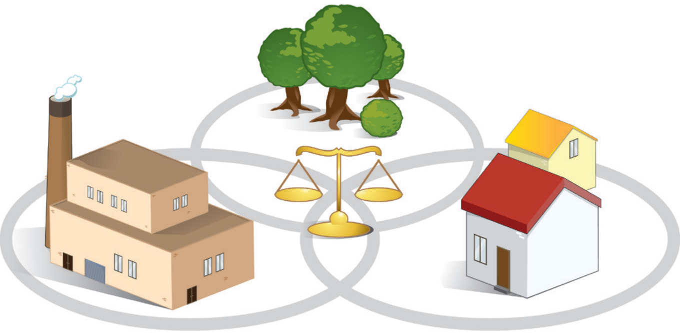
The Role of PU (PUR/PIR) Insulation in Achieving Sustainable Buildings

Oliver Loebel, Secretary General PU Europe[1]

1. What is sustainability in construction?

1.1 Sustainable development



In 1987 the Brundtland Report 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"[2].

Sometimes referred to as the 'triple botton 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. This paper explains how the sustainability definition is applied to construction, how product choices should be made and why PU (PUR / PIR) insulation is a key contributor to achieving sustainable buildings.

1.2 Sustainability in construction

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 such as accessibility and indoor air quality. It is widely acknowledged that the economic and environmental pillars of sustainability are largely dominated by the energy use in the building's use phase – in other words by the level of energy efficiency. Even for passive houses, higher initial investment costs are paid back through lower running costs within less than ten years[3].

As regards the environmental performance, the weight of impacts embodied in construction products increases when moving towards very low energy buildings due to the use of thicker insulation, triple glazing and solar panels, etc. At the same time energy use during the use phase is reduced by 80-95 %. Even under those circumstances, the use phase remains the dominating life cycle phase (**figure 1**).

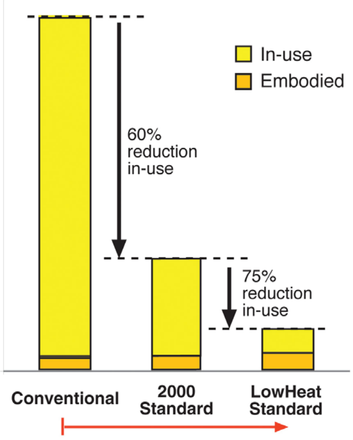


Figure 1: Environmental impacts from the construction and use phases for different building types

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[1] PU Europe is the European Polyurethane Insulation Manufacturers Association (www.pu-europe.eu)

[2] Brundtland Commission, United Nations Commission on Sustainable Development, 1987 European Commission, *Low energy buildings in Europe: current state of play, definitions and best practice*, 2009

[3] European Commission, *Low energy buildings in Europe: current state of play, definitions and best practice*, 2009

A crucial principle to respect is the so-called **trias energetica**. Its application ensures that energy generation capacity is not maintained or built up beyond what is really required. The **trias energetica** first requires minimising the energy demand of buildings by avoiding unnecessary energy losses. The remaining energy demand should be covered by renewable sources of energy to the largest extent possible. If required, this should be topped up by the efficient use of fossil fuels.

2. How to make product choices for sustainable buildings?

Too often, material choices are made solely on the basis of the initial product price without looking at their life cycle performance in a given building design. Another frequent selection criterion is the force of habit ("I have always used this stuff"). Finally, there is a trend towards specifying products claiming to be "green", "ecological", "environmentally friendly" or "sustainable". Such claims often do not stand a closer scrutiny, do not comply with industry-wide agreed basic communication principles and, at the end of the day, will not necessarily lead to more environmentally friendly buildings. This section explains how product choices should made to achieve sustainable buildings.

2.1 Fitness for use

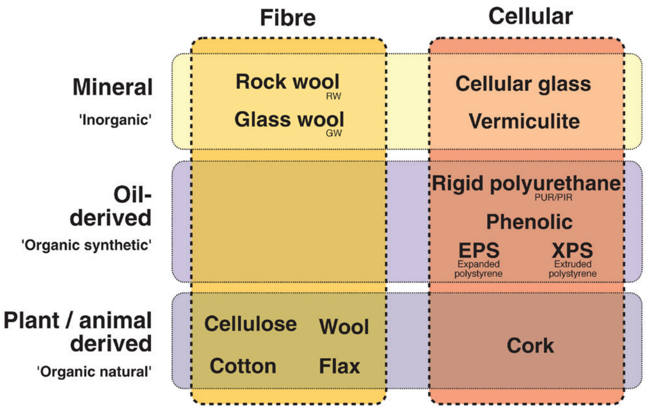

Figure 2: Classification of types of insulation

The first selection criterion is fitness for use. All declared performance values of a product must be derived from harmonised test methods.

Many different types of insulation materials are available today. They can be grouped in families, depending on their sourcing origins (mineral, petrochemical or renewable sources) and physical nature (fibrous or cellular).

Some products such as PU (PUR/PIR) can be used in all end-use applications. Each product has specific strong and weak points.

Depending on facings and thickness, PU can achieve a thermal conductivity starting from as low as 0.022 W/mK to 0.028 W/mK. This makes it the most efficient commonly available insulation material on the market. When compared to other materials, a much lower thickness of PU insulation is needed to obtain the same level of performance.

PU therefore obtains top rankings in terms of fitness for use in sustainable buildings which are first and foremost very low energy buildings.

	Pitched roofs	Walkable flat roofs	Walls	Ground floor
Polyurethane	✓	✓	✓	✓
EPS	✓	✓	✓	✓
XPS	✓	✓	✓	✓
Glass wool	✓	✗	✓	✓ (limited)
Stone wool	✓	✓	✓	✓
Cellulose	✓	✗	✓	✗
Hemp	✓	✗	✓	✗

Table 1: Fitness for use of insulation products in different end-use applications

As will be demonstrated further down, PU offers another key advantage. Thanks to its low air permeability, building envelope air-tightness solutions can be designed more easily.

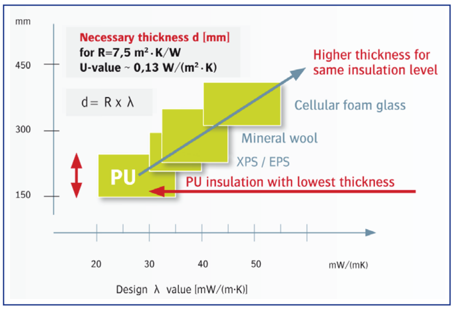

Figure 3: The impact of Lambda values on insulation thickness

2.2 Durability

Once fitness for use has been established, it must be verified whether the different insulation products maintain their declared performance values over the building's life cycle.

Ageing of thermal performance

TThe thermal performance of PU insulation products is changing over time and producers therefore only declare aged values.

	Age of the sample (years)	Thermal conductivity declared in year 1 (W/(m·K))	Thermal conductivity measured today (W/(m·K))
Pitched roof	28	0.030	0.0292
Flat roof	33	0.030	0.0272

Table 2: Results of the thermal conductivity tests conducted by the FIW[5]

With a view to responding to the market need for durable high performance insulants and building trust in the supply chain, PU Europe asked the **Forschungsinstitut für Wärmeschutz** (FIW, Munich) to evaluate decades-old PU specimens from existing buildings. The tests demonstrated that the specimens showed no damages, no holes, bubbles, cavities or other inhomogeneities. The PU insulation boards were still fully fit for use and reached all declared values and performances[4].

Impact of humidity on thermal performance

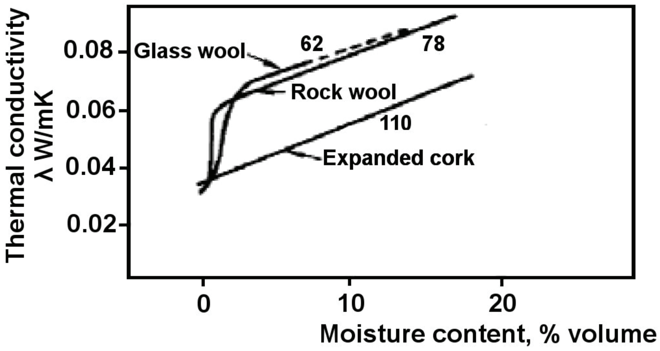

Figure 4: Thermal conductivity as a function of moisture content according to Jespersen: rock wool, 78 kg/m³, glass wool, 62 kg/m³, expanded cork, 110 kg/m³ [5]

Water or moisture ingress can significantly increase the thermal conductivity of some insulants. At about 1 % moisture content by volume, the thermal conductivity of certain fibrous materials rises steeply by about 85 %. This can lead to a significantly higher heat transfer through the insulation layer in applications such as perimeter or roofs (**figure 4**).

Due to its closed cell structure, PU insulation is barely affected by water or moisture: it does not absorb or transport water.

The ability of PU insulation to resist water and to quickly revert to former performance after exposure to excess moisture makes it a preferred choice for flood resilient building[6].

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[4] *Durability of polyurethane insulation products*, PU Europe, November 2011

[5] *Durability of polyurethane insulation products*, section A2 Thermal conductivity, FIW, May 2010

[6] UK Environment Agency Science Report SC040066/SR: *Improving the Flood Performance of New Buildings – Flood Resilient Constructions*

Impact of foot traffic on flat roofs: Walkability

Picture 1: Example of damaged flat roof

The increased use of solar panels on flat roofs has put this problem in the spotlight. Flat roofs are often exposed to dynamic mechanical loads e.g. by pedestrian traffic or small vehicles. These loads occur during construction of the building or for regular maintenance of installations on the roof.

After a few loads some materials tend to lose their compressive strength, resulting in a deeper imprint of e.g. the foot on the waterproofing. The stress in the waterproofing may lead to cracks, or to penetration of a mechanical fixer through the waterproofing if the imprint is close by. Therefore the insulation material and the waterproofing may be severely damaged, resulting in a leaking roof. In contrast to some fibrous insulation products, PU is unaffected by foot traffic and loading incurred in the course of normal maintenance.

2.3 Environmental performance

Environmental performance standards

In a third step, it should be established how material choices affect the environmental performance of the building over its whole life cycle by using the EN 15978 “Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method”.

Construction product manufacturers should provide third party certified Life Cycle Assessment Data or Environmental Product Declarations (EPDs) based on EN 15804 “Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products” and EN 15942 “Sustainability of construction works – Environmental product declarations – Communication format business-to-business”. Only the use of commonly agreed calculation and communication formats can ensure comparability of results.

Environmental performance of insulation products

A number of public authorities across the European Union are openly favouring natural insulants on the grounds that they would be more “ecological” because they are “natural”. Such claims are not only disregarding all principles of a serious life cycle analysis (LCA), they are also contradicting reality in many cases[7].

PU Europe asked the UK Building Research Establishment (BRE) to assess the environmental performance of several insulation materials in different end-use applications including one refurbishment case[8]. So-called natural insulants could not be included, as the BRE did not have

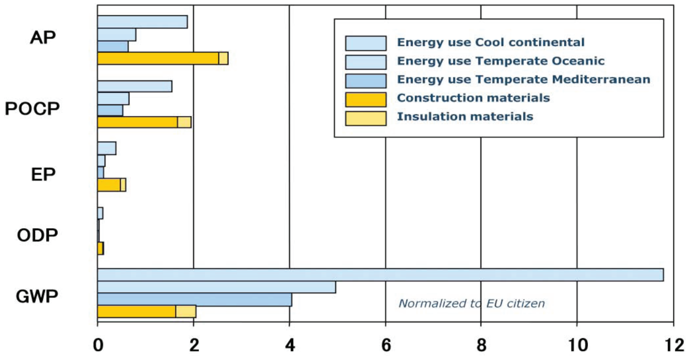

Figure 5: Normalised data – Energy use, construction materials and insulation

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[7] *Impact environnemental des toits à versants*, CSTC-Contact n° 28 (4-2010) and http://www.toutsurlisolation.com/Choisir-son-isolant/Comparer-les-isolants/L-impact-de-l-isolation-sur-l-environnement

[8] *Life Cycle Environmental and Economic Analysis of Polyurethane Insulation in Low Energy Buildings*, BRE Global, March 2010

access to good quality LCA data. Still, the study proved useful and its results can be summarised as follows:

- The overall impact of insulation materials in the environmental burden of buildings is small even in very low energy buildings. However, construction materials in general dominate impacts caused by acidification, POCP and eutrophication (**figure 5**).
- Generally, the environmental performance of insulation products is similar when measured at the building level independently from the functional unit.
  - > When the U-value is fix, the PU insulation layer is thinner than that of alternative insulants. Building elements are thinner and lighter and, hence, the overall material use can be reduced.
  - > When the thickness of the insulation layer is fix, which is often the case in refurbishment, PU will save more energy over the building live time than alternative insulants.
- When specific mechanical properties need to be achieved, for example in flat roofs, the use of PU can lead to a lower overall environmental impact (**figure 6**).

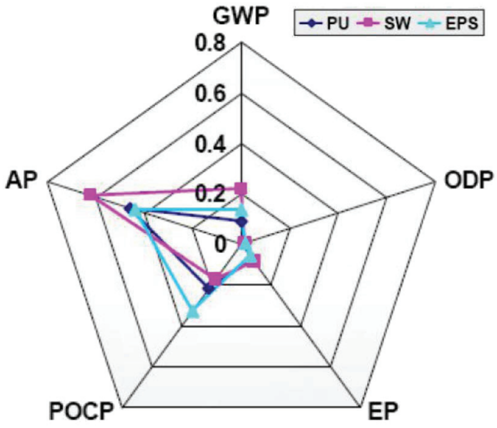


Figure 6: Flat roof: Normalised environmental impacts per impact category (roofing material and insulation)

The results of the study clearly confirm that the choice of insulation materials must first and foremost be based on their ability to provide highest energy performance at the building level and maintain specified performance levels over their whole life cycle.

Evolution of the environmental impacts of PU insulation

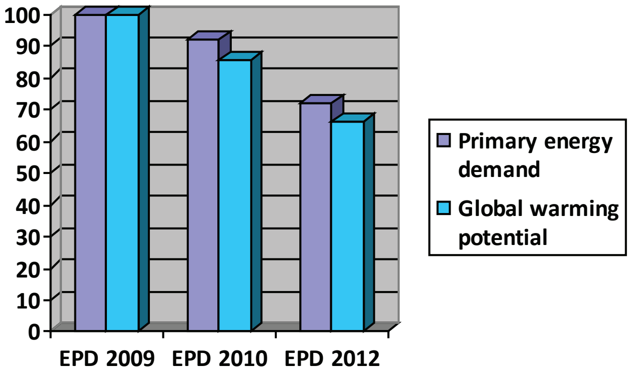
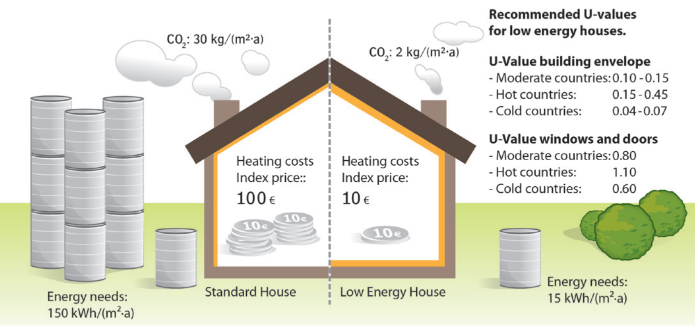


Figure 7: Reduction of the environmental impact of 1 kg of insulation board without facing (without energy recovery): 2009 = 100 %

The above has shown that the environmental performance of PU insulation is comparable to that of other insulants including mineral fibre when assessed at the building level. Nevertheless, there is room for further improvement in terms of production efficiency, use of renewable ingredients and end-of-life solutions. The PU insulation industry strives for a continuous reduction of the environmental footprint of its products.

Figure 7 shows the improvement in terms of primary energy demand and global warming potential between 2009 and 2012. The improvement was mainly achieved thanks to better data quality in the new eco-profiles for polyester polyols (2010) and MDI (2011).

2.4 Cost performance of PU insulation



Constructing very low energy or passive buildings can incur additional capital costs, such as increased levels of insulation or better performing windows. The extra cost of constructing at Passivhaus level is generally in the range of 0-14 % more than for the standard alternative[9].

Payback periods can vary but should be less than ten years based on current energy prices. With rising energy prices the additional investment will pay off even faster in the future. PU is still frequently perceived as a high price choice among the major insulation materials on the market today. In this context, PU Europe asked the BRE to calculate the life cycle costs of different insulation product choices at the building level. The same very low energy building designs were used as for the LCA study. The result showed that the PU solutions offered the lowest life cycle costs for all cases examined. The cost savings thanks to PU use varied between 5 % and 20 % (see **figure 8**).

In the case of fix U-values, the high efficiency of PU insulation reduced the knock-on effects on the building thanks to thinner walls, smaller roofs and thinner rafters. When the functional unit was "fix thickness of insulation" (refurbishment), the PU solution was most cost-effective thanks to higher life cycle energy savings.

The cost savings thanks to smaller building footprints or larger indoor areas were not taken into account.

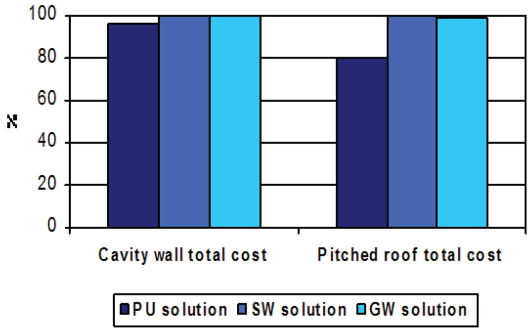
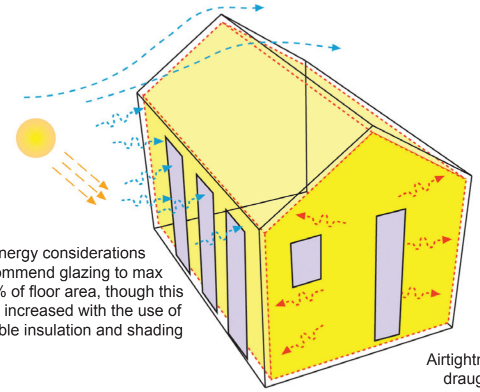


Figure 8: LCC of the cavity wall and pitched roof solutions for temperate oceanic climate (50 years cumulated costs, 3.5 % discount rate)

3. The importance of design and installation

The elements of material choices as described above cannot be disconnected from a holistic building design. One of the main design-related issues is the air tightness of the building envelope. This issue is particularly complex as it includes different supply chain members such as manufacturers of building envelope products, designers and contractors.

As the level of air permeability varies significantly between the different insulation materials, specific system solutions must be applied to each of them to achieve air-tight building envelopes. It will be equally important to ensure air-tight linkages between building components (between roof and



Energy considerations recommend glazing to max 20-30 % of floor area, though this can be increased with the use of moveable insulation and shading

Airtightness means that cold draughts cannot get in, and warm air cannot scape (except for ventilation air)

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[9] See footnote 3

wall, wall and windows, etc.). Thanks to the very low air permeability of PU insulation, air tight building envelopes can be designed and built more easily[10].

Once a highly-insulated and air-tight fabric has been created, adequate and controlled ventilation becomes essential to maintain a comfortable indoor climate and avoid humidity build-up. Again, the low air permeability of PU offers major advantages, as it avoids the build-up of condensation and, consequently, mould-related problems.

4. Current PU Europe activities

PU Europe will continue to provide scientific data and one-voice messages for use at European and national levels. They aim to present PU as "the modern and innovative insulant to meet the requirements of low energy building designs in terms of thermal conductivity, air tightness, sustainability and costs".

Current and future PU Europe activities focus on the following priorities:

- Providing generic and up-to-date environmental information on the performance of all major insulation products using PU foam. To this end, EPDs were developed for insulation boards and spray foam. Currently, EPDs are developed for PU sandwich panels and the existing EPDs are being adjusted to comply with the final versions of EN 15804 and EN 15942. Furthermore, the new LCI data for MDI are being included.
- A new LCA / LCC study is being prepared which will assess the environmental performance of several insulation products, including wood fibre, in different end-use applications. The new PU EPDs will be used.
- PU Europe will conduct a project on the impact of insulation product choices on the air tightness of buildings and in particular on linkages between building components. The costs of achieving the air tightness when using different insulants will also be examined.
- More generally, PU Europe promotes the CEN standards for sustainable buildings at all levels in particular in terms of applying a holistic approach to the building performance over its life cycle and the assessment of construction products at the building level.

5. Conclusions

Europe's buildings account for 40 % of today's total energy use and 35 % of CO_2 emissions. The EU will therefore not be able to meet its 2050 climate goals without reducing the energy demand of buildings by 80 % by that date. Sustainable construction is a major tool to achieve this goal as it, first of all, minimises energy demand in the building use phase and, in a second step, optimises material use.

PU Europe supports a harmonised European scheme for the assessment of the sustainability of buildings. PU insulation offers excellent performance characteristics that make it the insulation product of choice for sustainable buildings. These advantages need to be communicated more offensively in the market:

- Lowest thermal conductivity of all commonly available insulation products;
- Durability of performance characteristics of several decades;
- Low air permeability to facilitate air-tight building envelopes and avoid mould;
- Similar environmental performance as that of competitive products when measured according to TC350 standards;
- Life cycle costs for PU solutions lower than those of many competitive solutions.

On the other hand, the PU insulation industry must strongly reject the proliferation of additional

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[10] *Implementing zero energy buildings in harsh Nordic climate conditions*, Janne Jormalainen, M.Sc. (SPU Systems Oy, Finland)

European, national and regional sustainability schemes and oppose all attempts to deselect products for the simple reason that they do not bear the label "green", "ecological" or similar. Product selection must follow the steps listed below:

① Fitness for use

② Durability

③ Sustainability assessment at the building / component level

The environmental performance of insulation products can only be established in their end-use application on the basis of agreed European standards. Explaining this concept to public authorities and private clients will be one of the major tasks of the PU industry in the coming years.

Disclaimer

While all the information and recommendations in this publication are to the best of our knowledge, information and belief accurate at the date of publication, nothing herein is to be construed as a warranty, express or otherwise.

Biography

Oliver Loebel studied international trade in Berlin, Germany, and holds an MBA degree (Paris, France). In 1993, he joined the Leipzig Chamber of Commerce as export consultant. From 1994 to 97, he worked as national expert at the European Commission. From 1997 to 2008, he was the secretary general of the European specialist engineering contractors association (CEETB). He joined PU Europe in February 2008 as managing director.

Glossary

AP	Acidification of Air and Water potential
BRE	Building Research Establishment (UK)
CEN	Comité Européen de Normalisation (European Standardisation Organisation)
EP	Eutrophication potential
EPD	Environmental Product Declaration
EPS	Expanded Polystyrene
FIW	Forschungsinstitut für Wärmeschutz e. V. München (Research Institute for Thermal Insulation, Munich)
GW	Glass wool
GWP	Global Warming potential
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
MDI	Methylenediphenyldiisocyanate
ODP	Ozone Depletion potential
PIR	Polyisocyanurate
POCP	Photochemical Ozone Creation potential
PU	Polyurethane
PUR	Polyurethane
RW	Rock wool
SW	Stone wool
XPS	Extruded Polystyrene