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# SUSTAINABLE DEVELOPMENT

THE CASE FOR PUR/PIR INSULATION IN BUILDINGS





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**Sustainable Development –  
 “A continuing process of economic and  
 social development, in both developing  
 and industrialised nations, that meets  
 the needs of the present without  
 compromising the ability of future  
 generations to meet their own needs”**

The Bruntland Report 1987



## EXECUTIVE SUMMARY

Forty percent of all the energy generated in Europe is consumed in buildings, with space heating accounting for the largest proportion of the energy use. Insulation is widely accepted as the most effective way of reducing CO<sub>2</sub> emissions from buildings. Polyurethane (PUR) and polyisocyanurate (PIR) insulation products provide exceptional performance and this paper makes a clear case for their sustainability.

Buildings are an extremely important part of society's infrastructure as most people spend a large percentage of their time in them. Energy efficient buildings that offer a high level of comfort are a true asset. This combination can be achieved by ensuring adequate levels of insulation.

Eighty-six percent of the world's oil, gas and fossil fuels are burned to produce energy. Only 0.2% of the oil used in Europe is used for the manufacture of polyurethane products. PUR/PIR insulation products account for a fraction of the 0.2% and therefore are a resource efficient way to insulate buildings to reduce CO<sub>2</sub> emissions.

The Green Guide to Specification, an Environmental Profiling System for Building Materials and Components places PUR/PIR with zero ozone depletion potential comfortably inside the 'A' rating zone (the highest rating).

All current PUR/PIR insulation products for use in buildings do not utilise any chemicals damaging to the ozone layer.

BRUFMA and its members also fully support initiatives that lead to the eradication of fuel poverty and can offer insulation solutions that are able to increase comfort for the occupier by reducing demand for space heating.

There are more than 11,500 companies employing over a third of a million people in the rapidly growing PUR/PIR insulation products industry throughout Europe, which currently accounts for approximately £6 billion worth of trade. The industry therefore contributes significantly to Economic Development.



**86% of the world's  
oil, gas and fossil  
fuels are burned to  
produce energy**



## SUSTAINABLE DEVELOPMENT



**In 1990,  
6 billion  
tons of  
CO<sub>2</sub> were  
released  
into the  
atmosphere**

In 1987 Sustainable Development was defined by the Brundtland Commission of the United Nations as:

“A continuing process of economic and social development, in both developing and industrialised nations, that meets the needs of the present without compromising the ability of future generations to meet their own needs.”<sup>(1)</sup>

### THE THREE PILLARS

The three pillars of sustainable development are commonly defined as Economic Development, Social Responsibility and Environmental Protection. All three of the pillars are inextricably linked and are to be considered equally important. It is only possible to achieve significant and sustainable advances in one pillar

providing this would not create a detrimental effect in another.

For example, improving insulation levels in social housing would have a positive effect on environmental protection as homes would become more energy efficient and social benefits such as a reduction in fuel poverty and improved comfort levels would be delivered. However, these benefits could only be realised if economically viable.

### PUR/PIR INDUSTRY CONTRIBUTION

The PUR/PIR industry and its products make a considerable contribution to the delivery of Sustainable Development by impacting positively on all three pillars. The following sections of this document explore this in some detail.



# ECONOMIC DEVELOPMENT/SOCIAL RESPONSIBILITY

## ECONOMIC DEVELOPMENT

There are more than 11,500 companies employing over a third of a million people in the rapidly growing European PUR/PIR insulation products industry, which currently accounts for approximately £6 billion worth of trade<sup>(2)</sup>, all conforming to British Standards either existing or under preparation, for example BS 4841: Parts 1-6.<sup>(3-8)</sup>

In order to sustain economic growth it is important that profits from this trade are re-invested in research and development and new plant. The PUR/PIR industry has an excellent track record with regards to innovation and over the last few years has seen significant investment in new plant and machinery to cope with the growing demand for product.

Currently there is an ever increasing requirement for high performance thermally efficient buildings, driven partly by more demanding Building Regulations/Standards but also by the desire for reduced energy bills. The PUR/PIR industry supports Economic Development in a variety of industries by providing value products and building systems.

## SOCIAL RESPONSIBILITY

### Eradicating fuel poverty

The UK Government has renewed its commitment that no household in Britain should be living in fuel poverty by 2016-18. Fuel poverty is currently defined as more than 10% of household income being spent on fuel.

Tackling the problem of hard to heat homes by increasing insulation levels to reduce space heating demand is the most effective way of reducing fuel poverty.

The 1998 'Independent Inquiry into Inequalities in Health' (Acheson Report), which was commissioned by the Department of Health, showed that much of the variation in the nation's health was linked to material deprivation, and specifically recommended, "policies to improve insulation and heating systems in new and

existing buildings in order to reduce the prevalence of fuel poverty".

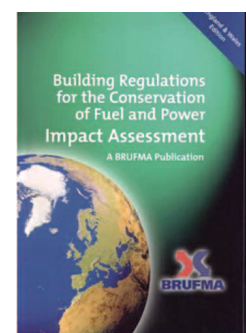
### Improving health

Poorly insulated, cold, damp homes which are inadequately heated have repeatedly been linked to ill health and early deaths amongst the most vulnerable people in society. This link between energy inefficient housing and ill health is well documented. It causes and exacerbates a number of medical conditions including hypothermia, cardiovascular disease, respiratory illnesses – such as bronchitis – and childhood asthma. In addition, people living in cold and damp conditions tend to suffer more from a range of common illnesses such as colds and flu, with elderly people and young children being particularly at risk.

An inter-departmental Government review of fuel poverty<sup>(9)</sup> published by the Department of Environment, Transport and the Regions in 1999 made a clear link between cold homes and poor health. It states "Typically 30,000 more people die in the winter in the UK than would be expected given the average death rate for the year ... it is much higher in the UK than in other countries, such as in Scandinavia, where winter outdoor conditions are more severe but homes are more energy efficient".

PUR/PIR is thermally superior to other commonly available insulation materials. Therefore, if there is only space for 50 mm of retrofit insulation in a cavity wall for example, then the use of PUR/PIR will provide significantly better thermal performance than 50 mm of blown man made mineral fibre. This superior thermal performance naturally leads to lower fuel requirements for space-heating.

In hard to heat homes e.g. solid walls, the use of PUR/PIR externally or internally can provide superior levels of insulation whilst having minimum impact on the overall footprint of the building or habitable space.



**BRUFMA has created a guide detailing insulation solutions for refurbishment applications.**

**An electronic copy of this document is available to download from the BRUFMA website [www.brufma.co.uk](http://www.brufma.co.uk)**



## ENVIRONMENTAL PROTECTION

When considering the environmental impact of a product or system it is essential to take a holistic approach and study all aspects of environmental performance. Only this approach can lead to a full understanding of the overall impact of the product or system.

The preferred tool to assess and compare the environmental impact is Life Cycle Assessment (LCA).

A BRE certified LCA has been carried out for PUR/PIR building insulation products<sup>(10)</sup>.

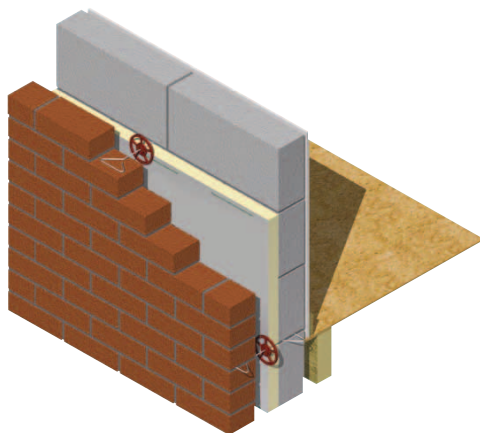
The pentane blown PUR/PIR insulation board assessed has a BRE certified Ecopoints rating of 0.071 which puts it comfortably inside the 'A' rating zone (the highest rating) used in the Green Guide to Specification<sup>(11)</sup>.

The environmental profile showed that when the product is used as insulation in a partial fill cavity wall in a typical semi-detached house, an average family of four would have more negative impact on the environment in a little over ten days than the whole life environmental impact of the insulation in their walls. Moreover, the family will continue to have an adverse impact on the environment, whereas the insulation in the walls will continue to keep the energy use down for the lifetime of the home and therefore reduce the CO<sub>2</sub> emissions over the same period.

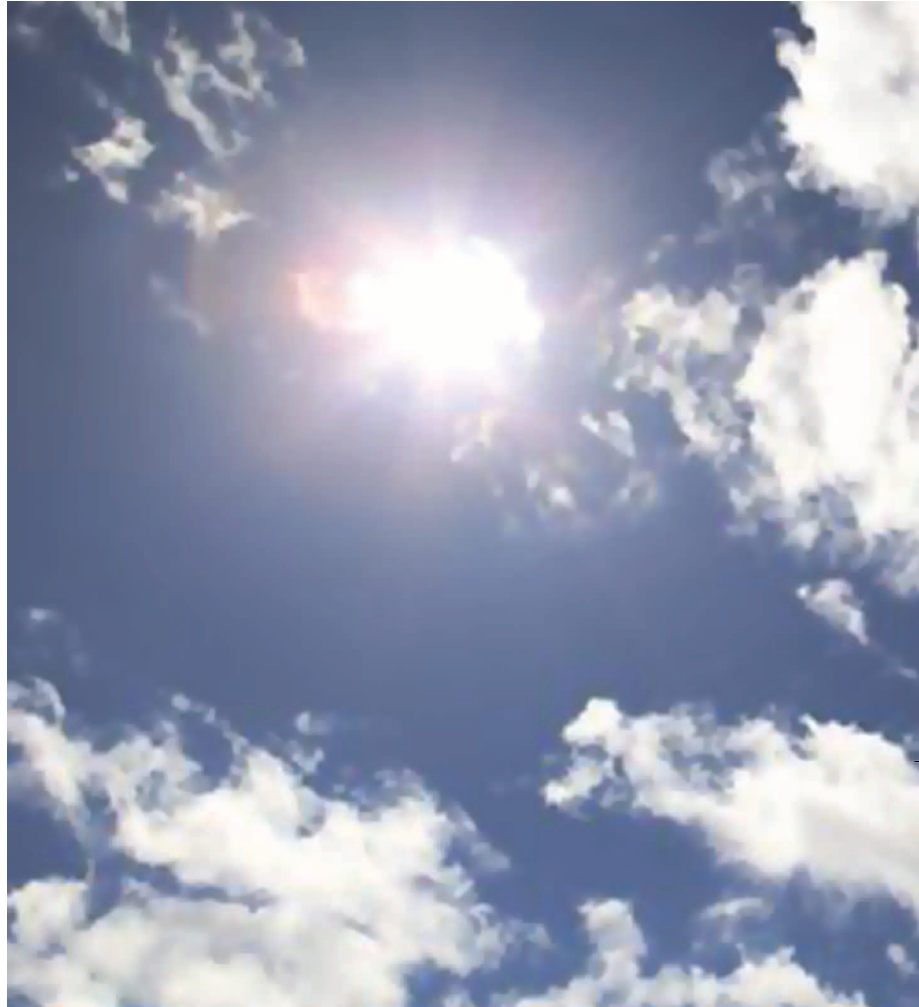
In order to further understand the environmental impact of these insulation products in the context of a complete construction, the BRE were asked to provide a 60-year environmental profile for 1 m<sup>2</sup> of a cavity wall. The wall construction was; standard medium density brick outer leaf, cavity partially filled with 30 mm of pentane blown PUR/PIR, and 100 mm aerated block internally lined with painted 12.5 mm plasterboard on dabs.

The pie chart opposite illustrates the significance of the various components used in the construction. The chart shows that the insulation product accounts for only 7% of the environmental impact of the wall, whereas the brick and the aerated block accounts for 56% and 18% respectively.

It brings into sharp relief the fact that if the



An average family in 10 days has a more negative impact on the environment than the pentane blown PUR/PIR insulation used in the cavity wall construction of their semi-detached home



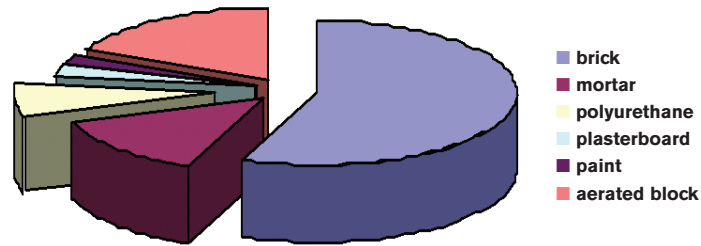
### LCA

**LCA is a profiling method which enables all the environmental impacts of building components to be considered. The BRE in their Green Guide to Specification describe LCA as "... a method of evaluating the environmental impacts of a system taking into account its full life cycle, from the cradle to the grave. This means taking into consideration all the impacts associated with the production and use of a system, from the first time that man has an impact on the environment till the last."**

The Building Research Establishment (BRE) have devised a methodology in partnership with Government and twenty-four trade associations from the construction products sector to provide a single, consistent approach for applying LCA to all types of construction products.

The LCA methodology used for BRE certified environmental profiles has been peer reviewed and complies with BS EN ISO 14041: 1998<sup>(12)</sup> which contains an internationally established approach for analysing the environmental impacts of products and processes. The system fits well with EMAS and ISO 14001 environmental management principles.

The methodology arrives at a BRE Ecopoints score (the lower the score the better the products environmental credentials) based on the impact of the product in question on the environment.



Pie chart showing the environmental impact (60 year) percentage per component of a dry-lined brick and aerated concrete block wall.

only a fraction of this small amount is consumed for the production of PUR/PIR products. Compared to the 86% of oil consumed to generate energy in one form or another, this represents a very small amount. Especially since PUR/PIR products make such a large contribution to improving energy efficiency and reducing the need for energy generation in the first place.<sup>(13)</sup>

The obvious conclusion is that the comparatively small amount of embodied energy and the relatively small amount of oil used in their production is massively outweighed by the benefits delivered by using PUR/PIR insulation products.

#### IMPACT IN USE

In use, buildings are reported to be responsible for up to 40%<sup>(14)</sup> of the energy used in OECD countries (Organisation for Economic Co-operation and Development). Global energy use is thereby a major contributor to the increase in greenhouse gases in the atmosphere. In 1990, worldwide energy use resulted in the release of 6 billion<sup>(15)</sup> tons of carbon dioxide (CO<sub>2</sub>) into the atmosphere.

Insulation is widely accepted to be one of the most effective ways of reducing CO<sub>2</sub> emissions from buildings. This is why in order to achieve its commitments under the Kyoto agreement, both the EU and the UK Government have focused their attention on the improvement of the energy ►

reduction of the embodied impact of a construction is of concern, it is the high mass components of a construction that should be considered. PUR/PIR Insulation is not a high mass component.

In line with the cradle to grave approach, it is useful to further consider the performance of PUR/PIR insulation under the headings Impact Before Use, Impact In Use and Impact at End of Use.

In addition, it should be recognised that companies across the PUR/PIR industry take a responsible and committed attitude towards Environmental Protection. Many of these companies are certified to Environmental Management schemes such as EMAS (Eco-management and Audit Scheme) and ISO 14001, the internationally recognised standard for Environmental Management Systems.

#### IMPACT BEFORE USE

In the past, the relative sustainability of insulation products has been compared with excessive emphasis on embodied energy. It is now clear that the embodied energy of insulation products is insignificant compared with the energy saved by insulation over the lifetime of a building in which it is used, and so is of limited importance.

Furthermore, in Western Europe only about 0.2% of oil consumed is used to make all polyurethanes;

#### KYOTO PROTOCOL

**The Kyoto Protocol, agreed at the United Nations summit meeting in December 1997, sets new limits on greenhouse gas emissions and will spur a huge policy drive among industrial countries for greater energy efficiency.**

**The agreement covers all six major greenhouse gases, namely carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrogen oxides (NO<sub>x</sub>), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF<sub>6</sub>).**

**The Protocol requires an average cut in greenhouse gas emissions by industrialised countries of 5.2% from 1990 levels between 2008 and 2012, with the EU committing to an 8% cut, just over half its pre-summit suggestion of 15%.**

**The Kyoto summit continued the work commenced in 1992 at the Rio Earth summit where industrialised countries pledged to reduce greenhouse gas emissions to 1990 levels by the year 2000 (about a 60% reduction in today's levels).**

Insulant	Thickness (mm) req. to achieve U-value of 0.25 W/m <sup>2</sup> K	Thickness (mm) req. to achieve U-value of 0.16 W/m <sup>2</sup> K
<b>Rigid Polyurethane Insulated Composite Panels</b>	<b>80</b>	<b>100-125</b>
<b>Site Built-up Twin Skin Systems (rock mineral fibre)</b>	<b>150+</b>	<b>240+</b>
<b>Site Built-up Twin Skin Systems (glass mineral fibre)</b>	<b>160+</b>	<b>250+</b>

NB Calculations are based on the aged thermal conductivity value of insulants and are calculated using the latest finite analysis treatment of effect of the profiled facings, joint details and spacer systems (where applicable)

► performance of buildings.

Under the Kyoto agreement the Government has committed to reducing the UK's CO<sub>2</sub> emissions by 12.5% from its 1990 levels by 2008-2012. Much of this saving will be achieved by increasing the energy efficiency performance of buildings.

In January 2003, European Directive 2002/91/EC on the Energy Performance of Buildings entered into force. UK legislation implementing the directive is being introduced. This will have a major impact on the design of new buildings and will encourage extensive refurbishment of existing buildings. The main scope of the directive is to reduce energy use.

The UK Government has also renewed its commitment that no household in Britain should be living in fuel poverty by 2016-18. This reduction in heating demand also has the effect of reducing CO<sub>2</sub> emissions.

PUR/PIR insulation products are recognised as one of the most thermally efficient group of insulating products available and are extensively used in the construction industry. The products are suitable for most building applications, and are especially suitable as insulation for roofs, walls, floors, pipes, ducts and tanks. Their use as building fabric insulation in new buildings and in the refurbishment of existing buildings allows a building's energy use to be significantly reduced through lower space-heating requirements, or in warmer climates through the reduction in energy needed to run air-conditioning units.

The use of high performance PUR/PIR insulation makes the goal of low energy buildings easily achievable.

Taking the example of a commercial building it can be seen that the PUR/PIR insulation system offers a thermal performance that can only be matched by lesser performing insulation by doubling the thickness.

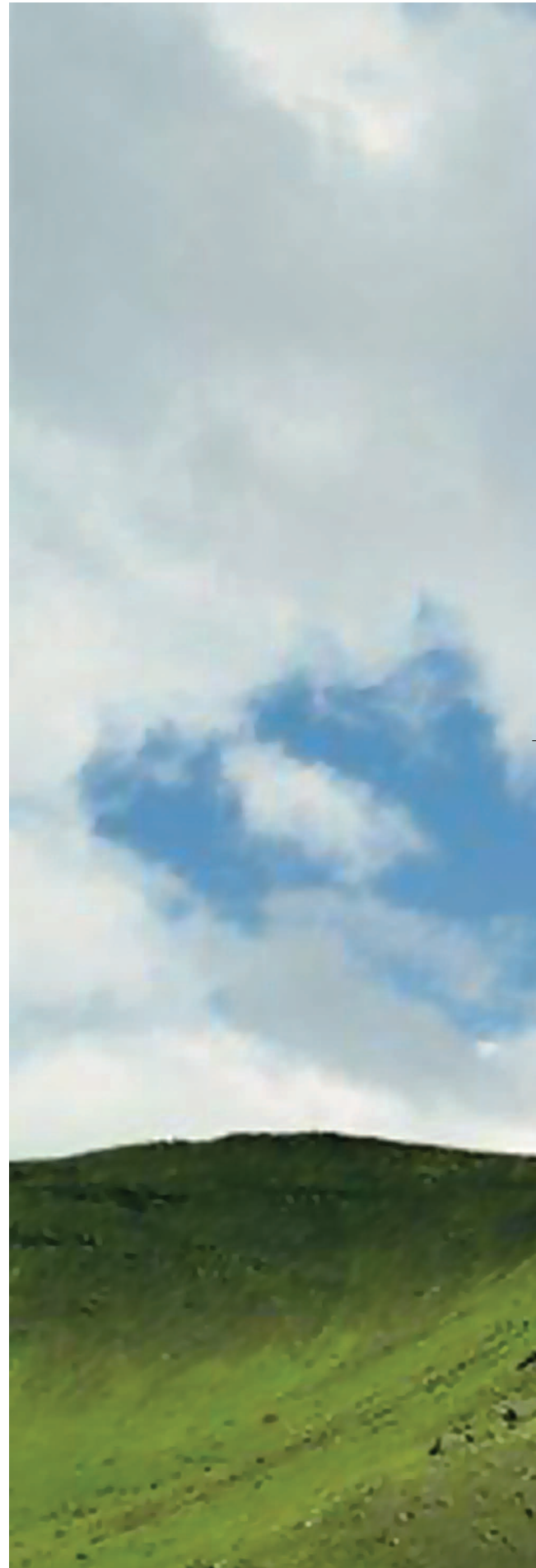
'Insulation for Sustainability'<sup>(16)</sup> was the result of a comprehensive research program by widely respected sustainable construction consultant XCO2 consisbee Ltd. In addition to describing the global warming problem, the study focused on how the choice of insulation product type impacted on environmental sustainability.

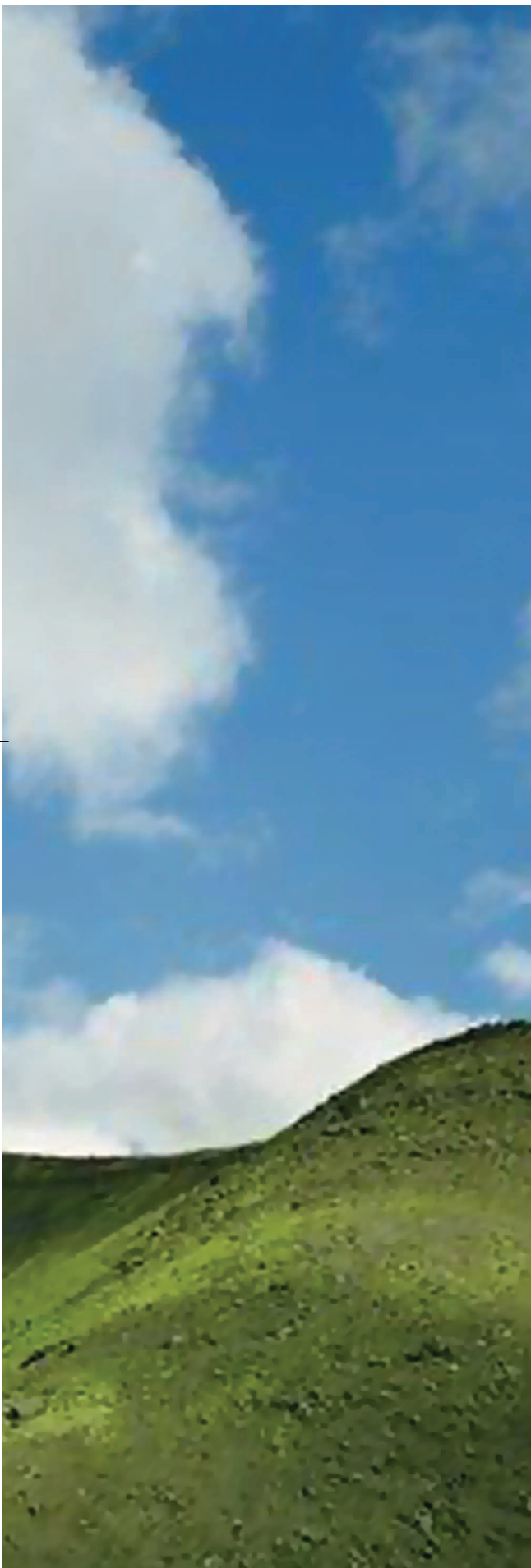
The study considered the most important criteria for choosing insulation to be long-term performance and ozone depletion potential. The study concluded that sustainable insulation should have zero ozone depletion potential and sustained high thermal performance that is unaffected by environmental changes i.e. that can be sustained for the life of the building.

**IMPACT AT END OF USE**

PUR/PIR insulation products have excellent longevity and depending on the construction application may be in service for more than 50 years. End of service life would generally result from the

Contact BRUFMA for information on how to obtain a copy of 'Insulation for Sustainability'. See back page for contact details





### **CFCS AND HCFCs**

**Old PUR/PIR insulation may contain CFCs or HCFCs, these blowing agents were used in the past because of their very low thermal conductivity but their use is now prohibited because they have an ozone depletion potential (ODP). The PUR/PIR industry in the EU has not used CFCs since 1994 and the use of HCFCs was banned in insulation from 1.1.2004. Today only zero ODP blowing agents are used.**

**Ozone depleting substances are damaging to the ozone layer only if released to the atmosphere. PUR/PIR insulation has a closed cell structure; blowing agents are encapsulated within the insulation and are not released during the products working life. The only possible way in which ozone depleting blowing agents could be released is when past products manufactured with CFCs and HCFCs are removed from buildings and disposed of irresponsibly.**

need to demolish a building as the insulation itself does not deteriorate over time.

Due to its longevity and low density, the amount of PUR/PIR insulation requiring disposal constitutes only a tiny percentage (approx. 0.01 wt%) of the total construction and demolition waste generated. Current legislation allows landfill to be used.

However, most insulation products, whether cellular or fibrous, will eventually be excluded from landfill, principally because of organic content and/or stability requirements of landfill sites.

The polyurethanes industry, therefore, actively encourages and participates in the development and study of recycling and recovery options for PIR/PUR insulation. These options include re-use, adhesive pressing, energy recovery, glycolysis, and re-use of particles.

The choice between the various technologies depends on several technical factors such as volume, qualities and consistency of waste streams, market capacity for recyclates and collection logistics. Local and regional conditions will be key in defining the most environmentally sensible and technically and economically feasible balance between the various waste management technologies

PUR/PIR insulation can be incinerated safely and modern state-of-the-art incinerators have greatly reduced emissions and can be managed safely.

The energy content of the insulation is approximately 25,000 kJ/kg<sup>(17)</sup> (roughly the same as coal) and its presence helps to incinerate other components in the MSW without the need for additional fuel. The energy from the insulation is recovered and the amount of primary fossil fuel required to run the process is reduced.

Incineration with energy recovery effectively deals with PUR/PIR insulation that may contain CFC or HCFC as they are completely destroyed in the process – this technique is recommended by the Parties to the Montreal Protocol to destroy ozone depleting substances in foams. It is recommended that PUR/PIR insulation be mixed with municipal solid waste (MSW) without being crushed to eliminate the risk of escape of any ODP gases present.

Depending on the application, the current blowing agents being used are pentane and HFCs. These agents are encapsulated within the insulation and can be safely managed when products are disposed of responsibly at end of use.



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5. Rigid polyisocyanurate (PIR) and polyurethane (PUR) products for building end-use applications. Part 3 Specification for laminated boards (roofboards) for use as roofboard thermal insulation under built-up bituminous roofing membranes
6. Rigid polyisocyanurate (PIR) and polyurethane (PUR) products for building end-use applications. Part 4 Specification for laminated board (roofboards) for use as roofboard thermal insulation under non-bituminous single-ply roofing membranes\*
7. Rigid polyisocyanurate (PIR) and polyurethane (PUR) products for building end-use applications. Part 5 Specification for laminated boards for use as thermal insulation boards for pitched roofs\*
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\* In the course of preparation

**The British Rigid Urethane Foam Manufacturers' Association (BRUFMA) is the representative body for the Rigid Polyurethane (PUR) and Polyisocyanurate (PIR) insulation products industry in the United Kingdom. Its membership comprises the major companies in the industry, both manufacturers of finished polyurethane (PUR) and polyisocyanurate (PIR) insulation products, suppliers of the various raw materials and machinery manufacturers.**



# BRUFMA MEMBERS

## INSULATION PRODUCT PRODUCERS

### 1 ADVANCED THERMAL COMPOSITES

Hangar 1, Wrights Lane, Burtonwood WA5 4DB  
Tel. 01925 711157 Fax. 01925 711158  
www.thermal-composites.co.uk

### 2 CORUS PANELS AND PROFILES

Llandybie, Ammanford, Carmarthenshire SA18 3JG  
Tel. 01269 850691 Fax. 01269 851081  
www.coruspanelsandprofiles.co.uk

### 3 FOSTER REFRIGERATION

Oldmedow Road, King's Lynn, Norfolk, PE30 4JU  
Tel. 01553 691122 Fax. 01553 691447  
www.foster-uk.com

### 4 KINGSPAN INSULATION LIMITED\*\*

Pembridge, Leominster, Herefordshire HR6 9LA  
Tel. 0870 850 8555 Fax. 0870 850 8666  
www.insulation.kingspan.com

### 5 KINGSPAN LIMITED (INSULATED PANELS DIVISION)\*\*

Greenfield Business Park No. 2, Holywell, Flintshire CH8 7GJ  
Tel. 01352 716100 Fax. 01352 710161  
www.kingspanpanels.com

### 6 ECOTHERM LIMITED

Harvey Rd, Basildon, Essex SS13 1QJ  
Tel. 01268 597239 Fax. 01268 597339  
www.ecotherm.co.uk

### 7 A STEADMAN & SON LIMITED

Warnell, Welton, Carlisle, Cumbria CA5 7HH  
Tel. 0169 74 78277 Fax. 0169 74 78530  
www.steadmans.co.uk

### 8 WARD INSULATED PANELS LIMITED

Sherburn, Malton, North Yorkshire YO17 8PQ  
Tel. 01944 710591 Fax. 01944 710777  
www.wards.co.uk

## PRODUCERS/SUPPLIERS OF RAW MATERIALS

### 9 A-GAS UK LIMITED

Banyard Road, Portbury West, Bristol BS20 7XH  
Tel. 0127 537 6600 Fax. 0127 537 6601  
www.agas.com

### 10 BOC GASES

The Priestley Centre, 10 Priestley Road, The Surrey Research Park, Guildford, Surrey GU2 5XY  
Tel. 01483 579857 Fax. 01483 532115  
www.boc.com

### 11 HARP INTERNATIONAL LIMITED

Gellihirion Industrial Estate, Pontypridd CF37 5SX  
Tel. 01443 842255 Fax. 01443 841805  
www.harpintl.com

### 12 HONEYWELL FLUORINE PRODUCTS EUROPE B.V.

Haasrode Research Park, Grauwmeer 1, B-3001 Heverlee, Belgium  
Tel. 0032 16 391 278 Fax. 0032 16 391 277  
www.honeywell.com

### 13 HYPERLAST LIMITED

Station Road, Birch Vale, High Peak SK22 1BR  
Tel. 01663 746518 Fax. 01663 746605  
www.hyperlast.com

### 14 IFS GROUP

Station Road, Roydon, King's Lynn, Norfolk, PE32 1AW  
Tel. 01485 601155 Fax. 01485 601144  
www.ifs-group.com

### 15 ISOTHANE LIMITED

Newhouse Rd, Huncoat Business Pk, Accrington, Lancs BB5 6NT  
Tel. 01254 872555 Fax. 01254 871522  
www.isothane.com

## ASSOCIATE MEMBERS

### 16 BAYER MATERIAL SCIENCE

Strawberry Hill, Newbury, Berkshire RG13 1JA  
Tel. 01635 563000 Fax. 01635 563272  
www.bayermaterialsociences.com

### 17 DOW CHEMICAL CO. LIMITED

#### (Raw materials)

2 Heathrow Boulevard, 284 Bath Road, West Drayton, Middlesex UB7 0DQ  
Tel. 020 8917 5000 Fax. 020 8917 5400  
www.dow.com

### 17 DOW CHEMICAL CO. LIMITED

#### (Foam systems)

Station Road, Elworth, Sandbach, Cheshire CW11 3JG  
Tel: 01270 750131 Fax. 01270 763894  
www.dow.com

### 18 ELASTOGRAN UK LIMITED

Alfreton Trading Estate, Wimsey Way, Somercotes, Derby DE55 4NL  
Tel. 01773 607161 Fax. 01773 602089  
www.elastogran.co.uk

### 19 EPIC

29 High Street, Ewell, Surrey KT17 1SB  
Tel. 020 8786 3619 Fax. 020 8786 8887  
www.epic.uk.com

### 20 HUNTSMAN POLYURETHANES

Higher Maltings, Charlton Estate, Shepton Mallet, Somerset BA4 5QE  
Tel. 01749 335333 Fax. 01749 346283  
www.huntsmanpolyurethanes.com

A list showing the main applications of PUR/PIR insulation products and suppliers of their components is given overleaf

\*\* A member of the Kingspan Group plc

# GUIDE TO PRODUCT SUPPLIERS



## APPLICATIONS OF RIGID POLYURETHANE AND POLYISOCYANURATE INSULATION PRODUCTS

The following list shows the main applications of PUR/PIR insulation products. The numbers given against each application refer to the Insulation Products Manufacturers and Systems Suppliers listed on page 11.

Flat roofs .....	6
Pitched roofs .....	1,4,5,6,7,8
Composite claddings .....	1,4,6,7
Domestic linings .....	2
Industrial linings .....	1,3,7,8
Cold rooms .....	1,3,5,7,8
Refrigeration/Cold stores .....	1,3,4,5,7,10
Containers .....	2,4
Transportation.....	2,4
Marine insulation and buoyancy .....	2,4
Pipe insulation .....	2,4
Model building .....	2,4
Moulded components.....	2,4
Portable buildings .....	1,2,4,5,6,7
In-situ insulation by dispensing and spraying .....	14,15,17,18
Tank insulation .....	2,4
Cavity wall insulation – partial filling .....	2
Cavity wall insulation – in-situ, injected complete filling .....	14,15,17,18
External wall insulation .....	1,2,3,4,5,7,8
Under floor insulation .....	4
Low temperature and cryogenic insulation .....	4
HVAC (Heating, Ventilation & Air Conditioning) .....	4
SIPS (Structural Insulated Panels).....	4

## COMPONENTS FOR RIGID INSULATION PRODUCTS

The numbers given against each type of component refer to the components suppliers listed above.

Raw materials and insulation product systems .....	14,16,17,18,20
Insulation product systems.....	13,14,15,17,18,20
Blowing agents .....	9,10,11,12