

REPURPOSE

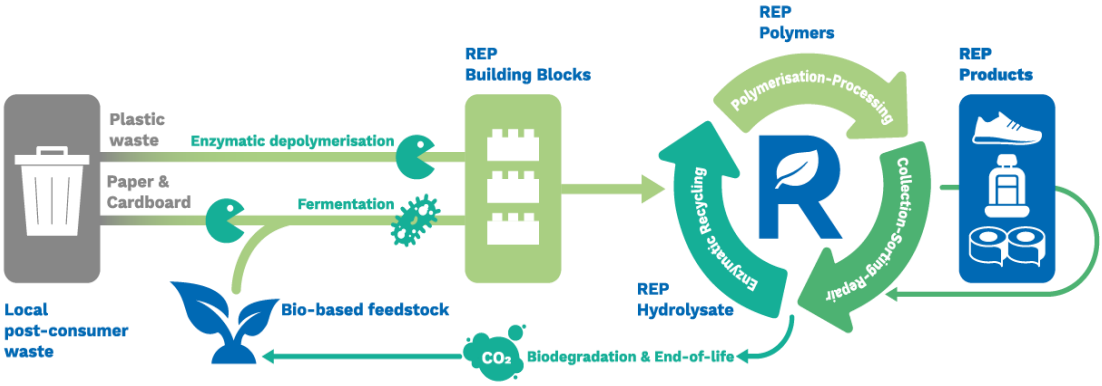
Turning local waste into safe, circular plastics

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The REPurpose project, funded by the European Union under Horizon Europe, has concluded after four years. Coordinated by Bio Base Europe Pilot Plant (BBEPP), a consortium of 12 partners from 9 European countries worked together to develop a Safe-and-Sustainable-by-Design platform where local post-consumer waste is upcycled into new polymers (REP polymers) for the high-value multifunctional thermoplastics market.

Most plastics are still made from fossil resources, and many contain additives that can harm people and the environment. These additives can account for up to 70% of a plastic's weight, with more than 200 listed by the EU as substances of very high concern. At the end of their lifetime, many plastic products remain difficult to sort and recycle, often resulting in incineration or disposal in landfill.

REPurpose addressed these challenges by developing an **integrated value chain from waste feedstocks to finished products**, with each partner contributing expertise at a specific stage.



From waste to new plastics

Paper and cardboard (P&C) from Municipal Solid Waste was transformed into a valuable source of 2nd generation fermentable sugars. After being sorted and pretreated by Renasci (now BlueAlp Ostend), the scalable enzymatic hydrolysis process was demonstrated at m^3 scale by BBEPP, producing a glucose–xylose-rich hydrolysate, which was successfully used for fermentation to higher-value dicarboxylic acids (glutaric and muconic acid) at lab (Saarland University (USAAR)) and at pilot scale (BBEPP). This created a pathway to valorise P&C waste through industrial biotechnology, enabling the production not only of biobased chemicals, but also biopolymers, biofuels, ingredients, biostimulants, pigments and other high-value products currently derived mainly from 1st generation sugars.

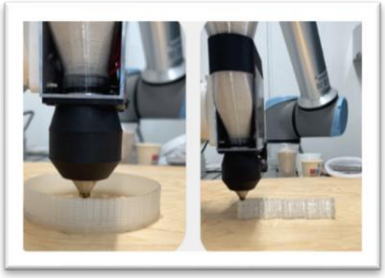
Lignin was also successfully valorised as an abundant 2nd generation feedstock, with USAAR's HTC (Hydrothermal Carbonisation) process converting it into an aromatic-rich hydrolysate that was transformed into muconic acid up to pilot scale. It can be used directly as a polymer building block or hydrogenated to adipic acid, providing a more sustainable route to nylon-6,6 and other polymers.

REPurpose also extended waste valorisation to polyester and polyamide streams. Enzyme production and enzymatic depolymerisation processes developed by BOKU University and Epoch Biodesign were scaled up by BBEPP and Epoch Biodesign. The resulting waste-derived monomers and oligomers were isolated in up to hundreds of kgs scale, while engineered polyolefinases have shown potential for converting polyolefin waste into mixed dicarboxylic acid monomers.

Aimplas and B4Plastics used the portfolio of waste- and bio-based building blocks (diols and diacids) to create polyester-based REP polymers. More than 20 formulations were designed in the lab, and the best 3 were successfully produced at the 10 kg scale.

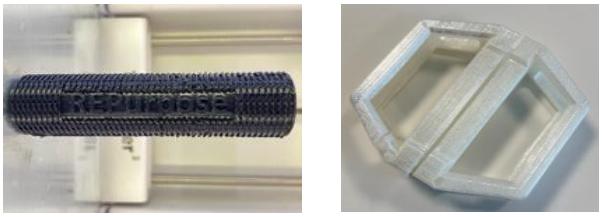
REPurpose prototypes

REP was processed using equipment already widely used in industry, including injection molding, thermoforming, heat pressing and 3D printing. In collaboration with prospective industrial end users (e.g., FAIR Bicycle, ATMAT and Werner Sobek), AAU developed REP prototypes for **three sectors**:



Robotic 3D printing.

- **Automotive:** a full-scale car door handle, an airbag cover and a driver footrest.
- **Sports and consumer goods:** bicycle grips, pedals and stands, and a screwdriver with a detachable handgrip.
- **Building and construction**: wall and floor panels, natural-fibre reinforced partitions, ceiling panels and a robotically 3D-printed planted wall module.



REPurpose prototypes of bicycle handlebar grips and pedals.



REPurpose prototypes of automotive footrest and interior door handle.



REPurpose interior-panel samples.

Designed for recycling, reuse and repair

Design for recycling was built into REPurpose at two levels.

- At polymer level REP polymers were designed with built-in "breaking points" that enzymes can recognise, so they can be taken apart again into building blocks. The project's own enzymes were

shown to break down REP, paving the way for enzymatic recycling of REP polymers. The REP polymers were also found to be reprocessable for mechanical recycling.

- At the product level, Aalborg University (AAU) investigated the reuse of REP sheet offcuts generated during prototyping by incorporating them into new partition components. This demonstrated that manufacturing residues can be retained in useful applications. Potential recovery pathways were also identified for failed prints and components unsuitable for direct reuse, including shredding and reprocessing into new REP semi-finished products. These results demonstrate a practical route for reusing REP production waste and provide a basis for developing further material recovery options.



Push-broom setup used for the final REP measurements.

Design for recycling also requires effective sorting and collection, in case REP products end up in waste streams. Photon Mission identified near-infrared hyperspectral imaging, a technology already used in sorting plants, as the most suitable technique to detect REP, and validated it in an experimental set-up directly relevant to industrial sorting. The final measurements showed that REP polymers have a distinctive "fingerprint" that sets them apart from conventional plastics, so they can be recognised and separated automatically from mixed plastic waste and sent to the right recycling route.

Finally, AAU followed Design for Disassembly principles by developing modular REP prototypes for bicycle components and building partitions, using detachable connections to make parts easier to repair, replace or rearrange. This can extend product life, reduce whole-product disposal and enable component reuse at end of life.

Safe and Sustainable by Design

REPurpose was among the first projects to implement the European Commission's Safe and Sustainable by Design (SSbD) framework in the development of novel polymers, integrating safety and sustainability considerations from the earliest stages of material development.

All building blocks used in the upscaled REP materials are registered for safe use already, as demonstrated on the ECHA website. No additives were used for the developed REP library, since functional behaviour was designed via the polymer backbone architecture. AIMPLAS found no harmful effects on human skin cells and no skin irritation, supporting their suitability for applications involving skin contact. Tests on algae and fish, conducted by the Hungarian University of Agriculture and Life Sciences (MATE), showed very low



toxicity and no hormone-disrupting effects, and in long-term tests on fish REP polymers performed better than widely used commercial counterparts. Post-composting assessments likewise detected no measurable ecotoxicity or harmful bioactivity in the tested residues, supporting safety across the evaluated end-of-life conditions. Together, **these outcomes provided experimental support for the project's SSbD approach and reduced reliance on potentially harmful additives**.

Italbiotec evaluated the performance of the REPurpose value chain through life cycle assessment, social life cycle assessment, and techno-economic analysis. Integrating these assessments during material and process development, well before market entry, can help identify the stages with the greatest environmental and cost impacts, inform research priorities at an early stage, and provide a basis for scale-up decisions.

REPurpose produced several resources to support safer polymer development and additive substitution:



- The project translated SSbD principles into practical polymer-development guidance in its **knowledge book on best practices on SSbD polymer and product development**. Based on consortium experience, it complements the hazardous-additives inventory and roadmap to support continued adoption of SSbD (soon available on our website).
- Additionally, a **report including recommendations for policymakers** related to the additives inventory, standardisation framework and proposals, and REP safety and regulatory compliance was also developed.
- **The Inventory of Plastic Additives complements ECHA and other sources** by consolidating information on additives' regulatory and chemical-safety profiles. It helps stakeholders identify information gaps and emerging concerns, anticipate restrictions, prioritise substances for substitution, and support regulatory screening, alternatives assessment and safer-by-design development. In AVEP's project survey, only 2% of 177 participating companies fully applied SSbD principles (the preliminary version of the Inventory, Deliverable 2.1, is already available on our website, while the final version will be published shortly).

Project impacts

Overall, the REPurpose project has significantly contributed to the following wider impacts:

- From an industrial perspective, the project gained significant insights into the transition from linear to circular plastics by demonstrating that these waste-based materials can meet the processing requirements of conventional manufacturing.

- Proving the commercial viability of these materials across diverse markets, including automotive, building and construction, and consumer goods, provides European manufacturers with a sustainable alternative to virgin resins.
- By replacing virgin fossil feedstocks with recycled monomers and incorporating natural-fiber reinforcements, the project significantly reduces the carbon footprint of structural components.
- In the longer term, REPurpose drives tangible environmental benefits by diverting difficult-to-recycle post-consumer plastic waste away from incineration and landfilling toward durable, high-value engineered products with extended lifespans.
- These efforts help accelerate the creation of secondary raw-material markets and enable downstream industries to align with tightening EU circular economy and ecodesign regulations.
- Overall, the implementation of SSbD criteria, alongside modularity and non-toxic profiles, ensures these next-generation materials remain safe and circular by design, directly advancing EU sustainability goal.



REPurpose consortium (October 2023, Wien).

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