

## Recycling PA6 from End-of-Life Vehicles into New High-Performance Parts

# Turning Old into New

So far, very little polyamide 6 from end-of-life vehicles has been recycled. To establish a recycling loop for this material, BASF has developed two recycling processes making it possible to produce high-quality recycled materials from end-of-life vehicles. The recycled materials have now been tested in real components in collaboration with industry partners.



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The European plastics industry is facing a profound transformation due to the EU's new End-of-Life Vehicle Regulation (ELVR). Under this regulation, the European Union is significantly tightening the requirements for the recycling of end-of-life vehicles (**Fig. 1**). About 200 kg of polymeric materials per vehicle have so far been primarily incinerated for energy or landfilled. The industry is facing dual pressure from ever-tougher regulatory requirements and growing expectations from OEMs and society to manage plastics in closed-loop systems. Raw material shortages and geopolitical uncertainties are reinforcing this trend.

There is a growing focus on such engineering plastics as polyamides because they are indispensable in mod-

ern vehicles but have so far been rarely recycled. At the K 2025 plastics trade fair, BASF presented two advanced-recycling technologies – depolymerization and solvent-based recycling – that can close the material loop for polyamide 6 (PA6) in automotive applications (**Fig. 2**).

To demonstrate the effectiveness of these processes, real components made from recycled materials were produced in cooperation with ZF, Pöppelmann, and Mercedes-Benz. These included a stabilizer link and a chain guide rail (**Fig. 3**). Initial life cycle assessments conducted in collaboration with ETH Zurich indicate that the Product Carbon Footprint (PCF) of the recycled PA6 grades is significantly smaller than that of virgin material.

### *Why Classical Recycling Has Its Limits*

Due to its high strength and resistance to heat and chemicals, PA6 is virtually irreplaceable in technical and safety-critical components. However, its production is energy-intensive and dependent on petrochemical feedstocks. Mechanical recycling processes quickly reach their limits, as material quality is compromised by thermal aging, additive degradation, shortening of glass fibers, and contamination. The ELVR not only requires higher material recovery rates but also explicitly calls for the reuse of recycled plastics in vehicles – a paradigm shift toward true vehicle-to-vehicle cycles. The two processes developed by BASF have the potential to enable the reuse of PA6 from end-of-life vehicles in new cars.

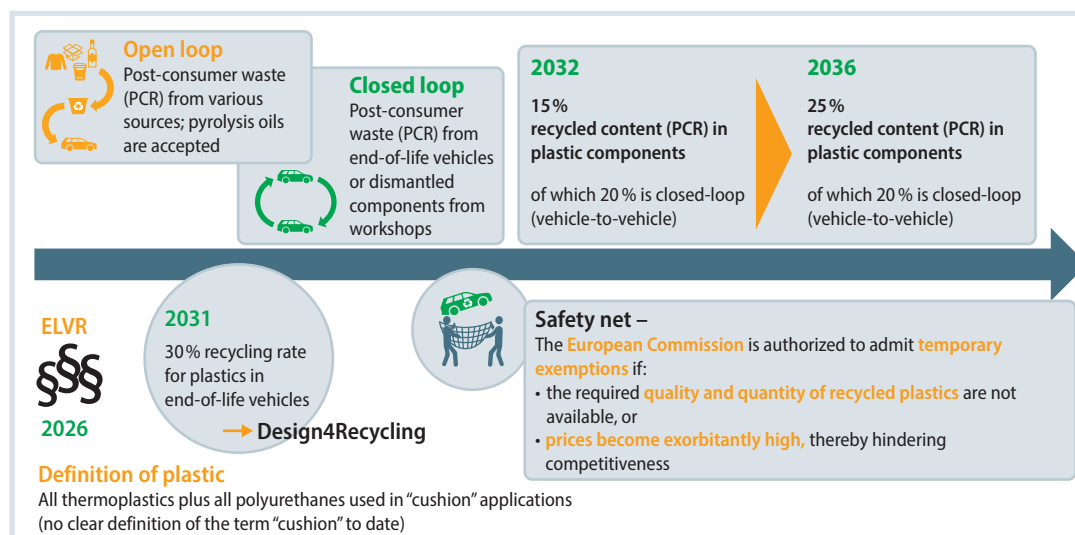


**Fig. 1.** Overview of the objectives of the End-of-Life Vehicle Regulation (ELVR).

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The depolymerization of PA6 is based on a chemical process in which polymer chains are selectively broken down into caprolactam, the original monomer. Contaminants from the material's service life – oil, additive degradation products, and foreign matter – which push mechanical recycling processes to their limits, play virtually no role in this process.

The purified caprolactam is polymerized again, resulting in PA6 whose properties match those of virgin material. Further processing into a glass-fiber-reinforced compound does not impose any special requirements on the compounding process, while allowing flexibility regarding glass-fiber content, additive package, and coloring. This facilitates a fully closed-loop cycle that is even suitable for safety-critical components.

### Recycled Material with Virgin-Grade Quality for Components

In the pilot project with ZF, used transmission oil pans from end-of-life vehicles served as the feedstock – plastic components that were previously considered non-recyclable because of their heavy soiling and contamination with oil and metal abrasion. Through depolymerization, it was possible to convert all the PA6 used back into caprolactam. ZF processed the glass-fiber-reinforced PA6 compound (product name: Ultramid B3WG12 RC4 40 SW23228) produced by BASF from this material into a stabilizer link – a heavily stressed chassis component – for Mercedes-Benz (Fig. 4).

Prototyping demonstrated robust processing behavior with no significant deviations from virgin material – mold filling, cycle time, and surface quality

met expectations. The pilot parts satisfied all relevant mechanical and processing requirements. The necessary dimensional stability, surface quality, and

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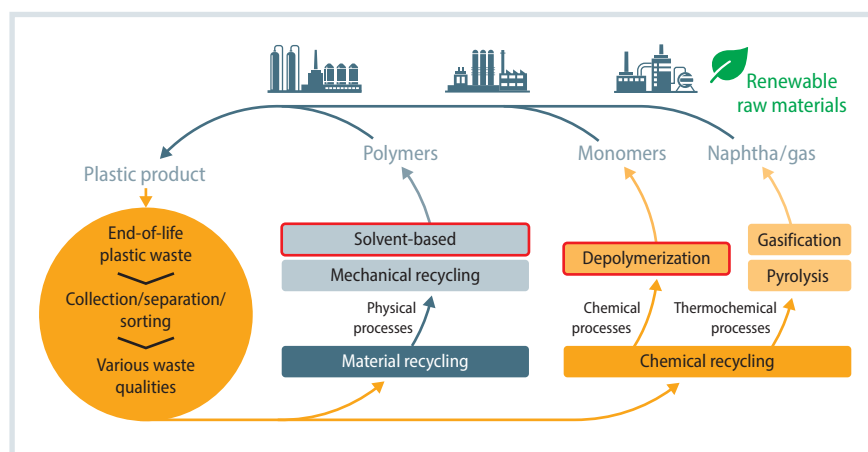


**Fig. 2.** Illustration of the various plastic recycling loops, highlighting the advanced recycling processes presented in the article. Source: BASF; graphic: © Hanser

**Fig. 3.** Closed-loop cycles with depolymerization and solvent-based recycling for PA6. Source: BASF; graphic: © Hanser

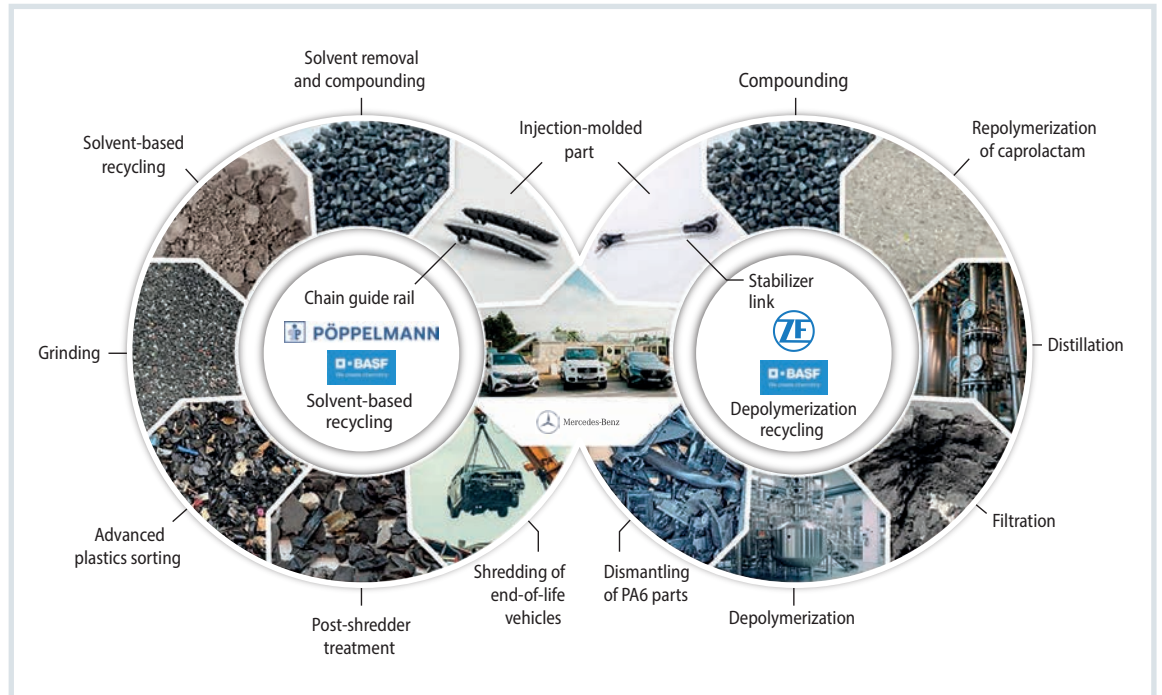


**Fig. 4.** Successful basic testing: ZF processed the recycled material into a technically sophisticated chassis component – a stabilizer link – for Mercedes-Benz. © BASF

mechanical properties were achieved. The recycled material matches at least virgin material quality in all key performance metrics (**Fig. 5**).

### **Pre-Production Testing as the Next Step**

The next crucial step toward the industrial implementation of depolymerization is pre-production testing of the developed components in endurance tests. Since the pilot project has already demonstrated that the PA6 produced from recycled material matches the properties of virgin material and meets all mechanical and processing requirements, the transition to real-world operating conditions can now be made. The performance demonstrated in the laboratory is to be confirmed even under long-term stress during vehicle operation.

The use of recycled material for heavily loaded components such as the stabilizer link underscores the high level of confidence all project partners have in the technology and the material quality. At the same time, this material technology marks an important step toward widespread application in production vehicles and, consequently,

toward closed material cycles in the automotive sector.

### **Solvent-Based Recycling of PA6**

Solvent-based recycling addresses a different waste stream, Automotive Shredder Residue (ASR). ASR is the shredder waste from vehicles after metals have been largely removed from them. It consists of a heterogeneous mixture of plastics, rubber, textiles, foams, and coatings. Together with partners, BASF tested new sorting and processing technologies to extract a largely pure PA fraction from it. The PA6 is dissolved through selective extraction, separated from contaminants and other polymers, purified, and thereby recovered. The resulting compound, Ultramid B3WG7 RC6 60 BK00564 from BASF, is of high quality and suitable for demanding technical applications.

## **Advantages of the Recycling Technologies at a Glance**

- Closed PA6 loop: Suitable for use in high-stress automotive components
- Virgin-grade quality from recycled material meets all mechanical and processing requirements
- Significantly reduced PCF compared to virgin material
- Utilization of complex waste streams: Even ASR and heavily contaminated materials can be recycled
- Reduced dependence on raw materials and higher value creation: New potential from previously unused waste

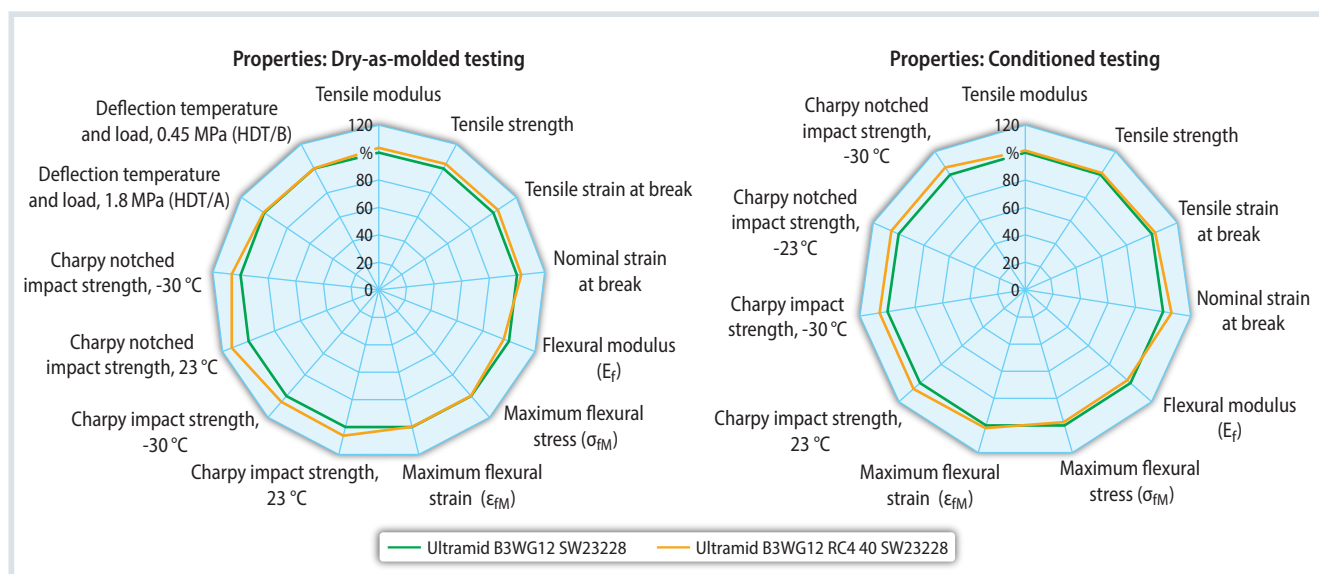


Fig. 5. Mechanical properties of the recycled material versus virgin material. Source: BASF; graphic: © Hanser



Fig. 6. From the recovered PA fraction, solvent-based recycling facilitated the production of a recycled PA6 compound, validated on a production-quality chain guide rail manufactured by Pöppelmann for Mercedes-Benz. © BASF

In collaboration with project partner Pöppelmann, this recycled material was processed into a chain guide rail for Mercedes-Benz – a heavily loaded functional component in the engine with strict requirements regarding resistance to wear, heat, and chemicals (Fig. 6). The results demonstrate that even more complex plastic fractions can be successfully processed. Solvent-based recycling thus represents a complementary technology to depolymerization, albeit for different waste fractions.

### *As Good as New and with a Significantly Reduced Product Carbon Footprint*

Both processes clearly demonstrate their unique selling points. Depolymerization is particularly suitable for heavily contaminated PA6 components such as

oil pans to remove contaminants and completely eliminate polymer history – thus restoring virgin material quality. Solvent-based recycling demonstrates its strengths with complex waste streams such as ASR: Where established sorting methods cannot achieve the separation of pure plastics by type, the solvent performs this task. Together, both technologies enable a significant increase in the material recovery rate of PA6 from end-of-life vehicles in accordance with the requirements of the ELVR.

The environmental benefits are also considerable: Initial life cycle assessments (LCA) conducted with ETH Zurich show that the PCF of the recycled PA6 grades is significantly smaller than that of virgin material. Depending on the process route,

savings in the double-digit percentage range are realistic. New economic opportunities are also emerging, as these processes reduce dependence on volatile raw material prices, unleash value-creation potential from unused waste streams, and enable OEMs to meet regulatory requirements early on.

### *Partnerships as the Key to Scaling up*

The collaboration between BASF, Mercedes-Benz, ZF, and Pöppelmann shows how industry partnerships are accelerating the transition. The pilot projects presented at K 2025 demonstrate that heavily used engineering plastics from end-of-life vehicles can be processed so that they can be reused in demanding automotive components. The combination of depolymerization, solvent-based recycling, thermochemical processes, strong partnerships, and regulatory pressure is ushering in the era of the circular economy for engineering plastics, and particularly for PA6. What was once considered non-recyclable is becoming a raw material for the next generation of vehicles.

However, the path to industrial implementation depends on demand. Scaling up facilities, expanding sorting technologies, integration into OEM supply chains, and obtaining certification to international standards will only succeed if there is a clear commitment to purchasing the resulting recyclates. ■