Waste management and polyurethane insulation in the context of resource efficiency

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Executive summary

PU (PUR/PIR) is the premium insulation material used in a wide range of building and technical applications. Thanks to its low thermal conductivity and high durability, it may save more than 100 times the energy needed for its production during its 50 years lifetime, or more, in buildings. When PU reaches its end of life after many decades in use, it enters the waste stream together with other construction products. Together with a large quantity of excavation waste, construction and demolition waste accounts for about 30% of all waste generated in the European Union. On the other hand, a life cycle assessment will show that construction and demolition waste only causes about 2% of the overall environmental burdens of a building.

In the current discussion on resource efficiency, regulators tend to propose recycling targets for construction and demolition waste. Such a simple

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approach does not take account of the complexity of the issue, as construction products are intermediate products and resource efficiency goals should be set at the building level based on life cycle performance.

Moreover, such requirements may lead to green-washing as recycling technologies may exist and are actively communicated, although their use remains limited in practice due to complex logistics and poor economies of scale.

This leaflet puts recycling in the context of European legislation and life cycle assessment (LCA). It shows that the viability of end-of-life options depends on various factors such as transport distances, burdens from recycling processes and raw material costs. This means that one-size-fits-all solutions do usually not exist. The paper then looks at the various end-of-life options for PU waste with their pros and cons. It concludes that the optimum waste management of PU consists of a good mix of recycling, recovery and high efficiency waste-to-energy options.

Given long-term trends in raw material prices and landfill costs, more recycling and recovery options will become economically viable and their use is therefore likely to increase in the foreseeable future. Because of the complex nature of demolition waste, these future recovery options need to be robust, cost-effective and able to treat mixed wastes streams.

Policy has an equally important role to play in diverting waste from landfill. As a prerequisite, the segregation of demolition waste into organic and inorganic fractions should become a legal requirement. More fractions could be envisaged. In any case, sufficient waste-to-energy capacity should be provided to ensure that the energy content of organic waste is recovered when recycling or product recovery is not an option.

What is polyurethane?

Polyurethane (PU) and its applications

Raw materials

Polyurethanes are polymers that are made by reacting polyisocyanates (mostly MDI for insulation foams) with a range of polyols. While most of the ingredients are hydrocarbon or mineral oil based, also plant-based content can be used. In particular, some polyols can contain up to 60 % of plant-based content coming from renewable sources. Although this should be seen as a step forward, conflicts with food production must be avoided and impacts on LCA indicators taken into account.

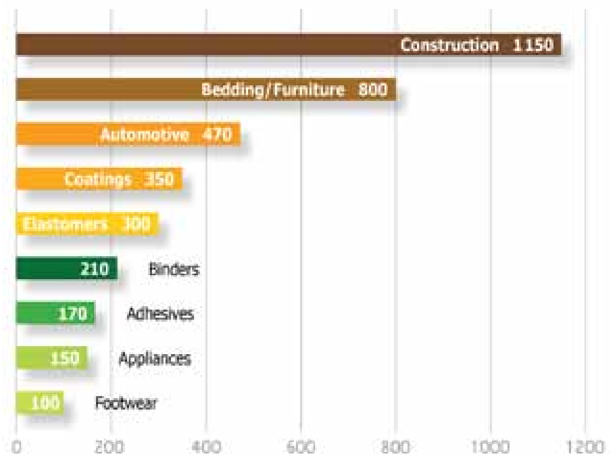
Polyols for use in PU products can also be made from recycled PET bottles. Another new and promising technology utilizes carbon dioxide as an additional raw material for the synthesis process of polyols. The carbon dioxide is a waste product provided from a power plant which would otherwise be emitted in the atmosphere. Furthermore, this process saves a part of the oil and energy that are needed in the conventional production of polyols.

[1] www.polyurethanes.org

Applications

PU is used in a wide variety of applications to create consumer and industrial products that play a crucial role in making people's lives more convenient, comfortable and environmentally friendly. The material is widely used in the food cold chain, in upholstered furniture and mattresses, shoes, cars, medical devices and, last but not least, for the thermal insulation of buildings and technical equipment[1].

In all these applications, polyurethanes contribute to reducing resource use by providing light weight and durable solutions. When used as coatings, they ensure longevity of the structural elements such as concrete and metals. As adhesives, PU plays an important role in the mechanical recycling of a variety of materials such wood and rubber wastes.



Europe PU Market by applications 2011 – 3 700 kto (Volumes in kto)

Polyurethane insulation

Thermal insulation has a crucial role to play in achieving nearly zero energy demand levels for Europe's new buildings and drastically reducing energy demand in the existing building stock. Thanks to its premium insulation performance and durability, PU (PUR/PIR) is the material of choice to reach these targets. PU drastically reduces energy resource use as it is capable of achieving very high insulation levels with minimal thickness. It also optimises the overall building material resource use by minimising the impact on ancillary elements such as the depth of eaves, joists, rafters or studs, lengths of fixings and the size and strength of overall structure. It also maximises the available space, making the most of building land and living space.

Thanks to its long lifetime i.e. high durability, resource use through repair and replacement are minimised. PU insulation is commonly used in a number of different applications:

- Insulation boards and block foam
- Sandwich panels
- Spray insulation
- Cavity-injected insulation
- Structural insulated panels
- Pipe-in-pipe insulation
- Insulation of industrial installations and pipes

[2] Commission Communication: *Strategy for the sustainable competitiveness of the construction sector and its Enterprises*, COM(2012) 433 final

[3] Commission Communication: *Roadmap to a Resource Efficient Europe*, COM(2011) 571 final

[4] See website of DG Environment: http://ec.europa.eu/environment/waste/construction_demolition.htm

[5] Caleb calculation based on UK Construction Resources & Waste Platform data

Societal challenges and EU legislation

Construction and waste generation

The construction sector plays an important role in the European economy. It generates almost 10 % of GDP and provides 20 million jobs, mainly in micro and small enterprises[2]. Buildings account for 42 % of our final energy consumption, about 35 % of our greenhouse gas emissions and (including civil engineering) more than 50 % of all extracted materials[3].

Construction and demolition waste is one of the heaviest and most voluminous waste streams generated in the EU. It accounts for approximately 25-30 % of all waste generated in the EU[4]. The share of construction and demolition waste stemming from buildings will be lower once waste from civil engineering works and excavated soil is deducted. In particular excavation waste streams account for almost 50 % of all construction and demolition waste[5]. Nevertheless, even by deducting these waste types, the quantity of end-of-life construction products remains significant.

On the other hand, buildings are part of our heritage and living space. They should be attractive and comfortable. With people spending about 90 % of their life in buildings, healthy indoor environments must be guaranteed.

Furthermore, with the move towards nearly zero energy buildings, the weight of construction products in the overall environmental balance of buildings is changing. Thicker insulation, triple glazing, ventilation systems, photovoltaic or solar thermal systems will all increase resource use in the construction phase and, at the end of their life, enter waste streams. This must be counterbalanced with the use phase, during which these products will help to drastically reduce the resource consumption of the building and hence the waste streams caused by energy generation.

The European Union adopted a number of laws to tackle this complex issue. A global strategy on the resource efficiency of buildings and waste management is still missing.

Waste framework directive

The Waste framework directive[6] adopted in 2008 introduces in article 4 a so-called waste hierarchy as a priority order:

- prevention;
- preparing for re-use;
- recycling;
- other recovery, e.g. energy recovery; and
- disposal.

Article 4 also invites Member States to "take measures to encourage the options that deliver the best overall environmental outcome". This includes the possibility to allow that certain waste streams depart "from the hierarchy where this is justified by life-cycle thinking on the overall impacts of the generation and management of such waste". As will be explained below, the flexibility provided for by this article is of relevance to construction and demolition waste management decisions.

Article 11 stipulates that, by 2020, at least 70% by weight of non-hazardous construction and demolition waste should be re-used, recycled or recovered. Whilst some countries already fulfil this requirement today, others will find it difficult to put the infrastructure in place before the target date.

Construction products regulation

This regulation[7] introduced a new basic requirement for construction works n° 7 "Sustainable use of natural resources". According to this requirement, construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable, amongst others by ensuring "reuse or recyclability of the construction works, their materials and parts after demolition".

It is still unclear how this requirement will be implemented at national level and how compliance can be measured. Many stakeholders, including construction products manufacturers see the standards developed by CEN/TC350 as the most appropriate tool.

Resource efficiency initiatives

A number of Commission documents including the "Roadmap to a resource efficient Europe" and the "Strategy for the sustainable competitiveness of the construction sector and its enterprises" address the management of construction and demolition waste as part of increased overall resource efficiency.

[6] Directive 2008/98/EC of 19 November 2008 on waste and repealing certain Directives

[7] Regulation (EU) No 305/2011 of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC

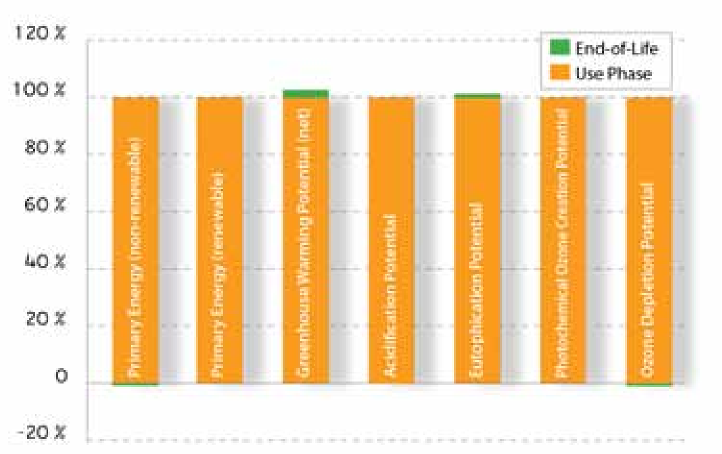
Waste in the context of LCA

Holistic approach on building performance according to TC350

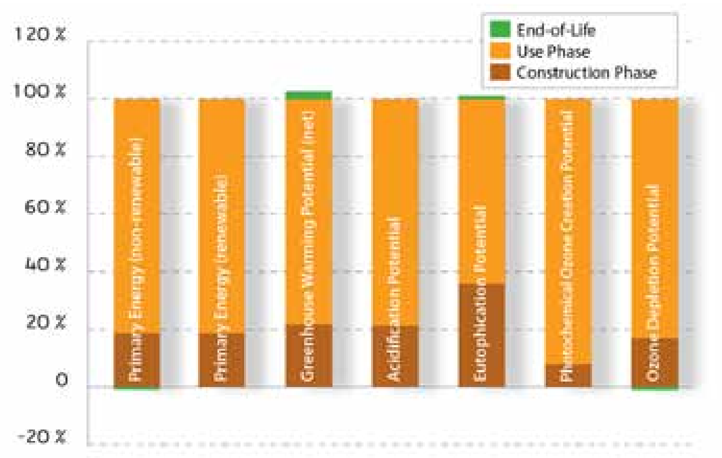
The standards developed by this CEN Technical committee put waste management and resource efficiency in the context of building sustainability. This concept combines environmental, economic and social aspects and enables specifiers to minimize resource use over the building life cycle.

The calculation of environmental burdens takes account of impacts from construction products communicated through environmental product declarations, and of the building design and use pattern. Based on this, designers can calculate the environmental performance of the building covering all life cycle phases and compare different options including the following:

- Reduced energy demand during the use phase versus higher material use and/or waste streams;
- Resource consumption and waste production of a product versus its longevity (need for replacement during the building life cycle);
- Different material choices and the effects on the building design and performance;
- Impact of construction and demolition waste on the overall life cycle performance (burdens from waste and credits through recovery or recycling).



Total environmental impacts of the building stock in the EU-25 according to life cycle phases (existing buildings)



Total environmental impacts of the building stock in the EU-25 according to life cycle phases (new buildings)

When applying such a life cycle approach, the burdens stemming from end-of-life are of minor importance. According to the IMPRO study of the Joint Research Centre[8], the end-of-life impact is small for both new and renovated buildings (-1.7 to 3.2% of the environmental impacts for new build). The impact should be somewhat higher in nearly zero energy buildings.

A closer look at PU and other insulation products shows that practically all these materials provide a high degree of resource efficiency, as they save considerably more resources than are required for their production and end-of-life treatment. In fact, many studies show that, for a given end-use application, the overall environmental balance of the various insulation products is fairly similar[9].

However, even if the environmental burden from construction and demolition waste seems small per building, it becomes relevant when extrapolated to the whole EU building stock. This is the reason why construction product manufacturers need to identify innovative solutions for the waste management of their products.

[8] Françoise Nemry, Andreas Uihlein (Joint Research Centre): *Environmental Improvement Potentials of Residential Buildings* (IMPRO-Building, 2008)

[9] PU Europe Factsheet n°15: *Life Cycle Environmental and Economic analysis of Polyurethane Insulation in Low Energy Buildings* (2010)

Factors determining the viability of waste recovery options

Strategies to increase resource efficiency must necessarily look at waste management. A closer analysis will show that even for one and the same construction product, a number of external factors affect the viability of waste treatment options. They include the following aspects:

Environmental aspects

- Transport distances between demolition site and end-of-life treatment facilities
- Environmental impact of recycling processes compared to the extraction and use of virgin materials

Technical aspects

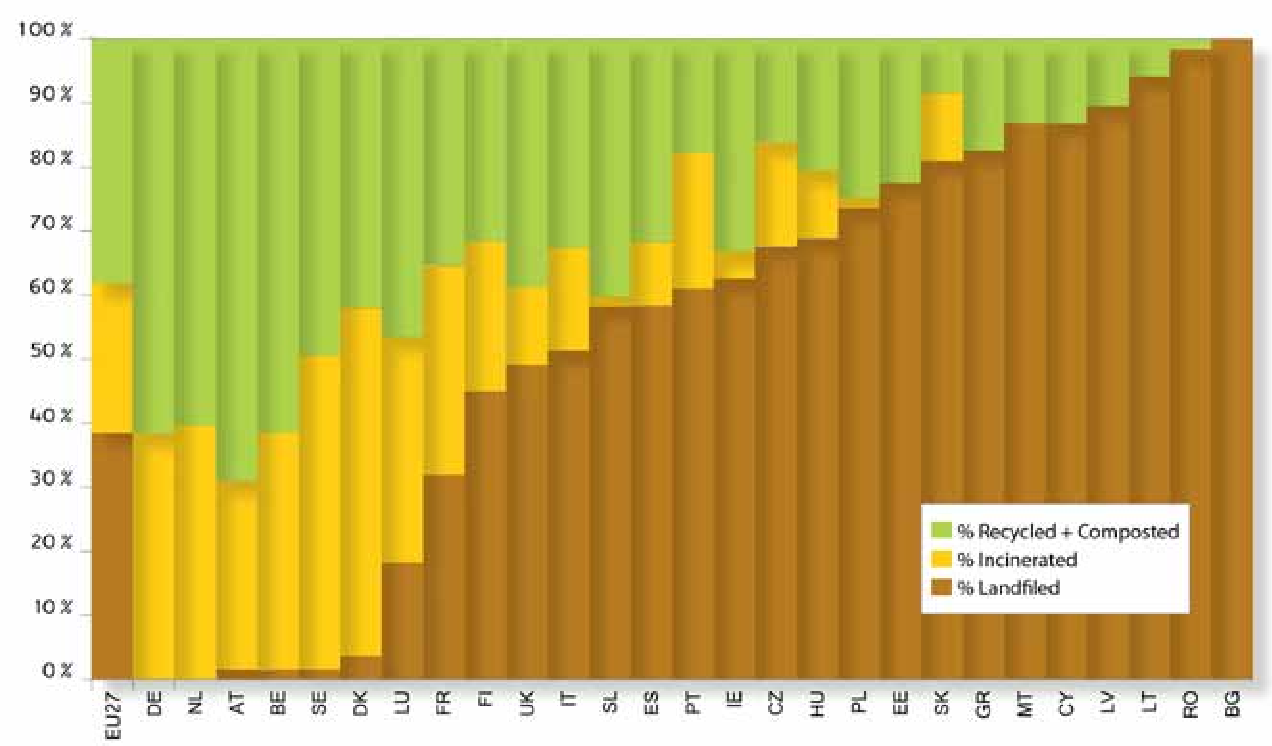
- Contamination by other substances or materials

Economic aspects

- Transport distances between demolition site and end-of-life treatment facilities
- Costs of waste segregation
- Cost of end-of-life options compared to raw material prices
- Economies of scale: quantity of waste (in total and per demolition site)
- Stability of waste streams

The above examples demonstrate the complexity of the challenge. A case-by-case assessment will be required to find the solution leading to the lowest societal burden from construction and demolition waste.

Generally, experience shows that waste is best diverted from landfill when a country combines different end-of-life strategies ranging from recycling to waste-to-energy (see graph below).



Municipal waste treatment in 2010 EU 27 (Graph by CEWEP, Source: EUROSTAT 2010)

Current PU waste options

PU insulation and waste streams

PU insulation consists of 97 % insulating gas captured in the closed cells of the foam and is therefore extremely light-weight. Its share in the total non-mineral construction and demolition waste should be around 0.3 % (figure for Germany) and around 0.05 % in the total construction and demolition waste (estimates for France and the UK).[10] Its lifetime is closely linked to that of buildings and building renovation cycles. Depending on the application, PU insulation will typically stay in place for 30 to 75 years or more. This very long life cycle may have an impact on end-of-life options, as

- The product is likely to be contaminated by others in its use phase (bitumen, adhesives, rust, render, etc.) and
- Substances used in the past are no longer admitted today.

The following chapters will introduce different end-of-life options for PU insulation following the "waste hierarchy" and highlight their pros and cons, relevance and potential future.

[10] Consultic GmbH for PU Europe: *Study on rigid PUR/PIR foam waste qualification and quantification at construction and demolition sites in 2007 and forecast to 2012/2020* (2008)

Prevention

Driven by high raw material prices, PU insulation manufacturers work actively on measures to lower wastage levels at production.

Tackling construction/installation waste is more complex. On a national level, some PU Europe members develop generic guidance and conduct case studies to achieve better design and site practices for installation waste minimisation of insulation products.

The trend towards prefabricated insulated composite building elements is another way to reduce construction waste. The elements are made to measure in the factory and installation is therefore quick and almost waste free.

Re-use

PU insulation is an extremely durable product, which is inert, does not rot and resists moisture uptake. In most cases, PU boards are mechanically fixed (pitched roofs, steel deck roofs), so the boards can be easily recovered and separated from other construction material. In particular insulation boards and sandwich panels can therefore be re-used, although usually in less demanding applications. It has been demonstrated that PU insulated roofs can be renovated without replacing the insulation layer even if moisture could penetrate the roof due to leakage in the water proofing layer. The thermal performance of the roof may be improved by an additional insulation layer[11]. It is estimated that between 5 and 10% of PU construction and demolition waste is re-used[12].

[11] Rainer Spilker, Aachener Institut für Bauschadensforschung und angewandte Bauphysik gGmbH: Flachdach-sanierung über durchfeuchteter Dämmschicht (2003), http://www.baufachinformation.de/artikel.jsp?v=209700

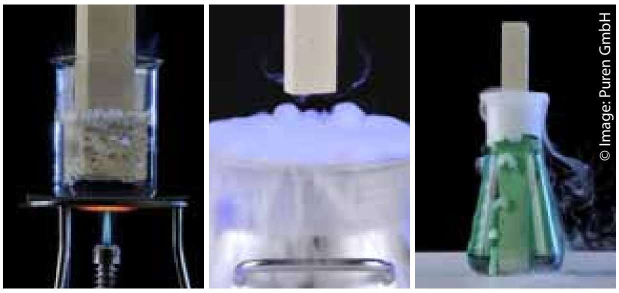
[12] See footnote 9

Recycling options

Recycling steel from sandwich panels

Steel is a valuable resource which can be recycled an unlimited number of times. As recycling comes with a cost, the economic viability largely depends on steel prices. These fluctuate a lot which means the economics may change significantly over time. Three options are currently applied:

- The steel facings from the sandwich panels are stripped and sent to recycling. This process is however time consuming.
- The steel can by recovered through a conventional shredder.
- The end-of-life panels can be processed through a fridge recycling plant when old foams containing ozone depleting substances can be expected, and provided no other undesired substances are present.



© Image: Puren GmbH

Transforming PU waste into new products

PU foam waste from production and construction can be ground and reprocessed into high density boards and profiles to replace wood and wood chipboards in construction. The recycled material is non-rotting, mould- and mildew-resistant. Thanks to its low thermal conductivity, light weight and outstanding moisture and mechanical resistance levels, it is used as construction element for façades, base material for window frames, partitions or doors, bathroom and nautical furniture and kitchen counter tops. It can be found in high speed trains, lorries and caravans.

Production waste is also transformed into other PU-based insulation products, in particular for

thermal and acoustic floor insulation. To this end, the waste foam is ground into granules and treated with additives and cellulose. It can then be evenly distributed on the floor.

Both applications can be economically and environmentally viable and are therefore proven options today.

Production and construction waste: Transforming PU waste into packaging material

PU foam waste can be transformed into packaging material for PU insulation products.

Other products made of waste PU foam

A number of other recycling options are currently being explored in pilot projects including the production of playground matting, reed bed buoyancy medium, hydroponic mats and oil/liquid absorption uses.

Chemical recycling

The term chemical recycling describes the chemical conversion of polyurethanes to produce polyols for further second life applications. Three technologies have been developed: hydrolysis, aminolysis and glycolysis. Today, a small number of glycolysis plants are operating in Europe. They process uncontaminated waste of a known composition, which is mainly production waste. According to the current state-of-the-art, about 30 % of the polyols used in rigid PU foam can come from glycolysis without affecting product quality.

No LCA is available to quantify the environmental benefits and burdens of these technologies. The main stumbling stone to a wider use include the removal of the facings, logistics and costs. Still, recent press announcements indicate that new glycolysis plants should be built in the near future.

Recovery (waste-to-energy)

If PU insulation waste cannot be re-used, recycled, or transformed into other products, the preferred option is energy recovery. PU contains a significant amount of energy, which makes it a very efficient feedstock for municipal incinerators that generate electricity and, increasingly, heat for use in buildings and industrial processes.

Thanks to new combustion techniques and post grate ash treatment this solution is also suited for contaminated and ODS containing waste from building demolition.

Some countries such as, Sweden and Switzerland, Denmark and Germany, transform practically all PU waste, which cannot be recycled or recovered otherwise, into energy. On average, it can be estimated that about half of the PU insulation waste is treated in this way in Europe.

From an LCA point of view, this option leads to credits in the energy balance, as the waste PU replaces fossil fuels. This is reflected in the lower primary energy content of the PU product compared to landfill. On the other hand, the global warming potential increases, as CO_2 is produced in the incineration process.

Landfill

PU insulation waste, which is free of ozone depleting substances, is not classified as hazardous waste. However, end-of-life PU insulation is too valuable to be land-filled. PU Europe and its members encourage national governments to mandate at least the segregation of demolition waste into mineral and organic fractions and provide sufficient waste-to-energy capacity to deal with non-recyclable organic waste. This is a prerequisite to diverting PU and other organic demolition wastes from landfill.

On the other hand, the industry is aware of its own responsibility. Trials are underway to introduce take-back schemes for construction waste with a view to diverting it from landfill and treat it according to the other end-of-life options.

Outlook

Future use of current waste options

Many end-of-life options exist for PU insulation waste. Recycling and recovery solutions have been developed and have proven their technical feasibility. Three principle obstacles to a wider deployment have been identified: logistics, economics and contamination by other building materials.

Raw material prices have been steadily increasing over the past years and are likely to continue this development. The cost for landfill is also going up. This will contribute to the economic viability of recycling and recovery options such as steel recycling and chemical recycling. Their relevance should therefore increase in a foreseeable future.

With the increasing use of PU insulation, the stability and volume of PU waste streams will increase over the years. This should contribute to overcoming a part of logistics-related problems.

Further research is necessary to deal with contaminated PU waste.

Future waste options

The PU industry is pro-actively exploring further options to divert end-of-life foam from landfill. They include the following:

Production and construction waste: Feeding PU dust back into production process

PU dust could be fed back into the process stream to produce new PU insulation boards/panels.

Construction waste: PU waste as party wall fill

Shredded PU waste can be used to guarantee high levels of thermal and acoustic insulation in party walls separating terraced houses. Trials are underway and first technical approvals have been obtained or are in preparation.

Add PU foam waste to light concrete & cement screeds

PU foam waste can be used as an additive for lightweight concrete. The product is versatile and can be prepared by hand, in a cement mixer or in a concreting plant. It has good thermal insulation qualities, fire resistance and durability. This is a viable solution for PU production waste and construction waste from major building sites.

Add PU foam waste to render for façades

Ground PU waste can be added to ready-mixed plaster for manual or spray plastering for new build and renovation. The PU particles significantly increase the thermal resistance of the wall while maintaining a high degree of vapour permeability.

Waste from all life cycle stages: Co-combustion in cement kilns

PU waste can be used as a fuel substitute in cement production. Technical feasibility has been proven. The main issues today include the cost of collection, sorting, pre-treatment and transport and the unpredictability of waste quantities. Pilot projects are underway.

Waste from all life cycle stages: Feedstock recycling of organic streams

A new technology has been brought to industrial scale. It produces pure gas through synthesis and thermal fission from biomass and other organic materials such as plastics without emitting toxic organic pollutants such as dioxins and furans and flue gases. The resulting gas is a mixture of methane, hydrogen and carbon monoxide and can be used as both a fully-fledged substitute for fossil fuels in industrial processes as well as a production feed material, for example in the manufacture of methanol.

The PU industry will continue its efforts to develop solutions that minimise environmental burdens from end-of-life products while ensuring economic viability. However, whatever solutions the future will bring, recycling for the sake of meeting a quota will not necessarily benefit the environment. Decisions will have to be taken on the basis of life cycle analyses and will be case-specific.

For more details on polyurethane insulation and waste management, see www.excellence-in-insulation.eu

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