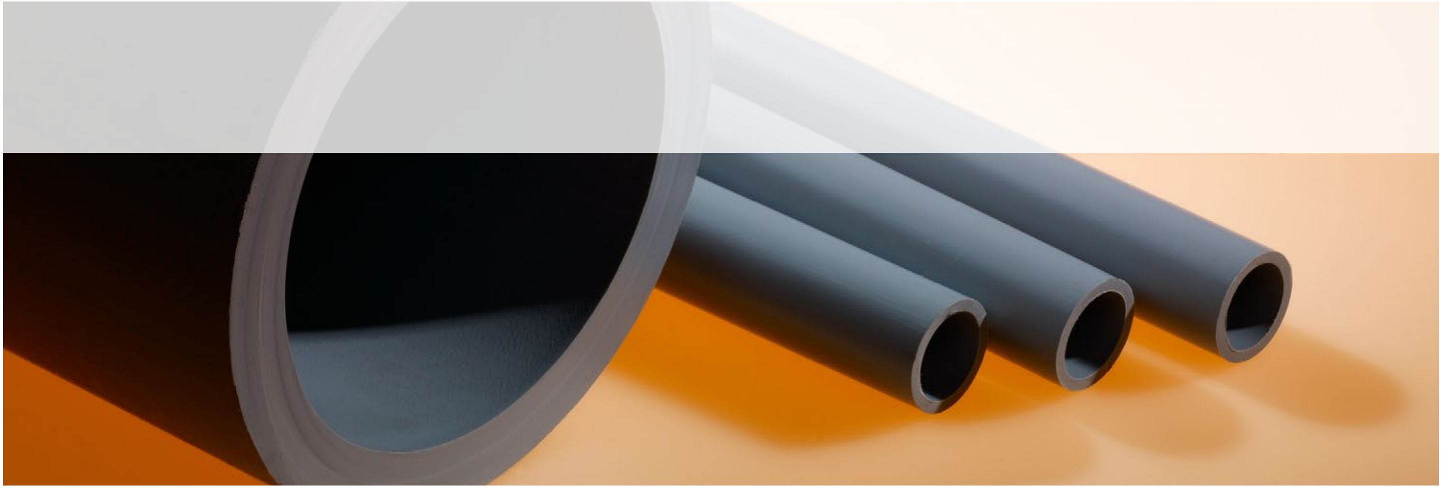
English

Polybutene
Piping Systems Association

Successful in the Past

Prepared for the Future



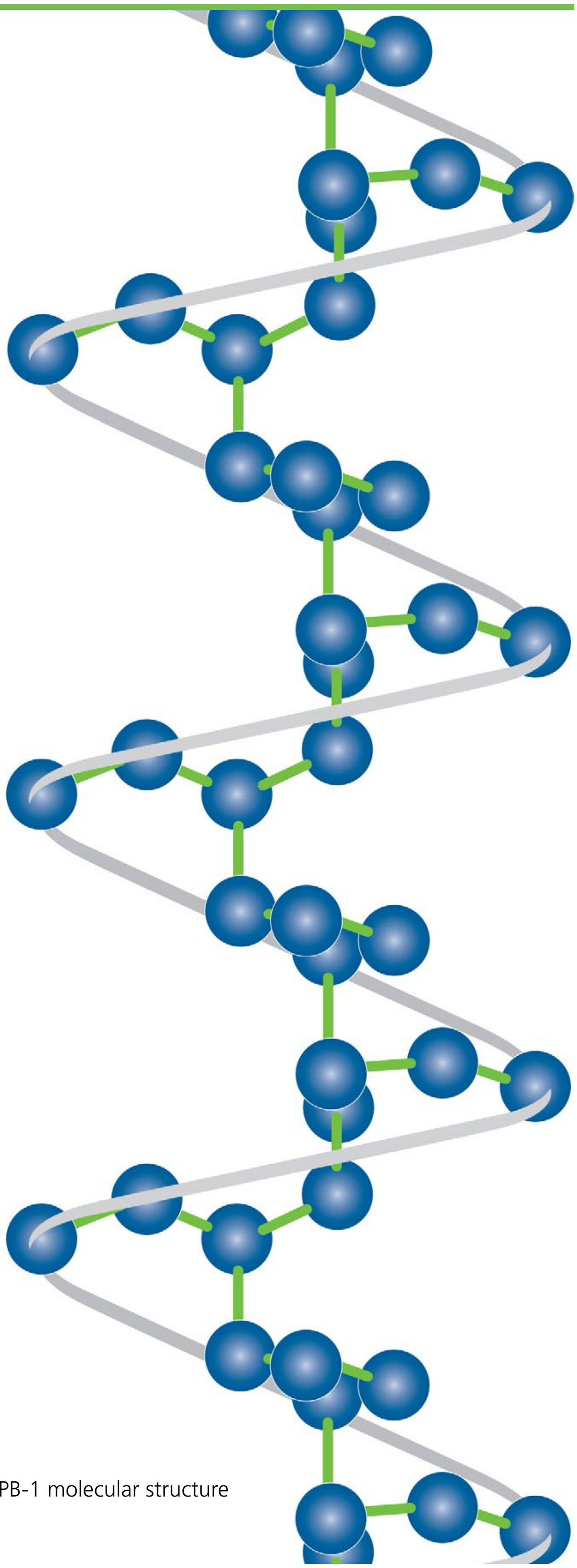
A review of the performance of Polybutene pressure piping systems in meeting the needs of sustainable building regulations.

www.pbpsa.com

An Introduction to Polybutene

Polybutene (also named Polybutylene) was discovered over 50 years ago. Its introduction into pressure piping applications started in the mid 1960s. Since then continuous research and development has resulted in optimised material characteristics, improved manufacturing technology and sophisticated designs of piping systems components.

Piping systems made from Polybutene demonstrate exceptional performance in a variety of demanding long-term applications and have become a vital part of modern energy-efficient and ecologically acceptable building technology resulting in a booming growth rate for the product in recent years.



PB-1 molecular structure

Performance Characteristics

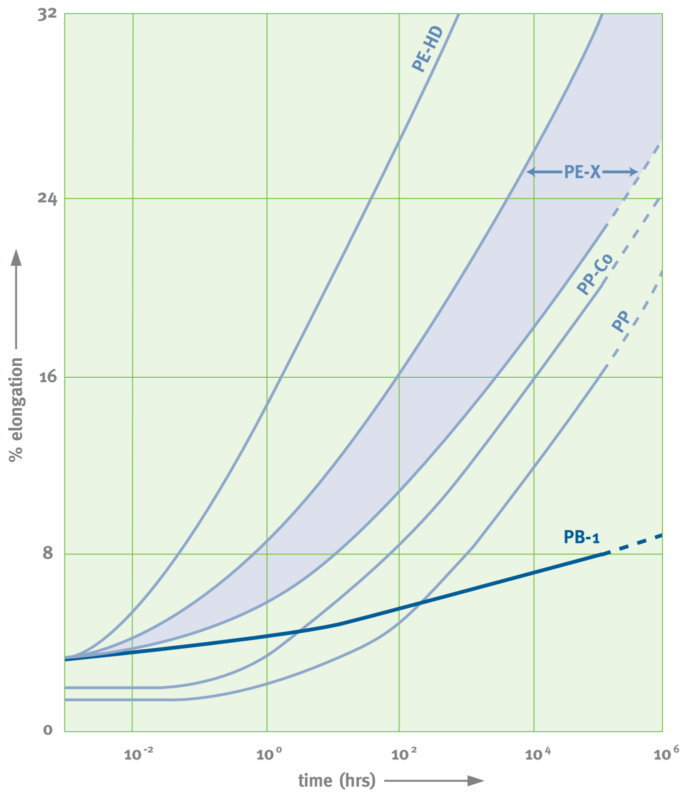
Polybutene exhibits a unique morphology and crystallisation behaviour which, combined with careful control of molecular parameters, gives Polybutene a profile of properties unrivalled in piping systems manufacture (**Figure 1**).

Figure 1: Comparison of Polymers used in Plumbing

	PB-1	PP-R	PE-X	PVC-C
Impact Toughness	●●●	●●	●●●	●
Chemical Resistance	●●●	●●●	●●●	●●●
Flexibility	●●●●	●●	●●●	●
Creep Resistance	●●●●	●●●	●●●	●●●
Thermal Pressure Resistance	●●●●	●●	●●●	●●●
Weldability	●●●●	●●●●	●	●●

Key	●●●●	●●●	●●	●
	Excellent	Good	Fair	Poor

Figure 2: Creep behaviour of polyolefins at room temperature (8 MPa)



The most important of these properties which sets Polybutene apart from competitive products is the combination of high flexibility and outstanding resistance to internal pressure creep resistance over a wide range of hot and cold water temperatures.

All polyolefinic materials tend to creep when exposed to continually applied stress over a long period of time. This cold flow behaviour can be suppressed by creating a three dimensional network in the polymer structure e.g. by physical or chemical cross linking as is the case in the manufacture of cross-linked Polyethene (PEX). However Polybutene displays superior inherent creep resistance (**Figure 2**) without the application of any additional cross linking, copolymerisation or compounding modification. In its simplest homopolymer form, its property profile is ideal for satisfying the demands of pressure piping applications.

In terms of flexibility, expressed in Figure 3 as an elastic modulus, Polybutylene is clearly the product of choice. Flexibility is a key factor because it enables easier and faster installation. The ease of cabling pipe through drilled holes and threading through confined spaces, combined with long pipe runs and a consequent reduction in the number of fittings required, are all factors which contribute to the speed of installation and associated reduction in costs. In addition, Polybutene offers many benefits in service to the consumer.

Figure 3: Flexural Elasticity Modulus (MPa) Method ISO 178

PVC-C	PP-R	PE-RT	PEX	PB-1
3500	800	550-650	600	**450**

(PE-RT – Raised Temperature Resistance polyethylene)

Performance Characteristics

It is designed to meet stringent organoleptic and food contact approvals (**Figure 4**) and hence is well suited for drinking water applications.

Figure 4: European Approvals

1	UK	BSI	BS 7291
2	UK	BBA	
3	UK	WRAS	Water Quality Approval UK
4	Germany	DVGW	W534/W544
5	Germany	DIN	DIN 16968/DIN 16969
6	Germany	KTW	Water Quality Approval Germany
7	Netherlands	KIWA	BRL K 536
8	Netherlands	KOMO (Heating)	BRL 5604/5
9	Netherlands	ATA	Water Quality Approval Netherlands
10	Poland	Polska Instal	TIN – BS 7291 & ISO 158756
11	Hungary	EMI	ISO 15876
12	Bulgaria	Executive Agency Cert & Testing	BS EN ISO 15876
13	Austria	ÖVGW	Önorm ISO 15876
14	Spain	AENOR	UNE EN ISO 15876
15	Portugal	LNEC	ISO 15876
16	France	CSTB	Avis Technique
17	Croatia	DVGW	W534/W544
18	Switzerland	SVGW	ISO 15876
19	Turkey	TSE	
20	Denmark	ETA	ISO 15876

Its inert chemical properties and apolar nature hinder limescale deposition thus ensuring long-term efficiency in water heating and circulation. Its resistance to freezing temperatures combined with its elastic properties ensures that when water freezes in the pipe the ensuing expansion is accommodated by a temporary increase in the pipe wall diameter, minimising the possibility of bursting by sub-zero temperatures during spells of cold weather.

Due to the low elastic modulus, low density and low thermal expansion, polybutene pipes have superior acoustic behaviour with no water hammer or other noise problems (**Figure 5**).

Figure 5: Sound Velocity in Materials

	Density (g/cm^3)	Elastic Modulus (MPa)	Sound Velocity (m/s)
Copper	7.2	110,000	3,900
PB-1	0.94	450	620
CPVC	1.56	3,500	2,350
PEX	0.95	600	800
Soft Rubber	0.90	90	320

Such excellent acoustic performance was a contributory factor in Polybutene being the material of choice for the renovation of London's Royal Albert Hall water piping system.

Finally, as an essentially 'pure' highly isotactic homopolymer, Polybutene is more easily specified than some alternative materials to consistently achieve quality performance, and when necessary, is easily recyclable.

Pipe Performance Comparison

The resistance of pipes to deformation and burst is determined by testing to international and national standards. Three piping systems standards exist in parallel, namely ISO 15876 for Polybutylene, ISO 15875 for PEX, and ISO 15874 for Polypropylene. The data presented in these standards provides a useful means of comparison between the performance of these three alternative plastics materials (**Figure 6**). A comparison with PE-RT is also included but since no published ISO standard exists to date the data presented was obtained from ISO/DIS 24033.

The data provided can then be used to calculate the maximum permitted hoop stress for hot water transportation according to a defined set of conditions referred to as temperature classes. These temperature classes are compiled to reflect the likely cross-section of service conditions for a 50-year period for a range of different heating and water supply applications. These internationally accepted temperature classes are stipulated in ISO standard 10508 and referred to in the systems standards for plastic piping systems (**Figure 7**).

Figure 6: Comparison of reference lines @ 70˚C for PB-1, PEX, PP-R and PE-R

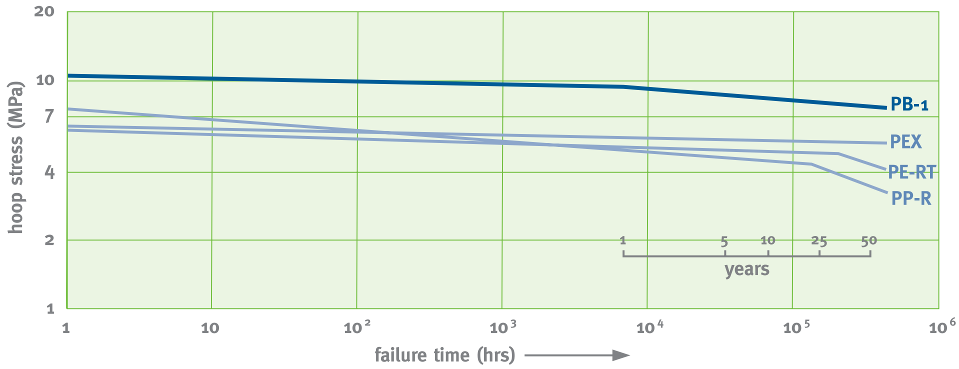


Figure 7: Classification of Service Conditions for 50 years CEN/ISO Classes

Service Conditions								
Class	**Application**	**Normal**		**Maximum**		**Malfunction**		
		Temp ˚C	**Time** years	**Temp** ˚C	**Time** years	**Temp** ˚C	**Time** hours	
1	**Hot Water Supply @ 60˚C**	60	49	80	1	95	100	
2	**Hot Water Supply @ 70˚C**	70	49	80	1	95	100	
4	**Underfloor Heating Low Temp. Heating Systems**	40	20	70	2.5	100	100	
		60	25					
5	**High Temp. Heating Systems**	60	25	90	1	100	100	
		80	10					

Pipe Performance Comparison

By employing standardised dimensional criteria presented in ISO 10508, it is possible to calculate the maximum allowable hoop stress of the alternative polyolefin pipes for the various applicational temperature classes. These calculations result in the comparisons presented in **Figure 8** where it is shown that the maximum allowable hoop stress or design stress for Polybutene pipes is some 35% higher than for cross-linked polyethylene PEX pipes, 45% higher than for Polypropylene PP-R pipes, and more than 50% higher than for non cross-linked PE-RT pipes.

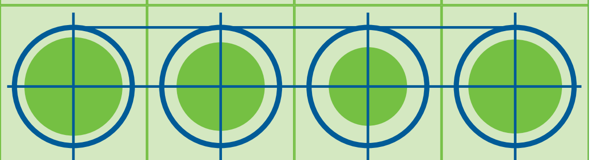
This effectively means that at equivalent thickness, Polybutene pipes offer a significant margin in design factor over these alternative plastic materials when pipe standards specify equivalent wall thickness.

However for the maximum allowable hoop stress, we can calculate a minimum allowable wall thickness. These calculations show that Polybutene pipes can be produced with a significantly reduced wall thickness when compared with alternative competitive materials dependent on applicational standards limitations. Lower wall thickness means, in addition to material savings, a larger internal bore for a given external pipe diameter, resulting in reduced head pressure loss and lower flow speeds to deliver a fixed volume of water. **Figure 9** illustrates the benefits of using Polybutene in comparison with competitive materials in a 40 mm diameter pipe for a 50-year life expectancy at a continuous operating temperature of 70°C including design factors.

Figure 8: Maximum allowable Hoop Stress (MPa) (Design Stress) of Polyolefin Pipes for Hot Water Transportation

	PB-1	PEX	PE-RT	PP-R
Temperature Class	Polybutene-1 (ISO 15876-2)	Cross-linked Polyethylene (ISO 15875-2)	Raised Temperature Resistance Polyethylene (ISO/DIS 22391-2)	Polypropylene Random-Copolymer (ISO 15874-2)
1 (HWS 60°C)	5.73	3.85	3.30	3.09
2 (HWS 70°C)	5.06	3.54	2.70	2.13
4 (UFH and low temperature radiators)	5.46	4.00	3.26	3.30
5 (High temperature radiators)	4.31	3.24	2.4	1.90

Figure 9: 50 Years life (70°C curve) including design factor

	PB-1	PEX	PP-R	PVC-C
Pipe dimension 40 mm OD x thickness (mm)	3,7	5,5	6,7/8,0	4,5
ID (Inner diameter) (mm)	32,6	29,0	26,6/24,0	31,0
Pipe inner surface (mm²)	834	660	555/462	754
Pressure rating	PN 16	PN 20	PN 20/ PN 25	PN 25
				
Flow speed *[m/s]* at $\dot{V}$ = 2,0 l/s	2,4	3,0	3,6/4,4	2,7
Loss of pressure *[mbar]* at $\dot{V}$ = 2,0 l/s	18,4	32,5	49,5/81,3 (SVGW/DVGW)	23,6
Ratio of Linear pipe weight	1	1,44	1,66	1,57

Sustainability and Environmental Compatibility

The issues of sustainability, energy efficiency and environmental impact have come to the fore over the last few years. The legislative pressure which affects the construction industry is being driven by the imminent EU 'Energy Performance in Buildings Directive' which has already had a profound influence on member governments who have independently introduced their own new building regulations. The guidelines for 'sustainable buildings' demand that the impact on the environment and the associated consumption of energy costs and resources is minimised throughout all phases of the life cycle of a building from planning to demolition.

With specific regard to the choice of a hot and cold water piping system for new building projects, Polybutene piping systems have clear benefits over competitive products.

Manufacturing

Polybutene is a derivative of the refining of crude oil. The monomer butene-1 is obtained from the olefins fraction of the cracking process, together with ethylene and propylene. Polybutene is produced by the polymerisation of butene-1 using a very high yield, low temperature catalyst system. This, together with the fact that polymerisation takes place in solution in the monomer, means there is no requirement to purify the resulting polymer. The unpolymerised monomer is simply recovered and recycled within the process. Polybutene is produced in Europe solely by LyondellBasell at their new production facility in The Netherlands (**Figure 10**).

Figure 10: Polybutene Manufacturing plant, Moerdijk, The Netherlands

The plant was only commissioned in 2003 and therefore had to satisfy the latest Dutch government regulations on environmental impact. It is both ISO 9001 and ISO 14001 certified (**Figure 11**).

Figure 11: DNV Management System Certificate

DNV

DET NORSKE VERITAS
MANAGEMENT SYSTEM CERTIFICATE

This is to certify that the mangement system of

Basell Polyolefins Europe Business

ISO 9001:2000

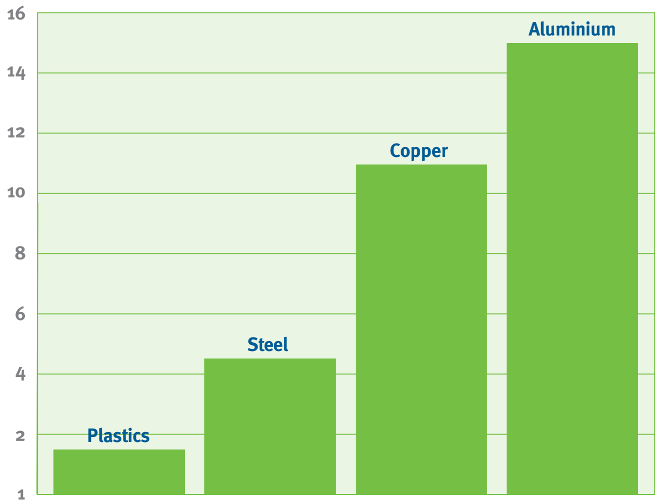
Production of Polyolefins and Advanced Polyolefins and Development and Marketing & Sales of Polyolefins Products.

This company has been certified since: 8 May 1991

Place and date: Rotterdam, 23 June 2005

Energy consumption of the manufacturing process is also extremely low in terms of consumption per unit finished product, and compares favourably with the raw material production of competitive piping systems. When compared with the raw material of traditional metal piping, Polybutene shows clear advantages in terms of kilograms oil equivalent per litre of material (**Figure 12**).

Figure 12: Kilograms Oil – Equivalent/Litre Material



Sustainability and Environmental Compatibility

Pipe Manufacture

All plastic pipes are manufactured via an extrusion process which involves raising the temperature of the raw material above its melting point, compressing the melted plastic through a die to form the pipe which is then cooled and coiled. Some plastics then require a second processing step to produce the finished product. Polybutene however is inherently fit for purpose without modification or secondary processing with the additional advantage that any uncontaminated off-specification production can be ground and recycled within the process. Raw material waste is therefore negligible.

Transportation

The Polybutene manufacturing plant is situated at Moerdijk in The Netherlands close to the oil refinery and port facilities at Rotterdam. Moerdijk is also close to the epicentre of the Polybutene piping systems business in Europe with the major pipe producers situated in The Netherlands, Switzerland, Germany, the UK and Austria (**Figure 13**).

Butene-1 feedstock is provided from European sources in the vicinity of the plant. Polybutene raw material is then transported by road either in bulk tanker consignments or semi-bulk recyclable board containers. The finished product pipe is also transported by road to the installation site. The majority of the Polybutene piping systems business is nationally or European based and hence transportation distances are relatively short. Clearly it is not possible to provide meaningful calculations on transportation energy consumption or environmental impact, but we feel confident that the Polybutene piping systems business compares favourably with all competitive systems.

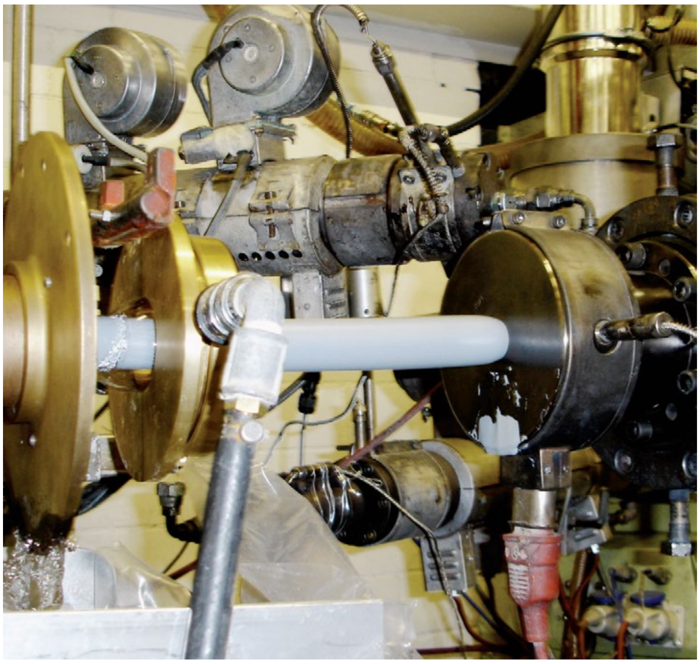


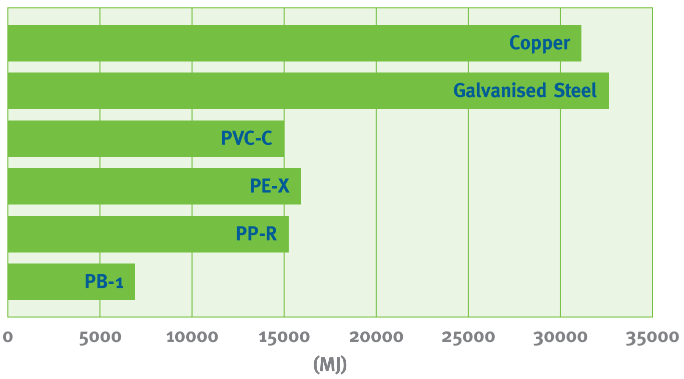
Figure 13: Locations of PBPSA members in Western Europe

Sustainability and Environmental Compatibility

Installations

Energy Efficiency – The Technical University of Berlin have conducted an energy efficiency and environmental impact analysis on hot and cold water pressurised piping systems. The study made a comparison of the total energy consumption for the production and installation of a piping system for a multiple dwelling with 16 apartments using a number of competitive metal and plastic systems. Due principally to their lighter weight, plastics materials had a distinct advantage over metal pipes, but the Polybutene piping system proved to be 50% lower in total energy consumption than the other plastics systems included in the study. This was due to its superior internal pressure performance, permitting the utilisation of pipes with smaller wall thickness (**Figure 14**).

Figure 14: Energy equivalent Value of the Complete Piping System for a 16 Family Housing Complex



Environmental Impact of Emissions – To provide a comparative analysis of emissions into soil, air and water the T.U. Berlin study developed a standardised comparison method, referred to as VENOB (Vergleichende Normierende Bewertung). This method allows a simplified and straightforward interpretation of the emissions data. Single emissions are recorded, standardised and then summarised in three individual and independent parameters: emissions into soil; emissions into water; and emissions into air. The lowest specific value of the six pipe materials compared was set to 1.0 and the other values were then calculated relative to this lowest value. The figures presented illustrate the results and show that in all three emissions, Polybutene piping systems have the least environmental impact (**Figures 15-17**).

Figure 15: Standardised Comparison (VENOB) of Various Pipe Materials Impact on the Environment – Emissions in Soil

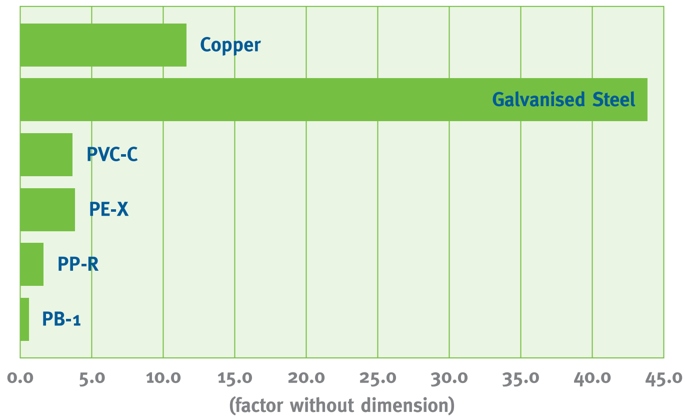


Figure 16: Standardised Comparison (VENOB) of Various Pipe Materials Impact on the Environment – Emissions in Water

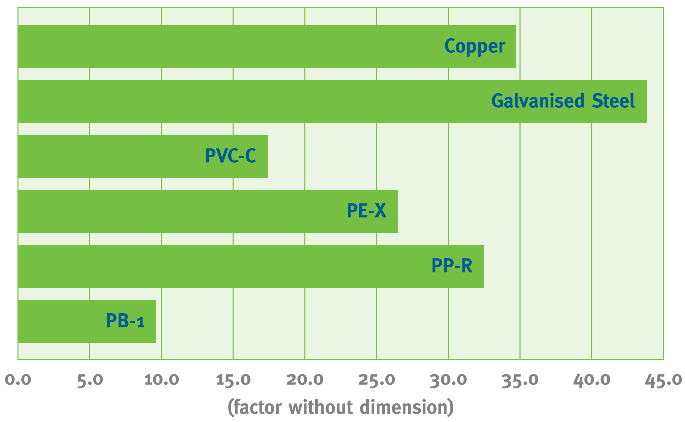
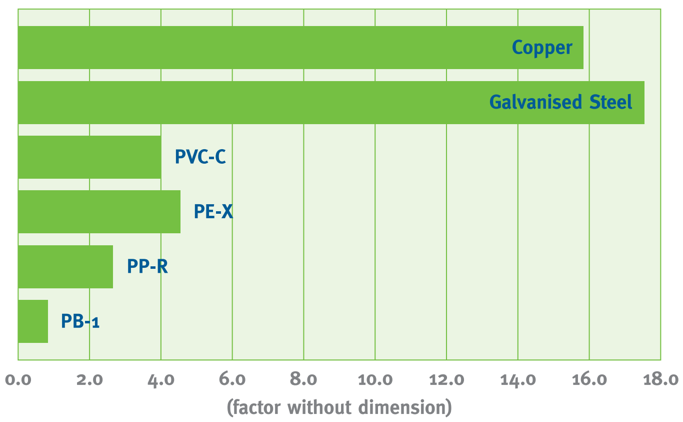


Figure 17: Standardised Comparison (VENOB) of Various Pipe Materials Impact on the Environment – Emissions in Air



Sustainability and Environmental Compatibility

Site Safety – Health and safety are key concerns in all construction projects. The ease of installation of Polybutene piping systems contributes considerably to good site safety. As previously discussed, the flexibility of Polybutene pipes means that it can be easily cabled through holes and tight spaces minimising the need for cutting and jointing. Many installations can be carried out without pre-measuring since it is easy to cut in situ.

Since no bending tools are required, a complete pipework installation can be completed requiring only a pair of cutters. No naked flame heating is required to make reliable watertight joints. For larger bore pipes, pre-fabricated socket fusion and/or in situ electrofusion systems can be installed using computerised easy-to-use electrofusion welding techniques. No solders, fluxes, greases or solvents are used with Polybutene systems.

Portable Electrofusion Welding Apparatus

Polybutene piping systems are also non-conductive, providing a safer system with minimum earthing requirements.

Butt fusion for large diameter pipes

Recycling

Recycling is undertaken at each stage in the manufacture and utilisation of Polybutene piping systems. However, the processes for producing the raw material, for manufacturing the pipe, and for the installation of the piping system into its end use application are all designed to maximise the use of the raw material with little waste.

The Polybutene production plant is a state-of-the-art design, commissioned in 2003, and as previously described, recycles butene-1 monomer within the process. During the extrusion of Polybutene into pipe, the molecular structure of the polymer remains essentially unchanged during the extrusion process. This is in contrast to some alternative materials whose structure is radically altered by the addition of chemicals or post-extrusion treatment and therefore unsuitable for in-line recycling.

The manufacturing processes for both the extrusion of pipe and the injection moulding of fittings are managed to minimise waste. ISO standard 15876 specifies that a manufacturer's own clean production waste can be re-granulated and re-used as long as it is the same grade of material to which it is being added, and that no other re-work is permissible. Any other contaminated or off-specification production waste can also be re-granulated and used in the production of 'lower' specification products.

Due to its flexibility and other versatile characteristics, the installation of Polybutene piping systems also generates very little waste. Smaller diameter pipe can be delivered to site in coils of typically 25 – 400 metres in length and cut in situ. Larger diameter joints are often pre-fabricated and delivered to site in sections, thus avoiding any on-site off-cuts.

Theoretically, after decades of service, Polybutene pipe is expected to retain its original polyolefin structure and if recovered, could be recycled by standard plastics conversion techniques into 'lower' specification products.

Prepared for the Future

Polybutene piping systems have been successfully used in pipe applications in Europe for almost 40 years. Installations in district and underfloor heating systems in Austria and Germany in the early 1970s are still in trouble-free operation today. Perhaps the most noteworthy success of Polybutylene pipes to date has been their use in the Vienna Geothermal project, which since 1974 has utilised very aggressive geothermal water as the heating medium and is still operating today at a constant temperature of 54°C and a pressure of 10 bar. In the same application, metal pipes had previously proved totally unsuitable due to rapid corrosion problems.

The sustainability of Polybutene piping systems is therefore a proven case based on actual end-use performance experience. Since these first installations, advances in both material technology and production processes, combined with the introduction of stringent standards have furthered the performance and reliability of Polybutylene piping systems. International standards protocols now specify a minimum performance for Polybutylene hot water pipes of 70˚C, 10 bar pressure for 50 years.

Compared to alternative materials, the environmental compatibility of Polybutene pipes rates very highly as illustrated by the data generated at the Technical University of Berlin. We can rightly claim that Polybutene piping systems are clearly the preferred choice in this respect.

With the advent of new building regulations and directives focused on the ecological factors of energy efficiency and environmental compatibility, we are confident that the versatile characteristics and exceptional long-term performance of Polybutene piping systems will meet the need of architects, specifiers and systems designers in fulfilling these new government standards. Polybutene piping systems suppliers provide complete systems including pipes, fittings and accessories, together with training on their installation, thus performance integrity can be guaranteed.

The Product Warranties vary slightly according to the manufacturer; however warranties of up to 50 years are available for Polybutene piping systems, reflecting their proven long-term performance even in the most stringent applications.

Polybutene piping being installed over 40 years ago

PBPSA I Polybutene Piping Systems Association

The Polybutene Piping Systems Association (PBPSA) is an international association of market leading companies committed to the use of the thermoplastic material, Polybutene-1 (PB-1) for the manufacture of piping systems. Also known as polybutylene, PB-1 is used worldwide in applications including piping systems for large-scale building projects, district energy networks, heating and cooling, and plumbing installations.

Polybutene Piping Systems Association
Postfach 3377
8021 Zürich
SWITZERLAND
info@pbpsa.com
www.pbpsa.com

PBPSA Members

HakaGerodur	www.hakagerodur.ch
John Guest	www.johnguest.com
lyondellbasell	www.lyondellbasell.com
NUEVA TERRAIN S.L.	www.nuevaterrain.com
thermaflex®	www.thermaflex.com

Before using a product made from Polybutene-1 users should make their own independent determination that the product is suitable for the intended use and can be used safely and legally. Polybutene-1 may not be used in the manufacture of any US FDA Class III Medical Device or Health Canada Class IV Medical Device and may not be used in the manufacture of any US FDA Class II Medical Device or Health Canada Class II or Class III Medical Device without the prior written approval by Seller of each specific product or application. Polybutene-1 is not sold by PBPSA members for use in pipe applications intended for use in North America, and those parties require their customers or distributors not to sell products made from PB-1 into pipe applications for North America.