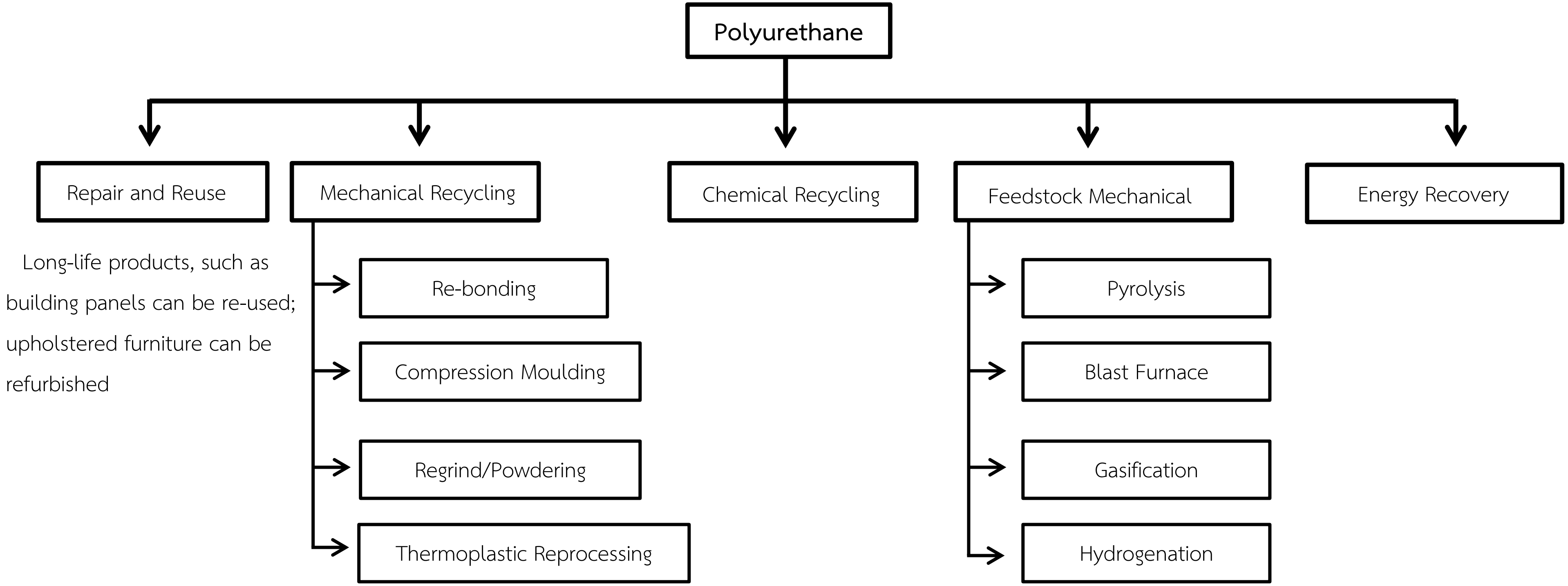
Options for Polyurethane Recycling and Recovery



Source: Fact Sheet "RECYCLING AND RECOVERING POLYURETHANES", ISOPA, 2001

Polyurethane Recycling Processes

Polyurethane is recycled in two primary ways: mechanical recycling, in which the material is reused in its polymer form, and chemical recycling that takes the material back to its various chemical constituents.

Mechanical Recycling

- **Re-bonding**

  Bonded foam properties can be varied over a wide range by careful selection of base material, particle size, compression ratio, type and quantity of the binder. As a consequence, rebonded flexible foam is gaining acceptance in applications which so far could not be satisfied by virgin foam material.

  The Process:

  1. foam collection and sorting
  2. shredding
  3. coating with adhesive binder
  4. compression to desired density and shape
  5. activation of adhesive binder
  6. curing of adhesive binder
  7. converting of rebonded foam parts

- **Compression Moulding**

  RIM and reinforced RIM polyurethanes are ground into fine particles and subjected to high pressure and heat to generate a material which is ideal for automotive applications. The grinding techniques and compression moulding process need to be controlled accurately for individual applications:

  - While there can be a small reduction in elongation or impact resistance, optimum timing, pressure and temperature can preserve the valuable properties of the original polyurethane.
  - The use of finely ground polyurethane powder in the compression moulding process allows for property recovery of up to 100%.

- **Regrind/Powdering**

  Regrind technology, sometimes also described as powdering, is a process to reuse ground polyurethane waste as filler in PU foams or elastomers. It involves two steps:

1. Grinding polyurethane material into a fine powder

   The first step in the regrind process is to reduce polyurethane production trim or post-consumer parts into small particles suitable for mixing and reuse. The optimum final particle size lies between 50 and 200 microns (0.05 - 0.2 mm), depending on the application.

   Another grinding process, successfully used at pilot scale for flexible foams, is the pellet mill. It consists of two or more metal rollers, which press the polyurethane foam through a metal plate with small holes (die).

   Other technologies, such the precision knife cutter, are also under evaluation for the grinding of flexible foams. A particular process combining cutting and mixing involves a high shear mixer installed in the polyol tank. The added benefit of this process is the prevention of any thermal degradation of the powder during size reduction.

   Glass filled RIM parts require special grinding methods. The impact disc mill appears to be suitable as technique for pulverising such very tough parts.

2. Mixing powder with the polyol component to make new polyurethanes

   At pilot scale, the high shear mixer appears to be suitable to provide the right mixing quality. The step to operational activity however, requires adequate metering of the powder alongside the polyol. The metering unit of the entire PU machine needs to be suitable for the handling of filled polyols. Such technologies do exist. These were developed when glass filled RIM was first introduced into the market or when melamine powder was introduced into the flexible foam industry. The moisture content of the powder is critical and drying of the powder could be necessary before mixing.

- **Thermoplastic Reprocessing:** For all themoplastic grades

Chemical Recycling

- **Glycolysis**—This process combines mixed industrial and post-consumer polyurethanes with diols at high heat, causing a chemical reaction that creates new polyols, a raw material used to make polyurethanes. These polyols can retain the properties and functionality of the original polyols and can be used in myriad applications.
- **Hydrolysis**—This process creates a reaction between used polyurethanes and water, resulting in polyols and various intermediate chemicals. The polyols can be used as fuel and the intermediates as raw materials for polyurethane.
- **Pyrolysis**—This process breaks down polyurethanes under an oxygen free environment to create gas and oils.

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Feedstock Mechanical

In reality, polyurethanes waste materials are more often found in mixed waste streams. So other feedstock recycling processes have been developed to recover oil and gas products from these mixed plastics wastes, of which polyurethanes materials could be one constituent.

- **Pyrolysis**

  In a pyrolysis process, the mixed plastics are heated in an inert atmosphere and the molecules broken down into liquid and gaseous hydrocarbons. Pyrolysis, in this context, is a feed preparation step. The products would be further processed in a range of petrochemical processes to obtain a variety of different products.

  A consortium of companies built a pilot plant in the UK trying to optimise the design for running a range of mixed plastics materials including packaging, electronic and electrical wastes and plastics from the automotive sector.

- **Blast Furnace**

  In the past, heavy oil or coal dust has been used as a reducing agent in the blast furnace for converting the iron ore to metallic iron. Now up to 30% of these materials can be replaced by mixed plastics, which are injected into the furnace.

  At temperatures in excess of 2000°C, the plastics are broken down into mainly carbon monoxide and hydrogen. These capture the oxygen from the iron ore, producing carbon dioxide, steam and pig iron.

  Other blast furnace operators are now showing an interest in a range of mixed plastics waste streams, and it is likely this option will provide a large volume solution for much of the waste which will become available in the near future.

- **Gasification**

  Of all the feedstock recycling processes, the gasification process is likely to prove the one of most interest for polyurethanes materials. In a two stage process, mixed plastics are heated, then combined with air or oxygen. A synthesis gas, consisting of carbon monoxide and hydrogen, is produced. This gaseous product can be used in a wide range of refinery processes as well as in production of methanol, ammonia, and oxo-alcohols.

  In trials, with polyurethanes materials forming a small part of the mixed plastics waste feed, the nitrogen inherent in polyurethanes has proved beneficial in the acid gas neutralisation process and thus improved the economics of the process.

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- **Hydrogenation**

  The plastics are treated with hydrogen under high temperature and pressure conditions causing the cracking of the polymer chains to liquid and gaseous hydrocarbons. These products can again be used in refineries and chemical plants.

  This process has been used in the past to upgrade refinery waste products and is now being applied to mixed plastics waste from the packaging waste stream in Germany. It is being trailed for non–packaging waste streams.

Energy Recovery

Incineration with energy recovery has an important role to play, viewed within the context of the growing range of recycling and re-uses options for plastics, including polyurethanes. With 86% of the world's oil, coal and gas being burnt for energy, there is a strong case for partial substitution of the energy resources with waste plastics. Where it is identified as the most appropriate waste management option, modern technology can now ensure that the emissions from waste combustion plants are safely managed.

Polyurethanes can be incinerated safely. Incineration in MSW or other state-of-the-art combustors is, therefore, a viable treatment where other options for recovery and recycling have no environmental benefits or are ecologically or economically more costly. The plastics content of MSW helps to incinerate other components in the MSW without the need for additional fuel. Trials with an addition of 2% by weight of polyurethanes (which can be more than 30% by volume) have been carried out with flexible and rigid polyurethane foam waste with very good results. An additional advantage is that the incineration process reduces the polyurethane foam waste to 1% or less of its original volume which strongly reduces the need for landfill.

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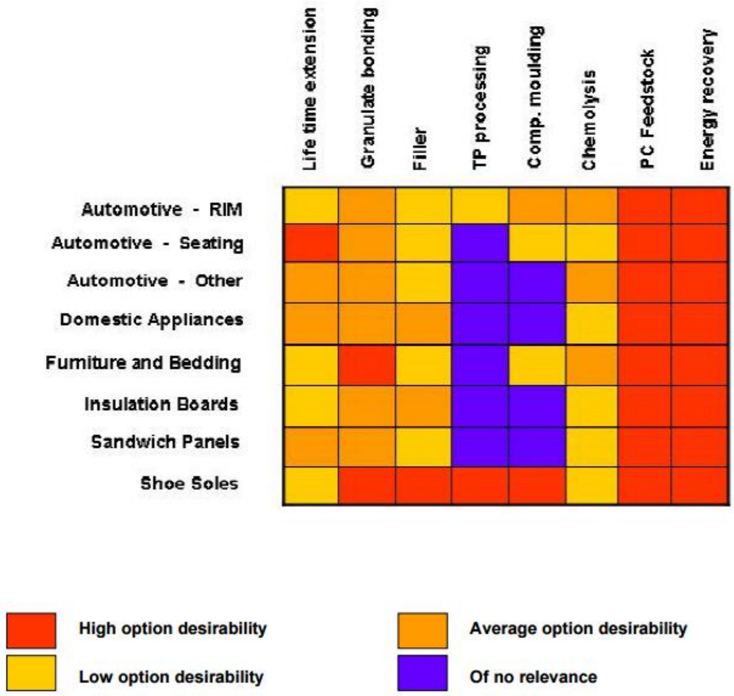
Applications areas/waste sectors and the recycling and recovery technologies which are relevant



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