INTRODUCTION

Polyurethane flexible foams exist in many forms and have been increasingly used over the last thirty years. Flexible foam is applied in durable products with long lifetimes, usually more than ten years. The products are as diverse as comfortable foam cushioning for furniture or lightweight seats to crash padding in cars. Polyurethane flexible foam products have become a valuable part of our modern life through improving comfort, increasing safety and reducing fuel consumption. In addition, they are recyclable.

Information about the various options for polyurethane foam recycling has been published by ISOPA in a series of Fact Sheets.

This Fact Sheet addresses the existing and emerging technologies for energy recovery from flexible polyurethane foams. The option of energy recovery may prove to be the most attractive long term answer to derive maximum value from all post-consumer plastics or other waste.
FLEXIBLE POLYURETHANE FOAMS

Main application areas, production methods and foam types for flexible polyurethane foam.

<table>
<thead>
<tr>
<th>APPLICATION</th>
<th>PRODUCTION METHOD</th>
<th>FOAM TYPE</th>
<th>PRODUCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furniture and bedding</td>
<td>Foam blocks</td>
<td>Standard</td>
<td>Cushion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High resilience</td>
<td>Mattress core</td>
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<tr>
<td></td>
<td></td>
<td>Combustion modified</td>
<td>Padding</td>
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<tr>
<td>Automotive</td>
<td>Cold cure moulding</td>
<td>Standard</td>
<td>Seating</td>
</tr>
<tr>
<td></td>
<td>Hot cure moulding</td>
<td>High resilience</td>
<td>Sound deadening material</td>
</tr>
<tr>
<td></td>
<td>Foam blocks</td>
<td></td>
<td>Roof liners</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Arm and head rest</td>
</tr>
</tbody>
</table>

Readily accessible trim foam, collected from the conversion of foam blocks into articles, has been recycled for decades into rebonded foam (ref. separate ISOPA Fact Sheet: “Rebonded Flexible Foam”).

The long lifetime of articles containing polyurethane foams means that the return of these products is a slow process. After a useful life, most flexible polyurethane post-consumer waste finds its way, if uncollectable or unidentifiable, into municipal solid waste (MSW). This is either landfilled or incinerated with or without energy recovery. With landfill and incineration without energy recovery, the valuable energy content is lost. These options must therefore be a last resort.

Energy recovery is now practised in many plastic recycling schemes. The German waste law (Kreislauf -wirtschafts-/Abfall-Gesetz) puts recycling and recovery on an equal acceptance level provided that certain efficiency criteria for energy recovery are met.

ISOPA members have consistently supported and encouraged the study of all aspects of polyurethanes incineration with energy recovery. Indications are that this approach, in its many forms, is increasingly being considered as an acceptable recovery option.

![Plastics waste as a fraction of the total Municipal Solid Waste (% by weight)](image)

Source: TN SOFRES Consulting for APME, 1998

Municipal Solid Waste in Europe
EXISTING TECHNOLOGIES

Various technologies are currently used for plastics or polyurethanes incineration with energy recovery.

Co-fuel in MSW combustors

Municipal solid waste combustors with state-of-the-art energy recovery and flue gas cleaning technology exist in various countries throughout Europe, Switzerland, Sweden, Germany and Denmark are examples of countries with high environmental standards where this technique is practised to provide local communities with electricity and heating schemes. Up to 10% of domestic electricity requirements can be generated by these units. The conversion of energy is even more efficient when the MSW combustor can be linked to district heating systems for the supply of hot water and process steam for industry.

There are considerable differences in the social acceptability of waste incineration throughout Europe. The polyurethanes industry has taken on the challenge of contributing to the change in this perception and has initiated a number of trials and studies to further the knowledge on all aspects of incineration with energy.

<table>
<thead>
<tr>
<th>EMISSION DATA (IN mg/m³ FLUE GAS)</th>
<th>STATUTORY REQUIREMENTS</th>
<th>GUARANTEED MAXIMUM EMISSIONS AT MSW INCINERATOR ALKMAAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>CO</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>SOx</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>NOx</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Cd, Hg</td>
<td>0.05</td>
<td>0.02-0.03</td>
</tr>
<tr>
<td>Other heavy metals</td>
<td>1.0</td>
<td>0.25</td>
</tr>
<tr>
<td>PCDD/PCDF</td>
<td>0.1 ng/m³</td>
<td>0.05 ng/m³</td>
</tr>
</tbody>
</table>

Emission levels for MSW incinerators in the Netherlands. Source: NV Huisvuilcentrale N-H.
recovery. One such trial took place at Cyclenergie, Pontivy (F), using Automotive Shredder Residue (ASR), of which a large part is formed by polyurethane foams. This was used as a co-combustion material in a rotary kiln type MSW combustion plant. The tests demonstrated that up to 15% ASR fluff can be added successfully, resulting in a more stable combustion with levels of emitted gases meeting European standards.

Post-consumer slabstock foam which often occurs in large pieces can (after processing in a guillotine or rotary compacting/shredding unit as installed on many state-of-the-art MSW combustors) be mixed with MSW to form a homogeneous fuel blend for the combustion process.

US trials, carried out by PURRC involved a full scale burn in a commercial scale MSW installation including up to 20% (by heat input) of flexible urethane foam. No perceptible changes to the combustion conditions or changes in emission were reported. To exclude ignition in the feeding device of the combustor and to balance the effects of the low density material, it is recommended to avoid localised high concentrations of foams and to mix the foams well with the MSW prior to feeding. Foam addition should not exceed 2% by weight which can be more than 30% by volume.

Emissions during the incineration of flame-retarded plastics have always been of concern. The PU industry therefore initiated a series of trials at the incineration test facility in Karlsruhe (TAMARA). Results from these trials demonstrate that there is no impact of rigid polyurethane foam containing chlorine, bromine and phosphorus on emissions. Hence flexible foams containing fire-retardant additives can also be safely co-fired with MSW.

MSW units are designed to operate at a maximum calorific value of 2000 kcal/ton. Current MSW has a calorific value of 1800 kcal/ton and therefore the scope for addition of plastics waste in general or polyurethanes in particular is limited. This explains why other techniques to recover energy have also been explored.
Co-fuel for cement kilns

The use of mixed plastics waste (MPW) (as co-fuel in cement kilns), either as a powder or in compacted form, is under study in several countries. Trials at Unterfaz in Switzerland, replacing primary fuel with up to 16% by weight of MPW, showed lower emissions for SOx and NOx. The use of MPW as a co-fuel at these levels will require strict specifications with respect to the quality of this secondary fuel. Successful energy recovery via this route will depend strongly on the economics of a collection system with facilities for sorting, mixing, grinding and processing of MPW into a proper quality fuel.

Polyurethane foams, after proper conditioning, can form a sensible contribution to this much larger stream of mixed plastics waste.

Co-fuel for industrial boilers

Co-combustion trials of coal with polyurethanes and other plastics, have been carried out in circulating and stationary fluidised bed boilers. The feed preparation encompasses a size and volume reduction step. Energy recovery from these mixed coal and plastics fuels is very efficient (80%) and a reduction in some emissions relative to coal alone were observed. Nitrogen oxides concentrations were similar to those for coal alone and HCN from nitrogen-containing materials was not found in quantities above the trace level.

Energy recovery of PU foams in high efficiency industrial boilers can become a cost-effective recovery option only after a suitable logistic framework to collect foam waste is in place and the costs of logistics and foam pre-treatment can be reduced. Limiting factors such as the concentration of halogen in the fuel must be considered.
OTHER TECHNOLOGIES

Mono-combustion

Mono-combustion comprises all processes which are designed for the combustion of one specific type of fuel such as plastics waste. Successful trials have been carried out in Japan using flexible polyurethane foam in a special fluidised bed incinerator.

A power plant using plastics as the only source of fuel appears to be attractive, however a disadvantage would be the transport of relatively low density material over long distances to only a few specialised incinerators.

Feedstock recovery in steel industries

Increasing attention is being paid to an option where plastics waste is used in blast furnaces. Plastics waste, introduced to the lower part of the blast furnace, is cracked at 2000°C into carbon monoxide and hydrogen which reduce the iron ore. Flexible PU foam, after appropriate densification, is suitable for this process as long as halogen concentrations are within acceptable limits (1.5% b.w. Cl specified by Stahlwerke Bremen at present). A particular feature of this approach is a yield of over 50% in feedstock recovery on top of which one also obtains about 30% energy recovery.

Conclusions

Polyurethane foams are recyclable but, like any other plastics material, not indefinitely. Rebonding of flexible polyurethane production waste is well established. In a similar fashion, post-consumer waste could be used for rebond foams. However, the volume streams for rebond foams in relation to the market capacity do not allow further expansion of this approach. Moreover, recycling cannot be the single goal. It must be a step towards a sustainable development, guaranteeing that current needs are met without compromising future requirements. Ultimately, therefore, energy recovery should become one of the essential end-of-life options for polyurethanes.

This Fact Sheet highlights the technical status of various options to recover the energy of flexible polyurethane foams. Costs will largely determine the viability of any option in a defined application. The continued development of recycling technologies, investment in infrastructure necessary to support them, the establishment of viable markets and participation by industry, government and consumers will ultimately determine how maximum value is derived from post-consumer PU waste.

With the need for the conservation of resources and the reduction of the environmental stress within the total eco-balance, acceptance of combustion with energy recovery by authorities and the public at large is essential. That is why ISOPA continues to support the use of carefully controlled incineration to convert Europe’s post-consumer waste into valuable energy.
Suggested Reading

"The influence of plastics on the combustion of municipal solid waste"; TNO Institute of Environmental and Energy Technology, 7300 AH Apeldoorn, The Netherlands.

"Waste to energy"; Brochure, APME, Avenue E van Nieuwenhuyse 4, Box 5, 1160 - Brussels, Belgium.

"PDF as a source of energy"; M. Frankenhauser, Neste OY, Finland, 1992 (available from APME, Avenue E van Nieuwenhuyse 4, Box 5, 1160 - Brussels, Belgium)


"Large scale energy recovery trials on polyurethane, PET, acrylic and nylon"; Dr. DJ Soderberg, RA Lenton, AR Boylett and DA Hicks, “Recycle ’93” Davos, March 1993, Switzerland.


ISOPA has produced a brochure and a series of fact sheets on polyurethane recycling options.

The following are now available:

- Recycling Polyurethanes (Brochure)
- PU in Perspective
- Densification/Grinding
- Rebonded Flexible Foam
- Adhesive Pressing/Particle Bonding
- Regrind/Powdering
- Compression Moulding
- Chemolysis
- Feedstock Recovery
- Energy Recovery
- Energy Recovery from Flexible PU Foams
- Recovery of Rigid Polyurethane Foam from Demolition Waste
- Options in Practice
- Re-use of Particles

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ISOPA - the European Isocyanates Producers’ Association - is an affiliated organisation within the European Chemical Industry Council (CEFIC).

EUROPUR - the European Flexible Polyurethane Block Foam Manufacturers Association brings together the National Associations representing some 80 companies in 15 European countries.

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