Certech
R&D partner in chemistry

Rue Jules Bordet, 45 - Zone Industrielle C • B 7180
SENEFFE - BELGIUM
Tel. +32 64 520 211
www.certech.be

Technical Information Note

February 2026

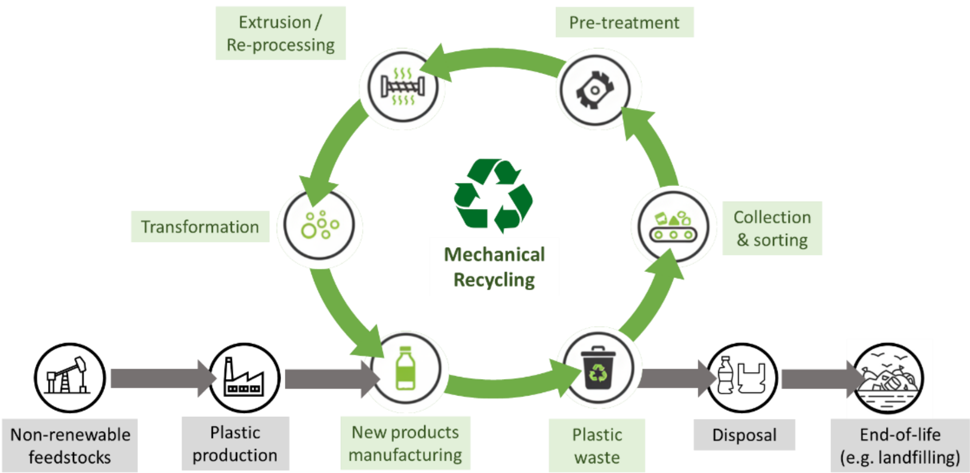
NIT/26/02

Mechanical recycling of plastics

Pierre Le Maître, Florian Cotin

Email: info@certech.be

ABSTRACT. Mechanical recycling is a cornerstone of plastic circularity, particularly for commodity thermoplastics such as polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), and polyvinyl chloride (PVC) that dominate European plastic waste streams. While recycling capacity has expanded significantly worldwide, the sector faces persistent challenges related to waste heterogeneity, contamination, and economic competition from virgin polymers, limiting recyclate quality and high-value applications. Recent advances in sorting, washing, and mechanical reprocessing—supported by improved extrusion, filtration, and additive technologies—are enhancing the consistency and performance of post-consumer recyclates. Growing regulatory and market demand for recycled content, coupled with eco-design principles and coordinated value-chain action, is expected to drive higher-quality mechanical recycling and strengthen its role within Europe's circular plastics economy.



© 2026 Certech

1. Context

Mechanical recycling refers to the series of operations—collection, sorting, washing, size-reduction, re-melting and re-granulation—by which plastic waste is transformed into secondary raw materials without altering the fundamental chemical structure of the polymer. This route is inherently aligned with thermoplastics, whose molecular architectures allow repeated melting and reshaping. As underlined by PlasticsEurope, thermoplastics remain "the backbone of circularity strategies" because they retain their polymer identity through multiple cycles when degradation is properly controlled. [1]

Market and Production

Thermoplastics dominate modern material consumption. In 2022, PP and PE alone accounted for ~37 % of total plastics production in Europe, followed by PVC at ~9%, PET and polystyrene (PS) both at ~5% and all engineering thermoplastics account for ~10%.[1] These polymers underpin key value chains such as packaging (the largest waste stream, ~39%,), building & construction (~7%), electrical &

Disclaimer: This technical information note is provided by Certech as a dissemination tool on a specific topic. It intends to provide a general knowledge to the public in a non-for-profit perspective. The content is provided for educational and informational purposes only. It may contain copyrighted material, which are used without the specific approval of the authors as a part of the exceptions defined in the European Union directive 2001/29/EC. In this case, the primary source of such material is systematically indicated in the References section of the document.

electronics (~6%), automotive (~5%), houseware, leisure & sports (~5%), as well as agriculture & farming (~4.5%). Because these sectors generate high volumes of post-consumer waste with relatively consistent polymer identities, they represent the priority fields for mechanical recycling development.

Mechanical recycling capacity in Europe has grown substantially over the past decades. According to the European Environment Agency, the installed capacity in European Union (EU) increased from ~2 Mt in 1996 to ~11 Mt in 2021, reflecting both regulatory pressure and industrial investment.[2] Recent industry data from Plastics Recyclers Europe indicate that by 2023, total installed recycling capacity reached ~13.2 Mt, with polyolefin films (~26 %) and PET (~13 %) constituting the largest processed categories.[3,4] Despite this progress, the supply of high-quality recyclate remains structurally constrained, partly due to insufficient sorting quality and contamination of waste streams.

Contribution to Circularity and Environmental Targets
PlasticsEurope reports that in 2022, post-consumer mechanical recycling contributed to 13.2 % of the total European plastics production. When including bio-based and CO_2-based plastics, "circular plastics" reached 11.7 Mt, corresponding to 19.7 % of production.[4] Increasing the share of mechanically recycled thermoplastics is essential to meeting European climate and resource-efficiency objectives, given that mechanical recycling typically provides the lowest greenhouse-gas footprint compared to chemical recycling or virgin production.[5]

Regulatory and Policy Landscape
EU regulatory frameworks strongly influence the development of mechanical recycling. Regulation (EU) 2022/1616 on recycled plastics in food-contact materials establishes detailed requirements on input waste streams, decontamination efficiency, and process traceability.[6] This regulation is particularly relevant for PET, which remains the only mechanically recycled polymer broadly authorised for direct food-contact applications.

Figure 1. Plastic packaging waste

The upcoming Packaging and Packaging Waste Regulation (PPWR) will further tighten design-for-recycling requirements and impose mandatory recycled-content targets for several packaging categories.[7] Industry organisations, including PlasticsEurope, support the ambition to reach 30 % recycled content in plastic packaging by 2030, reinforcing the central role of mechanically recycled thermoplastics in future compliance and market access strategies.

2. Pre-treatment of plastic waste

Pre-treatment is a decisive stage in any mechanical recycling workflow, as it determines the physical and chemical quality of the recyclate entering the extrusion or moulding step. Efficient pre-treatment directly impacts melt stability, colour, odour, and final mechanical performance of the recycled polymer. Its objectives are the removal of impurities, homogenisation of particle size and density, and moisture control.

Collection and Sorting
The first step involves the collection of post-industrial (PIR) or post-consumer recyclate (PCR). Industrial streams are generally more homogeneous (single polymer grades, known additives), while post-consumer streams exhibit a high degree of heterogeneity and contamination. Sorting can generally be performed at various levels of the value chain — either before or after size reduction and other pre-treatment steps. Sorting technologies include manual sorting, density-based separation(s), and automated optical sorting using near-infrared (NIR) spectroscopy or hyperspectral imaging. Modern facilities increasingly employ AI-assisted optical sorting and digital watermarking technologies (e.g., HolyGrail 2.0 initiative, supported by the European Brands Association) to improve sorting efficiency and polymer-grade purity, achieving purities >95 % for major commodity resins such as PE, PP, and PET[4].

Size Reduction
After sorting, polymers are reduced in size to ensure homogeneous feeding into the next process.

Figure 2. Shredded mixed-colour plastic waste

Shredders and granulators are used to convert bulky parts (containers, bumpers, films) into flakes of controlled size (typically 5–15 mm). Blade geometry and rotation speed must be adapted to polymer toughness to avoid excessive shear heating that may lead to partial melting and degradation. Cooling via water spray or cryogenic assistance can be used for low-melting materials. Proper sieving ensures uniform particle size and facilitates consistent melting behaviour during extrusion or agglomeration.

© 2026 Certech

Densification

Low-density materials such as foams or thin films are problematic for volumetric feeding. Densification or compacting transforms these low bulk density materials into higher-density agglomerates, improving feeding stability and throughput. Agglomerators apply mechanical friction to partially melt the polymer surface and allow coalescence into porous pellets. This process typically achieves bulk density gains of 200–400 %[8], depending on material type. For thermosensitive polymers, controlled heating profiles are critical to prevent chain scission or oxidation.

Separation and Purification

Contaminant removal is essential to prevent degradation, gel formation, or defects in the reprocessed material. Magnetic and eddy-current separators remove metallic contaminants, while density separation (float–sink) or hydrocyclone separation enables differentiation of polymer families (e.g. PP/PE vs. PET/PVC). For high-purity recyclates, additional washing (hot caustic, surfactant, or solvent-based) can be implemented, sometimes followed by dissolution–precipitation purification[9], which selectively dissolves target polymers while leaving additives or contaminants behind. Advanced triboelectric separation is increasingly applied to separate mixed polyolefin streams based on surface charge differences.[10]

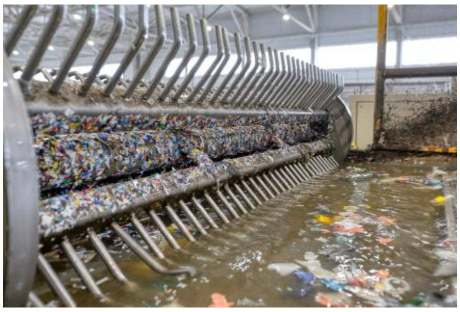


Figure 3. Pretreatment of post-consumer plastic waste

Drying

Before melt processing, drying is mandatory for hygroscopic polymers such as PET, polyamide (PA), and polycarbonate (PC) to avoid hydrolytic degradation and loss of molecular weight. Residual moisture levels should be minimized (e.g., below ~0.1 % wt, and for critical applications below ~0.05 % wt) — inadequate drying leads to hydrolytic chain-scission, property loss and processing defects.[11] Depending on the polymer, dryers can be of hot-air, desiccant, vacuum, or infrared type. For sensitive streams, in-line drying coupled to extrusion ensures optimal stability and prevents surface defects or haze in transparent polymers.

3. Extrusion in mechanical recycling of plastics

Extrusion plays a central role in mechanical recycling of plastics, both for pellet reprocessing and for certain purification and reformulation steps. The fundamental principle involves feeding an extruder (single or twin screw) with flakes or regrind, heating and melting them, homogenizing the melt, filtering and devolatilizing it before pelletizing.

General Principle

The polymer, usually pre-cleaned, dried, and shredded, is fed into the extruder hopper. In the screw–barrel section, the material is plasticized and then, under the action of the screw(s), melted, conveyed, and homogenized while subjected to controlled shear and heat. The molten polymer then passes through a filter to remove solid contaminants and aggregates. A devolatilization or degassing section (vacuum venting or gas stripping) may follow to eliminate volatile compounds and non-condensable gases. The extruded product is finally calibrated, cooled, and pelletized for reuse as regranulate [12].

Figure 4. Twin-screw extruder with a degassing vent

Challenges and Key Recommendations for Extrusion in Mechanical Recycling

In mechanical recycling, extrusion not only forms pellets but also determines the overall quality and performance of the recycled material. The process faces several technical challenges that require careful operational control and reformulation strategies.

- **Mixing and Homogenization** – Recyclate streams are often heterogeneous, containing various polymers, additives, and residues. The extruder must achieve uniform composition while avoiding overheating and excessive shear that can degrade polymer chains. Proper control of temperature profiles, screw speed, and residence time is essential to ensure efficient dispersion and maintain molecular integrity [13].
- **Filtration** – Efficient removal of contaminants such as non-plastic particles, pigments, and degradation residues is critical to prevent defects. The use of screen packs or self-cleaning melt filters ensures melt purity and stable downstream processing [14].
- **Devolatilization and Degassing** – Recycled polymers frequently contain volatile compounds, moisture, and absorbed gases. A degassing zone—operating under vacuum or inert gas—significantly improves recyclate quality by reducing volatile content, odours, and discoloration while enhancing thermal stability [15].
- **Thermal and Mechanical Degradation** – Exposure to multiple heating and shearing cycles can cause

© 2026 Certech

polymer chain scission, lowering molecular weight and mechanical performance. Process optimization, including controlled thermal profiles and the addition of stabilizers or chain extenders, helps mitigate degradation effects.

- **Reformulation and Compatibilization** – Targeted use of additives such as antioxidants, compatibilizers, and chain extenders can restore or improve the properties of recycled materials. These interventions are particularly important for mixed or contaminated waste streams, enabling their use in higher-value applications [13].

Figure 5. Homogeneous granulates of recycled plastic

Continuous monitoring of key quality indicators—molecular weight distribution, melt flow index, viscosity, and mechanical or visual properties—is essential to maintain consistency and optimize recyclate performance. Through precise process control, efficient purification, and smart additive integration, extrusion becomes a decisive step in enhancing both the technical and economic value of recycled plastics.

4. Other Mechanical Processes

While extrusion remains the dominant route for reprocessing recycled polymers, several complementary forming or conditioning operations can be used to valorise specific waste streams or improve feedstock quality.

Agglomeration

Agglomeration bridges the gap between grinding and extrusion, serving both densification and homogenisation purposes. The process takes place in a high-speed mixer or friction compactor, where flakes or thin films are partially melted by mechanical energy and consolidated into coarse, porous granules. These granules typically exhibit bulk densities between 300–600 kg m^{-3}, compared to <150 kg m^{-3} for loose films. The process not only facilitates handling and conveying but also allows pre-devolatilization and removal of moisture or low-molecular-weight species. For certain polyolefins (e.g. low-density polyethylene LDPE), agglomerates can be directly reused in blown film extrusion or rotational moulding, avoiding a full remelting step. Agglomeration efficiency depends on rotor speed, residence time, and cooling rate.

Injection moulding

Injection moulding offers a direct route to produce finished or semi-finished parts from recycled polymers. Post-industrial regrinds of PP, ABS, or PA are commonly reprocessed with limited reformulation. For post-consumer recyclates, mechanical properties and flow behaviour often require stabilisation packages (antioxidants, chain extenders) and melt filtration (50–200 µm) to ensure part integrity. Modern injection units equipped with vented barrels, melt filters, and gravimetric dosing systems can process up to 100 % regrind without significant performance loss, provided moisture and contamination are controlled. ISO 14021-compliant claims ("made with x % recycled content") increasingly rely on these controlled processes[16].

Compression and Blow Moulding

Compression moulding is frequently used for thermoset or thick-section thermoplastic recyclates (e.g. glass-fibre filled PP (PP-GF), PET sheets). It tolerates higher contamination and variable viscosity, making it suitable for mixed-polyolefin composites or fibre-reinforced recyclates. Blow moulding and thermoforming of recycled PET (rPET) are well established in beverage packaging; EFSA (European Food Safety Authority) and FDA (Food and Drug Administration) provide strict decontamination and traceability criteria for food-contact approval.

Emerging and Complementary Techniques

Beyond traditional methods, other types of shaping, such as rotational moulding, foam extrusion, and even pellet-based additive manufacturing are being explored for recycled polymers. Their success depends largely on the homogeneity and thermal stability achieved during pre-treatment and compounding. In the near future, hybrid mechanical–chemical recycling lines combining dissolution and melt reprocessing may further expand the achievable quality range for recycled thermoplastics.[17]

5. Conclusion & Perspectives

Mechanical recycling of plastics stands at a pivotal moment, shaped by increasing environmental urgency, evolving regulatory frameworks, and significant technological progress. As the backbone of plastic circularity, particularly for thermoplastics that can be repeatedly melted and reshaped, mechanical recycling plays a central role in Europe's climate, resource-efficiency, and circular-economy objectives. Commodity thermoplastics such as PE, PP, PET, and PVC dominate both production and waste streams, making them priority targets for recycling strategies.

Despite substantial growth in European recycling capacity—from approximately 2 Mt in the 1990s to more than 13 Mt by 2023—the sector continues to face structural challenges.[18] High variability in post-consumer waste streams, contamination, and mixed polymer compositions limit recyclate quality and restrict access to high-performance applications. In parallel, competition from low-cost imported virgin resins has reduced actual recycled plastics production, putting economic pressure on the

© 2026 Certech

European recycling sector. The problem persisted in 2024 and reached alarming proportions in 2025, resulting in the closure of numerous recycling facilities[19]. Meanwhile, the European Commission announced a new package of measures to tackle this issue at the end of December 2025[20].

At the same time, demand-side drivers are strengthening. Expectations from policymakers, brand owners, and consumers for recyclable products containing recycled content are accelerating the transition toward circularity. Regulatory instruments, including food-contact legislation and forthcoming recycled-content targets under the Packaging and Packaging Waste Regulation, are reinforcing market demand—particularly for high-quality mechanically recycled PET. These trends require fundamental changes in product design, including simplified material structures, reduced use of non-recyclable additives, improved polymer compatibility, and broader adoption of ecodesign principles.

Technological innovation is progressively addressing quality and consistency challenges. Advances in sorting and washing technologies—such as improved optical and spectroscopic detection, better separation of flexible films, and upgraded washing lines—are delivering cleaner and more reliable feedstock. In parallel, improvements in extrusion, filtration, degassing, and compounding, supported by advanced additives, compatibilizers, and stabilizers, are enhancing the mechanical and thermal performance of post-consumer recyclates. Complementary processing routes, including agglomeration, injection moulding, compression moulding, and emerging applications such as additive manufacturing, further expand valorisation pathways for recycled plastics.

Looking ahead, research and industrial initiatives are increasingly exploring hybrid recycling routes that combine mechanical, chemical, and biological processes, particularly for complex or highly contaminated waste streams. Together, these developments point toward a shift to higher-quality mechanical recycling that is more deeply integrated into the plastics value chain and increasingly competitive with virgin materials.

Ultimately, the success of this transition will depend on coordinated action across the entire value chain. Strong and stable regulatory support continued technological innovation, widespread eco-design implementation, and economically viable market conditions are essential to unlock the full potential of mechanical recycling as a cornerstone of Europe's plastics circular economy.

References

1. The Circular Economy for Plastics – A European Analysis 2024 • Plastics Europe https://plasticseurope.org/knowledge-hub/the-circular-economy-for-plastics-a-european-analysis-2024/.
2. The role of plastics in Europe's circular economy (2024). European Environment Agency. https://doi.org/10.2800/6297.
3. Team, E.A. Plastics Recycling Industry Figures 2023. EU Agenda. https://euagenda.eu/publications/plastics-recycling-industry-figures-2023.
4. Plastics – the fast Facts 2023 • Plastics Europe Plastics Europe. https://plasticseurope.org/knowledge-hub/plastics-the-fast-facts-2023/.
5. First circular economy action plan - Environment - European Commission https://environment.ec.europa.eu/topics/circular-economy-topics/first-circular-economy-action-plan_en.
6. Commission Regulation (EU) 2022/1616 on recycled plastic materials and articles intended to come into contact with foods | Circular Cities and Regions Initiative https://circular-cities-and-regions.ec.europa.eu/support-materials/eu-regulations-legislation/commission-regulation-eu-20221616-recycled-plastic.
7. Packaging & Packaging Waste Regulation - European Commission https://environment.ec.europa.eu/topics/waste-and-recycling/packaging-waste/packaging-packaging-waste-regulation_en.
8. Siempelkamp Size Reduction Solutions GmbH & Co. KG | Big in Size Reduction https://pallmann.eu/en/.
9. The CreaSolv® Process - CreaSolv https://www.creasolv.de/en/the-process.html/.
10. Wu, G., Li, J., and Xu, Z. (2013). Triboelectrostatic separation for granular plastic waste recycling: a review. Waste Manag *33*, 585–597. https://doi.org/10.1016/j.wasman.2012.10.014.
11. Interdependence of Hygroscopic Polymer Characteristics an... https://www.degruyterbrill.com/document/doi/10.3139/217.3960/html.
12. Li, H., A. Aguirre-Villegas, H., D. Allen, R., Bai, X., H. Benson, C., T. Beckham, G., L. Bradshaw, S., L. Brown, J., C. Brown, R., S. Cecon, V., et al. (2022). Expanding plastics recycling technologies: chemical aspects, technology status and challenges. Green Chemistry *24*, 8899–9002. https://doi.org/10.1039/D2GC02588D.
13. Schyns, Z.O.G., and Shaver, M.P. (2021). Mechanical Recycling of Packaging Plastics: A Review. Macromol Rapid Commun *42*, e2000415. https://doi.org/10.1002/marc.202000415.
14. Lamtai, A., Elkoun, S., Robert, M., Mighri, F., and Diez, C. (2023). Mechanical Recycling of Thermoplastics: A Review of Key Issues. Waste *1*, 860–883. https://doi.org/10.3390/waste1040050.
15. Bichler, L.P., Pinter, E., Jones, M.P., Koch, T., Krempl, N., and Archodoulaki, V.-M. (2024). Impacts of washing and deodorization treatment on packaging-sourced post-consumer polypropylene. J Mater Cycles Waste Manag *26*, 3824–3837. https://doi.org/10.1007/s10163-024-02085-4.
16. The Circular Economy for Plastics – A European Analysis 2024 • Plastics Europe Plastics Europe. https://plasticseurope.org/knowledge-hub/the-circular-economy-for-plastics-a-european-analysis-2024/.
17. Sharma, R., Singh, R., Batish, A., and Ranjan, N. (2022). Hybrid Mechanical and Chemical Recycling of Plastics. In Additive Manufacturing for Plastic Recycling (CRC Press).
18. EU's plastic waste mechanical recycling capacity (2024). https://www.eea.europa.eu/en/circularity/sectoral-modules/plastics/eus-plastic-waste-mechanical-recycling-capacity.
19. Plastics Value Chain Demands Immediate Action to Save EU Industry Plastics Recyclers Europe. https://www.plasticsrecyclers.eu/news/plastics-value-chain-demands-immediate-action-to-save-eu-industry/.
20. New package of measures to boost circular economy and strengthen Europe's plastic recycling European Commission - European Commission. https://ec.europa.eu/commission/presscorner/detail/en/ip_25_3151.

© 2026 Certech

Certech is a research & development partner and supplier of analytical and technological services for companies involved in activities related to (bio)chemistry: pharmaceutical, biotechnology, medical and healthcare; environment and energy; polymers; automotive and transport; packaging; construction.

Certech's mission is to provide innovative solutions for the improvement or development of products and processes, in agreement with the principles of sustainable chemistry and circular economy to meet industrial and societal needs.

Our multidisciplinary team is composed of 35 highly qualified and experienced employees. Responsive and customer-focused, they will answer your questions or needs in the field of materials, processes and environment:

- Polymer materials technology: bio-based polymer & composites, emissions and odors from materials, lightweight materials, mechanical recycling
- Chemistry and industrial processes: intensified/continuous process, micro/mesofluidic technologies, catalysis & synthesis, chemical recycling
- Environment: air quality, health & safety, energy, circular economy

Our services include R&D contract research, product and process development/improvement, analyses, problem solving, reverse engineering and consultancy.

More information: www.certech.be

Quality and recognition: https://www.certech.be/en/quality-and-recognition/

Contact: info@certech.be

Certech has been active for more than 25 years in the field of recycling and waste recovery. Certech is working with different industrial partners and has developed several pilot units for plastic waste valorisation at an industrial scale.

Mechanical Recycling (P to P):
- Thermoplastic compounding/processing
- Shredded composites valorisation
- Characterisation / Editing of technical data sheet
- Odour management of recyclates
- HSE management

Chemical Recycling (P to L, P to C, P to G):
- Conversion of non-recycled plastic waste into oil, waxes, hydrocarbons, and industrial feedstocks
- Thermo-chemical recycling (pyrolysis, depolymerisation, solvolysis, selective dissolution)
- Alternative feedstock from complex waste streams: ultimate waste, biowaste, urban mining, extraction of strategic raw materials,
- Characterization of recycled products, identification of contaminants (dimers, odorous and/or organoleptic compounds, NIAS (Non Intentionally Added Substances)

In addition to handling private research contracts, Certech is involved in different public-funded projects focused on the valorisation of recycled materials or waste.

© 2026 Certech