compile data gathered from Tasks 2 and 3 into the SimaPro LCA modelling software, coupling it to Australia relevant data compiled to a consistent methodology as far as possible.

***Task 5: Preliminary Impact Assessment and Ecopoint Modelling***
Conduct impact assessment in accordance with the Australian adapted CML 2002 protocol and the GBCA weightings data-set initially.

***Task 6: Sensitivity Analysis to identify Vulnerable/Crucial Data***
Sensitivity analysis was used to identify the key variables that dominate the outcome of the LCA and ensure that accurate and representative data was used for these crucial factors. In addition, these parameters are also highlighted as most important as the basis of an ecolable. This allows a relatively small number of key attributes (that are therefore cost effective to manage and assess and audit for accreditation) can assure the environmental credentials of the assessed products.

***Task 7: Confirmation/Refinement of Vulnerable/Crucial Data***
Scrutinise the quality of key data for its likely accuracy, representativeness and relevance to the Australian and product context. These data were compared with similar data from

international studies and any large discrepancies investigated and explained or their significance highlighted.

***Task 8: First Draft of LCA Report for Pipework (Product Criteria Report)***

***Task 9: Seek Comment from PIPA Members, DECC, Sydney Olympic Authority, GBCA***
Edge Environment will invite comment from any stakeholders on the first draft report and in particular from the consortium members and the pipe manufacturers. Edge Environment wish the report to have comprehensive review and consideration by all stakeholders to ensure its authority as the potential basis for ecolabelling or use to inform procurement decisions, green guides or product catalogues etc.

***Task 10: Refine Draft and Reissue/Present to Consortium***
Edge Environment will refine the draft and convene a meeting of the consortium members to discuss and resolve any final issues. Edge Environment will seek consensus support for the report from consortium members, but will publish the report with consortium member comments appended if only majority support can be obtained.

***Task 11: Finalise Report and Present to a Consortium Launch Event***
Edge Environment will finalise the report and prepare a presentation that can be used at a press event or similar as considered appropriate by the consortium members.

## *APPENDIX.B Inventory of Australian PVC Pipe - Results*

The generic inventory results for the production of PVC pipe showed most consistency when expressed per tonne of pipe manufactured. There were significant differences between manufacturing sites that Edge Environment were unable to clarify with manufacturers. Although the high, average and low results are included in this assessment, the use of the high range values would represent a conservative estimate of the industry's impacts.

The results are summarised in the 2 tables below, the first showing the inputs and the second showing the outputs.

The industry is very efficient at consuming its own and some imported post consumer PVC waste – there is significant capacity for greater use of recycled UPVC waste, especially into the core of foamed core pipe and conduit, but available material is in short supply.

For reasons of commercial confidentiality the results cannot be presented in greater detail.

***Table 2 – Australian Generic PVC Pipe Inventory Results - Inputs***

| Inventory of PVC Pipe Production | Inputs | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Electricity | LPG | Water | PVC Resin | Calcium Carbonate | Titanium Dioxide | Non-toxic Stabiliser | Organic Waxes | Process Aids | Azodicarb-onamide | Organic Pigment | On-site Recyclate |
| per tonne of pipe | kWh | dm3 | m3 | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes |
| Solid Wall | | | | | | | | | | | | |
| Standard Range Low | 293 | 2.16 | 0.15 | 0.78 | 0.02 | 0.008 | 0.021 | 0.0006 | - 0.005 | - | 0.00002 | 0.001 |
| Average | 380 | 2.38 | 0.19 | 0.83 | 0.08 | 0.011 | 0.022 | 0.0026 | 0.021 | - | 0.00011 | 0.032 |
| Standard Range High | 467 | 2.60 | 0.24 | 0.87 | 0.15 | 0.013 | 0.023 | 0.0047 | 0.047 | - | 0.00019 | 0.062 |
| Standard Deviation | 87 | 0.22 | 0.05 | 0.05 | 0.06 | 0.003 | 0.001 | 0.0021 | 0.026 | - | 0.00008 | 0.031 |
| Foamed Core | | | | | | | | | | | | |
| Standard Range Low | 222 | 1.03 | 0.09 | 0.32 | 0.03 | 0.003 | 0.009 | - 0.0014 | - 0.009 | 0.00017 | 0.00002 | - 0.001 |
| Average | 337 | 1.73 | 0.15 | 0.58 | 0.07 | 0.008 | 0.015 | 0.0011 | 0.008 | 0.00029 | 0.00008 | 0.016 |
| Standard Range High | 452 | 2.44 | 0.22 | 0.84 | 0.10 | 0.012 | 0.022 | 0.0037 | 0.025 | 0.00040 | 0.00015 | 0.033 |
| Standard Deviation | 115 | 0.71 | 0.06 | 0.26 | 0.03 | 0.004 | 0.007 | 0.0025 | 0.017 | 0.00012 | 0.00007 | 0.017 |

***Table 2 cont.d – Australian Generic PVC Pipe Inventory Results - Outputs***

| Inventory of PVC Pipe Production | Outputs | | Solid | Solid | |
|---|---|---|---|---|---|
| | PVC Pipe | Solid PVC Waste | Waste Palet | Waste Other | Liquid Effluent |
| per tonne of pipe | tonnes | tonnes | tonnes | tonnes | m3 |
| Solid Wall | | | | | |
| Standard Range Low | 1.00 | - | - | - | 0.09 |
| Average | 1.00 | - | - | - | 0.11 |
| Standard Range High | 1.00 | - | - | - | 0.14 |
| Standard Deviation | 1.00 | - | - | - | 0.03 |
| Foamed Core | | | | | |
| Standard Range Low | 1.00 | - | - | - | 0.05 |
| Average | 1.00 | - | - | - | 0.09 |
| Standard Range High | 1.00 | - | - | - | 0.13 |
| Standard Deviation | 1.00 | - | - | - | 0.04 |

# *APPENDIX.C Competing Material Pipe Products*

***Literature / Web Survey***

Web search located 5 documents of particular significance and relevance to this study and these are referenced below. The 5 documents were as follows:

1 *Life Cycle Assessment of PVC and of Principal Competing Materials* (2004) from the European Commission
2 *Assessment of the Technical Basis for a PVC Related Materials Credit for LEED*, (2007) from the US Green Building Council (USGBC)
3 *Adaptation of the USGBC TSAC Report for Relevance to Australian DWV Pipe* (2008) from BRANZ
4 *Life Cycle Assessment Drainage pipes for buildings***,** (2004) and
5 *Life Cycle Assessment Supply pipes for buildings*, (2004), both from Geberit Building Drainage Systems

The principal conclusion for pipes from the European Commission study was that:

> "The results on pipes are very heterogeneous. Some studies see clear advantages for concrete and fibre cement pipes, some report clear advantages for polymer pipes such as PVC and PE."

These variable conclusions are reflected in the findings reported in studies 2-6.

The USGBC TSAC report found that for US pipe:

> "Environmental Impacts: Cast iron pipe is generally the worst material relative to environmental impact categories amongst the alternatives studied
>
> Human Health Impacts: PVC is worst for cancer related impacts amongst the alternatives studied whilst cast iron or PVC is worse for overall health impacts depending on the assumptions when both end-of-life and occupational exposures are included. For the cradle-through-use, cast iron is worst overall among the alternatives studied from a human health point of view."

The BRANZ adaptation of the TSAC report for relevance to Australian DWV pipe confirmed the findings of the USGBC work, but showed greater benefits for PVC and PE pipe than were evident from the US data, in-part due to greater data availability on toxic emissions for ABS pipe and in-part due to the smaller mass per unit length of Australian PVC and PE pipe. In particular, the report drew attention to the sensitivity of the findings to the assumed incidence of accidental fires at landfill sites and the likely quantities of PVC pipe ending up in landfill.

Reports 4 and 5 substantially confirm the findings of this report in relation to the different pipes and their different levels of impact, with PVC and PP pipe best for drainage applications and PE-X best for pressure pipe with metal pipes performing significantly worse environmentally. These reports do not feature concrete pipes at all however.

It may be cause for concern that all material classes seem to be able to claim that LCA shows benefit to their products, emphasizing the need for consistent methodology between sectors and studies. Equally, it may be legitimate that in the countries and contexts, sizes and applications encountered the performance of the different systems is legitimately different showing that all materials and products do have legitimate applications where they can be environmentally preferable.

The SimaPro database provides life cycle inventory data linked to other source data for Australia. SimaPro data varies in the extent to which it is broken down into sub-processes and reliant on those sub-processes to describe the full inventory. Accordingly, the competing pipe data taken from SimaPro is presented only in its characterised, normalised and weighted form for comparison with the PVC pipe data. The characterised data used for this study for the alternatives (to PVC) materials is as follows:

***Characterised SimaPro Australian Dataset for non-PVC Pipe Alternatives***

| Impact Categories | | ABS / kg | CI / kg | Ductile Iron / kg | Cement / kg | Sand / kg | PE / kg | Copper / kg |
|---|---|---|---|---|---|---|---|---|
| **Land use** | **Ha a** | 2.48E-11 | 3.04E-07 | 3.04E-07 | 3.88E-08 | 1.32E-10 | 3.15E-07 | 1.66E-06 |
| **Water Use** | **KL H2O** | 0.0192301 | 0.0001847 | 0.0001847 | 0.0179065 | 0.0020007 | 0.0016391 | 0.0081252 |
| **Solid waste** | **kg** | 0.044751 | 0.1305214 | 0.1305214 | 0.0396857 | 2.57E-05 | 0.006896 | 0.0331439 |
| **Fossil fuels** | **MJ surplus** | 6.4698781 | 1.0118733 | 1.0118733 | 0.4482457 | 0.041798 | 7.380158 | 3.9993534 |
| **global warming (GWP100)** | **kg CO2 eq.** | 1.3874323 | 0.4794352 | 0.4794352 | 0.8051134 | 0.0393599 | 2.3896153 | 5.539288 |
| **ozone layer depletion (ODP)** | **kg CFC-11 eq** | 5.52E-06 | 0 | 0 | 0 | 0 | 0 | 0 |
| **human toxicity** | **kg 1,4-DB eq** | 0.0004597 | 0.0238732 | 0.0238732 | 0.010076 | 0.000221 | 0.0808759 | 0.3850931 |
| **fresh water aquatic ecotox.** | **kg 1,4-DB eq** | 9.10E-06 | 0.0001245 | 0.0001245 | 7.88E-05 | 4.72E-06 | 0.0005033 | 0.0027569 |
| **marine aquatic ecotoxicity** | **kg 1,4-DB eq** | 0.9078374 | 156.71692 | 156.71692 | 97.093031 | 1.562488 | 872.95348 | 4216.4417 |
| **terrestrial ecotoxicity** | **kg 1,4-DB eq** | 2.19E-05 | 0.0011553 | 0.0011553 | 0.0002414 | 3.52E-06 | 0.0005475 | 0.0025789 |
| **photochemical oxidation** | **kg C2H2** | 0.000513 | 0.0020218 | 0.0020218 | 8.30E-05 | 1.13E-05 | 0.0004303 | 0.0007976 |
| **acidification** | **kg SO2 eq** | 0.0341714 | 0.0047934 | 0.0047934 | 0.0026085 | 0.0001849 | 0.0131324 | 0.0450143 |
| **eutrophication** | **kg PO4--- eq** | 0.0021833 | 0.000406 | 0.000406 | 0.0002879 | 2.54E-05 | 0.0013878 | 0.002208 |

No data could be found to differentiate Ductile Iron from Cast Iron pipe, hence the results for Ductile Iron may be underestimated. The impact categories adopted are the most extensive set that Edge Environment can compile at this time drawing on best available data from SimaPro.

# APPENDIX.D Characterised Results – All Materials

The full characterised results are tabulated in Appendix E. Since many of the impact categories are measured in different units, it is very hard to interpret these results to allow any robust conclusions to be drawn. They are nonetheless a vital step in progressing to a useful impact assessment.

Characterised results are often presented in LCA studies to show the impacts of different products within the range of results for each impact category expressed relative to the largest result in the category. This provides an impression of how the products compare against each individual impact category, ***but can be highly misleading for making relatively trivial differences appear graphically significant***. These results are presented in figures 1 and 2 below for DWV and Pressure Pipe respectively. They are of interest because they illustrate where the different pipe products have the greatest relative impacts (but not whether that difference is significant overall).

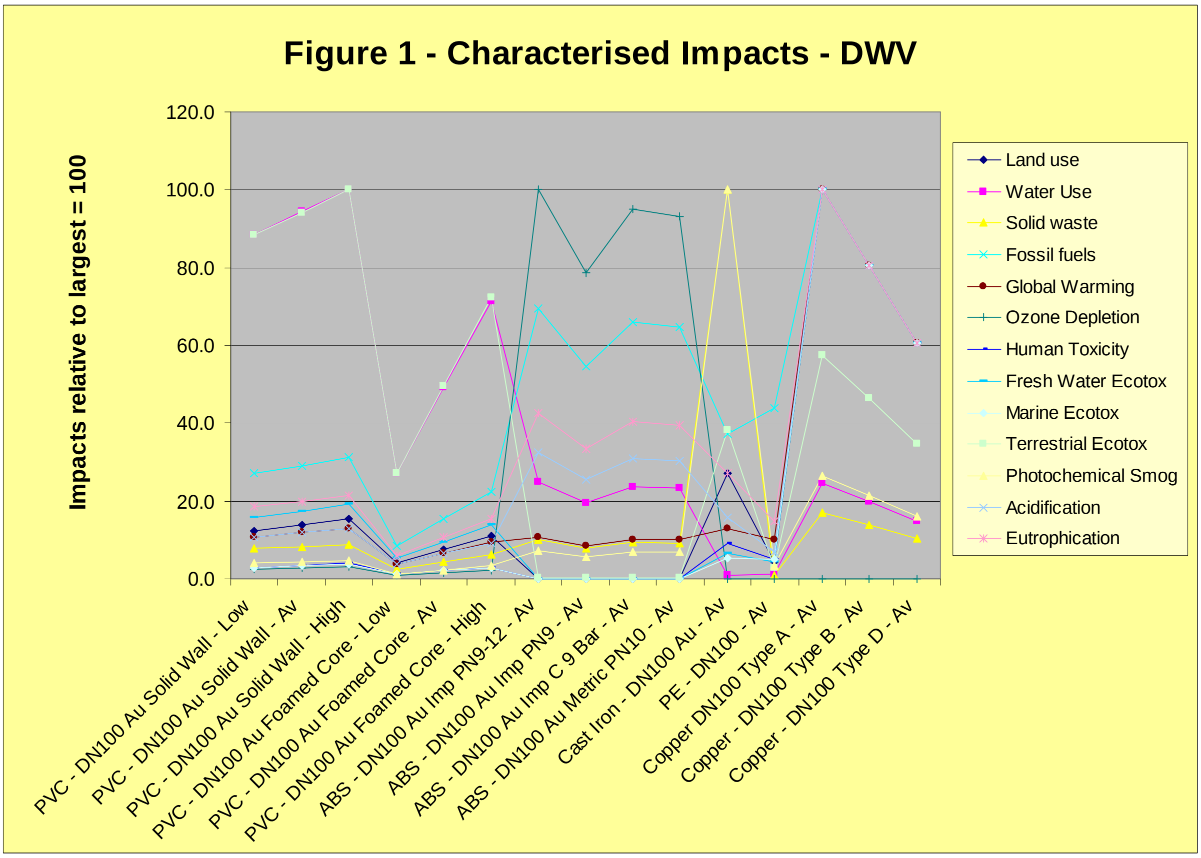
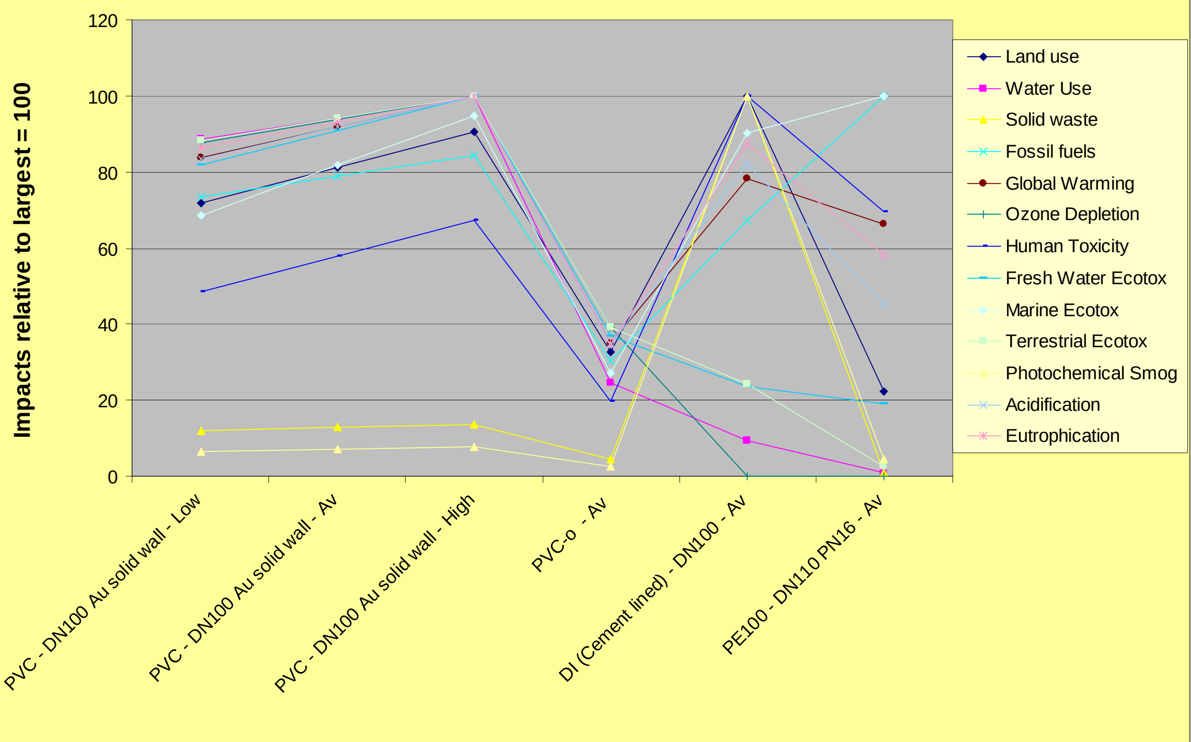


**Figure 2 - Characterised Impacts - Pressure Pipe**



# APPENDIX.E Characterised Results Table

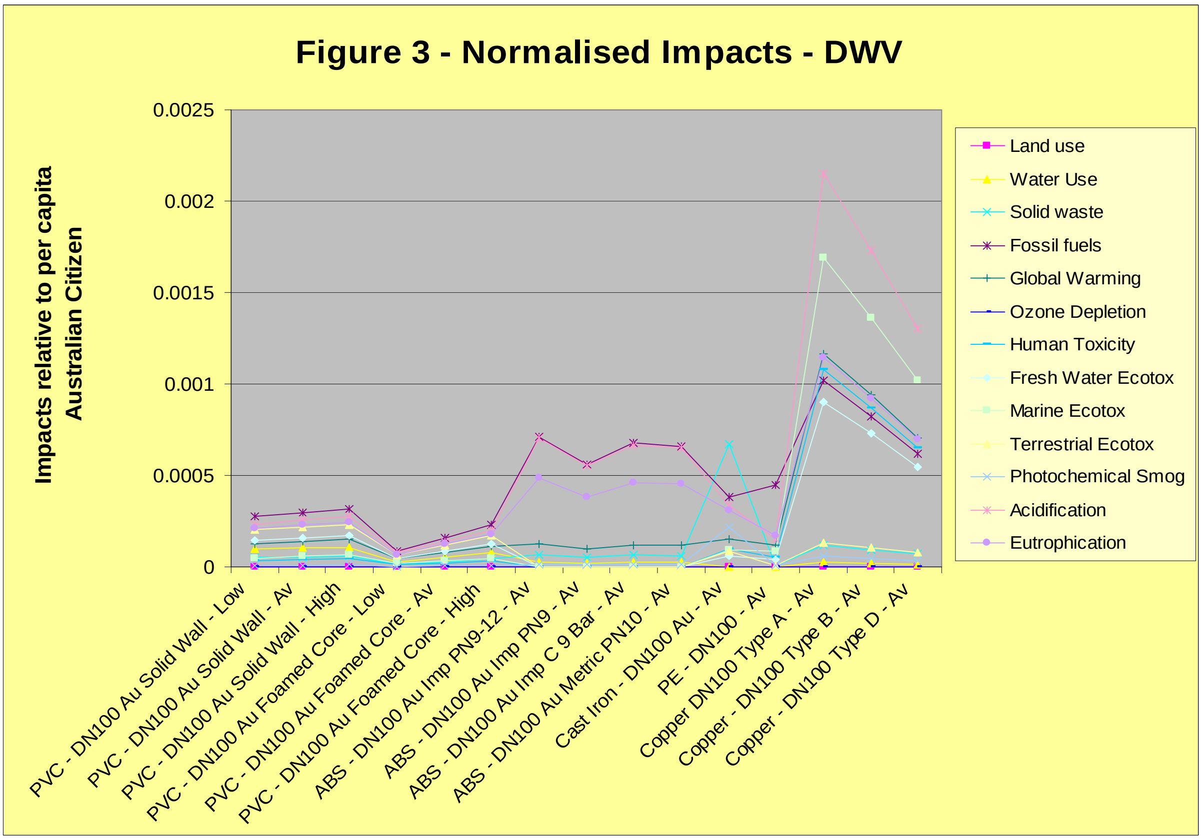
| Pipe type / Pipe sub-type / Impact category | | Inputs Electricity | LPG | Water | PVC Resin | Calcium Carbonate | Titanium Dioxide | Azodicarb-onamide | Total | Total per kg |
|---|---|---|---|---|---|---|---|---|---|---|
| | Inventory Unit | kWh | dm3 | M3 | tonnes | tonnes | tonnes | tonnes | | |
| | Unit Conversion | 3.6 | 0.001 | 1000 | 1000 | 1000 | 1000 | 1000 | | |
| | Characterisation Unit | 1 MJ | m3 | kg | kg | kg | kg | kg | | |
| **Characterised Impact per tonne of pipe** | | | | | | | | | | |
| Solid Wall | | | | | | | | | | |
| Low | | | | | | | | | | |
| Land use | Ha a | 9.22E-05 | 1.60E-09 | 4.92E-09 | 4.65E-04 | 3.57E-08 | 9.45E-05 | 6.58E-05 | 7.18E-04 | 7.18E-07 |
| Water Use | KL H2O | 4.52E-01 | 7.85E-06 | 1.46E-01 | 6.31E+01 | 1.76E-04 | 1.17E+00 | 3.88E+01 | 1.04E+02 | 1.04E-01 |
| Solid waste | kg | 1.85E+00 | 3.20E-05 | 1.08E-04 | 4.30E+01 | 3.99E-03 | 0.00E+00 | 8.33E+00 | 5.32E+01 | 5.32E-02 |
| Fossil fuels | MJ surplus | 1.98E+02 | 5.62E-01 | 1.07E-02 | 3.26E+03 | 3.79E-01 | 4.54E+01 | 3.30E+02 | 3.83E+03 | 3.83E+00 |
| global warming (GWP100) | kg CO2 eq. | 2.88E+02 | 6.29E-02 | 1.62E-02 | 1.56E+03 | 4.04E-01 | 3.19E+01 | 2.56E+02 | 2.14E+03 | 2.14E+00 |
| ozone layer depletion (ODP) | kg CFC-11 eq | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.16E-04 | 0.00E+00 | 6.45E-06 | 0.00E+00 | 2.22E-04 | 2.22E-07 |
| human toxicity | kg 1,4-DB eq | 2.14E+01 | 2.00E-03 | 1.20E-03 | 4.84E+00 | 9.85E-03 | 7.79E-01 | 1.30E+01 | 4.00E+01 | 4.00E-02 |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 1.53E-01 | 1.86E-05 | 7.26E-06 | 1.15E+00 | 8.84E-05 | 1.33E-01 | 9.88E-02 | 1.54E+00 | 1.54E-03 |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 2.34E+05 | 2.10E+01 | 1.30E+01 | 4.65E+04 | 1.00E+02 | 7.38E+02 | 1.43E+05 | 4.25E+05 | 4.25E+02 |
| terrestrial ecotoxicity | kg 1,4-DB eq | 1.42E-01 | 2.87E-05 | 6.24E-06 | 1.37E+01 | 7.91E-05 | 1.39E-01 | 1.01E-01 | 1.41E+01 | 1.41E-02 |
| photochemical oxidation | kg C2H2 | 3.46E-02 | 1.23E-05 | 1.92E-06 | 3.34E-01 | 1.49E-04 | 1.21E-02 | 4.38E-02 | 4.24E-01 | 4.24E-04 |
| acidification | kg SO2 eq | 2.38E+00 | 2.36E-04 | 1.36E-04 | 1.24E+01 | 2.77E-03 | 2.82E-01 | 2.19E+00 | 1.72E+01 | 1.72E-02 |
| eutrophication | kg PO4--- eq | 9.58E-02 | 1.74E-05 | 5.20E-06 | 1.17E+00 | 2.81E-04 | 1.60E-02 | 1.69E-01 | 1.45E+00 | 1.45E-03 |
| Average | | | | | | | | | | |
| Land use | Ha a | 1.20E-04 | 1.76E-09 | 6.46E-09 | 4.94E-04 | 1.37E-07 | 1.30E-04 | 6.97E-05 | 8.13E-04 | 8.13E-07 |
| Water Use | KL H2O | 5.87E-01 | 8.65E-06 | 1.91E-01 | 6.70E+01 | 6.74E-04 | 1.60E+00 | 4.10E+01 | 1.10E+02 | 1.10E-01 |
| Solid waste | kg | 2.40E+00 | 3.53E-05 | 1.42E-04 | 4.56E+01 | 1.53E-02 | 0.00E+00 | 8.81E+00 | 5.68E+01 | 5.68E-02 |
| Fossil fuels | MJ surplus | 2.57E+02 | 6.19E-01 | 1.40E-02 | 3.46E+03 | 1.45E+00 | 6.24E+01 | 3.49E+02 | 4.13E+03 | 4.13E+00 |
| global warming (GWP100) | kg CO2 eq. | 3.73E+02 | 6.93E-02 | 2.12E-02 | 1.66E+03 | 1.55E+00 | 4.39E+01 | 2.71E+02 | 2.35E+03 | 2.35E+00 |
| ozone layer depletion (ODP) | kg CFC-11 eq | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.29E-04 | 0.00E+00 | 8.87E-06 | 0.00E+00 | 2.37E-04 | 2.37E-07 |
| human toxicity | kg 1,4-DB eq | 2.77E+01 | 2.20E-03 | 1.58E-03 | 5.13E+00 | 3.78E-02 | 1.07E+00 | 1.38E+01 | 4.78E+01 | 4.78E-02 |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 1.98E-01 | 2.05E-05 | 9.53E-06 | 1.22E+00 | 3.39E-04 | 1.83E-01 | 1.05E-01 | 1.71E+00 | 1.71E-03 |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 3.04E+05 | 2.31E+01 | 1.71E+01 | 4.94E+04 | 3.84E+02 | 1.01E+03 | 1.51E+05 | 5.06E+05 | 5.06E+02 |
| terrestrial ecotoxicity | kg 1,4-DB eq | 1.85E-01 | 3.17E-05 | 8.19E-06 | 1.45E+01 | 3.04E-04 | 1.92E-01 | 1.07E-01 | 1.50E+01 | 1.50E-02 |
| photochemical oxidation | kg C2H2 | 4.49E-02 | 1.35E-05 | 2.52E-06 | 3.54E-01 | 5.71E-04 | 1.67E-02 | 4.63E-02 | 4.63E-01 | 4.63E-04 |
| acidification | kg SO2 eq | 3.09E+00 | 2.60E-04 | 1.78E-04 | 1.31E+01 | 1.06E-02 | 3.87E-01 | 2.32E+00 | 1.89E+01 | 1.89E-02 |
| eutrophication | kg PO4--- eq | 1.24E-01 | 1.92E-05 | 6.83E-06 | 1.24E+00 | 1.08E-03 | 2.20E-02 | 1.78E-01 | 1.57E+00 | 1.57E-03 |
| High | | | | | | | | | | |
| Land use | Ha a | 1.47E-04 | 1.93E-09 | 8.00E-09 | 5.22E-04 | 2.39E-07 | 1.65E-04 | 7.35E-05 | 9.08E-04 | 9.08E-07 |
| Water Use | KL H2O | 7.22E-01 | 9.45E-06 | 2.37E-01 | 7.08E+01 | 1.17E-03 | 2.04E+00 | 4.32E+01 | 1.17E+02 | 1.17E-01 |
| Solid waste | kg | 2.95E+00 | 3.86E-05 | 1.75E-04 | 4.82E+01 | 2.66E-02 | 0.00E+00 | 9.29E+00 | 6.05E+01 | 6.05E-02 |
| Fossil fuels | MJ surplus | 3.16E+02 | 6.76E-01 | 1.74E-02 | 3.66E+03 | 2.53E+00 | 7.94E+01 | 3.68E+02 | 4.42E+03 | 4.42E+00 |
| global warming (GWP100) | kg CO2 eq. | 4.59E+02 | 7.57E-02 | 2.63E-02 | 1.75E+03 | 2.70E+00 | 5.58E+01 | 2.86E+02 | 2.56E+03 | 2.56E+00 |
| ozone layer depletion (ODP) | kg CFC-11 eq | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.42E-04 | 0.00E+00 | 1.13E-05 | 0.00E+00 | 2.53E-04 | 2.53E-07 |
| human toxicity | kg 1,4-DB eq | 3.41E+01 | 2.40E-03 | 1.96E-03 | 5.43E+00 | 6.58E-02 | 1.36E+00 | 1.45E+01 | 5.55E+01 | 5.55E-02 |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 2.44E-01 | 2.24E-05 | 1.18E-05 | 1.29E+00 | 5.90E-04 | 2.32E-01 | 1.10E-01 | 1.88E+00 | 1.88E-03 |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 3.74E+05 | 2.53E+01 | 2.12E+01 | 5.22E+04 | 6.68E+02 | 1.29E+03 | 1.60E+05 | 5.88E+05 | 5.88E+02 |
| terrestrial ecotoxicity | kg 1,4-DB eq | 2.27E-01 | 3.46E-05 | 1.01E-05 | 1.53E+01 | 5.29E-04 | 2.44E-01 | 1.13E-01 | 1.59E+01 | 1.59E-02 |
| photochemical oxidation | kg C2H2 | 5.52E-02 | 1.48E-05 | 3.12E-06 | 3.74E-01 | 9.93E-04 | 2.12E-02 | 4.89E-02 | 5.01E-01 | 5.01E-04 |
| acidification | kg SO2 eq | 3.80E+00 | 2.84E-04 | 2.21E-04 | 1.39E+01 | 1.85E-02 | 4.93E-01 | 2.44E+00 | 2.06E+01 | 2.06E-02 |
| eutrophication | kg PO4--- eq | 1.53E-01 | 2.10E-05 | 8.46E-06 | 1.32E+00 | 1.88E-03 | 2.80E-02 | 1.88E-01 | 1.69E+00 | 1.69E-03 |
| Foamed Core | | | | | | | | | | |
| Low | | | | | | | | | | |
| Land use | Ha a | 7.00E-05 | 7.62E-10 | 2.93E-09 | 1.88E-04 | 5.43E-08 | 4.24E-05 | 2.74E-05 | 3.28E-04 | 3.28E-07 |
| Water Use | KL H2O | 3.44E-01 | 3.74E-06 | 8.68E-02 | 2.55E+01 | 2.67E-04 | 5.23E-01 | 1.61E+01 | 4.25E+01 | 4.25E-02 |
| Solid waste | kg | 1.40E+00 | 1.52E-05 | 6.42E-05 | 1.74E+01 | 6.06E-03 | 0.00E+00 | 3.46E+00 | 2.22E+01 | 2.22E-02 |
| Fossil fuels | MJ surplus | 1.50E+02 | 2.67E-01 | 6.36E-03 | 1.32E+03 | 5.76E-01 | 2.03E+01 | 1.37E+02 | 1.63E+03 | 1.63E+00 |
| global warming (GWP100) | kg CO2 eq. | 2.18E+02 | 3.00E-02 | 9.62E-03 | 6.31E+02 | 6.14E-01 | 1.43E+01 | 1.06E+02 | 9.71E+02 | 9.71E-01 |
| ozone layer depletion (ODP) | kg CFC-11 eq | 0.00E+00 | 0.00E+00 | 0.00E+00 | 8.70E-05 | 0.00E+00 | 2.89E-06 | 0.00E+00 | 8.99E-05 | 8.99E-08 |
| human toxicity | kg 1,4-DB eq | 1.62E+01 | 9.51E-04 | 7.16E-04 | 1.96E+00 | 1.50E-02 | 3.49E-01 | 5.41E+00 | 2.40E+01 | 2.40E-02 |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 1.16E-01 | 8.87E-06 | 4.32E-06 | 4.66E-01 | 1.34E-04 | 5.95E-02 | 4.10E-02 | 6.83E-01 | 6.83E-04 |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 1.78E+05 | 9.99E+00 | 7.76E+00 | 1.88E+04 | 1.52E+02 | 3.31E+02 | 5.94E+04 | 2.56E+05 | 2.56E+02 |
| terrestrial ecotoxicity | kg 1,4-DB eq | 1.08E-01 | 1.37E-05 | 3.71E-06 | 5.52E+00 | 1.20E-04 | 6.25E-02 | 4.20E-02 | 5.73E+00 | 5.73E-03 |
| photochemical oxidation | kg C2H2 | 2.62E-02 | 5.84E-06 | 1.14E-06 | 1.35E-01 | 2.26E-04 | 5.43E-03 | 1.82E-02 | 1.85E-01 | 1.85E-04 |
| acidification | kg SO2 eq | 1.81E+00 | 1.12E-04 | 8.08E-05 | 5.00E+00 | 4.21E-03 | 1.26E-01 | 9.10E-01 | 7.84E+00 | 7.84E-03 |
| eutrophication | kg PO4--- eq | 7.28E-02 | 8.29E-06 | 3.10E-06 | 4.74E-01 | 4.27E-04 | 7.18E-03 | 7.00E-02 | 6.24E-01 | 6.24E-04 |
| Average | | | | | | | | | | |
| Land use | Ha a | 1.06E-04 | 1.28E-09 | 5.11E-09 | 3.46E-04 | 1.11E-07 | 9.45E-05 | 4.81E-05 | 5.95E-04 | 5.95E-07 |
| Water Use | KL H2O | 5.22E-01 | 6.30E-06 | 1.51E-01 | 4.69E+01 | 5.46E-04 | 1.17E+00 | 2.83E+01 | 7.70E+01 | 7.70E-02 |
| Solid waste | kg | 2.13E+00 | 2.57E-05 | 1.12E-04 | 3.19E+01 | 1.24E-02 | 0.00E+00 | 6.08E+00 | 4.02E+01 | 4.02E-02 |
| Fossil fuels | MJ surplus | 2.28E+02 | 4.51E-01 | 1.11E-02 | 2.42E+03 | 1.18E+00 | 4.54E+01 | 2.41E+02 | 2.94E+03 | 2.94E+00 |
| global warming (GWP100) | kg CO2 eq. | 3.32E+02 | 5.05E-02 | 1.68E-02 | 1.16E+03 | 1.25E+00 | 3.19E+01 | 1.87E+02 | 1.71E+03 | 1.71E+00 |
| ozone layer depletion (ODP) | kg CFC-11 eq | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.60E-04 | 0.00E+00 | 6.45E-06 | 0.00E+00 | 1.67E-04 | 1.67E-07 |
| human toxicity | kg 1,4-DB eq | 2.46E+01 | 1.60E-03 | 1.25E-03 | 3.60E+00 | 3.06E-02 | 7.79E-01 | 9.52E+00 | 3.86E+01 | 3.86E-02 |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 1.76E-01 | 1.50E-05 | 7.53E-06 | 8.58E-01 | 2.75E-04 | 1.33E-01 | 7.22E-02 | 1.24E+00 | 1.24E-03 |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 2.70E+05 | 1.69E+01 | 1.35E+01 | 3.46E+04 | 3.11E+02 | 7.38E+02 | 1.04E+05 | 4.10E+05 | 4.10E+02 |
| terrestrial ecotoxicity | kg 1,4-DB eq | 1.64E-01 | 2.31E-05 | 6.48E-06 | 1.02E+01 | 2.46E-04 | 1.39E-01 | 7.39E-02 | 1.05E+01 | 1.05E-02 |
| photochemical oxidation | kg C2H2 | 3.98E-02 | 9.85E-06 | 1.99E-06 | 2.48E-01 | 4.62E-04 | 1.21E-02 | 3.20E-02 | 3.32E-01 | 3.32E-04 |
| acidification | kg SO2 eq | 2.74E+00 | 1.89E-04 | 1.41E-04 | 9.19E+00 | 8.61E-03 | 2.82E-01 | 1.60E+00 | 1.38E+01 | 1.38E-02 |
| eutrophication | kg PO4--- eq | 1.10E-01 | 1.40E-05 | 5.40E-06 | 8.72E-01 | 8.72E-04 | 1.60E-02 | 1.23E-01 | 1.12E+00 | 1.12E-03 |
| High | | | | | | | | | | |
| Land use | Ha a | 1.43E-04 | 1.81E-09 | 7.29E-09 | 5.03E-04 | 1.68E-07 | 1.47E-04 | 6.88E-05 | 8.62E-04 | 8.62E-07 |
| Water Use | KL H2O | 7.00E-01 | 8.87E-06 | 2.16E-01 | 6.83E+01 | 8.24E-04 | 1.81E+00 | 4.05E+01 | 1.12E+02 | 1.12E-01 |
| Solid waste | kg | 2.85E+00 | 3.62E-05 | 1.60E-04 | 4.65E+01 | 1.87E-02 | 0.00E+00 | 8.71E+00 | 5.81E+01 | 5.81E-02 |
| Fossil fuels | MJ surplus | 3.06E+02 | 6.35E-01 | 1.58E-02 | 3.53E+03 | 1.78E+00 | 7.04E+01 | 3.45E+02 | 4.25E+03 | 4.25E+00 |
| global warming (GWP100) | kg CO2 eq. | 4.45E+02 | 7.11E-02 | 2.39E-02 | 1.69E+03 | 1.89E+00 | 4.95E+01 | 2.68E+02 | 2.46E+03 | 2.46E+00 |
| ozone layer depletion (ODP) | kg CFC-11 eq | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.33E-04 | 0.00E+00 | 1.00E-05 | 0.00E+00 | 2.43E-04 | 2.43E-07 |
| human toxicity | kg 1,4-DB eq | 3.30E+01 | 2.26E-03 | 1.78E-03 | 5.24E+00 | 4.62E-02 | 1.21E+00 | 1.36E+01 | 5.32E+01 | 5.32E-02 |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 2.36E-01 | 2.10E-05 | 1.07E-05 | 1.25E+00 | 4.15E-04 | 2.06E-01 | 1.03E-01 | 1.80E+00 | 1.80E-03 |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 3.62E+05 | 2.37E+01 | 1.93E+01 | 5.03E+04 | 4.69E+02 | 1.14E+03 | 1.50E+05 | 5.64E+05 | 5.64E+02 |
| terrestrial ecotoxicity | kg 1,4-DB eq | 2.20E-01 | 3.25E-05 | 9.24E-06 | 1.48E+01 | 3.71E-04 | 2.16E-01 | 1.06E-01 | 1.53E+01 | 1.53E-02 |
| photochemical oxidation | kg C2H2 | 5.34E-02 | 1.39E-05 | 2.84E-06 | 3.61E-01 | 6.98E-04 | 1.88E-02 | 4.58E-02 | 4.80E-01 | 4.80E-04 |
| acidification | kg SO2 eq | 3.68E+00 | 2.66E-04 | 2.01E-04 | 1.34E+01 | 1.30E-02 | 4.37E-01 | 2.29E+00 | 1.98E+01 | 1.98E-02 |
| eutrophication | kg PO4--- eq | 1.48E-01 | 1.97E-05 | 7.71E-06 | 1.27E+00 | 1.32E-03 | 2.49E-02 | 1.76E-01 | 1.62E+00 | 1.62E-03 |

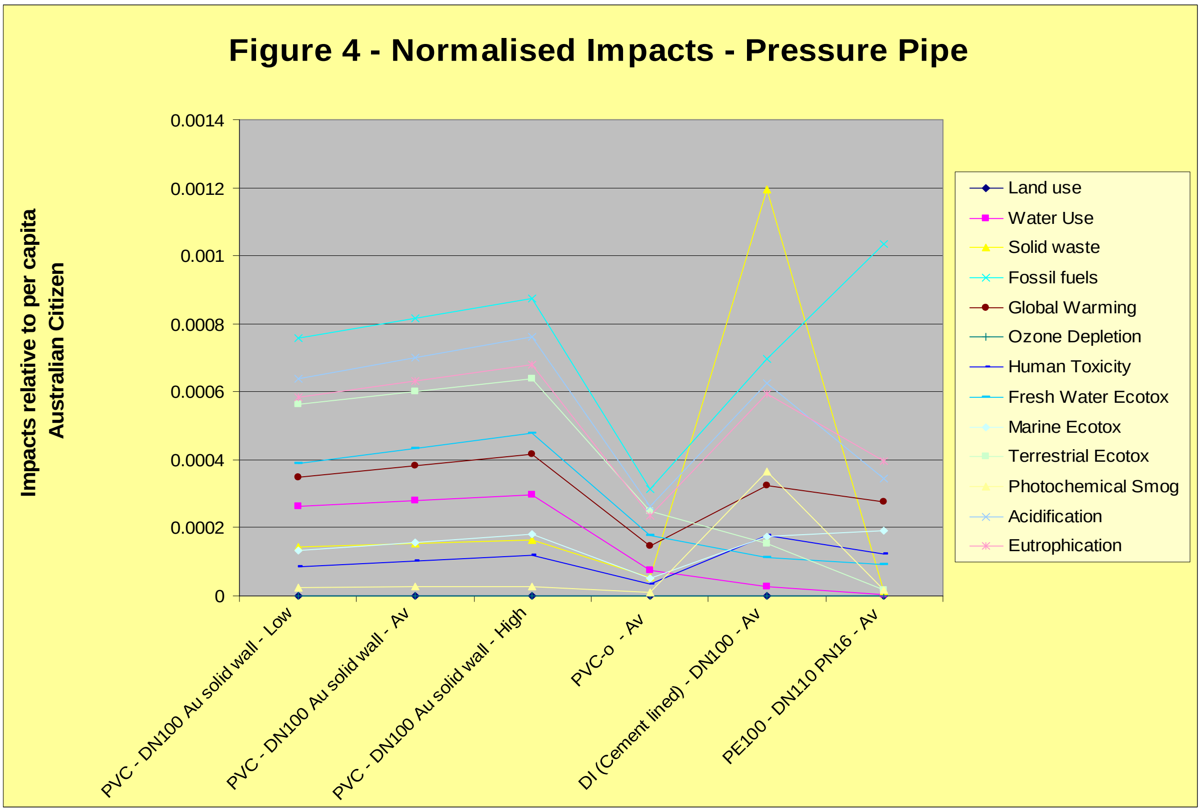
**Characterised impacts**

| **Impact Category** | | **Land use - Ha a** | **Water Use - KL H2O** | **Solid waste - kg** | **Fossil fuels - MJ Surplus** | **Global Warming - kg CO2-e** | **Ozone Depletion - kg CFC11-e** | **Human Toxicity - kg 1,4-DB-e** | **Fresh Water Ecotox - kg 1,4-DB-e** | **Marine Ecotox - kg 1,4-DB-e** | **Terrestrial Ecotoxicity - kg 1,4-DB-e** | **Photochemical Smog - kg C2H2-e** | **Acidification - kg SO2-e** | **Eutrophication - kg PO4-e** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Drain / Waste / Vent Pipe 100mm | **per metre length of pipe** | | | | | | | | | | | | | |
| PVC - DN100 Au Solid Wall - Low | | 1.15E-06 | 1.66E-01 | 8.51E-02 | 6.14E+00 | 3.42E+00 | 3.55E-07 | 6.41E-02 | 2.46E-03 | 6.79E+02 | 2.25E-02 | 6.79E-04 | 2.76E-02 | 2.33E-03 |
| PVC - DN100 Au Solid Wall - Av | | 1.30E-06 | 1.77E-01 | 9.09E-02 | 6.61E+00 | 3.76E+00 | 3.80E-07 | 7.64E-02 | 2.74E-03 | 8.10E+02 | 2.40E-02 | 7.40E-04 | 3.03E-02 | 2.51E-03 |
| PVC - DN100 Au Solid Wall - High | | 1.45E-06 | 1.87E-01 | 9.68E-02 | 7.08E+00 | 4.09E+00 | 4.05E-07 | 8.88E-02 | 3.01E-03 | 9.40E+02 | 2.55E-02 | 8.01E-04 | 3.30E-02 | 2.70E-03 |
| PVC - DN100 Au Foamed Core - Low | | 3.93E-07 | 5.11E-02 | 2.67E-02 | 1.95E+00 | 1.17E+00 | 1.08E-07 | 2.88E-02 | 8.20E-04 | 3.08E+02 | 6.88E-03 | 2.22E-04 | 9.41E-03 | 7.49E-04 |
| PVC - DN100 Au Foamed Core - Av | | 7.14E-07 | 9.25E-02 | 4.82E-02 | 3.53E+00 | 2.06E+00 | 2.00E-07 | 4.63E-02 | 1.49E-03 | 4.92E+02 | 1.26E-02 | 3.99E-04 | 1.66E-02 | 1.35E-03 |
| PVC - DN100 Au Foamed Core - High | | 1.03E-06 | 1.34E-01 | 6.97E-02 | 5.10E+00 | 2.95E+00 | 2.92E-07 | 6.38E-02 | 2.15E-03 | 6.76E+02 | 1.84E-02 | 5.76E-04 | 2.38E-02 | 1.94E-03 |
| ABS - DN100 Au Imp PN9-12 - Av | | 6.05E-11 | 4.69E-02 | 1.09E-01 | 1.58E+01 | 3.39E+00 | 1.35E-05 | 1.12E-03 | 2.22E-05 | 2.22E+00 | 5.33E-05 | 1.25E-03 | 8.34E-02 | 5.33E-03 |
| ABS - DN100 Au Imp PN9 - Av | | 4.76E-11 | 3.69E-02 | 8.59E-02 | 1.24E+01 | 2.66E+00 | 1.06E-05 | 8.83E-04 | 1.75E-05 | 1.74E+00 | 4.20E-05 | 9.85E-04 | 6.56E-02 | 4.19E-03 |
| ABS - DN100 Au Imp C 9 Bar - Av | | 5.75E-11 | 4.46E-02 | 1.04E-01 | 1.50E+01 | 3.22E+00 | 1.28E-05 | 1.07E-03 | 2.11E-05 | 2.11E+00 | 5.07E-05 | 1.19E-03 | 7.93E-02 | 5.07E-03 |
| ABS - DN100 Au Metric PN10 - Av | | 5.63E-11 | 4.37E-02 | 1.02E-01 | 1.47E+01 | 3.15E+00 | 1.25E-05 | 1.04E-03 | 2.07E-05 | 2.06E+00 | 4.96E-05 | 1.16E-03 | 7.76E-02 | 4.96E-03 |
| Cast Iron - DN100 Au - Av | | 2.55E-06 | 1.55E-03 | 1.10E+00 | 8.50E+00 | 4.03E+00 | 0.00E+00 | 2.01E-01 | 1.05E-03 | 1.32E+03 | 9.70E-03 | 1.70E-02 | 4.03E-02 | 3.41E-03 |
| PE - DN100 - Av | | 4.25E-07 | 2.21E-03 | 9.31E-03 | 9.96E+00 | 3.23E+00 | 0.00E+00 | 1.09E-01 | 6.79E-04 | 1.18E+03 | 7.39E-04 | 5.81E-04 | 1.77E-02 | 1.87E-03 |
| Copper DN100 Type A - Av | | 9.41E-06 | 4.62E-02 | 1.88E-01 | 2.27E+01 | 3.15E+01 | 0.00E+00 | 2.19E+00 | 1.57E-02 | 2.39E+04 | 1.46E-02 | 4.53E-03 | 2.56E-01 | 1.25E-02 |
| Copper - DN100 Type B - Av | | 7.59E-06 | 3.72E-02 | 1.52E-01 | 1.83E+01 | 2.54E+01 | 0.00E+00 | 1.76E+00 | 1.26E-02 | 1.93E+04 | 1.18E-02 | 3.65E-03 | 2.06E-01 | 1.01E-02 |
| Copper - DN100 Type D - Av | | 5.70E-06 | 2.80E-02 | 1.14E-01 | 1.38E+01 | 1.91E+01 | 0.00E+00 | 1.32E+00 | 9.48E-03 | 1.45E+04 | 8.87E-03 | 2.74E-03 | 1.55E-01 | 7.60E-03 |
| Pressure Pipe 100mm | **per metre length of pipe** | | | | | | | | | | | | | |
| PVC - DN100 Au solid wall - Low | | 3.16E-06 | 4.56E-01 | 2.34E-01 | 1.69E+01 | 9.41E+00 | 9.77E-07 | 1.76E-01 | 6.77E-03 | 1.87E+03 | 6.18E-02 | 1.87E-03 | 7.58E-02 | 6.40E-03 |
| PVC - DN100 Au solid wall - Av | | 3.58E-06 | 4.85E-01 | 2.50E-01 | 1.82E+01 | 1.03E+01 | 1.04E-06 | 2.10E-01 | 7.53E-03 | 2.23E+03 | 6.59E-02 | 2.04E-03 | 8.33E-02 | 6.91E-03 |
| PVC - DN100 Au solid wall - High | | 4.00E-06 | 5.15E-01 | 2.66E-01 | 1.95E+01 | 1.12E+01 | 1.11E-06 | 2.44E-01 | 8.28E-03 | 2.59E+03 | 7.00E-02 | 2.20E-03 | 9.08E-02 | 7.42E-03 |
| PVC-o - Av | | 1.44E-06 | 1.27E-01 | 8.85E-02 | 7.00E+00 | 3.92E+00 | 4.37E-07 | 7.12E-02 | 3.05E-03 | 7.44E+02 | 2.73E-02 | 7.79E-04 | 3.14E-02 | 2.59E-03 |
| DI (Cement lined) - DN100 - Av | | 4.41E-06 | 4.82E-02 | 1.95E+00 | 1.55E+01 | 8.79E+00 | 0.00E+00 | 3.63E-01 | 1.96E-03 | 2.46E+03 | 1.70E-02 | 2.89E-02 | 7.45E-02 | 6.48E-03 |
| PE100 - DN110 PN16 - Av | | 9.83E-07 | 5.11E-03 | 2.15E-02 | 2.30E+01 | 7.46E+00 | 0.00E+00 | 2.52E-01 | 1.57E-03 | 2.72E+03 | 1.71E-03 | 1.34E-03 | 4.10E-02 | 4.33E-03 |

# APPENDIX.F Normalised Results – All Materials

The normalised results comparing alternative pipe materials are tabulated in Appendix G, but summarised here for DWV pipe (Figure 3) and Pressure Pipe (Figure 4).



# APPENDIX.G Normalised Results

| | | Inputs | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Electricity | LPG | Water | PVC Resin | Calcium Carbonate | Titanium Dioxide | Azodicarb-onamide | **Total** |
| Pipe type | | | | | | | | | |
| Pipe sub-type | Inventory Unit | kWh | dm3 | M3 | tonnes | tonnes | tonnes | tonnes | |
| Impact category | Unit Conversion | 3.6 | 0.001 | 1000 | 1000 | 1000 | 1000 | 1000 | |
| | Characterisation Unit | 1 MJ | m3 | kg | kg | kg | kg | kg | |
| **Normalised Impact per tonne of pipe** | | | | | | | | | |
| Solid Wall | | | | | | | | | |
| Solid Wall Low | | | | | | | | | **-** |
| Land use | Ha a | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | **0.00** |
| Water Use | KL H2O | 0.0003 | 0.0000 | 0.0001 | 0.0365 | 0.0000 | 0.0007 | 0.0224 | **0.06** |
| Solid waste | kg | 0.0011 | 0.0000 | 0.0000 | 0.0264 | 0.0000 | - | 0.0051 | **0.03** |
| Fossil fuels | MJ surplus | 0.0089 | 0.0000 | 0.0000 | 0.1465 | 0.0000 | 0.0020 | 0.0148 | **0.17** |
| global warming (GWP100) | kg CO2 eq. | 0.0107 | 0.0000 | 0.0000 | 0.0580 | 0.0000 | 0.0012 | 0.0095 | **0.08** |
| ozone layer depletion (ODP) | kg CFC-11 eq | - | - | - | 0.0000 | - | 0.0000 | - | **0.00** |
| human toxicity | kg 1,4-DB eq | 0.0105 | 0.0000 | 0.0000 | 0.0024 | 0.0000 | 0.0004 | 0.0064 | **0.02** |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 0.0088 | 0.0000 | 0.0000 | 0.0665 | 0.0000 | 0.0077 | 0.0057 | **0.09** |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 0.0165 | 0.0000 | 0.0000 | 0.0033 | 0.0000 | 0.0001 | 0.0101 | **0.03** |
| terrestrial ecotoxicity | kg 1,4-DB eq | 0.0013 | 0.0000 | 0.0000 | 0.1249 | 0.0000 | 0.0013 | 0.0009 | **0.13** |
| photochemical oxidation | kg C2H2 | 0.0004 | 0.0000 | 0.0000 | 0.0042 | 0.0000 | 0.0002 | 0.0006 | **0.01** |
| acidification | kg SO2 eq | 0.0200 | 0.0000 | 0.0000 | 0.1040 | 0.0000 | 0.0024 | 0.0184 | **0.14** |
| eutrophication | kg PO4--- eq | 0.0088 | 0.0000 | 0.0000 | 0.1072 | 0.0000 | 0.0015 | 0.0154 | **0.13** |
| Solid Wall Average | | | | | | | | | **-** |
| Land use | Ha a | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | **0.00** |
| Water Use | KL H2O | 0.0003 | 0.0000 | 0.0001 | 0.0387 | 0.0000 | 0.0009 | 0.0237 | **0.06** |
| Solid waste | kg | 0.0015 | 0.0000 | 0.0000 | 0.0280 | 0.0000 | - | 0.0054 | **0.03** |
| Fossil fuels | MJ surplus | 0.0116 | 0.0000 | 0.0000 | 0.1554 | 0.0001 | 0.0028 | 0.0157 | **0.19** |
| global warming (GWP100) | kg CO2 eq. | 0.0138 | 0.0000 | 0.0000 | 0.0615 | 0.0001 | 0.0016 | 0.0101 | **0.09** |
| ozone layer depletion (ODP) | kg CFC-11 eq | - | - | - | 0.0000 | - | 0.0000 | - | **0.00** |
| human toxicity | kg 1,4-DB eq | 0.0137 | 0.0000 | 0.0000 | 0.0025 | 0.0000 | 0.0005 | 0.0068 | **0.02** |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 0.0114 | 0.0000 | 0.0000 | 0.0706 | 0.0000 | 0.0105 | 0.0060 | **0.10** |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 0.0214 | 0.0000 | 0.0000 | 0.0035 | 0.0000 | 0.0001 | 0.0107 | **0.04** |
| terrestrial ecotoxicity | kg 1,4-DB eq | 0.0017 | 0.0000 | 0.0000 | 0.1325 | 0.0000 | 0.0018 | 0.0010 | **0.14** |
| photochemical oxidation | kg C2H2 | 0.0006 | 0.0000 | 0.0000 | 0.0045 | 0.0000 | 0.0002 | 0.0006 | **0.01** |
| acidification | kg SO2 eq | 0.0260 | 0.0000 | 0.0000 | 0.1103 | 0.0001 | 0.0033 | 0.0195 | **0.16** |
| eutrophication | kg PO4--- eq | 0.0114 | 0.0000 | 0.0000 | 0.1137 | 0.0001 | 0.0020 | 0.0163 | **0.14** |
| Solid Wall High | | | | | | | | | **-** |
| Land use | Ha a | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | **0.00** |
| Water Use | KL H2O | 0.0004 | 0.0000 | 0.0001 | 0.0409 | 0.0000 | 0.0012 | 0.0250 | **0.07** |
| Solid waste | kg | 0.0018 | 0.0000 | 0.0000 | 0.0296 | 0.0000 | - | 0.0057 | **0.04** |
| Fossil fuels | MJ surplus | 0.0142 | 0.0000 | 0.0000 | 0.1643 | 0.0001 | 0.0036 | 0.0165 | **0.20** |
| global warming (GWP100) | kg CO2 eq. | 0.0170 | 0.0000 | 0.0000 | 0.0650 | 0.0001 | 0.0021 | 0.0106 | **0.09** |
| ozone layer depletion (ODP) | kg CFC-11 eq | - | - | - | 0.0000 | - | 0.0000 | - | **0.00** |
| human toxicity | kg 1,4-DB eq | 0.0168 | 0.0000 | 0.0000 | 0.0027 | 0.0000 | 0.0007 | 0.0072 | **0.03** |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 0.0141 | 0.0000 | 0.0000 | 0.0746 | 0.0000 | 0.0134 | 0.0064 | **0.11** |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 0.0263 | 0.0000 | 0.0000 | 0.0037 | 0.0000 | 0.0001 | 0.0112 | **0.04** |
| terrestrial ecotoxicity | kg 1,4-DB eq | 0.0021 | 0.0000 | 0.0000 | 0.1401 | 0.0000 | 0.0022 | 0.0010 | **0.15** |
| photochemical oxidation | kg C2H2 | 0.0007 | 0.0000 | 0.0000 | 0.0047 | 0.0000 | 0.0003 | 0.0006 | **0.01** |
| acidification | kg SO2 eq | 0.0319 | 0.0000 | 0.0000 | 0.1166 | 0.0002 | 0.0041 | 0.0205 | **0.17** |
| eutrophication | kg PO4--- eq | 0.0140 | 0.0000 | 0.0000 | 0.1202 | 0.0002 | 0.0026 | 0.0172 | **0.15** |
| Foamed Core | | | | | | | | | |
| Foamed Core Low | | | | | | | | | **-** |
| Land use | Ha a | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | **0.00** |
| Water Use | KL H2O | 0.0002 | 0.0000 | 0.0001 | 0.0147 | 0.0000 | 0.0003 | 0.0093 | **0.02** |
| Solid waste | kg | 0.0009 | 0.0000 | 0.0000 | 0.0107 | 0.0000 | - | 0.0021 | **0.01** |
| Fossil fuels | MJ surplus | 0.0068 | 0.0000 | 0.0000 | 0.0592 | 0.0000 | 0.0009 | 0.0062 | **0.07** |
| global warming (GWP100) | kg CO2 eq. | 0.0081 | 0.0000 | 0.0000 | 0.0234 | 0.0000 | 0.0005 | 0.0039 | **0.04** |
| ozone layer depletion (ODP) | kg CFC-11 eq | - | - | - | 0.0000 | - | 0.0000 | - | **0.00** |
| human toxicity | kg 1,4-DB eq | 0.0080 | 0.0000 | 0.0000 | 0.0010 | 0.0000 | 0.0002 | 0.0027 | **0.01** |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 0.0067 | 0.0000 | 0.0000 | 0.0269 | 0.0000 | 0.0034 | 0.0024 | **0.04** |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 0.0125 | 0.0000 | 0.0000 | 0.0013 | 0.0000 | 0.0000 | 0.0042 | **0.02** |
| terrestrial ecotoxicity | kg 1,4-DB eq | 0.0010 | 0.0000 | 0.0000 | 0.0504 | 0.0000 | 0.0006 | 0.0004 | **0.05** |
| photochemical oxidation | kg C2H2 | 0.0003 | 0.0000 | 0.0000 | 0.0017 | 0.0000 | 0.0001 | 0.0002 | **0.00** |
| acidification | kg SO2 eq | 0.0152 | 0.0000 | 0.0000 | 0.0420 | 0.0000 | 0.0011 | 0.0076 | **0.07** |
| eutrophication | kg PO4--- eq | 0.0067 | 0.0000 | 0.0000 | 0.0433 | 0.0000 | 0.0007 | 0.0064 | **0.06** |
| Foamed Core Average | | | | | | | | | **-** |
| Land use | Ha a | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | **0.00** |
| Water Use | KL H2O | 0.0003 | 0.0000 | 0.0001 | 0.0271 | 0.0000 | 0.0007 | 0.0164 | **0.04** |
| Solid waste | kg | 0.0013 | 0.0000 | 0.0000 | 0.0196 | 0.0000 | - | 0.0037 | **0.02** |
| Fossil fuels | MJ surplus | 0.0103 | 0.0000 | 0.0000 | 0.1089 | 0.0001 | 0.0020 | 0.0108 | **0.13** |
| global warming (GWP100) | kg CO2 eq. | 0.0123 | 0.0000 | 0.0000 | 0.0431 | 0.0000 | 0.0012 | 0.0069 | **0.06** |
| ozone layer depletion (ODP) | kg CFC-11 eq | - | - | - | 0.0000 | - | 0.0000 | - | **0.00** |
| human toxicity | kg 1,4-DB eq | 0.0121 | 0.0000 | 0.0000 | 0.0018 | 0.0000 | 0.0004 | 0.0047 | **0.02** |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 0.0102 | 0.0000 | 0.0000 | 0.0494 | 0.0000 | 0.0077 | 0.0042 | **0.07** |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 0.0190 | 0.0000 | 0.0000 | 0.0024 | 0.0000 | 0.0001 | 0.0074 | **0.03** |
| terrestrial ecotoxicity | kg 1,4-DB eq | 0.0015 | 0.0000 | 0.0000 | 0.0928 | 0.0000 | 0.0013 | 0.0007 | **0.10** |
| photochemical oxidation | kg C2H2 | 0.0005 | 0.0000 | 0.0000 | 0.0031 | 0.0000 | 0.0002 | 0.0004 | **0.00** |
| acidification | kg SO2 eq | 0.0231 | 0.0000 | 0.0000 | 0.0772 | 0.0001 | 0.0024 | 0.0134 | **0.12** |
| eutrophication | kg PO4--- eq | 0.0101 | 0.0000 | 0.0000 | 0.0797 | 0.0001 | 0.0015 | 0.0113 | **0.10** |
| Foamed Core High | | | | | | | | | **-** |
| Land use | Ha a | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | **0.00** |
| Water Use | KL H2O | 0.0004 | 0.0000 | 0.0001 | 0.0395 | 0.0000 | 0.0010 | 0.0234 | **0.06** |
| Solid waste | kg | 0.0018 | 0.0000 | 0.0000 | 0.0286 | 0.0000 | - | 0.0053 | **0.04** |
| Fossil fuels | MJ surplus | 0.0138 | 0.0000 | 0.0000 | 0.1586 | 0.0001 | 0.0032 | 0.0155 | **0.19** |
| global warming (GWP100) | kg CO2 eq. | 0.0165 | 0.0000 | 0.0000 | 0.0627 | 0.0001 | 0.0018 | 0.0099 | **0.09** |
| ozone layer depletion (ODP) | kg CFC-11 eq | - | - | - | 0.0000 | - | 0.0000 | - | **0.00** |
| human toxicity | kg 1,4-DB eq | 0.0163 | 0.0000 | 0.0000 | 0.0026 | 0.0000 | 0.0006 | 0.0067 | **0.03** |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 0.0136 | 0.0000 | 0.0000 | 0.0720 | 0.0000 | 0.0119 | 0.0060 | **0.10** |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 0.0255 | 0.0000 | 0.0000 | 0.0035 | 0.0000 | 0.0001 | 0.0105 | **0.04** |
| terrestrial ecotoxicity | kg 1,4-DB eq | 0.0020 | 0.0000 | 0.0000 | 0.1352 | 0.0000 | 0.0020 | 0.0010 | **0.14** |
| photochemical oxidation | kg C2H2 | 0.0007 | 0.0000 | 0.0000 | 0.0046 | 0.0000 | 0.0002 | 0.0006 | **0.01** |
| acidification | kg SO2 eq | 0.0309 | 0.0000 | 0.0000 | 0.1125 | 0.0001 | 0.0037 | 0.0192 | **0.17** |
| eutrophication | kg PO4--- eq | 0.0135 | 0.0000 | 0.0000 | 0.1160 | 0.0001 | 0.0023 | 0.0161 | **0.15** |

**Normalised impacts**

| Impact Category | | Land use - Ha a | Water Use - KL H2O | Solid waste - kg | Fossil fuels - MJ Surplus | Global Warming - kg CO2-e | Ozone Depletion - kg CFC11-e | Human Toxicity - kg 1,4-DB-e | Fresh Water Ecotox - kg 1,4-DB-e | Marine Ecotox - kg 1,4-DB-e | Terrestrial Ecotoxicity - kg 1,4-DB-e | Photochemical Smog - kg C2H2-e | Acidification - kg SO2-e | Eutrophication - kg PO4-e |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Drain / Waste / Vent Pipe 100mm | **per metre length of pipe** | | | | | | | | | | | | | |
| | PVC - DN100 Au Solid Wall - Low | 4.48E-08 | 9.585E-05 | 5.225E-05 | 2.36E-12 | 0.0001269 | 1.245E-09 | 3.155E-05 | 0.0001419 | 4.787E-05 | 0.0002055 | 8.574E-06 | 0.0002316 | 0.0002126 |
| | PVC - DN100 Au Solid Wall - Av | 5.073E-08 | 0.000102 | 5.583E-05 | 0.0002969 | 0.0001393 | 1.332E-09 | 3.765E-05 | 0.0001577 | 5.706E-05 | 0.0002191 | 9.342E-06 | 0.0002545 | 0.0002296 |
| | PVC - DN100 Au Solid Wall - High | 5.667E-08 | 0.0001082 | 5.942E-05 | 0.000318 | 0.0001517 | 1.419E-09 | 4.376E-05 | 0.0001735 | 6.625E-05 | 0.0002327 | 1.011E-05 | 0.0002774 | 0.0002466 |
| | PVC - DN100 Au Foamed Core - Low | 1.534E-08 | 2.951E-05 | 1.638E-05 | 8.766E-05 | 4.321E-05 | 3.784E-10 | 1.416E-05 | 4.724E-05 | 2.169E-05 | 6.287E-05 | 2.801E-06 | 7.911E-05 | 6.846E-05 |
| | PVC - DN100 Au Foamed Core - Av | 2.783E-08 | 5.344E-05 | 2.96E-05 | 0.0001585 | 7.624E-05 | 7.009E-10 | 2.28E-05 | 8.571E-05 | 3.468E-05 | 0.0001155 | 5.036E-06 | 0.0001394 | 0.0001231 |
| | PVC - DN100 Au Foamed Core - High | 4.033E-08 | 7.737E-05 | 4.282E-05 | 0.0002293 | 0.0001093 | 1.023E-09 | 3.143E-05 | 0.0001242 | 4.767E-05 | 0.0001681 | 7.271E-06 | 0.0001998 | 0.0001777 |
| | ABS - DN100 Au Imp PN9-12 - Av | 2.36E-12 | 2.712E-05 | 6.704E-05 | 0.0007094 | 0.0001255 | 4.726E-08 | 5.525E-07 | 1.28E-06 | 1.561E-07 | 4.873E-07 | 1.58E-05 | 0.0007008 | 0.0004869 |
| | ABS - DN100 Au Imp PN9 - Av | 1.857E-12 | 2.134E-05 | 5.276E-05 | 0.0005583 | 9.879E-05 | 3.719E-08 | 4.348E-07 | 1.007E-06 | 1.228E-07 | 3.834E-07 | 1.243E-05 | 0.0005514 | 0.0003832 |
| | ABS - DN100 Au Imp C 9 Bar - Av | 2.244E-12 | 2.579E-05 | 6.375E-05 | 0.0006746 | 0.0001194 | 4.494E-08 | 5.254E-07 | 1.217E-06 | 1.484E-07 | 4.633E-07 | 1.502E-05 | 0.0006663 | 0.000463 |
| | ABS - DN100 Au Metric PN10 - Av | 2.195E-12 | 2.523E-05 | 6.237E-05 | 0.00066 | 0.0001168 | 4.397E-08 | 5.14E-07 | 1.191E-06 | 1.452E-07 | 4.533E-07 | 1.47E-05 | 0.000652 | 0.000453 |
| | Cast Iron - DN100 Au - Av | 9.958E-08 | 8.967E-07 | 0.0006732 | 0.000382 | 0.0001493 | 0 | 9.878E-05 | 6.029E-05 | 9.278E-05 | 8.869E-05 | 0.0002144 | 0.0003384 | 0.0003117 |
| | PE - DN100 - Av | 1.659E-08 | 1.279E-06 | 5.716E-06 | 0.0004477 | 0.0001196 | 0 | 5.378E-05 | 3.916E-05 | 8.305E-05 | 6.755E-06 | 7.335E-06 | 0.000149 | 0.0001713 |
| | Copper DN100 Type A - Av | 3.669E-07 | 2.668E-05 | 0.0001156 | 0.0010209 | 0.0011668 | 0 | 0.0010774 | 0.0009025 | 0.0016879 | 0.0001339 | 5.719E-05 | 0.002149 | 0.0011463 |
| | Copper - DN100 Type B - Av | 2.958E-07 | 2.151E-05 | 9.32E-05 | 0.0008232 | 0.0009408 | 0 | 0.0008688 | 0.0007277 | 0.001361 | 0.0001079 | 4.612E-05 | 0.0017328 | 0.0009243 |
| | Copper - DN100 Type D - Av | 2.222E-07 | 1.616E-05 | 7.001E-05 | 0.0006183 | 0.0007066 | 0 | 0.0006525 | 0.0005466 | 0.0010222 | 8.107E-05 | 3.464E-05 | 0.0013015 | 0.0006942 |
| Pressure Pipe 100mm | **per metre length of pipe** | | | | | | | | | | | | | |
| | PVC - DN100 Au solid wall - Low | 1.232E-07 | 0.0002636 | 0.0001437 | 0.0007583 | 0.0003491 | 3.425E-09 | 8.677E-05 | 0.0003903 | 0.0001316 | 0.0005651 | 2.358E-05 | 0.000637 | 0.0005847 |
| | PVC - DN100 Au solid wall - Av | 1.395E-07 | 0.0002806 | 0.0001535 | 0.0008165 | 0.0003831 | 3.664E-09 | 0.0001035 | 0.0004337 | 0.0001569 | 0.0006024 | 2.569E-05 | 0.0006999 | 0.0006315 |
| | PVC - DN100 Au solid wall - High | 1.558E-07 | 0.0002976 | 0.0001634 | 0.0008746 | 0.0004171 | 3.903E-09 | 0.0001203 | 0.0004772 | 0.0001822 | 0.0006398 | 2.781E-05 | 0.0007628 | 0.0006782 |
| | PVC-o - Av | 5.604E-08 | 7.357E-05 | 5.432E-05 | 0.0003148 | 0.0001455 | 1.531E-09 | 3.505E-05 | 0.000176 | 5.243E-05 | 0.0002494 | 9.833E-06 | 0.0002641 | 0.0002365 |
| | DI (Cement lined) - DN100 - Av | 1.718E-07 | 2.784E-05 | 0.0011957 | 0.0006959 | 0.0003259 | 0 | 0.0001789 | 0.0001131 | 0.0001733 | 0.0001551 | 0.0003648 | 0.0006262 | 0.0005926 |
| | PE100 - DN110 PN16 - Av | 3.835E-08 | 2.956E-06 | 1.321E-05 | 0.0010348 | 0.0002765 | 0 | 0.0001243 | 9.051E-05 | 0.0001919 | 1.561E-05 | 1.695E-05 | 0.0003444 | 0.0003958 |

# *APPENDIX.H Weighted Results – All Materials*

The weighted results take account of a wide range of stakeholders views about their priorities of concern for different environmental impacts and provide a proper basis for valid comparisons. These results are presented graphically in the main report figures 2 to 5 and tabulated here.

| Pipe type / Pipe sub-type / Impact category | | Inputs Electricity | LPG | Water | PVC Resin | Calcium Carbonate | Titanium Dioxide | Azodicarb-onamide | Total |
|---|---|---|---|---|---|---|---|---|---|
| Pipe sub-type | Inventory Unit | kWh | dm3 | M3 | tonnes | tonnes | tonnes | tonnes | Ecopoints |
| Impact category | Unit Conversion | 3.6 | 0.001 | 1000 | 1000 | 1000 | 1000 | 1000 | |
| | Characterisation Unit | 1 MJ | m3 | kg | kg | kg | kg | kg | |
| **Weighted Impact per tonne of pipe** | **Ecopoints** | | | | | | | | |
| Solid Wall | | | | | | | | | |
| Solid Wall Low | | **6.04E-01** | **3.22E-04** | **3.86E-04** | **4.16E+00** | **7.34E-04** | **9.61E-02** | **6.84E-01** | **5.55E+00** |
| Land use | Ha a | 7.94E-05 | 1.38E-09 | 4.23E-09 | 4.00E-04 | 3.08E-08 | 8.13E-05 | 5.66E-05 | **6.18E-04** |
| Water Use | KL H2O | 1.10E-03 | 1.90E-08 | 3.53E-04 | 1.53E-01 | 4.25E-07 | 2.82E-03 | 9.38E-02 | **2.51E-01** |
| Solid waste | kg | 3.39E-03 | 5.89E-08 | 1.98E-07 | 7.90E-02 | 7.32E-06 | 0.00E+00 | 1.53E-02 | **9.77E-02** |
| Fossil fuels | MJ surplus | 8.67E-02 | 2.46E-04 | 4.67E-06 | 1.43E+00 | 1.66E-04 | 1.99E-02 | 1.44E-01 | **1.68E+00** |
| global warming (GWP100) | kg CO2 eq. | 1.79E-01 | 3.92E-05 | 1.01E-05 | 9.74E-01 | 2.52E-04 | 1.99E-02 | 1.60E-01 | **1.33E+00** |
| ozone layer depletion (ODP) | kg CFC-11 eq | 0.00E+00 | 0.00E+00 | 0.00E+00 | 4.95E-06 | 0.00E+00 | 1.48E-07 | 0.00E+00 | **5.10E-06** |
| human toxicity | kg 1,4-DB eq | 9.34E-02 | 8.73E-06 | 5.25E-06 | 2.11E-02 | 4.30E-05 | 3.40E-03 | 5.69E-02 | **1.75E-01** |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 3.43E-02 | 4.18E-06 | 1.63E-06 | 2.59E-01 | 1.98E-05 | 2.98E-02 | 2.22E-02 | **3.45E-01** |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 8.73E-02 | 7.83E-06 | 4.86E-06 | 1.74E-02 | 3.73E-05 | 2.75E-04 | 5.33E-02 | **1.58E-01** |
| terrestrial ecotoxicity | kg 1,4-DB eq | 3.89E-03 | 7.86E-07 | 1.71E-07 | 3.74E-01 | 2.16E-06 | 3.81E-03 | 2.77E-03 | **3.84E-01** |
| photochemical oxidation | kg C2H2 | 3.87E-03 | 1.37E-06 | 2.15E-07 | 3.74E-02 | 1.66E-05 | 1.36E-03 | 4.90E-03 | **4.75E-02** |
| acidification | kg SO2 eq | 7.70E-02 | 7.63E-06 | 4.39E-06 | 4.00E-01 | 8.96E-05 | 9.11E-03 | 7.08E-02 | **5.57E-01** |
| eutrophication | kg PO4--- eq | 3.41E-02 | 6.19E-06 | 1.85E-06 | 4.17E-01 | 9.98E-05 | 5.70E-03 | 5.99E-02 | **5.17E-01** |
| Solid Wall Average | | **7.85E-01** | **3.55E-04** | **5.07E-04** | **4.41E+00** | **2.82E-03** | **1.32E-01** | **7.24E-01** | **6.06E+00** |
| Land use | Ha a | 1.03E-04 | 1.52E-09 | 5.56E-09 | 4.25E-04 | 1.18E-07 | 1.12E-04 | 5.99E-05 | **7.00E-04** |
| Water Use | KL H2O | 1.42E-03 | 2.10E-08 | 4.64E-04 | 1.62E-01 | 1.63E-06 | 3.88E-03 | 9.93E-02 | **2.67E-01** |
| Solid waste | kg | 4.40E-03 | 6.49E-08 | 2.60E-07 | 8.38E-02 | 2.81E-05 | 0.00E+00 | 1.62E-02 | **1.04E-01** |
| Fossil fuels | MJ surplus | 1.13E-01 | 2.71E-04 | 6.14E-06 | 1.51E+00 | 6.36E-04 | 2.73E-02 | 1.53E-01 | **1.81E+00** |
| global warming (GWP100) | kg CO2 eq. | 2.33E-01 | 4.32E-05 | 1.32E-05 | 1.03E+00 | 9.66E-04 | 2.73E-02 | 1.69E-01 | **1.46E+00** |
| ozone layer depletion (ODP) | kg CFC-11 eq | 0.00E+00 | 0.00E+00 | 0.00E+00 | 5.26E-06 | 0.00E+00 | 2.04E-07 | 0.00E+00 | **5.46E-06** |
| human toxicity | kg 1,4-DB eq | 1.21E-01 | 9.62E-06 | 6.90E-06 | 2.24E-02 | 1.65E-04 | 4.68E-03 | 6.02E-02 | **2.09E-01** |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 4.45E-02 | 4.60E-06 | 2.14E-06 | 2.75E-01 | 7.61E-05 | 4.09E-02 | 2.34E-02 | **3.83E-01** |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 1.13E-01 | 8.63E-06 | 6.39E-06 | 1.84E-02 | 1.43E-04 | 3.78E-04 | 5.64E-02 | **1.89E-01** |
| terrestrial ecotoxicity | kg 1,4-DB eq | 5.05E-03 | 8.66E-07 | 2.24E-07 | 3.96E-01 | 8.31E-06 | 5.24E-03 | 2.93E-03 | **4.10E-01** |
| photochemical oxidation | kg C2H2 | 5.02E-03 | 1.51E-06 | 2.82E-07 | 3.96E-02 | 6.39E-05 | 1.87E-03 | 5.19E-03 | **5.18E-02** |
| acidification | kg SO2 eq | 1.00E-01 | 8.41E-06 | 5.77E-06 | 4.24E-01 | 3.44E-04 | 1.25E-02 | 7.49E-02 | **6.12E-01** |
| eutrophication | kg PO4--- eq | 4.42E-02 | 6.82E-06 | 2.43E-06 | 4.42E-01 | 3.83E-04 | 7.83E-03 | 6.34E-02 | **5.58E-01** |
| Solid Wall High | | **9.65E-01** | **3.88E-04** | **6.28E-04** | **4.66E+00** | **4.90E-03** | **1.68E-01** | **7.63E-01** | **6.57E+00** |
| Land use | Ha a | 1.27E-04 | 1.66E-09 | 6.88E-09 | 4.49E-04 | 2.05E-07 | 1.42E-04 | 6.32E-05 | **7.81E-04** |
| Water Use | KL H2O | 1.75E-03 | 2.29E-08 | 5.74E-04 | 1.71E-01 | 2.84E-06 | 4.94E-03 | 1.05E-01 | **2.83E-01** |
| Solid waste | kg | 5.41E-03 | 7.08E-08 | 3.22E-07 | 8.86E-02 | 4.89E-05 | 0.00E+00 | 1.71E-02 | **1.11E-01** |
| Fossil fuels | MJ surplus | 1.38E-01 | 2.96E-04 | 7.60E-06 | 1.60E+00 | 1.11E-03 | 3.48E-02 | 1.61E-01 | **1.94E+00** |
| global warming (GWP100) | kg CO2 eq. | 2.86E-01 | 4.72E-05 | 1.64E-05 | 1.09E+00 | 1.68E-03 | 3.48E-02 | 1.78E-01 | **1.59E+00** |
| ozone layer depletion (ODP) | kg CFC-11 eq | 0.00E+00 | 0.00E+00 | 0.00E+00 | 5.56E-06 | 0.00E+00 | 2.60E-07 | 0.00E+00 | **5.82E-06** |
| human toxicity | kg 1,4-DB eq | 1.49E-01 | 1.05E-05 | 8.54E-06 | 2.37E-02 | 2.87E-04 | 5.96E-03 | 6.35E-02 | **2.43E-01** |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 5.47E-02 | 5.03E-06 | 2.65E-06 | 2.90E-01 | 1.32E-04 | 5.21E-02 | 2.47E-02 | **4.22E-01** |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 1.39E-01 | 9.42E-06 | 7.91E-06 | 1.95E-02 | 2.49E-04 | 4.81E-04 | 5.95E-02 | **2.19E-01** |
| terrestrial ecotoxicity | kg 1,4-DB eq | 6.21E-03 | 9.46E-07 | 2.77E-07 | 4.19E-01 | 1.45E-05 | 6.67E-03 | 3.09E-03 | **4.35E-01** |
| photochemical oxidation | kg C2H2 | 6.18E-03 | 1.65E-06 | 3.50E-07 | 4.19E-02 | 1.11E-04 | 2.38E-03 | 5.47E-03 | **5.60E-02** |
| acidification | kg SO2 eq | 1.23E-01 | 9.18E-06 | 7.14E-06 | 4.49E-01 | 5.98E-04 | 1.59E-02 | 7.91E-02 | **6.67E-01** |
| eutrophication | kg PO4--- eq | 5.44E-02 | 7.45E-06 | 3.01E-06 | 4.68E-01 | 6.67E-04 | 9.97E-03 | 6.69E-02 | **6.00E-01** |
| Foamed Core | | | | | | | | | |
| Foamed Core Low | | **4.59E-01** | **1.53E-04** | **2.30E-04** | **1.68E+00** | **1.12E-03** | **4.31E-02** | **2.84E-01** | **2.47E+00** |
| Land use | Ha a | 6.03E-05 | 6.56E-10 | 2.52E-09 | 1.62E-04 | 4.68E-08 | 3.64E-05 | 2.35E-05 | **2.82E-04** |
| Water Use | KL H2O | 8.32E-04 | 9.05E-09 | 2.10E-04 | 6.17E-02 | 6.47E-07 | 1.27E-03 | 3.90E-02 | **1.03E-01** |
| Solid waste | kg | 2.58E-03 | 2.80E-08 | 1.18E-07 | 3.19E-02 | 1.11E-05 | 0.00E+00 | 6.36E-03 | **4.09E-02** |
| Fossil fuels | MJ surplus | 6.58E-02 | 1.17E-04 | 2.78E-06 | 5.76E-01 | 2.52E-04 | 8.90E-03 | 5.99E-02 | **7.11E-01** |
| global warming (GWP100) | kg CO2 eq. | 1.36E-01 | 1.87E-05 | 6.00E-06 | 3.94E-01 | 3.83E-04 | 8.92E-03 | 6.64E-02 | **6.05E-01** |
| ozone layer depletion (ODP) | kg CFC-11 eq | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.00E-06 | 0.00E+00 | 6.65E-08 | 0.00E+00 | **2.07E-06** |
| human toxicity | kg 1,4-DB eq | 7.09E-02 | 4.15E-06 | 3.13E-06 | 8.54E-03 | 6.54E-05 | 1.53E-03 | 2.36E-02 | **1.05E-01** |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 2.60E-02 | 1.99E-06 | 9.68E-07 | 1.05E-01 | 3.01E-05 | 1.33E-02 | 9.20E-03 | **1.53E-01** |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 6.63E-02 | 3.73E-06 | 2.90E-06 | 7.01E-03 | 5.67E-05 | 1.23E-04 | 2.22E-02 | **9.56E-02** |
| terrestrial ecotoxicity | kg 1,4-DB eq | 2.95E-03 | 3.74E-07 | 1.02E-07 | 1.51E-01 | 3.29E-06 | 1.71E-03 | 1.15E-03 | **1.57E-01** |
| photochemical oxidation | kg C2H2 | 2.94E-03 | 6.54E-07 | 1.28E-07 | 1.51E-02 | 2.53E-05 | 6.08E-04 | 2.04E-03 | **2.07E-02** |
| acidification | kg SO2 eq | 5.85E-02 | 3.63E-06 | 2.62E-06 | 1.62E-01 | 1.36E-04 | 4.08E-03 | 2.94E-02 | **2.54E-01** |
| eutrophication | kg PO4--- eq | 2.59E-02 | 2.95E-06 | 1.10E-06 | 1.68E-01 | 1.52E-04 | 2.55E-03 | 2.49E-02 | **2.22E-01** |
| Foamed Core Average | | **6.97E-01** | **2.58E-04** | **4.01E-04** | **3.09E+00** | **2.28E-03** | **9.61E-02** | **5.00E-01** | **4.39E+00** |
| Land use | Ha a | 9.15E-05 | 1.11E-09 | 4.40E-09 | 2.97E-04 | 9.55E-08 | 8.13E-05 | 4.14E-05 | **5.12E-04** |
| Water Use | KL H2O | 1.26E-03 | 1.53E-08 | 3.67E-04 | 1.14E-01 | 1.32E-06 | 2.83E-03 | 6.86E-02 | **1.87E-01** |
| Solid waste | kg | 3.91E-03 | 4.72E-08 | 2.06E-07 | 5.87E-02 | 2.28E-05 | 0.00E+00 | 1.12E-02 | **7.38E-02** |
| Fossil fuels | MJ surplus | 1.00E-01 | 1.97E-04 | 4.85E-06 | 1.06E+00 | 5.15E-04 | 1.99E-02 | 1.05E-01 | **1.29E+00** |
| global warming (GWP100) | kg CO2 eq. | 2.07E-01 | 3.15E-05 | 1.05E-05 | 7.24E-01 | 7.82E-04 | 1.99E-02 | 1.17E-01 | **1.07E+00** |
| ozone layer depletion (ODP) | kg CFC-11 eq | 0.00E+00 | 0.00E+00 | 0.00E+00 | 3.68E-06 | 0.00E+00 | 1.48E-07 | 0.00E+00 | **3.83E-06** |
| human toxicity | kg 1,4-DB eq | 1.08E-01 | 7.00E-06 | 5.45E-06 | 1.57E-02 | 1.34E-04 | 3.40E-03 | 4.16E-02 | **1.68E-01** |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 3.95E-02 | 3.35E-06 | 1.69E-06 | 1.92E-01 | 6.16E-05 | 2.98E-02 | 1.62E-02 | **2.78E-01** |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 1.01E-01 | 6.28E-06 | 5.05E-06 | 1.29E-02 | 1.16E-04 | 2.75E-04 | 3.90E-02 | **1.53E-01** |
| terrestrial ecotoxicity | kg 1,4-DB eq | 4.49E-03 | 6.31E-07 | 1.77E-07 | 2.78E-01 | 6.72E-06 | 3.81E-03 | 2.02E-03 | **2.88E-01** |
| photochemical oxidation | kg C2H2 | 4.46E-03 | 1.10E-06 | 2.23E-07 | 2.78E-02 | 5.17E-05 | 1.36E-03 | 3.58E-03 | **3.72E-02** |
| acidification | kg SO2 eq | 8.88E-02 | 6.12E-06 | 4.56E-06 | 2.97E-01 | 2.78E-04 | 9.11E-03 | 5.18E-02 | **4.47E-01** |
| eutrophication | kg PO4--- eq | 3.93E-02 | 4.97E-06 | 1.92E-06 | 3.10E-01 | 3.10E-04 | 5.70E-03 | 4.38E-02 | **3.99E-01** |
| Foamed Core High | | **9.35E-01** | **3.64E-04** | **5.72E-04** | **4.50E+00** | **3.44E-03** | **1.49E-01** | **7.15E-01** | **6.30E+00** |
| Land use | Ha a | 1.23E-04 | 1.56E-09 | 6.27E-09 | 4.33E-04 | 1.44E-07 | 1.26E-04 | 5.92E-05 | **7.41E-04** |
| Water Use | KL H2O | 1.69E-03 | 2.15E-08 | 5.23E-04 | 1.65E-01 | 2.00E-06 | 4.38E-03 | 9.81E-02 | **2.70E-01** |
| Solid waste | kg | 5.24E-03 | 6.65E-08 | 2.93E-07 | 8.55E-02 | 3.44E-05 | 0.00E+00 | 1.60E-02 | **1.07E-01** |
| Fossil fuels | MJ surplus | 1.34E-01 | 2.78E-04 | 6.92E-06 | 1.54E+00 | 7.78E-04 | 3.08E-02 | 1.51E-01 | **1.86E+00** |
| global warming (GWP100) | kg CO2 eq. | 2.77E-01 | 4.43E-05 | 1.49E-05 | 1.05E+00 | 1.18E-03 | 3.09E-02 | 1.67E-01 | **1.53E+00** |
| ozone layer depletion (ODP) | kg CFC-11 eq | 0.00E+00 | 0.00E+00 | 0.00E+00 | 5.36E-06 | 0.00E+00 | 2.30E-07 | 0.00E+00 | **5.59E-06** |
| human toxicity | kg 1,4-DB eq | 1.44E-01 | 9.85E-06 | 7.78E-06 | 2.29E-02 | 2.02E-04 | 5.28E-03 | 5.95E-02 | **2.32E-01** |
| fresh water aquatic ecotox. | kg 1,4-DB eq | 5.30E-02 | 4.72E-06 | 2.41E-06 | 2.80E-01 | 9.30E-05 | 4.62E-02 | 2.32E-02 | **4.03E-01** |
| marine aquatic ecotoxicity | kg 1,4-DB eq | 1.35E-01 | 8.84E-06 | 7.20E-06 | 1.88E-02 | 1.75E-04 | 4.27E-04 | 5.58E-02 | **2.10E-01** |
| terrestrial ecotoxicity | kg 1,4-DB eq | 6.02E-03 | 8.88E-07 | 2.53E-07 | 4.04E-01 | 1.02E-05 | 5.92E-03 | 2.89E-03 | **4.19E-01** |
| photochemical oxidation | kg C2H2 | 5.98E-03 | 1.55E-06 | 3.18E-07 | 4.04E-02 | 7.81E-05 | 2.11E-03 | 5.13E-03 | **5.37E-02** |
| acidification | kg SO2 eq | 1.19E-01 | 8.62E-06 | 6.51E-06 | 4.33E-01 | 4.21E-04 | 1.41E-02 | 7.41E-02 | **6.41E-01** |
| eutrophication | kg PO4--- eq | 5.27E-02 | 6.99E-06 | 2.74E-06 | 4.51E-01 | 4.69E-04 | 8.84E-03 | 6.27E-02 | **5.76E-01** |

| **Application per m of Pipe Material** | | **Total Ecopoints** |
|---|---|---|
| DWV | | |
| PVC - DN100 Au Solid Wall - Low | Low | 0.008873 |
| PVC - DN100 Au Solid Wall - Av | Average | 0.00969 |
| PVC - DN100 Au Solid Wall - High | High | 0.010506 |
| PVC - DN100 Au Foamed Core - Low | Low | 0.002961 |
| PVC - DN100 Au Foamed Core - Av | Average | 0.005263 |
| PVC - DN100 Au Foamed Core - High | High | 0.007565 |
| ABS - DN100 Au Imp PN9-12 - Av | Average | 0.014078 |
| ABS - DN100 Au Imp PN9 - Av | Average | 0.011078 |
| ABS - DN100 Au Imp C 9 Bar - Av | Average | 0.013386 |
| ABS - DN100 Au Metric PN10 - Av | Average | 0.013097 |
| Cast Iron - DN100 Au - Av | Average | 0.014535 |
| PE - DN100 - Av | Average | 0.008788 |
| Copper DN100 Type A - Av | Average | 0.065659 |
| Copper - DN100 Type B - Av | Average | 0.052943 |
| Copper - DN100 Type D - Av | Average | 0.039765 |
| Pressure Pipe | | |
| PVC - DN100 Au solid wall - Low | Low | 0.024401 |
| PVC - DN100 Au solid wall - Av | Average | 0.026647 |
| PVC - DN100 Au solid wall - High | High | 0.028892 |
| PVC-o - Av | Average | 0.010027 |
| DI (Cement lined) - DN100 - Av | Average | 0.027314 |
| PE100 - DN110 PN16 - Av | Average | 0.020311 |