

Sustainability and polyurethane insulation
Today's solution for tomorrow's needs



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tomorrow's needs

Why is sustainability important?

In 1987 the Brundtland Report¹ provided us with the most widely known and generally accepted definition of sustainable development, stating that it is:

“...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.”



1. Brundtland Commission, United Nations Commission on Sustainable Development – 1987



In other words, our actions, business, manufacturing methods – everything that represents our modern way of life – should be conducted in a way that considers how it will affect the environment, the economy and society, both now and into the future.

Sometimes referred to as the ‘triple bottom line’, these three ‘pillars’ of sustainable development – environment, economy and society – are each crucial if we are to continue to thrive, or even survive as a species.

In Europe, as in other parts of the developed world, the rate of industrialisation, rapid economic growth and consumerism has led to an unsustainable strain on resources and on the environment. As the developing world aspires to similar lifestyle choices and starts to work towards them, this strain will only increase and accelerate the environmental impacts already initiated by our development in the west.

The 2007 report from the Intergovernmental Panel on Climate Change (IPCC) confirmed that climate change is occurring, and that it is largely the result of human activity. One of the most significant impacts is the increase in greenhouse gases (GHGs), including carbon dioxide (CO₂), as the report indicates.

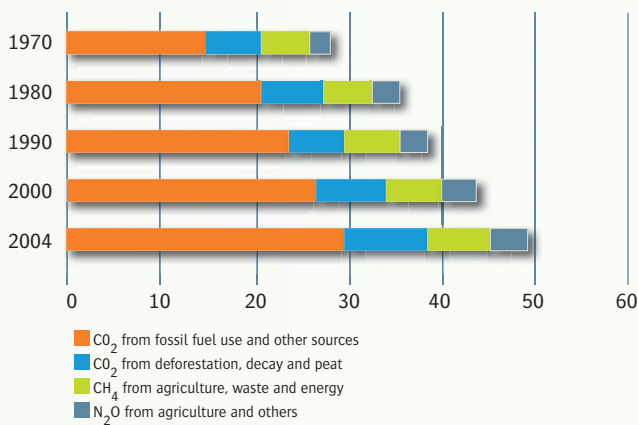
The report observes that CO₂ is the most important anthropogenic GHG, and that emissions of this gas have increased by 80% in the period between 1970 and 2004, contributing significantly to the acceleration of global warming and climate change. However, the impact is not simply an environmental one. The economic cost of climate change can be counted in the increase in damage to property and crops from drought, storms or flooding. The societal costs through loss of communities and livelihoods, and the human costs in terms of loss of life are potentially far greater.

“Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004.”²

2. Climate Change 2007: Synthesis Report. Summary for Policymakers. An Assessment of the Intergovernmental Panel on Climate Change, p. 3



Global anthropogenic GHG emissions



Global annual emissions of anthropogenic GHGs from 1970 to 2004³

The urgency of the situation was highlighted by the Stern Review⁴ published in 2006, which put the economic cost of the effects of climate change at a minimum of 5% and up to 20% of the world GDP each year. By comparison, the cost of reducing emissions in order to slow and eventually halt climate change would be an estimated 2% of GDP according to an update issued in June 2008.

The longer the delay, the greater the potential costs on all fronts and the more likely it is that the damage will be irreversible, so it is vital to look at what steps can reasonably be taken.

3. Idem, p. 5

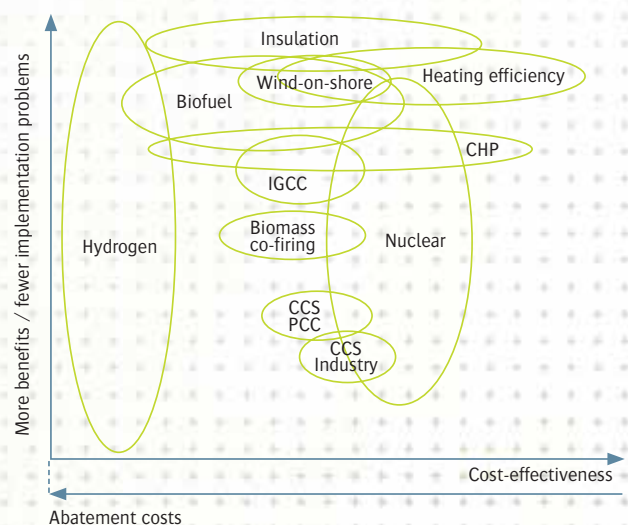
4. Stern Review on the Economics of Climate Change. Sir Nicholas Stern, 2006

Insulation – the simplest and most cost-effective solution

Since the production of GHGs, particularly CO₂, is responsible for much of the climate change we are experiencing, it seems logical to first examine how to reduce the emissions of these gases.

One of the greatest contributors to the production of CO₂ is the burning of fossil fuels to create energy in order to heat, cool or run our buildings. Reducing the amount of carbon dioxide we produce by making our buildings more energy efficient is paramount in dealing with this issue, and insulation is the simplest and most cost-effective way to start that process.

Climate Solutions - A cost-effective analysis



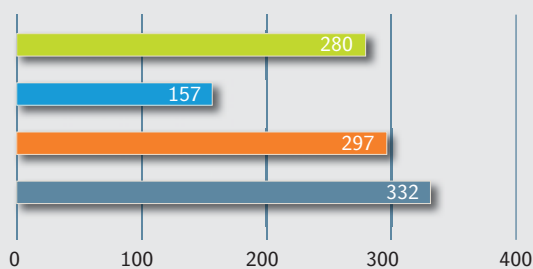
CEPS leaflet Tackling Climate Change – Why Demand Side Measures Supply Truly Cost-effective Solutions, 2007

Buildings – Europe’s highest energy savings potential

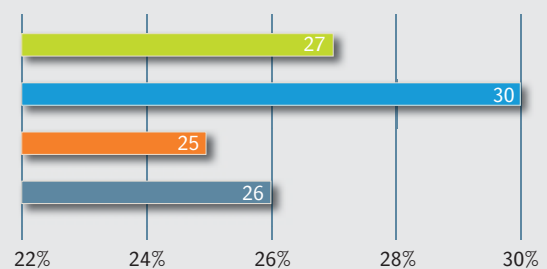
At 40%, the buildings sector – residential and commercial – is the largest user of energy, and at 36% also the largest CO₂ emitter in the EU. The sector has significant untapped potential for cost-effective energy

savings which, if realised, would mean that in 2020 the EU would consume 11% less final energy. With this, the buildings sector has the highest cost-efficient savings potential of all sectors.

**Energy Consumption
(Mtoe) 2005**



**Full Energy Consumption
Potential 2020 (%)**



The recast Energy Performance of Buildings Directive, adopted in May 2010, leads the way forward for new buildings. From 2019 onwards, all new public buildings and from 2021 onwards, all new buildings must have a “nearly zero energy” demand.

- Households (residential)
- Commercial buildings (tertiary)
- Manufacturing industry
- Transport

Source: COM (2006) 545 final, 2006



PU – insulation for sustainability

Applying the Brundtland definition to the building sector, sustainable construction could be described as the process of developing built environments that balance economic viability with conserving resources, reducing environmental impacts and taking into account social aspects.

All types of insulation can play a role in improving the energy efficiency of buildings and reducing CO₂ emissions, but the scope of this paper looks at the particular characteristics of PU insulation to see how it fits into the three pillar model of sustainability.

What is PU?

PU insulation stands for a group of insulation materials based on PUR (polyurethane) or PIR (polyisocyanurate). Their closed cell structure and high cross-linking density give them the characteristics of good heat stability, high compressive strength and excellent insulation properties. PU insulation has a very low thermal conductivity, starting from as low as 0.022 W/m.K, making it one of the most effective insulants available today for a wide range of applications.

Environmental impact

This is probably the easiest of the three pillars to measure and to act upon; environmental impact has up until recently also been the most high profile in the face of global warming, and people often talk about sustainability purely in the context of environmental impact rather than in the true holistic sense of the word.

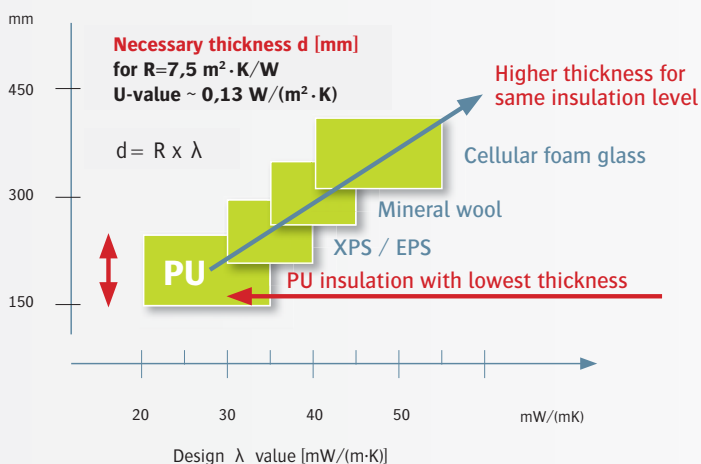
The issues:

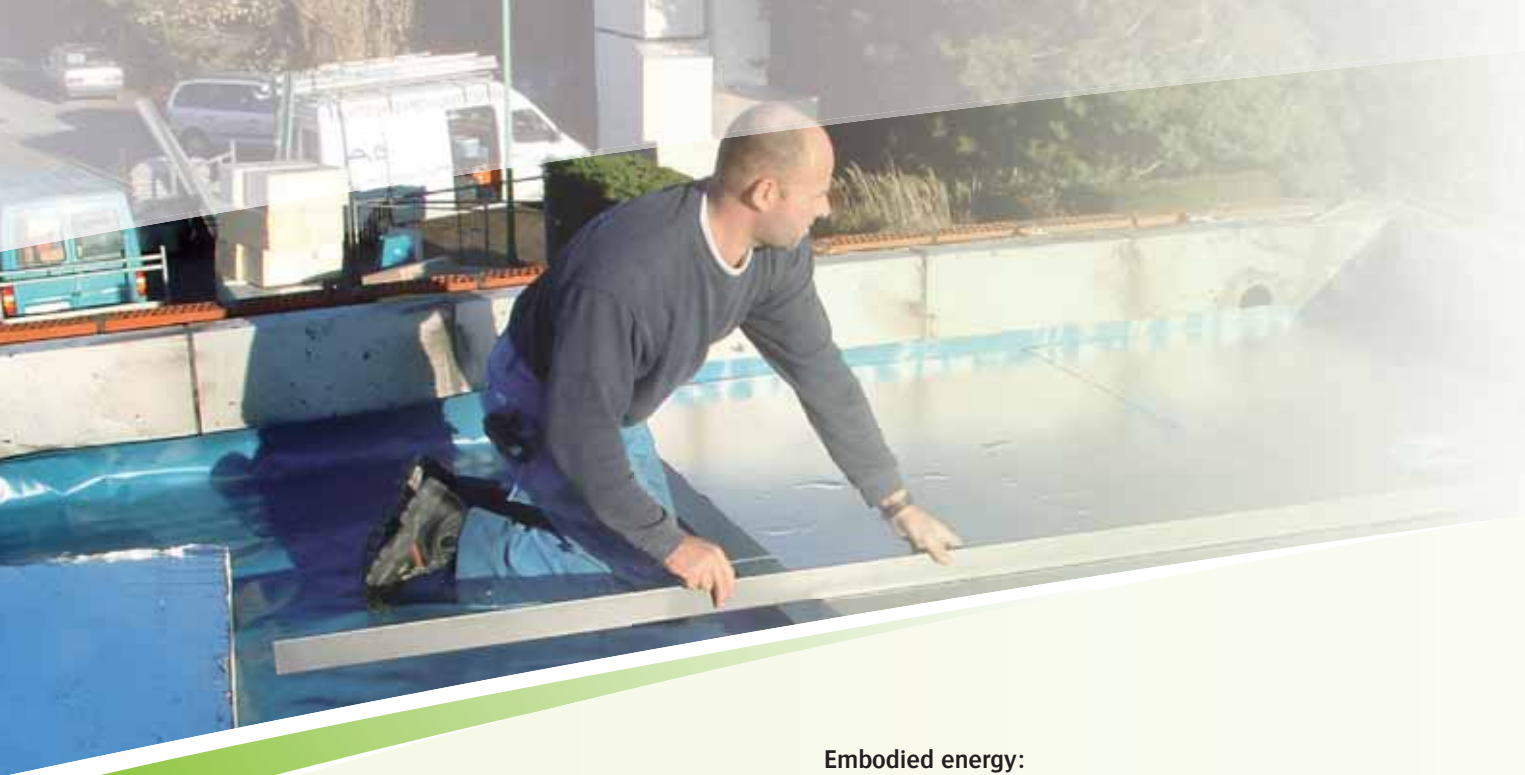
In Europe, around 40% of all energy used is in buildings, and up to 60% of that comes from heating and cooling them⁵. A large proportion of that energy involves the burning of fossil fuels, which in turn creates CO₂ emissions. Making our buildings more energy efficient is the simplest and most cost-effective way to reduce energy demand and cut CO₂.

The solution:

PU insulation is one of the most thermally efficient insulation materials available today, needing only minimal thickness to achieve maximum energy efficiency in a building envelope. It can be used in all kinds of buildings, and is just as simple to apply to existing buildings as it is to install in new ones. It is also extremely durable, so it will continue to perform at the same high level over the life of the building, enabling excellent long term energy savings.

Insulation thickness at same R-value





The myth:

Because sustainability is such a complex subject, it is interpreted and used in many different ways, and often wrongly claimed as an indicator of performance when only a single aspect is being examined such as recycled or bio-sourced content or embodied energy. Legitimate claims can only be made when the whole triple bottom line is analysed over the life cycle of the product in a specific end-use application. The following chapters will look at some of the myths and what remains of them, once a holistic approach is applied.

	Stone wool	PU insulation
Thickness to achieve 0.20 W/m ² ·K on a Steel Deck flat roof (mm)	185 – 190	110 – 120 (aluminium facing)
Density (kg/m ³)	150 – 180	32
Mass per 1 m ² (kg/m ²)	27.8 – 34.2	3.5 – 3.8
Embodied energy per kg (MJ/kg)*	16.8	95
Embodied energy per 1 m ² (MJ/m ²)	466 – 575	332 – 361

*Source: Hammond, G and Jones, C (2008). Inventory of carbon and energy (ICE). Version 1.6a

Embodied energy:

At first glance, PU insulation appears to have a high embodied energy. However, other insulation materials with a lower embodied energy per kilogram of product require much greater thickness to achieve the same levels of thermal performance, and some of them can be considerably denser for certain applications, so a comparison based purely on weight rather than on the quantity required to achieve the same level of performance in a specific application is invalid. However, if a comparison is made based on an equivalent functional unit, such as “1m² of a product required to achieve a specified U-value in a specified construction”, the embodied energy for these other materials can actually be higher than it is for PU insulation, as the table on the left clearly demonstrates.

Moreover, the embodied energy of an insulation product is largely irrelevant when set against the amount of energy it will save over the course of its lifetime in use, so as an indicator of environmental sustainability, embodied energy does not really apply and should never be used in isolation. Over its useful life, PU insulation saves over 100 times more energy than was used to make it.

The benefits:

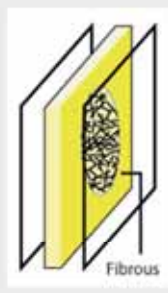
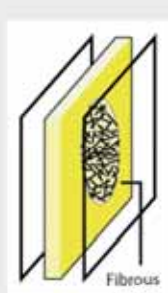
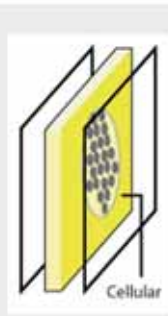
The real benefits of PU insulation in environmental terms are sometimes hidden, and can only be appreciated if the product is looked at holistically and in the context of its properties and effectiveness in use over time.

Saving energy:

First and foremost, PU insulation will save significantly more energy at similar thicknesses than almost all other insulation materials on the market today. As will be demonstrated later in this leaflet, the energy and hence cost savings can be substantial.

Durability:

PU insulation is resistant to moisture ingress, unaffected by air infiltration and is not easily compressed. All of these issues can cause serious degradation in the thermal performance of some other commonly used insulation materials, such as certain fibrous insulation products.

 <p>Fibrous</p>	<ul style="list-style-type: none"> Vapour permeability Permeable. Physical degradation Possible if insufficiently specified. Greater strength boards have higher binder %. <p>Detailed design issues</p>	<ul style="list-style-type: none"> Moisture / Condensation Possible in material; water causes large deterioration to thermal performance. Air movement Possible reduction to thermal performance through air movement at surface and thru. 	<h3>Mineral fibre</h3>
 <p>Fibrous</p>	<ul style="list-style-type: none"> Vapour permeability Permeable, see comment on 'breathing wall'. Not suitable for masonry applications. Physical degradation Settlement possible; especially if exposed to water or moisture. <p>Detailed design issues</p>	<ul style="list-style-type: none"> Moisture / Condensation Possible in material; water causes large deterioration to thermal performance and fabric. Air movement Low air permeability in some products. If wet-sprayed may help seal gaps. 	<h3>Plant / animal fibre</h3>
 <p>Cellular</p>	<ul style="list-style-type: none"> Vapour permeability Very low except at butt joints if poorly assembled. Physical degradation Only likely in cases of catastrophic degradation. <p>Detailed design issues</p>	<ul style="list-style-type: none"> Moisture / Condensation Possible on surface, only slight effect on thermal performance. Wetness may cause degradation of materials. Air movement Low permeability especially if joints are taped or interlocking. 	<h3>Cellular Plastic</h3>



Adaptation to climate change

The question of resistance to moisture is particularly important when considering how to improve the flood performance of buildings – an increasing problem in many parts of Europe. Research is currently underway to measure the effectiveness of different types of construction, but it is already clear that PU insulation offers the potential for reducing costly replacement. UK government guidance specifically recommends rigid closed cell insulation: “External insulation is better than cavity insulation because it is easily replaced if necessary. Cavity insulation should preferably incorporate rigid closed cell materials as these retain integrity and have low moisture take-up. Other common types, such as mineral fibre batts, are not generally recommended as they can remain wet several months after exposure to flood water which slows down the wall drying process. Blown-in insulation can slump due to excessive moisture uptake, and some types can retain high levels of moisture for long periods of time (under natural drying conditions)⁶.”

Because it is rigid, PU insulation will not sag or slump over time, reducing the likelihood of cold spots and thermal bridging, and facilitating high levels of air tightness. Age related degradation is also minimal, and properly installed PU insulation can be expected to continue to perform at the specified level over the lifetime of the building. This means that it will help to save energy from the time it is installed for many decades to come.

Reducing the environmental impact:

Because PU insulation has a very low thermal conductivity, it needs only minimal thickness to achieve the desired levels of thermal efficiency, considerably less than what most competing products would need.

This in turn has a positive effect on use of space, and on the structural demands of buildings: masonry cavities do not need to be as wide, timber studs do not need to be as deep, fixings do not need to be as long – all of which affect costs and have themselves an environmental impact. It also allows the best use to be made of available building land, and/or living space.

6. Improving the Flood Performance of New Buildings: Flood Resilient Construction, p. 76. Department for Communities and Local Government – May 2007



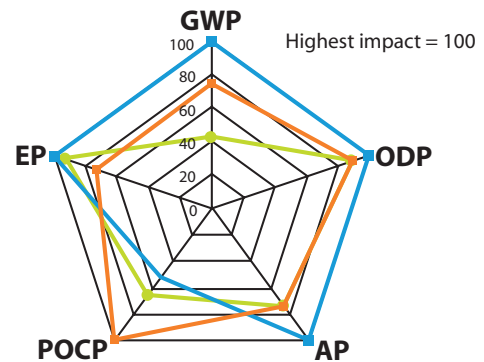
CASE STUDY: New warm deck flat roof (U-value = $0.15 \text{ W m}^{-2} \cdot \text{K}^{-1}$)⁸

The environmental indicators used in the following example are taken from CEN prEN 15643-2:2010 (chapter 6.2.2). For the specification of the flat roof see reference 7, p. 70.

Recent research⁷ has demonstrated that in particular in very low energy buildings, these “knock-on effects” have a significant impact on the overall environmental performance of insulation materials. As a result of this, and depending on the specific end-use application, PU insulation shows a similar or slightly lower overall environmental impact when compared to other commonly used materials. In low energy applications where other insulation materials show a slightly better environmental performance, the differences remain within the recognised statistical error margins.

Because PU insulation is relatively compact, light and thin, it needs fewer deliveries on site for insulating similar surfaces, thereby reducing the impact of transportation. Experience shows that the number of deliveries can be reduced by up to 30% when PU insulation is used.

Flat Roofs : Performance relative to maximum value in each impact category (lowest impact in spider web centre).



- **Stone wool total** (materials + insulation)
- **EPS total** (materials + insulation)
- **PU (pentane) total** (materials + insulation)

GWP: Global Warming potential
ODP: Ozone Depletion potential
AP: Acidification of Air and Water potential
POCP: Photochemical Ozone Creation potential
EP: Eutrophication potential

7. Life Cycle Environmental and Economic Analysis of Polyurethane Insulation in Low Energy Buildings, BRE Global (UK) 2010. The report is available at http://www.pu-europe.eu/site/fileadmin/Reports_public/LCA_LCC_PU_Europe.pdf

8. Idem





**Environmental impact –
in conclusion PU insulation offers:**

- **Excellent thermal efficiency** – leading to optimum energy savings and reduced CO₂ emissions
- **Relatively low environmental impact at the building level** – the product saves more than 100 times more energy than is used in its manufacture
- **Durability** – leading to long term performance and reducing the need for replacement, thereby saving resources and energy over time
- **Minimal thickness** – minimising building footprint and land use
- **Reduced knock on effect on overall structure** – depth of studs, size of fixings, structural loading, etc.
- **Transportation** – lighter and thinner insulation requiring fewer deliveries

Each of these aspects adds up to a product that can offer multiple sustained environmental benefits for relatively little initial environmental cost.



Economic impact

The economic impact can be assessed at two different levels: direct savings for investors, building owners and tenants and macro-economic benefits. Let's start with the direct savings.

The issues:

Adding insulation to an existing building to achieve ambitious performance levels is impossible without a significant investment. In the case of new build, the additional cost for a well insulated building envelop is significantly lower, but even here, adequate insulation levels are still the exception.

The solution:

In many cases, investments in insulation will have the shortest pay-back period when compared to other solutions to increase the building's energy efficiency or generate energy from renewable sources. In other words, the savings from reduced energy bills will have paid for the investment after only a few years. PU insulation offers the highest return on your investment in many end-use applications.

Additional costs for very low energy buildings

The additional costs cannot be predicted with precision, in all cases they depend on specific conditions. Up to 10% extra upfront investment costs are reported, but with clearly declining trend.

Indeed it can be shown that in Germany, Austria, or Sweden it is now possible to construct Passivhaus buildings for costs that are only 4-6 % higher than for the standard alternative. For the Swiss Minergie® P passive, the extra costs are estimated at 4-5 % but not more than 10 %. The HQE association in France, reports an additional cost of only 5% if the 'High Environmental Quality' parameters are taken into account early enough. The time span before energy savings neutralise the extra cost can be estimated at ten years for the Passivhaus.⁹

9. European Commission, DG TREN, Low Energy Buildings in Europe: Current State of Play, Definitions and Best Practice, September 2009



CASE STUDY: Annual savings and return on investment of PU insulation¹⁰

A pitched roof was renovated and insulated with 140mm of PU in Germany.

Heat losses through the roof before renovation:	17,250 kWh/a
Heat losses through the roof after renovation:	1,970 kWh/a
Heating oil prices 2009 (incl. auxiliary energy)	0.063 €/kWh
Annual heating oil savings	1,520 l/a
Cost savings for energy:	962 €/a

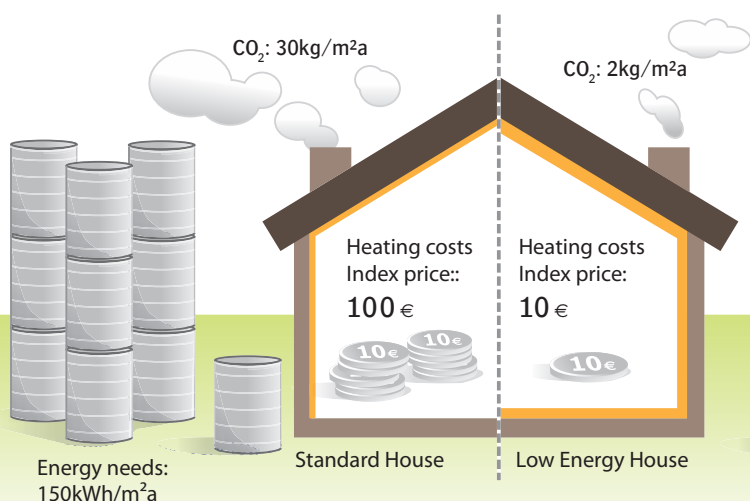
As the roof had to be renovated anyway, the additional cost for insulation was limited to 7,100€. This will lead to the following returns on investment for different expected oil price developments:

Increase in oil price p.a.	0%	4%	8%
Investment 2010	-7,100€	-7,100€	-7,100€
Return on investment p.a.	10.31%	14.17%	18.02%

The benefits:

When compared to other common insulation materials, PU offers the lowest life cycle cost (LCC) in a number of crucial insulation applications in low energy building designs, thanks to reduced material use. For example, the PU solution for the pitched roof does not require additional

rafters. In internal lining solutions, PU can be simply glued to the wall whereas other materials require mechanical fixing between studs. In the case of flat roofs, the higher costs of non PU solutions are mainly caused by the high densities required for this application.



Recommended U-values for low energy houses

U-Value building envelope

- Moderate countries: 0,1 - 0,15
- Hot countries: 0,15 - 0,45
- Cold countries: 0,04 - 0,07

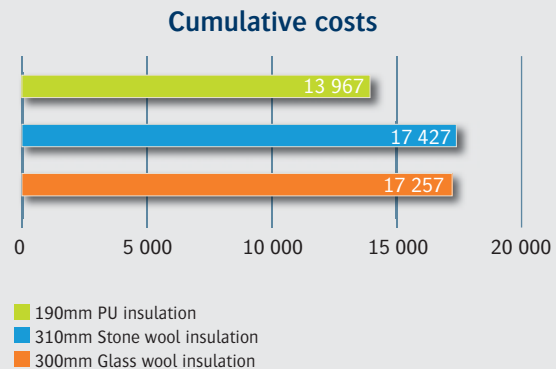
U-Value windows and doors

- Moderate countries: 0,8
- Hot countries: 1,1
- Cold countries: 0,6

CASE STUDY

New pitched roof insulation (3.5% discount rate, temperate oceanic climate, U-value: $0.13 \text{ Wm}^{-2} \cdot \text{K}^{-1}$, cumulative cost over a 50 year life cycle).¹¹

For detailed specifications of the pitched roof see reference 7, p. 68.



Towards the complete picture

Future LCC studies will have to adopt a truly holistic approach including all cost effects of material choices. For example, increased wall thickness required by less efficient insulants will lead to additional costs due to the larger building footprint. On a large building site this may affect the density or number of properties that could be built on the site, e.g. in the worst case, 8.00m^2 extra on the roof area for each property may mean that only nine properties could be fitted in an area that may be able to accommodate ten if the external walls were thinner and the roof not extending over such a large area. Coupled with this is the possible value of the land that is unable to be utilised. Although prices vary considerably, a realistic cost of land with planning permission in an urban area is $\text{€}250/\text{m}^2$. Related to the 8.00m^2 area noted above, this would equate to an additional $\text{€}2,000$ capital outlay for no additional return.¹²

Let's now look at the wider economy:

The issues:

The EU depends on energy imports for over 50% of its current consumption. On the basis of present trends, import dependency in 2030 will reach 90% for oil and 80% for gas¹³. Imports often come from politically instable regions.

The solution:

The pursuit of sustainable development through insulation offers real economic benefits in terms of increasing energy security, creating jobs and maintaining businesses. European and national legislation has made energy efficient building design a requirement, and with the Energy Performance of Buildings Directive introducing the assessment of performance over a building's life, PU insulation is particularly well placed to meet those requirements. PU insulation is especially suited to refurbishment projects: it can be applied in a number of different ways; its size and weight mean it has minimal impact on existing structures, and its effectiveness ensures a rapid simple payback on the original investment with immediate potential savings on energy bills.

10. Institut für Vorsorge und Finanzplanung GmbH, Energieeinsparung – der renditestarke Baustein für die finanzielle Zukunftssicherung (2010)

11. See reference 7, pages 47, 57 and 60

12. Idem (p. 53)

13. Commission Green Paper, "Energy Efficiency – or Doing More With Less" (COM(2005) 265 final) – 2005



CASE STUDY: Refurbishment of non-domestic building stock in UK

Refurbishment offers a major opportunity to cut CO₂ emissions and hit targets to tackle global warming. Upgrading our existing building stock is an essential element of protecting the environment, and it also has the potential to create large numbers of jobs. Recent research¹⁴ examines the issues surrounding energy efficiency in non-domestic refurbishment. It concludes that refurbishing all existing non-domestic building stock in the UK alone by 2022 to Energy Performance Certificate level 'C' could achieve the following outcomes:

- CO₂ savings – Annualised saving of 4.74M tons CO₂-eq by 2022 equivalent to 2% of the reduction needed to achieve the 2022 CCC non-traded carbon target
- Depending on the scheduling of work, between 50,000 and 75,000 long-term jobs could be created or retained within the construction sector
- Energy Cost Savings of £5.65 billion per year in 2022 with typical payback in less than 5 years (total energy cost saving of over £40 billion between 2010 and 2022)
- Energy Security – primary energy savings of 24,000 GWh per annum – equivalent to 1.25% of total UK primary energy requirements in 2022

The benefits:

As an industry, the production of PU insulation has the potential to increase jobs across Europe. In the battle to halt global warming the demand for efficient insulation in new buildings will only increase and the refurbishment market should also develop strongly. Manufacturers will need to be able to produce and distribute greater volumes, and construction workers can take advantage of the key characteristics of PU insulation to raise standards, maintain programme and seek new outlets for their skills.

Of course the PU industry as a whole comprises far more than just insulation, and it is estimated that it involves more than 23,560 companies, employs more than 817,610 workers, and generates a market value of over €125 billion. If you include associated activities you are talking about a further 71,000 companies and 2,040,000 employees – a massive socio-economic contribution.

Economic impact – in conclusion PU insulation offers:

- **Lowest life cycle costs** in many new build and refurbishment applications
- **Higher return on investment rates** than most common investments in financial products
- **Increased energy efficiency in buildings** – leading to immediate savings for the end user and increased disposable income
- **Increased income from rent and sales** – as consequence of low thickness
- **Significant numbers of jobs** – not just directly, but in associated industries
- **Potential for growth** – as the requirement for insulation in new build increases and as the refurbishment market develops

Each of these aspects adds up to a product that can offer multiple economic benefits, from manufacture to lifetime use.

14. The UK's approach to the thermal refurbishment of non-domestic buildings: A missed opportunity for bigger carbon emission reductions?, Caleb Management Services – February 2009



Societal impact

The last of our triple bottom line, and undoubtedly the hardest to quantify, yet there are clear societal benefits to be drawn from PU insulation.

The issues:

The effects of global warming are potentially devastating, affecting millions of people each year. Energy security is becoming an increasing concern as reliance on imported energy could be threatened by political agendas. Energy costs are rising and fossil fuel resources dwindling. Fuel poverty, with all of its associated risks to health and well being puts the most vulnerable members of our society at risk.

The solution:

Insulation cannot solve all of the world's problems, but as we have already seen, by making our buildings more energy efficient, it can make a significant contribution towards cutting CO₂ emissions and tackling global warming, as well as cutting energy bills and making our living and working environments more comfortable. It also helps in tackling fuel poverty, improving health, and is the source of a large number of jobs.

Reducing our overall demand for energy is a major step towards increasing energy security, making locally based micro or macro generation a more feasible source of supply to meet essential demands, and again increasing the potential for employment.

The benefits:

The production, distribution and installation of PU insulation can help to create employment, keeping communities together and maintaining standards of living.

Providing affordable, durable energy efficient homes helps to reduce fuel poverty and protect the most vulnerable members of our society.

Providing employment and reducing fuel poverty also reduces the burden on health and law enforcement services, and gives a boost to the economy by freeing up disposable income.

Energy efficient buildings provide increased comfort in our living and working environments.

Societal impact – in conclusion PU insulation offers:

- **Help in combating the effects of global warming**
- **Energy Security** – reducing reliance on imported energy by reducing demand
- **Employment** – new local jobs in the entire supply chain
- **A reduction in fuel poverty** – thanks to lower energy bills
- **Healthier and more comfortable buildings**

Each of these aspects adds up to a product that can offer multiple societal benefits, from the point of manufacture and throughout its life.



Conclusion: PU – the preferred insulation for sustainability

Balancing the triple bottom line is not an easy task. Inevitably there will be a weighting towards certain aspects, especially when many of the real benefits are so far removed from the point of manufacture, but if you are working towards sustainability in construction, then PU insulation is a very good place to start.

Polyurethane insulation: Today's solution for tomorrow's needs

For more details on the benefits of polyurethane insulation, see
www.excellence-in-insulation.eu



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