ALLIANCE TO END PLASTIC WASTE

The Challenges and Solutions for Flexible Plastic Packaging Waste

Insights for Europe and North America

Contents

About the Alliance to End Plastic Waste

The Alliance to End Plastic Waste is an independent global non-profit organisation with the purpose to end plastic waste entering the environment and to create circular systems that keep materials and products in use for as long as possible. We go beyond existing solutions, by building unique and impactful circular solutions.

The Alliance convenes companies across the plastic value chain, governments, local communities, civil society groups, intergovernmental organisations, and academia. The expertise, knowledge, experience, and resources of this network enable our work to help end plastic waste and pollution.

Together, we work towards economically viable, environmentally beneficial, and socially responsible solutions.

→ Find out more: endplasticwaste.org

We warmly welcome your views and input to further enrich these insights. For technical matters, please contact the principal author:

Martyn Tickner
Chief Technical Advisor to the Alliance
Martyn.tickner@endplasticwaste.org

If you wish to explore how you can get more engaged in the work of the Alliance, please contact:

Justin Wood
Vice-President Growth & Engagement
Justin.wood@endplasticwaste.org
or
Nicola Lelli
Flexible Packaging Program Lead
Nicola.lelli@endplasticwaste.org

1.

Summary

1. Summary

Flexible plastic packaging, such as films, wraps, pouches, sachets, and labels, has become an indispensable part of modern economies. It delivers cost-effective and low-carbon solutions which enable consumer convenience, extend food shelf life, and protect goods in shipment. Yet these same benefits create enormous challenges for end-of-life management.

Today, flexible plastic makes up more than

50%

of the total plastic packaging market,

and is expected to increase with rising consumer demand for convenience food and online retailing[1].

Addressing this issue is critical for advancing circularity, reducing environmental leakage, and unlocking new value in recycling systems.

This Insight Report has been developed for three main reasons:

FIRST
To share the Alliance to End Plastic Waste's experience and emerging insights with a broader audience and help strengthen collective understanding of the flexibles challenge and potential solutions.

SECOND
To invite key stakeholders to engage with and contribute to our programme addressing flexible plastic waste. Broad collaboration will be essential to scale solutions and enable systems change.

THIRD
To welcome feedback, including additions and challenges, on the concepts presented here.

The scope of the report is primarily Europe, the US and Canada – high-income countries with strong basic waste management, albeit at different levels of maturity in respect of achieving circular solutions.

[1] *Consumer Goods Forum, https://www.theconsumergoodsforum.com/planet/plastic-waste/key-projects/flexible-plastics/, Accessed on 24 September 2025*

1. Summary

The Challenges of Flexible Plastic Packaging Waste

Despite its functional advantages, there are currently challenges to recycling flexible plastic packaging post use.

1.
Complexity of materials

Flexible plastic packaging, which includes films, uses a wide range of polymers and other chemicals (PE, PP, PET, PA, EVOH, etc.), often in multi-material, multi-layer constructions together with inks, adhesives, and barrier coatings such as aluminium. These combinations deliver incredible functional performance but create challenges for both mechanical and chemical recycling.

2.
Lightweight nature

Flexible packaging and films are thin and light, which reduces material use but creates challenges for cost-efficient collection and processing. They clog equipment, stick to other waste, and, lacking adequate value, can be a significant inconvenience to waste management companies.

3.
Challenging quality requirements

Modern film production processes require very high-quality, high-consistency feedstock which the output from mechanical recycling struggles to meet. Chemical recycling processes are maturing but have a higher cost of production and currently face regulatory uncertainties.

4.
High relative cost

Virgin resin is produced at massive scale with significant cost advantages, while flexibles recycling remains small, fragmented, and costly. Consequently, recycled films struggle to compete, thereby limiting investment and capacity growth.

As a result, recycling of flexibles today is mostly limited to down-cycling into plastic lumber or other construction materials, or in the production of trash bags and bin-liners.

The Solutions for Flexible Plastic Packaging Waste

There are opportunities for reduction, reuse, or optimal substitution of plastic packaging with other materials. However, recycling will need to play a critical role in a circular economy for plastic packaging.

Where recycling is concerned, it is important to consider the selection of the most appropriate recycling technology. This is a function of available feedstock quality, determined by the approach to collection and sorting and the quality needs of the end-application. Options include:

- **Mechanical recycling**
  to convert homogeneous, clean feedstocks, generally to less quality-sensitive applications.
- **Dissolution**
  for improved decontamination and quality versus mechanical recycling.
- **Chemical recycling**
  (pyrolysis, depolymerisation, gasification) for multi-material feedstocks and to meet the most demanding quality applications, such as food-contact.

Circularity Enablers

While recycling technologies play an important role, achieving circularity for flexible packaging requires coordinated action across the entire value chain. The following insights highlight the foundational conditions and enablers necessary to drive systems change for flexible plastics.

Collection and sorting

To support mechanical recycling, segregated collection or highly granular sorting is required. Chemical recycling is less demanding in terms of single-polymer homogeneity, but requires low levels of certain contaminants, such as metals and oxygen or halogen containing molecules. Large commercial sources of waste provide high-quality feedstock which can help kick-start a recycling economy. For post-household streams, a municipal "Materials Recovery Facility" (MRF) will provide basic sorting into one or more bales of mixed flexible plastics. However, the process is significantly improved if films are segregated first of all by households — at a minimum from paper and cardboard, if not all other materials. Thereafter more granular sorting will be required. While this can be done by recyclers, deploying "secondary sorting" in large-scale Plastics Recovery Facilities (PRF) may be more effective and efficient. This will also enable the deployment of advanced detection technologies such as digital watermarking or AI-based recognition to improve the level of material homogeneity in feedstock for mechanical recycling and the purity for chemical recycling.

1. Summary

End-market demand

Without high-value applications for recyclates, there is no case for investment. End-market pull drives system viability, meaning demand and value for recyclates are required to drive investment throughout the chain. Mandated post-consumer recycled (PCR) content targets are one mechanism to create demand for high quality recyclates. Competitiveness against virgin plastic can also be created through Extended Producer Responsibility (EPR) schemes or other financial interventions which level the playing field.

Derisking investment

Long-term investments in collection, sorting and recycling infrastructure and technology require strong financial support. Instruments such as corporation tax relief, land use, energy and labour subsidies, or concessional loans, which collectively improve return on investment and reduce upfront risk, are essential to attract and sustain capital. Stable and predictable policy frameworks are vital in sustaining investor confidence, particularly in the case of chemical recycling where ongoing uncertainty around mass balance attribution, recycled content claims and overall legitimacy is deterring investments. Ensuring a level playing field against imported products is critical so that domestic recyclers are not undercut by lower-cost alternatives that do not meet equivalent standards.

Design for recyclability

Design guidelines encourage adoption of best practices to harmonise material choices, reduce complexity and barriers to recycling. Standards such as the CEFLEX guidelines, RecyClass (Europe) and APR protocols (US) provide a foundation.

Eco-modulation

Eco-modulated EPR fees can help drive rapid adoption of simpler packaging design, and ensure fair competition, by rewarding packaging that is both recyclable and cost-efficient to process. This supports adoption of design guidelines and helps achieve industry convergence on the best environmental solutions and reduced complexity for recyclers.

Building on these enablers, the Alliance's "Flexibles Program" seeks to chart a potential path towards systems change.

Path to System Change

In this context, the Alliance to End Plastic Waste launched a major multi-year initiative at the end of 2024 to work on improving the circularity of flexible packaging. This "Flexibles Program" is being designed and implemented in partnership with companies from across the flexibles value chain – polymer producers, technology companies, plastic converters, brand owners, waste managers, producer responsibility organisations and recyclers.

While the flexibles challenge is global, the Alliance sees the greatest near-term opportunity for impact in Europe and North America, where the foundational elements of a recycling economy, such as reliable waste management and enabling economic conditions, are already in place.

The Alliance's "Flexibles Program" proposes a three-part approach that builds on the insights and key enablers outlined above:

1.
Market mapping & system design

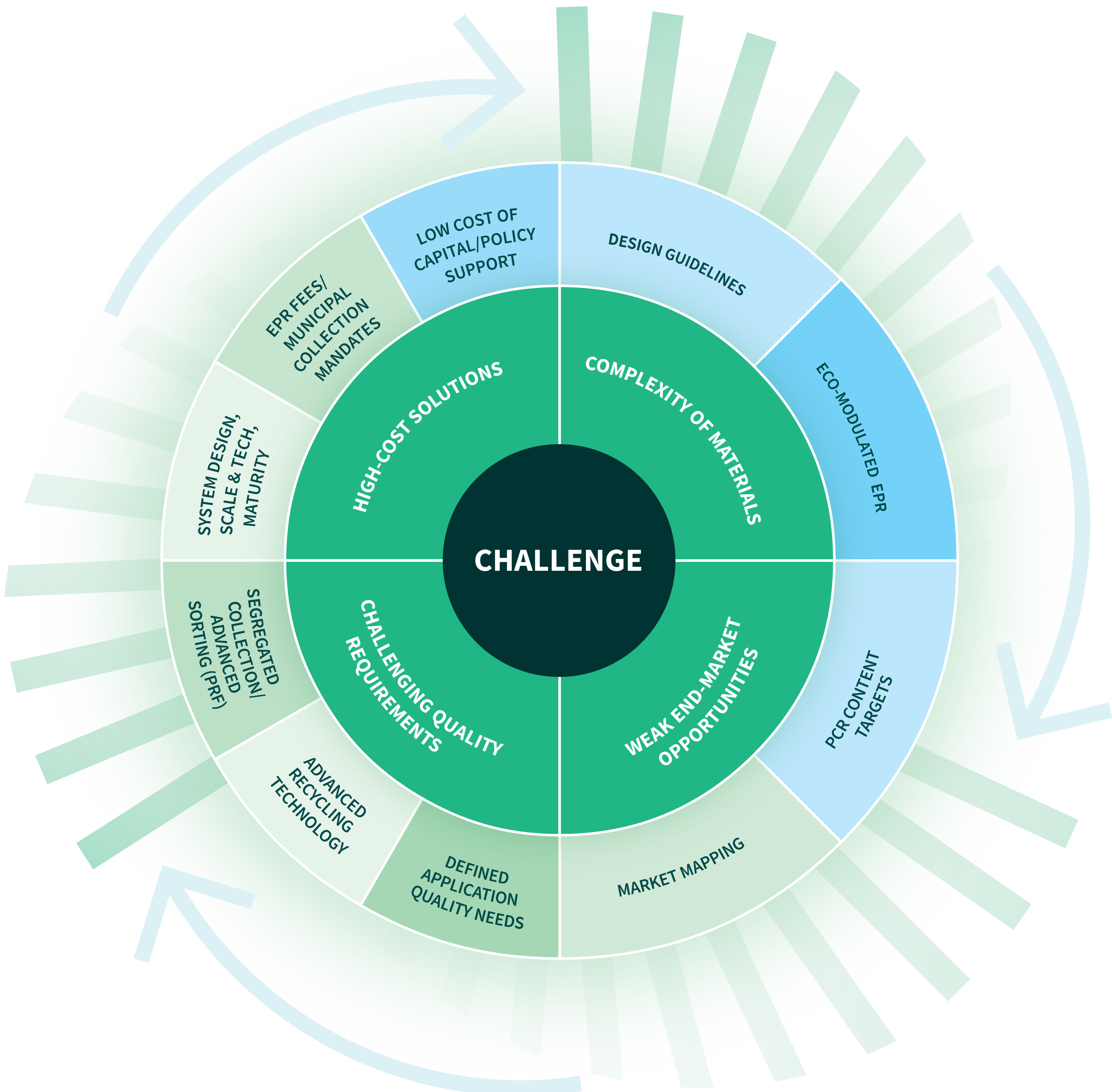
Quantify end-market opportunities and quality requirements. This then enables evaluation of the optimal recycling pathways and technology options that can address individual waste streams. Align stakeholders in a detailed understanding of holistic long-term solutions and the required enablers and investments, leading to a realistic roadmap from today's fragmented, unsatisfactory solutions to optimised circular systems.

2.
Showcase demonstrations

Engage broad stakeholder groups in developing showcase systems or partial-system solutions that establish technical, social and economic boundaries and build confidence in those solutions within communities, the private sector and government. This is key to subsequent scaling and geographic expansion, bringing about large-scale systems change.

3.
Enable Replication

Mobilise brands, recyclers, municipalities, and policymakers to understand what it takes to create and expand effective system solutions and replicate them across geographies.



Circularity for Flexible Plastic Packaging Waste

Conclusion

Delivering circularity for flexibles is a complex challenge, but it can be solved. The necessary technologies exist, regulatory momentum is building, and leading organisations are stepping up. What is needed now is simultaneous action across the system: showcasing solutions in the context of clear end-market opportunities, optimised system design and providing the required economic drivers. This in turn will build confidence to invest in necessary improvements in design and infrastructure for collection, sorting and recycling, leading to rapid adoption and eventual systems change.

The Alliance to End Plastic Waste is fully committed and uniquely placed to support this by convening stakeholders and key influencers, sharing insights gained from its member companies and projects all over the world, and showcasing practical solutions in Europe and North America. Our ambition is to demonstrate that practical solutions exist, regulatory compliance is achievable, and systems change is within reach – paving the way to end plastic waste and build a more sustainable materials system.

> As a leading producer of flexible plastic packaging, we recognise system change for circularity requires concerted action on design for recyclability, development of infrastructure and end-markets, as well as financing mechanisms such as EPR. The Alliance is uniquely placed to inform such actions through the translation of insights from geography to geography and spanning the perspectives and issues of the entire value chain.
>
> **Gerald Rebitzer**
> **Vice President Sustainability Operations & Advocacy**
> Amcor

2.

Flexible Packaging Waste
The Challenge

2. Flexible Packaging Waste The Challenge

All forms of plastic face challenges when it comes to effective waste management and circularity of use. However, "flexible plastic packaging" faces a specific set of challenges.

Complexity

There is tremendous complexity in the wide range of product composition and packaging formats driven by the need to meet specific and highly varied performance requirements. This complexity arises from the use of numerous varying polymer types, compositions, and multi-material constructions.

Most flexible plastic packaging is made from either low-density polyethylene (LLDPE or LDPE), used in stretch wrap, shrink wrap, food wrap, and refuse bags, or polypropylene (PP), commonly found in snack wrappers and food-contact films. Other frequently used polymers include polyethylene terephthalate (PET) and high-density polyethylene (HDPE).

Furthermore, each polymer product family contains variations in the length of polymer chains, molecular weight distribution and other characteristics needed for different film production technologies. Alongside the physical variations within a polymer family, complexity also arises from the chemical composition of the polymer, which often incorporates chemicals other than the basic monomer.

However, the greatest complexity arises from the wide variety of multi-material, multi-layer structures used in films and flexible plastic packaging, where the base polymer is complemented by layers of other polymers or non-polymer materials.

> The greatest complexity arises from the wide variety of multi-material, multi-layer structures used in films and flexible plastic packaging, where the base polymer is complemented by layers of other polymers or non-polymer materials.

These layers enable a significant reduction in the thickness of the film by providing essential functions like moisture and oxygen barriers or puncture resistance. Many films are thus complex sandwich-like structures of different materials that cannot be recycled together.

Finally, further complexity is introduced by the use of colourants, inks for printing and adhesives for labels, and the use of different physical formats ranging from small candy wrappers to large sheets of pallet wrap.

Much of this complexity has evolved to meet the distinct performance and cost requirements of different applications for flexible films – for example, meat packaging demands different properties compared to packaging for an electrical appliance. This adaptability is central to the success of plastics and why they are used so ubiquitously. Far from being simple, flexible plastic packaging is in fact highly-engineered and takes years to perfect.

As a result, we have a broad spectrum of films with unique chemical and physical properties that typically cannot be effectively combined at the end of their lifecycle to create new recycled film. They must be carefully sorted and processed, cognisant of all of their differences and the quality requirements of the desired recycled output. This is why recycling considerations must go beyond broad categories like "LDPE" or "PP" film. Effective recycling, whether mechanical, dissolution or (to a lesser degree) chemical, depends on precise control of polymer types and impurities in the recycling feedstock.

Lightweight

Flexible plastics are deliberately lightweight, due to decades of down-gauging and the use of advanced barrier layers or alternative polymers to reduce the amount of plastic used. This has lowered the cost of packaging and its carbon footprint while enhancing functional performance.

While its lightweight design lowers packaging costs and waste, it also increases the cost of collecting plastic waste when seeking to source-segregate it from other materials such as rigid plastic packaging, glass, metal, paper, and board.

Additionally, the lightweight, thin and flexible nature of films makes them inherently difficult to handle in high-speed waste-processing and sorting equipment. Such films tend to fly around, to ball-up, and adhere to other objects when processed. Separation of films from paper and board is particularly challenging, especially when wet.

Consequently, flexibles are often unwanted in a waste stream due to their complexity, difficulty in handling and lack of value – which in turn results in limited incentive to collect and make available as feedstock for recycling.

Product Quality

Technologies for conversion of polymer pellets into films and flexible packaging require materials with highly consistent composition and quality. This makes recycling plastic waste back into film applications – "closed-loop" recycling – significantly more challenging than mechanical recycling of rigid packaging.

Consider the production of metallised film for snack packaging. The polymers might be stretched into films with a thickness of just 20 microns – about a third of the width of a human hair. At this scale, even minor defects in the polymer quality or "gels" (small inclusions of incompatible polymers, other organic or inorganic materials) can compromise the strength and appearance of the film, making it unsuitable for sale and potentially causing costly production stoppages known as "line-breaks".

Value-capture

Value-capture is yet another challenge, as the costs of collection, sorting and recycling solutions for flexibles are high relative to the intrinsic end-market value of these recycled plastics.

Recycled materials must compete with the cost and quality of pristine virgin plastics. These virgin plastics are produced in highly optimised facilities operating with fifth or sixth-generation technologies at large scales of 500,000 tonnes per annum or higher. Such facilities typically rely on low-cost by-products or co-products from the oil and gas industry, which have historically been secondary outputs to the fuels and lubricants produced by refineries. Markets for virgin plastic have also been well-established over many decades, allowing efficient, large-scale global trading of cost-advantaged products.

By comparison, recycling processes are generally first – or at best second – generation technologies, producing on a scale of just 5,000-50,000 tonnes per annum in immature markets and with additional technical and logistical challenges as described above. It is unsurprising that recycled flexible plastics struggle to compete with virgin plastics on cost.

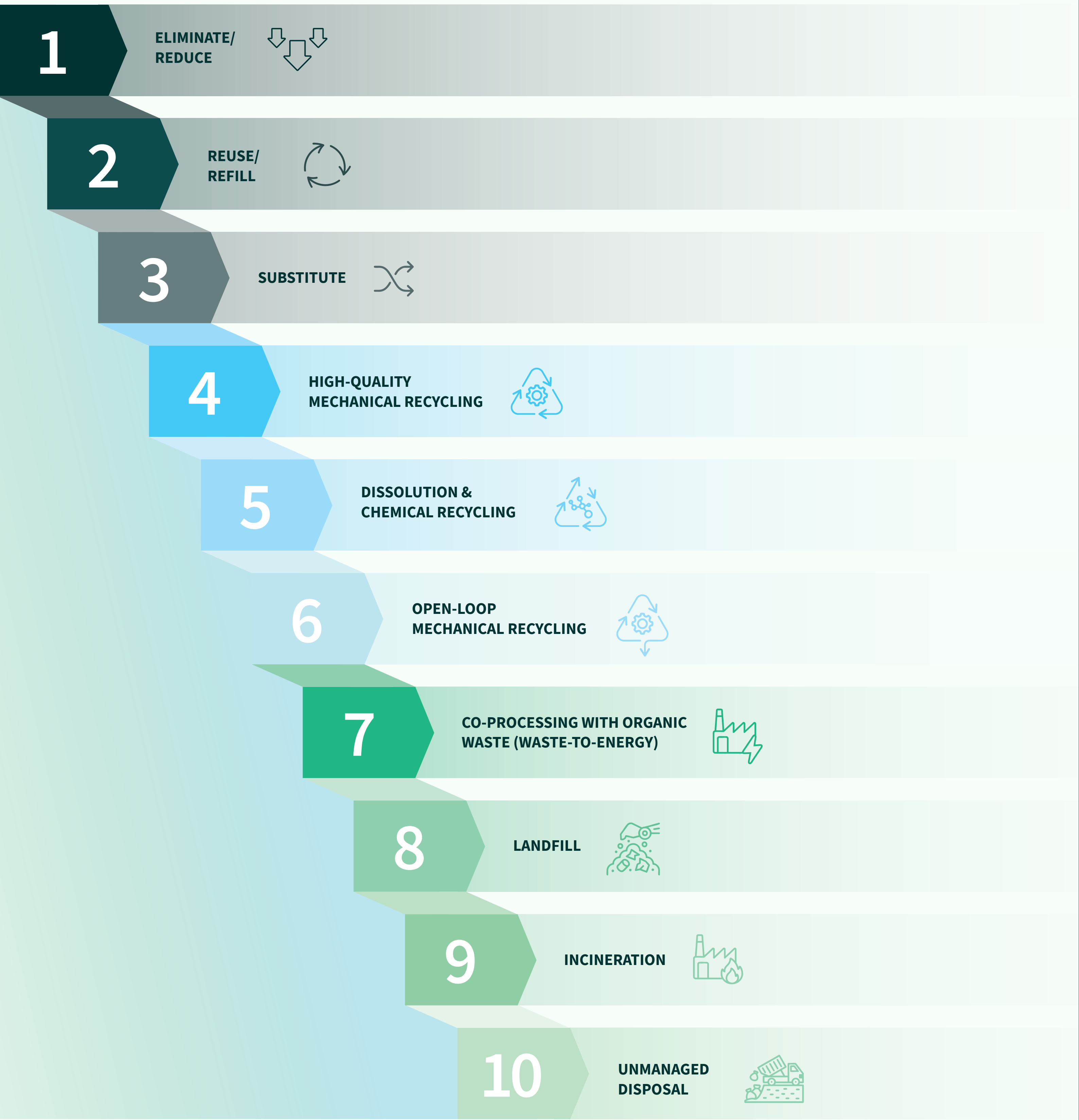
Quality is another significant challenge. While some recyclates produced by current (mechanical recycling) technologies can be of a good quality, much of the material output is not suitable for manufacturing new film. As a result, it is often downcycled into lower-value, non-film applications such as garden furniture or railway sleepers.

3.

Flexible Packaging Waste
The Most and Least-Favoured Solutions

In addressing the challenges listed in the previous chapter, there is a well understood hierarchy of preferred solutions – preferred from the perspective of carbon intensity and economic value capture. *(See illustration 1.)*

The Waste Hierarchy *Illustration 1.*



Most Optimal Solutions

The waste management solution hierarchy begins with "reduce" – eliminating unnecessary packaging or reducing the amount used. Packaging typically accounts for around 1% of a product's overall carbon footprint. Therefore, compromising on packaging to appear more environmentally friendly can be a false economy if it risks damaging the contents. Spoiled products lead to greater waste and emissions, ultimately undermining overarching sustainability goals. However, there are common examples of excessive use of packaging, such as double-bagging or individually wrapping every component of a product separately. Additionally, over-specifying the functional requirements of flexible packaging can also result in increased waste and hinder recyclability, for example, designing for a longer shelf-life than necessary or using certain inks to improve appearance for branding.

"Refill and Reuse" comes next in the hierarchy. Refill solutions for flexibles remain limited, constrained by challenges such as product safety and the economics of refill infrastructure – though there are some promising examples, such as refillable pouches. Reuse is more established, with the obvious example being plastic bags, but also reusable covers and hoods for pallets.

"Refill and Reuse" comes next in the hierarchy. Refill solutions for flexibles remain limited, constrained by challenges such as product safety and the economics of refill infrastructure – though there are some promising examples, such as refillable pouches. Reuse is more established, with the obvious example being plastic bags, but also reusable covers and hoods for pallets.

Third in the hierarchy is material substitution – replacing plastic with alternatives. However, public perceptions of using substitute materials are often over-simplified, and life cycle analysis (LCA) is essential to assess the true environmental benefit. Paper, for example, is commonly seen as a good alternative, but this depends on many factors, including the sustainability of forestry practices and water use in production and recycling, added coatings to improve moisture-resistance, higher transport emissions due to weight, reduced shelf-life, and limited recyclability as paper fibres deteriorate over time.

From an LCA perspective, the environmental impact of packaging materials depends on the specific challenge being addressed. In regions where waste is landfilled without biogas recovery, paper and cardboard can be more harmful than plastic due to their decomposition into methane, a greenhouse gas far more potent than carbon dioxide. Plastic is not biodegradable and so sequesters carbon in the ground over the long term. However, when plastic escapes into the environment and enters waterways, it poses serious risks to biodiversity and marine ecosystems.

Similar issues arise with biodegradable plastics. Their breakdown requires oxygen, heat, and UV light—conditions rarely found in natural environments like lakes or oceans. In landfills, anaerobic degradation of these materials can also produce significant methane emissions. Even when derived from bio-based feedstocks such as corn, which offer a more circular production model, the trade-off may involve replacing carbon dioxide emissions with methane release, which is not favourable from a climate perspective.

Having considered reduction, reuse, refill and substitution, the waste hierarchy moves into the areas of recycling, which are fully considered in the next section.

Least Optimal Solutions

At the bottom-end of the solution hierarchy is unmanaged waste – such as open dumping – which is an unacceptable outcome. Fortunately, this is rare in OECD countries, where well-established waste-management regulations, organised collection and anti-littering measures limit large-scale leakage.

Disposal of plastic in a well-managed landfill is not generally favoured, even though it can be considered an acceptable waste management solution where there is sufficient land space and fully adequate containment to prevent secondary leakage into the environment.

Incineration of plastic waste, waste-to-energy generation or co-processing of plastic waste in cement kilns are also not favoured solutions. Although these options do have environmental benefits in reducing methane emissions from organic waste and offer some energy recovery, this is a missed opportunity. Recycling delivers far greater carbon savings, as recycled plastics have a significantly lower carbon footprint than virgin production. [1]

[1] European Commission, https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/proper-waste-management-can-significantly-reduce-greenhouse-gas-emissions-eu-2025-08-14_en, Accessed 24 October 2025

4.

Flexible Packaging Waste
The Recycling Solutions

For plastic packaging, the responsible use, reuse and substitution are important areas for action. Nevertheless, if societies wish to continue benefiting from the advantages that flexible packaging offers, substantial quantities of plastic waste will be addressed through a recycling economy.

Market mapping

Historically, recycling solutions have been developed opportunistically, with entrepreneurial recyclers finding value through matching available feedstocks with end-market opportunities, using relatively simple recycling technologies. In the case of flexible plastics, this has typically meant targeting applications such as plastic lumber or garbage bags, which have less stringent quality requirements.

However, advanced waste management regulations increasingly require closed-loop recycling, turning flexible packaging back into new flexible packaging, which is a far more complex task.

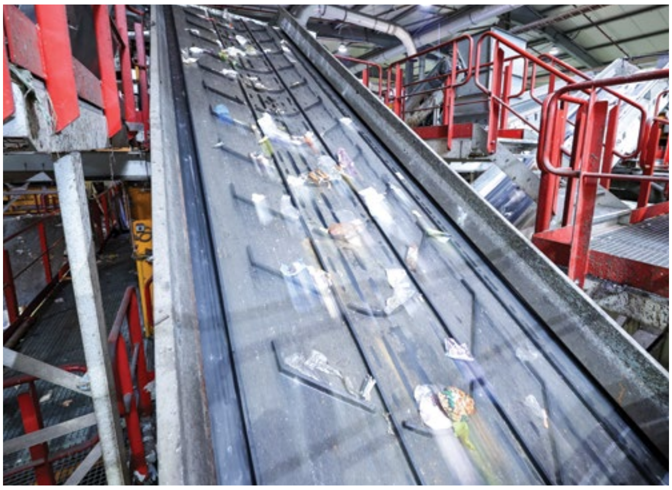
One vital step in resolving the challenge is to conduct a "market mapping" exercise. At its simplest, this involves identifying the market demand for recyclates driven by regulatory requirements, such as recycled content mandates, as well as the voluntary commitments from companies to use recycled content. A more comprehensive approach quantifies plastic waste generation to match waste streams to potential closed-loop and open-loop end uses.

To ensure the viability of these pathways, the feasibility of collecting, sorting and recycling each waste stream must be assessed. The best approach for doing this is to map out various pathways while considering required infrastructure, technologies and associated cost to create an optimised system. This can then be compared against the current state to create a detailed and shared understanding of the issues and opportunities at play.

A market mapping exercise should be conducted inclusively of all key stakeholders, including brands, retailers, waste management companies, recyclers and polymer producers. This will ensure a holistic view is taken, driving to the best environmental and economic outcome without bias towards particular solutions. Organisations such as the Alliance are well placed to guide such a process working alongside governments, industry bodies and in particular Product Recovery Organisations charged with achieving EPR mandates.

End-market quality requirements

Effective market mapping must also account not only for "quantity" but also for "quality". The idea is to measure not just how much material can be absorbed by end markets, but also how the recyclates produced can meet the physical and chemical specifications required by off-takers such as brand owners seeking to incorporate recycled content into new packaging.



Demand for recycled plastic will only grow if the quality of the recyclates produced is fit-for-purpose to partially or fully replace virgin polymers in targeted applications. To design a system that is optimised and well-balanced between economic realities and environmental ideals, it is vital to know the targets that the system is aiming for.

- What degree of segregation is needed at the household level?
- What degree of sorting is needed at the municipal waste facility?
- What value can be created by specialised secondary sorters?
- What technologies will provide the required purity levels?
- What is the holistic approach to integrate the different value-chain steps into an optimised and investable system?
- What is the net system cost that needs to be funded for it to be investible?

A further benefit of identifying the required quality needs for recycled plastic is that it will create more open, competitive and effective markets. Today, many of the relationships between recyclers and off-takers, such as brands and converters, are negotiated on a bespoke, customised basis. But if there is clarity on the quality needs for specific use cases for recycled plastic – e.g. LDPE blown film with 35% PCR incorporation – then the system would have targets on which it can coalesce, enabling efficient investment and market operation at scale.

The best recycling option for flexibles?

Many terms are used to describe different types of recycling – mechanical (basic or advanced), physical, dissolution, advanced, chemical, molecular – and then specific technologies within each type: depolymerisation, pyrolysis, hydrothermolysis, gasification, enzymatic. So which recycling technology is most appropriate for recycling films?

In reality, the different technologies all have a role to play, the extent of each determined by factors such as different collection and sorting approaches, different end-market demand and local technical sophistication.

For example, basic mechanical recycling uses simple technologies and relatively low-quality feedstock. This is widely used to create materials for construction products such as plastic lumber for decking, cladding, railway sleepers, blocks, bricks, pavers, and roofing tiles for use in building construction. Basic mechanical recycling can also produce products suitable for generic quality plastic applications such as garden furniture and paint buckets.

However, these “durable product” markets are typically low-value, and small in scale relative to the volume of flexible packaging waste. As a result, they can become saturated quickly, further depressing market value.

Advanced mechanical recycling and dissolution technologies can support closed-loop recycling of flexible packaging back into new film and flexibles, but only with high homogeneity of feedstock. This requires additional sorting and logistics together with more capital and energy-intensive recycling which will reduce to some degree the cost and carbon advantages of mechanical recycling relative to chemical recycling.

Advanced mechanical recycling and dissolution technologies can support closed-loop recycling of flexible packaging back into new film and flexibles, but only with high homogeneity of feedstock.

Chemical recycling offers the most obvious pathway back to virgin polymer quality subject to the right enabling conditions – feedstock that is free of certain contaminants, with mass-balance attribution and adequate market incentives to support the significant investment required. It should also be noted that as the technology matures to second- or third-generation designs, costs and energy intensity will reduce, further mitigating the gap to mechanical recycling.

> Brückner's vision is to maintain the manufacturing economics and quality of high-speed film production with increasing amounts of recycled resin. Different polymer types need different processing to provide the same or similar properties as virgin material and we share the insights here calling for multiple recycling technologies to collect, sort and process flexible packaging.

Thomas LeFevre
President/CEO
Brückner Group USA, Inc.

5.

Flexible Packaging Waste Collection & Sorting

5. Flexible Packaging Waste Collection & Sorting

In addition to identifying appropriate recycling technologies, it is also important to source feedstock of the right composition and quality.

When considering packaging waste, three major sources can be identified:

1. **Post-commercial streams from large enterprises**
   These include plastic packaging used in distribution centres, warehousing, back-of-store operations, hospitals, and shopping malls. Such sources often generate large-format, clean plastic sheets, such as (L)LDPE shrink-wrap or stretch-wrap used for pallet covers and multi-packs.
   These materials can be collected through business-to-business arrangements and typically offer high homogeneity and low contamination.
   As a result, they provide a valuable feedstock that can help establish profitable recycling operations, which may later expand to handle more complex materials.

2. **Post-commercial streams from small and medium-sized enterprises**
   Examples include high-street shops, smaller retailers, food and beverage outlets, and market stalls. While collection can be organised through dedicated business-to-business channels that encourage waste segregation, these streams are often absorbed into municipal waste systems. Although generally more homogeneous than household waste, contamination and separation from other materials remain challenging.

3. **Post-household streams**
   This is the largest source of flexible packaging waste and presents the greatest complexity. It includes thousands of different types of films and flexible items, varying in format, polymer type, multi-material composition, printing, and levels of food contamination. These factors make sorting and recycling significantly more difficult and resource-intensive.

The degree of sorting needed for flexible packaging waste will depend on the source and collection mode. Highly homogenous, segregated streams, for example from large-enterprise post-commercial use, can go directly to a recycler. However, in most cases the variety of materials present in the stream – especially post-household waste – is such that intensive sorting will be required.

The critical need for secondary sorting

Whichever recycling technology is used, all require the waste to be sorted into different waste fractions. The degree of sorting needed for flexible packaging waste will depend on the source and collection mode. Highly homogenous, segregated streams, for example from large-enterprise post-commercial use, can go directly to a recycler. However, in most cases the variety of materials present in the stream – especially post-household waste – is such that intensive sorting will be required.

For municipal waste, the first step is segregated collection at the household level. Segregated collection does represent an additional cost, particularly in less densely populated and remote areas. This additional cost of segregated collection from households may not be justifiable versus the reduction in sorting and recycling costs that it enables further down the line. In this case, the next best solution is partial segregation – to separate waste materials into a "dry" bin (plastic, paper, metal, glass etc.) and a "wet" bin for garden and kitchen waste. Bag-in-a-bin concepts can be used to provide some additional segregation.

For partially or non-segregated curbside collected material, the first stage of sorting is a municipal "Materials Recovery Facility" (MRF). These are typically located close to the sources of waste and provide a basic separation of materials from the incoming waste streams – paper, cardboard, metals, glass, rigid plastics, flexible plastics.

However, MRFs are prone to being overloaded, with waste generation frequently outgrowing the design capacity of the facility. Operations at a MRF are generally focused on high-throughput, maximising recovery of those streams that offer the highest value to the operator – often paper and board since these have established recycling infrastructure and market value. Flexibles, however, are unlikely to offer sufficient value to a MRF operator in the current environment.

As a result, the granular sorting of flexibles that is needed for mechanical recycling – or the elimination of problematic materials for chemical recycling – typically occurs as a secondary step at the recycler. However, the advanced technologies needed for separating flexible packaging waste into different fractions are expensive, limiting their adoption at the scale of individual recyclers.

This was illustrated in the Alliance's ValueFlex project jointly developed with CEFLEX to demonstrate the production of high-quality mechanical recyclates from household flexible waste. The project faced difficulties in demonstrating sufficient economic viability to attract investors with a recycling yield of only 50%, and approximately 30% of the total capital expenditure (around US$35m) required to support the necessary sorting, based on an output of 25,000 tonnes per year.

The Alliance believes a better alternative in many situations is secondary sorting in a dedicated "Plastics Recovery Facility" (PRF). Mixed plastic waste streams are aggregated from multiple MRFs to feed a large-scale PRF operation which would ideally process at least 100,000 tonnes per year. The PRF is designed to deploy advanced sorting technologies and operate as a business focused solely on providing high-quality and cost-effective feedstock needed by recyclers.

> As a leading provider of sorting technologies, we recognise the critical importance of concepts introduced in this Insights paper from the Alliance, in particular the role of secondary sorting, based on marking and/or AI technologies, to enable providing the feedstocks required for recycling at high quality and controlled as well as ensuring traceability.
>
> **Jean Henin**
> **Chairman & CEO**
> Pellenc ST

The importance of advanced sorting technologies

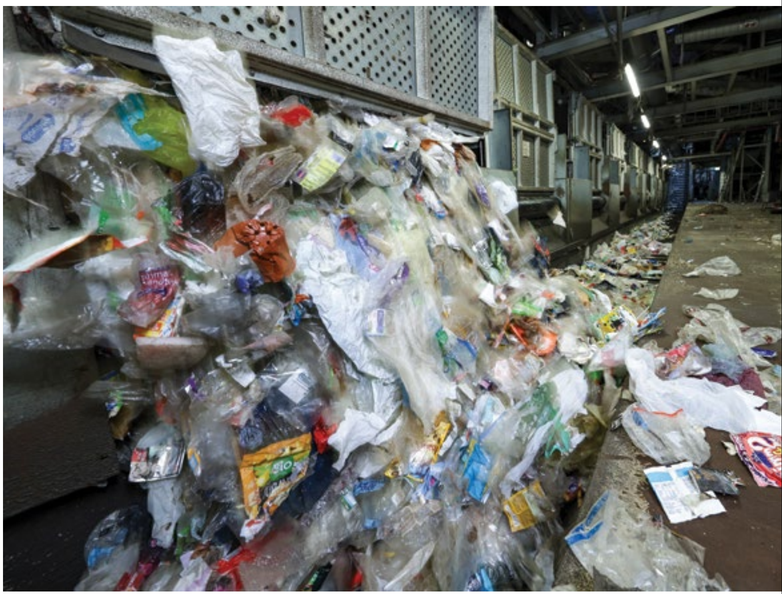
Today, automated sorting in MRFs and PRFs largely relies on near-infrared (NIR) spectroscopy for polymer detection, and optical recognition for colour detection. These detection systems are connected to high-speed pneumatic sorting machines that use bursts of air to divert different materials from one conveyor belt to another.

While NIR has served the industry well, it has limitations. NIR can detect, but not quantify, the presence of different polymers or additives in a piece of packaging. NIR also cannot identify types of packaging and hence cannot access packaging databases to look up additional product characteristics such as melt flow.

Two major advancements now offer the potential to revolutionise the identification of flexible packaging in sorting facilities.

> The Alliance believes a better alternative in many situations is secondary sorting in a dedicated "Plastics Recovery Facility" (PRF). Mixed plastic waste streams are aggregated from multiple MRFs to feed a large-scale PRF operation which would ideally process at least 100,000 tonnes per year. The PRF is designed to deploy advanced sorting technologies and operate as a business focused solely on providing high-quality and cost-effective feedstock needed by recyclers.

The first is the use of digital watermarks. These invisible codes, embedded throughout a package, function like imperceptible barcodes and are detected by overhead optical scanners. The technology can also support other use cases beyond sorting such as warehouse management, retail checkout, digital passports, quality control and generation of big data on recycling rates.



Digimarc has developed a proprietary digital watermark that has been fully demonstrated with films and flexibles under the "HolyGrail" project in Europe, jointly developed and funded by the Alliance to End Plastic Waste and the European Brands Association (AIM). The technology works well, but adoption has been slow due to up-front costs and concerns about locking into a single technology provider. However, the latter is easing as new providers enter the market.

A second new group of sorting technologies involves using object recognition coupled with AI learning algorithms. Such systems are trained to recognise different packaging types using visible characteristics such as brand logos, shapes and colours. Object recognition has an advantage in that the cost burden falls on the recycler rather than brand owners, which can ease adoption. However, object recognition has been mostly proven to date with rigid packaging. With films and flexible packaging, recognition may be hindered due to materials being balled-up, torn, covered in food or otherwise deformed.

The Alliance believes that digital watermarks are likely the more strategic choice given their multiple use cases. However, the more immediate priority is the accelerated deployment of advanced sorting infrastructure, regardless of detection method.

One area where technology still falls short is in respect of the physical sortation that follows once a packaging item has been identified.

A pneumatic sorting machine is essentially binary, allowing an object to either continue along a sorting line, or else be blown onto a new line. This can be improved with multi-pass and multi-channel configurations but remain capital, energy and space intensive.

Robotic sorters – which pick items off a conveyor one-by-one – can sort into multiple fractions and so offer potential to reduce the cost for granular sorting or complement pneumatic sorting by sitting on "dead" spaces in conveyors. However, today the speed and reliability of robots is in most cases not yet adequate for high-speed operation and hence are primarily used only for a last step of "polishing".

> The Alliance believes that digital watermarks are likely the more strategic choice. However, the most urgent need is to deploy advanced sorting infrastructure, regardless of detection method.

Food contact – a special case

A significant proportion of flexible packaging is used in food-contact, for example candy wrappers, cling-films, and food wraps. Recycling back into such applications presents additional challenges of quality control to meet the rigorous food-safety standards of the FDA in the US and EFSA in the EU. Recyclates must not contain harmful substances above permitted levels and must undergo rigorous decontamination to remove "not intentionally added substances" (NIAS) such as microbial contaminants, or decomposed polymers, additives and pigments.

Chemical recycling is the obvious choice to meet the requirements of food contact packaging since the waste feedstock is subjected to full decomposition and intense processing technologies. However, mechanical recycling is also possible with advanced decontamination technologies, especially when recyclers can demonstrate the original food-contact status of the material they are recycling. Mechanical recycling of polypropylene (PP) and polyethylene (PE) films is especially challenging due to their high absorbency compared to PET, which makes decontamination more difficult.

An example of emerging decontamination technologies is the Alliance's COtooCLEAN project with the partner company Nextek, using super-critical CO_2 as a washing and extraction solvent – a process used today for decaffeination of coffee and the extraction of spices, flavours and aromas. Under this technology, the super-critical CO_2 is able to reach deep into molecular structure of polyolefin films and scrub them clean of dirt, oil, other contaminants and most types of inks.

6.

Flexible Packaging Waste
Circularity Enablers

Solutions for recycling flexible packaging already exist but only at limited scale. For wide-scale adoption to bring about systems change these solutions must be investable. For private capital investment, there must be confidence in a reasonable return.

Key levers to improve investability of recycling for flexibles are:

1. **Collection and sorting**
   Efficient, segregated collection and secondary sorting systems are required to generate high-quality feedstock for recycling.

2. **Increase end-market demand**
   Strong demand and clear quality requirements for recyclates create commercial viability across the value chain.

3. **Derisking investment**
   Stable policies, predictable frameworks and fair competition reduce risks and enable long-term financing.

4. **Design for recyclability**
   Harmonised design guidelines reduce unnecessary complexity in packaging, making recycling more effective and scalable.

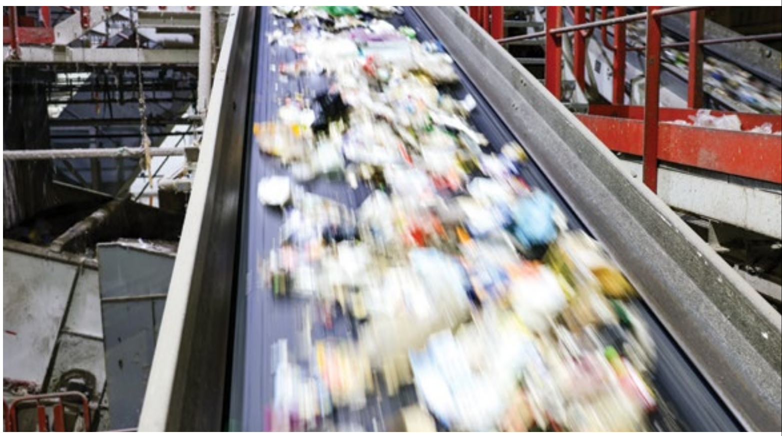
5. **Eco-modulation**
   Modulated EPR fees reward recyclable and cost-efficient designs, encouraging convergence on best practices.

Collection and sorting

In most OECD countries, waste collection and managed waste disposal are provided as a public service funded by the local authority. The question remaining is whether the collection lends itself to efficient sorting and feedstock supply for recycling.

As described earlier, recycling of flexibles is considerably easier with segregation of plastic, glass and paper at the household level. This comes at an additional cost. Municipalities typically struggle to justify this additional cost to the community they serve unless they can demonstrate that waste is being recycled effectively.

EPR schemes can close this funding gap by requiring packaging producers to finance collection and management of their products. An EPR fee can support both collection and sorting, while also improving the competitiveness of recyclates against virgin polymers.



> At Fost Plus, we are convinced of the importance of PROs and the corresponding EPR framework which is enabling Belgium to be one of the leading countries in the world in driving the adoption of circular solutions for plastics. We are proud to be able to support the Alliance in their Flexible Packaging Program.
>
> **Philippe Gendebien**
> **Business Development**
> Fost Plus, Belgium

Increase End-Market Demand

Without high-value applications for recyclates, there is no case for investment. End-market pull is essential to drive system viability.

The most effective way to stimulate demand for high-quality products from recycling is through commitments to PCR content. However, as with any policy intervention, careful design is needed to avoid unintended consequences.

- A single PCR target is an arbitrary fixed point, and does not reflect the varying technical feasibility across applications. Some uses can easily incorporate recycled content, while others (e.g. food-contact films) face greater challenges. Differentiated targets may be needed, including distinctions between films and rigid packaging.
- A target that is applied at the individual products rather than averaged across a brand owner's portfolio, does not incentivise using recyclates that can only be used at low levels, i.e., below the target, nor does it reward utilisation above target levels.
- If a target is too ambitious, brand owners may switch to higher-carbon alternative materials.

An alternative is to use market-based approaches that reward the use of recycled content through economic incentives, such as relief on EPR fees.

Other mechanisms also exist, such as taxing virgin polymer use or fully loading EPR fees to ensure recyclates can be made available at a lower cost than virgin polymer. However, any such mechanism needs to provide a level playing field versus alternative materials to ensure the most environmentally beneficial materials are used.

It is also critical to ensure robust verification standards for imported recyclates and packaging claiming recycled content, including stringent proof of provenance, quality and certification. Waste should be recycled within the local geography where there is sufficient scale to make this economically viable.

Derisking Investment

Unlocking investment dollars is essential for the large-scale adoption that drives systems change. Stable and predictable policy frameworks, long-term offtake agreements, and measures to ensure fair competition against imported products are key to reducing investment risk.

Other specific challenges exist around chemical recycling, including debates over mass-balance attribution methodologies and recycled content claims. These open questions can hinder investment in chemical recycling.

Governments can play a decisive role in reducing uncertainty through decisive and stable policies. Without this, investor confidence will remain low for capital-intensive recycling technologies.

It is also critical to ensure robust verification standards for imported recyclates and packaging claiming recycled content, including stringent proof of provenance, quality and certification. Waste should be recycled within the local geography where there is sufficient scale to make this economically viable.

Design for Recyclability

Reducing the complexity of flexible plastic packaging is vital to make recycling viable. While many functional requirements of packaging are legitimate, unnecessary complexity in design remains common and undermines the efficiency of recycling systems. For example, the wide use of reverse (laminated) printing embeds inks between polymer layers, preventing easy removal through standard washing and deinking processes.

Moving away from complex polymer structures and different barrier materials in an uncoordinated manner can also undermine system efficiency. A case in point is the pharmaceutical industry's effort to phase out PVC and aluminum-based medicinal blister packs which are difficult to recycle. While mono-material alternatives (PET, PP, or LDPE) exist, diverging choices by different companies could fragment the waste stream and thereby limit the potential to achieve scale.

Effective design must also consider the technologies most likely to be utilised in recycling. Packaging optimised for chemical recycling has different requirements from packaging designed for mechanical recycling. Chemical recycling performs best when halides and oxygen-containing polymers are avoided, whereas mechanical recycling is enabled by single-polymer construction, limited use of colourants and inks, and surface rather than reverse printing.

To address these challenges, industry convergence on harmonised design practices is essential. Common guidelines and standards provide a practical pathway to improve recyclability and reduce complexity across packaging formats. Notable examples include the CEFLEX design guidelines, the Association of Plastic Recyclers (APR) protocols in the United States, and the RecyClass standards in Europe. By following such frameworks, companies can align on best practices that balance functionality with recyclability, helping to create packaging systems that are more consistent, scalable and circular.

Effective design must also consider the technologies most likely to be utilised in recycling. Packaging optimised for chemical recycling has different requirements from packaging designed for mechanical recycling.

Eco-Modulation

Switching packaging design is costly, often involving write-offs of earlier equipment investments or exits from long-term contracts. Eco-modulated EPR fees help overcome this barrier by rewarding more recyclable and cost-efficient designs. By aligning economic incentives with recyclability, eco-modulation can accelerate industry-wide transformation.

7.

Creating Systems Change

7. Creating Systems Change

The sections above describe the significant challenges for creating circular systems for films and flexibles, while demonstrating solutions to overcome those challenges.

However, bringing about systems change requires numerous solutions to be implemented across the value chain in simultaneous manner. Failure to do so means decision makers could become stuck in complex dependencies where progress in one area is contingent on action in another, thus resulting in delays or inaction. For example:

- Waste management companies or municipalities may be more willing to support segregated collection of flexible packaging if there is clear downstream processing capacity in place.
- MRF operators or secondary sorters are more likely to invest in sorting infrastructure when there is strong and reliable demand from recyclers or end-markets.
- Recyclers are more inclined to scale capacity when they have access to consistent, high-quality feedstock and stable end-market value.
- Brands and converters are more likely to incorporate recycled plastics when supply is reliable, costs are competitive, and material performance meets application requirements.
- Adoption of design-for-recyclability guidelines becomes more feasible for brands when there is clarity that infrastructure exists to support recycling of improved packaging formats.
- Investors are more confident to deploy capital when supported by clear policy signals, viable business models, and coherent value chain efforts.

Although today's waste management systems are functional, they are not circular. The challenge is to transition towards a system that better utilises raw materials and reduces environmental impact, including a reduced carbon footprint. That means demonstrating a significantly better system, and enabling its rapid adoption, meaning doubling system capacity every 3-5 years. These complex dependency challenges and the need for subsequent rapid adoption can be overcome by parallel implementation of three key and inter-related initiatives.

1. Utilise market-mapping to build a deep understanding of the system solutions, infrastructure, and key enablers, including policy and economic levers required to make the system investable.

2. Demonstrate the required solutions to showcase the practical and economic boundaries for the different steps needed for systems change. Such demonstrations are most likely to comprise individual projects which may be undertaken before the system design work is complete, but which are expected to address key steps in the overall system. These projects will require funding since the enablers and efficiencies of scale will not yet be in place. Examples include:
   - Compare cost-efficiency, community engagement and effectiveness of different collection models for household flexibles, such as drop-off, loose in the bin, bag-in-the bin, separate bin.
   - Evaluate the cost-to-benefit ratio to retrofit MRF's with the capability to handle household flexibles versus building secondary sorting infrastructure.
   - Showcase establishing high-quality recycling from post-commercial large-enterprise waste streams.
   - Demonstrate the value-creation of secondary and/or advanced sorting.

3. Convene all the key stakeholders to engage in creating and driving rapid adoption of system solutions. Such influencers will be critical to support the success of solution showcases. Equally, it will be critical to engage these stakeholders in the market mapping exercise. Finally, enlist their support in the replication of solutions in other locations once a solution has proven successful.

> Achieving a circular economy for Flexible Plastics is the core-mission of CEFLEX. There are many hurdles to bring about system change but the solutions and required enablers are known and well-described in this report. We believe all actors across the whole plastics value chain need to collaborate to realise a circular economy for all plastic packaging materials in Europe. Key will be to realize it in an economically sustainable way which requires an aligned and coordinated effort now to act towards 2030.
>
> **Dana Mosora**
> **Work Package Consultant**
> CEFLEX

8.

Role of the Alliance

8. Role of the Alliance

A key learning from the Alliance's experience is that individual projects in different geographies and at different stages in the value chain can create valuable insights, while enabling a limited amount of replication and expansion. However, such individual projects do not readily coalesce to create effective system change and impact on a larger scale, which is what is needed.

Recognising this, the Alliance has refined its strategy to focus on specific programs in clearly defined geographies, seeking to orchestrate or complement engagement of all key stakeholders in overall systems change, rather than an individual project.

One such program is the Flexibles Thematic Program, targeting improving circularity and enabling compliance with existing or emerging regulations in Europe and North America, with a specific focus on US States that are setting the pace on circular economy commitments and EPR implementation.

Our unique value is in the ability to bring visionary insights and practical, cross-regional experience across all aspects of technology solutions, system enablers and implementation approaches, complemented by deep technical experience and some level of seed funding for individual projects.

This value is illustrated by our engagement in potential system-changing projects, a selection of which are listed below:

HolyGrail
Joint project with AIM in EU to demonstrate the technical viability of digital sorting and business benefit from deploying advanced sorting technologies

ValueFlex
Joint project with CEFLEX in EU aiming to commercialise a process for closed-loop mechanical recycling of flexibles in household waste streams

COtooCLEAN
Building a semi-commercial demonstration of the use of super-critical CO_2 to remove contaminants from polyolefin films to meet EFSA requirements

Quality of Recyclates
Supporting industry in the EU to identify key quality requirements for recyclates aimed at specific large-scale applications and demonstrating different approaches to meet these

Greenback
Small-scale modular chemical recycling for processing flexibles waste close to its source and/or integration with a flexibles recycling plant

CRDC
Basic recycling technology to utilise sorting/ recycling residues in structural cement with additional carbon capture

PLUGandPLAY
Innovation hub, surfacing and supporting many early-stage technologies

Engagement in the Alliance's Flexibles Thematic Program is ideally through membership, which provides a voice in the overall direction and priorities of the Alliance's programs. A targeted interest in only the Flexibles Thematic Program can be accommodated as a program supporter.

The Alliance as a 501(c)(3) charity does not engage in lobbying, nor act for the direct commercial interests of member companies, but informs key stakeholders based on practical demonstration, scientific facts, business realities and technology-agnostic solutions with the goal of ending plastic waste.

> The AEPW Insights Report accurately summarizes the challenges and solutions for recycling flexible plastics. Circular Action Alliance values ongoing collaboration and dialogue with global partners like AEPW to drive ambitious investments and progress in flexible plastics recycling.
>
> **Neil Menezes**
> **VP of Material Services**
> **Circular Action Alliance**

You can be part of the solution.
To find out more, visit **endplasticwaste.org**

ALLIANCE TO END PLASTIC WASTE®