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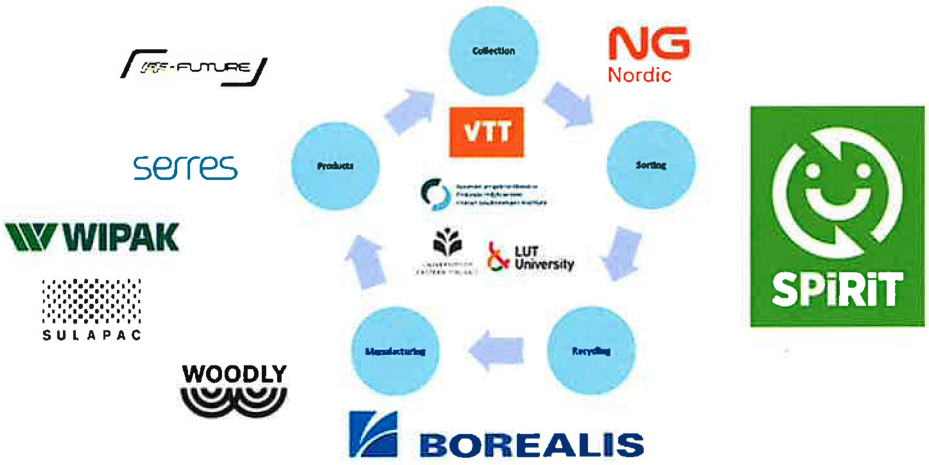

PlasticsCircularity

Creating business through circularity of plastic

Plastic-Containing Rejects from Mechanical Recycling: Current Management and Valorisation Pathways

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Summary

Mechanical-recycling rejects do not constitute a uniform material category; their valorisation potential depends on the origin and composition of the stream, the preceding sorting or recycling process, and the quality requirements of the intended downstream application. The findings support a feedstock-specific hierarchy of treatment routes. Polyolefin-rich residual streams that cannot be mechanically recycled may be suitable for pyrolysis where they can be characterised and pre-treated to meet the required feedstock specification. More heterogeneous fractions generally require further sorting, washing or purification and, where material recovery is not technically, environmentally and economically viable, energy recovery remains the prevailing treatment route. Pre-treatment can improve pyrolysis feedstock quality, although trade-offs remain between contaminant removal, material recovery and cost, and additional upgrading may still be required. Improved valorisation therefore depends on coordination across the value chain, including more effective collection and sorting, consistent feedstock characterisation, exchange of quality information, sufficient and certifiable supply, and stable end markets.

The study is based on interviews with experts from seven European companies operating in the field of plastics recycling, including both mechanical and chemical recyclers. It identifies recurring industry observations and development priorities but does not quantify the comparative technical, economic or environmental performance of the treatment alternatives.

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Tampere, 20.11.2026

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Preface

Improving plastics circularity requires not only more effective recycling of clean material streams, but also solutions for the fractions that current mechanical recycling processes cannot recover. These rejects may still contain valuable plastic resources, yet their heterogeneous and variable composition makes further recycling challenging. Better characterization, sorting and treatment of these streams can help retain more material value in circulation and reduce reliance on energy recovery.

This report was prepared as part of the *PlasticsCircularity* project. It examines the current management of plastic-containing rejects and explores how improved sorting, pre-treatment and complementary recycling routes could support their more sustainable valorization, while recognizing mechanical recycling as the primary route whenever material quality allows.

I wish to express my sincere appreciation to all interviewees and reviewers for sharing their expertise and contributing to the advancement of sustainable practices within the plastics sector. I would also like to extend particular thanks to Mona Arnold for conducting interviews and for providing valuable support in developing my understanding of the topic.

Tampere, 20.11.2026

Sanna Martin

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1. Introduction

This report examines plastic-containing reject streams generated in mechanical recycling, with particular focus on mixed plastics from post-consumer packaging sorting. It reviews current recycling and valorisation routes and combines literature evidence with interviews across the plastics recycling value chain to identify technical, market, regulatory and collaboration needs.

In 2022, 16.4 Mt of post-consumer plastic waste was collected separately in the EU. Of this amount, 49.4% was recycled, 39.6% was incinerated, and 11.0% was landfilled (The Circular Economy for Plastics – A European Analysis 2024 • Plastics Europe, n.d.). A similar share appears to have been incinerated in Finland: of the 68 kt of plastic packaging collected separately in 2022, 26 kt (38%) was not recycled and was presumably incinerated (Salminen, 2025).

Joint Research Centre (JRC) study concludes that the preferred management option for plastic waste should be selected on the basis of three principal criteria: (i) environmental performance, reflected in the maximisation of material recovery and the minimisation of processing impacts, particularly energy consumption; (ii) technical feasibility, taking into account the characteristics of the plastic waste stream and the treatment required; and (iii) economic feasibility. (Garcia-Gutierrez et al., 2023)

Chemical recycling is an important complementary tool for achieving plastic circularity by converting difficult-to-recycle plastics into valuable feedstocks and virgin-equivalent products, but its long-term success depends on overcoming technical, economic, environmental, and scaling challenges while being integrated with mechanical recycling, eco-design, separate collection, supportive policies, and consumer engagement. (Cafiero et al., 2025)

The sorting stage represents the most significant point of reject generation in the mechanical recycling of plastics. In Germany and the Netherlands, DerGrüne Punkt's specification Mixed Plastics DKR 350 is widely used as a reference specification for mixed-plastic fractions generated during the sorting of post-consumer plastic packaging. In Italy, a broadly comparable heterogeneous residual fraction generated by plastic-packaging sorting is commonly referred to as "plasmix"(Cafiero et al., 2025). Although the precise composition varies according to collection systems and sorting practices, plasmix is broadly comparable to material classified under DKR 350. Figure 1 presents the typical composition of DKR 350 fraction.

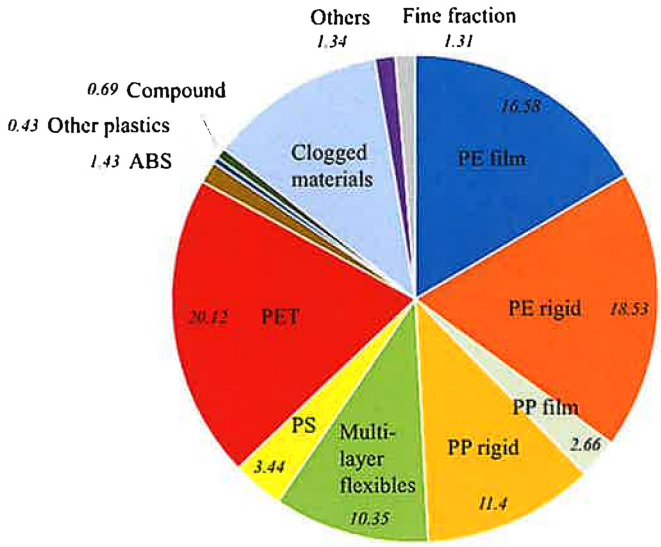

Figure 1. Composition (wt%) of DKR 350 stream from unwashed sorted plastic waste (Genuino et al., 2022).

In Germany, out of separately collected household packaging waste, 50% is not qualified for mechanical recycling. Half of this reject, meaning 25% of the collected volume is mixed plastics according to DKR 350 specification. This mixed plastics stream could be further sorted to separate PET fraction for solvolysis and MPO (mixed polyolefins) fraction for chemical recycling. Estimated volume in Europe for this MPO feedstock is appr. 600 kt/a. (AMI, 2022)

New Mixed Plastics specification DKR 352 excludes PET fraction and defines more narrowly specified mixed-plastics fraction than DKR 350. While DKR 350 includes PE, PP, PS and PET within the target material composition, DKR 352 is limited to packaging-related PE, PP and PS. Accordingly, PET is treated as an impurity in DKR 352, with a limit of <3 wt% for all PET articles, whereas DKR 350 specifies only specific limit of <4 wt% for transparent PET bottles. (Der Grüne Punkt, 2024a, 2024b)

2. Background and literature context

Pyrolysis of mixed plastic waste (DKR 350) has been studied in scientific research. The influence of different washing procedures on feedstock composition and pyrolysis product yields was investigated by Twente University. The results showed that high oxygen and chlorine content exist without additional sorting steps. This will cause unwanted effects on pyrolysis and require additional purification of the pyrolysis oil. (Genuino et al., 2022)

Ong et al. studied multi-level modelling of sorting and pretreatment pathways for mixed plastic waste (DKR 350) towards pyrolysis feedstock. They concluded that washing should be selected by balancing feedstock quality, polyolefin recovery and cost. Cold washing with density separation provided the strongest oxygen and chlorine removal but reduced recovery and increased costs, whereas dry washing was simpler and more economical, particularly for film-rich streams, but did not meet all chlorine limits. The main quality benefit of cold washing resulted from the density-separation step. (Ong et al., 2026)

In BF Urban Mill project (*SPIRIT Project UrbanMill*, 2025), Aalto University and VTT studied a Finnish reject from separately collected packaging waste as a feedstock for pyrolysis. The composition was confirmed to be very close to DKR350, as shown in Figure 2. The results demonstrated that sink-float separation can significantly improve the suitability of mixed plastic waste for pyrolysis. By concentrating polyolefins in the light fraction and removing PET and PVC into the heavy fraction, the process reduced halogen levels and notably decreased chlorine content relative to the original material. These results suggest that sink-float separation may provide a practical and cost-effective pre-treatment option for improving pyrolysis feedstock quality and reducing problematic contaminants.

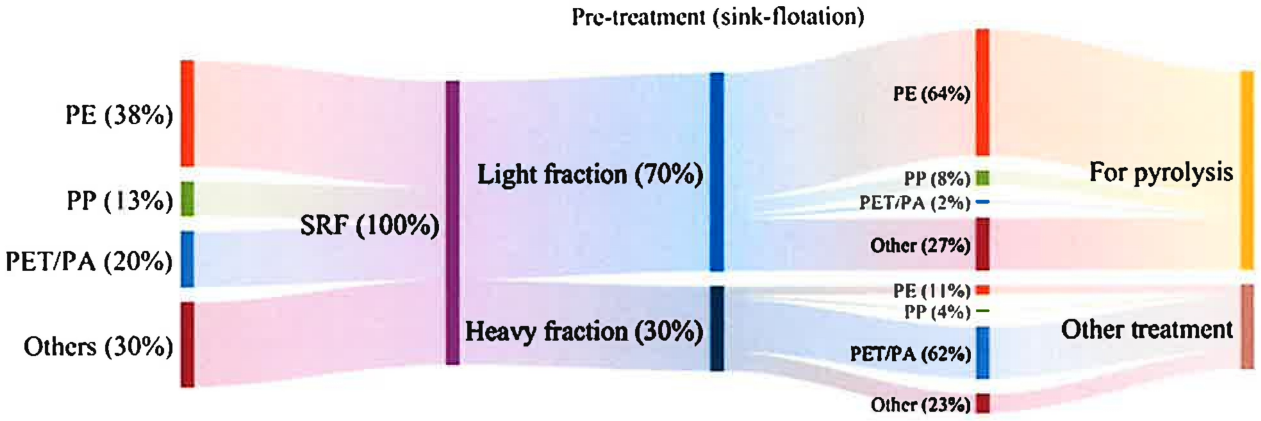

Figure 2. Using sink-floatation as a pre-treatment of separate collection plastic packaging waste reject for pyrolysis (SPIRIT Project UrbanMill, 2025).

Van Akker et al. (2025) reached similar conclusions in their pilot-scale study of DKR 350 sorting and pretreatment for pyrolysis. The results showed that, after sorting to recover PO-enriched streams, catalytic pyrolysis can effectively valorize the remaining PO-poor fraction. This finding demonstrates the technical viability of improving plastics recycling through targeted sorting and pyrolysis. A schematic diagram of the process is shown in Figure 3. (van Akker et al., 2025)

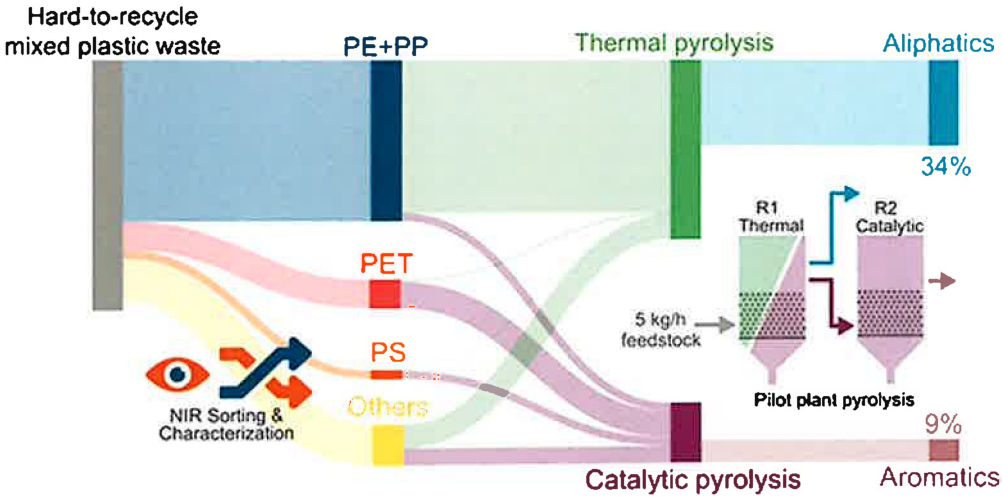

Figure 3. Visualisation of DKR 350 sorting and pretreatment for pyrolysis (van Akker et al., 2025).

At Site Zero, the Swedish Plastic Recycling facility in Motala, the most advanced sorting technology is utilised. Site Zero's output streams from the sorting of separately collected plastic packaging waste were classified in March 2023 performed pick analysis as green, yellow, or red fractions. Results are shown in Figure 4. Green fractions comprise plastics suitable for recycling into packaging-grade recyclates, thereby retaining a substantial proportion of their original material value. Yellow fractions are recycled into lower-value, non-packaging applications and are therefore considered downcycled. Red fractions comprise non-recyclable rejects directed to energy recovery. (Näringslivets Producentansvar, n.d.)

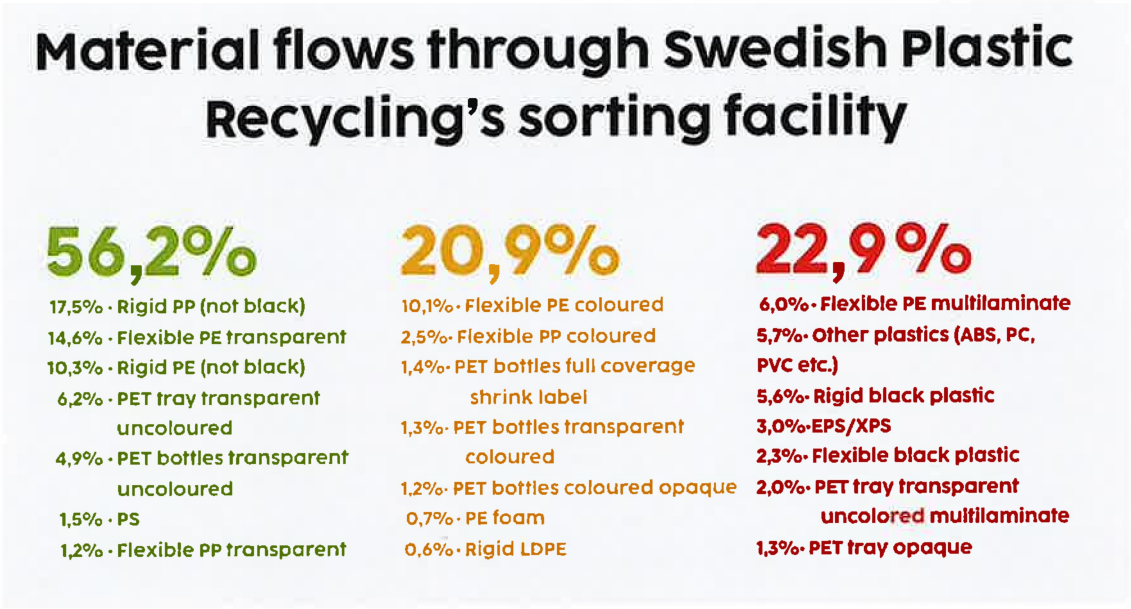

Figure 4. Material flows in plastics packaging sorting facility Site Zero in Sweden (Näringslivets Producentansvar, n.d.).

The composition of separately collected plastic packaging waste in Finland is expected to be broadly comparable to Sweden, and depending on the sorting technology the quality and the share of target streams and rejects can vary.

3. Methodology and limitations

The research was conducted through a series of interviews with experts from seven companies involved in plastic-waste sorting and mechanical or chemical recycling. The interviewed companies were European companies, most of them located in Finland. The interviews explored their views on the generation of plastic-containing rejects and opportunities for material recovery.

The interviews were conducted online using Microsoft Teams and transcribed for analysis. The transcripts were pseudonymised before analysis, and the findings presented in this report were anonymised.

This study is based on interviews with a limited group of industry experts, so the findings may not reflect all practices across the plastics recycling value chain. The results mainly describe the interviewees' views and experiences, as detailed company data was not used for comparison or verification. The study identifies key challenges and opportunities but does not quantify the technical, economic or environmental performance of different treatment options, and the findings may need to be updated as technologies, markets and regulations develop.

The interview highlighted that a reject is defined by the target fraction of a particular mechanical recycling process. Reject streams should therefore be characterised by their origin, sorting or recycling process, target fraction, and actual polymer and non-polymer composition rather than simply being classified as "mechanical recycling rejects".

4. Interview findings

4.1 Current state in industry

Chemical recycling is not currently considered suitable for all mixed plastic residues. Several interviewees reported that available reject streams contain organic matter, paper, textiles, wood, PET, PVC, polyamide and other contaminants that limit their suitability for pyrolysis. On the other hand, chemical recycling provides opportunities to increase recycled content in demanding applications. Different PE and PP grades, films, rigid products, multilayer structures and materials with different molecular characteristics can be difficult to combine in mechanical recycling even though they are all classified as polyolefins. This variation within the polyolefin family is less critical for pyrolysis, provided that the overall feedstock composition meets the required specification.

One interviewee, representative of a chemical recycling company, reported that the company had shifted its sourcing strategy away from refuse-derived fuel (RDF) toward polyolefin-rich waste streams, such as contaminated plastic films and rigid plastics, sourced primarily from pre-sorting facilities and collection systems. These materials are further purified and washed for chemical recycling. Chemical recycling company defines the required feedstock composition but does not necessarily prescribe how this quality should be achieved. Upstream actors, such as sorting and pre-treatment operators, determine whether additional sorting, washing, drying or other treatment steps are needed to meet the specification.

Clean polyolefin fractions are generally directed to mechanical recycling because it provides higher technical yields and recycling rates, whereas chemical recyclers increasingly target polyolefin-rich streams sourced from pre-sorters and collection systems. One interviewed chemical recycler also mentioned plans to use plastics separated from mixed waste after removing PVC and PET, initially without washing but with the possibility of adding a washing stage later.

4.2 Main technical and operational challenges

Generally, feedstock purity was considered by many interviewees the main technical constraint. Pyrolysis requires relatively clean, hydrocarbon-rich fractions and cannot efficiently process highly heterogeneous mixtures. Contaminants, particularly halogens and incompatible polymers, can reduce oil quality and complicate processing. However, feedstock suitability is not determined primarily by the technical capability of the pyrolysis reactor. Instead, the required quality of the pyrolysis oil for the downstream customer ultimately defines the acceptable feedstock composition. Feedstock specifications therefore reflect the targeted oil quality, yield and commercial requirements.

Operationally, chemical recycling also requires sufficient throughput: fixed costs for maintenance, personnel and other plant operations must be distributed across large material volumes. Interviewees noted that many start-ups struggle to achieve the scale required for profitable operation. Multi-stage sorting and reject recirculation reduce reject volumes. However, as the volume decreases, the composition of the remaining reject stream becomes increasingly challenging for downstream recovery and valorization. Incineration therefore remains the principal treatment route for the most heterogeneous fractions.

4.3 Market and value-chain barriers

The availability of suitable feedstock, recycling capacity, and stable end markets remains limited. Supplier selection is influenced by material purity, availability and price, and operators seek long-term relationships between suppliers and end users being able to deliver consistent, certified waste streams. A closer link between extended producer responsibility and sorting could strengthen the incentive to improve recovery yields.

Mixed plastic rejects can be used in composite products such as park benches, but domestic demand for these applications is limited and may require products or materials to be exported. Differences in polymer melting behaviour and thermal stability can cause degradation and poor mechanical properties. Although fibre reinforcement can improve performance, weak interfaces between polymers and fibres may limit these benefits. Additives can improve compatibility and consistency but increase cost and process complexity, particularly in multi-polymer mixtures. Variations in feedstock composition also make it difficult to achieve consistent stiffness, strength and durability.

An uncertain and fluctuating business environment is hindering investments in the further valorization of recycling rejects. Competition from low-cost virgin plastics, including imports from Asia, further weakens the market position of recycled materials.

4.4 Regulatory and customer-driven pressures

Interviewees identified slow and uncertain implementation of EU requirements as a barrier to investment and market development. At the same time, the Packaging and Packaging Waste Regulation is expected to increase demand for recycled content and influence the sector towards 2030. Customer and downstream quality requirements also shape feedstock acceptance, particularly where the quality of pyrolysis oil and its suitability for further processing must be demonstrated.

The interview distinguishes several regulatory issues that affect different parts of the chemical recycling value chain. Mass-balance allocation is particularly relevant when recycled feedstock is integrated into existing refinery and petrochemical infrastructure, whereas End-of-Waste (EoW) status determines when pyrolysis products can cease to be legally classified as products. EoW for chemical recycling has been studied in connection with defining Finnish national decree.

Cross-border feedstock sourcing introduces an additional regulatory layer through waste-shipment requirements.

4.5 Data, quality and certification needs

Reliable feedstock characterization and quality control are essential. Reported practices include pre-acceptance analysis, internal limits for contaminants such as halogens, and verification of material origin and composition. Different pyrolysis technologies can tolerate different levels and types of contaminants, depending on reactor design, process conditions and purification technologies. Consequently, detailed contaminant limits and feedstock specifications may constitute proprietary operational know-how and hence feedstock specifications are generally confidential. Nevertheless, the general direction is similar across technologies: polyolefin-rich feedstocks are preferred, while PET, PVC and other problematic contaminants should be limited.

ISCC PLUS certification was identified as an important requirement for traceability, compliance and product quality, and one operator specifically sought suppliers capable of providing certified waste streams.

4.6 R&D and collaboration needs

Further development is needed across the value chain rather than at a single process stage. Priorities include improving collection and upstream sorting, reducing non-plastic material entering recycling processes, and exchanging quality information between collectors, sorters and recyclers.

One interviewee explained that they aim to reduce the amount of waste by sharing information upstream and improving collection systems. The goal is to obtain better sorted material from the start, which reduces the amount of non-plastic packaging entering the process.

Another interviewee highlighted an apparent paradox: large quantities of plastic waste are generated, while chemical recyclers may still struggle to secure sufficient feedstock. The relevant question is therefore not the total amount of plastic waste generated, but how much material is actually collected, logistically accessible, available at sufficient scale and capable of being upgraded to the required feedstock specification.

Research is also needed to assess treatment routes for fractions unsuitable for pyrolysis, including gasification, and to evaluate carbon capture, storage and utilization options for fossil carbon dioxide emissions from waste incineration.

4.7 Future outlook

The future role of chemical recycling will depend on access to sufficiently clean feedstock, economically viable plant scale, clearer regulatory implementation and stronger demand for recycled products. Pyrolysis is unlikely to provide a solution for the most contaminated rejects without substantial improvements in sorting and pre-treatment.

Recycling company interviewee in a technical role: “In a nutshell, I don't see any option for our rejects unless the CR technology is gasification.”

Gasification may offer an alternative for these fractions, but interviewees considered the technology insufficiently mature where the objective is to recover monomers for new polymer production. If mechanical or chemical recycling is not economically and environmentally sustainable, energy recovery coupled with carbon capture, use and storage (CCUS) was identified as a long-term Plan B. While it may provide a viable pathway for the most challenging waste streams, it does not solve the immediate short-term problem.

5. Conclusions

The interviews collectively show that a mechanical-recycling reject is not a uniform material category but the residual fraction of a particular sorting or recycling process. Its valorization potential therefore cannot be inferred from the term *reject* alone. Assessment must consider the stream’s origin, the recovery target of the preceding process, its actual polymer and non-polymer composition, and the quality requirements of the intended downstream product. This distinction is particularly important because improved sorting can reduce the quantity of reject while simultaneously concentrating the most difficult materials in the remaining fraction.

The findings support a feedstock-specific hierarchy of treatment routes. Clean and sufficiently homogeneous polyolefin fractions should generally remain in mechanical recycling, whereas pyrolysis can complement mechanical recycling for polyolefin-rich fractions that cannot be mechanically recycled but can be upgraded to an acceptable specification. The most heterogeneous fractions—containing substantial amounts of organic matter, paper, textiles, wood, PET, polyamide, PVC or other problematic constituents—are not presently suitable for conventional pyrolysis without additional sorting, washing and purification. Energy recovery therefore remains the prevailing outlet where no technically, environmentally and economically viable material-recovery route is available. This hierarchy is consistent with the literature and with the JRC conclusion that treatment choices should maximize material recovery while considering the characteristics of the waste stream, processing impacts and economic feasibility.

The literature confirms that pre-treatment can substantially improve pyrolysis feedstock quality, but it does not eliminate all constraints. Washing of DKR 350 reduced biogenic, inorganic and halogen content, yet the resulting oil/wax still contained more than 150 ppm chlorine and required further upgrading (Genuino et al., 2022). Recent modelling indicates that sorting and washing configurations involve trade-offs between polyolefin recovery, contaminant removal and cost (Ong et al., 2026). VTT's UrbanMill project results similarly show that sink–float sorting can enrich polyolefins and that a combination of sorting, catalytic pyrolysis, adsorption and hydrotreatment can substantially reduce chlorine. Pilot-scale research by van Akker et al. (2025) further demonstrates that targeted sorting followed by different thermal and catalytic pyrolysis routes can valorize both polyolefin-rich and selected polyolefin-poor fractions. These results support pyrolysis as a potential pathway for characterized and purposefully prepared streams, not as a universal solution for all mechanical-recycling rejects.

A particularly important system-level finding is the distinction between the total amount of plastic waste and the amount of feedstock that is available to a recycler. Chemical recyclers may face feedstock shortages despite large overall waste volumes because only part of the material is collected, logistically accessible, available at sufficient scale, certifiable and capable of being upgraded to the required specification. Moreover, acceptable feedstock composition is ultimately governed by downstream product quality and customer requirements, whereas collectors, sorters and pre-treatment operators must determine how that quality is achieved. Valorization is therefore primarily a value-chain coordination challenge, rather than a problem that can be solved by an individual reactor or recycling plant.

The most immediate development priorities are to improve collection and upstream sorting; establish consistent feedstock characterization and quality-information exchange; and assess yields, losses, costs and environmental impacts across the entire pre-treatment, conversion and upgrading chain. Long-term supply relationships and appropriate chain-of-custody systems can reduce feedstock and market uncertainty.

Gasification should be treated as a potential development route for difficult fractions rather than an immediately available route to monomers. Overall, no single technology can valorize every reject stream. The most credible pathway combines prevention, improved collection and sorting, mechanical recycling wherever material quality can be retained, targeted chemical recycling for suitable residual streams, and controlled energy recovery for the remaining fractions.

These conclusions should be interpreted within the study's limitations. The interview evidence is based on experts from seven European companies operating in the field of plastics recycling, including both mechanical and chemical recyclers. Detailed company data were not available for independent comparison. The study therefore identifies recurring industry observations and development priorities but does not quantify the technical, economic or environmental performance of the treatment alternatives.

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