mpa
British Precast
Drainage Association

ADOPTING CONCRETE DRAINAGE
REDUCES WHOLE LIFE CARBON

The British Precast Drainage Association (BPDA) is the main trade association representing the interests of the manufacturers of concrete pipes, manholes, box culverts and sustainable drainage systems in the UK. The association is active in the research and promotion of the many technical, commercial and environmental benefits of precast concrete drainage systems. BPDA is a product association of the British Precast Concrete Federation Ltd.

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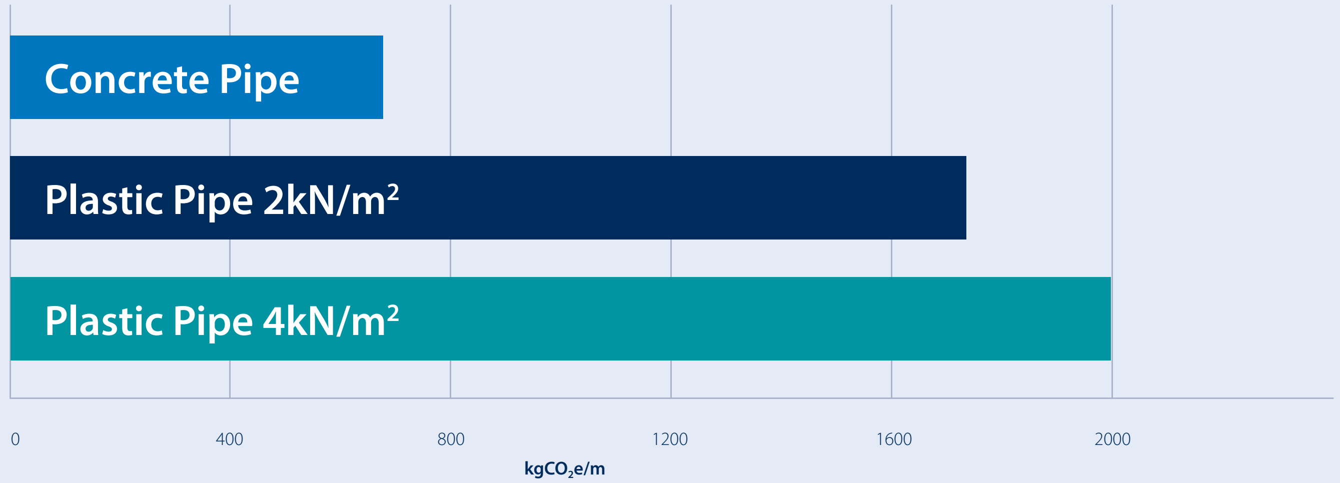
Whole life carbon comparison

The following document outlines the BPDA's approach to whole life carbon reduction and provides a comparison between the impact of concrete and plastic pipelines.

Fig 1: Concrete Pipes vs HDPE Plastic Pipes Cradle-to-Grave GWP comparison (DN2100 pipe). International Resin and Additional Adjustments. Assuming 50 year plastic pipe service life.



Key Findings

The BPDA research suggests that at the majority of pipe diameters, plastic pipe ring stiffness and resin sources evaluated in the study, installed concrete pipes have a lower Global Warming Potential (GWP) impact.

- For large diameter pipes the difference is the most marked with the GWP impact of 4 kN/m^2 (SN4) DN2100 plastic pipes as much as 47% higher than that of a concrete equivalent (assuming equal service lives).
- When the full pipeline lifecycle in taken into consideration the BPDA believe that the GWP impact of a plastic pipeline could be more than double the GWP impact of a concrete pipe. This is primarily due to the longer service life of concrete pipes.

The carbon comparison

The impact of construction projects generally, and building materials specifically, is becoming of greater importance as the UK strives to reach net zero carbon. A construction project's materials choice can be a significant factor in a projects ecological impact. To help understand this impact, the following brochure compares the global warming potential of concrete and plastic pipelines.

Improving sustainability performance

The UK precast concrete industry has a responsibility to understand and improve its environmental impacts and performance on sustainability. For the British Precast Drainage Association (BPDA), the need for sustainable drainage systems, in both new construction and existing developments, is driving change within all areas of the industry. This study is just one part of this commitment.

The case for concrete - getting stronger over time

Like concrete itself, the environmental argument for precast drainage systems keeps getting stronger. Not only have the reductions in concrete's carbon footprint contributed significantly to this case, but the methods of measuring the sustainability of a drainage system have become increasingly rigorous and if these methods are followed properly, they can provide even more robust and reliable results.

The BPDA's Aim

Increasing rigour means increasing demands on available data, reliable sources and robust and transparent methodology.

The BPDA's aim is to provide clear, accurate and transparent environmental information about the products manufactured by our members using research aligned to the latest internationally recognised standards. This document details our approach.
The comprehensiveness and complexity of this does not lend itself to simple 'soundbites' and 'greenwashing'. We therefore offer a structured argument with detailed methodology that presents the case for concrete in terms of Global Warming Potential (GWP), the most widely used and understood global indicator.

The BPDA approach

The BPDA commissioned a study to assess the impact of our members' precast concrete pipes against the relevant international standards and to compare these with equivalent plastic pipes. These are our guiding principles.

Dependable data and substantiated sources

The methods of measuring the sustainability of a drainage system have become increasingly rigorous with the emergence of multi-indicator life cycle analysis (LCA), in the form of Environmental Product Declarations (EPDs), as the dominant methodology.

The most widely used indicator is the 'carbon footprint' or more accurately, the Global Warming Potential (GWP). However, when considering the 'carbon footprint' of a material, product or system, it is vital that all relevant greenhouse gases are identified and the assessment is not exclusively based on carbon dioxide. A true 'carbon footprint' is reported as carbon dioxide equivalent (CO_2e). Claims made on single activities, such as transportation or assessments based on only part of an asset's life cycle, can be misleading and lead to false conclusions.

Verified and published EPD

As stated, the BPDA have published a fully EN 15804 compliant EPD for 1m of DN600 precast concrete pipe with Class B bedding. This is an Association declaration (sector generic EPD) which uses average primary data from member companies. It is a cradle-to-grave assessment based on data from UK factories covering a period of 12 months (2014). Interrogation of the LCA showed that the cradle-to-grave GWP impact of 1m length of DN600 concrete pipe with Class B bedding is between (a) 74 kgCO_2e (exhumation and recycling/landfilling at end of life); (b) 77 kgCO_2e (abandonment with no grouting at end of life); and (c) 122 kgCO_2e (abandonment with grouting at end of life).

The production phase of the products life cycle accounts for 57% of the impact with carbonation in the use phase reducing the overall impact by 2%. The process of grouting a pipe at the end of life contributes 37% of the cradle-to-grave GWP impact. Comparisons with plastic pipes within this document do not include the grouting of the pipe at the end of life because this impact is the same regardless of pipe material.

An LCA study of this type enables us to perform a hotspot analysis identifying the areas of the product life cycle which have the largest impact. This allows us to focus our efforts on sustainability and bring down the life cycle carbon footprint of our products.

To view and download the full verified EPD visit our sustainability section on *www.britishprecast.org*

Whole Life Carbon

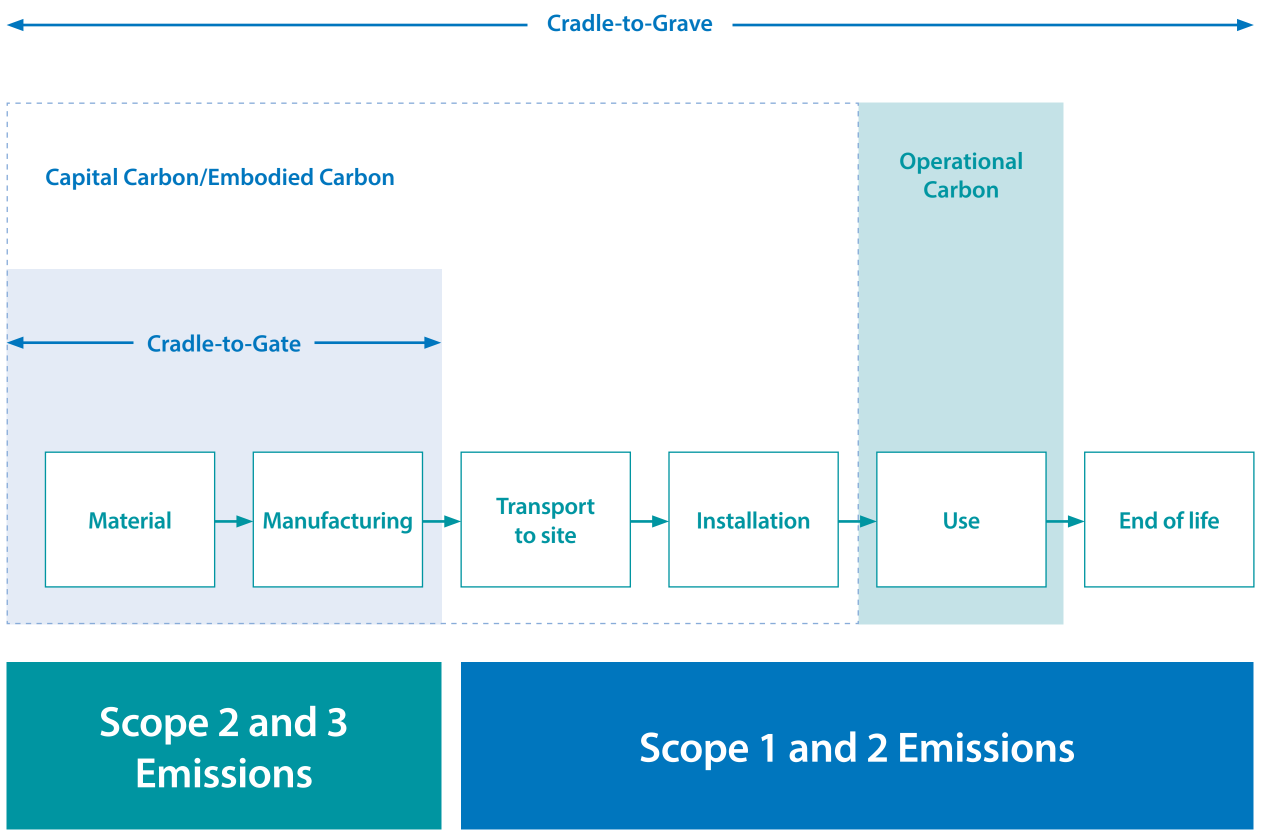


Fig 2: Understanding 'Carbon' Terminology.

Common European Standards

If the construction and infrastructure sectors are to make informed decisions and draw comparisons between products, then a consistent methodology, carried out to internationally recognised Standards is paramount.

To find a common European approach and to eliminate barriers to trade, the European Committee for Standardisation (CEN) developed standards for the environmental impact assessment of buildings (EN 15978), and relevant product information (EN 15804). These are the standards which should be referred to when making declarations on the environmental performance of construction products.

The use of EN 15804 and EN 15978 is supported by the methodology of the Carbon Management in Infrastructure Standard, PAS 2080: 2016. PAS 2080 notes that data consistent with the modular LCA approach and principles set out in EN 15978 and EN 15804 should be used in comparisons of this type.

The comparisons carried out by BPDA are not entirely compliant with the standards described because of a lack of verifiably compliant plastic pipe data. The data for the concrete pipes used in this study is however based on our externally verified EN15804 EPD and calculator.

PAS2080 Approach: It is the total carbon, i.e. the sum of carbon across all the lifecycle stages of an asset that should be assessed and reduced. This is to avoid making a carbon reduction in one lifecycle stage which leads to an increase in carbon in a later lifecycle stage and therefore to a net increase in whole life carbon. For example, specifiers should make sure that using low-carbon materials to reduce 'capital carbon' during installation does not lead to more carbon from material replacements during the operational stage.

Embodied Carbon:

The greenhouse gas emissions (GHGs) that are released throughout a production supply chain to produce a material or product.

Capital Carbon:

The GHGs associated with the creation of construction materials and the construction of the asset.

Operational Carbon:

The GHGs associated with the operation of infrastructure.

Whole life Carbon:

The sum of GHGs across all life cycle stages.

The GHG Protocol classifies a company's GHGs into three 'scopes'.

Scope 1 emissions

Direct emissions from owned or controlled sources.

Scope 2 emissions

Indirect emissions from the generation of purchased energy.

Scope 3 emissions

All other indirect emissions due to the activities of an organisation.

Fig 3:

The BPDA life cycle approach to carbon emissions

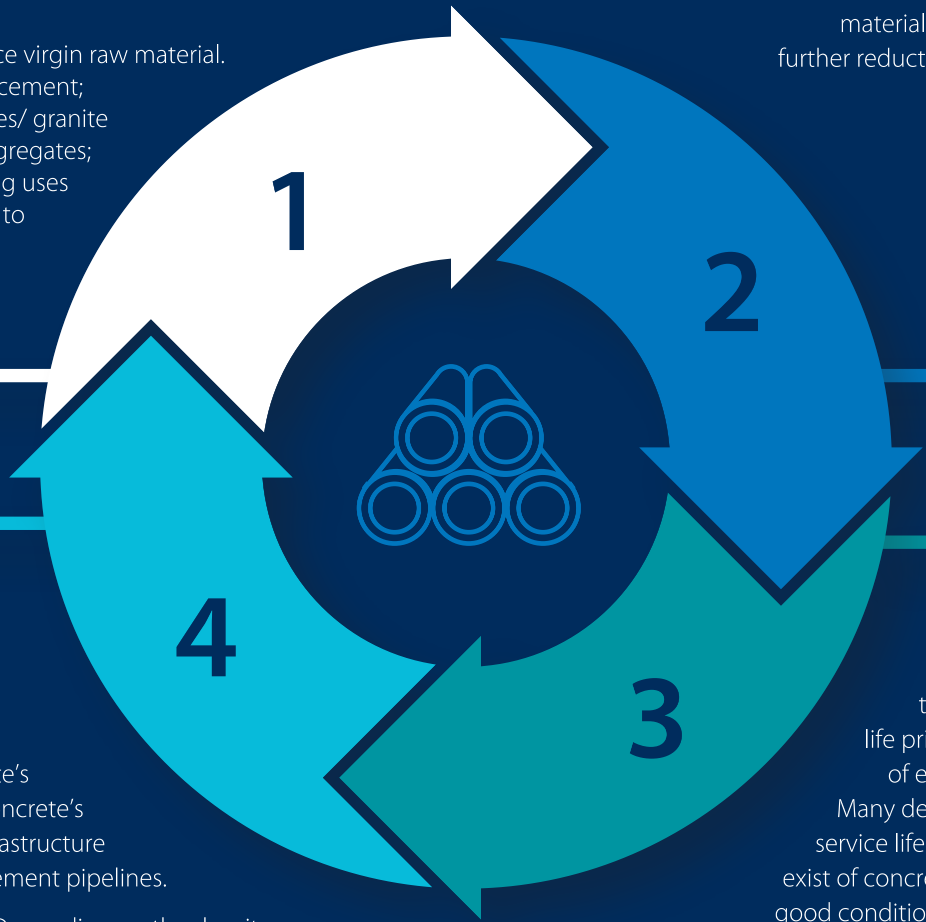
1. Product Stage

The majority of raw materials used in the manufacture of precast concrete are locally sourced with a short transparent supply chain. This predominantly local supply chain gives assurance that the majority of cement and aggregates produced in the UK are certified to very good or excellent level under the BES 6001 responsible sourcing scheme. The transparent supply chain also reduces the risk of modern slavery concerns and protects biodiversity through the Mineral Products association (MPA) biodiversity action plan. With concrete manufacture being a local operation, transport distances for raw materials are low and correspondingly, lead to very low transport emissions per tonne of product.

Recycled material is extensively used to reduce or replace virgin raw material. BPDA manufacturers use 100% recycled steel for reinforcement; secondary aggregates (crushed concrete/ limestone fines/ granite dust/ ground glass) are used to substitute some fine aggregates; fly ash and GGBS to minimise cement use. Manufacturing uses efficient, modern production technology to keep waste to a minimum and any concrete waste is recycled.

2. Installation Stage

The installation of gravity sewerage (non-pressure) pipelines usually requires transport to site plus an amount of granular bedding material. Concrete pipes are structural elements and unlike flexible plastic pipes, the integrity of the installed pipeline is derived mainly from the pipe itself. This means that it is often possible to use a bedding design that requires less granular materials than typically required for flexible (plastic) pipes – and reuse the excavated material for embedment. Emissions associated with the provision and transport of the granular material are therefore reduced. Additionally, there is potential for further reductions as there is no transport requirement for the disposal of excavated material to landfill.



4. End of Life Stage

Case studies exist where, following testing to today's standards, concrete pipes originally installed 50-100 years ago have been exhumed and successfully reused, thus minimising emissions. This is one aspect of concrete's circular economy potential. The most fundamental is concrete's exceptional long life which can extend the life of an infrastructure development or building, reducing the need for replacement pipelines.

Concrete also has the ability to absorb carbon dioxide. Depending on the density of the material and porosity of the surface, carbon dioxide can be absorbed into concrete throughout its service life. For structural concrete, the rate of carbonation is kept to a minimum in order to protect reinforcing steel. However, one potential end of life scenario for a pipeline is exhumation and the concrete broken up as rubble. The large surface area then exposed to the atmosphere can lead to rapid absorption of CO_2, meaning that concrete can have a carbon negative contribution at the end of life. For example, with modern waste handling systems and short retention times, an average value for carbon dioxide absorption on the demolition site and stockpile is 5kg CO_2/m^3 of concrete (EN 16757). However, if waste is handled to maximise carbonation the amount of carbon dioxide absorbed could be increased many times over.

3. Use Stage

As set out in the National Infrastructure Plan 2010, the UK government is committed to ensuring that whole life principles are adopted in making effective and smarter use of existing assets. Concrete is an extremely durable material. Many design standards and specifications acknowledge the long service life of concrete stating a design life of 120+ years; examples exist of concrete pipes that are well over 120 years old and are in such good condition that they can be expected to last for many more years. This demonstrable track record of long service life provides confidence that a concrete pipeline system should operate successfully for many years with minimal intervention, keeping emissions associated with repair or replacement to a minimum.

This is particularly important because in a real-world scenario outside the scenarios described in this document, a pipe may be required to perform a function for longer, possibly much longer than the design life. Looking at the rate of renovation/replacement of existing assets it is clear that the resilience of a product which can outperform its design life is crucial. It is recognised in HM Governments 'Water for Life' document that replacement and renovation could become a big issue. "Between 2000 and 2008 just over 3,000km, or 1% of public sewers in England and Wales were replaced or rehabilitated. At that rate it will be 800 years before the whole system is covered."

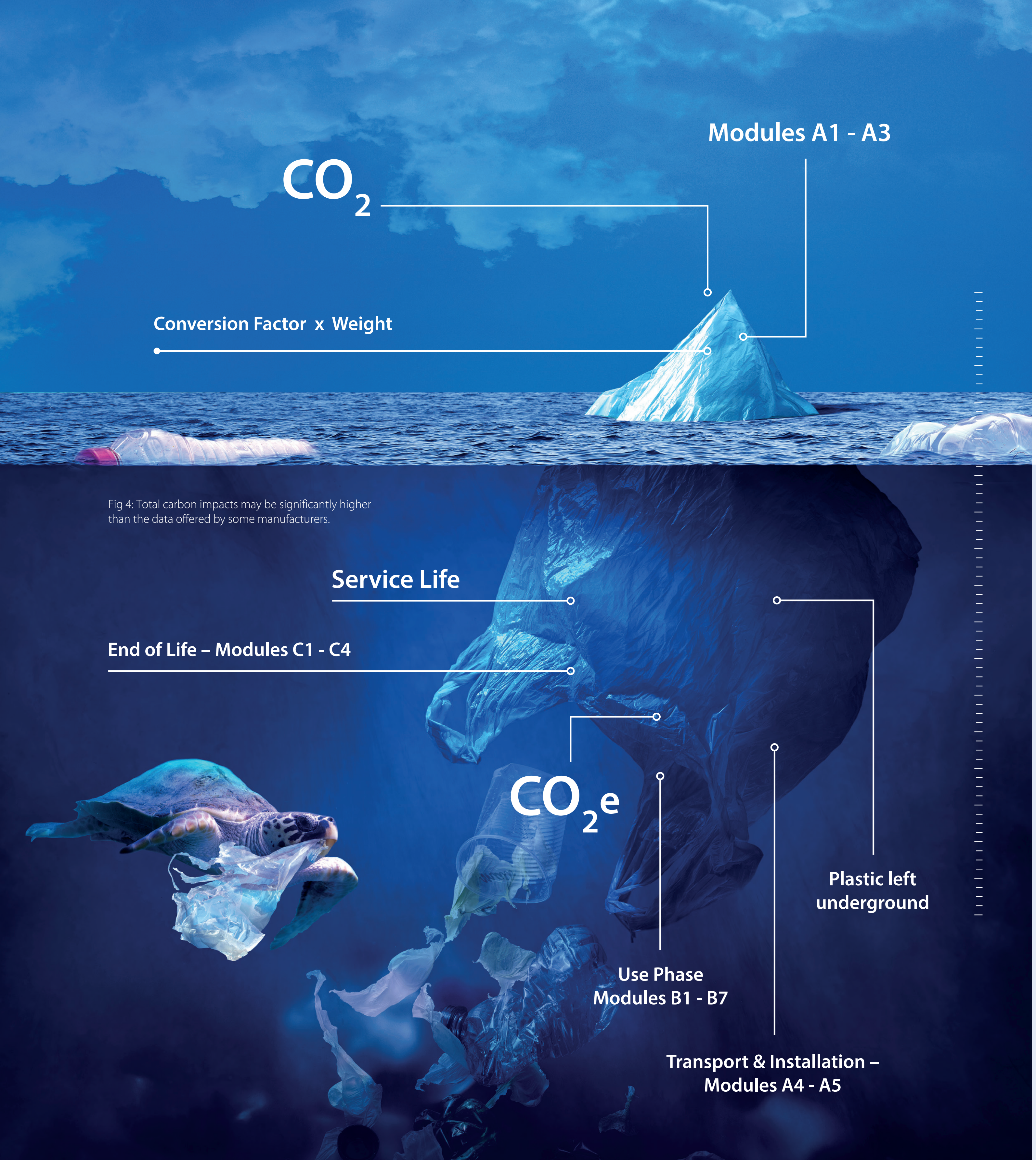


Fig 4: Total carbon impacts may be significantly higher than the data offered by some manufacturers.

The Full Picture on Embodied Carbon

Not all embodied carbon impacts are visible in the studies conducted by drainage systems manufacturers. Think of it as an iceberg – whilst the top of the iceberg is visible to all, it actually extends hundreds of metres under the sea. Whilst this is invisible to a surface scan, the integrity of the results must acknowledge its existence.

Whole life carbon

At the heart of the study is the concept of 'whole life carbon' – highlighted in PAS 2080 – which is the sum of GHGs across all life cycle stages. Some plastic pipe studies may have under-reported the true level of embodied carbon emissions in their assessments by not taking account of multiple greenhouse gases or not including all life cycle stages. On a limited life cycle stage assessment, you can miss important impacts further into the asset's life span.

Comparing the relative GWP impact of concrete and plastic pipelines

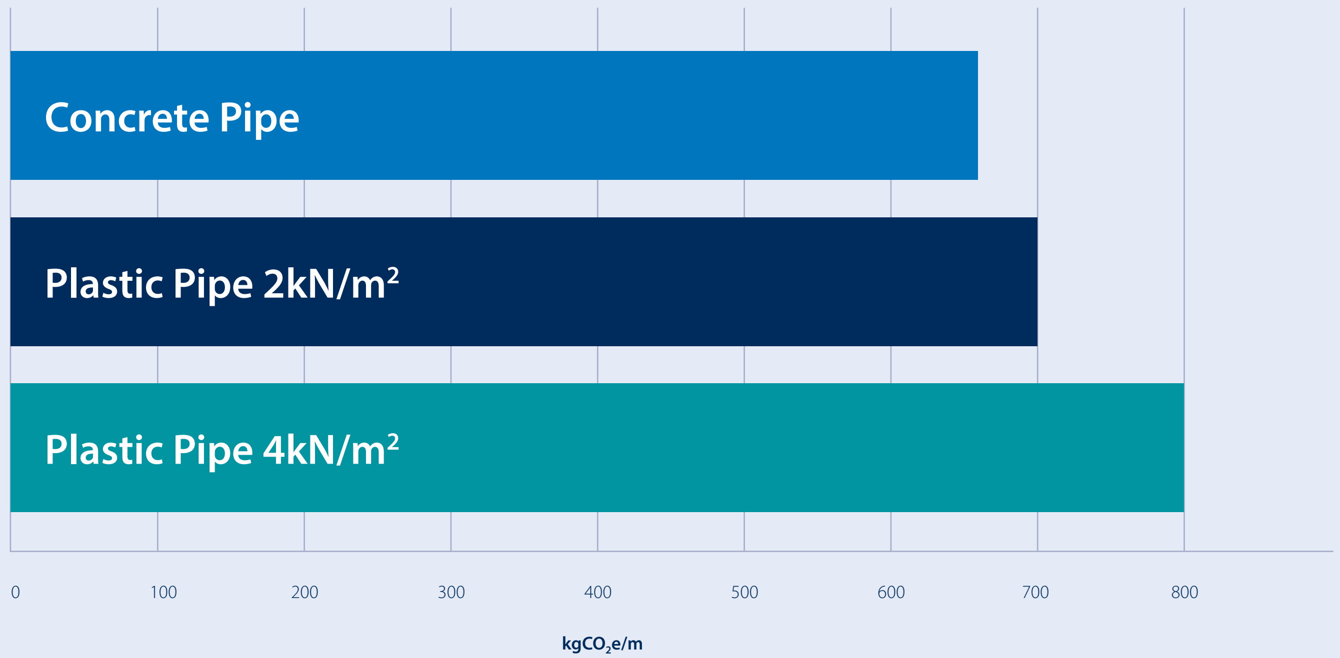
To achieve the aim of comparing the relative impact of material choice on the carbon footprint of an installed pipeline, a reliable set of values needed to be modelled for plastic pipes. The BPDA was able to model a typical and realistic 'Base Case' scenario for plastic pipes manufactured from European resin. This scenario utilised a sensitivity analysis, carried out by the consultancy Circular Ecology, on data published by Plastics Europe, the trade association for resin suppliers in Europe, in 2015.

The chart below shows that a concrete pipeline has a lower GWP impact over the life cycle of a pipeline system. In many cases, by using concrete, you are able to use one pipe where two plastic pipes would be required. This not only results in lower carbon emissions but also has significant material efficiency and long-term cost benefits. As table 1 shows, even when compared on an equal service life basis, concrete pipes have a lower impact. The difference is made even greater when compared to plastic pipes made from resin sourced from outside of the EU, which is common within the UK market. Concrete is the low carbon choice on a cradle-to-grave analysis at all pipe diameters and the difference is particularly marked for large pipe diameters.

Table 1: GWP $kgCO_2e/m$ of different pipe sizes – concrete pipes and HDPE Plastic Pipes. Base Case.

Pipe Type	Pipe Diameter *values in brackets denote values assuming equal service life					
	600	900	1200	1500	1800	2100
Concrete	89	164	278	409	552	688
Plastic Pipe $2kN/m^2$	156 (78)	295 (147.5)	509 (254.5)	722 (361)	951 (475.5)	1,396 (698)
Plastic Pipe $4kN/m^2$	191 (95.5)	356 (178)	626 (313)	950 (475)	1,154 (577)	1,598 (799)

Fig 5: DN2100 European Base Case Comparison assuming equal service life.



At the sizes and ring stiffnesses studied, concrete pipes have a lower carbon impact than the HDPE plastic pipe equivalent.

The 'Base Case' for our comparison was designed to be conservative with several factors required by EN 15804 not included in the assessment. BPDA believe that the true impact of plastic pipes is significantly higher still when further adjustments are made for:

(i) use of internationally sourced resin

(ii) accurate plastic pipe factory waste

(iii) the correct use of volumetric transport assumptions

(iv) plastic pipe decay emissions (within 100 years)

Accurate wastage rates

If accurate wastage rates in plastic pipe factories were publicly available and transport data adjusted to volume constraints, not weight, then the impact of plastic pipes would rise and concrete pipes would fall.

The correct use of volumetric transport assumptions

For large items such as a plastic pipe, transport is likely to be volume constrained before mass. Additional calculations were carried out using pipe truckload capacities from BPDA members in addition to a UK thermoplastics pipe supplier.

End of Life Modelling

Base case values for this study are modelled with the assumption that the two forms of pipe are treated in the same way at the end of life, with the pipes being abandoned underground with no further emissions. In the latest version of EN15804+A2, it is required that the end of life modules C1-C4 are considered in LCA studies of this type.

In the absence of reliable data for the end of life destination for pipelines, BPDA modelled scenarios for both concrete and plastic pipes. For concrete end of life routes considered are recycling (including carbonation while in use and at EoL), landfilling and reuse. For plastic the end of life routes considered are recycling, landfilling, abandonment with plastic decay within 100 years (highlighted as important in both EN15643 and EN15804) and incineration.

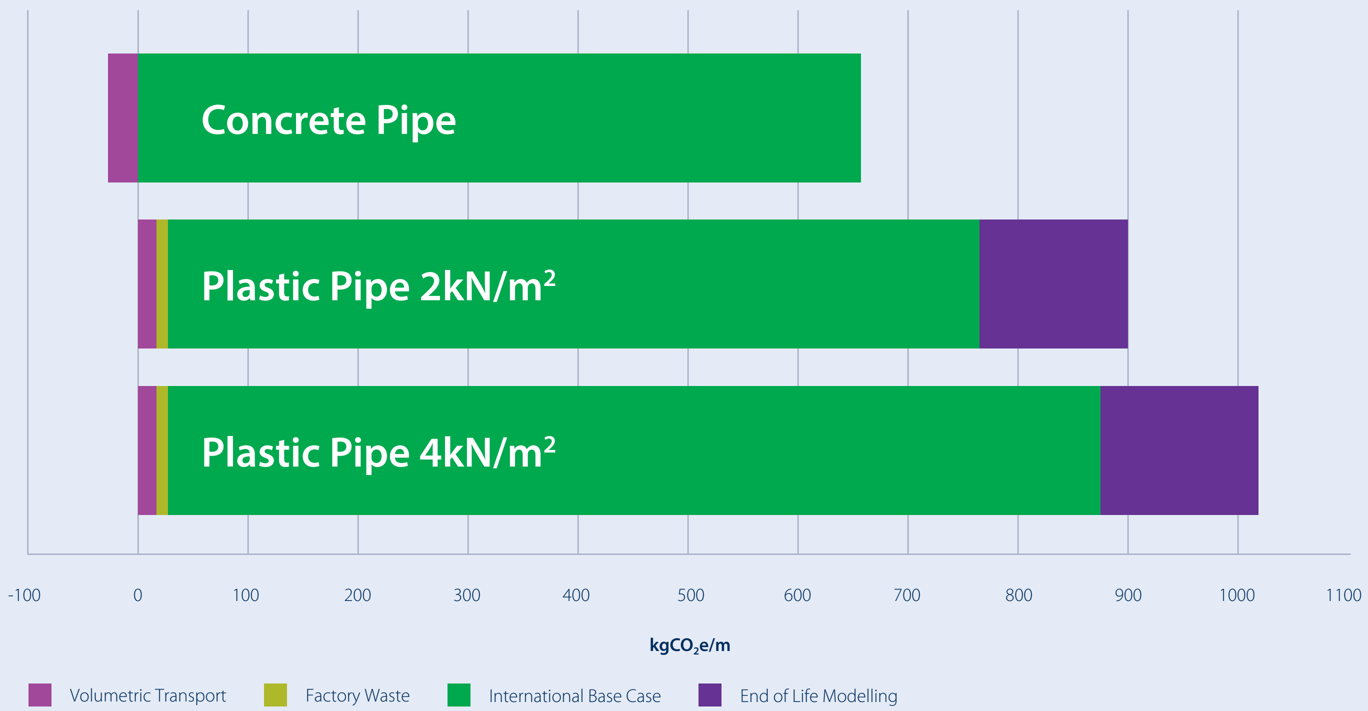
Concrete durability

One of the many strengths of concrete is its durability and long life. From the Colosseum in Rome to a 100-year old concrete pipe excavated from the ground, concretes ability to fulfil a 120-year service life is not in doubt. This is important because pipes installed today may be required to perform a function much longer than the design life, looking at the rate of renovation/replacement of existing assets.

It is recognised in HM Governments 'Water for Life' document that replacement and renovation could become a big issue. *"Between 2000 and 2008 just over 3,000km, or 1% of public sewers in England and Wales were replaced or rehabilitated. At that rate it will be 800 years before the whole system is covered."*

Water for Life states that: *"at some point we or future generations will need to increase that rate of investment if those networks are to continue to function at the same standard. Investing at a rate which maintains the long-term serviceability of the network must remain a priority."*

Fig 6: International Resin sources and Additional Adjustments. Concrete Pipes Vs HDPE Plastic Pipes Cradle-to-Grave GWP comparison (DN2100 pipe). (Assuming equal service life).



A separate BPDA study of all the Water and Sewerage Companies (WaSCs) asset renovation/replacement suggests that, based on current rates of renovation and replacement, the service life requirement for a new section of the 'critical' sewer network would be 576 years. Concrete pipes have been in general use since the introduction of sewers in Victorian times around 160 years ago. There is no evidence to prove that plastic pipes can achieve comparable long-term performance. This is something that BPDA believes that water companies and other sewerage infrastructure asset owners should take seriously. Whole life value and future proofing the network against premature failure and high replacement costs should be a priority.

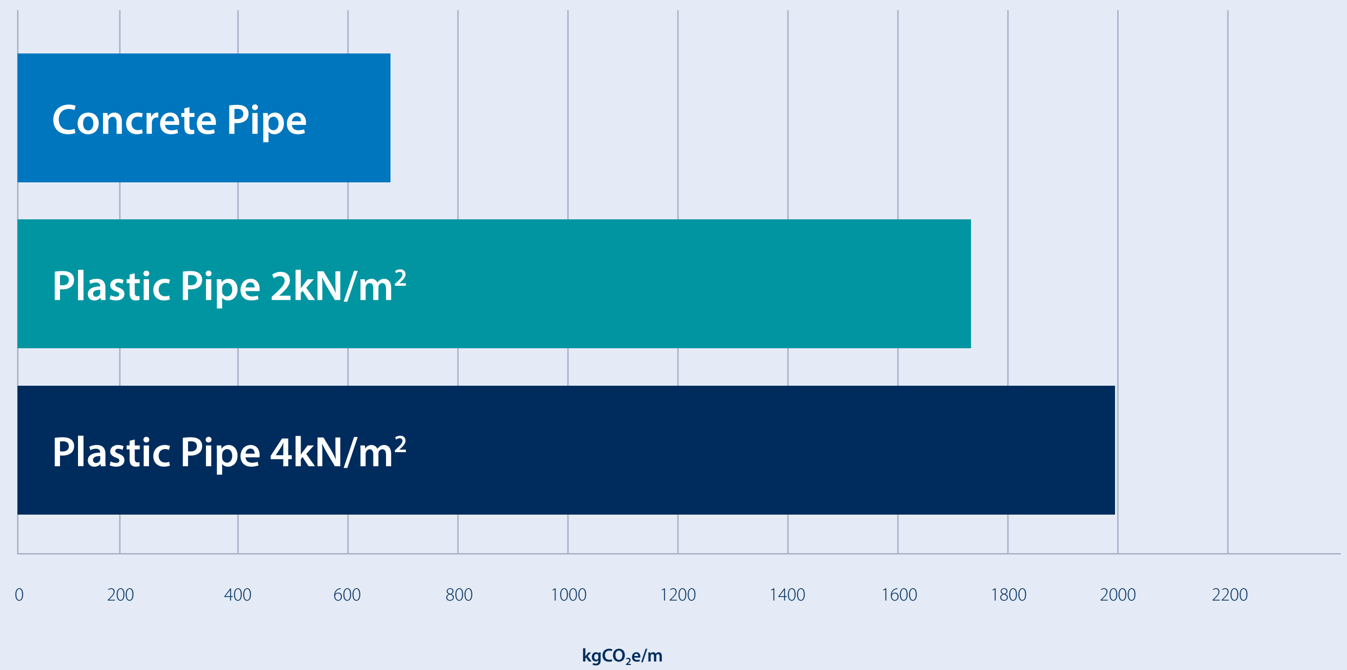
The UK Government's Infrastructure Charter states that delivery should seek the best whole life outcome. Extended asset life and reduced replacement/renovation costs should form a key part of this decision-making process.

Currently in the UK, the design life requirement for sewerage pipes ranges from 50 – 130 years depending on asset owner and pipe diameter. Currently the British Board of Agrément (BBA) assurance for plastic pipes is currently 50 – 60 years in the majority of cases. This means that under a PAS2080 or EN 15804 a strong argument could be made for the reference service life (RSL) of plastic pipes being 60 years and concrete pipes 120 years.

Table 2: GWP of DN2100 pipes adjusted for additional impact factors.

Pipe Type	International Resin Base Case	Factory Waste	Volumetric Transport	End of Life Modeling	Total
Concrete	688	0	-17	6	677
Plastic Pipe $2kN/m^2$	744	5	12	106	867
Plastic Pipe $4kN/m^2$	855	6	10	127	998

Fig 7: International Resin Base Case and Additional Adjustments. Concrete Pipes vs HDPE Plastic Pipes Cradle-to-Grave GWP comparison (DN2100 pipe). (Assuming 50 year plastic pipe service life).



Avoided emissions from choosing concrete pipes

This BPDA study shows that concrete pipelines have lower carbon impacts across their whole life compared to plastic pipelines.
By choosing concrete pipes, especially those specifying sustainable concrete, you are avoiding certain sources of carbon emissions.

Through the use of cementitious replacements, pulverised Fly Ash (PFA) and Ground Granulated Blast Furnace Slag (GGBS), the embodied carbon footprint of concrete can be reduced significantly. This is one of many design decisions that can be made through discussions with suppliers to specify sustainable concrete.

Concrete's extended service life, more than double that of plastic pipes in many cases, removes the need for replacements within the assets design life. Its durability also extends past the design life, reducing risks associated with current projected service life requirements of UK water assets of up to 800 years.

Selecting concrete pipes also reduces bedding requirements which in turn lowers the amount of imported granular bedding material required for installation. This not only reduces the carbon impact of transporting and quarrying the bedding material but also increases the material efficiency of the development. The use of plastic has the opposite effect as oil- based products are non-renewable.

The naturally occurring process of carbonation can absorb CO_2 from the atmosphere. If concrete pipes were to be exhumed at the end of life and crushed this carbon uptake would be dramatically increased.

> "Selecting concrete pipes also reduces bedding requirements which in turn lowers the amount of imported granular bedding material required for installation."

Fig 8: Avoided emissions from choosing concrete pipes.

Reducing embodied CO_2 –

Cutting the embodied carbon of concrete through the use of cementitious replacements.

Long service life –

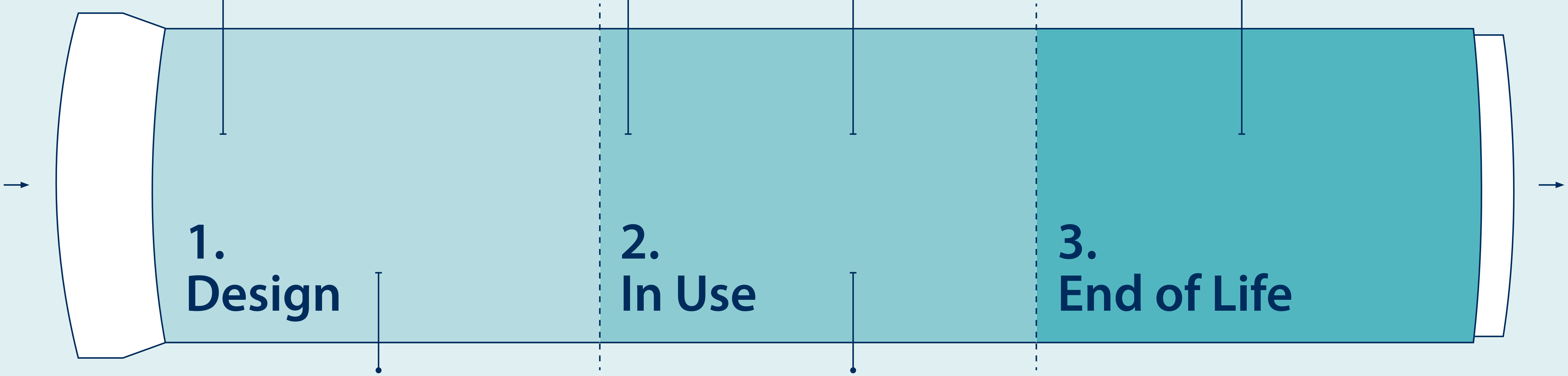
Concrete pipes have a proven and long service life, generally considered double that of plastic, removing the need for replacement within the infrastructure design life.

Use beyond the end of design life –

At the current rate of pipeline renovation and replacement in the UK an average service life of 800 years is required.

Carbonation at end of life –

If concrete pipes are exhumed at end of life and crushed, the increased surface area results in increased absorption of atmospheric CO_2.



Reduced bedding requirements –

The use of concrete pipes can reduce the amount of imported granular bedding material required for installation.

Carbonation –

Concrete pipes absorb atmospheric CO_2 over their life cycle.

Details of the full analysis undertaken by British Precast is available on request by contacting the BPDA on **email@precastdrainage.co.uk**

Plastic in our Ecosystem

According to the United Nations Environment Programme, more than 8 billion tonnes of plastic has been produced since the early 1950s, and around 60% of that plastic has ended up in either landfill or the natural environment. One estimate suggests that just nine per cent is recycled. The impact of all this plastic on the environment is very serious and is causing widespread damage to our ecosystem. In our oceans for example plastic pollution is known to harm more than 600 species, contributing to what some believe is the beginning of the sixth mass extinction of life on Earth.

The construction industry consumes 23% of all plastic produced in the UK. Piping and conduits are the largest uses of polymers in construction and consume around 35% of production.

By using concrete pipes there are a number of points in an asset's life span where significant amounts of carbon dioxide emissions can be avoided. But the use of concrete pipes also provides us with a route to prevent large amounts of entirely unnecessary plastic from entering the environment. The planet is entering a new epoch, the Anthropocene and the build-up of plastic in the environment will be one of its defining characteristics. This plastic will even be evident in rocks beneath our feet as the proliferation of plastic will form a noticeable line in the sedimentary rocks of the future. Our assessment of the end of life disposal of pipes further reinforces this, with the majority of assets abandoned at the end of life leaving the plastic in the ground. Even if the plastic pipes were to be dug up, most would be incinerated rather than recycled producing a significant amount of additional CO_2.

Summary

The BPDA research suggests that at the majority of pipe diameters, plastic pipe ring stiffness and resin sources evaluated in the study, installed concrete pipes have a lower GWP impact.

- For large diameter pipes the difference is the most marked with the GWP impact of 4 kN/m^2 (SN4) DN2100 plastic pipes as much as 47% higher than that of a concrete equivalent (assuming equal service lives).
- When the full lifecycle is taken into consideration the BPDA believe that the GWP impact of a plastic pipeline could be more than double the GWP impact of a concrete pipe. This is primarily due to the longer service life of concrete pipes.

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