CAN FLEXIBLE FOOD PACKAGING GO CIRCULAR?

POLICY BRIEF, FEBRUARY 2025

Packaging waste sorting center_bale preparation © SUEZ

- Mechanical and physical processes for sorting and recycling household packaging waste
- Effective purification via Tracer-Based-Sorting, delamination/deinking, dissolution & deodorization
- Application of recycled PE in home & personal care packaging
- Applied in food packaging behind migration barrier
- Evaluation of economy, sustainability and risks

The Horizon 2020 project **CIRCULAR FoodPack**, leveraging its advanced sorting and physical recycling technologies – including mechanical and dissolution-based processes – provides pioneering solutions to the challenge of converting post-consumer flexible packaging waste into purified recycled Polyethylene (PE). Beyond addressing sorting and recycling challenges, the project also offers solutions for the effective integration of these post-consumer PE recyclates (PE PCR) in packaging applications for personal care and home care. For food packaging products, significant progress has been achieved, highlighting further research needs for food safety. This policy brief begins with a concise overview of the specific challenges and concludes with targeted policy recommendations drafted by the CIRCULAR FoodPack industry and research partners.

The challenge in a nutshell

In **contact-sensitive packaging** (see PPWR, Art. 3 Definitions, point 49), such as food packaging applications, the responsible and safe selection of materials is mandatory. Strict regulations govern the use of polymers and additives in direct food contact as well as on the outer surfaces of packaging materials. Recycling and circular use of recyclates play a crucial role in ensuring sustainable raw material supply. For example, recycling flexible plastic packaging waste is up to five times more effective at reducing CO_2 emissions (kg CO_2-eq./t) [https://publications.jrc.ec.europa.eu/repository/handle/JRC132067] compared to incineration with energy recovery, making it a significantly better option for mitigating climate change.

In response to these challenges, the new **Packaging and Packaging Waste Regulation (PPWR) 2025/40**, which entered into force on February 11, 2025, sets clear targets for increasing the uptake of recycled content in packaging, including food packaging. However, the recycling industry still faces challenges, particularly in achieving sufficient purification efficiency with current sorting and recycling technologies.

The CIRCULAR FoodPack project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101003806.

RESEARCH CONCEPT

Building on established post-consumer flexible packaging waste streams in Europe, the Horizon 2020 project CIRCULAR FoodPack has tested combinations of advanced sorting and purification methods to separate and remove materials and compounds from waste packaging that could pose risks in the production of contact-sensitive packaging. Additionally, mono-material packaging concepts were developed to enhance recyclability and ensure material safety while incorporating purified PE PCR. These innovations were complemented by studies to ensure food compliance and to assess sustainability and economic feasibility.

PROJECT RESULTS

Tracer-Based-Sorting (TBS) enables the identification and sorting of food packaging from non-food items with **>99% purity**, meeting the stringent requirements set by the European Food Safety Authority (EFSA) for waste plastics intended for reuse in food packaging. It achieves an unmatched sorting yield of 96%, a level that has never been reached using Near-Infrared (NIR) or AI-based sorting technologies.

Integrating tracers into printing inks has proven to be advantageous, as they can be washed off during purification of sorted fractions, such as through deinking or dissolution-based recycling.

TBS can be retrofitted into existing sorting facilities with a capital investment of approximately **10,000 EUR** allowing conventional NIR sorting machines to be upgraded. With an additional cost of just **20 EUR** per ton of packaging, the increased sales value of recovered materials far outweighs the initial investment, making TBS a **highly cost-effective solution**.

However, when implemented in this way, TBS occupies up to one existing sorting stage per fraction. Its full potential is realised when integrated into a broader system that combines singulation of waste items with technologies such as tracer recognition, conventional NIR, color measurement, mid-infrared (for black polymers), AI-based object recognition, or other suitable methods. This comprehensive approach is captured under the Sort4Circle® (S4C) process.

CIRCULAR FoodPack Approach			
Sorting food packs	Separate inks, multilayers (ML) and contaminants		Deodorization
Tracer-Based-Sorting to separate food from non-food packaging items as the latter may apply compounds critical in food contact.	Advanced delamination and deinking to remove printing inks, lacquers, adhesives critical in second life plastic processing.	Dissolution-based recycling uses solvents to purify inks, ML, as well as to extract and remove contaminants including non-volatiles.	Venting IR-tempered recyclates to evaporate volatiles from recycled PE, improving both, safety and odour.
A comprehensive **Design4Recycling** implemented **PE PCR** and combined recyclable mono-material structures with deinkable printing, including tracer concept and migration barriers for consumer safety.			
Demonstration of recycling cascades and circular use in packaging for home and personal care and food packaging			
LCA	LCC / Economy	Safety Assessment	

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Purification and recycling through advanced mechanical processes and dissolution

The Advanced Mechanical Route: Purification through washing, delamination and deinking plays a crucial role in separating non-targeted materials and inks from flexible packaging waste, which would otherwise hinder the PE PCR purity during closed-loop recycling. However, issues such as color, odor, gels and black specks—resulting from binder and pigment degradation or polymer incompatibilities—pose significant challenges. While water- and detergent-based delamination and deinking processes are partially implemented in current mechanical recycling plants, these methods have limitations in effectively processing all common flexible packaging structures. Additionally, issues such as curling and color staining have been observed during these processes.

To overcome these challenges, solvent-based delamination and deinking offer a more versatile alternative. This method can handle a broader range of adhesives and ink binders, achieve deeper cleaning of polymers, and potentially meet higher quality standards than the aqueous methods. However, the lack of large-scale infrastructure in Europe for solvent-based processes remains a major barrier to widespread implementation.

The challenge test

Both, mechanical and dissolution-based recycling were tested for their ability to purify and recycle artificially contaminated flexible packaging waste. The mechanical route removed 84-99% of spiked contaminants, demonstrating strong efficiency in eliminating volatile organic compounds (VOC) but showing limitations with larger molecules.

Dissolution-based recycling achieved purification levels above 99%, including the removal of larger molecules (e.g. 370 g/mol), highlighting its potential to provide recyclates for sensitive goods, including food packaging, in future.

The Dissolution Route: The dissolution of PE from post-consumer flexible household packaging waste was achieved using selective solvents. During purification, non-PE multilayers (MLs), inks, and colors were effectively separated, while odors were removed in the final drying step.

A key advantage of dissolution is its ability to process unsorted flexible packaging waste, as it can handle higher shares of non-PE polymers. Additionally, its newly developed enhanced cleaning step ensures the **efficient removal of semi-volatile and less volatile molecules,** which cannot be sufficiently eliminated by traditional deodorization methods. Despite these promising results, a large-scale industrial infrastructure for dissolution-based recycling is still missing. As is the case with solvent-based delamination and deinking, significant investment and commercialization are required to scale up the technology to an industrial level.

Design for circularity of flexible packaging for sensitive applications including food

The integration of physically recycled post-consumer resin (PCR) into packaging is essential for sustainable development. New packaging designs focus on adaptable structures that meet performance requirements while complying with recycling guidelines. These designs address key limitations, such as the maximum allowable PE PCR content without compromising sealing or processability, as well as the application limits of emerging technologies like delamination primers.

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During production and conversion, the risk of offset migration, which could compromise product safety, has been carefully considered. Scaling up these strategies will significantly enhance the adoption of PE PCR in packaging, contributing to a more sustainable and efficient recycling process while expanding the applicability of recyclates across various packaging solutions.

Implementation of circularity into food packaging value chain

The applicability and processability of PCR-containing flexible packaging materials have been validated across three use cases: home care, personal care, and food packaging. These innovative mono-material-based solutions, designed for both food and non-food applications, were successfully tested on existing Vertical Form Fill and Seal (VFFS) lines. They operated at competitive speeds within a reasonable sealing window, requiring only minor machine modifications. For **non-food packaging**, a duplex structure with **62% PCR content** was achieved, while **food packaging** demonstrated optimal performance with **30% PCR content**.

However, the positive evaluation of 30% PCR in food packaging, equipped with a double migration barrier, is based on a single PCR production campaign at demonstration scale.

While this meets European Food Safety Authority (EFSA) regulatory requirements, it highlights the need for further research to ensure broader applicability and regulatory compliance.

Key research priorities include:

- Advancing purification techniques to produce high-quality PCR for contact-sensitive packaging applications.
- Harmonizing challenge test procedures for polyolefins to assess decontamination efficiency in new recycling processes.
- Improving PCR quality by enhancing the recyclability of non-polyolefin components in mono-material PE laminates (e.g., masterbatches, inks, adhesives).
- Confirming the long-term effectiveness of functional barriers in reducing migration for safely incorporating PCRs into food packaging.
- Certifying recycling processes for producing food-grade PE PCRs.

Design for Recycling	Design from Recycling
• **To achieve a clean and pure** food packaging **material stream through TBS:** Tracer-doped ink was implemented, enabling >99% sorting efficiency with only 50 µg/cm² of **FDA** (US Food and Drug Administration) **approved tracers**. • **Delamination primers** enhance deinking and removal of non-**polyolefin** contaminants during wet-treatment processes. Prioritizing surface printing may further facilitate contaminant removal.	• **Thorough PCR cleaning** is essential to safely incorporate **high-purity PE PCR** into packaging structures. • **Functional barriers** are recommended to mitigate residual contaminants in PE PCR. Coextruded **EVOH** and **primered SiOx layers** (~60-80 nm) help keep contaminants below critical migration limits. A **double-barrier system** sandwiches PCR to prevent **set-off migration**, ensuring food safety.

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CIRCULAR FoodPack packaging demonstrators utilising PE PCR produced in three demo-loops.
Use cases: Food packaging, Home and Personal Care packaging © Amcor

Within CIRCULAR FoodPack, we successfully achieved up to 50% use of dissolution-derived PE PCR in Machine Direction Oriented PE (MDOPE) — a highly demanding structural element of future packaging. This progress paves the way to meeting the 2040 targets of post-consumer recycled content in food packaging.

Life cycle sustainability assessment (LCSA)

Life Cycle Assessment (LCA): Compared to the conventional end-of-life option (incineration with energy recovery and landfill), the newly developed technologies (TBS and/or advanced mechanical/ physical recycling with purification) outperform for managing post-consumer flexible packaging waste. For example, per ton of PE-rich sorted household flexible packaging waste with advanced physical recycling using selective dissolution purification, resulting in flexible non-food packaging with 54% PE PCR, the climate change impact can be lowered by 27%.

Compared to virgin non-recyclable flexible food packaging, replacing virgin materials with PE PCR derived from household flexible packaging waste by 34% can considerably reduce the environmental impact (e.g. climate change impact reduction of 56% per m² of flexible food packaging).

Increasing the recycled content in flexible food packaging (e.g., from 34% to 50%) on the other hand, may increase the environmental impact, in case the laminate specifications (such as thickness, surface weight and structure) need to be modified to support the higher recycled content.

These modifications, if they result in a thicker and heavier laminate, may pose challenges to processability, especially during the sealing of the packaging according to the assessments performed in the project.

Life Cycle Costing (LCC): Both dissolution-based and water-based deinking technologies result in feasible business cases, giving competitive PE PCR costs to the virgin PE costs. Still, the conventional end-of-life option remains more cost-effective than the newly developed alternatives in the CIRCULAR FoodPack project, due to lower waste disposal costs and the current affordability of virgin materials.

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On the one hand, processing PE-rich household flexible packaging waste using advanced physical recycling with selective dissolution purification—resulting in flexible non-food packaging with 54% PE PCR—can lead to an economic impact increase 16% per ton.

Alternatively, an advanced sorting and recycling approach that separates food (25%) and non-food (75%) packaging waste based on tracer identification, followed by purification through delamination, deinking, or dissolution enables the production of mono-material multilayer laminates.

The resulting food packaging features a triplex structure with e.g. 50% recycled PE, while the non-food version adopts a duplex structure with 54% PE PCR—leading to a 30% increase in economic impact compared to the conventional end-of-life option (incineration with energy recovery and landfill).

However, considering potential revenue losses from not recycling PE-rich flexible waste, the newly developed recycling options could prove more economically viable in the long run.

Consumer acceptance and market demand

Consumer surveys have confirmed that the project's proposed solution can be widely accepted by consumers, provided that the introduction of the new material is supported by effective communication. Consumers generally favor sustainable packaging and show a clear preference for recycled materials.

The evolving regulatory landscape is further encouraging brand owners to adopt new packaging, with PE PCR emerging as a viable option. Additionally, processors across different levels of the value chain have expressed significant interest in the packaging approach developed by CIRCULAR FoodPack.

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POLICY RECOMMENDATIONS

CIRCULAR FoodPack partners propose policy measures and urgent actions to tackle regulatory, technical, and financial obstacles in the recycling industry, with a particular focus on food packaging materials. These actions aim to **enhance Europe's recycling efficiency**, boost its competitiveness against recycled feedstock from outside the EU, promote sustainable practices, and **reinforce Europe's leadership in environmental technologies**.

Ultimately, these efforts will contribute to greater industrial sustainability and resource independence across Europe. The consortium strongly supports the **adoption of the PPWR**, as it sets new targets across Europe and provides a clear framework for the packaging value chain. The stepwise target-setting approach is particularly welcomed, as it enables a gradual implementation and allows for necessary infrastructure improvements.

REGULATORY REFORMS

Advancements in sorting and recycling could be co-financed through mechanisms such as **Extended Producer Responsibility (EPR) fees**. However, financial support should be specifically directed toward waste packaging, particularly flexible packaging waste materials, which continue to face infrastructure challenges and a lack of high-quality post-consumer recyclates (PCR).

The Packaging and Packaging Waste Regulation (PPWR) requires more detailed legislation to establish up-to-date, standardized design guidelines that integrate advanced recycling technologies. Additional legislative efforts should focus on:

- Expanding regulatory reforms for food packaging, ensuring more recyclable options while maintaining consumer convenience.
- Reducing complexity in recycling infrastructure and material selection.
- Promoting sustainable business models across industry and retail.

For successful implementation in food packaging, it is crucial to **streamline the legal approval process for recycled materials**. A simplified and more efficient approval procedure would accelerate market acceptance of circular packaging solutions and facilitate the industry-wide transition toward sustainability.

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INVESTMENT IN INFRASTRUCTURE

CIRCULAR FoodPack technologies, including Sort4Circle®, dissolution, and delamination/deinking, outperform conventional mechanical recycling methods for flexible packaging when used in combination. However, scaling these technologies to a commercial level remains a key challenge. To facilitate this transition, we advocate for a supportive funding environment that encourages **investment in large-scale waste sorting systems and recycling infrastructure across Europe**. This would help secure high-quality input materials and ensure sufficient volumes for effective recycling.

Grants and subsidies could play a vital role in helping SMEs adopt sustainable packaging practices. Additionally, the adoption of innovative sorting and recycling technologies should be incentivized, with a **strong focus on optimizing sorting lines for flexible packaging**. This is crucial to improving the quality of PCR-grade material and enabling a more efficient circular economy.

FURTHER RESEARCH AND INNOVATION

Although this project has successfully demonstrated the use of 30% PCR in food packaging, significant potential for improvement remains, particularly for contact-sensitive applications. **Research funding is essential** to enhance circularity, with a focus on:

- Advanced sorting, decontamination, and purification technologies (e.g., dissolution)
- Sustainable packaging designs that integrate PCR more effectively

Progress is needed at multiple levels:

- Technological advancements (e.g., tracer technology, deodorization, delamination/deinking primers)
- Hardware improvements (e.g., scaling up production capacities, optimizing sorting systems)
- Enhancements in existing technologies (e.g., more recyclable adhesives, extractable masterbatches, non-bleeding ink pigments)

R&D should also support the adaptation of packaging machinery to process recycled materials, facilitated through grants or co-financing opportunities.
To accelerate technology development and commercialization, **public-private partnerships** should be encouraged. Additionally, policy measures should promote information exchange and **capacity-building initiatives** to address common industry challenges and drive innovation across the sector.

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INDUSTRIAL STANDARDS

Innovation in the circular value chain for flexible packaging requires the standardization and harmonization of recycled grades and recycling processes, driven by industry organizations like CEFLEX or Flexible Packaging Europe. A key priority should be the **development of standardized, machine-readable marking solutions for food-grade packaging** that are widely accessible and accepted by brand owners. Moving toward a preferred solution—or ideally, a single universal standard—would streamline adoption and enhance efficiency. This is particularly critical for ensuring proper separation of food-only grades in flexible packaging waste management, as required by EFSA for circular food packaging.

Additionally, the industry must **refine regulatory guidelines for recycling** to guarantee that high-quality PCR is used sustainably, ensuring safe, practical packaging while supporting efficient circular waste management at the end of life. At the same time, targeted consumer education campaigns should be launched to increase awareness of the benefits of recycled and recyclable packaging. These initiatives should emphasize the environmental impact of recycling and the critical role consumers play in building a sustainable packaging ecosystem.

CONCLUSIONS

Collaboration across the entire value chain—including collection, sorting, recycling, packaging conversion, and brand ownership—is essential to meeting legislative requirements, such as PCR content mandates and design-for-recycling standards.

To enable business predictability, mitigate financial risks, and drive investment in infrastructure, the EU must **establish clear and consistent regulations**, alongside well-defined targets for flexible packaging and waste management.

Additionally, **ongoing research is critical** to addressing remaining challenges and ensuring the scalability and efficiency of innovative recycling solutions.

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All public results will be published on the **CIRCULAR FoodPack website**: http://www.circular-foodpack.eu

Led by the Fraunhofer Institute for Process Engineering and Packaging IVV in Freising, the CIRCULAR FoodPack consortium consists of fifteen companies and research institutes from Belgium, The Netherlands, France, Germany, Greece, Spain and Switzerland.

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