

LIFE ABSolutely Circular Layperson's report

Project Number: LIFE19 ENV/DE/000652





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1. The project

Plastic waste is a major environmental challenge. In Europe, only a small share of plastic waste is effectively recycled, and polystyrene (PS) recycling rates are particularly low.

The LIFE ABSolutely Circular project set out to show a new path: using chemical recycling technology to turn post-consumer PS (a common plastic type used in many applications like household devices, electronics or packaging items like yoghurt pots) waste back into its base building block—styrene monomer—and then using this recycled styrene monomer to make high-quality polymers again. This brings us closer to a practical circular economy for styrenics.



Standard ABS

The project pursued three practical objectives:

1. Incorporate recycled styrene monomer into ABS (acrylonitrile butadiene styrene) to create a copolymer with 60% recycled attribution.
2. Prove the material's compatibility for customer applications in highly demanding pilot consumer products.
3. Assess environmental and economic performance of chemical recycling within a circular plastics system.

With an overall spend of 2.5M€ complemented by 1.4M€ of EU contributions across five years of run time (September 2020 until December 2025), the ABSolutely Circular project contributed significant innovation for a European and global transition to a more sustainable future.

2. The approach

The project used depolymerisation, a thermochemical process that breaks PS molecules back up into shorter styrene monomers. This process of recycling the waste straight back to the raw material only works for very few plastic types, including PS. The recycled monomer can then be purified and fed into any existing styrenics-based polymer production asset, such as for ABS production. This “drop-in” approach allows recycled feedstock to be used in chemical value chains without major adjustments to the proven industrial processes for polymer applications, which significantly supports the transition to a circular economy.

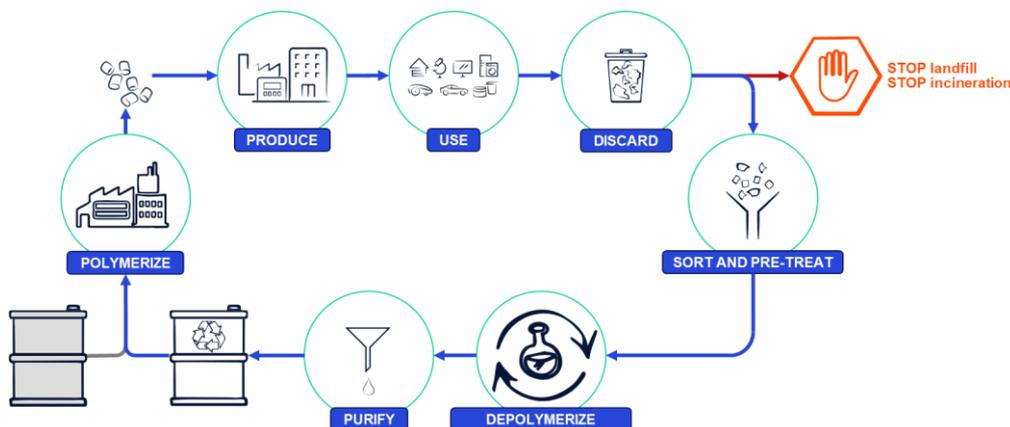


Figure 1: Depolymerisation as a pathway to a circular economy

Styrene is the basis for many kinds of plastics used in all areas of modern life. They make our commutes faster, our appliances more durable, our hospitals more sanitary, our lives safer – in short, modern life would not be what it is today without them. In providing lighter, simpler, and more flexible solutions, they often make up the more sustainable alternatives when it comes to raw material choices.

Repurposing plastic waste streams as a feedstock for the same or other plastic applications, using production processes as energy efficient as possible, addresses two challenges at once: it stops plastics from

ending up in our environment and lowers the industry's emissions. Therefore, depolymerisation is an important and powerful innovation for the chemical industry and its transition to a truly circular economy.

3. The progress

The project moved along the following milestones:

Feedstock secured

More than 10,000 tonnes per year of separately collected PS waste from household streams made available for depolymerisation.



Bales of household waste

Infrastructure built

Indaver constructed a 26 kt/year chemical recycling demo plant in Antwerp, supported by a dedicated waste pre-treatment unit.



Indaver P2C site in Antwerp

First deliveries

After commissioning and quality optimisation, the first on-spec recycled styrene monomer was delivered to INEOS Styrolution in August 2025.



INEOS Styrolution welcoming the first delivery of recycled styrene monomer

Industrial integration

INEOS Styrolution processed the recycled styrene monomer in its Antwerp operations, producing ABS with a 60% circular (recycling content) attribution (ABrS) via mass balance.



The entire value chain, from waste over styrene monomer to copolymer, is certified as per

the ISCC PLUS standard, ensuring a robust chain of custody to trace the flow of alternative feedstocks through complex value chains such as the one of chemical products.

During the production process, certified feedstocks are mixed with conventional materials, resulting in products that are physically indistinguishable from those made solely from conventional feedstock. By using the mass balance system, companies can document and track the exact amount of alternative feedstock used, ensuring that the quantity of alternative feedstock allocated to the product matches the quantity sourced at the start of the production.

Consumer-relevant testing

A project partner, which is a leading ABS user in a highly demanding and sensitive consumer goods industry, received 500 kg of ABrS. Their extensive trial showed that the material matched conventional ABS on all key properties and processing behaviour, meeting all necessary requirements.



ISO test elements moulded from ABrS

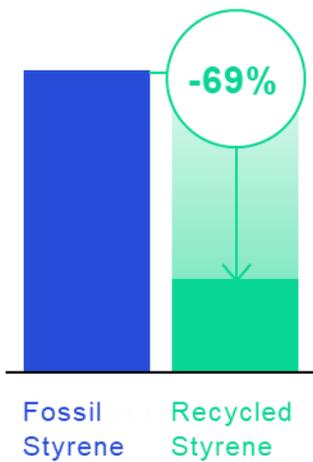
4. The benefits

Over the course of its runtime, from 2020 to 2025, the project diverted significant amounts of post-consumer PS waste from landfill, incineration or leakage to produce recycled styrene. Three sources of climate benefit were demonstrated:

- avoided emissions by replacing virgin styrene production,
- avoided emissions from waste disposal, and
- reduced plastic leakage by creating value for post-consumer PS waste streams.

In order to ensure success of the project and estimate its positive impact on the environment early on, a Life Cycle Assessment (LCA) was conducted, based on small-scale samples and upscaling expectations.

As expected, the study found that the utilisation of PS waste as a raw material delivers a significant environmental improvement compared with the reference scenario of waste incineration. Furthermore, the production of styrene monomer from PS waste also proved to be favourable over fossil resources, and so the confidence in the project's viability was further cemented. Then the study's results were only left to be proven in practice.

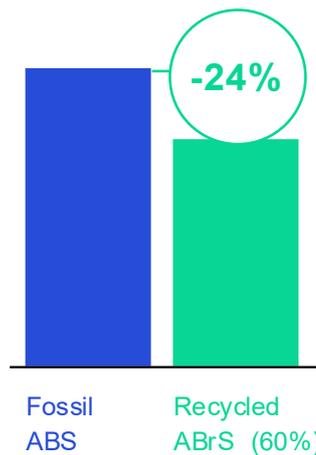


PCF comparison to styrene

Indaver's depolymerisation plant eventually came online in 2025. Based on the latest production information, the carbon footprint of recycled styrene is lower than its fossil counterpart, as expected. However, as production is increasing gradually during a ramp-up phase, the actual recorded emission measurements are not yet representative of a fully scaled-up, continuously operating plant. Therefore, the carbon footprint saving for recycled styrene will increase even further in future. To gain a better understanding of this additional carbon footprint benefit, several production scenarios were modelled, focusing on improvements such as the recycled styrene yield.

These carbon footprint calculations demonstrate that switching from fossil styrene to recycled styrene made from post-consumer PS waste has the potential to reduce greenhouse gas (GHG) emissions by up to 69%, per tonne of styrene produced.

ABS, a copolymer manufactured from acrylonitrile, butadiene and styrene, makes up a large portion of the styrene-based applications. However, since styrene is only one of the three major building blocks of this copolymer, the maximum possible share of chemically recycled material from depolymerisation amounted to roughly 60% in the final grade.



PCF comparison of ABS

One of Europe's largest ABS users cooperated on the business case for this pilot grade. The pilot grade of ABS has a carbon footprint that is 24% lower than fossil ABS, when substituting the full styrene portion and taking a conservative approach on the emission savings for the pre-cursor styrene.

The emission data can be updated once the plant runs reliably at scale and delivers the designated volumes to its off-takers. As operations scale up, the absolute environmental benefits will increase.

5. The economics

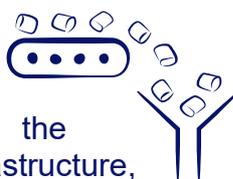
The project anchored significant private investment (about €75 million for the chemical recycling unit and €30 million for pre-treatment). It created and supported qualified jobs across the value chain—waste management, recycling, polymer production, and downstream applications. While recycled styrene currently carries a cost premium versus virgin material, scaling, learning, and supportive regulation to incentivise recycling are expected to narrow this gap over time.

6. The outlook

The project delivered evidence that recycled styrene monomer can be used as feedstock for styrene-based applications. However, for this knowledge to have real impact, it must be widely adopted and scaled up. Several factors already contribute to a positive outlook for this blueprint of a chemical supply chain.

Drop-in use

The recycled styrene monomer can be used in existing styrenics production plants without any technical modifications or additional regulatory requirements, enabling a rapid replication across the industry. In an industry built on highly engineered infrastructure, this aspect is critical to enable adaptation and amplify impact.



Sector reach

ABS, PS, and other styrene-based polymers are used in appliances, automotive interiors, electronics, consumer goods, and many more applications—offering many routes to scale. And given its drop-in use, the entry barrier to other markets is attractively low.



Geographic scalability

The model can be expanded wherever PS waste streams and polymer assets exist, effectively allowing adoption of the method on a global scale.



7. The commitments

All project partners plan to continue, scale and commercialise the pathway demonstrated in this project. Indaver will focus on ramp-up and realising the plans for a potential expansion to 65 kt/year of capacity.

INEOS Styrolution plans broader adoption of circular styrene across its entire portfolio, enabling customers across the board access to recycled materials. Especially in sensitive applications where mechanical recycling of waste is not (yet) an option, chemical recycling can create new opportunities. It can also convert waste portions that do not have suitable quality for mechanical recycling, broadening the applications for high-quality recycling.

Customers will evaluate the full-scale integration of recycled styrenics as part of the 2027 tender cycle and beyond. With maturing legislation (e.g., recycled-content requirements) and maturing markets, volumes of recycled styrene monomer and polymer are expected to increase, delivering sustained GHG reductions and keeping more plastics in circular productive use.

8. The challenges

The project had to deal with many challenges across its five years of run time:

- Economic downturns
- Regulatory uncertainty
- Demand uncertainty
- New technology risk
- Risk of delays in new construction builds

Economic downturns like the current one create two issues: Investments are being made more difficult due to the low profitability of the industries, leading to a higher scrutiny and less appetite to direct financial resources to risky, innovative projects. At the same time, downstream demand is lowering and, in particular, the ability of companies to pay a premium for innovative materials like recycled plastics is significantly reduced, lowering demand for recycled products.

High quality plastics recycling is in scale-up. As it was not broadly available, the regulatory and legislative framework has not yet been established. Throughout the duration of the project, the EU, member

states and other institutions were working on defining the rules. It is a complex and lengthy process before final legislations are defined and implemented. This is in conflict with the planning certainty required for large investment projects like this or other recycling investments in the industry: A final investment decision must be taken without clarity on the regulatory framework, making such investments difficult to plan and inherently risky.

Regulatory uncertainty also trickles down to plastics converters. It took a long time to define measures such as mandatory recycling content targets in plastics packaging, and it will still take years more before they are enforced. Therefore, converters struggle to determine the right transition strategy. At the same time, consumers are not yet used to recycled plastics in sensitive applications like food packaging or toys and need to be informed about these products to create a market pull.

Finally, recycling technologies like depolymerisation of PS are innovations. It is therefore normal to encounter surprises and learnings during the process, which can lead to changes in the approach, longer timelines, and changes in yields and costs.

To address these challenges, EU funding like in the LIFE programme plays a crucial role in enabling innovative recycling solutions.

Glossary

ABS: Copolymer manufactured from **A**crylonitrile, **B**utadiene and **S**tyrene

GHG: **G**reen**H**ouse **G**as

ISCC: **I**nternational **S**ustainability & **C**arbon **C**ertification

LCA: **L**ife-**C**ycle **A**ssessment, a methodology for assessing the impacts associated with all the stages of the life cycle of a commercial product, process, or service.

PCF: **P**roduct **C**arbon **F**ootprint, a calculated value or index that makes it possible to compare the total amount of greenhouse gases that an activity, product, company or country adds to the atmosphere.

Post-consumer: A waste type produced by the end consumer of a material stream, where the waste-producing use did not involve the production of another product

PS: **P**oly**S**tirene

For more information on the project as well as related press releases and other published documents, check out the project website www.absolutely-circular.com.