Sustainable Construction with EPS Insulation

EUMEPS

EPS: expanding into a sustainable future

What is EUMEPS?

Founded in 1989, the European Manufacturers of Expanded Polystyrene (EUMEPS) is an association which supports and promotes the European EPS industry through National Associations. It is divided into two interest groups, reflecting the main applications for Expanded PolyStyrene (EPS): Packaging and Building & Construction.
Membership of EUMEPS is open to the National Associations, raw material producers and multinational converters of EPS.

EUMEPS Building & Construction Group

The common interest between members is a belief that EPS is the most cost effective insulation material for building and construction. EPS comprises about 35 per cent of the total thermal insulation market in Europe with over 55,000 people employed in the EPS industry. EUMEPS membership represents over 90% of the manufacturing industry. The proactive, co-ordinating role of EUMEPS is to ensure that awareness of the advantages of EPS is brought to a larger audience, in order to build understanding of the benefits of increased use. The way this is achieved includes information sharing to enable an informed dialogue with builders, architects, regulators and regulatory bodies, on a national and European level. EUMEPS also monitors and co-ordinates a process of continuous improvement in European EPS manufacture and quality. The objective is for EPS to take its proper place in ensuring safe, comfortable and energy efficient buildings, whilst also contributing strongly to the mitigation of greenhouse gas emission.

Vision: Expanding EPS for a sustainable future.

Mission: EUMEPS construction acts as the driving force for the EPS industry to achieve a positive perception of EPS amongst the building and civil engineering community, making EPS the preferred material to achieve sustainable, efficient building solutions.

Objectives:
1. Successful co-ordination of the EPS industry
2. Generate credibility, trust and relationships within the broader construction industry and influencers to this industry
3. Be the knowledge center for the production and application of EPS
4. Be the proactive voice of the EPS industry in Europe and establish positions in key areas (e.g. Insulation performance, Energy Efficiency, Fire performance, Sustainability, HSE-issues) so that the industry can speak as one
5. Active representation of the interests of EPS converters and producers at the European level
6. Active support of the interests of EPS converters and producers at the national level
7. Advocate EPS in the key areas, proving to the market that our facts are correct and that EPS offers undisputed advantages.
8. Be aware of the competitive environment and the ability to react in a timely manner to any negative influences upon EPS
9. Grow EPS construction faster than the generic insulation market

Core Values:
- Responsable stewardship of the members interests
- Support the insulation industry whilst promoting the particular advantages of EPS without unfair representation of our competition
- Commitment from all the participants to contribute, sharing knowledge and experiences
- Open and transparent communication
- Fair and honest comparisons with competitive materials, supported by third party data
- Value the input of all discussion partners

EPS: 98% AIR

EUMEPS

Introduction

Today we hear a lot about the need for Sustainability, but what is this exactly and do we all have the same understanding? We can consider a definition from the United Nations in 1987:

> 'Meeting the needs of the present generation without compromising the ability of future generations to meet their own needs.'

Experience suggests that whilst we all have ideals, these are often compromised when economic factors hit our pockets. Hence, if we are to grow into a sustainable future, then we will need to meet the requirements of both societal and economic elements. Whilst there is general concern over all sustainability issues, there is a focus today on energy efficiency and global warming. The discussion around energy sustainability has merged with the environmental concerns of global warming and in particular carbon dioxide emissions. The European Community continues to refine its energy policy[1]. The drivers for this are complex and interrelated, but they include the need to become less dependent upon energy sources from outside the EU, the desire to be a good citizen of the world from an environmental perspective and a push to improve the global competitiveness of the EU[2]. The key elements of the challenge today are that a growing demand for comfort and economic expansion globally necessitates a greater efficiency of use to limit increased supply of power. All the indications are that time is running out to address climate change.

The building sector has a major role to play, since buildings in Europe account for 40% of the energy demand, over 60% of this being for heating and cooling purposes. Appropriate thermal insulation is recognised as one of the most rapid and cost effective ways of reducing energy demand whilst simultaneously reducing greenhouse gas emissions, in a society where today 80% of energy is derived from fossil fuels.

This brochure gives an overview of environmental data relating to insulation in general and specifically EPS. It explains how and why EPS insulation answers today's environmental concerns and why EPS fits with sustainable design, incorporating the key aspects of Planet, Profit and People.

[1] *For up to date information please consult www.ec.europa.eu/energy*

[2] *Lisbon Strategy - www.ec.europa.eu*

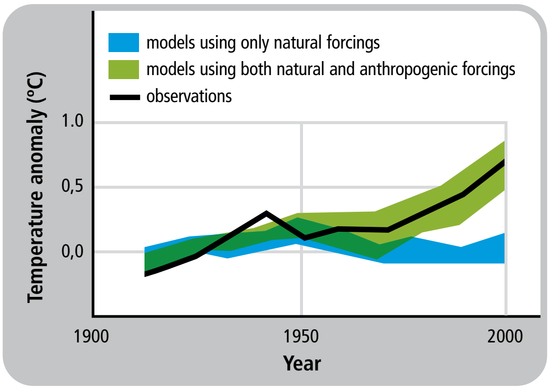
1 Climate change and energy efficiency

1.1 Climate change and global warming

Little doubt is left about the fact that humans influence climate change. Recent temperature developments do not fit into models that do not take into account the human impact.

There is growing awareness on the need for a global energy revolution which breaks with historic trends and patterns of energy production and use. This emerges from the need to ensure energy security, from the urgency of controlling local pollution due to combustion of different fuels as well as the challenge of climate change from global warming.

Many problems and risks are associated with climate change such as the melting of ice caps and glaciers causing much higher variations in the water levels in rivers, rising sea water levels, change in ocean water circulation, shrinking arable land, growing water scarcity and deforestation.



IPPC-Models proof human influence on global warming. [ref 1]

Coping with the threats of climate change is arguably the biggest challenge the world faces at this moment. According to the EU parliament 'Climate change could reach catastrophic levels this century unless we quickly and sharply reduce emissions of greenhouse gases'. 'The risk consequences of ignoring climate change will be very much bigger than the consequences of ignoring risks in the financial system', said Nicholas Stern (2008), a former British Treasury economist, who released an influential report in 2006 and 'emissions blamed for global warming could cause economic pain equal to the Great Depression.'

1.2 Regulatory landscape

• From Kyoto to Copenhagen

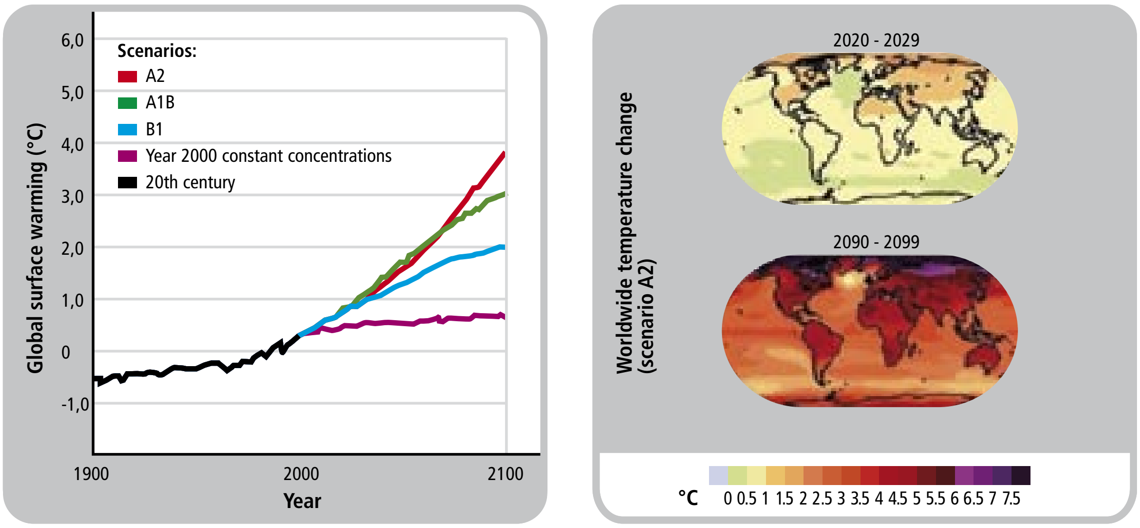
Negotiations have been going on for a long time at all levels: from UN, to EU, to national level and down to local city level. Strategies are being formulated and measures taken to try to combat climate change by reduction of emissions, by the development and the transfer of low-carbon technologies and by adaptation strategies.

In 1992 the UN launched the United Nations Framework Convention on Climate Change (UNFCCC). The Kyoto Protocol, drafted in 1997, made a significant step forward for a specific list of 40 developed countries. This was eventually ratified in February 2005 once Russia had signed to the agreement. The protocol included a set of commitments and defined legally binding quantitative targets for emissions reductions. The overall goal was for the listed countries to reduce their combined total greenhouse gas emissions by five percent below 1990 levels by the period 2008-2012. The overall European contribution was an 8% reduction shared amongst the Member States to a greater or lesser degree.

The Intergovernmental Panel on Climate Change (IPCC) provides the scientific basis for these strategic discussions. Scientists still dispute the limit value for the amount of CO_2 needed to meet this target. Opinions varying between 550 and 400 ppm CO_2 in the atmosphere. The current target set by the IPPC panel is to limit global warming to an average global temperatures rise to 2° C (scenario B1). In this scenario warming at the north pole at the end of this century is still expected to be about 5° C.

At the G8 meeting in July 2009, the biggest economies in the world agreed, for the first time including the USA, that worldwide temperatures must not rise more than 2 degrees Celsius. The G8 leaders vowed to seek 80 percent cuts in greenhouse-gas emissions by 2050. This is only achievable by a swift and rigorous shift in our patterns for consumption and production of energy.

The complex question of how this reduction of CO_2 emission will be partitioned amongst different countries was at the heart of the discussion at the Copenhagen meeting in meeting in December 2009 and will continue at subsequent meetings which will consider the post-Kyoto international agreement.

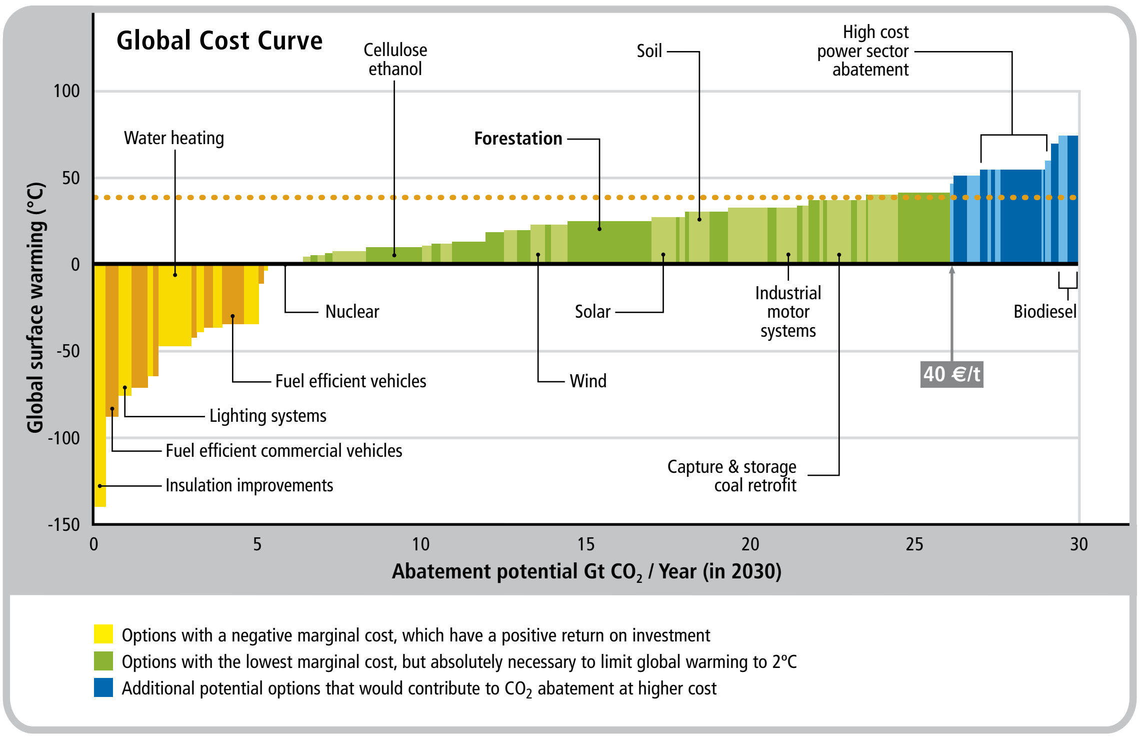


Overview of different scenario's for global warming. [ref 1]

It would be logical if politicians would take into account the cost effectiveness of CO_2 abatement options and only start considering more expensive options if less expensive options would not deliver sufficient effect. Analysis by McKinsey [ref 3] has demonstrated the range of measures necessary to achieve different targets and the cost effectiveness for each of these. The analysis shows that measures reducing energy demand, such as building insulation improvements, are amongst the most cost effective measures to mitigate CO_2 emission.

• EU climate change and energy package

As a consequence of the ongoing UN negotiations for a follow up on the Kyoto protocol after 2012, the European parliament in April 2009 formally adopted the Climate and Energy package, also called the 20/20/20 agreement: 20% reduction in energy demand and 20% use of renewable energy sources by 2020. If international agreement can be achieved the 20% reduction target will be increased to 30%.
The EU Climate Change Package supports an Emissions Trading Scheme (ETS) to control emissions.



McKinsey Cost Curve for CO_2 abatement options. [ref 3]

For sectors currently under the ETS (i.e. power plants and energy-intensive industries) the EU Climate Change Package agreed upon a cut of emissions to 21% below 2005 levels by 2020.
For sectors not covered by the ETS (e.g. transport, farming, waste and households) emissions must be cut to 10% below 2005 levels by 2020. EU countries agreed on binding national targets. Through the effort sharing principle, national reduction targets compared to 2005 varied from -20% to +20%. Higher reductions targets were agreed upon for richer countries and limited increases for the poorest ones. [ref 4]

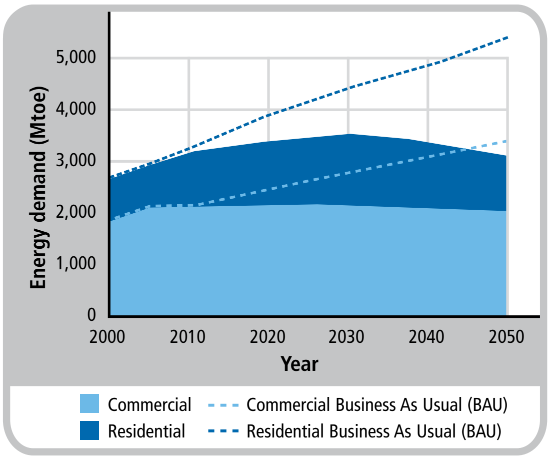
Renewables should produce 20% of all the EU's energy by 2020. EU countries agreed on binding national targets (from 10% for Malta to 49% for Sweden) and at least 10% of transport fuel in each country must be renewable (bio fuels, hydrogen, 'green' electricity, etc.).
Progress in reaching the national targets is reported trough the National Energy Efficiency Action Plans, the NEEAPS.

• Energy Performance in Buildings Directive (EPBD)

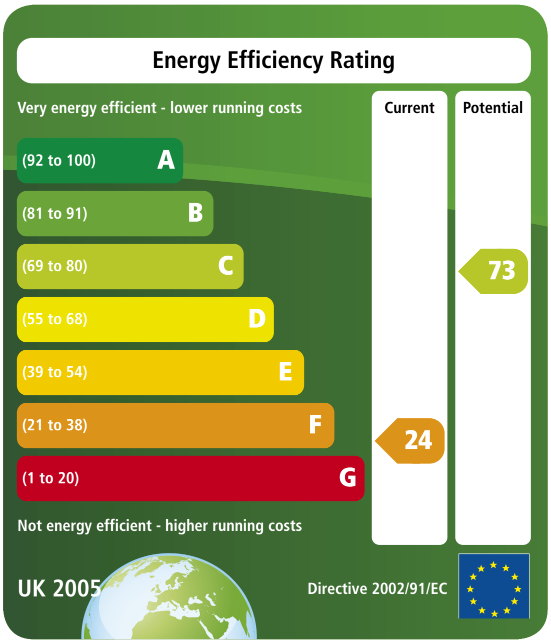
Europe is facing a massive challenge to curb greenhouse gas emissions. Energy efficiency in the building sector can make a major contribution to meet this challenge and tackle climate change in a cost effective manner. Over 40% of European energy is consumed in buildings and over 60% of this is for heating and cooling purposes. If no measures are taken and we go on as usual (Business As Usual - BAU) energy demand by the building sector will nearly double by 2050.

The most important instrument to tackle this development on the EU level is the Energy Performance in Buildings Directive (EPBD). This EU Directive was accepted in 2006 with the Member States mandated to incorporate the objectives into their national legislation by 2009. This directive stipulates that building standards across Europe must place a high emphasis on minimising energy consumption. The EPBD is a vital part of the EU's strategy to meet its Kyoto Protocol commitments. The main components of the EPBD are:

- A common calculation methodology for the energy performance buildings
- A requirement for member states to define minimum standards for energy performance for new buildings and for major refurbishments of existing large buildings (more than 1000 m²). Research shows that more than one fifth of present energy consumption could be saved by 2010 by applying tougher standards to new buildings and to buildings undergoing major refurbishment
- A system of energy consumption certification for buildings
- Regular inspection of boilers and air conditioning systems
- Public buildings to display their energy performance

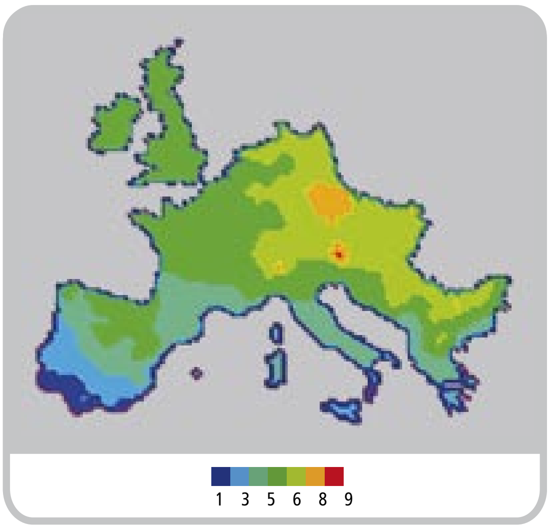


Evolution of buildings energy demand. [ref 5]



Since the implementation of this first EPBD there has been considerable discussion in order to improve it further as the current EPBD has been shown to capture only 10% of the technical potential. This has been prompted by the increasing international pressure to take tougher action against climate change. The most important amendments related to insulation in the revision of the EPBD, which was decided upon in November 2009, are:

- Tightening of the definition of major renovation and removal of the 1000 m² floor surface threshold. This means refurbishment requirements now cover almost all buildings.



Average possible saving in kWh/m² by improving south oriented facades [ref 2]

- Development of an EU reference calculation method determining the cost optimum level of energy efficiency measures. Comparison of requirements in countries should stimulate to align them with cost optimal levels.
- Development of an EU definition of net or near zero energy and mandatory planning of national implementation of this kind of buildings including concrete targets for 2015 and 2020.
- Public buildings shall lead by example

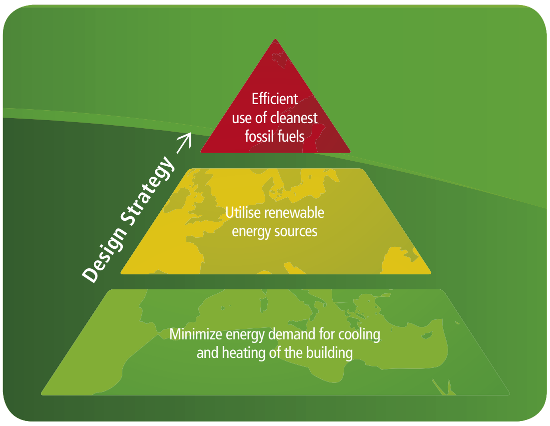
It is expected that the amended EPBD will lead to an annual capital investment cost of 3.9 billion euros. However, the annual energy costs savings from buildings will be leading to an annual saving by 2015 projected to be 7,5 billion euros a year.

• National regulation

National regulation has the largest impact on building projects. Influenced by the EPBD and its foreseen revision, the EU mandated National Energy Efficiency Action Plans (NEEAPs[1]) have indicated raising the levels of energy efficiency requirements in most European countries. Many countries set levels for all new buildings to be net zero energy buildings between 2015 and 2020. Such measures are necessary, since:

- Current national requirements for new residential buildings are not at an optimum level from a cost effectiveness stand point and will not allow Europe to achieve its long term climate goals;
- Recommended U-values are identical for new as well as for existing buildings
- Even in southern Europe, where insulation levels have traditionally been low, good thermal insulation can dramatically reduce the energy need for cooling

[3] *For details on the status of NEEAP per country see: http://ec.europa.eu/energy/efficiency/end-use_en.htm*



Energy and Environmental Design Strategy. [ref 6]

1.3 Impact of insulation in buildings

• Trias Energetica

We have seen that measures reducing energy demand are amongst the most cost effective measures to mitigate CO_2 emission. This focus on demand side measures is the basis of the Trias Energetica principle. Applying this approach to construction, design of low energy buildings starts with a building envelope that prevents unnecessary loss of energy. The key parameters are thermal insulation and air tightness of the building. Only after the building envelope is established are the higher levels of the triangle considered. This integrated design strategy follows three steps:

1. Minimise energy demand for cooling and heating of the building

Optimise building form and zoning; apply highly insulated and air tight conventional envelope constructions; ensure low pressure drops in ventilation air paths; apply efficient appliances to reduce heat load, etc. Apply responsive building elements if appropriate, including advanced facades with optimum window orientation, exploitation of daylight, proper use of thermal mass, redistribution of heat within the building, dynamic insulation, etc. Provide intelligent control of systems including demand control of heating, ventilation, lighting and equipment.

2. Utilise renewable energy sources

Provide optimal use of passive solar heating, natural lighting, natural ventilation, night cooling, etc. Apply solar collectors, solar cells, geothermal energy, ground water storage, biomass, etc. Optimise the use of renewable energy by application of low energy systems.

3. Efficient use of cleanest fossil fuels

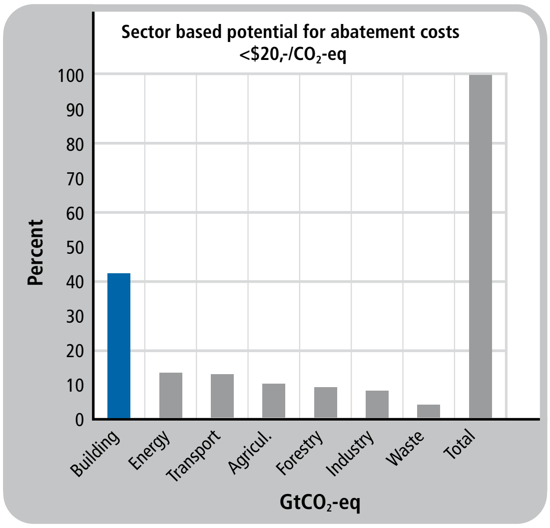
If any auxiliary energy is needed produce it by using the least polluting fossil fuels and in an efficient way, e.g. heat pumps, high-efficient gas fired boilers, gas fired combined heating and power (CHP) units, etc. Apply efficient heat recovery of ventilation air during the heating season; Apply energy efficient electric lighting.

• The role of insulation

Appropriate thermal insulation is the largest single factor which influences the energy performance of buildings. According to the climate alliance [ref 7] energy efficient buildings could reduce carbon dioxide emissions by 460 million tonnes a year (more than Europe's total Kyoto commitment) and could reduce energy use by the equivalent of 3.3 million barrels of oil a day and save Europe 270 billion Euro a year in energy costs. Other results would be improved energy security, reduced air pollution, job creation and poverty alleviation.

In Europe considerable building activity can be expected over the coming decades. New buildings will continue to be erected but probably more important will be the fate of old building stock which either needs to be refurbished or demolished in order to meet new regulations. In Germany, for example, already 70% of all insulation activity is related to renovation and this percentage is expected to rise even further as a direct consequence of the need for improved energy efficiency.

Building design and performance will need to change as legislative awareness increases about the need for energy efficiency and reduction of greenhouse gas emissions. As already highlighted, the building sector has a major role to play and the IPPC indicates that it could contribute to over 40% of the total greenhouse gas emission reduction. Appropriate thermal insulation is recognised as one of the most rapid and



IPPC:Sector based CO_2 abatement potentials below $20,-/ton CO_2-equivalent. [ref 1]

cost effective ways of reducing energy demand whilst simultaneously reducing greenhouse gas emissions.

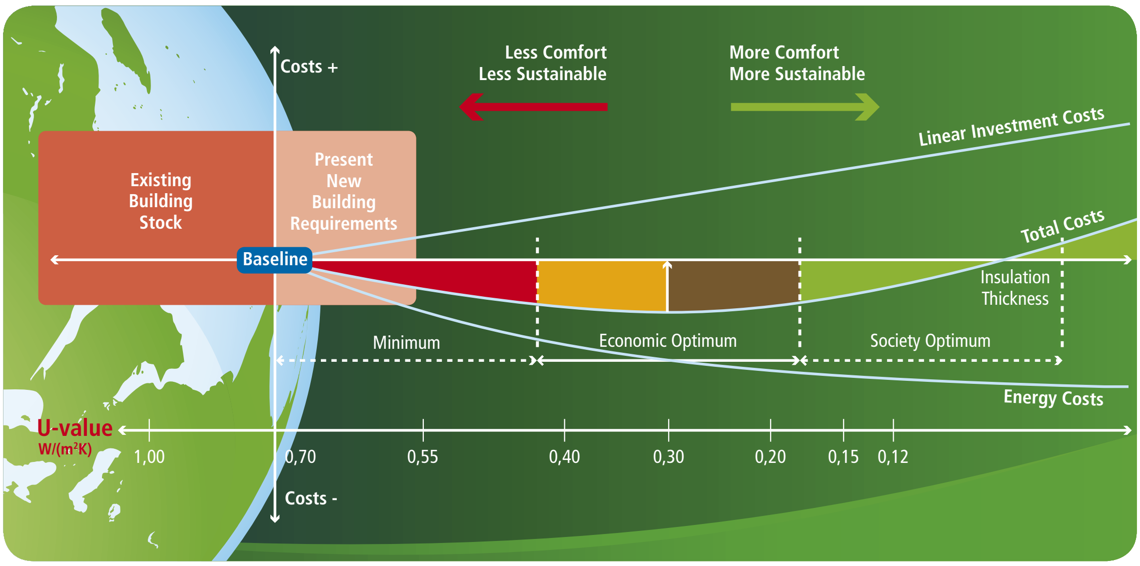
Progress can start immediately, because the knowledge and technology exist today to significantly reduce the energy consumption of buildings by better insulation, while at the same time improving levels of comfort. Supply side solutions require high capital and large tracts of land and/or water surfaces. The ability to implement these depends upon political will and this is largely outside of the control of the end user of energy. Demand side solutions are local and are very much under the control of the energy consumer. We can all make a difference on the demand side.

• Optimum insulation value

A frequent argument against increasing insulation thickness is the perceived high fabrication energy of the insulation material. The energy savings of the additional insulation is thought to be less than the fabrication energy of the extra material. A study by the Gesellschaft für umfassende Analysen GmbH (GUA) [ref 8] analysed the energy savings from plastic insulation boards applied to external walls in Europe. This highlights that the energy savings that accrue from the use of insulation over the lifetime of a building are 150 times more than that needed for the fabrication of the insulation.

The Ecofys study 'U-Values for Better Energy Performance of Buildings' in 2007 [ref 9] examined the cost optimum insulation value. They found that there is an optimum thickness for the individual building owner which is defined by a cost benefit curve, derived from subtracting the investment costs for insulation from the energy cost savings.

In the assessment no complementary savings were included from the potential need for smaller boilers or from the reduced need of air conditioning as insulation performance is improved. In addition, no value was attached to climate mitigation effects or other societal benefits.



Analysis of optimal insulation value.

- The area where the total cost savings are at their optimum lies around a U-value of 0,3 W/(m²K). Any U-value to the left or right means that the individual building owner would be gaining less money over the lifetime of the investment.
- On the other hand, if we compare insulation with other CO_2 abatement options a better approach would be to aim for a level that would be at least at cost neutral level, maybe accompanied by government incentives.
- Insulation will still deliver an almost optimum solution. Reduced greenhouse gas emission at these higher insulation levels will still be cost effective, albeit at a less than individual optimum cost position. As we have seen: other CO_2 abatement options necessary to achieve the necessary reduction in emission to limit global warming to less than 2°C will cost at least upto at least € 40,-/ton CO_2

The actual cost effectiveness is location dependent and depends upon other factors such as the energy costs; the heating degree hours; and the different costs for building materials, labour and insulation around Europe. Most new building requirements in Europe are left of the "Best Practice Zone" and are therefore not yet optimised for insulation levels. For existing housing requirements the best practice zone is even further away

From both an energy and cost balance perspective, increasing the thermal insulation in buildings makes sense. Improving insulation levels will have a major economic and societal benefit.

2 EPS Insulation

2.1 Polystyrene: a material with a long successful history

Polystyrene was discovered in 1839 by an apothecary in Berlin. From storax, the natural resin of the sweetgum tree (Liquidambar Styraciflua), he distilled an oily substance, a monomer which he named styrol. Several days later, he found that the styrol had thickened, presumably from oxidation, into a jelly he called styrol oxide (‘Styroloxyd’). It took more than 80 years before it was realised that heating of styrol starts a chain reaction which produces macromolecules. This eventually led to the substance receiving its present name, polystyrene.

In 1930, the scientists at BASF in Ludwigshafen, Germany developed a way to commercially manufacture polystyrene. They developed a reactor vessel that extruded polystyrene through a heated tube and cutter, producing polystyrene in pellet form.

In 1954 foamed polystyrene was accidentally invented in the USA. A chemist trying to find a less brittle flexible electrical insulation based upon polystyrene, combined styrene with isobutylene, a volatile liquid, under pressure. The result was polystyrene foam, 30 times lighter than regular rigid polystyrene. EPS is a versatile durable material that offers excellent insulation properties. As the structure of EPS consists of 98% air, its initial thermal properties are maintained throughout its working life. It is non-toxic, moisture resistant and rot proof. EPS is primarily used as an effective thermal insulation material for walls, roofs and floors in all kinds of buildings. It can be manufactured in a wide range of properties, shapes and sizes. Therefore it is also used in many other construction applications such as void-forming fill material in civil engineering projects, as lightweight fill in road and railway construction and as flotation material in the construction of floating pontoons in yachting marinas. It is also used in many other applications such as packaging.

Liquidambar Styraciflua

2.2 Key properties of EPS insulation

• Light weight

EPS is effectively 98% air captured within a 2% cellular matrix and so is very light weight. Densities of between 10 and 35kg/m^2 allow light and safe construction work. It is also easy to transport and the low weight saves fuel in transport. The low weight of EPS also makes it easy to handle on the site, especially since lifting of heavy insulation products is becoming an increasingly important health and safety issue. EPS insulating boards can be laid quickly and in any weather conditions, since it is unaffected by moisture. The exceptional lightweight to insulating performance of EPS is of major benefit in low energy buildings where thicker insulation layers are required. The structural load needs to be considered since this has an important impact on the construction. For example, light weight flat roofs of industrial buildings based upon profiled metal sheet. At a U-value of 0,2 W/(m^{2}K), a difference of nearly 40 kg/m^2 between EPS, with superior dynamic loading properties, and possible alternative insulation materials needs to be taken into account by the constructor of the building. In other applications, such as insulation of facades, the light weight of EPS can prevent problems associated with insufficient load bearing capacity of mechanical fixings.

EPS is an excellent substitute for infill materials and ballast where it also brings load and fill times down in time-critical build projects. For civil engineering applications, settling time and maintenance costs caused by continuing soil settling is a decisive factor. In a growing number of applications the combination of light weight with considerable and durable compressive strength is used in load bearing applications of EPS.

• Strength, structural stability and walkability

In spite of its light weight, the unique structure of EPS brings the benefits of exceptional compressive strength. Wetting of the material will not result in settlement of the material or other performance characteristics. This means it is ideal for use in many construction and civil engineering applications, particularly as a structural base infill, for example in road, railway and bridge infrastructures. Strength tests performed on EPS, after almost 30 years underground, showed that it routinely exceeded the original minimum design strength of 100kPa. EPS bridge foundations, which had been subject to many years of sustained loading, showed creep deformation of less that 1.3%: only half as much as had been theoretically predicted. Most importantly, EPS stability does not deteriorate with age.

EPS has excellent mechanical properties making it good choice for the repetitive loading of roof insulation (walkability), sub-pavement flooring, road building and as a general load bearing insulation. With its flexible production process, the mechanical properties of EPS can be adjusted to suit every specified application.

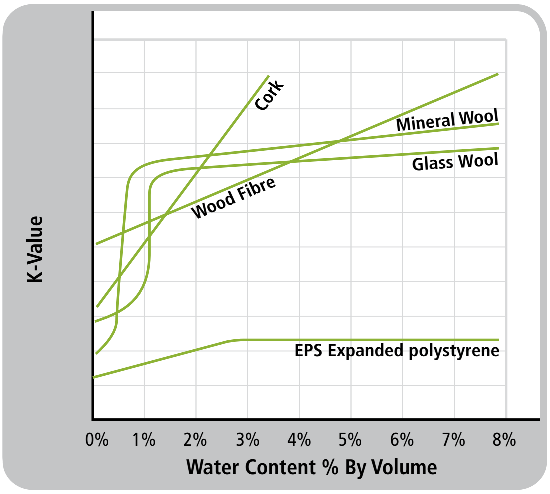
• Economy

EPS is a well established material for the construction industry and offers a proven, economic solution which helps specifiers to keep building costs within budget. In terms of price per unit of thermal insulation performance, EPS is one of the most economical of all the insulation materials. Couple this with the safety of handling, ease of cutting to size, light weight, long term properties and the fact that it is unaffected by moisture, EPS offers the best price/performance ratio of all insulation materials, with savings on both material and labour.

As an effective insulation material EPS prevents energy loss and therefore helps to save money by reducing energy bills, conserving fossil fuels and reducing carbon dioxide emissions which impact global warming.

• Resistance to moisture

EPS does not absorb moisture and resists degradation of the mechanical and insulation properties due to water, damp, humidity or moisture. Water vapour condensation is a major threat to the structure of a house. In cold climates, water from warm, moist indoor air can diffuse into exterior walls and attics. and can condensate as it cools. In warm climates the reverse happens. Water from warm, humid outdoor air enters the construction and encounters cooler areas where, it condensates into liquid water. This is the main reason why many buildings in warm as well as in cold climates have problems with mould and rotten wood. In warm climates this is especially the case after air conditioners have been fitted.



"The Effect of Moisture on Insulating Materials", technical data from ASHRAE and International Institute of Refrigeration. [ref 10]

EPS is one of the most resistant products to the adverse effects due to moisture of all materials used for insulation applications. Moisture spreading at installation or after accidental leakage will only marginally influence the thermal performance of EPS. This results in lifetime durability. Nevertheless careful planning of the construction is important, including vapour barriers where necessary, to prevent condensation, which may build up within any insulation material under critical vapour flow conditions.

After almost 30 years in the ground, samples of EPS retrieved from locations as little as 200 mm above the groundwater level all showed less than 1% water content by volume, whilst blocks which are periodically entirely submerged show less than 4% water content - performance notably superior to other foamed plastic materials. EPS has been used for floating decks as a base for river housing.

As there is political pressure to identify new building areas in Europe, increasingly land lying in potential flood areas is being released for development. The reinstatement of flood damaged buildings is a much quicker, more practical and less costly procedure if building structures feature non-water-absorbing insulation material.

An important factor in indoor air quality is the prevention of airborne bacteria, mould, and other fungi through a building envelope design that avoids moisture intrusion. In the USA the EPS Molders Association (EPSMA) sponsored a test program focusing on EPS and mould resistance in January 2004. EPSMA contracted SGS U.S. Testing Company for test services on EPS applying ASTM C1338, 'Standard Method for Determining Fungi Resistance of Insulation Materials and Facings.' Test samples representing a typical product for most building and construction applications, were evaluated. The test subjected the EPS to five specific fungi to check for growth. The results show that in a laboratory under ideal conditions, fungi did not grow. Although EPS is not impermeable it does have a high degree of resistance to moisture absorption. This controls humidity and air infiltration, which can help prevent the development of mould.

• Handling and installation

EPS is a light weight, rigid material without being brittle. It is practical and safe to handle and install. Shape moulding allows the factory production of complex shapes to match the most demanding architectural and design requirements. Flexible processing machinery enables delivery of products with the correct specified density, insulation and mechanical properties, dimensions and shape which will minimise waste on the building site. On-site customising is possible without the need for specialist cutting tools. It is possible to cut to size using simple means such as a knife or a handsaw. Handling of the material presents no dangers to health during transport, installation, use and demolition as no radiation, fibres or other substances are released. EPS can be handled and processed comfortably without causing irritation, eczema or inflammation of skin, lung or eyes. This means breathing masks, goggles and protective clothing and gloves are not required for working with EPS.

Cement, lime, gypsum, anhydrite and mortar modified by plastics dispersions have no effect on EPS, so it can confidently be used in conjunction with all conventional types of mortar, plaster and concrete encountered in building construction. All of this makes it entirely safe and practical in use across all of its construction applications including subterranean and marine environments.

• Fire performance

In common with most organic building materials, EPS foam is combustible. When burning, EPS behaves like other hydrocarbons and mainly gives off combustion products of carbon dioxide and water. At temperature above 100°C EPS begins to soften, contract and finally melts. At higher temperatures gaseous combustible products are formed by decomposition of the melt. Combustible gases are only formed at temperatures above 350°C. EPS is produced in the majority of building insulation products in a 'self extinguishing' (SE) version that includes a fire retardant. The inherent burning properties depend upon whether the EPS contains a fire retardant addi-

tive or not. The presence of fire retardant additives leads to a better fire behaviour. The fire retardant 'SE' grades are more difficult to ignite and considerably reduce the rate of spread of flame during a fire and hence give fire fighters more time to evacuate burning buildings. The additives cause flame quenching, so that when the ignition source is removed the EPS will not continue to burn. Molten EPS-SE will not be ignited by welding sparks, glowing cigarettes or small burning items. In the presence of large ignition sources, from fires involving other materials, EPS-SE will eventually burn. In such instances the building is usually beyond the point of rescue.

Plastic insulation used to be associated with increased fire risk. This was caused by fires in large agricultural buildings where non-fire retardant insulation was used unprotected. In practice, EPS burning behaviour depends upon the conditions under which it is used.

The best way to avoid fire spread is by appropriate protection of the insulation from any ignition source. Any insulation material should not be used uncovered, not only for fire performance but also for mechanical and long-term insulation properties. It is recommended by the industry that EPS is used with a covering material like brick, concrete, gypsum, etc.

• Recycling

EPS is already one of the most widely recycled plastics. It is collected through a Europe-wide network of collection points. Unlike the main competitive insulation materials, polystyrene is easily recycled and recycling results in real environmental and financial gain. Not only do EPS manufacturers recycle factory waste into insulation boards, but post-consumer packaging waste is collected and included to optimise costs and the need for virgin EPS material.

EPS insulation has a long lifetime in buildings and so at the moment there is still little need to recycle EPS insulation material, since EPS does not degrade or deteriorate, At the end of its useful lifetime it can be recycled in several ways .

• Indoor air quality

Statistically, Europeans spend 90% of their time indoors therefore the indoor air quality (IAQ) of a building has a significant impact on the health and productivity of its occupants. Occupant comfort, both thermal and acoustical, is an essential component of IAQ. EPS insulation helps maintain a consistent air temperature, providing thermal comfort, and can also act as sound deadening, preventing noise transmission through both interior and exterior walls.

EPS is manufactured with pentane, a hydrocarbon blowing agent that is not harmful to the stratospheric ozone layer and which diffuses out during or shortly after the production process is complete. Since the blowing agent is rapidly replaced by air, the installed insulation does not experience any significant off-gassing of pentane or other substances that may affect indoor air quality. [ref 11]

The American Lung Association's (ALA) Health House guidelines are amongst the toughest in the world for indoor air quality. They acknowledge EPS as a safe material to insulate foundation walls and floors. Other ALA registered homes have incorporated EPS insulating concrete forms (ICFs) in order to meet their stringent requirements. Although ALA representatives do not promote specific materials or products, they cite that walls insulated with EPS release no lung damaging fibres.

As described earlier, the fact that EPS has no nutrient value and does not support mould or fungi growth means that there is no negative influence from EPS insulation on IAQ from mould or fungi growth.

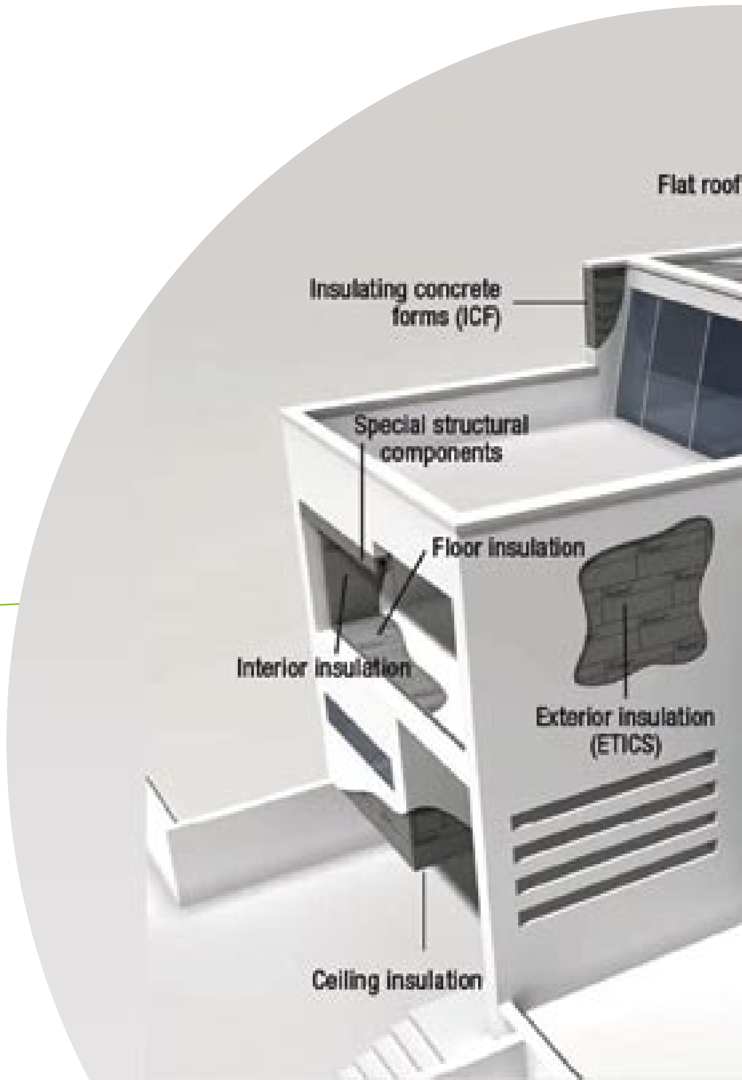
• Certified insulation quality

EPS insulation has a long, proven track record for quality and is produced under CE-label according to EU mandated CEN standards, e.g. EN 13163. In many countries additional voluntary quality labels are used, especially to have independent attestation of fitness for use of the product in the intended application. This is the guarantee to the builder and the home owner that EPS insulation fulfils at minimum all the legislative requirements. National EPS Associations can give further information about regional quality schemes [4].

[4] *www.eumeps.org has a list of all National Associations for EPS.*

2.3 Important applications of EPS in construction

Expanded polystyrene (EPS) is the perfect choice for many applications. In 2007 about 1,1 million tons of EPS was used in construction, with a mean density around 20 kg/m³ this equals 55 million m³ of EPS products. EPS primarily is used as an insulating material, but is also used for many other construction applications. In all those applications it will provide a constant performance during the full service life of the building.



- **EPS is used mainly in construction for a broad variety of applications:**
- Flat and pitched roof insulation
- Loft insulation
- Floor insulation as 'slab-on-ground' insulation, as blocks between concrete beams and radon control systems
- Interior wall insulation combined with gypsum board
- Exterior wall insulation or ETICS (External Insulated Composite Systems) and cavity wall insulation (boards and loose fill)
- Civil engineering applications such as void-fill blocks and substructures
- Insulated concrete forms (ICF), foundation systems and other void forming systems
- Load bearing foundation applications
- Core material for sandwich and stressed skin panels (metal and wood fibreboard)
- Floor heating systems
- Sound insulation in floating floors (to avoid transmission of contact sound)
- In cold stores and as thermal insulation for building equipment and industrial applications (e.g. in cryogen installations). EPS is often used thanks to its excellent behaviour at low temperatures
- Light weight fill and frost insulation for civil engineering applications (CEA) primarily for railway constructions, enlarging motorways, as backfill in bridge abutments and as foundation in areas with peat sub soils
- In floating structures, islands for golf courses and foundations in wet areas as a consequence of the rigidness and the low water uptake
- Interior and exterior decorative mouldings
- In decorative panels, sculpture or art work, as lost foam for casting iron and for weight reduction in concrete applications. Also the ideal material for foam structures for light weight TV props, for building and construction models and also for model boats, airplanes etc.

In addition, EPS is used in many applications outside the construction industry, such as shape moulded products: industrial protective packaging (consumer electronics, appliances), agricultural applications (seed trays, soil aeration), food packaging (fish, meat, meals), insulated food containers (cups, trays), general protective packaging (building materials, furniture), flotation devices, child car seats, etc.

3 EPS and sustainability

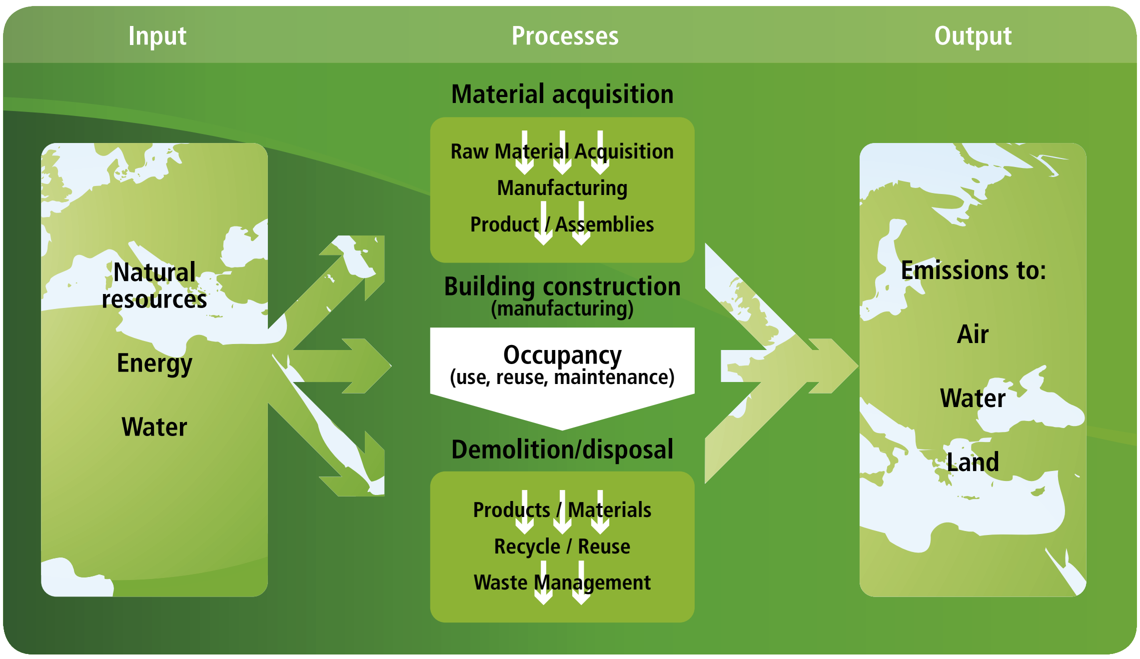
3.1 Life cycle analysis methodology

Protection of the environment is a complex geopolitical issue. The desire and ambition to move forward often leads to simplistic answers. The result can be confusion caused by numerous contradicting eco-methods, eco-events and eco-organisations and the science becomes lost.

Often ends and means tend to become confused. Many current eco-labelling systems use prescriptive requirements, e.g. 'Reduce the use and depletion of finite raw materials and long-cycle renewable materials by replacing them with rapidly renewable building materials.' This requirement is an over simplification of the real environmental impact. It fails to consider the impact of the use of land for mass agriculture on the scale that would be necessary to produce these renewables, although land may be the most critical non-renewable resource. It could significantly increase the depletion of top soil and the resulting sedimentation of rivers and nearby waterways caused by soil erosion. In addition, due consideration is needed about of the use of fertilisers, pesticides, herbicides and the effects of harvesting and processing and the use of water. In further processing of these renewable feedstock materials many additives are often necessary to fulfil technical requirements.

One known example of such environmental zeal has been the destruction of tropical rainforests to make place for palm oil plantations in order to fulfil the prescriptive requirements on renewable content requirements for automotive fuel.

Other prescriptive requirements, such as recycled content and regional purchasing are means that might contribute to sustainability but have to be seen in an holistic perspective. Prescribing regionally produced products or products with a high recycled content which are incompatible with requirements for the end use application, e.g. cellulose insulation in moist conditions, should not be recommended. Whilst the concept of sustainability is here to stay, we can only design greener buildings if we take the environment into account early in the process. We should be able to make functionally equivalent material comparisons. For this we need to know how each of the component parts, such as insulation, affects the environment. Only if the environmental effects at each stage in the building materials' life cycle are known, from cradle-to-grave, can effective choices be made. The only sensible approach is to look at the entire life cycle of a building: the LCA approach. In an LCA the total impact of a product during its production, distribution, use and recycling, treatment or disposal is quantified. It is a powerful environmental assessment



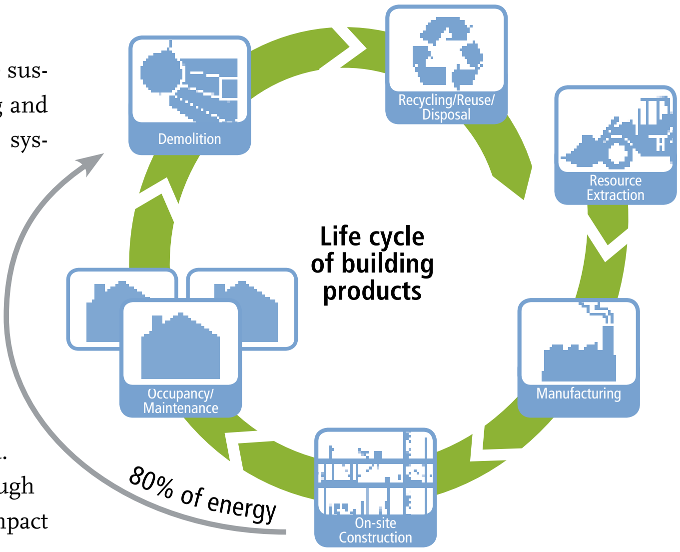
approach, of key importance in efforts to achieve sustainability and the only way to replace confusing and sometimes misleading alternative assessment systems.

As individuals, and as organisations, all our daily actions have an impact on the environment. We use energy and resources, generate emissions into the atmosphere, pollute water and produce waste. This is where life cycle analysis starts, with the inventory data which tracks energy use and emissions to air, water and land. Responsible organisations will conduct a thorough life cycle analysis of a product, to calculate its impact on the environment and to find ways to reduce it.

LCA developments need coordination and standardisation. ISO, the International Standards Organisation, is probably the most visible and certainly most quoted organisation in this field. The ISO 14000 series of environmental management standards includes the 14040 sub-series on life cycle assessment.

3.2 Life cycle analysis of building products

Probably the most important way in which the ecological impact of a building can be reduced is by designing it for optimal energy utilisation. The operational phase, the actual use of the building, has the biggest environmental impact and energy consumption is the dominant factor. Energy consumption of a building has implications for climate change, natural resources, health, comfort and cost. Heating energy accounts for 60 % of all building energy use. Other important energy contributors are cooling, lighting and use of appliances. Heating and cooling requirements for buildings are significantly influenced by the level of insulation present.



3.3 Contributing to a sustainable environment with EPS

Using EPS insulation actively contributes to a better environment during the entire working life cycle of the building. EPS offers substantial environmental advantages through energy saving and greenhouse gas emission reduction and is therefore ideally suited to the creation of environment-friendly new building projects. It is easy to handle, safe, non-hazardous and has proven constant mechanical and insulation properties for the life time of the building in which it is used. EPS doesn't contain or use any ozone depleting chemicals at any stage of its life cycle. At every stage of its life cycle, from manufacture, to application, to

'Insulation and thermal design can dramatically reduce heat loss and help stop climate change. Energy demand for heating in existing buildings can be reduced on average by 30-50%. In new buildings it can be reduced by 90-95% using widely available and competitive technology and design.

Heat losses can be easily detected with thermographic photos. A thermographic camera shows details the eye cannot detect. Parts of the building that have a higher surface temperature than the rest appear in yellow and red. This means that in these areas heat is leaking through gaps and poor insulating materials, and valuable energy is being lost. This results both in damage to the environment through a waste of energy resources and to unnecessary costs for home owners and tenants.

Typical weak points are window panes and frames and thin walls below windows, where radiators are commonly positioned and insulation should be optimal.'

Greenpeace, Energy Revolution 2007. [ref 13]

		density (kg/m²)	λ (W/m.K)	R-value (W/m².K)	thickness (mm)	EE (MJ/kg)	EE appl (MJ/m²)
Flat roof	SW	160	0,040	6,0	240	16,7	641
	EPS	20	0,034	5,9	200	88,6	354
Floor	SW	n.a.	-	-	-	-	n.a.
	EPS	20	0,034	5,9	200	88,6	354
ETICS	SW	95	0,040	6,0	240	16,7	381
	EPS	20	0,034	5,9	200	88,6	354
Cavity Wall	SW	40	0,040	5,5	220	16,7	147
	EPS	15	0,036	5,5	200	88,6	266

EE = Embodied Energy, SW = Stone Wool. [ref 14, 15]

recycling and final disposal of EPS, it offers exceptional eco-credentials. All manufacturing processes comply with current environmental regulation.

The most important environmental aspect of an insulation material is its thermal performance throughout the lifetime of the building. The environmental impact of the material itself is only of secondary importance. As consultancy firm XCO_2 Conisbee highlighted in their 'Insulation for Sustainability - A Guide' [ref 16]:
'The most important design issue is to ensure longevity of performance over the lifetime of the material.'
So it is important that optimum insulation possesses properties which allow for long term performance:
- Low moisture pick up
- Delivered lambda is final lambda
- Mechanical strength to withstand normal levels of handling and walking
- Material that does not rot or decay
- Resistant to rodents

These are inherent properties of EPS.

• Efficient use of natural resources
EPS is made from oil, a non renewable resource, but the use of oil for this purpose is not a waste. EPS consists of 98% plain air. Only 0,1% of all oil being used is used for the production of EPS. This can be seen as a valuable investment, because every litre of oil used for EPS insulation over the building life time saves 150 litres of oil in savings of heating energy. At worst, at the end of life after demolition, the EPS will be burned with energy recovery at an efficiency close to that of a power plant:

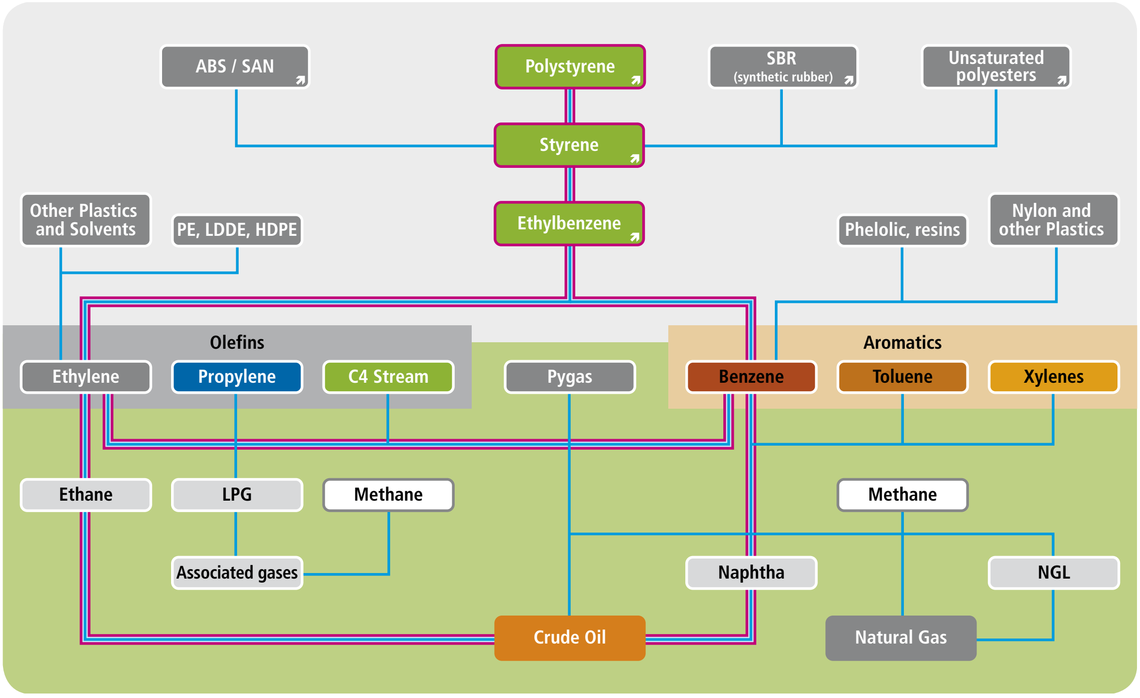
The table above gives the energy required for the manufacture of a square meter metre of EPS, including the calorific value of the oil EPS is made of, compared with another common material, for some typical application.

3.4 Life cycle analysis of EPS in buildings

It is instructive to consider the key inputs to the life cycle analysis in more detail to understand why use of EPS insulation in buildings is sustainable.

Manufacturing is the stage that often accounts for the largest proportion of energy consumption and emissions associated with the life cycle of a building product. In the case of insulation materials it is not the manufacturing phase but the use phase that dominates the overall environmental impact. The actual impact is dependent upon the type and level of insulation.

STAGE 1: RESOURCE EXTRACTION/ RAW MATERIAL PRODUCTION



EPS raw material chemistry flow chart [5]

• Raw material production [5]

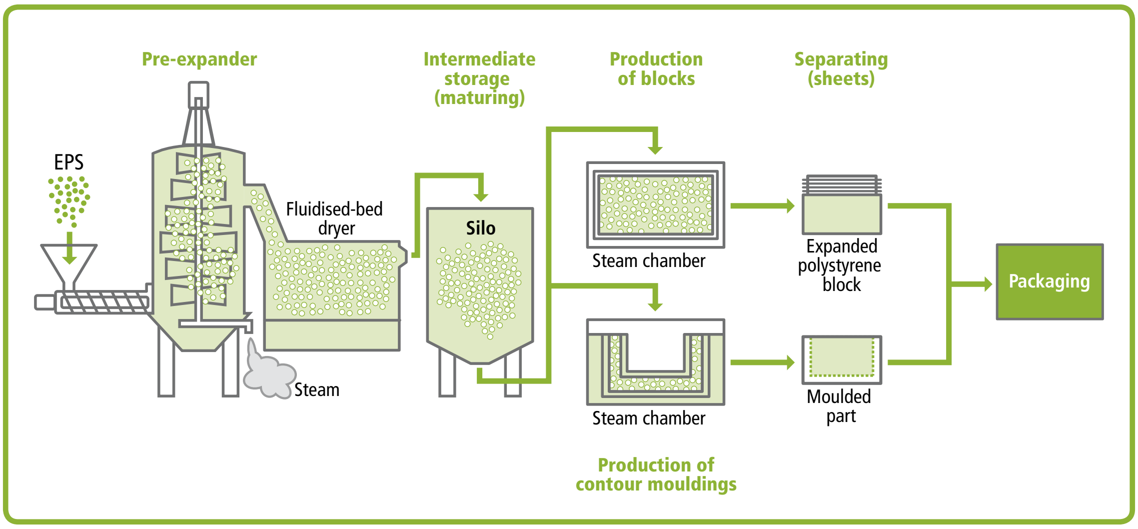
The life cycle analysis of building products starts with the extraction of raw resources needed to made the products. In the case of EPS insulation this is crude oil. Overall, 83% of all the derivatives of crude oil are directly transformed into energy in one form or another, e.g. transportation fuel, electricity generation, heating. Only 4% is used as a raw material for making plastics and less than 0,1 % to produce EPS. Using oil to manufacture EPS for building insulation applications is an efficient use of this natural resource. Each kilogram of oil used to produce EPS insulation creates a saving of 150kg of oil used for heating buildings (calculated over a service life of a 50 year period). After its service life the embodied energy is still available and could be released, as an ultimate recycling option, by safely burning to recover the energy in ecological incinerators. Using oil to produce EPS therefore can be seen as borrowing oil with a high dividend. Future generations may well question why oil was used for fuel instead of using it to produce energy efficient light weight plastics.

Styrene is produced by refinery and chemical processing. As part of the cracking of petroleum or natural gas, naphtha in a steam cracker is broken down into organic compounds. The by-products ethylene and benzene are used to produce ethylbenzene from which styrene is produced. Styrene, the monomer building block of polystyrene, is polymerised to form translucent spherical polystyrene pellets, about the size of sugar granules. EPS raw material is delivered to EPS processors usually in special boxes (octabins) or bulk bags, of up to 1100kg in weight.

During production of the solid granules of polystyrene raw material a small amount of a blowing agent, a low boiling point hydrocarbon, pentane, is dissolved in the solid polystyrene pellets to assist expansion during subsequent processing. The blowing agent, pentane, is neither a CFC nor an HCFC and is not an ozone depleting chemical. Neither CFCs nor HCFCs have ever been used in the production of EPS.

[5] *More information about the upstream processes you can find at: http://www.petrochemistry.net/flowchart/flowchart.htm*

STAGE 2: CONVERSION OF EPS



The manufacturing stages of EPS

The conversion process of EPS bead to foamed insulation consists various manufacturing stages:

• Pre-expansion

The EPS raw material is heated in special equipment called pre-expanders using steam at temperatures between 80-100°C. During this process the beads are stirred continuously. Pentane, a liquid at room temperature, evaporates above 30° C and expands with the heat. During this process of pre-expansion, the EPS compact beads turn into cellular plastic beads or pearls with small non-interconnecting closed cells. After cooling, the entrapped pentane condenses within the pearl creating a vacuum within the pearl. This vacuum is rapidly filled up with air. This process is called the conditioning of the EPS beads. The beads occupy approximately 50 times the original volume after expansion. In this process the final density of EPS is determined. The bulk density of the material drops from about 630 kg/m^3 to values typically between 10 and 35kg/m^3.

• Intermediate conditioning and stabilisation

After pre-expansion the expanded beads are cooled and dried in a fluidised bed drier, before being pneumatically conveyed to aerated storage silos for maturing, typically over a period of 24 hours. After expansion, the recently expanded beads still contain small quantities of both condensed steam and pentane gas. With cooling in the silos a partial vacuum is created in their interior which must be equalised. Air gradually diffuses into the pores until equilibrium is reached replacing, in part, the other components until the beads contain up to 98% air. At this stage the beads achieve greater mechanical elasticity and regain expansion capacity - a very important factor in the subsequent transformation stage.

• Expansion and Moulding

In the third stage of processing, known as the moulding stage, the stabilised pre-expanded beads are transported to moulds, where they are heated again using steam. Under the influence of steam, the beads soften and start to expand again. However, as they are contained in a mould they cannot expand freely, and therefore create an internal pressure within the mould and the softened beads fuse together. Following fusion the mould is cooled and moisture is removed, usually under the influence of vacuum. The moulded product is ejected from the mould at the completion of the cycle. During processing, the pentane gas is depleted, so that the finished products contain little residual pentane. After a short time the residual pentane diffuses out of the material to make place for normal air in the cells. Enclosed air is known to be one of the best insulations in nature.

There are generally two types of moulding processes for EPS. One is called block moulding and produces large blocks of EPS up to 10 metres in length. After a short cooling period, the moulded block is removed from the machine and after a further conditioning is cut into shapes or sheets using hot-wire elements or other appropriate techniques.

The second moulding process is known as shape moulding, requiring customised moulds, and produces shaped parts in appropriate forms, ready to use in a wide range of applications. In some cases the products can incorporate metal or rigid plastic inserts, e.g. for mechanical strength. Concrete floor systems, floor heating systems and Insulated Concrete Forms (ICF) are examples of applications where shape moulded EPS is used extensively.

• Post-production processing

The finished product can be further processed to a variety of different products. Depending on the application it can be laminated on one side with foils, plastics, roofing felt, fibreboard or other facings such as roof or wall cladding sheets. If laminated on both sides with steel or fibreboard a sandwich structure is created delivering extra-ordinary strength using a minimum of natural resources.

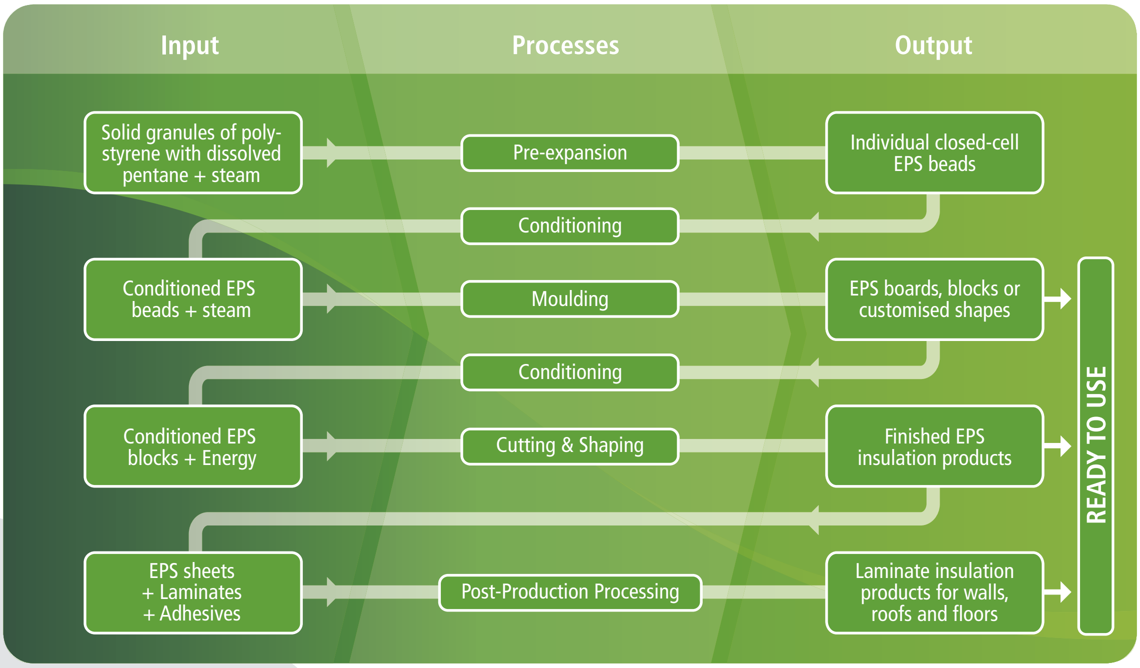
• Steam, water and solid waste

Steam is used for transmission of energy in the manufacturing of EPS. The steam is produced in boilers mainly using natural gas as fuel. Water consumption for manufacturing EPS is low. Water is reused many times in the process. There is no solid waste generated during manufacturing of EPS, since cut-offs and other EPS factory waste are recycled back into the production process. Often clean post-consumer packaging waste can be recycled into new product using this method. There is negligible pollution to the surface or underground water supplies near an EPS plant because atmospheric and liquid emissions are very low during the manufacture of EPS.

STAGE 3: ON-SITE CONSTRUCTION

The on-site construction stage is like an additional manufacturing step where individual products, components and sub-assemblies come together in the manufacture of the building. Although often overlooked in life cycle assessments, this stage is very important in terms of energy use and other environmental effects. Depending on the size of a building and the structural systems used, on-site construction can account for 3 to 15 per cent of total initial embodied energy and, depending on the materials and systems, it can result in the generation of significant amounts of waste.

The on-site construction comprises the transportation of the EPS insulation products and assemblies from plants via distributors or direct to the building sites. Transport is very important in terms of energy use and other environmental effects, because of the high volume of insulation products. The EPS supply chain is optimally structured to minimise the environmental impact of transport. EPS raw material is transported from one of the few European raw material producers to the EPS converter. Although this can involve transport over relatively long distances, it can be done very



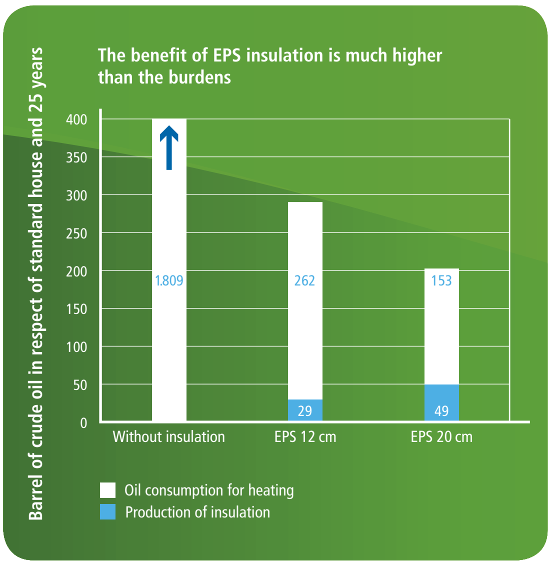
Process flow of EPS conversion

effectively since the material is still in its unexpanded form. On the other hand, there are hundreds of EPS converters in Europe, so the transport of the voluminous EPS insulation product to the client is typically only over a small distance. EPS insulation is a perfect example of a locally produced product. The impact of transport is positively influenced by the comparatively low weight of EPS insulation products.

STAGE 4: OCCUPANCY AND MAINTENANCE OF THE BUILDING

The occupancy stage takes into account functions like heating, cooling, lighting and heated water use. As indicated earlier, EPS insulation has a huge impact on environmental performance through reduced heating and cooling needs, this impact dramatically exceeding that of the embedded energy of the product. Future amendments of national standards for insulation value will soon require buildings with net zero energy use, where the small energy requirements can be met from sustainable energy sources.

EPS products are available for nearly all building insulation applications: floor, wall and roof insulation in new and in renovated buildings. The proven durability of EPS makes it a material of choice for sustainable buildings, with constant insulation and mechanical properties over time, unaffected by moisture and typical in-use mechanical stresses.
The revision of the EU EPBD (Energy Performance of Buildings Directive) foresees mandatory thermal



Ref: TNO LCA study.

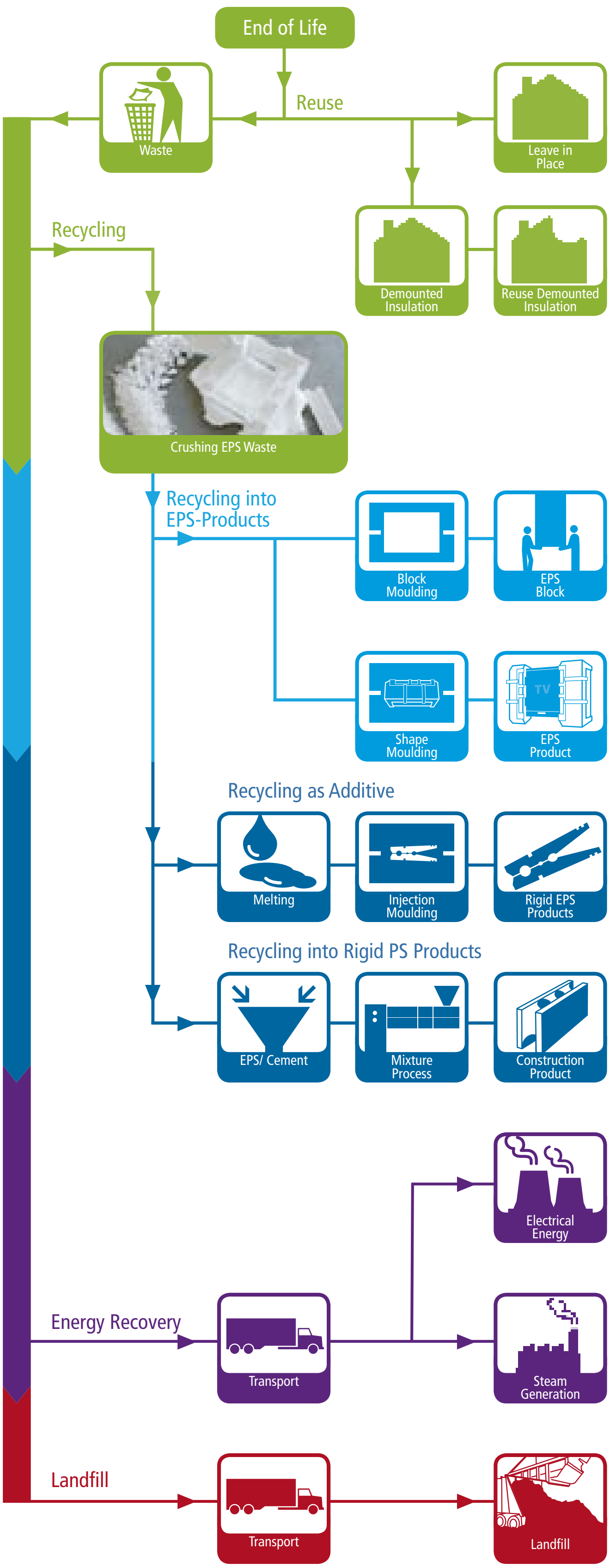
renovation for all existing buildings. Building maintenance and renovation will be of increasing importance in order to meet political objectives associated with climate change. Often maintenance requirements are initiated by moisture or leakage problems, especially in case of flat roofs or exterior walls (ETICS). If EPS has been used initially, any damaged area will generally be much reduced because EPS properties are largely unaffected by the moisture and the existing insulation does not need to be removed. This saves on new material needs, as well as costs for removing and disposal of the old material, compared to some other insulation materials.

STAGE 5: DEMOLITION

Demolition marks the end of a building's life cycle, but it is not necessarily the end for the component materials or products, which face subsequent recycling, reuse or disposal. A recycling structure for EPS is in place in nearly all European countries, focused on the collection and processing of EPS post-consumer packaging and off-cuts during construction. The volume of EPS originating from demolition of buildings is still quite limited. In most cases this is due to the fact that older buildings being demolished have limited insulation. When the volumes increase it is important to know that the recycling of EPS demolition waste has an existing infrastructure, is technically feasible, and can be profitable. Recycling of EPS is effective because after grinding of the material to the required size it can be fed into the process without further treatment and therefore without any further costs or environmental burden.

STAGE 6: REDUCE/ REUSE/ RECYCLING/ ENERGY RECOVERY/ LANDFILL

This is the final stage in the life cycle of the individual components or products comprising a building. It can be a difficult area for the life cycle assessment for a building being designed now since we are trying to predict practices that are far into the future. For EPS insulation we assume current practices. Current solutions have already proven themselves to be technically and economically viable at this moment. This is a huge advantage and different to a number of other materials where many options are theoretically possible but where currently no such structure exists. In some cases it even is doubtful whether recycling would result in reduced environmental burden com-



pared with virgin material. On the other hand, for some of these materials recycling maybe preferable to landfill.

Normally five options are recognised as potential options to avoid or reduce waste. From an environmental point of view there is a hierarchy in the five options te handle waste:

1. Reduce
2. Reuse
3. Recycle
4. Energy recovery
5. Landfill

For EPS all five of these options are possible. Depending on the specific situation the most appropriate solution in terms of environmental as well as economic impact can be selected.

• Reduce

The best way to deal with waste is to not have any! It is a common misconception that our waste problems are largely caused by plastics. In fact, the total amount of plastics in our municipal solid waste is about 7% by weight. EPS accounts for only 0.1% of this and the large majority is from packaging applications.

A number of policies are widely applied in the industry to reduce that small part of waste originating from EPS insulation. To reduce off-cuts waste produced on the building site, EPS insulation panels are manufactured to meet building design dimensions. Similarly, building design can accommodate standard insulation panel sizes. Factory EPS off-cuts normally remain clean and are therefore easy to recycle back into the production, making environmental and economical sense.

EPS insulation is not sensitive to moisture so it does not need a lot of packaging. Most EPS insulation products are packed with minimal plastic film to enable storage, handling and labelling of the product and to avoid damage.

• Reuse

Re-using items saves a lot of energy and money and prevents generation of waste. For example, during renovation of a flat roof or a façade, due to moisture or leakage problems, it is possible to leave the existing insulation in place and apply additional EPS insulation. Especially if EPS was used as the original insulation material, the damaged area generally will be much smaller compared to many competitive insulation materials because EPS properties are essentially unaffected by moisture. Walkability is also unaffected and the moisture will not result in the formation of fungus or mould. This reduces the requirement for new material and also saves costs for removing and disposal of the old material.

If a building is designed with disassembly in mind, it will be possible to reuse and or recycle demounted products more easily.

• Recycle

Recycling saves money, energy and reduces the impact on the environment. EPS is not seen as waste in most EU countries but as a valuable resource. EPS is the most easily recycled of all the insulating materials and therefore most easy to align with the "cradle to cradle (C2C)" principle. Producers of EPS have used integrated chain management principles for decades. This includes manufacturing EPS in optimum shapes and sizes for minimal use of raw material, reuse of cut-offs during production and inclusion of post-consumer waste EPS. The economic driving force for this also helps meet environmental targets.

EPS organisations from more than 25 countries around the world have signed the International Agreement on Recycling. This agreement commits to:

- Enhance existing programmes and initiate new ones which enable EPS protective foam packaging to continue to meet individual, domestic environmental standards, regardless of its country of origin
- Continue to promote the use of recycled polystyrene in a wide variety of end use applications;
- Work toward uniform and consistent international environmental standards regarding EPS protective foam packaging, especially in the area of solid waste
- Establish a network to exchange information about EPS environmental and solid waste management programmes between packaging professionals, product manufacturers, government officials, association members and consumers

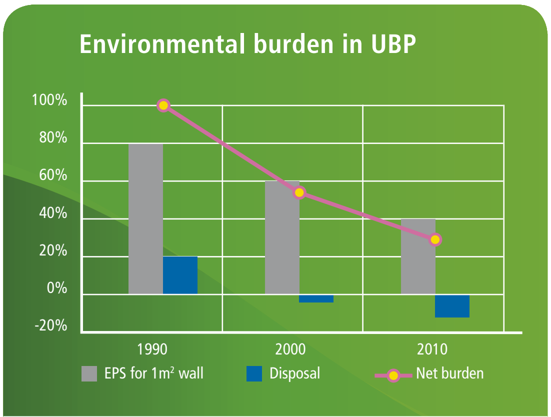
EPS is already one of the most widely recycled plastics. It is collected through a Europe-wide network of collection points, organised both by local authorities and commercial enterprises. Unlike the main competitive insulation materials, polystyrene is easily recycled. Not only do EPS manufacturers recycle factory waste into insulation boards, but post-consumer packaging waste is collected and included to optimise costs and the need for virgin EPS material.

Legislation is moving in the direction of requiring a certain level of recycle content for building products, which has to be declared on the product label. By promoting such a demand for building products that incorporate recycled content, the need for use of virgin material can be reduced. An analysis of the increased recycling of EPS products demonstrates the positive environmental impact over the past 20 years:
EPS has a long lifetime in buildings and so there is only limited current need to recycle this material. However, since EPS does not degrade or deteriorate, it can be recycled in several ways at the end of its useful lifetime:

- Added back into new EPS insulation boards. Current technical considerations limit the level of recycled content, normally to below 25 percent, in order to maintain the technical performance. However, technical developments in block mould production make it possible to apply higher recycled content levels and in some cases it is possible with specialised processes to produce EPS products out of 100% recycling.
- There are a number of non-foam applications. Recycled EPS can be moulded into new applications such as coat hangers, flower pots, park benches or fence posts.
- EPS waste can also be reground and mixed with concrete to produce building products such as prefabricated light weight concrete blocks. Adding EPS regrind also increases the thermal performance of these products. EPS in soil can aid aeration for better regeneration.

• Energy recovery

Energy recovery is usually in the form of heat from the incineration of waste. The process gives materials,



	1990	2000	2010
Reduction of density (kg/m³)	25	20	15
Integration of old material in new material (%)	0	5	20
Use of old material (%)	0	30	60

UBP = Umwelt Belastungs Punkte or Evironmental Impact Points, by Dutch research institute TNO

which cannot be recycled economically, a genuine post-consumer use. Energy recovery is a safe and environmentally sound means of generating real environmental and economical value from EPS used for fish boxes, horticultural trays or other contaminated EPS waste. In a modern incinerator, EPS releases most of its energy as heat, aiding the burning of municipal solid waste and emitting only carbon-dioxide, water vapour and trace non-toxic ash. Pollution control equipment such as scrubbers and filters reduce pollutants released during the incineration process. EPS is safely burned in this process without giving off toxic or environmentally damaging fumes. Ash and other residues are landfilled.

Waste-to-Energy incineration facilities accept EPS waste and are pleased to use it, because EPS has a relatively high calorific value per kilogram and therefore it reduces their need for fuel to keep the incineration process at the correct high temperatures. The energy gained can be used for local heating and the generation of electricity. The heat is used to convert water into steam, which is used to drive turbines generating electricity. The efficiency of this process in a modern incineration is only slightly lower compared to the efficiency of a typical power plant.

- **Landfill**

Landfills are the last of the various solid waste management options that should be considered. In many countries it is not allowed to landfill combustible waste, such as EPS, because better alternatives are widely available. Modern landfills are constructed and operated to strict environmental standards, including liners to protect groundwater.

Many people assume that because EPS does not degrade it must be a major problem in landfill. However, even “degradable” materials such as paper, plastic or foodstuffs do not break down in a landfill - and they are not supposed to. Modern landfills are specifically designed to reduce the air, water and sunlight needed for biodegradation, in order to prevent the generation of volatile methane gas and leachate (liquid run-off) which could contaminate ground water. In essence, materials ‘mummify’ in the oxygen-deprived or anaerobic environment of modern landfills. EPS can be advantageous to landfill management: since it is inert and non-toxic the landfill site becomes more stable. Since EPS does not degrade it will not leach substances into the groundwater or form explosive methane gas.

3.5 Life cycle analysis of EPS quantified

Contrary to common perception, not all recycling or use of renewables has a positive impact on the environment. If the harmful emissions to land, air and water are more from recycling or renewables than that from using virgin product, then the net balance may be negative. However, other factors, such as depletion of non-sustainable resources, also have to be taken into account. A formal product Life Cycle Analysis tries to accommodate these factors but the output often needs expert interpretation.

An LCA for EPS was carried out by PRC-Bouwcentrum in the Netherlands according to ISO 14040 and follows in detail the life cycle stages of EPS manufacture, use, recycling and disposal. The outcome is a table with data which can be used to feed LCA analysis tools to support the decision making process during the design of a building.

At a product level, Environmental Product Declarations (EPD) according to ISO 14025 offer a basis of information for life cycle analyses and hence are part of the requirements for the sustainability certification of buildings.

Environmental effect/aspect	Abbreviation	Unit	Characteristic scores	Normalisation scores
Environmental impact				
Abiotic depletion	ADP	-	0,83	1,04E-11
Global warming	GWP	kg	5,98	1,42E-12
Ozone depletion	ODP	kg	2,11E-06	3,75E-14
Human toxicity	HCT	kg	0,0357	9,06E-13
Aquatic ecotoxicity	ECA	m^3	101	2,29E-13
Smog	POCP	kg	0,0207	3,28E-12
Acidification	AP	kg	0,0278	8,19E-13
Nutrification	NP	kg	0,00241	2,81E-13
Land use	LU*t	m^2.yr	0,00274	
Environmental indicator				
Cumulative energy demand (excluding feedstock energy)	CED-	MJ (lhv)*	48,9	8,45E-13
Cumulative energy demand (including feedstock energy)	CED+	MJ (lhv)	93,1	1,61E-12
Not toxic final waste	W-NT	kg	0,0453	8,43E-14
Toxic final waste	W-T	kg	0,0124	3,09E-13

* lhv = lower heating value

[ref 17]

Insulation materials come from a variety of source materials: minerals, plastics and organics. Each of these has a different production process and hence a different environmental profile. In order to compare the materials life cycle analysis techniques need to be employed to understand the material, energy and water resources that are needed to manufacture the products and the emissions to land, air and water as well as the final waste resulting from the production of the insulation. One of the most comprehensive approaches to date has been undertaken by the Building Research Establishment (BRE) in the UK. They have assessed, and continue to add to their database, a wide range of insulation materials as well as building structures. Their approach is to compare environmental impact on a number of factors, including: climate change, fossil fuel depletion, ozone depletion, transport, human toxicity, waste disposal, water extraction, acid deposition, ecotoxicity, eutrophication, summer smog and mineral extraction. They achieve this by deriving a point score for each material (or structure), with a given thermal insulation value, for each factor against a normalised impact (in this case the impact of one average UK human during one year) and then adding the scores for each issue multiplied by a percentage weighting. The result is an 'Ecopoint' rating which for simplicity is then separated into an A-E environmental ranking. The information is collated in the BRE Green Guide to Specification and includes more than 1200 specifications used in different kinds of buildings. EPS is assessed with the highest possible BRE 'A-plus' rating[6].

3.6 Composition; substances and emissions from EPS

Polystyrene is a substance which has been produced from styrene on an industrial scale for more than 60 years. EPS is 98 percent air and only 2 percent of polystyrene. In case of a fire retardant grade EPS, about 0,7% of fire retardant is added. EPS raw material contains pentane to allow expansion during conversion, which is emitted at this stage or shortly after. In addition there may be residuals, in very small, hardly measurable quantities, from previous production stages.

• Pentane and (H)CFC'S

EPS has never contained or used (H)CFCs as a blowing agent at any production stage. The raw material used for production of EPS typically contains about 5-6% of the blowing agent pentane. Pentane is a hydrocarbon similar to methane or propane. Pentane

[6] *Available on the internet at www.thegreenguide.org.uk*

is not toxic and does not affect the upper ozone layer like (H)CFCs, but can contribute to low-level smog formation.
Therefore, manufacturers use state-of-the-art technology to minimise, capture and recover pentane emissions. The amount used in the production process for EPS does not represent an environmental burden. It is rapidly converted to water and carbon dioxide in the atmosphere. Much larger amounts of the greenhouse warming gas, methane, are produced during the decomposition of household waste.

• Styrene monomer and other residuals

As for nearly all plastics and many other materials, it is possible to find traces of substances from previous production stages in the end product. Styrene monomer is the raw material from which polystyrene is produced. It is used in many other materials as well and also occuring naturally in strawberries, beans, nuts, coffee and beer. The levels at which these substances like styrene, ethylene, benzene and ethylbenzene are found are far below any level of concern. As many reports confirm [ref 11, 18, 19, 20], even if polystyrene is used as food packaging material, styrene does not pose a risk. e.g. drinking coffee from an EPS cup is not harmful.

• Flame retardent

In order to comply with building regulations for fire performance most EPS boards are supplied in flame retardant quality. The flame retardant properties are achieved by the addition of a small amount, about 0,7 % w/w of a brominated flame retardent (HBCD), which is bound into the polymer matrix. There is no significant emission of HBCD coming from EPS boards [ref 12]. Whilst posing no risk to the insulation board consumers, HBCD has been identified under a recent EU Risk Assessment as a PBT substance. It is therefore recommended for authorisation under the EU REACH Regulation. Industry disagrees with the identification of HBCD as a PBT. However, industry is committed to working with the relevant authorities under the REACH process to ensure continued use of flame retarded polystyrene foam. In response to this evolving regulatory situation, industry has introduced emission control programmes and is actively engaged in the search for suitable alternative flame retardants.

4 Conclusion

Energy demand reduction can meet immediate political and environmental requirements for energy efficiency and reduced greenhouse gas emissions. Priority has to be given to limit demand through rational use of energy, followed by renewable energy sources and with use of fossil fuels only where necessary and then used as cleanly as possible[8]. Improved insulation has been demonstrated to be the factor making the most significant difference to energy efficiency in the large building and construction sector. Our industry has a responsibility to encourage renovation of all buildings as the key to making an immediate impact, as well as advocating low energy and passive housing for all new constructions. Supply side energy developments will take longer to come to fruition and so by optimising the demand side we buy time for supply side developments. There is sufficient evidence to show that all major insulation types are sustainable, differences between materials are insignificant compared to the total building envelope. However, sustainability arguments do not address all aspects of product performance and we need to be aware of the properties required of insulation to maximise its performance during construction and over the lifetime of the building. EPS has a demonstrated advantage in terms of cost-effectiveness and long term performance. Well insulated buildings not only help preserve the environment for subsequent generations, they also allow for more comfortable living for the people using them and have a strong economic benefit to the individual and the community.

EPS insulation in buildings benefits the three pillars of Sustainability: Planet, Profit and People.

REFERENCE LIST

[1] IPPC Climate Change, Synthesis Report 2007

[2] The Passivhaus standard in European warm climates: design guidelines for comfortable low energy homes. Part 1. A review of comfortable low energy homes. Passive-on, 2007

[3] Climate map 2030, Vattenval, 2007

[4] EU decision 406/2009/EC on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020, 23 April 2009

[5] Climate change - a business revolution? How tackling climate change could create or destroy company value, Carbon Trust, 2009

[6] Working Report: Integrated Building Concepts State-of-the-Art Review, IEA, 2006

[7] Keep cool, stay warm, insulate, Climate alliance and Eurima, 2008,

[8] Energy Savings by Plastics Insulation, GUA, 2006

[9] U-values for better insulation, Ecofys, 2007

[10] Moisture transport in building materials, Frauenhofer Institut, 2001

[11] Fraunhofer IBP Test Report 028/2009/281: "Analysis of the rigid foam insulating boards 'Styropor F15' for the Emission of volatile organic compounds"

[12] Emission von Flammschutzmitteln, BAM, 2003

[13] Energy revolution, Greenpeace, 2007

[14] Life cycle inventories of building products v2, EcoInvent, 2007

[15] Inventory of carbon and energy, University of Bath, 2008

[16] Insulation for Sustainability- A Guide. XCO_2 Conisbee, 2002

[17] EPS the environmental truth, results of the life cycle assessment, EUMEPS, 2002

[18] The polystyrene industry answering your questions, APME, 1992

[19] Residual ethylbenzene in styrene and styrene polymers, International Styrene Industry Forum ISIF, 1999

[20] Styrene & mouse lung tumours, International Styrene Industry Forum ISIF, 1999

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UN's secretary-general Ban Ki Moon,
26th November 2009

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