ISSN 1831-9424

EU-wide end-of-waste criteria for plastic waste

JRC technical proposals

Pierri, E., Egle, L., Milios, L., Saveyn, H.

2024

Joint Research Centre

EUR 40122

Contact information
Name: European Commission – Joint Research Centre, Fair and Sustainable Economy, Circular Economy and Sustainable Industry
Address: Edificio EXPO, Calle Inca Garcilaso 3, 41092 Seville, Spain
Email: JRC-END-OF-WASTE@ec.europa.eu

EU Science Hub
https://joint-research-centre.ec.europa.eu

JRC139303

EUR 40122

PDF ISBN 978-92-68-22184-6 ISSN 1831-9424 doi:10.2760/9234350 KJ-01-24-158-EN-N

Luxembourg: Publications Office of the European Union, 2024

How to cite this report: European Commission, Joint Research Centre, Pierri, E., Egle, L., Milios, L. and Saveyn, H., *EU-wide end-of-waste criteria for plastic waste*, Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2760/9234350, JRC139303.

Contents

Abstract

The absence of a consistent legal framework on end-of-waste for certain waste streams creates uncertainty for waste operators and for entities trading and using secondary raw materials. The implementation of EU-wide end-of-waste criteria can address these disparities between Member States and across different actors in the value chain, ultimately increasing the uptake of high-quality secondary raw materials in manufacturing processes.

The aim of this study was to develop technical proposals for EU-wide end-of-waste criteria for plastic waste, in accordance with Article 6 of Directive 2008/98/EC. The selection of this waste stream stems from the results of a scoping study carried out by the JRC to identify top-candidate streams for the development of EU-wide end-of-waste or by-product criteria. Plastic waste was ranked as the first priority stream for end-of-waste criteria.

The report contains background information on plastics, plastic waste and the recycling value chain and additional information that is of relevance for the development of EU-wide end-of-waste criteria, namely market-related aspects, technical requirements and standards, relevant legislation as well as environmental and human health impacts. It also includes an overview and detailed analysis of national end-of-waste criteria for plastic waste in Member States.

The technical recommendations have been produced by the JRC based on the contributions of relevant stakeholders in the plastic value chain. They consist of a proposal for a set of EU-wide end-of-waste criteria, including requirements on input materials, treatment processes and techniques, product quality, quality assurance and provision of information.

Acknowledgements

The authors would like to acknowledge the support offered by the stakeholders who participated in the workshops and written consultations.

Below is a list of organisations that gave their consent to being explicitly mentioned:

Anfra Packaging	Hungarian Waste Management Federation (HOSZ)
Association for European Manufacturers of Expanded Polystyrene (EUMEPS)	International Sustainability & Carbon Certification (ISCC)
British Plastics Federation (BPF)	Itero Technologies
Centexbel-VK	Ministry of Environment - Finland
Chemical Recycling Europe (CRE)	Ministry of Environment - Lithuania
Circular Economy for Flexible Packaging (CEFLEX)	Ministry of Infrastructure and Water Management – The Netherlands
Coolrec BV	MOL Group
Ecostandard (ECOS)	Müller-Guttenbrunn Gruppe (MGG)
Environmental Investigation Agency (EIA)	Mura Technology
Environmental Protection Agency - Sweden	Neste
Environmental Protection Agency - Ireland	Plastics Europe
European Association of Plastics Recycling and Recovery Organisations (EPRO)	Polish Chamber of Chemical Industry
European Chemical Industry Council (CEFIC)	Polyfor
European Electronics Recyclers Association (EERA)	Polyolefin Circular Economy Platform (PCEP)
European Environmental Bureau (EEB)	Professional Recycle SRL
European PVC Profiles and Related Building Products Association (EPPA)	Public Waste Agency of Flanders (OVAM)
European Recycling Industries' Confederation (EuRIC)	Reckit
European Waste Management Association (FEAD)	Remondis
Evertis Ibérica	Rethink Plastics Alliance (RPA)
Evonik	Saudi Basic Industries Corporation (SABIC)
Extended Producer Responsibility Alliance (EXPRA)	Styrenics Circular Solutions (SCS)
Federación Española de la Recuperación y el Reciclaje (FER)	Taghleef Industries
Fédération Nationale des Activités de la Dépollution et de l'Environnment (FNADE)	Tomra
Federation of the Chemical Industry and Life Sciences (ESSENSCIA)	Valoregen
Fraunhofer ICT	Zero Waste Europe (ZWE)

We are especially grateful to our colleague Enrique Garcia John for his invaluable input and active engagement throughout the project.

Additionally, we thank our colleagues in DG Environment for their support, in particular Peter Wessman, Florian Flachenecker, Julia Roettgerding, Roberto Scazzola, Yorg Aerts, Hendrik Engelkamp, Kathrin Kutlescha, Mihkel Krusberg, Daniele Ape, Jaco Huisman, Ioannis Antonopoulos, Katarina Pirselova, Valentina Bertato, Viviane André and Wolfgang Trunk.

Finally, we thank our JRC colleagues Peter Eder and Davide Tonini for providing relevant input and for contributing to the technical discussions as well as our colleague Anna Atkinson for proofreading the report.

Authors

Pierri, Erika[1]

Egle, Lukas[1]

Milios, Leonidas[1]

Saveyn, Hans[1]

[1] European Commission, Joint Research Centre, Directorate B Fair and Sustainable Economy - Circular Economy and Sustainable Industry Unit (B5)

Executive summary

Policy context

One of the main purposes of establishing end-of-waste criteria is to facilitate and promote recycling and the uptake of secondary raw materials, while ensuring a high level of environmental protection, reducing the consumption of natural resources and the amount of waste sent for disposal. Currently, the recycling of certain wastes is sometimes hampered by several factors that could be overcome by determining in a harmonised way when a waste ceases to be waste and becomes a secondary raw material that can freely circulate on the EU single market like any other product.

Article 6(1) of the Waste Framework Directive (WFD) 2008/98/EC, as amended by Directive (EU) 2018/851, lays down the conditions that a waste has to meet to cease to be waste after undergoing a recycling or other recovery operation, namely that:

> *"(a) the substance or object is to be used for specific purposes;*
> *(b) a market or demand exists for such a substance or object;*
> *(c) the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and*
> *(d) the use of the substance or object will not lead to overall adverse environmental or human health impacts".*

Article 6(2) empowers the Commission to adopt implementing acts to the Directive in order to establish detailed criteria for certain types of waste. Those criteria shall include:

> *"(a) permissible waste input material for the recovery operation;*
> *(b) allowed treatment processes and techniques;*
> *(c) quality criteria for end-of-waste materials resulting from the recovery operation in line with the applicable product standards, including limit values for pollutants where necessary;*
> *(d) requirements for management systems to demonstrate compliance with the end-of-waste criteria, including for quality control and self-monitoring, and accreditation, where appropriate; and*
> *(e) a requirement for a statement of conformity."*

As established in that Article, *"When adopting those implementing acts, the Commission shall take account of the relevant criteria established by Member States [...] and shall take as a starting point the most stringent and environmentally protective of those criteria".*

Further to the commitment to assess the scope to develop EU-wide end-of-waste (EoW) or by-product criteria for certain waste streams[1], the Commission carried out a scoping exercise (Orveillon et al., 2022) to identify possible candidate streams. Plastic waste was ranked as the first priority stream for the development of EU-wide end-of-waste criteria.

This study was commissioned by the Directorate-General for the Environment and aims to develop technical proposals for EU-wide end-of-waste criteria for plastic waste. The technical recommendations presented herein are meant to serve as basis for the legal adoption process, to be possibly undertaken by the Commission.

Related and future JRC work

This study presents an in-depth review of the EU-wide end-of-waste criteria for plastic waste for conversion proposed by the JRC in 2014 (Villanueva & Eder, 2014), which were not transposed into legislation.

---

[1] COM/2020/98 final: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN

EoW criteria have already been successfully laid down for: iron, steel and aluminium scrap (Council Regulation (EU) 333/2011), based on the JRC proposals for aluminium and aluminium alloy scrap (Muchova & Eder, 2010a) and for iron and steel scrap (Muchova & Eder, 2010b); copper scrap (Commission Regulation (EU) 715/2013), based on the JRC proposals for copper and copper alloy scrap (Muchova et al., 2011); and glass cullet (Commission Regulation (EU) No 1179/2012), based on the related JRC proposals (Rodriguez Vieitez et al., 2011).

Besides, based on the JRC proposals for biodegradable waste subjected to biological treatment (Saveyn & Eder, 2014), the Commission adopted Component Material Criteria (CMC) for waste materials that can cease to be waste pursuant to Article 19 of the Fertilising Products Regulation (EU) No 2019/1009, including criteria for: CMC 3 (compost) and CMC 5 (digestate other than fresh crop digestate) under Regulation (EU) No 2019/1009; CMC 12 (precipitated phosphate salts and derivates) under Commission Delegated Regulation (EU) No 2021/2086); CMC 13 (thermal oxidation materials and derivates) under Commission Delegated Regulation (EU) No 2021/2087; CMC 14 (pyrolysis and gasification materials) under Commission Delegated Regulation (EU) No 2021/2088 and CMC 15 (recovered high purity materials) under Commission Delegated Regulation (EU) No 2022/1171.

At present, the JRC is working on the development of technical proposals for the development of end-of-waste criteria for textile waste and for mineral construction and demolition waste.

Quick guide

This document outlines and applies a methodology for the development of technical proposals for EU-wide end-of-waste criteria for plastic waste, and provides relevant background information on the plastic value chain, including the characterisation of polymers and the conversion process, as well as on the classification of plastic waste, management options and market-related aspects. It also includes key information for the development of end-of-waste criteria, namely standards and relevant legislative aspects, environmental and human health impacts, complemented by a mapping of existing end-of-waste criteria in Member States. Moreover, this report presents technical proposals for end-of-waste criteria for plastic waste, by each category of requirements, while also reporting the stakeholders' feedback and the related assessment, also taking into account national end-of-waste criteria.

Technical proposals for EU-wide end-of-waste criteria for plastic waste

This study was carried out by the JRC and aimed at supporting the Commission in the implementation of Article 6 of Directive 2008/98/EC, by developing technical proposals for EU-wide end-of-waste (EoW) criteria for plastic waste (see **Table 1**).

The scope of the present proposals is limited to possible EoW status for **all thermoplastic polymer waste and blends of thermoplastic polymer waste**, regardless of the polymer type and source.

In addition, it is proposed to further limit the scope of the EoW criteria presented herein to **recycling processes that are able to treat thermoplastic polymer waste and blends of thermoplastic polymer waste without deliberately altering the molecular structure of the polymers**[2], with the exception of damage that is repaired within the process[3]. It should be noted that these limitations do not pre-empt any conclusion on a possible future scope extension or separate study on EoW criteria for materials recovered from plastic waste through other recovery operations (e.g. chemical recycling of plastic waste).

Finally, the system boundaries of the present proposals do not comprise the point at which articles are formed. Consequently, a consignment of recycled plastic ceases to be waste when it is a substance or a mixture that is ready for use in the production of new plastic products or articles containing plastic parts and it fulfils the full set of EoW criteria.

It is pointed out that if the plastic material that has ceased to be waste is discarded or is used for any other purpose than for the production of new plastic products or articles containing plastic parts, such as for energy recovery, as input material for chemical or fuel production (e.g. via chemical recycling), or for backfilling operations, the user of the plastic material will have to handle it as waste.

Table 1: JRC technical proposals for EU-wide end-of-waste criteria and self-monitoring requirements for plastic waste

No	Proposed end-of-waste criteria	Proposed self-monitoring requirements
Requirements on input materials		
1.1	Hazardous plastic waste and plastic waste containing hazardous substances shall not be used as input, unless they can be treated to the extent that the output plastic[4], resulting from the recycling operation is not classified as hazardous pursuant to Article 3 of and Annex I to Regulation (EC) No 1272/2008 (CLP).	Acceptance control by visual inspection of all plastic waste received and of the accompanying documentation shall be carried out by qualified staff. In particular, the operator shall request documentation on the origin of the material. The operator of the treatment facility shall apply appropriate control measures to detect hazardous waste and waste containing

2 Including mechanical recycling and physical recycling using solvent, among others.

3 For example through solid-state polycondensation (SSP).

4 The output of a recovery operation can result: i) in a substance on its own, ii) in a mixture (e.g. plastics, rubber) or, iii) potentially, in an article recovered directly from waste, as referred to in the Guidance on Waste and Recovered Substances (ECHA, 2010). It is to be noted that the CLP Regulation does not cover the hazard classification of articles (except for explosive and pyrotechnic articles). Nonetheless, the system boundaries of the present technical proposals for the EoW criteria exclude the point at which articles are formed (see section 6.1.3). In line with this, the reference to hazardousness should apply to the classification of the material as a mixture, if the operator considers the output to be a mixture, or otherwise, as a substance (including a UVCB substance). As indicated in the referred guidance, it is up to the relevant operator to decide which of the two options best fits the characteristics of the material.

	Plastic waste containing substances restricted under Regulation (EC) No 1907/2006 (REACH) shall not be used as input, unless it can be treated to the extent that substances on their own or in mixtures, resulting from the recycling operation comply with that Regulation, including but not limited to compliance with Article 56 setting out authorisation provisions for uses of substances listed in Annex XIV to REACH and for their placing on the market as well as the conditions laid down in Article 67 for the manufacture, placing on the market and use of substances restricted in Annex XVII[5] to REACH. Plastic waste containing POP concentrations above the limit values pursuant to Annex IV to Regulation (EU) No 2019/1021[6] on persistent organic pollutants (POPs) shall not be used as input, unless: (a) a (pre-)treatment step is in place that is able to generate an input fraction for the recycling operation with POP concentrations below the limit values defined in Annex IV to that Regulation; and (b) the applied treatment processes and techniques are able to treat this input fraction, to the extent that substances on their own or in mixtures, resulting from the recycling operation meet the provisions limiting the manufacturing, placing on the market and use of persistent organic pollutants (POPs) pursuant to Article 3 of and Annex I to Regulation (EU) No 2019/1021.	hazardous substances or other substances restricted under the REACH and POP Regulations. The control measures shall be documented under the quality management system. Particular attention shall be paid to plastic material input originating from waste electric and electronic equipment (WEEE), end-of-life vehicles (ELVs), construction and demolition waste (CDW) as well as waste batteries, which are more likely to contain those substances. For plastic waste containing POPs, the (pre-)treatment steps to separate the POPs content shall be documented under the quality management system.
1.2	Plastic waste to be used as input may originate from any source of waste containing plastics. The following materials shall not be used as input: (a) healthcare waste, except non-hazardous plastic healthcare waste that has been segregated at source; and (b) used absorbent hygiene products.	The operator of the treatment facility shall define appropriate risk management measures to identify and remove contaminated batches. Acceptance control by visual inspection and analysis of accompanying documentation of all plastic-containing waste received shall be carried out by qualified staff who are trained on how to recognise plastic-containing input restricted under this criterion. The operator of the treatment facility shall apply appropriate control measures to ensure that plastic healthcare waste used as input does not present hazardous properties. Specifically, the operator shall request documentation on the origin, segregation, storage and transport of this waste stream. The control measures shall be

[5] Including the latest amendment of Annex XVII (Regulation (EU) No 2023/923).

[6] Including the last amendment of Annexes IV and V (Regulation (EU) 2022/2400).

		documented under the quality management system. The operator of the treatment facility shall keep track of the plastic waste used as input material (date of receipt, supplier, origin, type and quantity of plastic waste received) and the plastic waste streams that have been rejected (date of rejection, supplier, origin, type, quantity of plastic waste and reason for rejection). The data shall be recorded under the quality management system.
1.3	Additional treatment requirements shall apply to input materials originating from selected sources: (a) input materials that originate from waste electrical or electronic equipment shall have undergone all treatments[7] required by Article 8 of and Annex VII to Directive (EU) No 2012/19 (WEEE); and (b) input materials that originate from end-of-life vehicles shall have undergone all treatments required by Article 6 of and Annex I to Directive (EU) No 2000/53 (ELVs).	When accepting input materials originating from WEEE and ELVs, the operator of the treatment facility shall request the previous holder to provide documentation of compliance with the relevant treatment requirements for WEEE and ELVs. This documentation shall be recorded under the quality management system.
Requirements on treatment processes and techniques		
2.1	Plastic waste eligible to be used as input material shall, once received by the operator of the treatment facility, be stored separately from non-eligible input materials, to avoid contamination. Output materials that comply with the EoW criteria shall be stored separately from any waste material not complying with the EoW criteria.	The procedures carried out to fulfil the separate storage requirements for input and output materials laid down in this criterion shall be documented under the quality management system.
2.2	The recycling operation shall be able to treat plastic waste without deliberately altering the molecular structure of the polymers, with the exception of damage that is repaired within the process. The recycling operation shall include all treatment steps needed to prepare the output plastic to be used as input for the production of plastic products or articles containing plastic parts.	The sequence of treatment steps shall be documented under the quality management system.

[7] The removal of plastic containing brominated flame retardants from separately collected WEEE can be seen as an integral part of the plastic recycling process.

2.3	Materials originating from any source that are eligible to be used as input (cf. Criteria 1.1, 1.2 and 1.3) shall be treated to the extent that: (a) the output plastic[8] resulting from the recycling operation is not classified as hazardous pursuant to Article 3 of and Annex I to Regulation (EC) No 1272/2008 (CLP); (b) substances on their own or in mixtures, resulting from the recycling operation comply with Regulation (EC) No 1907/2006 (REACH), including but not limited to compliance with Article 56 setting out authorisation provisions for uses of substances listed in Annex XIV to REACH and for their placing on the market as well as the conditions laid down in Article 67 for the manufacture, placing on the market and use of substances restricted in Annex XVII[9] to REACH; and (c) substances on their own or in mixtures, resulting from the recycling operation meet the provisions limiting the manufacturing, placing on the market and use of persistent organic pollutants (POPs) pursuant to Article 3 of and Annex I to Regulation (EU) No 2019/1021. As per Article 18(1) of Directive 2008/98/EC, hazardous plastic waste used as input shall not be mixed with the sole purpose of dilution. The derogations established in Article 18(2) shall apply. The same restrictions shall apply to plastic waste with POP concentrations above the limit values established in Annex IV to Regulation (EU) No 2019/1021.	Particular attention shall be paid to the processing of hazardous waste and plastic waste that may contain hazardous substances or other substances restricted under the REACH and POP Regulations, as indicated in the criterion. The procedure and method used to comply with the substance concentration requirements of the CLP, REACH and POP Regulations shall be documented under the quality management system.
Requirements on product quality		
3.1	The following conditions shall be fulfilled: (a) the output plastic[10] resulting from the recycling operation shall not be classified as hazardous pursuant to Article 3 of and Annex I to Regulation (EC) No 1272/2008 (CLP); (b) substances on their own or in mixtures, resulting from the recycling operation shall comply with Regulation (EC) No	The assessment of compliance with Regulation (EC) No 1272/2008 (CLP), Regulation (EC) No 1907/2006 (REACH) and Regulation (EU) No 2019/1021 (POPs) has to be concluded from a qualitative and quantitative characterisation of the output plastic in the consignment. Relevant exemptions laid down in the REACH, CLP and POP Regulations shall apply. At appropriate intervals subject to review if significant changes in the operating process are

[8] See footnote 4.
[9] Including the latest amendment of Annex XVII (Regulation (EU) No 2023/923).
[10] See footnote 4.

	1907/2006 (REACH), including but not limited to compliance with Article 56 setting out authorisation provisions for uses of substances listed in Annex XIV to REACH and for their placing on the market as well as the conditions laid down in Article 67 for the manufacture, placing on the market and use of substances restricted in Annex XVII[11] to REACH; and (c) substances on their own or in mixtures, resulting from the recycling operation shall meet the provisions limiting the manufacturing, placing on the market and use of persistent organic pollutants (POPs) pursuant to Article 3 of and Annex I to Regulation (EU) No 2019/1021.	made, representative samples of the output plastic shall be analysed to measure the concentration and nature of hazardous substances and substances restricted under the REACH and POP Regulations, as indicated in the criterion. The appropriate frequencies of monitoring by sampling shall be established taking into account the following factors: (1) the expected pattern of variability of the output plastic composition (for example as shown by historical results); (2) the inherent risk of variability in the quality of the waste used as input for the recycling operation and any subsequent processing, for instance the higher average content of plastics containing hazardous substances and substances restricted under the REACH and POP Regulations; (3) the inherent precision of the monitoring method; and (4) the proximity of results to the concentration thresholds that render the material hazardous or restrict its commercialisation. The process of determining monitoring frequencies shall be documented as part of the quality management system.
3.2	The output plastic shall demonstrably fulfil all legal requirements and shall comply with customer specifications, industry specifications or standards for the use of the material in the production of plastic products or articles containing plastic parts.	Qualified staff shall verify that each batch in the consignment complies with the legal requirements and appropriate specifications or standards. The frequency of verification shall be defined in accordance with the characteristics of the plastic waste stream treated.
3.3	If the output plastic is intended to be used within the European Union, the total amount of foreign materials shall be ≤ 2% of moisture-free output plastic weight. If the output plastic is intended to be exported to countries outside the EU, the threshold of foreign materials shall be ≤ 0.5% of moisture-free output plastic weight and the output plastic shall consist of one thermoplastic polymer, except for mixtures of polyethylene (PE), polypropylene (PP) and/or polyethylene terephthalate (PET). Foreign materials are polymers other than thermoplastics, non-targeted polymers in the recycling operation and non-plastic components.	Qualified staff shall carry out visual inspection of each batch in the consignment, to detect anomalies in product qualities. At appropriate intervals subject to review if significant changes in the operating process are made, representative samples of the moisture-free output plastic shall be analysed gravimetrically to measure the content and nature of foreign materials. The content of foreign materials shall be analysed by weighing in moisture-free conditions. Complementary analytical techniques may be used in the determination of the foreign materials content, such as chromatography or

[11] Including the latest amendment of Annex XVII (Regulation (EU) No 2023/923).

	Components that are bound to the polymer matrix as a result of intentional addition with the purpose of enhancing the properties of the polymer (like fillers, barriers, pigments, additives or any other active ingredients typically used in the compounding of plastics) are not counted as non-plastic components. Examples of non-plastic components are metals, paper, glass, earth, sand, ash, dust, wax, bitumen, ceramics and wood.	infrared spectroscopy, especially for the purpose of inspection. When the material has undergone thermal treatment to agglomerate or pelletise it, the content of foreign material has to be determined at the latest stage of reprocessing before thermal treatment is applied to the plastic to agglomerate or pelletise it. The appropriate frequencies of monitoring by sampling shall be established taking into account the following factors: (1) the expected pattern of variability of the output plastic composition (for example as shown by historical results); (2) the inherent risk of variability in the quality of the plastic waste used as input for the recycling operation and any subsequent processing; (3) the inherent precision of the monitoring method; and (4) the proximity of results to the limitation of the foreign materials content. The sampling frequency shall in any case be maintained at a suitable level to detect trends and/or other changes in the input materials and shall not be less than 6 months. The process of determining monitoring frequencies shall be documented as part of the quality management system.
Requirements on quality assurance procedures		
4.1	1. The operator of the treatment facility shall implement a quality management system suitable to demonstrate compliance with the end-of-waste criteria. 2. The quality management system shall include a set of documented procedures concerning each of the following aspects: (a) monitoring of waste used as input material for the recycling operation and acceptance control (including risk management and control measures); (b) monitoring of the treatment processes and techniques; (c) monitoring of the quality of the output plastic resulting from the recycling operation (including instructions for sampling and analysis and frequency of verification); (d) feedback from customers concerning the quality of the output plastic; (e) record-keeping of the results of monitoring conducted under points (a) to (c); (f) record-keeping of the actions taken to improve the performance of the recycling operation, in the case of non-conformity with the end-of-waste criteria; (g) review and improvement of the quality management system; and (h) training of staff. 3. The quality management system shall also prescribe the specific self-monitoring requirements set out in the end-of-waste criteria for each criterion. 4. The quality management system shall be certified by a conformity assessment body which is accredited by an accreditation body successfully peer-evaluated for this activity by the body	

	recognised in Article 14 of Regulation (EC) No 765/2008[12], or by an environmental verifier which is accredited or licensed by an accreditation or licensing body, as defined respectively in Article 2(30) and 2(31) of Regulation (EC) No 1221/2009[13], which is also subject to peer-evaluation according to Article 31 of Regulation (EC) No 1221/2009. Verifiers who want to operate in third countries must obtain a specific accreditation or licence, in accordance with the specifications laid down in Regulation (EC) No 765/2008 or Regulation (EC) No 1221/2009, the latter together with Commission Decision (EU) No 2011/832[14]. 5. The importer of plastic material resulting as output of treatment facilities based in third countries shall require third-country suppliers to implement a quality management system which complies with the requirements of points 1, 2 and 3 of this criterion and which has been verified by an independent external verifier. 6. A conformity assessment body, as defined in Regulation (EC) No 765/2008, which has obtained accreditation in accordance with that Regulation, or an environmental verifier, as defined in Article 2(20)(b) of Regulation (EC) No 1221/2009, which is accredited or licensed in accordance with that Regulation, shall verify that the quality management system fulfils the requirements on quality assurance procedures. The verification shall be carried out every 3 years. 7. Only verifiers with the following scopes of accreditation or licence based on the NACE Codes as specified in Regulation (EC) No 1893/2006[15] are regarded as having sufficient specific experience to perform the verification mentioned in this Regulation: – NACE Code 20 (Manufacture of chemicals and chemical products); or – NACE Code 22 (Manufacture of rubber and plastic products); or – NACE Code 38 (Waste collection, treatment and disposal activities; material recovery). 8. The operator of the treatment facility shall give competent authorities, as defined in Article 2(26) of Regulation (EC) No 1121/2009, access to the quality management system upon request.
Requirements on provision of information	
5.1	The producer or the importer shall issue, for each consignment of output plastic complying with end-of-waste criteria, a statement of conformity as set out in the template. The producer or the importer shall transmit the statement of conformity to the next holder of the consignment. They shall retain a copy of the statement of conformity for at least 3 years after its date of issue and shall make it available to competent authorities upon request. The statement of conformity is preferably issued in electronic form.

Table 2 contains the proposal for the statement of conformity to be used by the producer/importer of the plastic EoW material.

Table 2: JRC technical proposal for the statement of conformity template

1.	Unique identification code of the consignment: Producer/importer of the plastic recyclate:

[12] Regulation on setting out the requirements for accreditation and market surveillance relating to the marketing of products and repealing Regulation (EEC) No 339/93.

[13] Regulation on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS), repealing Regulation (EC) No 761/2001 and Commission Decisions (EC) No 2001/681 and (EC) No 2006/193.

[14] Commission Decision concerning a guide on EU corporate registration, third country and global registration under Regulation (EC) No 1221/2009 of the European Parliament and of the Council on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS).

[15] Regulation on establishing the statistical classification of economic activities NACE Revision 2 and amending Council Regulation (EEC) No 3037/90 as well as certain EC Regulations on specific statistical domains. Text with EEA relevance.

	Name: Address: Contact person: Tel.: E-mail:
2.	Quantity of the consignment in tonnes:
3.	a) Name or code of the plastic recyclate category in accordance with a customer specification, an industry specification or standard: b) Main technical provisions of the customer specification, industry specification or standard, including compliance with end-of-waste product quality requirements for foreign materials:
4.	The plastic recyclate consignment complies with a customer specification, industry specification or a standard referred to in point 3.
5.	The plastic recyclate consignment meets the criteria on input materials (1.1, 1.2 and 1.3), on treatment processes and techniques (2.1, 2.2 and 2.3), and on product quality (3.1, 3.2 and 3.3).
6.	The plastic recyclate in this consignment is not classified as hazardous pursuant to Article 3 of and Annex I to Regulation (EC) No 1272/2008 (CLP); The substances contained within the plastic recyclate in this consignment comply with Regulation (EC) No 1907/2006 (REACH), including but not limited to compliance with Article 56 setting out authorisation provisions for uses of substances listed in Annex XIV to REACH and for their placing on the market as well as the conditions laid down in Article 67 for the manufacture, placing on the market and use of substances restricted in Annex XVII[16] to REACH; and The substances contained within the plastic recyclate in this consignment meet the provisions limiting the manufacturing, placing on the market and use of persistent organic pollutants (POPs) pursuant to Article 3 of and Annex I to Regulation (EU) No 2019/1021.
7.	The producer of the plastic recyclate applies a quality management system verified by an accredited conformity assessment body or by an environmental verifier or, where plastic waste which has ceased to be waste is imported into the customs territory of the European Union, by an independent external verifier.
8.	The material in this consignment is intended to be used exclusively for the manufacture of plastic products or articles containing plastic parts. It must not be converted directly or indirectly to energy or non-plastic materials or used for any other purpose. Where these conditions are not met, the user of the plastic recyclate shall handle it as waste and shall inform the producer, for the purpose of maintaining and reporting correct information on end-of-waste volumes.
9.	Declaration of the producer/importer of the plastic recyclate: I certify that the above information is complete and correct to the best of my knowledge: Name: Date: Signature:

[16] Including the latest amendment of Annex XVII (Regulation (EU) No 2023/923).

1 Introduction

1.1 EU regulatory framework on end-of-waste

The purpose of defining end-of-waste criteria is to facilitate and promote recycling and the uptake of secondary raw materials, while ensuring a high level of environmental protection, reducing the consumption of natural resources and the amount of waste sent for disposal. Currently, the recycling of certain wastes is sometimes hampered by several factors that could be overcome by determining when a waste ceases to be waste and becomes a secondary raw material that can freely circulate on the EU single market like any other product.

The Waste Framework Directive (WFD) 2008/98/EC as amended by Directive (EU) 2018/851 defines in Article 6(1) the general conditions that a waste material has to fulfil to cease to be waste:

"[…] waste which has undergone a recycling or other recovery operation is considered to have ceased to be waste if it complies with the following conditions:

*(a) the substance or object is to be used for **specific purposes**;*
*(b) a **market or demand** exists for such a substance or object;*
*(c) the substance or object fulfils the **technical requirements** for the specific purposes and meets the **existing legislation** and **standards** applicable to products; and*
*(d) the use of the substance or object will not lead to overall **adverse environmental or human health impacts**".*

In 2009, the Joint Research Centre (JRC) published a general methodology analysing the principles according to which the criteria should be set and providing the related methodological framework required to determine end-of-waste (EoW) criteria (Delgado et al., 2009). This methodology was incorporated into Article 6(2) of the Waste Framework Directive (EU) No 2018/851 in the following terms:

"The Commission shall monitor the development of national end-of-waste criteria in Member States, and assess the need to develop Union-wide criteria on this basis. To that end, and where appropriate, the Commission shall adopt implementing acts in order to establish detailed criteria on the uniform application of the conditions laid down in paragraph 1 to certain types of waste.

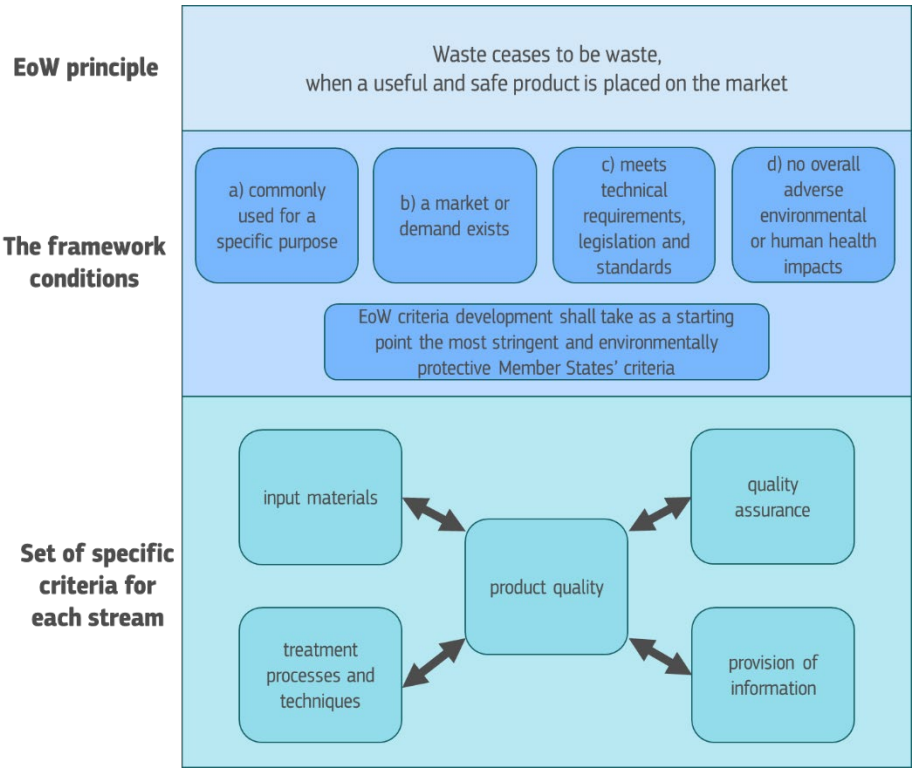
Those detailed criteria shall ensure a high level of protection of the environment and human health and facilitate the prudent and rational utilisation of natural resources. They shall include:

a) permissible waste input material for the recovery operation;
b) allowed treatment processes and techniques;
c) quality criteria for end-of-waste materials resulting from the recovery operation in line with the applicable product standards, including limit values for pollutants where necessary;
d) requirements for management systems to demonstrate compliance with the end-of-waste criteria, including for quality control and self-monitoring, and accreditation, where appropriate; and
e) a requirement for a statement of conformity."

Article 6(2) also mentions that *"When adopting those implementing acts, the Commission shall take account of the relevant criteria established by Member States in accordance with paragraph 3 and shall take as a starting point the most stringent and environmentally protective of those criteria".*

Figure 1 shows the conceptual approach and framework conditions for the development of EoW criteria, including the five categories of criteria and the consideration of national EoW criteria.

Figure 1: Conceptual approach of the EoW mechanism, framework conditions and elements of EoW criteria



EoW criteria have been already successfully laid down for:

- iron, steel and aluminium scrap (Council Regulation (EU) 333/2011);
- glass cullet (Commission Regulation (EU) No 1179/2012);
- copper scrap (Commission Regulation (EU) 715/2013).

In addition to the EoW criteria listed above, the Commission has adopted Component Material Criteria (CMC) for waste materials that can cease to be waste pursuant to Article 19 of the Fertilising Products Regulation (EU) No 2019/1009[17]. They include criteria for:

- CMC 3 (compost) and CMC 5 (digestate other than fresh crop digestate) under Regulation (EU) No 2019/1009;
- CMC 12 (precipitated phosphate salts and derivates) under Commission Delegated Regulation (EU) No 2021/2086);
- CMC 13 (thermal oxidation materials and derivates) under Commission Delegated Regulation (EU) No 2021/2087;
- CMC 14 (pyrolysis and gasification materials) under Commission Delegated Regulation (EU) No 2021/2088;
- CMC 15 (recovered high purity materials) under Commission Delegated Regulation (EU) No 2022/1171.

[17] Regulation (EU) 2019/1009: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02019R1009-20230316#M2-2

1.2 Scoping exercise

Further to the commitment to assess the scope to develop EU-wide EoW or by-product criteria for certain waste streams[18], the Commission carried out a scoping exercise (Orveillon et al., 2022). The study aimed to support the Commission in the implementation of the Circular Economy Action Plan (CEAP) and the Waste Framework Directive by:

1. identifying a priority ranking of waste or by-product streams for which to develop further EU-wide end-of-waste or by-product criteria (scoping); and
2. deriving a shortlist of top-candidate streams for which to develop further EU-wide end-of-waste or by-product criteria.

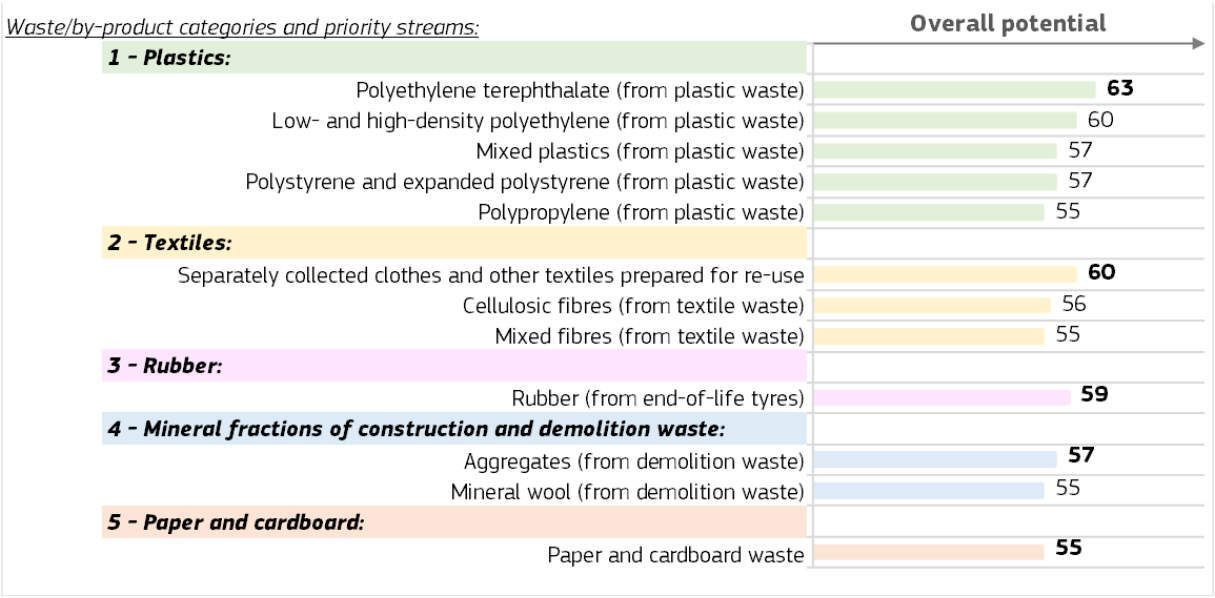
A total of 12 candidate streams were ranked based on their overall potential for the further development of EU-wide end-of-waste or by-product criteria, using the following ranking criteria:

- level of support from stakeholders to develop further EU-wide end-of-waste or by-product criteria;
- current collection and material reuse/recycling rates;
- identified uses, types of uses (recycling versus other recovery operations) and impacted economic sectors;
- estimated EU market value;
- intra- and extra-EU shipments;
- purity/composition of recovered materials and possibility to recover critical raw materials;
- evidence of demand;
- existence of relevant international or national product standards;
- existence of national or regional end-of-waste or by-product criteria;
- expected environmental and human health impacts.

Figure 2 presents the results of the scoping study, grouped by category of waste/by-product, highlighting the five waste categories with the greatest overall potential. Different plastic polymers were ranked as priority streams. Overall, **plastic waste** was classified as the **first priority stream** for the development of **EoW criteria**.

[18] COM/2020/98 final: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN

Figure 2: List of priority streams grouped per category and ranked based on their overall potential



Source: (Orveillon et al., 2022)

1.3 Rationale and objectives of this study

One of the barriers to a European circular economy is the lack of an EU-wide legal framework for end-of-waste across Member States. Possible impacts of the implementation of EU-wide EoW criteria are:

— **Environmental and human health impacts**:

- The implementation of EU-wide EoW criteria may lead to increased collection and recycling rates of plastic waste in the EU, particularly in Member States with lower collection rates. The possibility for plastic recyclates to obtain a legally recognised EoW status can in fact be seen as an incentive to treat additional volumes of plastic waste. This can possibly result in savings in energy use and greenhouse gas emissions associated with the production of virgin plastics.
- By improving quality control, the production of high-quality plastics is encouraged. By these means, the implementation of EoW criteria can limit environmental and human health impacts associated with the use of recycled plastics.
- EoW criteria for plastic waste will expand the range of regulatory mechanisms available to promote environmentally favourable options for waste management. By facilitating the recycling of high-quality plastic, EoW criteria can incentivise choosing this option when feasible, aligning with the waste hierarchy's goal of maximising environmental benefits.
- A theoretical risk arising from the implementation of EoW criteria for plastic waste is that, once complying with the criteria, plastic recyclates will no longer be subject to the legal provisions on the shipment of waste and the related control mechanisms under the waste regime. Nonetheless, by requiring that output materials of plastic recycling should be of high quality, it should also be ensured that recyclates can be safely shipped within and outside the EU.

— **Market impacts**:

- The implementation of EU-wide EoW criteria is expected to provide support to recycling markets and to reduce administrative burdens. This may result in a reduction of

administrative costs related to the shipment of waste. Transporting secondary materials with a recognised legal status as product is, in fact, less onerous than the shipment of waste.

- EoW criteria can also strengthen the perception of recycled plastic as a valuable resource, potentially leading to higher value for this material and its recycling chain. This may also lead to new investments in the recycling sector.
- Implementation of EoW criteria by the industry may require changes in current practices, resulting in potential costs in the short term. These can be particularly burdensome for small recyclers. However, in the long term, these additional costs could be offset by the advantages of EoW criteria.

— **Legal impacts**:

- EoW criteria will contribute to the legal framework on plastic circularity, supporting the goals of the Circular Economy Action Plan.
- The quality requirements of EoW criteria developed at national level may differ from Member State to Member State, generating complexity and legal uncertainty for waste operators and for entities trading or using secondary raw materials across different Member States. The harmonisation of EoW criteria at EU level is expected to create a level playing field and to provide legal certainty for operators.
- EoW criteria will increase awareness of the need for recycled plastic to comply with relevant obligations set under the chemicals legislation and of the need to trace substances of concern in the plastic value chain.

Considering the impacts mentioned above and in line with the results of the scoping exercise presented in Section 1.2, there is a case for developing **EU-wide EoW criteria for plastic waste**. This study aims to deliver a technical proposal, covering plastic flows that are currently considered valuable by the industry, while also fulfilling the conditions of Article 6 of the Waste Framework Directive and maintaining strict quality standards.

DISCLAIMER: Following publication of the present document and its technical proposals for EoW criteria, DG Environment may decide to initiate the process towards the potential adoption of an implementing act. Nonetheless, it is important to note that the drawing up of technical recommendations by the JRC does not imply any commitment whatsoever by the Commission to adopt EU-wide EoW criteria for plastic waste. Moreover, the Commission, should it decide to proceed with adopting EU-wide EoW criteria, is not bound by the proposals in this document and is free to introduce further changes to the proposals.

1.4 Structure of this document

This document is structured as follows:

— Chapter 2 describes the methodology applied within this study for the development of technical proposals for EU-wide end-of-waste criteria for plastic waste;

— Chapter 3 contains relevant background information on the plastic value chain, including the characterisation of polymers and the conversion process;

— Chapter 4 contains relevant background information on plastic waste and the recycling value chain, including the classification of plastic waste, management options as well as market-related aspects;

— Chapter 5 contains additional information that is key for the development of EoW criteria, namely standards and relevant legislative aspects, environmental and human health impacts, complemented by a mapping of existing EoW criteria in Member States;

— Chapter 6 presents the technical proposals for EoW criteria for plastic waste by each category of requirements, reporting the stakeholders' feedback and the related assessment, thereby also taking into account national EoW criteria;

— Chapter 7 presents the conclusions of this work and the consolidated technical proposals for EoW criteria for plastic waste.

2 Methodology for the development of technical proposals

In 2014, the Joint Research Centre (JRC) developed technical proposals for EoW criteria for plastic waste for conversion (Villanueva & Eder, 2014). The proposals were not transposed into legislation at the time. Those criteria were used as a starting point in the current work.

Figure 3 provides an overview of the project timeline and the methodology.

Figure 3: Project timeline and methodology

The project was launched on 31 May 2022 with a kick-off meeting hosted by the JRC. The scope of the meeting was:

- to present the initial scope for the development of EoW criteria for plastic waste;
- to provide an overview of the criteria proposed by Villanueva & Eder (2014);
- to present preliminary information gathered in-house, including market data, relevant product legislation and standards as well as EoW criteria for plastic waste in Member States;
- to launch the first stakeholder consultation.

The first consultation round (June to September 2022) aimed at gathering feedback on the EoW criteria proposed by Villanueva & Eder (2014) and to collect new information and data (e.g. for different polymers to consolidate the scope definition, on use, market, existing standards and specifications as well as on environmental and health impacts). Complementary information on existing national EoW criteria was also requested, to validate the mapping exercise conducted in-house. Stakeholders were asked to fill in a questionnaire with targeted questions on the aforementioned topics.

To obtain a deeper understanding of the plastic recycling process, the JRC carried out site visits throughout the project. Bilateral meetings with some of the organisations involved were also key to clarifying specific issues and gathering additional viewpoints on relevant aspects.

Based on the insights derived from the consultation, site visits and bilateral meetings, the JRC developed the first draft proposals in close cooperation with the Directorate-General for the Environment (DG ENV).

The draft proposals were presented in the second stakeholder meeting on 20 April 2023. The subjects were:

- polymers and recycling technologies under scope;
- possible point of EoW;
- proposed requirements on input materials;
- proposed requirements on processes and techniques;
- proposed requirements on product quality;

— proposed requirements on quality assurance;

— proposed requirements on provision of information.

A second stakeholder consultation was conducted between April and September 2023. This consultation aimed at gathering feedback on the preliminary proposals for EoW criteria for plastic waste presented during the meeting. As with the first consultation, stakeholders were asked to fill in an extensive questionnaire with targeted questions and to provide arguments in favour of or against the proposals.

After a thorough analysis of the feedback received, complemented by bilateral meetings and further investigation on specific points, the JRC drafted the technical recommendations presented in Chapter 6.

The JRC assessment also encompasses an analysis of national EoW criteria for plastic waste (see Annex 2 of this document). In line with the requirements of Article 6(2), the criteria have been developed not only based on stakeholders' feedback, but also by making a comparison with national provisions in terms of environmental protection (see Section 6.7).

3 Background information on the plastic value chain

Plastic is a highly versatile material covering a wide range of applications in everyday life and can be found nearly everywhere, from households to all kinds of industry. Vital economic activities as diverse as packaging, construction, transportation, healthcare and electronics depend heavily on plastics as raw materials.

The rapid growth of plastics is due to their unique properties, exhibiting high strength-to-weight ratio, high moldability, impermeability to liquids and gases, resistance to physical and chemical degradation, and low cost. However, some of the desirable qualities of plastics are also their key limitations. Plastics are highly resistant to physical and chemical degradation, which also means that they can persist as waste in the environment for decades or even centuries (OECD, 2022).

Background information on the plastic value chain is given in the following sections. Particular attention is paid to the different types of polymers, the most common additives and the characteristics they confer to the polymers.

3.1 Characterisation of plastic polymers

Plastics can be characterised by polymer type, by the physical characteristics and by the sources (e.g. fossil-based, bio-based). Additives can be used to confer specific properties to the polymers. During the production process the polymers are modified and shaped based on the specific requirements for the targeted application.

3.1.1 Definition

Plastic is a synthetic material or modified natural material, either a polymer or combination of polymers of high molecular mass modified or compounded with additives such as fillers, plasticisers, stabilisers, flame retardants and colourants (UNEP, 2023b).

There are several definitions of plastic in the literature and in the different national or international technical and policy documents. For example, according to the International Organisation for Standardisation (ISO), the standard 472:2013 defines plastic as *"a material which contains as an essential ingredient a high polymer and which, at some stage in its processing into finished products, can be shaped by flow"*. Polymers are natural or synthetic substances composed of very large molecules (macromolecules) that are multiples of simpler chemical units called monomers.

Plastic is defined in EU legislation through Directive (EU) 2019/904 on the reduction of the impact of certain plastic products on the environment. Article 3(1) of the Directive states: "*'plastic' means a material consisting of a polymer as defined in point 5 of Article 3 of Regulation (EC) No 1907/2006*[19]*, to which additives or other substances may have been added, and which can function as a main structural component of final products, with the exception of natural polymers that have not been chemically modified."*

[19] Article 3(5): polymer means a substance consisting of molecules characterised by the sequence of one or more types of monomer units. Such molecules must be distributed over a range of molecular weights wherein differences in the molecular weight are primarily attributable to differences in the number of monomer units. A polymer comprises the following: (a) a simple weight majority of molecules containing at least three monomer units which are covalently bound to at least one other monomer unit or other reactant; (b) less than a simple weight majority of molecules of the same molecular weight. In the context of this definition a 'monomer unit' means the reacted form of a monomer substance in a polymer. Article 3(6): monomer means a substance which is capable of forming covalent bonds with a sequence of additional like or unlike molecules under the conditions of the relevant polymer-forming reaction used for the particular process (Regulation (EC) No 1907/2006).

3.1.2 Polymer types

There is a wide variety of different types of polymers and it can be challenging to classify them in a comprehensive manner. One of the most common ways of classifying polymers is to distinguish between thermoplastics and thermosets (Rosato, D. V., & Rosato, 2004).

Thermoplastics are the polymers that have the ability to soften with the application of heat and can solidify again upon cooling, allowing them to be remoulded and recycled. This process can be repeated several times. Examples of thermoplastics are polyethylene (PE), polypropylene (PP), and polystyrene (PS), which constitute the most common consumer plastics, also referred to as commodity plastics.

Thermosets are the polymers that are shaped into the desired form under heat and pressure, normally with a chemical reaction taking place, and cannot be resoftened or reshaped again. Examples of thermosets include urea formaldehyde (UF) resins, phenol formaldehyde (PF) resins, and melamine formaldehyde (MF) resins. Thermosets are often used for high-heat and impact-resistant applications, such as electronic equipment, construction, and insulation.

The properties and typical applications of common polymer types are presented in **Table 3**.

Table 3: The most common polymers and their typical applications

Polymer type	Properties	Typical applications	Label
Polyethylene terephthalate (PET)	clear and resistant to heat, cold, and chemicals	plastic bottles (water, soft drinks, etc.) food packaging film, strapping, carpets, vehicle tyre cords and fibres	
High-density polyethylene (HDPE)	durable and resistant to shock and cold	packaging film, industrial film, bottles, tubs, cups, closures, toys, tanks, drums, cable insulation, pipes, gasoline tanks, shipping containers, seating and household goods	
Polyvinyl chloride (PVC)	rigid or soft via plasticisers, resistant to water and solvents and flame retardant	piping, vinyl flooring, cabling insulation, window frames and roof sheeting	
Low-density polyethylene (LDPE)	lightweight, flexible, and resistant to shock and cold	packaging film, cling-film, bags/sacks, lids, toys, coatings, flexible containers, tubing, irrigation pipes and vehicle dashboards	
Polypropylene (PP)	lightweight and resistant to heat, water and chemicals	yogurt pots, snack wrappers, packaging films, bottles/caps, automotive battery cases, parts and body components, electrical components, carpet pile and backing, drainage goods	
Polystyrene (PS)	lightweight, structurally weak, and easily thermoformed or expanded	packaging applications, dairy product containers, cups, coat hangers and electrical appliances	
Acrylonitrile butadiene styrene (ABS)	durable, stiff, hard and resistant to shock	computers, televisions, kitchen appliances, toys, musical instruments, electrical products and automobile component parts	

Styrene acrylonitrile (SAN)	clear, lightweight, structurally weak but resistant to shock	food containers, water bottles, kitchenware, computer products, packaging material, battery cases, plastic optical fibres	
Polycarbonates (PC)	clear, resistant to shock and heat and flame retardant	electronic applications, products in construction industry (e.g. for dome lights, flat or curved glazing, and sound walls), CDs, Blu-ray discs, automotive, aircraft and railway parts	
Poly methyl methacrylate (PMMA)	strong, tough, and lightweight material, good impact strength, transparent	transparent glass substitute, daylight redirection, lenses of exterior lights of automobiles, medical technologies and implants, artistic and aesthetic uses	
Polyethers	resistant to heat, chemicals, flame retardants, oils, grease and abrasion	electrical components, medical equipment, and automobile components	
Polyamides (PA)	wear resistance, good coefficient of friction, good temperature resistance and impact strength	textiles, automotive industry, carpets, kitchen utensils, sportswear	
Polyurethane (PUR)	wear and tear resistance, flexibility, good electrical insulating and strong bonding properties	cleaning products, furniture, automobile seats, hoses, sculptures, decorations, filling of spaces and cavities	

Source: UNEP (2023b)

Polymers can be produced from a variety of primary and secondary **sources**, either from materials produced from fossil fuels (**fossil-based**), from biomass (**bio-based**), or from captured CO_2. Irrespective of their source, polymers can have identical chemical and physical properties, and can be either biodegradable or non-biodegradable. **Biodegradable plastics** are broadly understood to refer to plastics that can be degraded under specific conditions, such as temperature, UV radiation, humidity, oxygen content and pH, by microorganisms in nature or controlled conditions, such as bacteria and algae, and turn into carbon dioxide and other small molecules (UNEP, 2023b).

Plastic polymers are also available in several composite forms, consisting of polymer blends, layered polymers, or polymers mixed with other materials to form multi-material composites.

Polymer blends combine different polymer types that each confer desired properties in specific applications. Miscibility and compatibility increase between polymers of the same family (e.g. PE and PP belong to the polyolefin family and PS and ABS belong to the styrenics family). Moreover, compatibility can be enhanced by the use of additives to bring polymers together in a physical blend (e.g. compatibiliser additive technology).

3.1.3 Additives

Polymers can include additives to improve the base-polymer's physical properties or to reduce costs. Additives are substances that are added to plastics to change a wide variety of the polymers' characteristics and are usually included in the polymer matrix by blending in the melt phase, but are

not necessarily chemically bonded. This may result in the potential release of the additives to the environment during their production, use and waste phases.

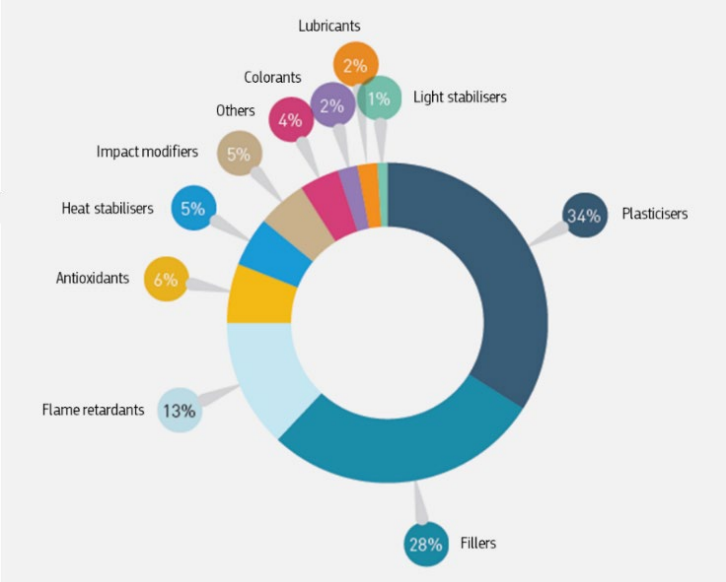
Most plastics typically consist of the polymer matrix, followed by fillers and plasticisers. Other additives such as pigments or stabilisers are required in smaller amounts compared to the overall polymer mass. On average, 4% of the weight of plastics consists of additives (Bouwmeester et al., 2015), but different polymers present different amounts. For instance, plasticisers can make up over 50% of the total weight of a PVC-based plastic (Net et al., 2015).

Generally, all the existing additives that are included in plastics can be broadly divided in the following four categories (Hahladakis et al., 2018):

- **Functional additives** (stabilisers, antistatic agents, flame retardants, plasticisers, lubricants, slip agents, curing agents, foaming agents, biocides, etc.) influence specific properties such as stability against UV light and heat, resistance to microbes, flame retardancy, durability, softness, hardness, aesthetics, etc.
- **Colourants** (pigments, soluble azocolourants, etc.) impart colour to the final plastic product.
- **Fillers** (mica, talc, kaolin, clay, calcium carbonate, barium sulphate) improve specific properties (e.g. tensile strength, electrical conductivity, surface gloss); they replace expensive resins to reduce costs.
- **Reinforcements** (e.g. glass fibres, carbon fibres) are used to enhance mechanical properties such as the strength and elasticity of plastics.

Figure 4 depicts the share of the main additive types used in plastics production at the global scale.

Figure 4: Share of main additive types used in global plastics production (2000–2014)



Source: UNEP (2023a)

Table 4 provides a general overview of different additive groups by category of additives, as defined above, together with examples of common types of applications, chemical compounds, and the typical range of each additive content in plastics. Plasticisers are the most widely used additives, followed by fillers and flame retardants.

Table 4: Examples of additives for the four main additives categories

Additive category	Additive group	Common application	Chemical compounds	Typical amount range (% w/w)
Functional additives	Plasticisers (softeners)	PVC, cellulose plastic	Phthalates, benzoates, citrates, phosphates, and short- and medium-chain chlorinated paraffins (SCCPs/MCCPs)	10–70
	Flame retardants	Foam, plastic	Halogenated flame retardants including brominated and chlorinated flame retardants (BFRs/CFRs), phosphorus-based flame retardants, metal hydroxide flame retardants including aluminum trihydroxides and magnesium dihydroxides, melamine-based flame retardants, and silicone-based flame retardants	2–28
	Antioxidants	LDPE, HDPE, high-impact polystyrene (HIPS) and ABS	Phenolic antioxidants, phosphites	0.05–3
	Heat stabilisers	PVC	Nonylphenol, barium and calcium salts	0.1–3
	Light stabilisers	PE, PP, PVC	Phenolic benzotriazoles (e.g. UV-328)	0.1-10
	Antistatic agents	PE films, PE & PP foams, PVC, PP injection moulding applications	Long-chain alkyl phenols, ethoxylated amines, glycerol esters such as glycerol monostearate	0–1
	Slip agents	LDPE, PP	Erucamide, oleamide, stearamide	0.05–0.15
	Lubricants	PVC, PS/ABS, PP, PE	Fatty acid esters, hydrocarbon waxes, metal stearates, amide waxes, ester waxes	0.1–3
	Curing agents (hardeners)	Epoxy resins	4,4'-Diaminodiphenylmethane, 2,2'-dichloro-4,4'-methylenedianiline	0.1–2
	Biocides	PUR, PVC	Organic tin compounds, arsenic compounds, triclosan	0.001–1
	Catalyst	PVC, PE, PP and other non-specified plastics, PUR	Chromium and chromium compounds (e.g. chromium trioxide), mercury and mercury compounds	0.1–0.3

	Fragrances	PE, PP, PS, PC, PET, PLA, nanoparticles	Natural extracts; synthetic fragrances	no information
Colourants	Pigments	PVC, PE, PP and other non-specified plastics	Cadmium compounds (e.g. cadmium sulphide), chromium compounds; lead chromates	0.01–5
	Soluble azocolourants	polyethersulfone (PES), PA, acrylic	Organic-based colourants	0.25-5
Fillers	Minerals	All plastics	Mica, talc, kaolin, clay, calcium carbonate, barium sulphate	up to 50-70
Reinforcements	Glass fibres	All plastics	Glass fibres	15–30
	Carbon fibres	All plastics	Carbon fibres	no information

Source: Hahladakis et al. (2018); UNEP (2023a)

3.2 Conversion to plastic products

3.2.1 Production volumes and common applications

Global plastics production reached **400.3 Mt** in 2022 (Plastics Europe, 2024). **Europe**[20] produced **14%** of that plastic, showing a sustained downward trend in plastics production, from 20% of global plastics production in 2014 and 22% in 2006. On the other hand, the hotspot of global plastics production has shifted to Asia, which in 2022 produced roughly 60% of total plastics, up from 44% in 2006. The strong upward trend was due to the massive expansion of the Chinese plastic production industry, which in 2022 produced almost one third (32%) of all plastics in the world, up from just one fifth (21%) of global production in 2006.

The total **European plastics production** in 2022 was **58.8 Mt**. Of this, **primary plastics production** (**47.2 Mt**) was concentrated mostly in five EU Member States, accounting for over 50% of the total plastics production in Europe. These were Germany (10.2 Mt), Belgium (6.9 Mt), the Netherlands (5.5 Mt), France (4.5 Mt) and Spain (4.2 Mt). Polypropylene (PP) and polyethylene (PE) continued to represent a significant share of European plastics production, with a combined share of around 37%, followed by polyvinylchloride (PVC) at around 9%. The European **secondary plastics production** (**11.7 Mt**) showed significant development in three EU Member States, with Germany (2.6 Mt), Italy (1.6 Mt), and Spain (1.2 Mt) leading the way, while each of the remaining EU Member States produced less than 1 Mt of recycled plastics (Plastics Europe, 2024).

The demand for **plastic conversion** in 2022 was **54.1 Mt**, with Germany (12.7 Mt), Italy (7.6 Mt) and France (5 Mt) together using approximately half of this amount for their domestic plastics industry. The polymers with the highest demand for plastic conversion in 2022 were polyethylene (LDPE 14%; HDPE 10.5%), polyethylene terephthalate (PET) with 7% and polypropylene (PP) with 16% of the total. Polyvinylchloride (PVC) followed with 7% of the total plastic demand. Packaging as well as building and construction applications represented by far the largest end-use markets for plastics in Europe. The third biggest end-use market was the automotive sector (see **Figure 5**).

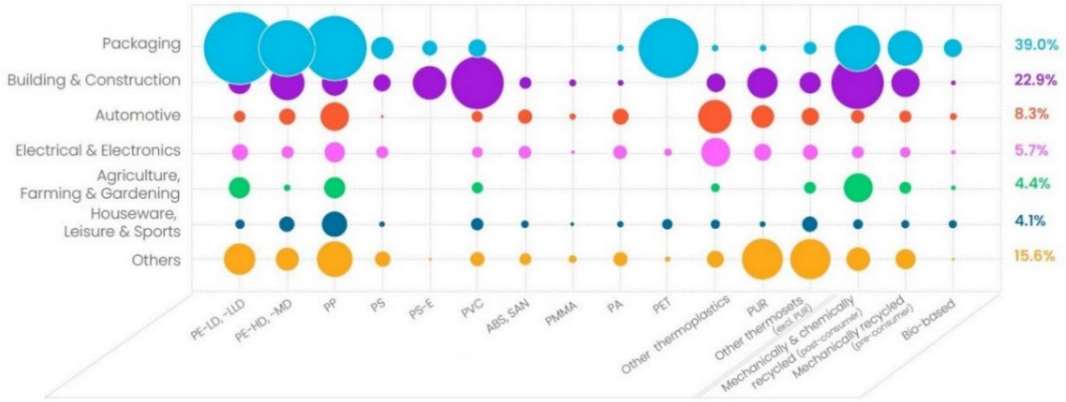
[20] EU27 + UK, Switzerland and Norway.

Figure 5: European plastics conversion by application

Source: Plastics Europe (2024)

In **Figure 6**, the breakdown of polymer demand for plastic product conversion in 2022 is presented, grouped by each respective application, and in **Table 5** an overview of plastic products that belong to each application is outlined.

Figure 6: European plastics conversion by application



Source: Plastics Europe (2024)
Note: Plastics Europe provided the data on mechanically and chemically recycled (post-consumer) plastics aggregated, and no distinction is made on the different secondary polymers. Chemically recycled plastics represent a very small share of the total post-consumer recycled plastics, approximately 0.2% in packaging, construction, and automotive applications.

Table 5: Overview of common plastics applications and products

Applications	**Common products**
Packaging	Packaging foils/films (including shrink and stretch films, bubble wrap, shipping foil, etc.), household films (bags and sacks (excluding garbage sacks)), bottles (including drinking bottles and other bottles for non-food applications), caps, seals and closures, tubs, cans, trays, blister packs (for pharmaceutical and other applications), crates, plastic containers (including storage containers for food applications), barrels, canisters, buckets (for packaging purposes, e.g. paint buckets), transport packaging (e.g. plastic pallets, intermediate bulk containers, transport boxes, technical packaging).

Building & Construction	Pipes and fittings (e.g. for drinking water, gas or sewage), window profiles and other plastic profiles, roof/rainwater gutters, drainage systems, cladding, shutters, flooring, wall covering, roofing and weatherproofing membranes, sheets (e.g. corrugated sheets and other sheets), wallpapers, toilet lids/seats, films for construction applications, construction cables, road construction products (e.g. base plates, pillars, traffic cones/traffic cylinders, barriers).
Automotive	Parts in passenger cars and light commercial vehicles, such as battery housings, connectors, wire harnesses, automotive cables, lights and other "under the hood" applications in road vehicles, interior trim, dashboards, window seals and gaskets, specific automotive profiles, mirrors, bumpers and other exterior components, foamed films, coated fabrics.
Electrical & Electronics	Components in all types of electrical and electronic devices, such as major household appliances (e.g. washing machines, dishwashers, refrigerators), small household appliances (e.g. microwave ovens, coffeemakers, toasters, vacuum cleaners, electric heating devices, fans, lighting equipment), consumer electronics (e.g. telecommunication devices, radio sets, television sets, housings and components for computers/laptops, keyboards), electrical power tools, components for electrical devices or electrical engineering (e.g. plugs and switches).
Agriculture, Farming & Gardening	Plastic products and components for agricultural applications (e.g. vegetable/animal production), gardening/horticulture and forestry. Agricultural foils/films (e.g. greenhouse films, mulching films, silage films, stretch films), bale nets, farm technology, flowerpots and planting pots, cultivation pallets, watering cans, rain barrels and irrigation systems, composters, raised beds, gardening hand tools, garden hoses, gardening decoration articles and other gardening articles.
Houseware, Leisure & Sports	Tableware and kitchen utensils (e.g. mixing bowls, stirring spoons, spatulas/flippers), bath equipment and toiletries (e.g. toothbrushes, soap dispensers), combs and hair clasps, housekeeping articles (e.g. boxes/cases for the storage of food or other articles, folding boxes, waste containers), clothes-hangers, decorative articles, sport/leisure/camping accessories, bathing and swimming articles, toys, etc.
Others	Medical applications (e.g. blood bags, orthopaedic and sanitary equipment), synthetic textiles (e.g. clothing, footwear, interior textiles), furniture (e.g. garden furniture, plastic chairs, furniture fittings), office and school supplies, waste disposal bags, railways, aviation and shipping, technical components for machines and mechanical engineering, petrol driven tools for gardening/forestry/agricultural applications (e.g. lawnmowers, chain saws), compact discs and vinyls, etc.

Source: Plastics Europe (2024)

3.2.2 Production process

To manufacture a plastic product, an extensive series of production and conversion stages usually takes place, each with its own unique procedures and techniques. The raw materials used in plastic manufacturing are typically petrochemicals, although several alternative sources can be utilised (e.g. biogenic and CO_2). Initially, the production of polymers involves a series of steps in which the raw materials are progressively processed to produce formulated polymeric materials that meet specific requirements for a wide range of applications.

The **primary raw material**, e.g. oil, is initially 'cracked' in a petrochemical process producing a range of products from which naphtha is passed to the next stage of monomer production. The **monomer** is then converted to the desired grade of **polymer** as determined for each application. The polymerisation process is commonly achieved by heating the raw materials in the presence of a

catalyst, which helps to link the molecules together into chains. The resulting material is a resin that is used as a base for making plastic. After polymerisation, **additives** (such as colours, plasticisers, or impact modifiers) are mixed with the resin to give the plastic its desired properties (Villanueva & Eder, 2014).

Plastic articles are produced from the polymer, usually in powder, granulate, pellet or flake form, by a range of different processes, generally termed conversion. Plastic products can be shaped into the desired form via a variety of techniques, e.g. injection moulding, blow moulding, extrusion and spinning (in the case of synthetic fibres production). All of them are typically carried out at a high temperature and often require the application of a certain amount of pressure. The type of processing technique is based on the polymer thermal properties, size, and geometry of the finished product. For instance, rigid packaging such as bottles and drums use a moulding process where an extruded length of tube is inflated whilst still above its softening point into a mould which forms the shape/size of the container. Conversely, flexible packaging film is produced by extrusion techniques depending on the material and the thickness (Villanueva & Eder, 2014).

For thermoplastic polymers, pressure must be applied and maintained during the entire cooling process to guarantee the shape retention of the finished product. Thermoplastic polymers can be remelted and reformed many times. On the other hand, thermoset polymers harden upon heating and, once formed, cannot be melted. The fabrication of thermosets generally consists of a two-step process. The first stage consists of forming the so-called pre-polymer, a linear low-molecular-weight polymer in liquid form. Subsequently, the pre-polymer is transferred into a mould with the desired shape and subjected to the curing process, which provides the final features of the product. The curing procedure is a chemical process that involves the application of heat and/or catalysts, generally conducted under pressure. During this process, the pre-polymer undergoes crosslinking reactions, and an insoluble and infusible polymeric network is generated. The cured material is structurally stable and can be removed immediately from the mould without cooling it down. Finally, at the last stage of plastic manufacturing, any excess material from the moulded product is removed and any final product elements are added, such as labelling or packaging. The finished products are then ready for distribution to the market.

4 Background information on plastic waste and the recycling value chain

In the following sections, background information on plastic waste and the recycling value chain is given, including a classification of plastic waste by source and the management of plastic waste (encompassing collection, sorting, recycling and reconversion).

As mentioned in Section 1.1, two of the four conditions for a waste stream to cease to be waste, as defined in Article 6(1) of the Waste Framework Directive, are that the recovered material shall have a specific purpose and a market or demand shall exist. In this context, an overview of the plastic flows in the EU is provided and the common applications for plastic recyclates are briefly introduced.

4.1 Classification of plastic waste

Plastic waste can be classified into two main categories (CPA, 2021b; UNEP, 2023b):

- **pre-consumer plastic waste**: plastic waste generated during conversion or manufacturing processes and that is discarded;
- **post-consumer plastic waste**: plastic waste that has been generated from plastic products that have been supplied for distribution, consumption or use and placed on the market of a Member State or of a third country.

Examples of pre-consumer and post-consumer plastic waste originating from different sources are listed in **Table 6** and **Table 7**, respectively.

Table 6: Non-exhaustive overview of pre-consumer plastic waste originating from various steps of the production process

Source	**Pre-consumer plastic waste generated**
Polymer production and compounding	Waste from industrial packaging; pre-production cut-offs; sweepings; off-specification plastic.
Plastic conversion	Waste from moulding and extrusion (e.g. sheet edge trimmings and mould flow sprues).
Plastic assembly or installation	Waste from plastic assembly and installation (e.g. damaged assemblies, component handling tabs, failed trial polymer applications).

Source: Adapted from UNEP (2023b)

Table 7: Non-exhaustive overview of post-consumer plastic waste originating from different sources

Source	**Post-consumer plastic waste generated**
Municipal solid waste	Plastic packaging (e.g. bottles, trays, films). Garden plastics (e.g. flowerpots, buckets). Household products (e.g. kitchenware). Furnishing (e.g. seating foams, mattresses). Sport and leisure equipment (e.g. rackets, balls, protective footwear).
Commercial and industrial activities	Packaging and containers (e.g. bags, films, crates).

Healthcare facilities	Packaging, medical and laboratory supplies, personal protective equipment (e.g. masks, protective clothing and footwear).
Waste electrical and electronic equipment	Printed circuit boards, fans, pipes, capacitors and resistances.
End-of-life vehicles	Car bumpers, interior trim panels, seat foams, battery casing.
Waste batteries	Casing, cables, separator foils.
Maritime activities	Fishing nets, ropes, floats.
Riverine and marine litter	Plastic items that are deliberately discarded into the sea or rivers or on beaches and shores are brought indirectly to the sea by rivers, sewage, storm water or winds, or are accidentally lost.
Construction and demolition waste	Window frames and doors, roofing sheets, insulation panels, drainage pipes.
Textile waste	Apparel, household textiles, technical textiles.
Cables	Cable jackets.

Source: Adapted from UNEP (2023b)

4.2 Management of plastic waste

The recycling value chain includes a series of steps, from collection, to sorting up to recycling and reconversion to new plastic products or articles containing plastic parts. In the following sections the different phases and the key aspects are described. Emphasis is given to the main sources of plastic waste.

4.2.1 Collection

There is a wide variety of collection systems for plastic waste, depending on the type and the origin of the waste stream. The greatest distinction in origin is related to the waste produced by private consumers (e.g. households, small businesses, and public utility spaces – also referred to as municipal waste), or by private (and/or public) enterprises, such as industrial, commercial and institutional waste (e.g. healthcare waste). The major types of plastic waste categories are packaging waste, construction and demolition waste (CDW), end-of-life vehicles (ELVs), waste electrical and electronic equipment (WEEE), and agricultural waste. The collection system of each plastic waste category is described briefly below.

4.2.1.1 Packaging waste

Packaging mainly originates from private consumption in households and commercial activities, and from industry and the transport of goods. There is a distinction between consumer packaging, which is related to municipal waste collection systems, and commercial/industrial packaging, which is organised separately.

Municipal plastic waste is typically collected for further processing in three main configurations:

— source-segregated recyclable waste;

— commingled recyclable waste;

— residual (mixed) municipal solid waste.

Whether plastic waste is collected separately or mixed, there are three widely used modes of collection (Albizzati et al., 2023):

— Kerbside collection (door-to-door): This system includes containers at ground level for collection from the street, either serving a single household (single-family houses) or an apartment block (multi-family housing). Packaging plastic wastes are collected as a single stream or commingled with a different waste fraction.

— Bring system (drop-off): Consumers bring their plastic wastes such as plastic bottles and plastic bags to a certain collection site, usually serving a local neighbourhood (city-block), depending on the residential density of each location. These drop-off points are typically unstaffed and include large volume containers for selective collection of (mainly) packaging waste fractions.

— Civic amenity sites (recycling centres): This collection option includes specially designated collection sites in a few locations, covering adequately the geography of a city/region, and include municipal staffed collection sites (in some cases these could be unstaffed as well), where several types of wastes (e.g. waste electrical and electronic equipment (WEEE) and bulky waste from households) can be brought by residents.

A special case of a bring system type of collection is the deposit-refund (return) system (DRS). DRS is a system whereby consumers pay an additional amount of money (a deposit) when buying a product, which will be reimbursed upon the return of the packaging or product to a collection point. The system is based on offering an economic incentive for consumers to return empty containers to ensure that they will be reused or recycled. For beverage containers, these systems are already operating in many countries.

Commercial and industrial (C&I) packaging collection is done through individual commercial arrangements between waste management operators and waste producers. The generated waste is directly collected from the waste producers' site and then delivered to a waste management company site or in some cases directly to a recycler. Since most C&I plastic packaging does not require sorting, or requires only minimal manual sorting, it is typically baled and bulked at waste management sites rather than undergoing more complex sorting. In some countries, EPR scheme(s) organise drop-off points for C&I plastics where waste producers can drop off material free of charge. These are typically used for plastic with a low value, meaning that the collection by a waste management company would actually incur a charge for a company and thus become a burden. By providing the collection service free of charge, the illegal deposition of plastic waste is minimised (CPA, 2020c).

4.2.1.2 Construction and demolition waste

The collection of plastics from construction and demolition activities does not differ significantly across EU-27 Member States, and it is typically done according to one or more of the following modes of collection:

— unsorted waste collected in a container with mixed construction waste;

— waste separated on site as combustible waste;

— waste separated as recyclable plastics on site;

— waste separated on site into various recyclable plastic waste fractions.

Generally, construction and demolition waste is collected by private waste management companies. In some cases, the waste is collected via contracts with municipalities. For high-value waste with a known recycling outlet or secondary use, waste is sorted on site into the various categories in separate containers (CPA, 2020d).

4.2.1.3 End-of-life vehicles

The management of end-of-life vehicles (ELVs) in the EU is laid down in Directive 2000/53/EC[21]. Economic operators[22] are obliged to establish a reception system for ELVs, to guarantee an adequate collection coverage of the territory they are responsible for, and to assume potential negative market values.

There are two main approaches for establishing a reception system with an adequate territorial coverage in the different Member States, with the most common being the following:

- Individual systems, where each producer sets up its network of authorised treatment facilities (ATFs). Vehicle producers would usually look for ATFs willing to become part of their network and then they would sign a business contract with them.
- Collective systems, where a group of producers (or even all producers) decide to use an external entity to provide them with an ATF network where the last vehicle owners can deliver their vehicles free of charge.

Producers can decide to adopt any of these systems, unless a particular regulation exists at national/regional level (CIRC-ELV, 2022).

The authorised treatment facilities (ATFs) constitute the first collection points for ELVs. There are nearly 14 000 treatment facilities in the EU, which correspond to approximately one treatment facility per 40 000 inhabitants (CPA, 2020b). Once an ELV enters an ATF, the ELV recycling operation starts, following a standard process of depollution (removing hazardous components such as batteries, fuels and lubricating oils), dismantling (where sometimes plastics are dismantled, e.g. bumpers, dashboards, and fluid containers), and shredding (where the rest of the materials are mixed as heterogeneous waste called automotive shredder residue – ASR).

4.2.1.4 Waste electrical and electronic equipment

The conditions for the responsible collection and treatment of waste electrical and electronic equipment (WEEE) are laid down in the recast WEEE Directive 2012/19/EU[23], which has been transposed in national legislation by EU Member States. Compliant WEEE collection activities are performed by designated Producer Responsibility Organisations (PROs), operating within the principle of Extended Producer Responsibility (EPR).

Collection of WEEE mostly happens via retailers, municipal collection points (CAS or even collection containers), and/or pick-up services provided by the municipality. The collected WEEE is transported to a final compliant treatment facility, with the explicit aim of recovering the valuable recyclable materials and reusable components and of treating other materials in an environmentally sound manner.

4.2.1.5 Agricultural waste

There is no specific legislation in the EU for the end-of-life management of non-packaging agricultural plastics. Thus, non-packaging agricultural plastic waste falls under the general waste legislation. At the farm, it is the responsibility of the farmer to manage this waste stream under the "polluter pays" principle (CPA, 2020e).

---

21 Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of-life vehicles. https://eur-lex.europa.eu/eli/dir/2000/53/oj

22 Producers, distributors, collectors, motor vehicle insurance companies, dismantlers, shredders, recoverers, recyclers and other treatment operators of end-of-life vehicles, including their components and materials (as defined by Directive 2000/53/EC).

23 Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE). http://data.europa.eu/eli/dir/2012/19/oj

In the EU agricultural sector many countries have implemented collection schemes, funded by producers, which allow farmers to bring collected farm plastic wastes to organised hubs at specific dates and times during the year. This process facilitates the efficient manual sorting and baling of the various plastic types at those collection hubs by using mobile baling equipment, prior to transportation to the final reprocessing facilities. Plastic packaging waste from hazardous pesticides, herbicides and other bio-active substances is collected separately, keeping it away from the common agricultural plastic waste which exhibits high recycling potential.

4.2.1.6 Waste from other sources

Besides the defined waste sources described above, there is a large variety of post-consumer plastic products ending up as waste, which do not belong to any formal (or informal) system of collection (e.g. plastic waste from maritime activities). This also applies to other products containing plastics (e.g. furniture, toys, personal hygiene products) which are often disposed of within the residual waste fraction.

4.2.2 Sorting

The different modes of collection, as described above, have a direct impact on the level of purity of the plastic waste stream that is destined for recycling. In most instances, even in the case of separate mono-material collection, the plastic waste stream may present impurities (non-plastic material) and contain several types of plastic. This may cause difficulties in the recycling process downstream, but could also greatly affect the quality of the products produced using plastic recyclates. Therefore, plastic waste should be separated from other non-plastic waste through sorting processes and, where appropriate and feasible, be sorted into single polymer types. There are many different ways to sort plastic waste, and generally sorting includes the following processes: manual sorting, automated/mechanical sorting, sensor-based sorting, liquid density separation, electrostatic separation (Lange, 2021).

Manual sorting relies on the identification of the plastic items by their shape and colour within the collected waste stream. Manual sorting operations could consist of a pre-sorting stage before or after mechanical sorting, in order to remove unwanted or contaminated input materials and improve the efficiency of a downstream automated process. Manual sorting may also be used in final quality checks at the end of a sorting process to ensure that sorted plastics meet technical specifications.

Automated/mechanical sorting technologies include screen separators, air separators, ballistic separators and film grabbers with the ability to sort items based on particle shape, size and density. The exact method of identification, separation and sorting may depend upon a wide range of physical and chemical properties of the plastic and the contaminant materials, as well as the size, shape and format in which it is presented to the sorting equipment. Automated mechanical sorting systems for plastic wastes may include a very wide range of technologies and separation methods. Screen separators, air classifiers and ballistic separators are used for the removal of small, light, flat pieces such as film and paper and for removal of heavy pieces such as glass and stone. The separation method depends upon the physical size, shape (i.e. two or three dimensions), density and mass of the sorted items. The creation of a waste stream which has a uniform range of particles or items within a controlled size and shape format is important for the successful application of downstream sorting methods (UNEP, 2023b).

For removing metallic items that are unintentionally present in the plastics (or mixed) waste stream, automated sorting technologies include over-band/conveyor head-roller magnets (removal of magnetic/ferrous metals), eddy current separators (sorting of non-ferrous metals), and induction sensors (sorting of stainless steel and composites). Over-band magnets can be used to lift ferrous metals from the moving waste stream, and often move the trapped metal items away to a side-located metal waste bin. Belt-conveyor head-roller magnets attract and hold ferrous metal items onto the conveyor belt as it passes over and back under the cylindrical top-roller, while other non-

magnetic waste drops down its natural ballistic path under gravity. Eddy current separators are used to separate non-ferrous metal contaminant items, e.g. copper, aluminium, zinc. The plastic waste stream is passed over a very high-speed rotating magnetic roller that induces a rapidly changing magnetic flux field up through the transfer conveying belt and this causes an induced electric current inside each moving conductive metal particle. The resulting repulsive force causes the metal item to 'jump up' and away from the belt, so that it follows a higher trajectory ballistic path, enabling a separation plate to divert most metals away from the bulk plastic stream (UNEP, 2023b).

Beside removing impurities and foreign items that are present in the plastic waste stream, **automatic sensor-based technologies** (see **Table 8**) enable the separation of plastics by polymer type, plastic density and colour. Mixed plastic wastes are laid on a fast-moving conveyor belt under a strong light or X-ray source where high-speed sensing cameras record the position, shape and reflected light or wave signals and make instant analysis of the received spectrum. This allows the polymer type and certain additive chemicals to be identified. After detection, precisely controlled compressed air-jets are used to eject the sorted items away from the bulk material flow at the end of the transport cover, with splitting plates positioned to affect the final separation process. Automated sensor-based sorting can also be used to separate plastic waste from mixed MSW, and plastic waste separated and extracted from bulk flow streams of other waste streams, such as WEEE, ELVs and CDW.

Table 8: Overview of sensor-based technologies used in plastic waste sorting

Technology	**Mode of Use**
Near infrared (NIR)	Used to differentiate between plastic types and to differentiate plastic waste from mixed MSW and other materials such as paper and metals.
Visual spectrometry (VIS)	Used to identify materials based on colour.
X-ray fluorescence (XRF)	Used to differentiate between metals / alloys (for example, copper from steel). Also used for potential POPs or SVHC screening of brominated and chlorinated plastic additives.
X-ray transmission (XRT)	Identifies materials based on atomic density – for example, halogens and organic components, mineral fillers, hidden metal particles inside plastic parts etc.
High-speed laser spectroscopy / Raman spectroscopy	Fast process, able to sort black plastics, precise, no need for clean or smooth surface.
Terahertz spectroscopy	Non-destructive, very precise, may require low operation temperatures, measures the dielectric properties of non-conducting materials, able to sort black plastics.

Source: UNEP (2023a); Yli-Rantala, E., Bachér, J., Kaartinen, T., Vincenti, N., & Zhan (2020)

Robotic sorting is an advanced form of automated sorting. Robots can identify specific products using cameras and analyse images against an internal database of products identified by shape, size, colour and texture. Typically, rapid mechanical arms and grabbers are used to pick up and deflect the selected items from the bulk material flow. The databases used to identify the plastic types can be enhanced with artificial intelligence applications to improve the sorting efficiency of the waste streams, by allowing a machine learning process (Wilts et al., 2021).

In certain cases, **liquid density separation** (also called float-sink separation) can be used to separate various types of polymers. For float-sink separation, small flakes or particles of mixed plastic are fed into a vessel or tank filled with liquid of a known and controlled density. Plastics in

the mix which have a solid density lower than the liquid separation medium will float; those plastics heavier than the liquid density will sink. Float-sink separation in water can effectively separate polyolefins (PP, HDPE, LDPE) from PVC, PET and PS. Use of different liquid media can allow separation of PS from PET, but PVC cannot be removed from PET in this manner as their density ranges overlap (UNEP, 2023b).

Float-sink separation is not effective for separating plastics with similar density. **Electrostatic separation** can be used to separate polymeric materials of the same or very similar density (e.g. ABS and PS). The principle of electrostatic separation is based on differences in electrostatic forces acting on particles of the mixture exposed to the electric field. The effectiveness of electrostatic separation depends, among others, on the size and shape of particles in the mixture, environmental conditions like humidity, pressure and temperature, the moisture content of the mixture as well as its voltage level, the configuration of the electrode system, and the position of the feeding unit (Regulski & Dariusz, 2020).

4.2.2.1 Packaging waste

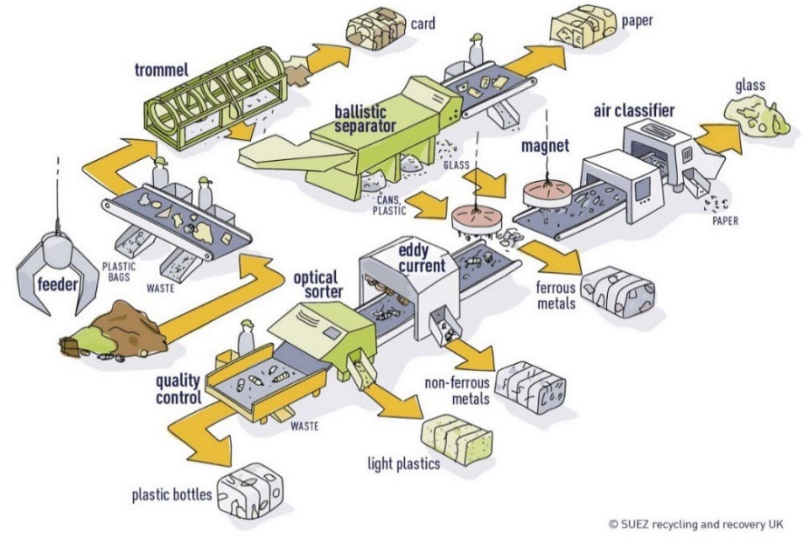
As mentioned above, the separation at source of the plastic waste stream increases the efficiency and reduces the costs related to the sorting of mixed waste, and can improve the quality of the outputs from downstream recycling or recovery operations. Source separation entails the sorting of plastic waste from other types of waste before collection as opposed to separation from other waste after collection. Source separation can be described as a form of multi-stream collection system in which the waste generator is responsible for manually sorting plastic waste items and placing them into designated bins or bags, to keep them separate by type or according to certain established criteria.

Source separation of post-consumer plastic packaging waste is usually performed in two ways: (i) mono-material separation, where plastic waste items are separated at source as one material fraction, including more than one type of plastic together (as mixed plastics), or targeting specific plastic types (e.g. PET bottles, or rigid plastics such as pots, tubs and trays); and (ii) commingled separation, where several types of source-separated dry wastes (e.g. metal and plastic wastes) are collected together.

In the former case, sorting is employed essentially to separate the different polymers and acquire mono-polymer fractions for high-quality recycling. In certain cases, plastics with similar properties and structural characteristics may be grouped together in the sorting process (e.g. polyolefins). For this, sorting technologies that separate the different types of plastics are employed, such as mechanical sorting, sensor-based sorting, float-sink and electrostatic separation, as described above.

In the latter case, where plastics are commingled in the dry recycling fraction, the whole spectrum of the sorting technologies described above may be required. An illustrative representation of the sorting process is provided in **Figure 7**, including the typical sorting processes that take place in a commingled Material Recovery Facility (MRF) for dry recyclables (packaging).

Figure 7: Sorting operations in a Material Recovery Facility (MRF) for packaging waste



4.2.2.2 Construction and demolition waste

Construction material is either sorted on site or collected mixed with other waste in containers and separated at a waste transfer station. Most sorting of CDW is still undertaken by hand in the initial phase. Containers are emptied onto the floor or into waste bunkers and easy-to-identify objects, such as windows, will be sorted out of the mixed pile using a mechanical grab. The remaining material will be placed in a trommel to remove any small pieces, such as dust and dirt, and the rest is sent to a sorting belt, where non-ferrous metals are separated from ferrous materials. In a further stage, hand sorting is still common, whereby pickers sort specific materials out of the waste stream for recycling. Some commercial sites may have more sophisticated NIR equipment to identify different plastics, but these are not widely used in the construction waste sector yet (CPA, 2020d). Increasingly, new technologies are starting to be deployed for the separation of CDW, such as robotic equipment (Wahlström et al., 2020).

4.2.2.3 End-of-life vehicles

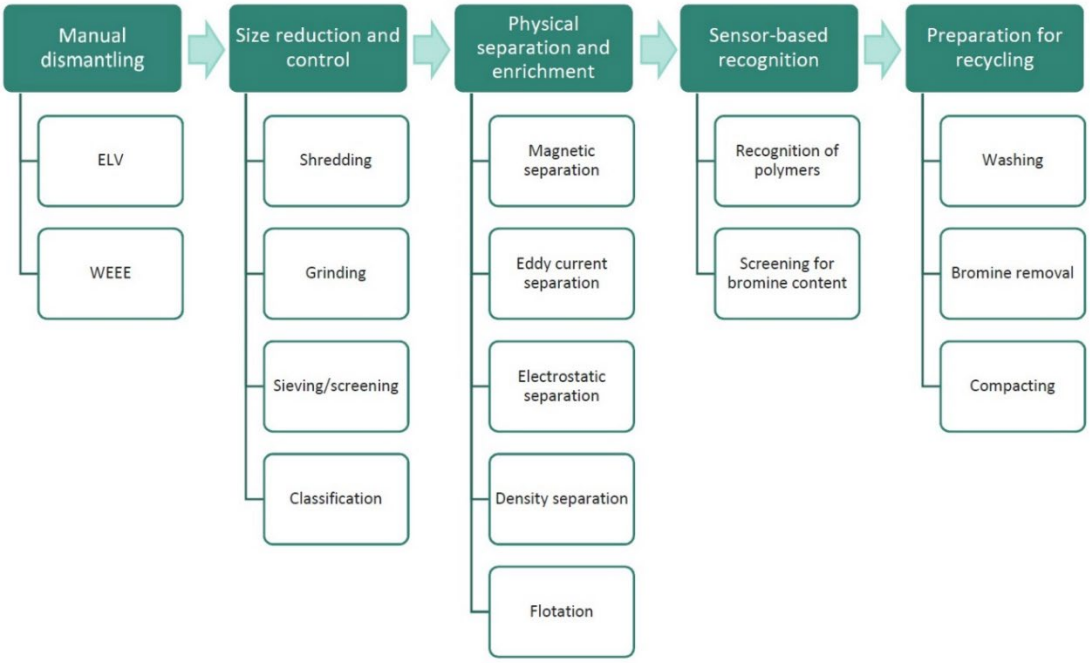
ELVs that enter an authorised treatment facility (ATF) are subject to the following pre-treatment processes (Kalverkamp & Raabe, 2018): (1) depollution, which is mandatory, aiming at removing most of the hazardous components such as batteries, fuels and lubricating oils; (2) dismantling, where non-metal components (sometimes including plastics, mainly bumpers) are dismantled to be sold as spare parts; and (3) shredding, where all the other materials – apart from the metal hull of the vehicle – form a heterogeneous waste called Automotive Shredder Residue (ASR), which includes plastics, glass, rubber, fabrics and others (up to 20–25% of ELV weight).

The ASR generated can be divided into two streams (Cossu & Lai, 2015): (1) a light fraction, which includes a larger proportion of light materials such as plastic, foam, textiles and rubber; and (2) a heavy fraction, which includes a larger proportion of heavy materials like glass and metal fines, produced during separation of the various metal streams. Plastics constitute a significant fraction of ASR (up to 45% w/w) (Rey et al., 2016), but they need to be separated further into individual polymers, or grouped, for recycling. Almost 27 different types of polymeric materials are present in the ASR; about 60% of the plastic components are made of polypropylene (PP), polyurethane (PUR), polyvinylchloride (PVC) or acrylonitrile butadiene styrene (ABS) (Santini et al., 2010).

The treatment of ASR may include several stages of separation and cleaning aimed both at obtaining a separate fraction and improving the quality of the residue to be submitted to subsequent treatments. Different steps of float-sink separation are most commonly used in the

separation of mixed plastics on the basis of density differences. Other techniques for plastic separation have been developed such as froth flotation or laser and infrared systems (Fourier technique) used to separate plastics based on colour (Cossu & Lai, 2015). Optical sorting of plastics by NIR is a state-of-the-art technology; however, there are certain limitations concerning the ASR such as the presence of humidity, oil residue, coatings and colouring of plastics with carbon black. Moreover, there is the added difficulty presented by some materials, in which 10 to 20 years of wear and tear in a vehicle – in combination with chemical and UV exposure – has led to a degeneration of properties that hampers high-quality mechanical recycling. Legacy substances impose an additional challenge to simple mechanical recycling (CIRC-ELV, 2022). The typical process for sorting and pre-treatment of plastics from ELVs is presented in **Figure 8**, following the minimum treatment requirements for ELVs in accordance with Article 6(1) and (3) of and Annex I to Directive (EC) No 2000/53.

Figure 8: Sorting and pre-treatment steps of ELVs and WEEE



Source: Yli-Rantala, E., Bachér, J., Kaartinen, T., Vincenti, N., & Zhan (2020)

4.2.2.4 Waste electrical and electronic equipment

WEEE collected by PROs are sorted into several fractions at the first collection point, or later in the collection process. All WEEE is sorted in various streams (e.g. cooling and freezing appliances, white goods, televisions and monitors, lamps, other WEEE) at the latest when entering a (pre-)treatment site. WEEE undergoes disassembly and depollution, shredding, and mechanical sorting. Plastic is just one of the several output fractions of the WEEE treatment process, among other fractions of mainly valuable metals (e.g. copper, gold, silver, cobalt) that are primarily targeted for recycling in the WEEE stream (CPA, 2020e).

The main polymers obtained from the collected WEEE, after pre-treatment and sorting, are ABS (25.4%), PP (24.3%) and PS (17.3%), with the remainder comprising minimal fractions (CPA, 2020e).

The typical process for sorting and pre-treatment of plastics from WEEE is presented above in **Figure 8**, following the selective treatment for materials and components of WEEE referred to in Article 8(2) of and Annex VII to Directive (EU) No 2012/19.

4.2.2.5 Agricultural waste

As mentioned above, plastic waste in agriculture is initially sorted separately for collection on the farm, which is a prerequisite and determinant for the waste to reach the recycling stage. Plastic waste must be prepared in a proper way to reduce soil content. As soon as the waste reaches the collection areas, it is grouped in adapted quantities to optimise transport. In the so-called grouping centres, quality control is performed, and the traceability of the product is ensured. The waste may be routed directly to either the recycler, or a pre-treatment centre. For this last part, plastics may be baled, or – for heavily soiled products such as mulching – the plastic is pre-treated (shredded, washed and baled), before it is delivered to a recycler (CPA, 2020a).

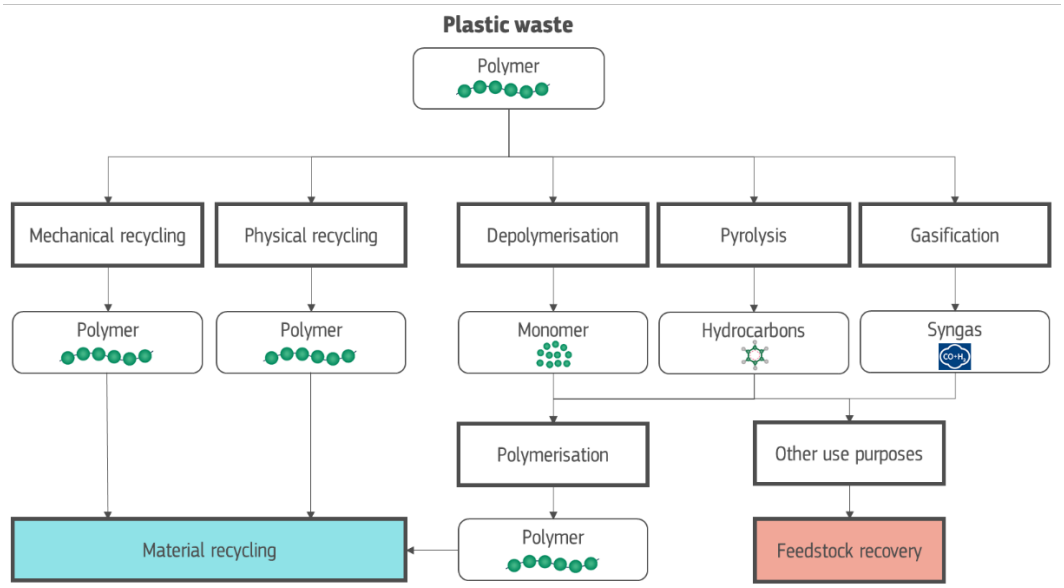
4.2.3 Recycling

The following sections provide a concise overview of plastic waste recycling technologies, including mechanical, physical and chemical recycling (**Figure 9**).

Mechanical and physical recycling processes usually preserve the chemical structure of polymers, allowing the recovered polymers to be used for new or similar plastic applications.

Chemical recycling approaches can be broadly categorised into depolymerisation, pyrolysis and gasification. These methods involve steps altering the chemical structure of the polymers to produce intermediates such as monomers, hydrocarbons (e.g. pyrolysis oil) or syngas (Klotz et al., 2024). These intermediates can be utilised for producing new polymers or for various other applications.

Figure 9: Schematic overview of plastic waste recycling technologies



Source: Based on CreaSolv (2024)

4.2.3.1 Mechanical recycling

Mechanical recycling is the most widespread plastic recycling technique (Naderi Kalali et al., 2023). The output materials can be used for the production of new plastic products. During the recycling process, the chemical structure of the polymer is not altered. The process steps applied may vary depending on the input plastic waste. They may include: visual inspection, sorting, shredding, washing, removal of hazardous substances or persistent organic pollutants (POPs), drying, sorting, and further processing to recover a polymer in the form of flakes, granulates, micronised plastics, agglomerates or pellets, among others (Schyns & Shaver, 2021).

With regards to the removal of surface contamination and the removal of substances within the plastic matrix, the following applies:

- **Removal of surface contamination**: cleaning steps are used to remove surface contamination such as organics, oils, solvents, paints, fatty foodstuffs or certain substances adsorbed onto plastic. This step usually involves washing with cold or hot water, which may include detergents or alkali to remove adsorbed substances.
- **Removal of plastic fractions containing pollutants embedded in the plastic matrix**: current mechanical recycling processes are capable of removing hazardous substances and/or POPs for example with float-sink techniques in fluids with different density (Bill et al., 2019) to an extent that the recycled plastics can in some cases even be used for the original purpose. WEEE plastic recycling facilities for example apply a series of treatment steps, in most cases including a stepwise density separation, to produce bromide-rich and bromide-poor fractions (Haarman et al., 2020). Furthermore, during the melting and reprocessing of plastic waste, high temperatures can help to break down and evaporate volatile hazardous substances.

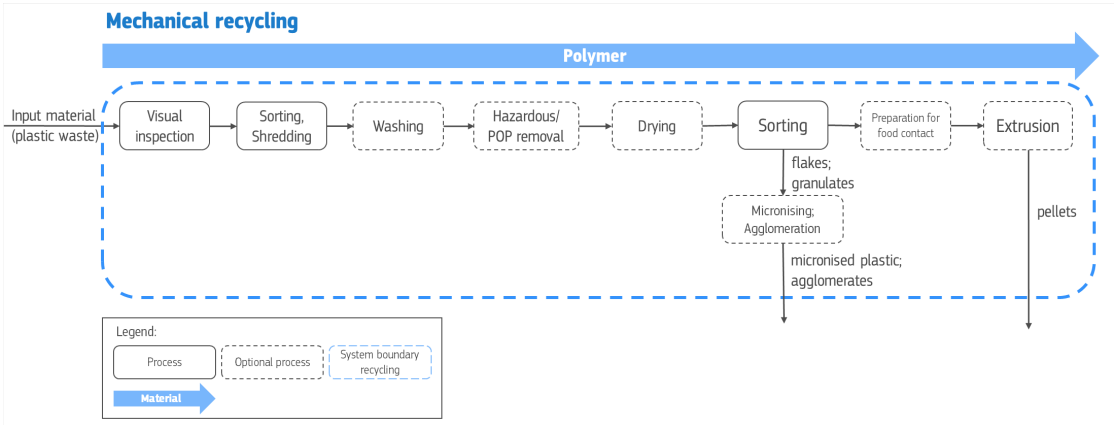
If the recycled plastic is intended to be used for the production of food contact material, it has to comply with Regulation (EC) No 1935/2004 and Regulation (EU) No 2022/1616 and the food contact goods must be manufactured in accordance with Good Manufacturing Practices (Commission Regulation (EC) No 2023/2006). Thus additional process steps may be applied during recycling to prepare the plastic for food contact applications.

At this point it should be noted that at the time of drafting this report there is no mechanical recycling technology approved as a suitable recycling technology for polymers other than PET under Regulation (EU) No 2022/1616. The only exception applies to closed loop systems, which are however very limited in scope (e.g. food crates).

As mentioned above, thermoplastics have the unique ability to be melted and solidified multiple times through standard processing methods such as extrusion or injection moulding. This characteristic makes them highly versatile and suitable for a wide range of applications.

One of the main challenges faced within the mechanical recycling process is related to the polymer degradation during the plastic life and reprocessing operations, decreasing the plastics quality with each mechanical processing step (Mantia & Mistretta, 2020; Velásquez et al., 2024). Another issue is the accumulation of additives and contaminants over the lifetime and multiple cycles that cannot be removed during the recycling process. A reduced quality could imply that the plastic is no longer suitable for certain applications such as safety-related components in the automotive industry.

Figure 10: Schematic overview of mechanical plastic waste recycling

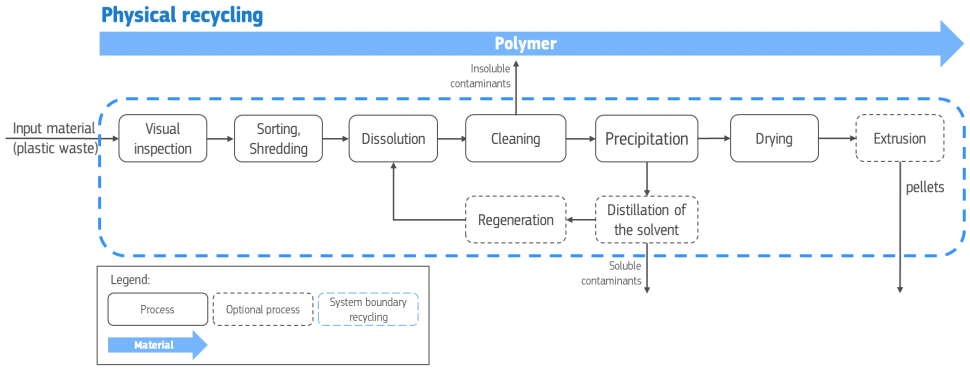


4.2.3.2 Physical recycling

The most common physical recycling approach for plastic waste is the so-called **solvent-based recycling**, also called **dissolution**. Several solvent-based processes have been developed for the recovery of plastic waste (Klotz et al., 2024). These technologies are considered to be an effective way to recycle complex plastic packaging (e.g. composite packaging) that is difficult to recycle using traditional mechanical recycling methods.

The first steps include visual inspection, sorting and shredding, similar to mechanical recycling. As a next step, different technological approaches may be applied to change the material's physical state. Based on their polarity, the solvent molecules interact with the polymer macromolecules to form a polymer solution (Martinez Sanz et al., 2022). This allows an intensive purification of the polymer solution at the molecular level. This purification step is followed by precipitation and heating, to remove the solvent and return the entire polymer to the loop. Contaminants can be removed either at the cleaning step (insoluble contaminants) or after the distillation of the solvent for regeneration purposes (soluble contaminants). If no polymer degradation has taken place during the plastic life, the recovered polymers may have properties similar to virgin polymer materials. **Figure 11** depicts an exemplary overview of physical recycling.

Figure 11: Schematic overview of physical plastic waste recycling (solvent-based approach)



4.2.3.3 Chemical recycling

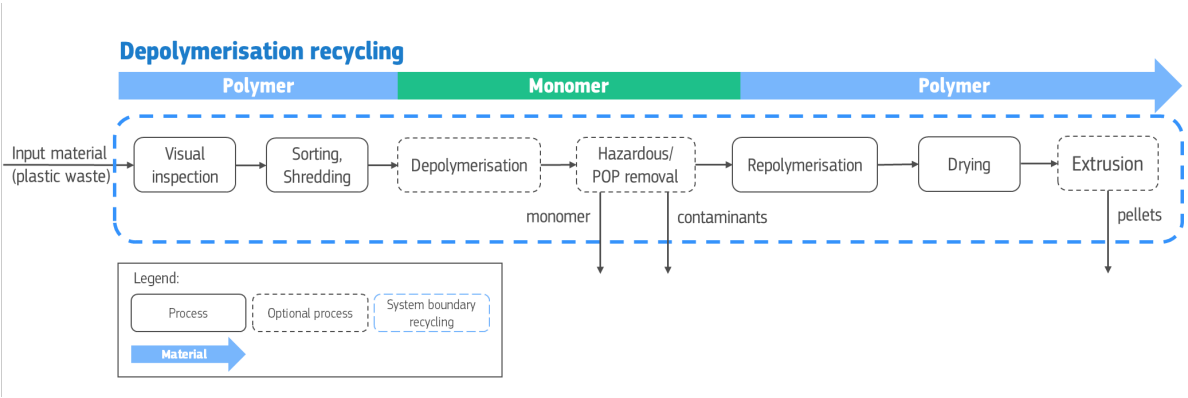
In contrast to mechanical or physical recycling, chemical recycling methods tend to alter the polymer structure of plastic waste. The output material usually consists of smaller molecules that can be used as feedstock to further chemical processes (Schlummer et al., 2020).

Chemical recycling technologies for plastic waste are still emerging and are seen by many as a promising option to complement traditional recycling approaches and increase the overall plastic recycling rate (Lase et al., 2023). However, to date, chemical recycling has not been widely commercialised. The following sections describe the main chemical recycling processes, namely depolymerisation, pyrolysis and gasification.

Depolymerisation

Depolymerisation methods involve breaking down the long chains of polymers into the original monomer units. Several depolymerisation methods can be applied, including for example hydrolysis, glycolysis, methanolysis and enzymatic depolymerisation (Clark & Shaver, 2024; Dai et al., 2022; Jung et al., 2023). Different combinations of chemistry, solvents and heat are used to break down the polymers into monomers. After a depolymerisation process, the monomer can be purified and sold as a raw material or can be fed into a repolymerisation step (see **Figure 12**).

Figure 12: Schematic overview of depolymerisation plastic waste recycling



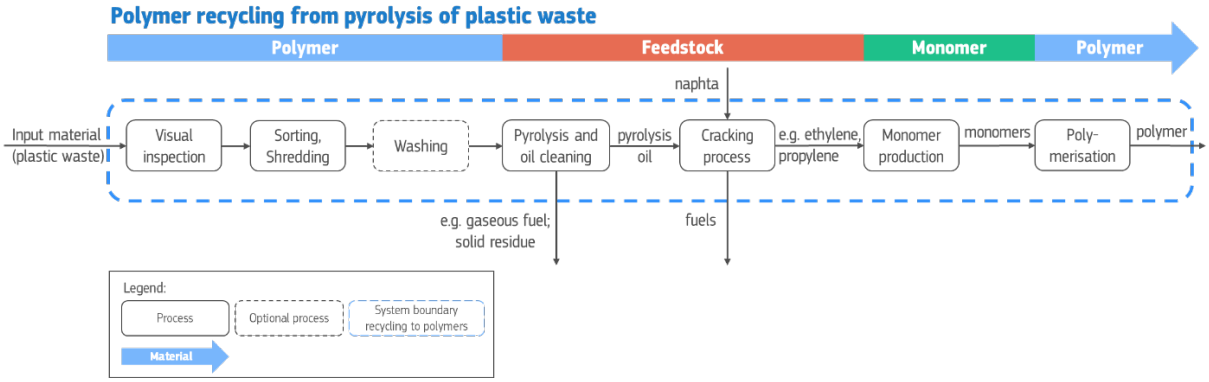
Pyrolysis

Pyrolysis is a process that involves breaking down plastic waste at high temperatures in the absence of oxygen, resulting in the production of liquid and gaseous fuels, as well as a solid residue (carbon black or activated carbon) (Anuar Sharuddin et al., 2016; Kunwar et al., 2016). The pyrolysis process typically involves the following steps (Shah et al., 2023):

1. Pre-processing of the plastic waste such as sorting, shredding and cleaning.
2. The shredded plastic waste is then fed into a pyrolysis reactor, where it is heated at high temperatures in the absence of oxygen. This causes the plastic to break down into its constituent hydrocarbons, producing liquid and gaseous fuels and other compounds (nitrogen, carbon monoxide, carbon dioxide, hydrogen and methane), as well as a solid residue.
3. The liquid output, also known as pyrolysis oil, goes through an oil purification step and is then fed into a cracking process.
4. The cracker breaks down the hydrocarbon feedstock, such as pyrolysis oil, into smaller molecules, including various olefins and aromatics.

To recover polymers, the smaller molecules from the cracker serve as the building blocks for the production of monomers (e.g. ethylene, propylene) and subsequently for polymers (see **Figure 13**). In many cases, however, pyrolysis oil is not specifically used for the production of new polymers, but is mixed in existing refineries with virgin feedstock. The output from these petrochemical installations typically comprises a wide spectrum of chemicals, including precursors to other fine chemicals. Moreover, the pyrolysis process and downstream processes generally see some of the input material being converted directly or indirectly to energy, e.g. as process heat or through the production of fuels. For this reason, pyrolysis of plastic waste should be seen as a step in a plastic waste treatment process that typically combines elements of recycling and energy recovery to varying degrees.

Figure 13: Schematic overview of pyrolysis of plastic waste and exemplary treatment steps for polymer recovery



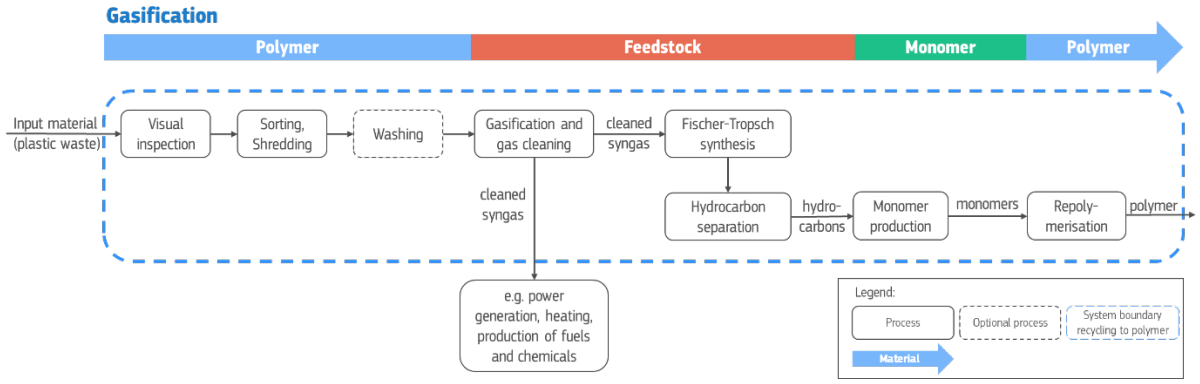
Gasification

In this process, the plastic waste is heated in a low-oxygen environment, causing it to break down into its basic chemical components (Saebea et al., 2020). This results in the production of a mixture of gases, including nitrogen, carbon monoxide, carbon dioxide, hydrogen and methane, which is known as syngas (Lopez et al., 2018). The gasification process typically involves the following steps (Shah et al., 2023):

1. Pre-processing of the plastic waste such as sorting, shredding and cleaning.
2. The cleaned plastic waste is then fed into a gasifier (a high-temperature reactor). In the gasifier, the plastic waste is heated at temperatures of around 700–900 °C in a low-oxygen environment. This causes the plastic to thermally decompose, releasing syngas.
3. The syngas produced contains impurities such as tars, particulates, and sulphur compounds. These impurities are removed through a series of cleaning processes (e.g. filtration, scrubbing, and catalytic conversion).
4. The clean syngas can then be used as fuel for power generation, as an energy carrier (such as H_2), or as feedstock for the production of chemicals (e.g. methanol, paraffins, olefins) and fuels.

To recover polymers, the cleaned syngas is fed into a Fischer-Tropsch process, where it undergoes a catalysed reaction to produce long-chain hydrocarbons, such as paraffins and olefins. These hydrocarbons serve as the foundation for the production of monomers, which are then utilised in subsequent repolymerisation processes to generate new polymers (**Figure 14**). As in the case of pyrolysis, the gasification process and downstream processes generally see some of the input material being converted directly or indirectly to energy, e.g. as process heat or through the production of (gaseous) fuels. For this reason, gasification of plastic waste should also be seen as a step in a plastic waste treatment process that typically combines elements of recycling and energy recovery to varying degrees.

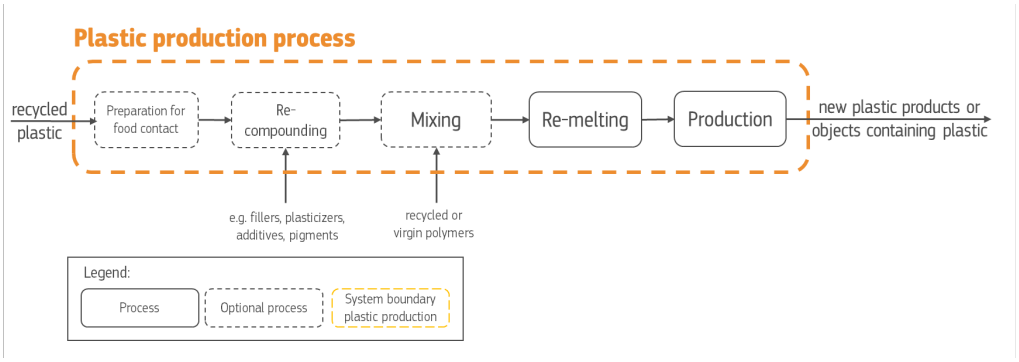
Figure 14: Schematic overview of gasification of plastic waste and exemplary treatment steps for polymer recovery



4.2.4 Reconversion

The polymer recovered through a recycling or other recovery operation can either be used directly for the production of new plastic products or articles containing plastic parts, or can be subjected to various common industrial processes beforehand. These processes may involve preparing the recycled polymer for food contact (according to Regulation (EU) No 2022/1616), re-compounding (e.g. adding fillers, plasticisers, additives or pigments), mixing with other recycled or virgin polymers before being remelted (**Figure 15**).

Figure 15: Schematic overview of plastic production processes using recycled plastic



4.3 Plastic flows in the EU

The **total demand** of **EU-27 manufacturing**, in the five most significant sectors of plastic use (packaging, building & construction, automotive, electrical & electronic, agriculture) for the fabrication of plastic products was **45.4 Mt** in 2019[24], with **39.8 Mt** originating **from primary raw materials** (mostly fossil-based) and **5.6 Mt from secondary (recycled) plastics**, of which **4.3 Mt originated from recycling within the EU** (see **Figure 16**). The majority of this demand was directed to the production of packaging, amounting to 30 Mt, with the construction sector following, using about 10 Mt of plastics. Out of the production of plastic products in the EU-27 (in the five sectors), 43.2 Mt was used by consumers within the Union and ultimately 18.7 Mt ended up

[24] Despite being older, 2019 data are considered to be more representative than pandemic and post-pandemic data, in light of the shock and rebound effects on the plastic sector.

as waste. The remaining plastic was either accumulated as stock in the EU-27 or lost to the environment (mismanaged), potentially dispersed in land and water.

The amount of **plastic** that was **collected for recycling** was **7.2 Mt**, which after going through the sorting and recycling processes, resulted in **4.3 Mt of recycled plastic** for use in EU-27 manufacturing as a secondary material input (excluding the **recycled plastic** that was **exported**, about **1 Mt**).

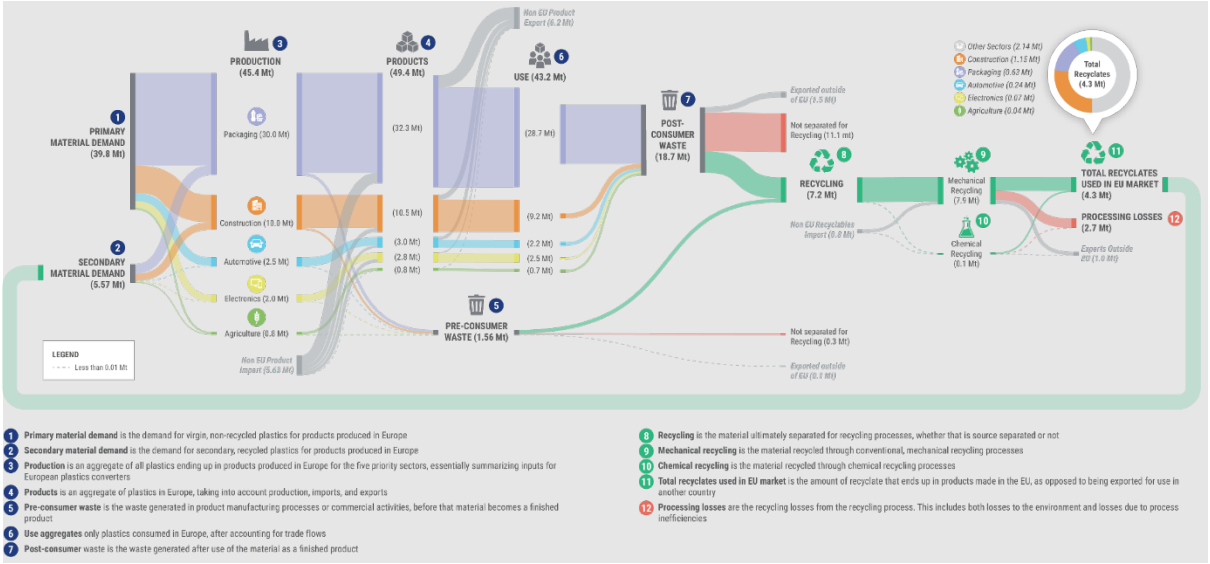
Less than **40% of plastic waste** in the EU-27 was **collected for recycling** in 2019, with the remaining plastic being mostly used for energy recovery, either in industrial facilities (as refuse-derived fuels (RDF)) or municipal facilities (i.e. incinerators with energy recovery for the production of heat and/or electricity).

Recycling of plastic waste is primarily done mechanically, with the contribution of chemical recycling being minimal. About 33% of the total amount of plastic that enters the mechanical recycling process is lost due to inefficiencies and impurities in the incoming waste.

There is a slight variation in the plastic material flow models that exist in literature, giving a range of figures which are largely dependent on methodological choices, e.g. the number of sectors included. For the material demand for plastics, the figures range from 36.9 Mt to 49 Mt, with most studies presenting similar figures at 45.4 Mt (Souder et al., 2024), 45.1 Mt (CPA, 2021a), and 44.8 Mt (Amadei & Ardente, 2022).

Concerning the amount of **recycled plastics** that becomes **available for use** in the EU-27 at the end of the plastics value chain, the studies are fairly consistent, presenting figures in the range of **4.3–4.6 Mt** (Souder et al., 2024) (see **Figure 16**).

Figure 16: Plastic flows for the EU-27 by sector, reference year 2019



1 **Primary material demand** is the demand for virgin, non-recycled plastics for products produced in Europe
2 **Secondary material demand** is the demand for secondary, recycled plastics for products produced in Europe
3 **Production** is an aggregate of all plastics ending up in products produced in Europe for the five priority sectors, essentially summarizing inputs for European plastics converters
4 **Products** is an aggregate of plastics in Europe, taking into account production, imports, and exports
5 **Pre-consumer waste** is the waste generated in product manufacturing processes or commercial activities, before that material becomes a finished product
6 **Use aggregates** only plastics consumed in Europe, after accounting for trade flows
7 **Post-consumer** waste is the waste generated after use of the material as a finished product
8 **Recycling** is the material ultimately separated for recycling processes, whether that is source separated or not
9 **Mechanical recycling** is the material recycled through conventional, mechanical recycling processes
10 **Chemical recycling** is the material recycled through chemical recycling processes
11 **Total recyclates used in EU market** is the amount of recyclate that ends up in products made in the EU, as opposed to being exported for use in another country
12 **Processing losses** are the recycling losses from the recycling process. This includes both losses to the environment and losses due to process inefficiencies

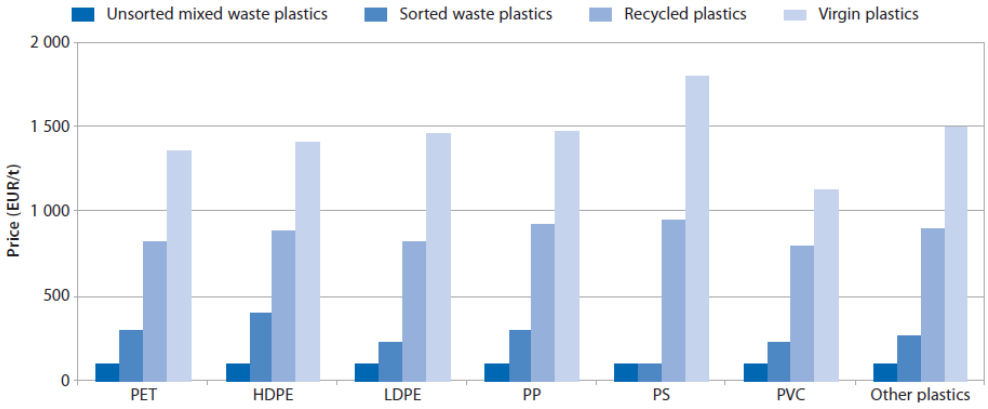
Source: Souder et al. (2024)

4.4 Market and common applications for plastic recyclates

The secondary plastic market is still lagging behind the primary one, as most sectors rely mostly on virgin plastics. The preference for virgin plastics is driven, amongst other factors, by the perceived quality and is linked to the physical and aesthetic requirements of the product. The quality of secondary plastics depends upon different factors, including not only the recycling process itself, but also collection and sorting schemes, as described above. The price of secondary plastics is correlated with the market price of primary plastics (see **Figure 17**). Hence plastic recyclates are

also subject to price fluctuations, which in turn affect the economic viability of recycling (OECD, 2022).

Figure 17: Market value of the main polymers



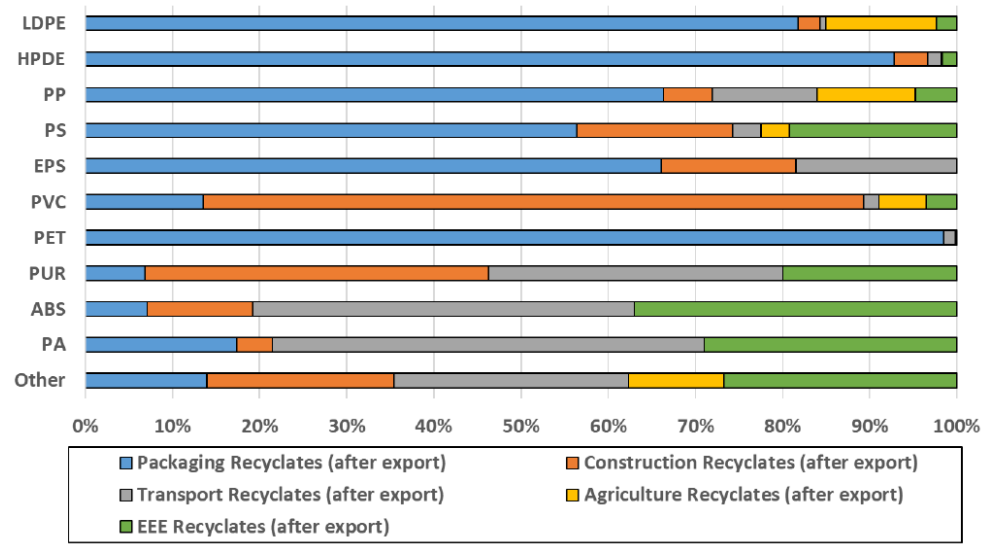
Source: OECD (2018)

The latest policy developments on plastics tend to promote domestic processing and recycling, possibly leading to an increased availability of secondary plastics on domestic markets (OECD, 2022).

Policies on recycled content targets in Europe are expected to increase the uptake of secondary plastics in specific sectors (e.g. automotive, packaging). In 2022, the recycling rate reached 26.9% (8.7 Mt), marking the first time that the amount of plastic waste recycled exceeded the amount sent to landfills.

Amadei & Ardente (2022) developed a material flow analysis for 10 polymers to estimate the contribution of the main sectors, namely packaging, construction, transport, agriculture and electrical and electronic equipment, accounting for 80% of the overall EU-27 demand for plastics. **Figure 18** depicts the contribution of each sector to the total amount of recyclates produced by polymer type. Polymer-specific shares for each sector are expressed as percentages.

Figure 18: Contribution of each sector to the total plastic recyclates produced



Source: Amadei & Ardente (2022)

It is very hard to quantify the final destinations of recyclates by polymer types. Souder et al. (2024) estimated that **more than 50%** of the **recyclates** produced are redirected for **use in other sectors**, with recycled plastics rarely finding application in the same sector that generated it as waste. The sector with the **highest uptake** of recycled plastic is the **building and construction sector**, using about **27% of the recycled plastic** produced in the EU-27 (see **Figure 16**).

5 Background information for the development of end-of-waste criteria

Article 6(1)(c) of the Waste Framework Directive states that the recovered material shall fulfil technical requirements and meet existing legislation and standards applicable to products. An overview of requirements, standards and regulations applicable to plastic products or reyclates is given in Sections 5.1 and 5.2. This information is complemented by standards on quality management, of relevance for the requirements on quality assurance. Key aspects related to the regulatory framework on waste classification and shipment are also introduced, to highlight possible links with EoW legislation.

The fourth condition for a waste stream to leave the waste regime defined in Article 6(1)(d) of the Waste Framework Directive is that the use of the substance shall not lead to environmental and human health impacts. These aspects are discussed in Section 5.3.

Finally in Section 5.4 an overview of existing end-of-waste criteria for plastic waste in individual EU Member States is given.

5.1 Technical requirements and standards

Technical requirements and standards are widely used in the industry as references for classification, quality control and price-setting. Another important goal of technical requirements and standards is to ensure that products, materials and processes meet certain quality and safety criteria, which is essential for protecting consumers and the environment. When it comes to plastic recycling, technical requirements and standards are of particular importance. Plastic recyclers work with waste streams that can vary in quality, so having clear technical requirements and standards is crucial. Additionally, the market demands recyclates with consistent and specific characteristics, making standardisation even more important.

Several standards were developed to characterise recyclates, while other standards give quality recommendations and guidelines for application of plastic recyclates in products. The following sections give an overview of technical requirements and standards for sorted plastic waste and plastic recyclates.

An overview of relevant standards for quality management is also provided, to identify key elements that could serve as a source of inspiration or reference for the quality procedures for EoW.

5.1.1 Standards and specifications for sorted plastics and recyclates

The JRC has identified a series of standards of relevance for plastic recycling.

EN 15347 specifies the procedures and requirements for the assessment and classification of sorted plastic materials based on their physical, chemical and mechanical properties. It outlines methods for determining parameters such as composition, contamination levels, and quality of recycled plastics.

European standards such as EN 15342, 15344-46 and 15348 define methods of specifying delivery conditions of certain polymers. These standards define the most important characteristics and associated test methods for assessing polymers and list the quality parameters and their test procedures. It is also specified whether the characterisation of a quality parameter is mandatory or optional. No limit values for the quality parameter are defined, as they must be agreed between the recycler and the customer.

With the most recent standard EN 18064, quality recommendations and specifications for the application of plastic recyclates in products are defined for PE, PP, PET, PVC, PS and ABS. This standard deals with recyclates after the recycling operation and prior to converting and compounding (when applicable). The standard provides relevant characteristics and typical values for plastic recyclates intended to be used for the manufacturing of (intermediate) products within

specific applications (e.g. boxes, packaging, pipes for construction, agriculture foils). The relevant characteristics and typical values (e.g. for melt mass flow rate, ash residues, density) for different product families are derived from the performance requirements of the products belonging to that family, including requirements for product manufacturing processes, where applicable.

The two technical specifications defined by CEN (CEN/TS 16010 and 16011) describe the sampling procedure and sample preparation for recycled plastics. In addition to European standards, industry initiatives led to the development of best practices and guidelines on characterisation for a broad range of polymers.

Table 9 provides a non-exhaustive overview of the standards mentioned. Further standards, including the globally utilised ASTM[25] standards, technical reports or technical specifications related to recycled plastic are also listed for the sake of completeness.

Table 9: Overview of existing standards, technical reports and technical specifications for recycled plastic (non-exhaustive list)

Number	Type	Title	Year
Standards			
EN 13430	Standard	Packaging - Requirements for packaging recoverable by material recycling	2004
EN 13437	Standard	Packaging and material recycling - Criteria for recycling methods. Description of recycling processes and flow chart	2003
EN 15342	Standard	Plastics - Recycled Plastics - Characterisation of PS recyclates	2007
EN 15344	Standard	Plastics - Recycled Plastics - Characterisation of PE recyclates	2020
EN 15345	Standard	Plastics - Recycled Plastics - Characterisation of PP recyclates	2007
EN 15346	Standard	Plastics - Recycled Plastics - Characterisation of PVC recyclates	2007
EN 15347	Standard	Plastics - Recycled plastics - Characterisation of sorted plastics wastes	2022
EN 15348	Standard	Plastics - Recycled Plastics - Characterisation of PET recyclates	2013
EN 17410	Standard	Controlled loop recycling of PVC profiles from windows and doors	2020
EN 18064	Standard	Plastics - Quality recommendations and basis for specifications for application of plastic recyclates in products. Part 1-7 (general aspects, PE, PP, PET, PVC, PS, ABS).	2024

[25] ASTM International (American Society for Testing and Materials)

DIN SPEC 91446	Standard	Classification of recycled plastics based on Data Quality Levels for use and (digital) trading	2021
UNI 10667-18	Standard	Secondary raw plastics - Part 18: Mixtures of heterogeneous polyolefin-based plastics from industrial residues and/or post-consumer materials	2022
ASTM D 5033	Standard	Standard guide for the development of standards relating to recycling and use of recycled plastics	2000
ASTM D 5991	Standard	Standard practice for separation and identification of PVC contamination in PET flake.	1996
ASTM D 6288	Standard	Standard practice for separation and washing of recycled plastics prior to testing.	2023
ASTM D 5814	Standard	Standard practice for determination of contamination in recycled PET flakes and chips using a plaque test.	2023
ASTM D 5577	Standard	Standard Guide for Techniques to Separate and Identify Contaminants in Recycled Plastics	2019
ASTM D 5676	Standard	Standard Specification for Recycled Polystyrene Moulding and Extrusion Materials	1999
ASTM D 5203	Standard	Standard Specification for Polyethylene Plastics Moulding and Extrusion Materials from Recycled Post-Consumer (HDPE) Sources	2007
ASTM D 5491	Standard	Standard Classification for Recycled Post-Consumer PE Film Source for Moulding and Extrusion Materials	2022
Technical reports			
CEN/TR 15353	Technical report	Plastics - Recycled plastics - Guidelines for the development of standards for recycled plastics	2007
Technical specifications			
CEN/TS 16010	Technical specification	Plastics - Recycled plastics - Sampling procedures for testing plastics waste and recyclates	2022
CEN/TS 16011	Technical specification	Plastics - Recycled plastics - Sample preparation	2013
Rigid Foam Industry Association (IVH)	Technical specification	EPS guidelines for reuse & recycling[26]	2021

[26] https://www.ivh.de/wp-content/uploads/EPS-Leitfaden-Weiterverwertung-Recycling-12-2021_IVH_VDPM.pdf

Plastic Recyclers Europe	Technical specification	Characterisation of recycling inputs and recyclates for various polymers[27]	2022
CEN	Standard	European standardisation deliverable(s) on quality grades for sorted plastics wastes: HPDE, LDPE, PP, PET, PVC, PS, EPS	requested[28]

5.1.2 Standards and specifications for quality management

As mentioned above, standards for quality management can serve as a basis for the quality procedures the operator of the treatment facility has to carry out to demonstrate compliance with EoW criteria.

The relevant standards for quality management and traceability are described below and listed in **Table 10**.

Standard EN 15343 aims to describe the necessary procedures for mechanical recycling that are required for products that are being manufactured completely (or in part) from recycled plastics, including:

- control of input materials;
- control of the recyclates production process;
- plastics recyclates characterisation;
- traceability.

This standard also provides the procedure for the calculation of the recycled content in a given product.

ISO standards define a framework for quality or environmental management. The most relevant ISO standards in relation to quality and environmental management are ISO 9001, ISO 14001 and ISO 17021.

ISO 9001 provides a framework for organisations to implement and maintain an effective quality management system. It outlines requirements for processes, procedures and documentation to ensure that products and services consistently meet customer and regulatory requirements.

ISO 14001 provides a framework for organisations to establish an effective environmental management system. It defines requirements for identifying and managing environmental impacts, complying with environmental regulations, and continually improving environmental performance.

ISO 17021 defines the requirements for bodies carrying out audit and certification of management systems.

[27] https://www.plasticsrecyclers.eu/recyclates-characterisation

[28] Commission Implementing Decision of 1.8.2022 on a standardisation request to the European Committee for Standardisation and the European Committee for Electrotechnical Standardisation as regards plastics recycling and recycled plastics in support of the European Strategy for Plastics in a Circular Economy (M/584) https://cdnmedia.eurofins.com/corporate-eurofins/media/12159510/m584-en.pdf

Table 10: Overview of existing standards on quality management systems and conformity assessment

Number	Type	Title	Year
EN 15343	Standard	Plastics - Recycled Plastics - Plastics recycling traceability and assessment of conformity and recycled content	2007
ISO 14001	Standard	Environmental management systems - Requirements with guidance for use	2015
ISO 17021-1	Standard	Conformity assessment - Requirements for bodies providing audit and certification of management systems. Part 1: Requirements	2015
ISO 17021-2	Standard	Conformity assessment - Requirements for bodies providing audit and certification of management systems. Part 2: Competence requirements for auditing and certification of environmental management systems	
ISO 17021-3	Standard	Conformity assessment — Requirements for bodies providing audit and certification of management systems — Part 3: Competence requirements for auditing and certification of quality management systems	2019
ISO 9001	Standard	Quality management systems	2015

5.2 Legislative aspects

Of direct relevance for the requirements on input materials are the rules on waste classification, laid down in the Waste Framework Directive and the EU List of Waste. The waste legislation is no longer applicable to the output materials of the recycling operations, once EoW status is granted. However, a thorough understanding of the key regulatory framework on waste shipment is necessary, to evaluate the possible impacts deriving from the implementation of EU-wide EoW criteria on trade of plastic recyclates. The key legislative references for waste classification and waste shipment are presented in Section 5.2.1.

Legislation applicable to products with possible relevance for EoW is described in Section 5.2.2.

5.2.1 Relevant waste legislation

Waste legislation applies when the plastic material is still in the waste regime, namely at the point of accepting the waste as input to the recycling operation and during processing.

Particularly relevant for the development of EoW criteria are the classification of waste as hazardous or non-hazardous, provisions on waste shipment and on the sound management of plastic waste.

5.2.1.1 Legislation on hazardousness classification of waste

The **Waste Framework Directive** (WFD) 2008/98/EC is the key legislative document on waste in the EU.

The classification of waste as hazardous or non-hazardous is regulated in Annex III to the Waste Framework Directive, and the classification laid down in the Annex to Commission Decision (EC) No 2000/532 on the **List of Waste**.

Commission Notice 2018/C 124/01 on the classification of waste provides technical guidance on the correct interpretation of the provisions on waste classification. Although some criteria of Annex III to the Waste Framework Directive make reference to CLP hazard classes and statements, the CLP Regulation and the provisions on hazardousness classification are only applicable to substances and mixtures (i.e. to output materials of a recycling operation), not to waste.

5.2.1.2 Basel Convention

The Basel Convention is an international treaty aiming at reducing the transboundary movements of hazardous waste, and specifically at preventing shipment of hazardous waste from developed to less developed countries. The convention also seeks to minimise the amount and toxicity of hazardous waste generated and to ensure its environmentally sound management (UNEP, 2019a).

The amendment of the Basel Convention adopted in May 2019 aimed to enhance the control of transboundary movement of plastic waste and clarify the scope of the Convention. The following entries have been included (effective as of 1 January 2021)[29]:

- **Y48** (in Annex II): Plastic waste, including mixtures of such waste, unless these are hazardous or presumed to be hazardous.
- **A3210** (in Annex VIII): Plastic waste, including mixtures of such waste, presumed to be hazardous.
- **B3011** (in Annex IX) - replacing entry B3010: Plastic waste presumed to be non-hazardous. It includes cured resins, non-halogenated and fluorinated polymers and mixtures of plastic waste (PE, PP, PET).

5.2.1.3 Waste Shipment Regulation

The Waste Shipment Regulation (henceforth: WSR) (EC No 1013/2006, as amended by Regulation (EU) 2024/1157) controls the shipment of waste within EU Member States, from third countries to the EU, from the EU to third countries and in transit through the EU. It lays down shipment rules, depending on the origin, destination and route, the type of waste and the type of treatment.

The Basel Convention entries **Y48**, **A3210** and **B3011** have been implemented in the EU through **Delegated Regulation (EU) No 2020/2174 on plastic waste shipments**[30]. Beside these entries, new entries for the shipment of plastic waste within the OECD (**AC300**) and the EU (**EU48** and **EU3011**) have been introduced (effective as of January 2021). The entries EU48 and EU3011 for non-hazardous plastic waste mostly mirror the entries agreed in the Basel Convention, but present some differences.

In Delegated Regulation (EU) No 2020/2174 new provisions on exports, imports and intra-EU shipments have been introduced. Those apply to the following plastic wastes (excerpt from (European Commission, 2020)):

- Exports of plastics from the EU**:**

[29] For the relevant Basel Convention entries, the plastic wastes considered are listed in Annex II, Annex VIII and Annex IX to the Basel Convention (UNEP, 2019a)

[30] Commission Delegated Regulation (EU) No 2020/2174 of 19 October 2020 amending Annexes IC, III, IIIA, IV, V, VII and VIII to Regulation (EC) No 1013/2006 of the European Parliament and of the Council on shipments of waste.

- Exporting hazardous plastic waste (**A3210**) and plastic waste that is hard to recycle (**Y48**) from the EU to non-OECD countries will be banned.
- Exporting clean, non-hazardous waste (which is destined for recycling) (**B3011**) from the EU to non-OECD countries will only be authorised under specific conditions. The importing country must indicate which rules apply to such imports to the European Commission ((EC) No 1418/2007[31]).
- Exporting hazardous plastic waste (**AC300**) and plastic waste that is hard to recycle (**Y48**) from the EU to OECD countries will be subject to the *'prior notification and consent procedure'*. Under this procedure, both the importing and exporting country must authorise the shipment.

— Imports into the EU**:**

- Importing hazardous plastic waste and plastic waste that is hard to recycle into the EU from third countries will be subject to the *'prior notification and consent procedure'*. Under this procedure, both the importing and exporting country must authorise the shipment.

— Intra-EU shipments**:**

- The *'prior notification and consent procedure'* will also apply to intra-EU shipments of hazardous plastic waste (**AC300**), and of non-hazardous plastic waste that is difficult to recycle (**EU48**).
- All intra-EU shipments of non-hazardous waste for recovery (**EU3011**) will be exempt from these new controls.

The **Correspondent Guidelines No 12 on the classification of plastic waste**[32] provide guidelines for Member States on the interpretation of the Waste Shipment Regulation. Notably, the terms '*almost free from contamination and other types of wastes*' and '*almost exclusively consisting of*' are interpreted.

Waste listed under the entry **EU3011** (relevant for intra-EU plastic waste shipment) is considered almost free from contamination under the following conditions:

— *'In a consignment of plastic waste classified under entry **EU3011**, the content of contamination, other types of wastes*[33] *or non-halogenated polymers, cured resins or condensation products, or fluorinated polymers, other than the one non-halogenated polymer, cured resin or condensation product, or fluorinated polymer that makes up the bulk of the plastic waste should not exceed a total **maximum of 6%** of the weight of the consignment*[34]*'.*

---

[31] Commission Regulation (EC) No 1418/2007 of 29 November 2007 concerning the export for recovery of certain waste listed in Annex III or IIIA to Regulation (EC) No 1013/2006 of the European Parliament and of the Council to certain countries to which the OECD Decision on the control of transboundary movements of wastes does not apply

[32] Waste shipment correspondent guidelines No 12: https://environment.ec.europa.eu/system/files/2021-12/Correspondents'%20guidelines%20No%2012%20final%20Nov%202021%20corr1.pdf

[33] "Other types of wastes" may include PVC in this case. It is noted that PVC is listed in entry EU3011 in its fourth indent, but not in entry B3011.

[34] A Member State may decide to apply at a national level, for waste classified under entry EU3011, a total maximum level of 2%, identical to the total maximum for waste classified under entry B3011. In this case the correspondent from the Member State concerned should inform the Commission in writing of this, along with a rationale for this approach. The Commission should inform correspondents in other Member States and actors involved in shipments of plastic waste and publish such information on its website.

— *'In a consignment of PVC waste classified under entry **EU3011**, the content of contamination and other types of wastes should not exceed a total **maximum of 6%** of the weight of the consignment'.*

Waste listed under the entry **B3011** (relevant for export of plastic waste from the EU to OECD countries / import of plastic waste into the EU from OECD countries, and export of plastic waste from the EU to non-OECD countries / import of plastic waste into the EU from non-OECD countries) is considered almost free from contamination under the following conditions:

— *'In a consignment of plastic waste classified under entry **B3011**, the content of contamination, other types of waste*[35] *or non-halogenated polymers, cured resins or condensation products, or fluorinated polymers other than the one non-halogenated polymer, cured resin or condensation product, or fluorinated polymer that makes up the bulk of the plastic waste should not exceed a total **maximum of 2%** of the weight of the consignment'.*

— *'In a consignment of mixtures of plastic waste (consisting of PE, PP and/or PET) classified under entry B3011, the content of contamination and other types of wastes should not exceed a total **maximum of 2%** of the weight of the consignment'.*

On 20 May 2024 the **new Regulation on Waste Shipment** (**Regulation (EU) No 2024/1157**, amending Regulations (EU) No 1257/2013 and (EU) 2020/1056 and repealing Regulation (EC) No 1013/2006)[36] entered into force.

The new Regulation aims to tackle the increase of EU waste exports, the recovery activities in environmentally unsound conditions in the importing countries and the illegal shipment of waste. As part of the European Strategy for Plastics in a Circular Economy[37] and the ambition to reduce plastic waste and improve its management, the Regulation also aims to address the environmental and human health impacts caused by plastic pollution.

To this end, exports between OECD countries will be monitored in terms of environmental and human health impacts in the country of destination (cf. Article 45). As of May 2026, OECD countries importing significant volumes of **plastic waste** from the EU shall be subject to specific scrutiny by the Commission.

Exports of hazardous waste and certain other waste to non-OECD countries will be prohibited (cf. Article 39), with specific exceptions.

As of November 2026, export of **plastic waste** classified under the Basel Convention entry **B3011** to non-OECD countries shall be prohibited (cf. Article 39(1)(d)), with a possible exemption upon request from the importing country (cf. Article 42(4)). The country making the request shall also demonstrate that: i) it has a comprehensive waste management system in place; ii) it has a legal framework for waste management, including prohibition to incinerate or landfill separately collected waste; and iii) that plastic waste imported from the EU does not have adverse effects on the management of plastic waste generated locally.

5.2.1.4 Other rules on waste shipment in third countries

In recent years, many countries, first and foremost countries in Asia (e.g. China, Malaysia, Thailand and Vietnam), have adopted a stricter control or have banned the import of plastic waste. These

---

35 "Other types of wastes" may include PVC in this case.

36 Regulation (EU) No 2024/1157 on shipments of waste: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AL_202401157

37 Communication of the Commission of 16 January 2018: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2018:28:FIN

bans have been put in place due to concerns over the environmental impact of plastic waste, as well as the potential for illegal dumping.

The territory of Hong Kong implemented guidelines for the trade of plastic waste, including limit values for contamination: plastic waste is considered 'uncontaminated' if it is clean and it contains no more than 0.5% impurities (other types of plastics, paper, glass, etc.) by total weight (EPD-HK, 2020).

5.2.2 Relevant product legislation

One of the objectives of EoW criteria is the minimisation of environmental and health concerns. Both waste and product legislation address environmental and human health impacts. Once EoW status is granted, the material enters the product regime, hence having to comply with legislation applicable to products. The main concerns to be addressed in EoW criteria are related to the hazardousness of the output materials and the presence of substances that are restricted under the chemicals legislation. The main regulatory references on chemicals of concern are briefly introduced below.

5.2.2.1 CLP Regulation

Regulation (EC) No 1272/2008 on Classification, Labelling and Packaging of substances and mixtures (henceforth: **CLP Regulation**) aims to ensure a high level of protection of human health and the environment as well as to facilitate the free movement of substances, mixtures and articles.

It provides harmonised criteria for the classification of substances and mixtures. It stipulates that entities placing substances and mixtures on the market shall classify and label them according to the requirements set forth in the Regulation.

As per Article 1(3) of the CLP Regulation, waste is not a substance, mixture or article. Hence, the provisions laid down in the CLP Regulation are not applicable to input materials (i.e. plastic waste) of the recycling operation.

Article 3 and Annex I (Parts 2 to 5) set out the criteria for classification in hazard classes and in their differentiations and set out additional provisions on how the criteria may be met. Those are particularly relevant in the context of EoW.

As outlined in the Guidance on Waste and Recovered Substances (ECHA, 2010), the output of a recovery operation can result in a substance on its own, in a mixture or, potentially, in an article recovered directly from waste. While under the CLP Regulation substances and mixtures fall within the scope of the hazard classification, articles are not covered (except in the case of explosive and pyrotechnic articles). Nonetheless, it is noted that the system boundaries of the present proposals do not comprise the point at which articles are formed (see section 6.1.3). Hence, hazard classification is limited to substances and mixtures under the currently proposed EoW criteria.

5.2.2.2 REACH Regulation

Regulation (EC) No 1907/2006 (henceforth: **REACH Regulation**) aims to ensure a high level of protection of human health and the environment, including the assessment of hazardousness of substances and their free circulation on the market.

It lays down provisions for the manufacturing, placing on the market and use of substances and mixtures.

Analogously to Article 1(3) of the CLP Regulation, as per Article 2(2) of the REACH Regulation, waste is not considered a substance, mixture or article under REACH. Consequently, this regulation does not apply to waste. However, once the output material of the recycling operation ceases to be waste, REACH becomes applicable, along with the obligations defined therein for substances on their own, in mixtures and in articles.

Relevant obligations for plastic recyclates include substances listed in Annex XIV, for which an authorisation is required to place them on the market or to use them in the EU, pursuant to Article 56.

Annex XVII includes restrictions on the manufacture, placing on the market and use of certain dangerous substances. In particular, substances (on their own, in mixtures or in articles) not fulfilling the conditions of the restrictions established in Annex XVII shall not be placed on the market. Nonetheless, as indicated above, it is noted that the system boundaries of the present proposals do not comprise the point at which articles are formed (see section 6.1.3). Hence, reference to articles is omitted from the currently proposed EoW criteria.

In the latest amendment of Annex XVII to REACH (Regulation (EU) No 2023/923) derogations on the use of recovered rigid PVC have been laid down. As defined in Annex XVII, entry 63, column 2, paragraphs 18 (a) to (d), the use of recovered rigid PVC with lead concentrations below 1.5% is allowed for specific applications.

5.2.2.3 POP Regulation

Persistent Organic Pollutants (POPs) are chemicals that persist in the environment, accumulate in living organisms and carry the potential to cause significant adverse effects to human health or the environment.

Regulation EU 2019/1021 (henceforth: **POP Regulation**) is designed to safeguard human health and the environment and aims to prohibit, phase out or restrict the manufacturing, placing on the market and use of POPs.

Article 7 lays down provisions for the management of POPs waste. Notably, "*waste consisting of, containing or contaminated by any substance listed in Annex IV to this Regulation shall be disposed of or recovered, without undue delay and in accordance with Part 1 of Annex V to this Regulation, in such a way as to ensure that the POP content is destroyed or irreversibly transformed so that the remaining waste and releases do not exhibit the characteristics of POPs"*.

By way of derogation, Article 4(a) states: "*waste containing or contaminated by any substance listed in Annex IV may be otherwise disposed of or recovered in accordance with the relevant Union legislation, provided that the content of the listed substances in the waste is below the concentration limits specified in Annex IV*".

Those provisions are relevant for the treatment of plastic waste containing substances listed in Annex IV and are hence applicable to input materials of the recycling operation.

Article 2(1) of the POP Regulation defines 'placing on the market' in accordance with point 12 of Article 3 of the REACH Regulation. Article 3 of the POP Regulation prohibits the manufacturing, placing on the market and use of POPs listed in Annex I, whether on their own, in mixtures or in articles, unless they fall under any of the exemptions in Article 4. This encompasses the use of the substance at lab scale for research, as a standard or if the substance is present below its 'unintentional trace contaminant' limit value (defined for some POPs in Annex I).

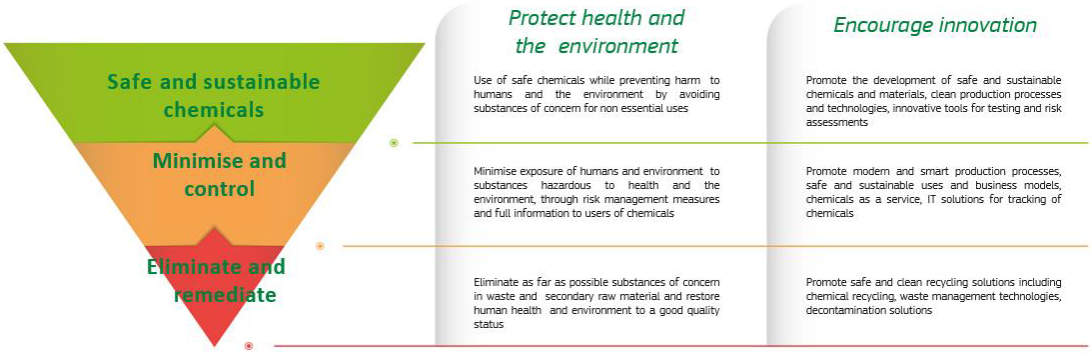
Recycled plastics that attain EoW status will have to comply with the POP Regulation, including the limit values imposed therein. Nonetheless, as indicated above, it is noted that the system boundaries of the present proposals do not comprise the point at which articles are formed (see section 6.1.3). Hence, reference to articles is omitted from the currently proposed EoW criteria.

5.2.2.4 Chemicals Strategy for Sustainability

In the **Chemicals Strategy for Sustainability** (COM (2020) 667 final)[38], the Commission outlines a number of key actions to promote a safe and sustainable use of chemicals in the EU (see **Figure 19**). These include reviewing and updating relevant legislation to ensure the safe use of chemicals, promoting the shift to safer and more sustainable chemicals, addressing hazardous substances in products, improving the safety of chemicals in consumer goods, enhancing protection for vulnerable groups, advancing the use of non-toxic material cycles, and encouraging innovation and digitalisation in the chemical industry. The strategy also stresses the importance of international cooperation and engagement in promoting global chemical safety standards.

Of particular importance for the development of EoW criteria are the new hazard classes and criteria for the classification, labelling and packaging of substances and mixtures integrated in the CLP Regulation through the Commission Delegated Regulation (EU) 2023/707. These criteria are based on growing knowledge and expertise in identifying endocrine disruptors, persistent, bio-accumulative, toxic chemicals, and very persistent, very mobile substances and mixtures. The Commission also aims to develop a common open data platform on chemicals, to increase traceability.

Figure 19: Chemicals Strategy for Sustainability - The toxic-free hierarchy – a new hierarchy in chemicals management



Source: COM (2020) 667 final[36]

5.2.2.5 Ecodesign for Sustainable Products Regulation (ESPR)

The Ecodesign for Sustainable Products Regulation (ESPR) ((EC) No 2024/1781), which came into force on 18 July 2024, is part of a set of measures aimed at achieving the goals of the Circular Economy Action Plan. The primary goal of the Regulation is to promote sustainability of products over the whole life cycle by establishing eco-design requirements.

Article 2(27) lays down a comprehensive definition for substances of concern (SoC), including substances meeting the criteria of Article 57 of the REACH Regulation, substances classified as hazardous pursuant to Annex VI to the CLP Regulation, substances regulated under the POP Regulation and other substances negatively affecting the reuse and recycling of materials in the product in which they are present.

The ESPR does not prescribe restrictions for substances of concern. Those may be introduced in Delegated Acts to the Regulation.

[38] Chemicals Strategy for Sustainability Towards a Toxic-Free Environment: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A667%3AFIN

Article 7 of the Regulation introduces information requirements for those substances, which shall be given either on the product or shall be accessible via a digital passport accompanying the product. Information requirements for specific product groups will be laid down in secondary legislation.

5.3 Environmental and human health impacts

Impacts to the environment and human health can occur in different phases of the recycling value chain, as outlined in Section 5.3.1.

Condition (d) of Article 6(1) of the Waste Framework Directive defines that "*the use of the substance or object will not lead to overall adverse environmental or human health impacts*". Impacts related to the use of the recovered material derive mostly from the presence of chemicals of concern or other harmful substances. The concentration of those substances in the output material of a recycling operation depends on the waste used as feedstock and the effectiveness of the process. Those aspects are presented in Sections 5.3.2 and 5.3.3.

Impacts related to marine plastic litter and microplastics are also briefly presented in Section 5.3.4.

5.3.1 Impacts in the recycling value chain

The environmental impacts of plastic waste collection, sorting and recycling, including storage and transport of recycled materials include among others:

- energy uses;
- resource uses;
- greenhouse gas emissions (e.g. CO_2);
- other air emissions (toxic and/or environmentally harmful substances and dust);
- unintentional distribution of plastics in the environment;
- leaching or leakage of liquid components to the underground;
- fire hazards.

The preferred waste management option from a life cycle assessment (LCA) perspective is, in principle, the one maximising material recovery while minimising impacts from waste processing (e.g. energy consumption, emissions). Any recycling option (mechanical, physical or chemical) is, in principle, preferable to energy recovery (Garcia-Gutierrez et al., 2023). Furthermore, according to most LCA studies, mechanical recycling of most plastic waste types generally contributes the most to overall energy and air emission savings compared to other recycling technologies and also compared to the production of virgin polymers[39] (Martín-lara et al., 2022).

Plastic recycling avoids the disposal of plastics in landfills, which is still taking place in a large number of EU countries and is the least favourable option according to the waste hierarchy. Energy recovery from waste plastic through incineration is an option to avoid landfilling but is generally less preferable than recycling or other options higher up in the waste hierarchy.

In countries with less stringent regulation or lower environmental concern, plastic could enter the environment (e.g. landscape, water bodies) during storage of plastic waste and recycled plastic at recycling facilities. Furthermore, less stringent regulation could lead to additional emissions from

[39] Factors that influence the result of life-cycle-based studies are (1) the degree of substitution of virgin material, (2) the energy mix used for recycling and the energy sources substituted by virgin material production avoidance and incineration, (3) the technologies and techniques for recycling and incineration, (4) as well as and the waste management context.

solid waste and waste water originating from the recycling process. Plastic waste can also be lost into the environment from landfills through wind transport or scavenging animals.

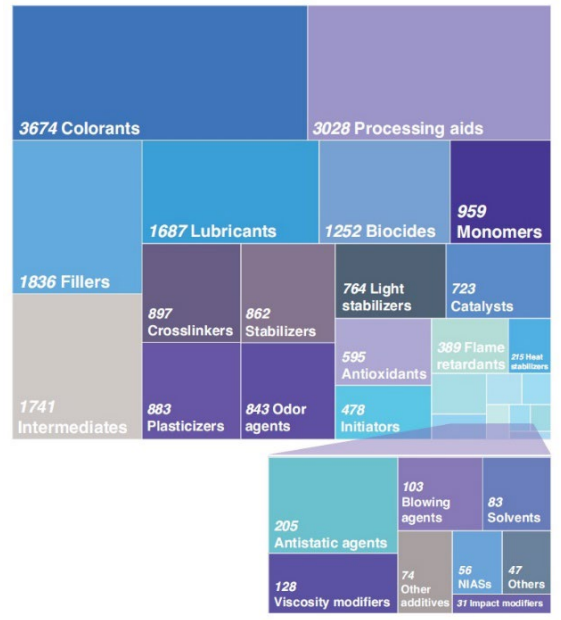
In a few cases, plastic recycling could have a negative impact on human health, in particular if sorting is still performed manually. Workers may risk injuries for example due to a lack of proper protective gear and risk physical wear and tear. Workers can also be exposed to particle and gaseous emissions from the recycling process in unventilated areas (e.g. shredding and melting of plastics). They could come into contact with infectious substances while sorting, especially in the case of waste received from healthcare facilities that has not been segregated properly.

5.3.2 Chemicals of concern

In addition to polymers and additives, other chemicals might be present in plastics, including other intentionally used substances such as solvents, unreacted monomers, starting substances, and processing aids, as well as non-intentionally added substances (NIAS), which include impurities, reaction by-products, and breakdown products (Groh et al., 2019). As mentioned above, from a chemical perspective, plastic products are complex mixtures of one or more polymers, fillers, several additives, and many (often unidentified) NIAS. The presence of such potentially hazardous additives or processing aids renders plastic waste hazardous, making it particularly difficult to recycle or not suitable for recycling at all.

According to the state-of-the-art report by (Wagner et al., 2024), there are at least 16 000 known chemicals in plastics. The report identified 16 325 compounds that are potentially used intentionally or unintentionally in plastics. Almost 4 000 compounds are high-production-volume chemicals, each produced at ≥ 1 000 tonnes per year. Of all the compounds analysed, at least 6 300 have a high exposure potential. These compounds are known to be used or present in plastics, including over 1 500 compounds that are known to be released from plastic materials and products. **Figure 20** presents an overview of all plastic chemicals (number of chemicals by function) that have been characterised so far.

Figure 20: Overview of the functions of plastic chemicals.



Source: Wagner et al. (2024)
Note that many compounds have more than one function

Over 1 800 chemicals of concern are known to be present in plastics. This includes more than 500 chemicals of concern that are released from plastic materials and products, indicating potential for human and environmental exposure. Less than 1% of plastic chemicals may be classified as non-hazardous. However, a complete hazard assessment is lacking, implying that their safety cannot be determined conclusively. Each of the major polymer types can contain at least 400 chemicals of concern. Polyurethanes (PUR), polycarbonates (PC), and polyvinyl chloride (PVC) are most likely to contain such compounds (Wagner et al., 2024).

Hazardous properties that can be considered in the chemicals of concern include carcinogenicity, mutagenicity, reproductive toxicity, endocrine disruption and ecotoxicity to aquatic organisms as classified according to the United Nations (UN)'s Globally Harmonized System of Classification and Labelling of Chemicals (GHS) and the CLP Regulation. Moreover, it has been evidenced that over 1 000 different chemicals can migrate from plastic food contact materials into food (Geueke et al., 2022).

The most relevant groups of chemicals of concern due to their toxicity and potential migration from plastics are presented below, together with their documented effects on human health (UNEP, 2023a).

- flame retardants (toxicity, endocrine disruption, developmental neurotoxicity, reproductive disorders, and carcinogenicity);
- per- and polyfluoroalkyl substances (PFAS) (carcinogenicity, neonatal mortality, endocrine disruption, delays in physical development, delayed pregnancy, and reduced sperm quality);
- phthalates (reproductive disorders with potential transgenerational or multigenerational effects, endocrine disruption, asthma-inducing, allergenic for children, obesity and diabetes in older women);
- bisphenols (reproductive toxicant with impacts on female reproduction as well as potential to affect male reproductive systems, statistically significant weight gain, altering hormone metabolic profiles, and altering maternal behaviour);
- certain alkylphenols and alkylphenol ethoxylates (APEOs) (endocrine disruption and suspected toxicity to reproduction);
- polycyclic aromatic hydrocarbons (PAHs) (carcinogenic, mutagenic, or toxic for reproduction);
- biocides (irritants and sensitisers and act on the skin, eyes and mucous membranes, can lead to allergic contact dermatitis and asthma);
- UV stabilisers (estrogenic and hormonal activities in vitro);
- metals and metalloids (respiratory irritation, pneumoconiosis, and gastrointestinal effects, possibly carcinogenic, systemic health effects including neurological, cardiovascular, and endocrine deficits);
- non-intentionally added substances.

The listed chemicals of concern are emphasised due to their persistent nature (long-exposure timeframes), which has prompted relevant processes of regulation, either globally or in individual national entities.

5.3.3 Potential concerns by waste source

The UNEP technical guidelines on the environmentally sound management of plastic wastes (UNEP, 2023b) include a list of plastic wastes that can be presumed to be hazardous. Those include, among others, waste contaminated with heavy metals, e.g. rigid PVC and batteries, waste contaminated with brominated flame retardants (BFRs) or containing per- and polyfluoroalkyl substances (PFAS), waste contaminated with hazardous substances or certain additives with hazardous characteristics and plastic waste from medical care.

Potential concerns related to different sources of plastic waste are reported below.

5.3.3.1 Healthcare waste

The management and disposal of healthcare waste can indirectly pose health hazards by releasing pathogens and toxic pollutants into the environment. Improper disposal of untreated healthcare waste in landfills can contaminate drinking, surface and ground waters. Treatment of healthcare waste with chemical disinfectants can also lead to the release of harmful substances into the environment. Waste treated with chlorine-containing compounds can result in the generation of dioxins and furans, which have carcinogenic effects. Incineration of waste containing heavy metals (lead, mercury and cadmium) can result in the accumulation of toxic metals in the environment. Alternative methods such as autoclaving, microwaving, and steam treatment can minimise the formation and release of chemicals (WHO, 2018).

Biomedical and healthcare waste consists of a fraction not associated with hazards, similar to municipal waste, which represents the majority of this waste stream (85%), and a smaller fraction presenting hazardous properties. The hazardous nature of this waste stream may be due to the presence of one or a combination of the following (UNEP, 2003):

- infectious agents, including contaminated sharps;
- toxic or hazardous chemicals or pharmaceuticals;
- cytotoxic or genotoxic substances;
- radioactive substances.

Hazards from infectious waste

Infectious waste may contain pathogenic microorganisms that may infect the human body via absorption through a crack or cut in the skin, absorption through the mucous membranes, and by inhalation and ingestion (UNEP, 2003).

Hazards from sharps

Due to the dual risk of injury and disease transmission, sharp objects are considered to present an acute human health hazard. The primary concern is the transmission of infections through the introduction of the agent into the bloodstream. Of particular concern are syringe needles, as they are a significant component of sharp objects and are frequently contaminated with patients' blood (UNEP, 2003).

Hazards from chemical and pharmaceutical waste

Many chemicals and pharmaceuticals used in healthcare facilities are hazardous, with toxic, corrosive, flammable, reactive or other hazardous properties. These substances can cause toxic effects through acute or chronic exposure, leading to injuries such as burns and intoxications. Of particular concern are mercury, commonly found in medical devices, and disinfectants, which are often corrosive.

Hazards from cytotoxic and genotoxic waste

Health hazards for healthcare workers handling cytotoxic and genotoxic waste are determined by the combined impact of the substance's toxicity and the level of exposure that can occur during waste handling or disposal. Exposure to cytotoxic and genotoxic substances can also happen during treatment preparation. The primary routes of exposure include inhaling dust or aerosols, absorbing substances through the skin, or accidentally ingesting contaminated food.

Hazards from radioactive waste

Radioactive materials can cause harm through both external radiation and ingestion, with the severity of harm depending on the quantity and type of radioactive material. Exposure to high-activity sources, like those used in radiotherapy, can result in serious injuries, such as burns, and

fatalities. Even though radioactive waste from nuclear medicine is less active, it still presents a risk of carcinogenesis. Hospitals and laboratories have implemented protocols to reduce these risks and to safely store and dispose of radioactive waste.

5.3.3.2 Personal hygiene products

Personal hygiene products contain cosmetic products, substances or mixtures intended to be placed in contact with the external parts of the human body or with the teeth and the mucous membranes of the oral cavity, as defined in Regulation (EC) No 1223/2009. Examples of cosmetic products are soap, shampoo, toothpaste, deodorant, etc.

Absorbent hygiene products (AHP) are part of this category and can in turn be categorised into (Pérez-Camacho et al., 2023):

- adult incontinence care products, including disposable incontinence products;
- baby diapers and nappies, including disposable and reusable baby diapers and nappies;
- feminine sanitary protection, including disposable and reusable sanitary pads or towels, disposable and reusable panty liners, disposable tampons, disposable and reusable nursing pads.

Menstrual cups fall under another subcategory of personal hygiene products.

Baby diapers, feminine care pads and adult diapers have a similar structure. Baby diapers consist of four functional layers: the top sheet (made of soft, porous polypropylene), the acquisition layer (made of cellulose and polyester), the absorbent layer (made of a superabsorbent polymer gel blended with cellulose and contained within a porous polymer non-woven layer) and the backsheet (made of textured polypropylene laminated with a polyethylene film) (Dey et al., 2016).

AHP can contain biocides and antimicrobial agents (e.g. nanosilver, triclocarban) as well as fragrances and lotions (e.g. vaseline, aloe vera) (Pérez-Camacho et al., 2023).

Commission Decision (EU) 2023/1809 establishes the EU Ecolabel criteria for absorbent hygiene products and reusable menstrual cups, including the presence of chemicals of concern.

RVIM (2019) carried out a risk assessment of diapers and incontinence products, which was meant to serve as a framework for the recovery of materials from AHP waste. They highlight three groups of potentially harmful substances that accumulate in AHP during the use phase:

- pathogens (e.g. bacteria, viruses, protozoa), associated with the risk of infection;
- pharmaceutical residues, associated with risks of toxicity, endocrine disturbances, carcinogenic properties;
- other substances, including substances of very high concern, that were already present in the material before the use phase.

5.3.3.3 Plastic packaging waste

Plastic packaging consists of various polymers that contain additives and non-intentionally added substances. The database of '*Chemicals associated with Plastic Packaging*' (CPPdb) lists more than 4 000 substances[40] as very likely or possibly used during manufacturing of plastic packaging or as present in the final packaging articles (Groh et al., 2018). Of the 906 substances very likely associated with plastic packaging, 63 rank highest for human health hazards and 68 for environmental hazards according to the harmonised hazard classifications assigned by ECHA within

[40] 906 chemicals are very likely associated with plastic packaging and 3 377 substances are possibly associated with plastic packaging.

the CLP Regulation. Of the 906 substances, 7 are classified in the EU as persistent, bio-accumulative and toxic, or very persistent andvery bio-accumulative, and 15 as endocrine-disrupting (Groh et al., 2019).

During the use, disposal and recycling, these substances may transfer into products, such as foods and cosmetics, or in the environment (Hermabessiere et al., 2017).

Among the 63 substances ranked highest for human health hazards, Geueke et al. (2018) further ranked the five most critical substances in plastic packaging:

- benzyl butyl phthalate (BBP);
- dibutyl phthalate (DBP);
- diisobutyl phthalate (DiBP);
- bis(2-ethylhexyl) phthalate (DEHP);
- dicyclohexyl phthalate (DCHP).

5.3.3.4 Mixed municipal solid waste

To achieve the ambitious targets of 55% of all plastic packaging being recycled by 2030, and that 65% of municipal waste shall be prepared for reuse and recycling by 2035, other plastic waste sources such as mixed municipal solid waste (MSW) are increasingly being exploited (Cimpan et al., 2015). Plastic waste that ends up in municipal solid waste comes into contact with other waste fractions, including fractions with potentially infectious properties (e.g. diapers, other personal hygiene products) or hazardous properties (e.g. batteries).

Depending on the retention time in a container, the content of organic waste or other waste fractions that affect the smell of waste, and seasonal effects (e.g. high temperature increases the reactivity of organic waste), the plastic fraction can take up different odorants. Cabanes, Strangl, et al. (2020) and Cabanes, Valdés, et al. (2020) highlight that the overall odour intensity is significantly higher for recycled plastic that originates from mixed MSW than for recycled plastic originating from plastic that has been collected separately. Additional (cleaning) steps may be required to remove surface impurities and substances that have penetrated the polymer matrix.

5.3.3.5 Construction and demolition waste

Plastic is an essential material for many components in buildings and infrastructures (e.g. pipes, cables, storage tanks). The predominant plastic parts found in construction and demolition waste (CDW) are PVC pipes and fittings, plastic insulation materials, plastic sheeting and tarps, plastic window frames and doors, and plastic flooring materials (Hernandez et al., 2023; Santos et al., 2023).

Certain plastics such as PVC or EPS typically contain problematic substances that could lead to environmental and health issues.

PVC is commonly used in construction materials such as pipes, fittings, window frames, and flooring. Some of the problematic substances associated with PVC are chloride[41], phthalates[42], and heavy metals such as lead, cadmium and mercury. Even though current legislation restricts the permitted content of those substances in specific products, it needs to be considered that plastics in

[41] PVC is made from vinyl chloride (known to be a human carcinogen), and the production and disposal of PVC can release chlorine gas, which is toxic if inhaled.

[42] Plasticisers are added to make the material flexible. Some phthalates are known to be endocrine disruptors and can have adverse effects on human health.

CDW may have been produced decades ago. Another problem is that during the production and disposal of PVC, there is a risk of dioxin formation, which is a highly toxic group of chemicals that can persist in the environment.

EPS is mainly known for its use in buildings as insulation in walls and roofs, but also as a lightweight filling material for other purposes. If used for insulation, the material has to be fire-resistant. Therefore, EPS can contain flame retardants such as hexabromocyclododecane (HBCD) or other halogenated compounds. Many BFRs are persistent and have been found to be toxic to humans and wildlife. They can potentially disrupt hormone function, impact the nervous system, and have been associated with adverse health effects, such as developmental and reproductive problems (EFSA, 2024). EPS is lightweight and bulky, making it challenging to transport and dispose of. It can be recycled, although the process is not as widespread or efficient as for other materials. Solvent-based recycling seems most promising from an economic and environmental perspective (Schleier et al., 2022).

5.3.3.6 Waste electrical and electronic equipment

Plastics represent on average 25% by weight in WEEE and consist of a complex mixture of different polymers (ABS, PP, (HI)PS, PC-ABS, PU, PA (6/66) and PVC) containing a wide range of additives (e.g. flame retardants, fillers, pigments and stabilisers). As highlighted by Haarman et al. (2020), one of the main challenges is the presence of legacy additives, substances that were added into plastics in the past but whose use has been discontinued (voluntarily or by law), due to concerns regarding human health and the environment. These additives include phthalates (DEHP, BBP, DBP and DIBP, used as plasticiser), heavy metals (such as lead and cadmium compounds, used as stabilisers) and some brominated flame retardants (octaBDE and decaBDE, used in external housings and HBCD, used in foams).

5.3.3.7 End-of-life vehicles

Modern cars can contain up to 50% by volume (EURIC, 2020) (or 12–15% by weight (Plastics Europe, 2013)) of plastic materials that can be found for example in bumpers, dashboards, interior trim, seating, and various under-the-hood parts. A car is comprised of a wide array of components, each with specific durability and performance requirements. To meet this demand, a variety of plastics, often combined with additives and reinforcements to form composite materials, are utilised. These composite materials often pose challenges for recycling, due to the difficulty in separating the components. Furthermore, certain plastic parts, such as tanks, lines and pipes, are in contact with hazardous substances, such as fuel, engine oil and brake fluid, which can also negatively affect recycling.

5.3.3.8 Waste batteries

The use of plastics for battery technologies offers a variety of advantages, such as withstanding high impact and at the same time providing low weight, corrosion resistance, electrical insulation and resistance to high temperatures and chemicals (e.g. acids, alkalis, salts).

The casing of **lead-acid batteries**, currently the most common type of battery used in combustion-engine vehicles, is predominantly made of polypropylene (PP). This polymer is often chosen for lead-acid battery casings due to its ability to safely contain the sulphuric acid electrolyte. During lead-acid battery recycling, the casing is removed from the battery cell (Li et al., 2016). The casing is then shredded and washed to recover the PP for manifold new applications (WHO, 2017).

The introduction of new battery technologies, especially in the field of electro-mobility, also brings new requirements for the plastics used in casings. **Lithium-ion batteries**, the most widespread battery chemistry for electric vehicle applications, are susceptible to thermal runaway. The plastic casing must be flame retardant to prevent the spread of fire in case of a malfunction. Standard flame retardants used in battery casings are similar to those in electrical and electronic equipment. However, these flame retardants raise concerns for health and the environment.

In newly developed battery casings fibre-reinforced (e.g. glass-fibres or carbon-fibres) polymers are used (Azzopardi et al., 2023). They support the demand for lighter, thinner and more crash-resistant battery modules and offer thin-wall moulding capability to reduce weight and accommodate more battery cells. However, the addition of such non-plastic components has in turn negative implications on recyclability.

In cable insulation and conduits, PVC is often used due to its high chemical resistance, hardness and rigidity. The environmental and health impacts of PVC were discussed in Section 5.3.3.5.

5.3.4 Impacts of marine plastic litter and microplastics

The negative impacts of marine litter and microplastics on global ecosystems and economies have been widely recognised. Plastics represent the largest and most persistent fraction of marine litter, with adverse impacts on the environment and human health. The direct effects on the marine fauna include entanglement, drowning, deprivation of oxygen and light and toxicological harm, among others. The negative effects on marine ecosystems also affect their carbon sequestration capacity and consequently the global carbon cycle.

Although most plastic polymeric materials are biochemically inert, additives may leach out into the marine environment from the polymeric matrix. The transfer rate of chemicals contained in plastics (e.g. additives and pigments) to wildlife depends on the nature and strength of the bond between the additive and the polymer and physical properties, e.g. temperature and pressure.

When plastic litter breaks down in the marine environment, microplastics are transferred to marine food chains. Microplastics are of increasing concern, as they represent a threat to the survival of certain marine organisms and can potentially expose humans to chemicals, through the ingestion of contaminated seafood. However, the exposure levels and impacts on human health are still uncertain at the moment (UNEP, 2022b).

The United Nations Environment Assembly (UNEA) has adopted four resolutions on marine plastic litter and microplastics: UNEA-1 resolution 6 (2014), UNEA-2 resolution 11 (2016), UNEA-3 resolution 7 (2017), UNEA-4 resolution 6 (2019). The issue has also been addressed in the UNEA 5.2 resolution 5/4 (UNEP, 2022a), where it is affirmed that there is an *"urgent need to strengthen global coordination, cooperation and governance to take immediate action towards the long-term elimination of plastic pollution in marine and other environments, and to avoid detriment from plastic pollution to ecosystems and the human activities dependent on them."*

In 2023 the Commission published a proposal for a Regulation on preventing plastic pellet losses to reduce microplastic pollution[43]. In the impact assessment by the Commission[44] accompanying the proposal it is recognised that most of the negative impacts are related to microplastics in general, due to a lack of research specifically assessing the impact of pellets. Besides, while impacts on the environment, climate and economy are relatively well known and documented, further research efforts are required to elucidate impacts on human health.

As a subset of microplastics, it is assumed that most of the impacts of pellets are comparable to those of microplastics. Indeed, around 80% of all plastic raw materials produced are approximately 2-5 mm in diameter, therefore well within the usual size of microplastics (up to 5mm). Of the remaining 20%, a significant portion is smaller than 2 mm, such as powders, and a minor part can

[43] Proposal for a Regulation on preventing plastic pellet losses to reduce microplastic pollution: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023PC0645

[44] COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT REPORT Combatting microplastic pollution in the European Union Accompanying the document Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on preventing plastic pellet losses to reduce microplastic pollution: https://ec.europa.eu/transparency/documents-register/detail?ref=SWD(2023)332&lang=en&lang=en

be slightly bigger. The portion with the smallest pellets can have an impact on health. The disintegration of pellets into smaller particles also increases the potential impacts.

5.4 Mapping existing end-of-waste criteria in Member States

As defined in Article 6(2) of the Waste Framework Directive, *'the Commission shall **monitor the development of national EoW criteria** in Member States and assess the need to develop Union-wide criteria on this basis. To that end, and where appropriate, the Commission shall adopt implementing acts in order to establish detailed criteria on the uniform application of the conditions laid down in Section 1.1'.*

Furthermore, '*when adopting those implementing acts, the Commission shall take account of the relevant criteria established by Member States [...] and shall take as a **starting point the most stringent and environmentally protective** of those criteria'.*

Based on these requirements, the JRC carried out a mapping exercise to identify EoW criteria for plastic waste implemented or under development by Member States (non-exhaustive overview given in **Table 11**). The exercise revealed that three Member States (Finland, Portugal and Spain) have already implemented or are developing **national EoW criteria for plastic waste**. Other countries such as Ireland, Italy and the Netherlands take a more individualised approach, adopting **case-by-case decisions** to define EoW status for specific polymers from given sources. The case-by-case decisions are usually the result of a request from an individual applicant to obtain EoW status for a specific plastic recyclate. France developed EoW criteria for **waste in general**, including plastic waste. Flanders, a region in Belgium, provides a manual to support self-assessment of EoW status.

The national EoW criteria for plastic waste were analysed in depth (see Annex 2). Case-by-case decisions are reported in **Table 11** as well but not examined in detail, as there is no obligation for Member States to notify those decisions to the Commission[45]. The national EoW criteria of Belgium and France do not specifically target plastic waste and it is hence not possible to use them as a starting point for the development of EU-wide EoW criteria for plastic waste.

Beside the detailed analysis provided in Annex 2, in Section 6.7 the JRC proposal for EU-wide EoW criteria is compared with the national EoW criteria by Portugal, Spain and Finland.

Table 11: National EoW criteria for plastic waste, case-by-case decisions on EoW status for plastic waste and other EoW criteria in EU Member States

Member State	**Scope**[46]	**Available documents**	**Status**
National EoW criteria for plastic waste			
Finland (FI)	Thermoplastic waste from selected sources (defined by waste codes)	**National government Decree** on EoW criteria for mechanically recycled plastics.	Draft Government Decree

[45] Article 6(4) of the Waste Framework Directive states: *"Where criteria have not been set at either Union or national level under paragraph 2 or 3, respectively, a Member State may decide on a case-by-case basis, or take appropriate measures to verify, that certain waste has ceased to be waste on the basis of the conditions laid down in paragraph 1 and, where necessary, reflecting the requirements laid down in points (a) to (e) of paragraph 2, and taking into account limit values for pollutants and any possible adverse environmental and human health impacts. Such case-by-case decisions are not required to be notified to the Commission in accordance with Directive (EU) 2015/1535. Member States may make information about case-by-case decisions and about the results of verification by competent authorities publicly available by electronic means."*

[46] The plastic wastes under scope in the Member States are described in detail in Annex 2 of this document.

		https://technical-regulation-information-system.ec.europa.eu/en/notification/25189/text/D/EN	(notified[47])
Portugal (PT)	All thermoplastic waste	**Portuguese Decree** (No. 245/2017 of 2nd August) https://files.dre.pt/1s/2017/08/14800/04442044448.pdf	Implemented
Spain (ES)	Thermoplastic waste from selected sources (defined by waste codes)	**Ministerial Order** (TED/646/2023 of 9 June) establishing the criteria for determining when thermoplastic waste subject to mechanical treatment and intended for the manufacture of plastic products ceases to be waste, pursuant to Law 7/2022 of 8 April on contaminated waste and soils for a circular economy. https://www.boe.es/eli/es/o/2023/06/09/ted646	Implemented
Case-by-case decisions for plastic waste			
Ireland (IE)	– Recycled LDPE pellets – PET recyclate – PE and PP recyclate pellet – Plastic flakes from plastic packaging	**Case-by-case decisions** https://www.epa.ie/our-services/licensing/waste/end-of-waste-art-28/end-of-waste-criteria-in-ireland/	Implemented
Italy (IT)	– Mixed plastics from packaging waste – Heterogeneous plastics from pulper waste	N/A	Under development
The Netherlands (NL)	PVC granulate	**Case-by-case decision** https://www.afvalcirculair.nl/publish/pages/223178/rechtsoordeel_status_einde-afval_pvc-granulaat_31_januari_2018.pdf	Implemented
Other EoW criteria at regional or national level			
Belgium (BE) (Flanders)	All waste types	**Manual to support self-assessment** of fulfilment of end-of-waste and by-product criteria. EoW status when complying with REACH/CLP and use in production processes without further treatment. https://publicaties.vlaanderen.be/view-file/56454	Publicly available
France (FR)	All waste types, with certain exceptions[48]	**Ministerial Order** (JORF n° 0052 du 02/03/2019) https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000038190409	Implemented
		National Decree (No. 2021-380 of April 1, 2021) https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000043327059	Implemented

[47] Draft Government Decree on end-of-waste status for mechanically recycled secondary plastic raw materials: https://technical-regulation-information-system.ec.europa.eu/en/notification/25189

[48] France developed EoW criteria for all types of waste with certain exceptions. Plastic waste is part of that regulation, but not explicitly mentioned.

Italy (IT)	Absorbent hygiene products (AHP)	**National decree on EoW status for AHP recycling** (Decreto 15 maggio 2019, n. 62). The regulation establishes the specific criteria under which the heterogeneous polyolefin-based plastics, superabsorbent polymer and cellulose from the recycling of AHP no longer qualify as waste. https://www.gazzettaufficiale.it/eli/id/2019/07/08/19G00071/sg	Implemented

NB: non-exhaustive list, EoW criteria for intermediate/output fractions of chemical recycling are not listed.

6 End-of-waste criteria development for plastic waste

In 2014, the JRC published a first series of technical proposals for EoW criteria for plastic waste for conversion (Villanueva & Eder, 2014). The proposals were developed based on a comprehensive techno-economic analysis of the plastic waste production chain and an assessment of the economic, environmental and legal impacts when such plastic waste leaves the waste regime.

Those proposals have been used as starting point for the development of EoW criteria presented in this document.

In the following sections the scope, system boundaries and the EoW criteria are presented and discussed in detail. The feedback and additional evidence received from stakeholders within the consultation rounds, as well as during bilateral meetings and site visits, was thoroughly examined and critically assessed and served to build the grounds for the revised proposal. The requirements laid down in national EoW criteria presented in section 5.4 and further explained in Annex 2 have been taken into account in the assessment.

6.1 Scope and system boundaries

6.1.1 Recycling processes under scope

This work was **initially** focused on **mechanical recycling**, building upon the draft proposal by Villanueva & Eder (2014). Considering suggestions on a possible extension of the scope made by some stakeholders during the kick-off meeting, the JRC decided to explore the possibility of including other plastic recycling processes, often referred to as physical or chemical recycling.

6.1.1.1 Stakeholders' feedback

— The main arguments brought forward by stakeholders **in favour of an extension of the scope** to other recycling processes were as follows:

- EoW criteria should be technology-neutral and should be focused on quality specifications for the output material; hence in principle all recycling processes should be under the scope, as long as the output materials meet all requirements on product quality.
- The restriction to mechanical recycling may hamper innovations for other recycling technologies.
- Some recycling processes can be considered equivalent to mechanical recycling, in particular those processes not altering the molecular structure of the polymers throughout the treatment (e.g. physical recycling).
- Although some chemical recycling processes are more energy-intensive than mechanical recycling processes, life cycle benefits for certain environmental impact categories may be greater.
- Certain chemical recycling processes are able to convert plastic waste into monomers, substances or oligomers with a quality comparable to virgin materials. Compared to mechanical recycling, some of these processes are capable of treating a broader spectrum of plastic polymers and of removing contaminants to a greater extent. Hence the inclusion of chemical recycling would allow the treatment of additional volumes, possibly increasing the overall plastic recycling rate in the EU.

— The main arguments brought forward by stakeholders **against an extension of the scope** to other recycling processes were as follows:

- Many chemical recycling processes produce a complex mixture of intermediates and output materials, with different downstream applications. As the JRC draft proposal

focuses on *polymer-to-polymer* recycling, it would need significant revision and expansion to various sets of sub-criteria in order to properly address all recycling technologies on the market.

- Many chemical recycling technologies are still under development with a limited number of commercial-scale plants in operation at the time of this study and very limited total output material volumes.
- The designation 'recycling' technology may only be partially true for some of the current plastic waste treatment processes. For several of those technologies, substantial direct conversion to energy or indirect conversion to fuels takes place during the recycling operation and/or downstream processes and only part of the input material is actually recycled into new materials or substances.
- Despite the claims on the ability of chemical recycling to treat plastic waste of lower quality, there is not enough proof of the removal of substances of concern or other harmful substances. Moreover, several chemical recycling processes are known to require high-quality input materials or proper pre-treatment of the incoming plastic waste.
- With the point of EoW after repolymerisation, the introduction of a broad scope for EoW criteria covering all recycling technologies could create ambiguity in the market, as intermediates could still be considered waste (e.g. pyrolysis oil). For instance, refineries and chemical facilities that currently use intermediates from chemical recycling as feedstock to produce plastics or other chemicals, e.g. while working under national EoW criteria for such intermediates, could see their input materials becoming classified as waste, resulting in the need for a waste permit or a licence to handle waste.

6.1.1.2 JRC assessment of feedback

In **national EoW criteria** for plastic waste developed by Member States (Spain, Portugal and Finland; see Annex 2) the scope is limited to mechanical recycling only. The JRC recognises the importance of adopting an approach that is as neutral as reasonably possible towards applied technologies, to consider all current operating recycling processes but also to allow innovative processes to enter the market and to increase the overall plastic recycling rate. Despite deviating from the scope delineated in national EoW criteria, the JRC is in favour of including in the scope *polymer-to-polymer* recycling technologies that do not deliberately alter the molecular structure of the polymer, including mechanical recycling and those physical recycling processes that meet this condition (e.g. dissolution).

In contrast, chemical recycling processes (e.g. pyrolysis, gasification, depolymerisation - see **Figure 9**) change the chemical structure of the polymer to produce substances that can be used as raw materials for the production of plastic products and other chemicals as well as for the production of fuels (Hann et al., 2022).

In order to produce plastics, intermediates of pyrolysis and gasification processes (i.e. pyrolysis oil and syngas, respectively) need to be reconverted into monomers through steam cracking. This process is typically carried out by chemical companies, whereby intermediates of chemical recycling are mixed with virgin raw materials (e.g. naphtha) (Hann et al., 2022). The JRC understands that an explicit inclusion within the scope of recycling technologies based on pyrolysis and gasification might not be desirable for many stakeholders. As outlined above, the reason is that such an inclusion in the scope would result in the intermediate outputs potentially being considered waste materials and the further processing of these intermediate outputs by chemical companies being considered a waste management operation. This might even be the case where EoW criteria already

exist for such materials in certain Member States[49] and lead to legal uncertainty for the chemical value chain. Such disruptions are not desired and could potentially impede technological progress in the field of chemical recycling.

Besides, it is to be noted that only a fraction of pyrolysis oil/syngas is converted to monomers, the rest is coverted to fuels. It is not possible to physically trace the exact amount of plastic waste used as feedstock in the pyrolysis/gasification recycling process that is reconverted to monomers (Hann et al., 2022). In line with the waste hierarchy, where recycling ranks higher than energy recovery, priority in developing EoW criteria should also be given to processes and technologies that convert a maximum of input material back into output materials other than fuels or precursors to fuels.

When looking at chemical depolymerisation, the output of the recycling process consists of monomers. The conversion to polymers is typically carried out by polymer producers, whereby recycled monomers are mixed with virgin monomers (Hann et al., 2022). Considering that the point of EoW is at polymer level (see Section 6.1.3), a similar issue arises, namely that polymer production from recycled monomers could be considered a waste management operation.

Another point that needs to be taken into account is that chemical recycling processes and value chains have different technology readiness levels. Notwithstanding the potential for chemical recycling to become complementary to mechanical recycling, the economic viability of various technologies remains uncertain at this stage. Rushing into the development of EoW criteria within the current rapidly evolving landscape of chemical recycling technologies could mean that some sets of criteria quickly become obsolete, while new processes around the corner may not even be covered.

Since recycling processes falling under the category of chemical recycling greatly differ from mechanical and physical recycling and also bearing in mind that output materials of chemical recycling are very diverse, it would not be possible to come up with a single set of EoW criteria within the current proposal. A thorough assessment of all the existing processes and value chains would be needed to draft specific requirements for each single process. This would require additional data collection rounds, specifically to obtain data on removal of contaminants and hazardous properties. It is clear that such an undertaking would hamper a possible swift legal implementation of EoW criteria for plastic waste.

For all of the above reasons, the JRC favours a clearly delineated scope for the current study so that all processes that are *not covered* by this scope are equally *not affected* by the proposed EoW requirements applicable to output materials of the recycling operation.

6.1.1.3 JRC proposal

The current proposal consists of **one single set of EoW criteria** that should be applicable to all recycling processes under the scope.

The JRC proposes to limit the scope to **recycling processes that are able to treat plastic waste without deliberately altering the molecular structure of the polymers**[50], with the exception of damage that is repaired within the process[51].

It should be noted that these limitations do not pre-empt any conclusion on a possible future scope extension or separate study on EoW criteria for materials recovered from plastic waste through other recycling or recovery operations (e.g. chemical recycling of plastic waste).

---

[49] NL implemented a case-by-case decision on EoW criteria for TACOIL: https://www.afvalcirculair.nl/publish/pages/223178/rechtsoordeel-einde-afval-tacoil-als-grondstof-voor-kunststofproductie-22-april-2020.pdf

[50] Including mechanical recycling and physical recycling using solvent, among others.

[51] For example through solid-state polycondensation (SSP).

6.1.2 Polymers under scope

As mentioned in Section 1.2, the scoping study carried out by the JRC in 2022 (Orveillon et al., 2022) appraised the potential for EoW or by-product criteria for different streams. Based on the outcome of the scoping study, the current work was initially focused on **PET**, **LDPE/HDPE**, **PP**, **PS**, **EPS** and **mixed plastic grades**, which were ranked as priority streams within the category of plastic waste. The scoping study also included and analysed the potential for EoW criteria for other polymers (PVC, ABS, PU, PC, and 'other plastics'). Those were ranked as non-priority streams and were initially not included in the scope of EoW criteria. In the course of the project, the JRC evaluated the possibility of extending the scope to other polymer grades.

6.1.2.1 Stakeholders' feedback

The comments received from stakeholders on the polymers under the scope are summarised below:

— The majority of stakeholders agreed that the selected polymers are the most market-relevant. It was requested to clarify the term 'mixed plastic'.

— Some stakeholders suggested expanding the scope to additional polymers such as PVC and other non-halogenated polymers such as ABS, POM, PA, PC and PMMA. The main argument was that these polymers are already recycled and have a market, fulfilling the condition for EoW criteria laid down in Article 6(1)(b) of the Waste Framework Directive.

— Other stakeholders argued that an expansion of the scope to other polymers could risk the failure of the objective of fostering a non-toxic environment. For instance, polymers originating from construction and demolition waste (e.g. PVC) can contain hazardous substances, such as lead, mercury and flame retardants. Other polymers recovered from WEEE and ELVs are also considered potentially problematic.

— Some stakeholders argued that recycling technologies, such as chemical recycling, are able to treat a wider range of polymers, and therefore all types of polymers including thermoplastic and thermoset polymers, and even rubber, should be under the scope.

6.1.2.2 JRC assessment of feedback

By focusing exclusively on the priority polymers from the scoping study at the initial stage of the project, only around two thirds of the polymers that are currently used by plastic converters in the EU would be covered.

With this limitation, certain polymer grades recovered from WEEE, ELVs and CDW would be excluded. Full-scale plastic recycling facilities in the EU already recover polymer types like PVC, HIPS, ABS, PMMA or PC from WEEE, ELVs and CDW.

EU legislation calls for targeted depollution of WEEE (Annex VII to Directive 2012/19/EU) and ELVs (Annex I (3) to Directive 2000/53/EC), as explained in Section 4.2. This limits the contamination of the plastic fraction for subsequent recycling received from these specific waste streams. The ELV Directive requires the separate removal of certain plastic parts from ELVs (large plastic components such as bumpers, dashboards, fluid containers) before shredding, to promote recycling. This is an additional measure to keep plastic waste fractions as clean as possible.

Besides, current mechanical recycling processes are already capable of removing hazardous substances and/or POPs, e.g. with float-sink techniques in fluids with different density (Bill et al., 2019), to an extent that the recycled plastics can be used for the original purpose (e.g. recovered polymers from WEEE plastic waste to be used in new electronic devices). This was also illustrated during site visits performed by the JRC in the course of the project. However, it must be clarified that the options for removal of substances of concern through mechanical recycling are limited.

As mentioned by stakeholders, new recycling technologies (e.g. dissolution/physical and chemical recycling) are evolving and entering the market with the potential to remove substances that are

bound to the polymer matrix. Chemical recycling approaches have the potential to effectively treat thermoset polymers and rubber. However, since the proposed scope of recycling processes is clearly delineated (see paragraph 6.1.1), the polymers under the scope should be those that can be treated in recycling processes not altering the polymer structure, namely thermoplastic polymers.

As explained in Annex 2, the **national EoW criteria** in Spain and Portugal cover all thermoplastics waste, in line with the JRC approach. Finland does not explicitly define the scope of polymers, but does specify that the scope of recycling technologies is limited to mechanical recycling. Considering that mechanical recycling of plastic waste is technically feasible only for thermoplastics, one can deduce that in the Finnish EoW criteria the scope is also limited to thermoplastics.

6.1.2.3 JRC proposal

The JRC proposes that **all thermoplastic polymer waste** shall be eligible to reach EoW status, regardless of the polymer type and source.

As regards mixed polymers, with the extension to all thermoplastic polymers, all **blends of thermoplastic polymer waste** (e.g. polyolefin mix (PE/PP) or PC/ABS mix) shall also be eligible to reach EoW status.

6.1.3 Point of end-of-waste and system boundaries

Stakeholders were asked to provide suggestions for a possible point in the waste management chain where plastic waste can cease to be waste: at the sorting output (e.g. bale), at the recycling output (e.g. flake, pellet), or at the converter output (e.g. final new plastic product).

In a preliminary proposal subject to consultation, the JRC proposed that '*End-of-waste status can only be granted to plastics, i.e. synthesized polymers with or without additives, at the point at which the output plastic is ready for re-melting and direct use in the production of plastics products or objects made of plastics'.*

6.1.3.1 Stakeholders' feedback

Comments received from stakeholders on the point of end-of-waste are summarised below:

— **Point of EoW**:

- In the case of mechanical and physical recycling, the majority of stakeholders would be in favour of granting EoW status to the output materials of the recycling operation (i.e. plastic recyclate).
- Few stakeholders suggested that EoW status could be granted at the input of a plastic converter instead (stricter approach).
- A relatively large number of stakeholders highlighted that applying the same approach for mechanical/physical and chemical recycling would overlook the differences in technologies and output materials, ultimately creating disincentives for chemical recycling. Besides, granting EoW status at the recycling output in the form of a polymer would require repolymerisation of any intermediates, such as monomers, pyrolysis oil, or syngas. Therefore, if chemical recycling were to be included in the scope it would be necessary to propose a different point of EoW.

— **Physical specification**:

- It was highlighted by several stakeholders that the point of EoW should not be related to a specific physical form of the output material. In some cases, EoW criteria could already be met at flake level, as extrusion to pellets is not always required. Therefore, EoW status can be achieved as soon as the output material complies with all requirements laid down in the EoW criteria, regardless of the shape. That could be at

the level of flakes or granulates, after extrusion to pellets, after micronising, or after agglomeration.

- Some stakeholders mentioned that lumps should not be an eligible output material to reach EoW, as this output is very unspecific and needs further treatment before it can be used in the production of new plastic products.
- One stakeholder suggested that the EoW status could be granted to output materials of a given size (in mm).

— **Direct use**: Stakeholders argued that, depending on intended use, the output material from a plastic recycling plant can undergo different processes, including preparation for food contact, re-compounding (e.g. mixing with other plastics or elastomers, additives or pigments), mixing with virgin polymers or remelting before a new plastic product is produced.

6.1.3.2 JRC assessment of feedback

Point of EoW

Considering the limitation of the proposed scope to recycling processes not altering the polymer structure, as outlined in Section 6.1.1, it seems appropriate to set the EoW point at the end of the recycling operation, once the output material complies with the EoW criteria. This is in line with **national EoW criteria** (see Annex 2).

Physical specification

Considering that all thermoplastic polymers from any source are under the scope and bearing in mind that recycling processes are very different, the JRC advises not to prescribe a specific physical form for the output material. The size is not decisive, the output material must meet the specification defined by the customer. This is in line with **national EoW criteria** (see Annex 2).

Direct use

The JRC recognises that it is standard industrial practice to pre-treat recycled plastic before remelting for conversion to new plastic products. As described in Section 4.2.4, pre-treatment steps include for example preparation for food contact (which can also be part of the recycling process), compounding with additives such as fillers, plasticisers or pigments, as well as mixing with other recycled or virgin polymers.

The JRC proposal is in line with **national EoW criteria**, which also state that the output materials can only be used for the production of new plastic products or articles containing plastic parts. Finland established a list of plastic products for which recycled plastics can be used. The JRC would refrain from limiting the use of recycled plastics to pre-defined plastic products, as plastic applications are very diverse. Limitations could be a hindrance to the circular economy.

6.1.3.3 JRC proposal

End-of-waste status is granted at the moment at which the **output material of the recycling operation is a polymer or plastic that is ready for use in the production of new plastic products or articles containing plastic parts and complies with the full set of EoW criteria**. The EoW point is not linked to a specific physical shape.

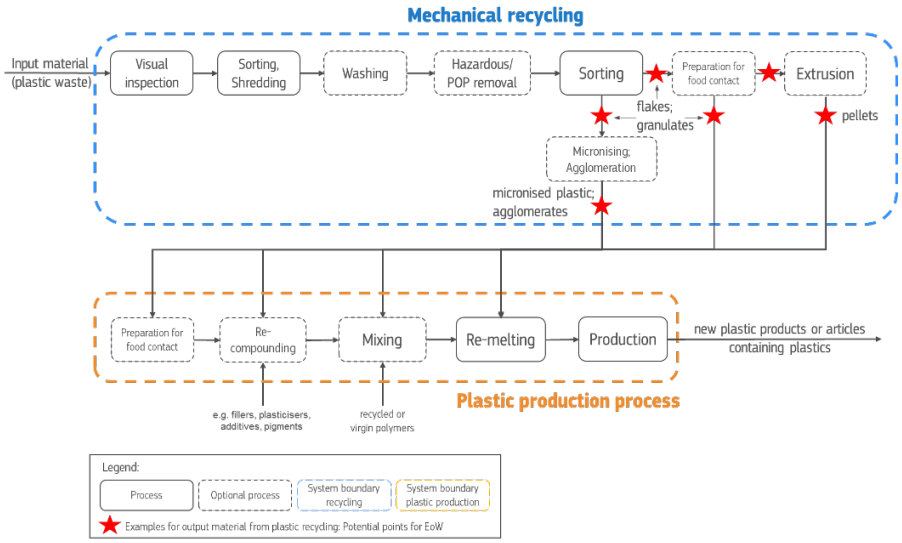
It is to be highlighted that the production of plastic articles is outside the system boundaries of this proposal. Therefore the assessment of compliance with EoW is to be carried out at the output of the recycling operation at the stage when the candidate EoW material becomes a product that is a **substance or a mixture** upon ceasing to be waste.

It is pointed out that if the plastic material that has ceased to be waste is discarded or is used for any other purpose than for the production of new plastic products or articles containing plastic

parts, such as for energy recovery, as input material for chemicals or fuels production (e.g. via chemical recycling), or for backfilling operations, the user of the plastic material will have to handle it as waste.

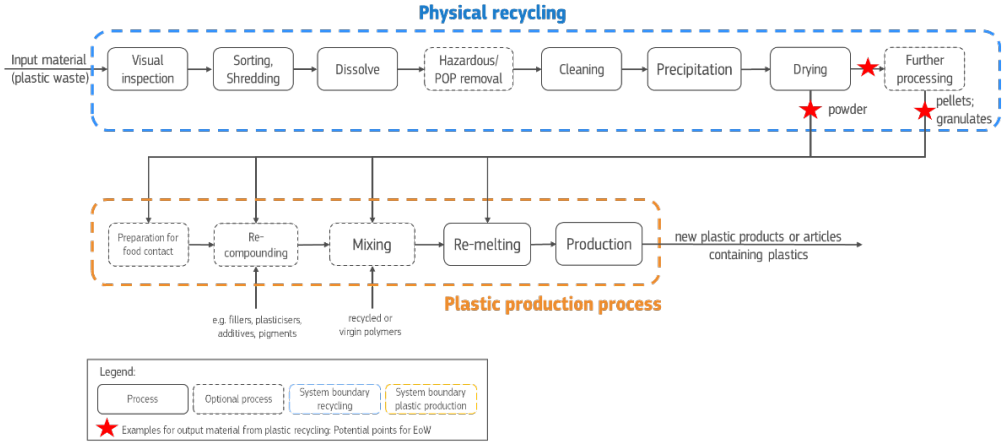
Figure 21 and **Figure 22** present the system boundaries for exemplary recycling processes (mechanical recycling and physical recycling processes, respectively).

Figure 21: Exemplary scheme for mechanical recycling of plastic waste



NB: potential points for EoW (represented by red stars) and subsequent processes for the production of new plastic products or articles (blue: system boundary mechanical recycling; orange: system boundary for plastic production)

Figure 22: Exemplary scheme for physical recycling of plastic waste



NB: potential points for EoW (represented by red stars) and subsequent processes for the production of new plastic products or articles (blue: system boundary physical recycling; orange: system boundary for plastic production)

6.2 Requirements on input materials

The purpose of this category of criteria is to set specific limitations for input materials that could compromise the recycling operation and, as a consequence, the quality of the output product. The rationale behind this is that sometimes it is more straightforward to limit certain input materials, rather than having to introduce extensive and expensive testing of the output materials. Two main approaches have been identified by Villanueva & Eder (2014): the first one is a negative list, limiting input materials or sources that could result in environmental or human health impacts if not

treated properly; the other option is to set a positive list, listing all input materials that are potentially allowed as feedstock.

Villanueva & Eder (2014) proposed to prescribe restrictions on input materials (negative list) and additional requirements for problematic waste streams (e.g. waste containing hazardous substances). By imposing restrictions or strict requirements on waste streams containing harmful substances, it is possible to set more lenient testing requirements on the output materials.

6.2.1 Criterion 1.1: Hazardous waste and waste containing hazardous substances or other restricted substances

Villanueva & Eder (2014) proposed to allow the use of hazardous waste as feedstock, on the condition that the process is able to remove hazardous properties, as specified in the product quality requirements. No restrictions on POPs-containing waste were included in the 2014 proposals.

6.2.1.1 Stakeholders' feedback

The main comments received from stakeholders can be summarised as follows:

— **Hazardous waste and plastic waste containing hazardous substances or other substances restricted under REACH**:

- It was requested to clarify the term 'hazardous', as the formulation used in the first draft proposal was ambiguous (classification of hazardous waste versus classification of materials with hazardous substances).
- It was suggested to make a clear distinction between i) plastic waste that contains legacy hazardous substances that are no longer allowed in new products and ii) plastic waste that contains hazardous substances that are allowed.
- Regarding possible restrictions of input materials, stakeholders had different views:
    - The majority was in favour of a lenient approach, allowing the use of hazardous waste and plastic waste containing hazardous substances as input, as long as output materials comply with the relevant product legislation.
    - Some were in favour of a more restrictive approach, allowing the use of a contaminated plastic waste stream either after a pre-treatment step (e.g. washing, decontamination) or on the condition that proof of elimination of hazardous substances is provided.
    - A few were in favour of a stricter approach, to reduce the need for mandatory testing on the output materials. For this approach, the two alternatives proposed were: i) to allow only plastic waste streams which do not contain hazardous additives and contaminants (demonstrated by testing); and ii) to request testing on the input materials and allow only plastic waste streams which are not classified as hazardous according to the CLP Regulation, not containing substances restricted under the REACH Regulation or POPs above the limit values set in Annex I to the POP Regulation (JRC note: these restrictions are actually applicable to products, not to waste).
- Stakeholders suggested to complement this criterion by making reference to the compliance of the recycling output with the REACH Regulation, including requirements on recycled products.

— **Plastic waste containing substances restricted under the POP Regulation**:

- Stakeholders proposed to make explicit reference to plastic waste containing POPs and the related limit values defined in the POP Regulation.

- Stakeholders had different opinions on the inclusion of additional requirements for POPs-containing waste:
    - Some proposed a less restrictive approach, allowing the use of POPs-containing plastic waste, as long as the process is able to remove POPs to the extent that output materials present values below the thresholds established in Annex I to the POP Regulation.
    - Others proposed a stricter approach, not allowing the use of POPs-containing waste at all. The main argument was that mechanical recycling is not able or only partly able to remove POPs and other harmful substances.

— **Self-monitoring requirements**: Criticism was raised on the fact that the proposed self-monitoring requirements did not provide clear guidelines on how to detect and monitor the presence of hazardous substances or other substances restricted under REACH or POP. It was proposed to include clear guidelines on labelling or tracing mechanisms to detect those substances. Suggested approaches were: i) to prescribe analyses on the input materials; ii) to request proper documentation on the origin of the waste that can indicate the possibility of contamination; and iii) to include requirements for traceability (following for example EN 15343) or characterisation of inputs (following for example EN 15347).

6.2.1.2 JRC assessment of feedback

Hazardous waste and plastic waste containing hazardous substances or other restricted substances

The JRC addressed comments related to the unclear definition of hazards by clarifying that the classification of waste as hazardous or non-hazardous is regulated by Annex III to the Waste Framework Directive 2008/98/EC, and the classification laid down in the Annex to Commission Decision (EC) No 2000/532 on the List of Waste. The Commission Notice 2018/C 124/01 on the classification of waste provides technical guidance on the correct interpretation of the provisions on waste classification (see also Section 5.2.2.1).

Some criteria of Annex III to the Waste Framework Directive make direct reference to CLP hazard classes and statements. However, the CLP Regulation and the relevant provisions on hazardousness classification are only applicable to substances and mixtures, i.e. to output materials of the recycling operation, not to plastic waste used as input. Analogously, the provisions of the REACH Regulation apply to substances in products, not to waste streams (see Section 5.2.2.2). Hence the suggestion made by some stakeholders to restrict the use of input materials containing substances triggering hazardousness classification under CLP or restricted under REACH or POP does not have a legal basis.

A restriction to non-hazardous plastic waste would exclude plastic waste originating from different sources (e.g. WEEE, ELVs, CDW), already being recycled today.

The other approach proposed by some stakeholders of requesting a pre-treatment step for those streams, as a pre-condition to using them as input materials, would require imposing testing on input materials, which seems too onerous.

In **national EoW criteria** (Spain and Portugal) hazardous waste is allowed as input on the condition that the process is capable of removing hazardous substances. Finland adopted a strict approach by listing only non-hazardous waste as allowed input (positive list of waste codes based on the EU List of Waste). In addition, Finland specifies that plastic waste that meets one or more of the definitions and criteria for hazardous classification is not allowed as input, with the exception of plastic waste separately collected from households.

In line with EoW criteria from Spain and Portugal and with the suggestions made by some stakeholders (in favour of a more lenient approach), the JRC proposes to allow hazardous waste

and plastic waste containing hazardous substances or other restricted substances as feedstock, as long as the process is able to produce an output plastic that is not classified as hazardous under the CLP Regulation (as per Article 3 and Annex I of CLP). Plastic waste containing substances restricted under the REACH Regulation can be used as feedstock, as long as the recovered substances (on their own or in mixtures) comply with REACH, including with the provisions laid down in Article 56 on authorisation for use of substances listed in in Annex XIV and the ones laid down in Article 67 on the manufacture, placing on the market and use of substances restricted in Annex XVII.

Plastic waste containing POPs

When looking at **national EoW criteria**, Spain adopted a restriction for plastic waste containing POPs above the limit values defined in Annex IV to the POP Regulation. Portugal does not explicitly mention POPs-containing plastic waste. Finland indirectly restricts POPs waste by not including sources of plastic waste that typically contain POPs in the positive list of materials allowed as input.

Recycling of plastic waste containing POPs is technically viable at present for specific sources of plastic waste (e.g. WEEE containing brominated flame retardants). There are guidelines to safely recover plastics from WEEE while ensuring compliance with the POP Regulation (Bill et al., 2019).

According to the findings by Souder et al. (2024), Europe generates 2.5 Mt of WEEE plastics per year. Only around 0.4 Mt/year reach WEEE plastic recycling companies in the EU; the rest is disposed of via incineration or landfilling or exported to third countries (BSEF, 2023; Souder et al., 2024). Considering that there are over 40 WEEE plastics recycling facilities across Europe, with an overall combined capacity of 0.8 Mt/year, as estimated by BSEF (2023), the JRC is in favour of promoting the recycling of WEEE plastics, to divert these materials from incineration and landfills.

Other sources of plastic waste containing different types of POPs are ELVs and CDW, among others (Vencovsky et al., 2021). Those streams represent a relatively big share of plastic waste: in the EU 2.2 Mt of ELV plastic waste and 9.2 Mt of CDW plastic waste are generated annually. Around 0.22 Mt of ELV plastics and 0.77 Mt of CDW plastics (see also Sections 4.3 and 4.4) are recycled in the EU each year (Souder et al., 2024).

Casings of battery modules and packs are typically made of plastics and are also likely to contain flame retardants (see Section 5.3.3.8). The volumes of plastics originating from waste batteries are expected to grow in the future due to the increase in electric mobility and energy storage.

In order to increase the collection and recycling rates of those waste streams, the JRC suggests to deviate from the stringent approach of Spain, by allowing the use of plastic waste containing POP concentrations above the limit values established in Annex IV to the POP Regulation, but only on the condition that the recycling process is able to lower POP concentrations in a pre-treatment step, to meet the thresholds in Annex IV (applicable to waste), and to subsequently treat the pre-treated fraction, to the extent that the recovered substances (on their own or in mixtures) meet the provisions on manufacturing, placing on the market and use of POPs laid down in Article 3 and Annex I of the POP Regulation.

These requirements should guarantee an adequate level of protection of human health and the environment (relevant provisions of the POP Regulation are described in Section 5.2.2.3).

Self-monitoring requirements

Self-monitoring requirements were adapted accordingly, mentioning the presence of hazardous substances or other restricted substances in plastics from waste electric and electronic equipment (WEEE), construction and demolition waste (CDW), end-of-life vehicles (ELVs) as well as batteries.

Despite acknowledging the lack of clear guidelines in relation to detection of hazardous substances or other substances restricted in the chemicals legislation, the proposed approaches on prescribing traceability or testing requirements on the input materials have been ruled out, as they would require possibly disproportional administrative or financial efforts for the operators of the

treatment facilities. It is proposed that operators have to apply appropriate control measures for the detection of waste containing substances restricted under the REACH and POP Regulations in the materials to be used as input. It is also proposed that the operator shall apply appropriate control measures for the detection of hazardous waste and waste containing hazardous substances. Those measures shall be duly documented in the quality management system.

6.2.1.3 JRC proposal

The proposal on restrictions applicable to hazardous waste and waste containing hazardous substances or other substances restricted in the chemicals legislation is presented in **Table 12**.

Table 12: Requirements on input materials – Criterion 1.1

No.	Proposed EoW criteria on input materials	Self-monitoring requirements
1.1	Hazardous plastic waste and plastic waste containing hazardous substances shall not be used as input, unless it can be treated to the extent that the output plastic[52] resulting from the recycling operation is not classified as hazardous pursuant to Article 3 of and Annex I to Regulation (EC) No 1272/2008 (CLP). Plastic waste containing substances restricted under Regulation (EC) No 1907/2006 (REACH) shall not be used as input, unless it can be treated to the extent that substances on their own or in mixtures, resulting from the recycling operation comply with that Regulation, including but not limited to compliance with Article 56 setting out authorisation provisions for uses of substances listed in Annex XIV to REACH and for their placing on the market as well as the conditions laid down in Article 67 for the manufacture, placing on the market and use of substances restricted in Annex XVII[53] to REACH. Plastic waste containing POP concentrations above the limit values pursuant to Annex IV to Regulation (EU) No 2019/1021[54] on persistent organic pollutants (POP) shall not be used as input, unless: (a) a (pre-)treatment step is in place that is able to generate an input fraction for the recycling operation with POP concentrations below the limit values defined in Annex IV to that Regulation; and	Acceptance control by visual inspection of all plastic waste received and of the accompanying documentation shall be carried out by qualified staff. In particular, the operator shall request documentation on the origin of the material. The operator of the treatment facility shall apply appropriate control measures to detect hazardous waste and waste containing hazardous substances or other substances restricted under the REACH and POP Regulations. The control measures shall be documented under the quality management system. Particular attention shall be paid to plastic material input originating from waste electric and electronic equipment (WEEE), end-of-life vehicles (ELVs), construction and demolition waste (CDW) as well as waste batteries, which are more likely to contain those substances. For plastic waste containing POPs, the (pre-)treatment steps to separate the POPs content shall be documented under the quality management system.

[52] The output of a recovery operation can result: i) in a substance on its own, ii) in a mixture (e.g. plastics, rubber) or, iii) potentially, in an article recovered directly from waste, as referred to in the Guidance on Waste and Recovered Substances (ECHA, 2010). It is to be noted that the CLP Regulation does not cover the hazard classification of articles (except for explosive and pyrotechnic articles). Nonetheless, the system boundaries of the present technical proposals for the EoW criteria exclude the point at which articles are formed (see section 6.1.3). In line with this, the reference to hazardousness should apply to the classification of the material as a mixture, if the operator considers the output to be a mixture, or otherwise, as a substance (including a UVCB substance). As indicated in the referred guidance, it is up to the relevant operator to decide which of the two options best fits the characteristics of the material.

[53] Including the latest amendment of Annex XVII (Regulation (EU) No 2023/923).

[54] Including the last amendment of Annexes IV and V (Regulation (EU) 2022/2400).

	(b) the applied treatment processes and techniques are able to treat this input fraction, to the extent that substances on their own or in mixtures, resulting from the recycling operation meet the provisions limiting the manufacturing, placing on the market and use of persistent organic pollutants (POPs) pursuant to Article 3 of and Annex I to Regulation (EU) No 2019/1021.	

6.2.2 Criterion 1.2: Restrictions on feedstock

The list of restricted feedstock proposed by Villanueva & Eder (2014) included bio-waste, healthcare waste and used personal hygiene products.

6.2.2.1 Stakeholders' feedback

The comments on these restrictions received from stakeholders can be summarised as follows:

- **Sources of plastic waste**: Certain stakeholders suggested, on the one hand, that only separately collected post-consumer plastic waste should be allowed as input. Others indicated, on the other hand, that cascades of sorting can achieve high-polymeric-content fractions, even from mixed municipal solid waste. Hence, the latter argued that the limitations should not be too strict, to allow innovation and on-going developments to enter the market. The majority of stakeholders were in favour of not limiting any source of plastic waste used as input. Limiting input materials is necessary only if the use of a given material as feedstock could compromise the recycling process and potentially the final use.
- **Bio-waste**: Some stakeholders commented that there are safe cleaning techniques to separate bio-waste in contact with plastic waste. Limiting this waste stream does not seem relevant in their opinion.
- **Healthcare waste**: Some stakeholders suggested that it could be meaningful to allow exemptions for waste fractions originating from healthcare waste that were not in direct contact with infectious substances or contaminants (e.g. packaging). Other stakeholders argued that it is challenging to trace the presence of infectious substances, being in favour of limiting the whole stream instead. It was also highlighted that chemical recycling is able to treat infectious healthcare waste, after appropriate decontamination or sterilisation processes. It was requested to clarify the term 'hazardous' in relation to this category (i.e. which characteristics make healthcare waste hazardous).
- **Used products of personal hygiene**: Stakeholders requested to specify which streams fall under the category of personal hygiene products. They argued that the exclusion of this waste stream could hamper technological innovation in recycling of absorbent hygiene products (AHP), already under development in the EU. A few stakeholders proposed to allow the use of this stream as input, as long as the process is able to remove contaminants. Italy implemented EoW criteria for AHP waste[55] and other Member States revealed they are planning to develop EoW criteria for used personal hygiene products or AHP waste. It was proposed to set specific criteria for AHP (e.g. no contamination with blood, sterilisation process mandatory, testing of the output materials), to allow this material as input.

[55] Decreto 15 maggio 2019, n. 62: https://www.gazzettaufficiale.it/eli/id/2019/07/08/19G00071/sq

— **Additional restrictions**:

- Some stakeholders proposed to specify the limitation to thermoplastics in the input materials requirements, while others were against, arguing that mixed plastic waste can contain thermosets, which can be sorted and removed.
- Some stakeholders proposed to include specific polymers in the negative list, namely PVC and PTFE, which are not listed under B3011[56] in Annex IX to the Basel Convention, indicating possible hazardousness.

— **Self-monitoring requirements**: Stakeholders remarked that visual inspection is not the best evaluation method to detect hazardous waste or waste containing hazardous substances. Laboratory tests might be necessary, which, however, are costly. A solution could be to require documentation on the origin of the input materials, which can indicate possible contamination.

— **Others**: It was argued that it is not feasible to apply one single set of requirements on input materials to all recycling technologies. The main argument was that chemical recycling is also able to treat low-quality or contaminated materials, hence requirements on input materials could be less strict for chemical recycling.

6.2.2.2 JRC assessment of feedback

Sources of plastic waste

The feedback received on some of the criteria proposed revealed that the system boundaries of the EoW criteria were not fully clear to stakeholders. These have already been clarified in Section 6.1.3. Notably, it is not trivial to identify the starting point of the recycling operation, i.e. at which point waste can be considered an input material.

To date there are no regulations or standards that define a minimum content of plastic to classify a plastic product as such (product category). Certain waste streams, such as WEEE, ELVs, CDW and batteries can contain low concentration of plastics, making them unsuitable as direct feedstock for plastic recycling (see Section 5.3.3). However, with the application of pre-sorting techniques and pre-treatment steps, it becomes feasible to generate plastic fractions that can subsequently be processed by a plastic recycler, even from mixed municipal solid waste.

The same is valid for some streams of packaging waste with a lower content of plastics, like in the case of composite materials such as beverage cartons, where plastic is not the predominant material (it accounts for approximately 20% by weight (ACE, 2024)) or in the case of textile waste, such as clothing made of blended fibres (e.g. poly-cotton).

Composites are usually made of a combination of plastics and non-plastics materials. The plastics may be bound to other materials to create multi-material packaging such as metal (e.g. metallised wrappers and sachets) or paper-based materials (e.g. in beverage cartons). Composite materials typically have properties superior to each of the individual materials. Another way to produce composites is to integrate plastics and non-plastics materials into a new material, such as plastics filled with glass-fibres which have superior physical mechanical properties or wood-plastics composites that look like wood but do not require the same maintenance efforts as wood.

In the case of beverage cartons, the targeted fractions to be recovered are the fibres for the production of fibre-based products. Non-targeted materials in the pulping process, such as plastics, can be recovered in a separate process to obtain different plastic grades such as LDPE, HDPE, PP or other materials such as PolyAl[57] (Plastigram, 2024).

---

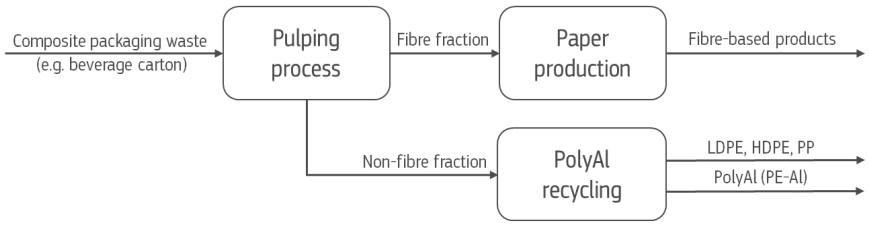
[56] List B3011 of the Basel Convention: Non-hazardous plastic waste destined for recycling.

[57] PolyAl contains LDPE with a high content of aluminium (e.g. 18%) and traces of other plastics such as LLDPE, HDPE, PP (Plastigram, 2024).

The JRC would like to clarify that the **eligible input material** for the recycling operation within the boundaries of the current work (i.e. recycling processes not altering the molecular structure of the polymer) is **plastic waste, not its precursors**.

In the case of beverage cartons (illustrated in **Figure 23**), the part of the process falling under the boundaries of EoW criteria is only the one recovering the plastic fractions (i.e. LDPE, HDPE and PP in the illustrated example). Those fractions are eligible for EoW, whereas the PolyAl fraction is out of the scope.

Figure 23: Exemplary scheme for the recovery of plastics from composite packaging waste (e.g. beverage cartons)



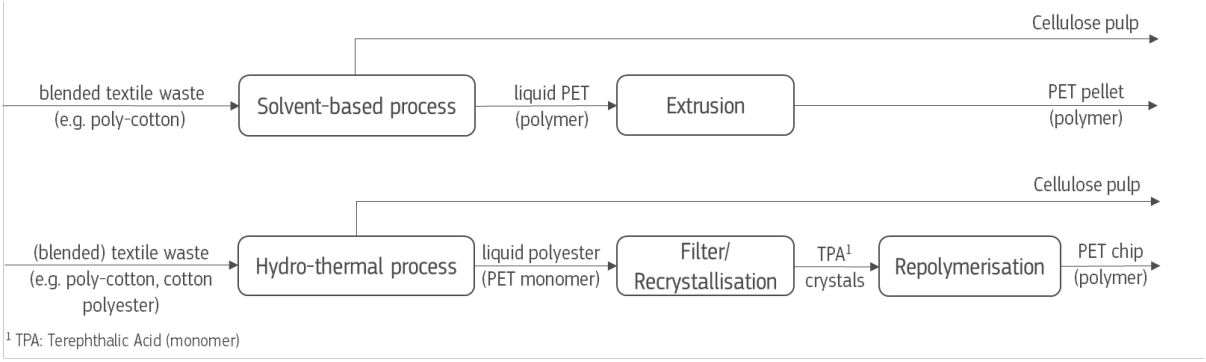
Source: Based on ACE (2024) and Veolia (2018)

Textile waste can consist fully or partly of synthetic polymer fibres such as polyester (PES), nylon, polyamide (PA), acrylic (PAC), polypropylene (PP), or elastane (EL). Textile blends made of natural and synthetic fibres, such as poly-cotton, can have a polymer content between 10% and 65%. With about 50% of textiles made of blends on a global scale, the polymer recycling potential is high. Certain technologies (e.g. solvent-based or hydro-thermal recycling, see **Figure 24**) are capable of recovering polymers from textile waste made of poly-cotton. In the solvent-based process, the polymer chains remain unaltered and PET pellets can be recovered after an extrusion of the intermediate liquid PET. Other technologies, such as the hydro-thermal process, transform the input polymer first into a monomer which is then re-polymerised (Stubbe et al., 2024; Wu et al., 2023).

Only technologies not altering the molecular structure of the polymer are under the scope in the current proposals, thus the solvent-based process for the recovery of PET from poly-cotton textile waste falls within the boundaries of this work. The hydro-thermal process does alter the polymer and is therefore not covered[58].

[58] NOTE: In parallel to the proposals for EoW criteria for plastic waste presented in this document, the JRC is working on EoW criteria for textile waste. The scope and system boundaries of textile waste recycling are still under development.

Figure 24: Exemplary scheme for the recovery of polymers and intermediates from textile waste made of blended fibres (e.g. poly-cotton)



Source: Based on Stubbe et al. (2024) and Wu et al. (2023)

Other relevant sources are polymers originating from **solid marine litter**. In line with the latest policy developments (see Section 5.3.4), the JRC supports the collection and treatment of this waste stream. Plastic waste from solid marine litter is therefore an eligible input material for the plastic recycling operation.

In summary, plastics originating from various sources of waste containing plastics should in principle be eligible to be used as feedstock for the recycling operation, as long as the plastic recyclate fulfils the EoW criteria.

When looking at **national EoW criteria**, Spain and Finland imposed indirect restrictions for specific sources and types of plastic waste by defining a positive list of allowed input materials (waste codes based on the EU List of Waste). The JRC would refrain from excluding individual plastic waste streams from specific sectors to increase the recycling rate and consequently the uptake of secondary raw materials. Besides, the proposal to have a positive list of input materials with waste codes might be difficult to implement and would possibly lead to the need for regular amendments, in order to keep up with the introduction of new materials and technological progress in the field.

Bio-waste

In **national EoW criteria** (Spain and Portugal), bio-waste is restricted as input material (see Annex 2). This is mainly due to the fact that those criteria were developed based on the proposal by Villanueva & Eder (2014), where bio-waste was restricted.

The JRC agrees with the arguments presented by stakeholders on the existence of safe cleaning techniques and proposes not to include any explicit restriction for bio-waste.

Healthcare waste

As elaborated on in Section 5.3.3.1, hazardous healthcare waste is composed of sharps, infectious wastes, pathological wastes (e.g. human tissues, organs or fluids), pharmaceutical wastes, cytotoxic wastes (e.g. waste containing drugs used for cancer treatment), chemical wastes, and radioactive wastes (UNEP, 2003; WHO, 2016). As defined in the UNEP technical guidelines on the environmentally sound management of biomedical and healthcare wastes, hazardous healthcare waste can be either incinerated or disinfected (using chemicals, or autoclave/microwave techniques) (UNEP, 2003). Given that the present proposal for EoW criteria does not target chemical recycling, hazardous healthcare waste cannot be allowed as input material, as there is no proof that mechanical or physical recycling processes are able to safely treat this stream. The possibility of allowing the material as input, on the condition that it undergoes disinfection, would lead to the need for additional requirements on output materials. The JRC suggests possibly regulating the recovery of this specific waste stream in dedicated guidelines, not under the present proposals.

In relation to the suggestion made by some stakeholders, to narrow down the restriction only to the portion of the stream that poses a threat to human health or the environment (i.e. hazardous healthcare waste), the JRC collected additional evidence in-house. According to the findings by Chartier et al. (2014) and WHO (2018), only 15% of the total amount of waste generated by healthcare activities presents hazardous characteristics. The remaining fraction, covering the majority of the overall stream, is comparable to separately collected packaging waste generated by households or businesses. It consists for instance of packaging material that has not come into direct contact with infectious or other hazardous substances and it comes mostly from administrative/housekeeping and maintenance of healthcare facilities. It would thus seem reasonable to allow this non-hazardous healthcare waste as feedstock for the recycling operation. Yet, it is fundamental to ensure the non-hazardousness of the stream. The UNEP technical guidelines on the environmentally sound management of biomedical and healthcare waste prescribe waste segregation at source as a basic requirement for recycling of the non-hazardous component of healthcare waste (UNEP, 2003). If the streams are accidentally mixed, the whole mixture should be handled as hazardous healthcare waste (UNEP, 2020).

After a thorough evaluation, the JRC proposes to restrict hazardous healthcare waste, with the exception of non-hazardous plastic healthcare waste that has been segregated at source. As part of the self-monitoring requirements it is proposed that the recycler shall request documentation on the origin, segregation, storage and transport of this waste stream, to ensure that it does not present hazardous properties.

This approach aligns with the most stringent requirements set in **national EoW criteria**. Portugal restricts hazardous healthcare waste, and follows the same approach suggested by the JRC to limit only hazardous healthcare waste as input material (see Annex 2).

Used personal hygiene products

National EoW criteria (Spain and Portugal) include a restriction for used personal hygiene products, based on the proposals by Villanueva & Eder (2014).

As mentioned in Section 5.3.3.2, personal hygiene products encompass a wide variety of products ranging from packaging of cosmetic products (e.g. soap, shampoo, deodorant) to absorbent hygiene products (AHP). Thermoplastics (specifically PE, PP, ABS, PVC, among others) are the most common materials used in cosmetic packaging (Jordan Gantt & Refalo, 2022).

As suggested by some stakeholders, plastic packaging of cosmetic products or other products used for personal care should not be restricted, as they are collected separately along with other plastic packaging. In line with the objectives of the Circular Economy Action Plan (COM/2020/98 final)[59], recycling of plastic packaging should be incentivised to increase the EU recycling rate.

Yet, some stakeholders expressed concerns in relation to a specific subcategory of personal hygiene products, namely AHP. AHP include baby diapers, sanitary protection pads, tampons and adult incontinence products, among others. As discussed in Section 5.3.3.2, AHP waste can contain pathogens, infectious substances, pharmaceutical residues and degradation products of pharmaceuticals.

Italy developed an EoW decree specifically regulating the end-of-waste status for AHP waste[60] (see **Table 11**), targeting the recovery of mixed polyolefins, super absorbent polymers and cellulose. It prescribes, among others, chemical analysis on the input materials (at least every 6 months). The output materials have to fulfil strict testing requirements on microbiological and chemical

[59] A new Circular Economy Action Plan for a cleaner and more competitive Europe (COM/2020/98 final): https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN

[60] Decreto 15 maggio 2019, n. 62: https://www.gazzettaufficiale.it/eli/id/2019/07/08/19G00071/sg

contaminants. The operator has to verify the absence of cytotoxic substances and skin sensitisers. The recovered fractions can be used only for specific purposes.

From the EoW decree on AHP, it can be concluded that the recovery of polyolefins from AHP waste requires strict testing requirements on the input and output materials and the application of targeted decontamination techniques. Therefore, the inclusion of AHP waste as input material would increase the complexity of EU-wide plastics EoW criteria. Besides, after mapping AHP facilities in Europe and holding bilateral discussions with some operators, the JRC has come to the conclusion that AHP recycling cannot be considered a mature technology at present in the EU.

Concerns raised by stakeholders over the removal of hazardous properties were related to AHP, rather than to the broad category of personal hygiene products. Hence the JRC recommends deviating from the restriction imposed in national EoW criteria and to narrow them only to **absorbent hygiene products**. This should not prevent AHP waste from being recycled in specialised treatment facilities and the recovered polymers eventually obtaining national EoW status, in compliance with national EoW criteria or case-by-case decisions.

Additional restrictions

The exclusion of thermoset polymers suggested by stakeholders reflects the restrictions imposed in some of the **national EoW criteria** (namely Spain and Portugal, see Annex 2).

Taking into account that mixed plastic waste can contain polymers other than thermoplastics, the exclusion of thermosets as input materials would imply that the whole stream is not eligible to reach EoW. As argued by some stakeholders, thermosets contained in plastic waste used as input can be removed during the sorting and recycling process. A restriction on the use of thermosets as input materials would require a thorough analysis to differentiate thermoplastics and thermosets, which is not feasible through visual inspection. Considering that the scope of EoW criteria is limited to thermoplastics and the main purpose is that the plastic recyclate is composed solely of thermoplastics[61], the JRC does not consider it necessary to introduce an additional requirement in this criterion.

Section 6.1.2 already revealed that decontamination techniques exist to eliminate hazardous substances. Hence no restrictions on PVC and PTFE are proposed in this category.

Self-monitoring requirements

Additional monitoring requirements to assess potential hazardous properties in plastic healthcare waste have been included, to address the concerns on classification of the input materials.

6.2.2.3 JRC proposal

The JRC proposal on restrictions of feedstock is presented in **Table 13**.

Table 13. Requirements on input materials – Criterion 1.2

No.	Proposed EoW criteria on input materials	Self-monitoring requirements
1.2	Plastic waste to be used as input may originate from any source of waste containing plastics. The following materials shall not be used as input: (a) healthcare waste, except non-hazardous plastic healthcare waste that has been segregated at source; and	The operator of the treatment facility shall define appropriate risk management measures to identify and remove contaminated batches. Acceptance control by visual inspection and analysis of accompanying documentation of all plastic-containing waste received shall be carried out by qualified staff who are trained on

[61] Except for a certain amount of foreign materials, as defined in Criterion 3.3.

	(b) used absorbent hygiene products.	how to recognise plastic-containing input restricted under this criterion. The operator of the treatment facility shall apply appropriate control measures to ensure that plastic healthcare waste used as input does not present hazardous properties. Specifically, the operator shall request documentation on the origin, segregation, storage and transport of this waste stream. The control measures shall be documented under the quality management system. The operator of the treatment facility shall keep track of the plastic waste used as input material (date of receipt, supplier, origin, type and quantity of plastic waste received) and the plastic waste streams that have been rejected (date of rejection, supplier, origin, type, quantity of plastic waste and reason for rejection). The data shall be recorded under the quality management system.

6.2.3 Criterion 1.3: Eligibility of input materials originating from WEEE and ELVs

Villanueva & Eder (2014) suggested that input materials originating from WEEE or ELVs should have undergone all treatments required by the WEEE and ELV Directives, respectively. These requirements were proposed as part of the processes and techniques section. However, considering that they are related to the eligibility of input materials, we report the stakeholders' feedback and the JRC proposal under this section.

6.2.3.1 Stakeholders' feedback

Some stakeholders argued that the proposal by Villanueva & Eder (2014) (also maintained in the draft subject to consultation in 2023) to refer to treatment requirements for WEEE and ELV plastics under criteria for processes and techniques could lead to misunderstandings.

The main argument was that plastics originating from WEEE and ELVs do not necessarily contain hazardous substances or POPs and the WEEE and ELV Directives only specify the components that must be removed. The treatment requirements laid down in the WEEE and ELV Directives should be applicable to all plastics originating from those sources, not only the ones containing hazardous substances or POPs[62].

6.2.3.2 JRC assessment of feedback

The **WEEE Directive (EU) No 2012/19** defines in Annex VII the selective treatment for materials and components of waste electrical and electronic equipment referred to in Article 8(2).

The **ELV Directive (EC) No 2000/53** defines in Annex I the minimum technical requirements for treatment in accordance with Article 6(1) and (3). Annex I includes treatment operations for depollution as well as treatment operations to promote recycling.

When looking at **national EoW criteria**, in Finland the use of plastics originating from WEEE or ELVs is indirectly restricted, as WEEE/ELV plastics are not listed in the positive list of allowed input materials. This is due to the fact that no recycling facilities to recover plastics from these sources

[62] Please note that those are addressed separately in Criterion 1.1.

are available in Finland. In Spain and Portugal, plastic waste from WEEE and ELVs can be used as input materials, as long as the pre-treatment requirements laid down in the WEEE and ELV Directives are met.

Only around 0.43 Mt of WEEE plastics and 0.22 Mt of ELV plastics are currently sent for recycling in the EU every year (Souder et al., 2024). With a view to promoting higher recycling rates for these fractions, the JRC recommends allowing the use of plastic waste originating from those sources. In particular, as a prerequisite to be eligible as input materials, plastic waste originating from WEEE and ELVs shall fulfil the treatment requirements of the WEEE and ELV Directives, respectively.

6.2.3.3 JRC proposal

The proposal on eligibility of input materials from selected sources is presented in **Table 14**.

Table 14. Requirements on input materials – Criterion 1.3

No.	Proposed EoW criteria on input materials	Self-monitoring requirements
1.3	Additional treatment requirements shall apply to input materials originating from selected sources: (a) input materials that originate from waste electrical or electronic equipment shall have undergone all treatments[63] required by Article 8 of and Annex VII to Directive (EU) No 2012/19 (WEEE); and (b) input materials that originate from end-of-life vehicles shall have undergone all treatments required by Article 6 of and Annex I to Directive (EU) No 2000/53 (ELVs).	When accepting input materials originating from WEEE and ELVs, the operator of the treatment facility shall request the previous holder to provide documentation of compliance with the relevant treatment requirements for WEEE and ELVs. This documentation shall be recorded under the quality management system.

6.3 Requirements on treatment processes and techniques

The purpose of introducing requirements on processes and techniques is to define minimum treatment conditions to achieve an output plastic with quality suitable for EoW status. This means that the material is ready for use in the production of new plastic products or articles containing plastic parts.

It may be necessary to impose requirements on the storage conditions of the input materials, to avoid contamination. It also needs to be evaluated whether specific treatment steps should be mandatory to obtain an output material with the desired quality. Plastic waste originating from specific sources is more likely to contain harmful substances; it is hence fundamental to define specific requirements to treat problematic waste streams.

6.3.1 Criterion 2.1: Separate storage

Villanueva & Eder (2014) defined requirements on separate storage for input materials, namely that once received by the producer or importer, this waste should be kept permanently separate and out of contact with any other waste. They also referred to potential dilution of the input materials, asserting that intentional dilution should not be allowed.

[63] The removal of plastic containing brominated flame retardants from separately collected WEEE can be seen as an integral part of the plastic recycling process.

6.3.1.1 Stakeholders' feedback

The comments received from stakeholders on these requirements can be summarised as follows:

— **Separate storage of input materials**:

- The majority of stakeholders agreed that input material eligible for the production of EoW plastic should be stored separately from other types of waste that are not eligible to be used as input material, to fulfil the requirements on input materials (Criteria 1.1 and 1.2). It was argued that separate storage of different plastic input materials is not always relevant for chemical recycling, because the polymer matrix is broken down during the recycling process, resulting in a homogenous output, even when it comes from mixed waste and/or contaminated input.
- Numerous stakeholders commented that it is common industrial practice to mix different plastic waste grades received from different producers, as long as the waste streams are technically compatible (e.g. different quality of the same polymer or mixing of different polymers (PP, PE)). Stakeholders emphasised that, after a costly separation of the different plastic waste grades, it is in the interest of the whole plastic value chain to keep the quality of the material high and thus not remix the polymer grades, or contaminate them with other waste. The cost of separating individual input waste streams (in terms of building physical barriers) is high and could mean an additional financial burden for the recyclers. Furthermore, most individual waste streams are too small to be converted into entire batches of recyclates at industrial scale. The mixing of waste of a different quality and from different producers is also a necessity to ensure the homogeneity of a recyclate over time.
- Stakeholders requested to clarify the term 'permanent' in relation to storage of input materials, as it could be interpreted as a prohibition to treat different input qualities (eligible/not eligible as input materials) on the same process line (e.g. in campaign operation).

— **Separate storage of output materials**: Stakeholders suggested that the EoW output material should be packed, marked accordingly and kept separate from output materials that do not fulfil the EoW criteria and from any other waste.

6.3.1.2 JRC assessment of feedback

Separate storage of input materials

In all the **national EoW criteria** specifically developed for plastic waste (Spain, Portugal and Finland; see Annex 2), it is required that input plastic waste shall be stored separately from any other type of waste. Additionally, Portugal specifies that different types of plastic waste shall be stored separately. Finland proposes that plastic waste that is meant to be recycled and to be used for food contact applications shall be stored separately from any other type of plastic waste and other waste. Furthermore, Finland requests that plastic waste from construction shall be stored separately from plastic waste from demolition.

The JRC believes that at EU level it is not appropriate to request separate storage of plastic waste eligible for EoW with different grades, as this is not a standard procedure in the plastic recycling industry. The specific requirements laid down in the Finnish EoW decree to separate plastic waste based on the origin or on the application is based on standard practices in Finland. However, it seems too onerous for EU-wide EoW criteria.

The JRC proposes that plastic waste eligible for to be used as EoW input shall be stored separately from any other waste not eligible to be used as input. As part of the self-monitoring requirements, the recycler shall document these handling procedures in the quality management system.

Separate storage of output materials

The JRC welcomes the proposal made by stakeholders to additionally prescribe separate storage of EoW output materials. This is in line with the approach adopted in some of the **national EoW criteria** (namely Finland and Portugal). It is proposed to document these procedures in the quality management system.

6.3.1.3 JRC proposal

The JRC proposal on requirements for separate storage is presented in **Table 15**.

Table 15. Requirements on processes and techniques – Criterion 2.1

No.	Proposed EoW criteria on processes and techniques	Self-monitoring requirements
2.1	Plastic waste eligible to be used as input material shall, once received by the operator of the treatment facility, be stored separately from non-eligible input materials, to avoid contamination. Output materials that comply with the EoW criteria shall be stored separately from any waste material not complying with the EoW criteria.	The procedures carried out to fulfil the separate storage requirements for input and output materials laid down in this criterion shall be documented under the quality management system.

6.3.2 Criterion 2.2: Treatment steps

This section refers to the general requirement to complete all relevant treatment steps, regardless of the technology and sequence of treatments used. As the primary objective of EoW criteria is ensuring the quality of the output materials, the treatment process should include all the steps necessary to reach the targeted quality. Villanueva & Eder (2014) proposed that all treatments needed to prepare the waste plastic for direct input in a free-flowing form to manufacturing of plastic products (such as de-baling, sorting, separating, size reduction, cleaning, melting, filtering, regranulating, or grading) should have been completed.

6.3.2.1 Stakeholders' feedback

The comments on this requirement received from stakeholders can be summarised as follows:

— **Treatment steps**:

- Certain stakeholders were in favour of adding specific treatment steps (e.g. wet and dry cleaning) or suggested providing an even more accurate description of the treatment steps, to guarantee that products with sufficient quality are obtained. It was mentioned that wet cleaning ensures impurity removal. However, certain fractions do not need this step, or apply a dry cleaning process instead. It was argued that a more detailed list of mandatory treatment steps would simplify the verification procedure by third parties to comply with the requirements on quality assurance.
- Other stakeholders suggested not to specify treatment steps. The main argument was that there is a wide range of specific processes and techniques that can be adopted by the plastic recycler to achieve high-quality output materials (e.g. de-baling, sorting, size reduction, sorting, wet and dry washing, extrusion, further processes to achieve food-grade quality). Not all of these treatment steps are always necessary to achieve the quality requested by the customer. Depending on the type of polymer, the source, the content of hazardous substances and impurities, and the intended use, different process configurations are used. Furthermore, new technological approaches (e.g. physical recycling) are still largely under development and the individual process steps are

subject to change. Stakeholders mentioned that the requirements on processes and techniques are focused exclusively on plastic-to-plastic recycling and are not always applicable to chemical recycling.

— **Direct input to manufacturing**: Stakeholders suggested to remove the term 'direct', as this is not always applicable. The customer might use the recycled plastic to make a blend (e.g. PC/ABS blend with virgin PC and recycled ABS; e.g. blend of virgin with a certain percentage of recyclate) or to produce compounds (e.g. adding pigment, filler material).

6.3.2.2 JRC assessment of feedback

Treatment steps

It is important to keep in mind that the quality of the output material is the main focus of EoW criteria, rather than the source of the plastic waste or the treatment processes and techniques it undergoes. As mentioned in Annex 2, **national EoW criteria** request that all necessary treatment steps shall have been completed. Spain includes a list of the necessary treatment steps (e.g. sorting, shredding, and removal of non-plastic materials). Further mechanical treatments may be carried out depending on the type of plastic waste and the intended application (e.g. mechanical size reduction by rolling or micronising, washing, centrifuging, drying, filtering, agglomerating, extruding and pelletising).

The JRC believes that, if a plastic recyclate meets the EoW quality criteria, it is preferable to refrain from dictating how this is achieved, as this could hinder innovation. Therefore, it does not seem appropriate to impose mandatory treatment steps. However, it is specified that the recycling operation shall not alter the molecular structure of the polymer, in line with the scope definition (see Section 6.1.3).

Direct input to manufacturing

The JRC proposes to remove the term 'direct' to avoid misinterpretation. See also Section 6.1.3 on the discussion regarding direct use.

6.3.2.3 JRC proposal

The proposal on treatment steps is presented in **Table 16**.

Table 16. Requirements on processes and techniques – Criterion 2.2

No.	Proposed EoW criteria on processes and techniques	Self-monitoring requirements
2.2	The recycling operation shall be able to treat plastic waste without deliberately altering the molecular structure of the polymers, with the exception of damage that is repaired within the process. The recycling operation shall include all treatment steps needed to prepare the output plastic to be used as input for the production of plastic products or articles containing plastic parts.	The sequence of treatment steps shall be documented under the quality management system.

6.3.3 Criterion 2.3: Treatment of hazardous waste and waste containing hazardous substances or other restricted substances

Villanueva & Eder (2014) suggested including a specific requirement for hazardous waste to be efficiently removed in a process which is approved by the competent authority.

The self-monitoring requirements proposed in 2014 also included a clause mentioning that mixing materials from CDW, WEEE and ELVs (such as shredding before removal of hazardous substances) should be avoided.

6.3.3.1 Stakeholders' feedback

— **Treatment of hazardous waste, waste containing hazardous substances or other restricted substances:**

- Some stakeholders were in favour of a strict approach, suggesting that when using plastic waste containing hazardous substances, substances restricted under REACH, or POPs above the limit values of the POP Regulation as input materials, a pre-treatment step or specific decontamination steps should be prescribed.
- Other stakeholders proposed a more lenient approach, arguing that it should be permitted to remove hazardous properties within the recycling operation. In this case, it should be requested that the recycling operation include all treatment steps needed to remove hazardous/restricted substances and POPs, to the extent that the output complies with the relevant product legislation.

— **Mixing hazardous waste and POPs-containing waste:**

- A relatively large number of stakeholders asked for clarification regarding the blending of plastic waste, in particular of hazardous/non-hazardous plastic waste and plastic waste with POP concentrations exceeding/not exceeding the limit values defined in Annex IV to Regulation EU 2019/1021.
- Some stakeholders highlighted that mixing input materials from different sources, for instance from WEEE and ELVs, is a common practice and should be allowed. Plastic waste streams originating from WEEE and ELVs often go through the same process and can be mixed upstream to obtain a recycled plastic grade that fits the specification of a certain customer. It was hence suggested that the operator should assess separate treatment on a case-by-case basis.

6.3.3.2 JRC assessment of feedback

Treatment of hazardous waste and waste containing hazardous substances or other restricted substances

Some **national EoW criteria** demand the pre-treatment of plastic waste to be used as input. Notably, Finland and Portugal require that plastic waste high in material impurities and contaminants shall be removed in a pre-treatment step to the greatest extent possible (see Annex 2).

As discussed above, the JRC recommends prescribing (pre-)treatment of input materials only for specific types of plastic waste, namely for waste containing POP concentrations above the limit values set in Annex IV to the POP Regulation (Criterion 1.1) and for plastic waste originating from WEEE and ELVs (Criterion 1.3).

As regards the proposal made by stakeholders to prescribe specific decontamination steps for hazardous waste and waste containing hazardous substances or other substances restricted under REACH or POP, it has already been mentioned above that strict testing requirements on the input materials are not favourable. The JRC proposes that plastic waste originating from any source shall be treated to the extent that the output materials meet relevant provisions laid down in the CLP, REACH and POP Regulations. The procedure used to comply with the substance concentration requirements laid down in those regulations shall be documented under the QMS. This is in line with the approach applied in the Spanish EoW decree.

Mixing hazardous waste and POP containing waste

In **national EoW criteria** (specifically in Spain) it is demanded that plastic waste potentially containing hazardous substances or POPs shall be treated separately and shall not be mixed with other plastic waste.

The JRC would like to clarify that different types of input materials (e.g. WEEE and ELV plastics) may be mixed with the purpose of obtaining a homogeneous feedstock or to optimise treatment efficiency (UNEP, 2019b), as long as they are eligible to be used as input and fulfil the requirements on input materials. However, hazardous waste may not be mixed with the sole purpose of dilution. The intentional blending of hazardous plastic waste in order to dilute the pollutant content to fall below certain limit values is prohibited as per Article 18(1) of the Waste Framework Directive. Member States may apply specific derogations (as defined in Article 18(2)). The same applies to the intentional mixing of hazardous plastic waste or POPs-containing plastic waste exceeding the limit values pursuant to Annex IV to Regulation EU 2019/1021, which can be tolerated with the purpose of treatment optimisation, but not if it is done with the sole purpose of dilution, in order to be compliant with pollutant concentration limits. The JRC proposes to add a clause on dilution in Criterion 2.3, for clarification purposes.

6.3.3.3 *JRC proposal*

The JRC proposal on treatment of hazardous waste, waste containing hazardous substances or other restricted substances is presented in **Table 17**.

Table 17. Requirements on processes and techniques – Criterion 2.3

No.	Proposed EoW criteria on processes and techniques	Self-monitoring requirements
2.3	Materials originating from any source that are eligible to be used as input (cf. Criteria 1.1, 1.2 and 1.3) shall be treated to the extent that: (a) the output plastic[64] resulting from the recycling operation is not classified as hazardous pursuant to Article 3 of and Annex I to Regulation (EC) No 1272/2008 (CLP); (b) substances on their own or in mixtures, resulting from the recycling operation comply with Regulation (EC) No 1907/2006 (REACH), including but not limited to compliance with Article 56 setting out authorisation provisions for uses of substances listed in Annex XIV to REACH and for their placing on the market as well as the conditions laid down in Article 67 for the manufacture, placing on the market and use of substances restricted in Annex XVII[65] to REACH; and (c) substances on their own or in mixtures, resulting from the recycling operation meet the provisions limiting the manufacturing,	Particular attention shall be paid to the processing of hazardous waste and plastic waste that may contain hazardous substances or other substances restricted under the REACH and POP Regulations, as indicated in the criterion. The procedure and method used to comply with the substance concentration requirements of the CLP, REACH and POP Regulations shall be documented under the quality management system.

[64] See footnote 52.
[65] Including the latest amendment of Annex XVII (Regulation (EU) No 2023/923).

	placing on the market and use of persistent organic pollutants (POPs) pursuant to Article 3 of and Annex I to Regulation (EU) No 2019/1021. As per Article 18(1) of Directive 2008/98/EC, hazardous plastic waste used as input shall not be mixed with the sole purpose of dilution. The derogations established in Article 18(2) shall apply. The same restrictions shall apply to plastic waste with POP concentrations above the limit values established in Annex IV to Regulation (EU) No 2019/1021.	

6.4 Requirements on product quality

Product quality is referred to as the quality of the output plastic that results from a recycling operation. This category of criteria aims at ensuring that the output plastic can substitute primary raw materials, without posing any risk to human health and the environment.

Hence, requirements on the output materials should aim primarily at limiting the presence of hazardous substances and other restricted substances, including POPs. As described in Section 5.2.2, relevant provisions are laid down in the chemicals legislation, specifically:

- Regulation (EC) No 1272/2008 on Classification, Labelling and Packaging of substances and mixtures (CLP)[66];
- Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)[67];
- Regulation (EU) No 2019/1021 on Persistent Organic Pollutants (POPs)[68].

The criteria should also enhance the suitability of the recycled plastics for the intended use, i.e. conversion to plastic products. In this sense, output materials have to fulfil industry and customer specifications. Existing standards can be used as a reference for the characterisation of the plastic recyclate. The presence of impurities and contaminants can compromise the suitability of the plastic recyclate for the production of new plastic products or articles containing plastic parts. Thus additional requirements on foreign materials and other contaminants are also needed.

6.4.1 Criterion 3.1: Compliance with product legislation

Villanueva & Eder (2014) proposed that the output plastic should not be classified as hazardous and should comply with the relevant provisions of the CLP, REACH and POP Regulations.

6.4.1.1 Stakeholders' feedback

Comments received from stakeholders on the proposed compliance with the individual pieces of legislation are summarised below:

- **CLP Regulation**: diverging opinions were received:

[66] The CLP Regulation establishes the requirement to classify, label and package hazardous chemicals appropriately before placing them on the market. The requirements apply to manufacturers and importers.

[67] The REACH Regulation has been adopted with the aim of reducing the risks posed by chemicals on human health and on the environment, by restricting the use of certain substances (e.g. substances of very high concern (SVHC)) in products placed on the market.

[68] The POP Regulation aims at protecting human health and the environment with specific control measures and restrictions on POPs. POPs are chemical substances that persist in the environment, bio-accumulate through the food web, and pose a risk of causing adverse effects to human health and the environment.

- Various stakeholders agreed with the proposed requirements, without any major changes.
- Other stakeholders were in favour of a stricter approach, requesting to clarify that additives and leachable substances should also be non-hazardous pursuant to the CLP Regulation.
- Some stakeholders criticised the suggested approach, claiming that placing hazardous substances on the market is not prohibited per se for virgin plastics, and it should not be prohibited for recycled plastics either. The main concern is the reference to Article 3 of the CLP Regulation, which could result in the risk of disqualifying a large share of recycled plastics that could be suitable for specific applications.

— **REACH Regulation**:

- The majority of stakeholders were in favour of making specific reference to relevant provisions of the REACH Regulation, not only regarding restrictions on substances of very high concern (SVHC) but also regarding general market restrictions for dangerous substances listed in Annex XVII. Some recommended to also evaluate the possibility of including additional restrictions for substances from the 2022 REACH Restriction Roadmap (e.g. PVC and its additives, PFAS, bisphenols).
- A few stakeholders pointed out that certain recycled plastics may benefit from specific REACH derogations related to substances of concern (SoC) thresholds, such as in the case of PVC ((EU) No 2023/923 derogates the use of PVC recyclate containing lead under certain conditions).
- It was remarked that although the assessment of REACH compliance should be focused on SVHC and other restricted substances, many recycling operators would also need to comply with registration of recycled substances. For substances that have already been registered it may be possible for waste operators to refer to Article 2(7)(d) (as mentioned in the ECHA guidance on waste and recovered substances (ECHA, 2010)).

— **POP Regulation**: The majority of stakeholders agree that the output plastics shall meet the limit values set in Annex I to the POP Regulation. Some stakeholders remarked that reference to Annex IV should also be made.

— **Additional restrictions**:

- Some stakeholders remarked that the output plastic should also comply with Regulation (EC) No 1935/2004 on materials and articles intended to come into contact with food - referred to as the Food Contact Material (FCM) Regulation - and Regulation (EC) No 2022/1616 on recycled plastic materials and articles intended to come into contact with foods.
- Additional restrictions for sensitive uses, such as for the production of toys, should be evaluated, according to some stakeholders.
- Some stakeholders commented that, in order to ensure that the output plastic will not lead to negative impacts on the environment or human health, requirements should be aligned with the updated objectives of the Waste Shipment Regulation, Article 13 of the Waste Framework Directive and with the Chemicals Strategy for Sustainability[69].

[69] Chemicals Strategy for Sustainability Towards a Toxic-Free Environment: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A667%3AFIN

— **Self-monitoring requirements**:

- A relatively large group of stakeholders criticised the proposed formulation of the self-monitoring requirements, arguing that they are very unspecific and might be interpreted differently by recyclers and authorities performing inspections. Formulations such as 'appropriate intervals', 'appropriate frequencies', 'qualitative characterisation' leave too much room for interpretation, according to them. It was requested to develop clear guidelines on the methodology to provide proof of compliance with product legislation.
- Other stakeholders remarked that evidence of compliance with the CLP, REACH and POP Regulations requires analyses in external laboratories that are time- and cost-intensive, which may represent a disadvantage for small and medium-sized recycling companies. An alternative to reduce the burden of performing tests on the output materials would be to have stricter requirements on the input materials. For output plastic materials with less severe hazard classifications it could be sufficient to provide safety data sheets. It was also proposed to give recyclers the option of possibly replacing measurement data with product passports, given the on-going initiatives in the context of the SCiP database by ECHA[70].

6.4.1.2 JRC assessment of feedback

Compliance with the CLP Regulation

As per Article 6 of the Waste Framework Directive, the use of EoW materials should not pose a risk to human health and the environment. It is therefore essential that the output material does not contain legacy additives or other hazardous substances that could compromise the overall quality of the final product.

The CLP Regulation is the main reference for classification of the hazardousness of substances and mixtures, in particular Article 3 and Annex I relating to physical, health and environmental hazards (Parts 2 to 5). The JRC proposes to make reference to those provisions in this criterion. This approach is consistent with the one used in some of the **national EoW criteria** (Spain and Portugal). Finland does not request compliance with product legislation, arguing that it should be avoided to repeat existing legislation in EoW criteria (see Annex 2).

Compliance with the REACH Regulation

In the **national EoW criteria** implemented in Spain and Portugal it is required that the output material comply with the REACH Regulation. Similarly to the reference to the CLP Regulation, Finland refrains from explicitly requesting compliance with REACH (see Annex 2).

The JRC proposes to request full compliance with REACH for output materials, including compliance with Article 56 of and Annex XIV to REACH as well as with Article 67 of and Annex XVII to the Regulation, as suggested by stakeholders.

The latest amendment to Annex XVII (Regulation (EU) No 2023/923) related to the use of recovered rigid PVC with lead concentrations below 1.5% for specific applications (as defined in Annex XVII, entry 63, column 2, paragraph 18 (a) to (d)) shall apply.

The JRC is aware of the latest developments under the 2022 REACH Restriction Roadmap[71] under the Chemicals Strategy for Sustainability (COM (2020) 667 final)[72]. However, considering that those

---

[70] SCIP is the database for information on Substances of Concern in articles as such or in complex objects (Products) established under the Waste Framework Directive (2008/98/EC) https://www.echa.europa.eu/scip-database

[71] Roadmap on restrictions of hazardous chemicals proposed (25 April 2022): https://ec.europa.eu/newsroom/env/items/752367/en

[72] Chemicals Strategy for Sustainability Towards a Toxic-Free Environment: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A667%3AFIN

restrictions are not in place yet, no specific reference is given in the criterion. This may need to be re-evaluated during the legal adoption process.

Article 2(7) of the REACH Regulation lays down exemptions from the obligation to register substances obtained from recycling processes. Those exemptions apply if the substances (on their own, in mixtures or in articles) have been registered and are recovered in the EU, if it can be demonstrated that the resulting substance is the same as a registered substance and if the treatment facility possesses the information required by Article 31 or 32 (requirements for safety data sheets). The JRC would like to clarify that the registration of recycled substances is regulated under REACH. The guidance on waste and recovered substances (ECHA, 2010) as well as the specific guidance for monomers and polymers (ECHA, 2023) should remain the main references to address the application of Article 2(7)(d) of REACH and the relevant exemptions, until further guidance is provided.

Compliance with the POP Regulation

Stakeholders seem to agree on the proposed requirements to comply with the POP Regulation. The suggested reference to Annex IV is not deemed relevant for this category of EoW criteria, as it is related to waste management provisions under Article 7, which is duly referred to in the requirements on the input materials (Criterion 1.2).

In the **national EoW criteria** implemented in Spain and Portugal, it is required that the output material shall comply with the POP Regulation, whereas in the Finnish EoW decree there is no specific reference to this Regulation. It also needs to be noted that in Finland the use of POPs waste as feedstock is indirectly restricted.

Additional restrictions

When looking at **national EoW criteria**, in Section 1 of the Finnish EoW decree it is clarified that "*the manufacture of secondary plastic raw materials intended to come into contact with food are governed by Commission Regulation (EU) 2022/1616 [...] and Regulation (EC) No 1935/2004 of the European Parliament and of the Council on materials and articles intended to come into contact with food*". Specific requirements for plastic recyclates to be used for food contact applications are laid down (i.e. separate storage, separate processing line; see Annex 2).

A similar approach is used in the Spanish EoW decree, containing specific requirements for recyclates to be used in food contact applications. Notably, in Article 4 of the decree it is specified that if the the output material is intended to come in contact with food, it has to additionally comply with Regulation (EC) No 1935/2004 and Regulation (EC) No 2022/1616 to obtain EoW status. Other requirements for food contact EoW plastics relate to the complete absence of POPs as well as a complete absence of non-plastic components.

The JRC recommends not to refer to Regulation (EC) No 1935/2004 and Regulation (EC) No 2022/1616 (food contact material). The main reason is that the current EoW proposal is not limited to food contact applications. Criteria for food contact applications established by EFSA are likely to be stricter than EoW requirements and should apply only to relevant materials intended to come into contact with food. As explained in Section 6.1.3, treatment steps applied by the manufacturer of new plastic articles do not fall under the scope of the proposed EoW criteria.

The same considerations apply to other sensitive applications, such as toys.

The JRC considers that compliance with the CLP, REACH and POP Regulations should ensure a high level of protection of human health and the environment. Hence no additional restrictions are proposed.

Self-monitoring requirements

It is clarified that only relevant substances for the specific waste stream treated will need to be analysed in the assessment of compliance with the REACH, CLP and POP Regulations.

Good practice for setting an appropriate monitoring frequency is to evaluate when potentially harmful trends may occur (European Commission, 2003). This is defined in ISO 9001 as the risk-based approach. The JRC proposes to adopt this approach, allowing the operators to determine the frequency of sampling based on the risk of non-compliance and on relevant changes in the process.

6.4.1.3 JRC proposal

The JRC proposal on compliance with relevant product legislation is presented in **Table 18**.

Table 18: EoW criteria on product quality – Criterion 3.1

No.	Proposed EoW criteria on product quality	Self-monitoring requirements
3.1	The following conditions shall be fulfilled: a) the output plastic[73] resulting from the recycling operation shall not be classified as hazardous pursuant to Article 3 of and Annex I to Regulation (EC) No 1272/2008 (CLP); b) substances on their own, in mixtures or in articles, resulting from the recycling operation shall comply with Regulation (EC) No 1907/2006 (REACH), including but not limited to compliance with Article 56 setting out authorisation provisions for uses of substances listed in Annex XIV to REACH and for their placing on the market as well as the conditions laid down in Article 67 for the manufacture, placing on the market and use of substances restricted in Annex XVII[74] to REACH; and c) substances on their own, in mixtures or in articles, resulting from the recycling operation shall meet the provisions limiting the manufacturing, placing on the market and use of persistent organic pollutants (POPs) pursuant to Article 3 of and Annex I to Regulation (EU) No 2019/1021.	The assessment of compliance with Regulation (EC) No 1272/2008 (CLP), Regulation (EC) No 1907/2006 (REACH) and Regulation (EU) No 2019/1021 (POPs) has to be concluded from a qualitative and quantitative characterisation of the output plastic in the consignment. Relevant exemptions laid down in the REACH, CLP and POP Regulations shall apply. At appropriate intervals subject to review if significant changes in the operating process are made, representative samples of the output plastic shall be analysed to measure the concentration and nature of hazardous substances and substances restricted under the REACH and POP Regulations, as indicated in the criterion. The appropriate frequencies of monitoring by sampling shall be established taking into account the following factors: (1) the expected pattern of variability of the output plastic composition (for example as shown by historical results); (2) the inherent risk of variability in the quality of the waste used as input for the recycling operation and any subsequent processing, for instance the higher average content of plastics containing hazardous substances and substances restricted under the REACH and POP Regulations; (3) the inherent precision of the monitoring method; and (4) the proximity of results to the concentration thresholds that render

[73] See footnote 52.
[74] Including the latest amendment of Annex XVII (Regulation (EU) No 2023/923).

		the material hazardous or restrict its commercialisation. The process of determining monitoring frequencies shall be documented as part of the quality management system.

6.4.2 Criterion 3.2: Compliance with standards and technical specifications

The criteria proposed by Villanueva & Eder (2014) included the requirement for the output materials to "*comply with a customer or industry specification for direct use in the production of plastic substances or objects by remelting in plastic manufacturing facilities."* A list of standards for the characterisation of plastic recyclates was also given. Villanueva & Eder (2014) also proposed that the operator should verify that each batch in the consignment complies with the appropriate specification.

6.4.2.1 Stakeholders' feedback

The comments received from stakeholders on these requirements can be summarised as follows:

— **Customer and industry specifications**:

- Most stakeholders agreed that EoW criteria should be based on quality specifications for the end-product or on customer specifications. One organisation remarked that fulfilling a customer specification for a specific application should not automatically lead to the achievement of EoW status for any possible use. It was also suggested to clarify the meaning of the term 'industry specifications' and to provide a few examples in the report.
- Stakeholders commented that third countries may apply more lenient customer or industry specifications than EU manufacturers. This could have unintended consequences, as low-grade material meeting those specifications could be labelled as EoW, thereby circumventing possible EU export bans on specific waste streams. EoW plastics exported outside the EU should meet the same EoW criteria as recycled plastics that are shipped within the EU as EoW material.

— **Standards**: Some stakeholders highlighted that linking standardisation with EoW criteria might not be appropriate, as standards are revised periodically. Listing standards for specific polymers would result in a non-exhaustive list (as was the case in the 2014 proposals). The lack of standards for certain plastic streams shall not prevent them from being eligible for EoW status. Besides, EU standards on plastic recyclates include an extensive set of parameters that need to be examined (e.g. colour, density, impact strength, melt flow rate, shape, and particle size). In addition, the standards define different requirements (qualitative and quantitative) for different polymers. The extensive examination required in the standards is not always common practice in the plastic recycling industry. The general opinion is that standards should not be mandatory, and should only serve as an informative reference for the operator.

— **Direct use / properties of output plastics**: Some stakeholders argued that direct conversion to new plastic products is not always technically feasible. There are alternative industrial applications to possibly substitute virgin raw materials with EoW flakes, granules or agglomerates. According to some stakeholders, the legal status of a plastic recyclate should not change depending on the application, as long as it meets the condition of being used in the production of new plastic products or articles containing plastic parts.

— **Self-monitoring requirements**: One organisation proposed a more flexible approach for verification in the self-monitoring requirements, i.e. that the frequency of verification shall be defined in accordance with the plastic stream treated.

6.4.2.2 JRC assessment of feedback

Customer and industry specifications

There is overall consensus among stakeholders on the requirement for the output material to comply with customer and industry specifications. The specifications shall be targeted to the final application. This is also in line with the approach used in **national EoW criteria** (see Annex 2).

In order to make the EoW criteria future-proof, the JRC suggests including a *catch-all* clause on **compliance of the output materials with all legal requirements**, beyond compliance with the CLP, REACH and POP Regulations required in Criterion 3.1. These include for instance relevant provisions on substances of concern laid down in the Ecodesign for Sustainable Products Regulation (ESPR) (Regulation (EU) No 2024/1781) (see section 5.2.2.5) and in future Delegated Acts to the Regulation (e.g. possible restrictions of substances of concern).

In reply to the comments of some stakeholders, it is clarified that, if transposed into legislation, EU-wide EoW criteria will apply to the EU territory, as one of the main goals is to facilitate intra-EU shipment between Member States. The recognition of EoW status in third countries is not granted automatically, as third countries may want to put a good on the market only if it complies with the local product legislation.

It is also clarified that the term 'industry specifications' refers to specific requirements and guidelines set by the recycling industry on the quality of the output materials and the processing methods. This definition has been included in the glossary.

Standards

When looking at **national EoW criteria**, Spain and Portugal specify that output materials must adhere to certain standards (e.g. EN 15342 (PS), EN 15344 (PE), or EN 15345 (PP)), while Finland opts for a more flexible approach, mandating that the materials must meet market and customer specifications (see Annex 2).

The JRC agrees with the stakeholders that it is not meaningful to include a list of standards, which would in any case be non-exhaustive (see Section 5.1.1.). Besides, standards are updated periodically. It is therefore recommended not to include a list of specific standards.

Direct use / properties of output plastics

The JRC acknowledges that there are different recycling pathways and the output material is not always 'ready for direct conversion' in the strict sense of the term. It may be necessary to perform some additional steps, according to the intended use (e.g. for food contact materials). Hence it would be preferable not to refer to direct conversion in this criterion (see also Section 6.1.3).

Self-monitoring requirements

The JRC agrees with the proposal to establish the frequency of verification as appropriate, depending on the characteristics of the waste stream treated. This has been clarified in the self-monitoring requirements.

6.4.2.3 JRC proposal

The JRC proposal on compliance with standards and technical specifications is presented in **Table 19**.

Table 19: EoW criteria on product quality – Criterion 3.2

No.	Proposed EoW criteria on product quality	Self-monitoring requirements
3.2	The output plastic shall demonstrably fulfil all legal requirements and shall comply with customer	Qualified staff shall verify that each batch in the consignment complies with the legal

	specifications, industry specifications or standards for the use of the material in the production of plastic products or articles containing plastic parts.	requirements and appropriate specifications or standards. The frequency of verification shall be defined in accordance with the characteristics of the plastic waste stream treated.

6.4.3 Criterion 3.3: Thresholds of foreign materials

The JRC's initial proposal (by Villanueva & Eder, 2014) was to establish a threshold of non-plastic components at 2% of moisture-free weight. A non-plastic components was defined as "*any material different from plastic, which is present in waste plastic for recycling. Examples of non- plastic components are metals, paper, glass, natural textiles, earth, sand, ash, dust, wax, bitumen, ceramics, rubber, organic matter and wood, except when these materials are integral constituents of the plastic structure before it is re-melt, such as talc, limestone, glassfibre or wood fibres used as fillers and structural or mechanical reinforcements*".

6.4.3.1 Stakeholders' feedback

— **Non-plastic components**: The opinion of stakeholders was split among five main views:

- Certain stakeholders were in favour of the proposed threshold, but requested clarification on counting fillers and additives as impurities. In this regard some stakeholders suggested to count them as impurities, and others suggested otherwise: '*material that is part of a compound or polymeric object (e.g. fillers, barriers, pigments, additives) should be excluded from the threshold and only macro-contaminants are to be considered as impurities*'. It was argued by some stakeholders that in the case of composite materials (e.g. plastic/aluminium) used as input materials, the non-plastic component (in this case aluminium) is an integral part of the input material and should hence not be counted as non-plastic material in the output materials.
- Other stakeholders (including some of the Member States' representatives that actively participated in the consultation) were of the opinion that the value of 2% is not strict enough, as it equals the limit value for the trade of plastic waste listed under the Basel Convention entry B3011 between the EU and OECD countries, defined in the Waste Shipment Regulation.
- According to a few stakeholders, this value does not guarantee a high level of protection of human health and the environment. It was also noted that in the proposed amendment to the Waste Shipment Regulation the Commission is empowered to adopt measures to establish contamination level thresholds for waste listed in Annex III, IIIA, IIIB or IV. It was suggested to lower the threshold to 0.5%, to align with values set at international level (e.g. Hong Kong (EPD-HK, 2020)).
- Other stakeholders (mostly those representing the recycling industry) requested to have a higher tolerance, especially for mixed plastic waste streams, according to the specific technical requirements of the end application. It was argued that different applications may allow higher thresholds (up to 6% if additives and fillers are not accounted for). For certain applications, even higher levels of non-plastic components may be tolerated (e.g. 20% for furniture and automotive, 40–50% for electrical and electronic equipment (EEE)).
- Some stakeholders (including one Member State representative) challenged the need for this threshold, especially if no requirement to perform analyses is prescribed to prove conformity. The main argument against having a defined limit value is that it may hinder possible uses of the output material. It was suggested that this parameter may be better dealt with through market specifications between supplier and buyer. It was mentioned that setting a given threshold is not in line with the approach proposed by

the Circular Plastics Alliance (CPA). Another point is that for chemical recycling this requirement is not meaningful (thus highlighting again the need for a separate set of criteria for chemical recycling).

- Some stakeholders pointed out that it may be meaningful to consider a complementary limitation for **non-targeted plastics** (in the case of output plastics made of one single polymer grade).

— **Self-monitoring requirements**: As for criterion 3.1, it was criticised by some stakeholders that no clear measurement method or frequency of testing are prescribed. A few stakeholders proposed to align the testing approach with Regulation (EC) No 2022/1616 on recycled plastic materials and articles intended to come into contact with food, which prescribes testing for every batch of food contact plastics.

6.4.3.2 JRC assessment of feedback

Non-plastic components / Non-targeted plastics - Foreign materials

The Circular Plastic Alliance (CPA) asserted that the quality of a recyclate is specific to the targeted application. In order to support the uptake of recycled plastics, it is important to match the quality of the recyclate with the quality demanded by the market (CPA, 2022). The JRC views this approach favourably, considering that the criteria proposed should not be application-specific.

As a reaction to the suggestion by some stakeholders of not setting a threshold, the JRC would like to clarify that this could imply that plastic recyclates with a high level of contaminants could enter the EU market and could be exported to third countries as products. It could also mean that composite materials could receive EoW status and be considered equivalent to plastic products.

Setting a limit value for macro contaminants imposes certain restrictions on the intended use and leads to the need for additional monitoring requirements to prove conformity. Nevertheless, this is a key parameter to ensure that the material is ready for use in the production of new plastic products or articles containing plastic parts and that it is not diverted to other uses. It should be seen as an incentive to improve the quality of the recyclates on the EU market and beyond. The JRC hence recommends to set a limit value for contaminants.

The technical guidelines on the environmentally sound management of plastic wastes (UNEP, 2023b) define contaminants as unwanted materials present in plastic waste that can derive from the production, use or waste phases of the plastic life cycle. The JRC agrees that components that are bound to the polymer matrix as a result of intentional addition with the purpose of enhancing the properties of the polymer (e.g. fillers, barriers, pigments, additives or any other active ingredients typically used in the compounding of plastics) should not be counted as non-plastic components. However, it needs to be clarified that materials or substances that were not part of the polymer matrix in the input plastic and migrate into the polymer matrix during the recycling process are considered contaminants. For instance, in the case of the non-fibre fraction containing plastic and aluminium that is obtained through pulping of paper-based composite packaging (e.g. beverage cartons), the aluminium particles bind with the plastic during the recycling process, creating PolyAl (as described in Section 6.2.2.2). The aluminium (metal) is counted as a non-plastic component (see definition in the glossary).

Taking into account the comments from stakeholders on complementary limitations for non-targeted plastics and in order to better align with the definitions used in the Waste Shipment Regulation, the JRC suggests adopting the term '**foreign materials**', defined as "*polymers other than thermoplastics, non-targeted polymers in the recycling operation and non-plastic components.*"

EoW criteria aim at determining when waste has been sufficiently treated to the point where it can be used as a secondary raw material, without posing a risk to human health or the environment, while no longer covered by protective measures from waste legislation. EoW criteria also have direct implications for the transboundary shipment, as they determine when a material can be

shipped as a product. The Waste Shipment Regulation and EoW criteria are hence linked. In this context, it is important to recall some key concepts (see also Section 5.2.1.3):

- The Waste Shipment Regulation (WSR) lays down provisions for the notification and consent procedure for shipment of waste, as well as requirements for labelling and documentation. It also sets out guidelines for the environmentally sound treatment of waste. The new rules on waste shipment aim to ensure exports of waste from the EU are managed in a sustainable manner and to avoid the environmental burden of treating/disposing of waste being shifted to countries outside the EU.
- The ban on shipment of plastic waste to non-OECD countries concerns plastic waste that needs further treatment to be used. Shipment of plastic waste to non-OECD countries is allowed only on the condition that the receiving country notifies the Commission of its willingness to import the material and demonstrates its ability to treat it in an environmentally sound manner. The request to import EU plastic waste can only cover non-hazardous plastic waste (B3011).
- In the WSR plastic waste is classified as green-listed waste if it is *'almost free from contamination and other types of waste'*. Based on the definitions provided in the Correspondent Guidelines No 12, in the footnotes of the new WSR it is clarified what this concretely entails for each of the classifications of plastic waste (EU3011 and B3011):

    - Entry **EU3011**, which covers **intra-EU shipments** of non-hazardous plastic waste for recovery, includes plastic waste almost exclusively consisting of one non-halogenated polymer (including PE, PP, PS, ABS, PET, PC, others); plastic waste almost exclusively consisting of one cured resin or condensation product; plastic waste almost exclusively consisting of one fluorinated polymer. The footnote makes the following clarification:

      "*For the purpose of this Regulation, the terms **'almost free from contamination and other types of waste'** and where relevant 'almost exclusively consisting of' shall be understood to mean that in a consignment of plastic waste or mixtures of plastic waste, classified under entry **EU3011**, the content of contamination, other types of wastes or non-halogenated polymers, cured resins or condensation products, or fluorinated polymers, other than the one non-halogenated polymer, cured resin or condensation product, or fluorinated polymer that makes up the bulk of the plastic waste **shall not exceed a total maximum of 6 % of the weight of the consignment**.*"

    - Entry B3011, which covers exports from the EU of clean, non-hazardous plastic waste destined for recycling, includes plastic waste almost exclusively consisting of one non-halogenated polymer (including PE, PP, PS, ABS, PET, PC, others); plastic waste almost exclusively consisting of one cured resin or condensation product; plastic waste almost exclusively consisting of one fluorinated polymer; mixtures of plastic waste, consisting of polyethylene (PE), polypropylene (PP) and/or polyethylene terephthalate (PET), provided they are destined for separate recycling of each material and in an environmentally sound manner, and almost free from contamination and other types of wastes. The footnote makes the following clarification:

      "*For the purpose of this Regulation the terms **'almost free from contamination and other types of waste'** and where relevant 'almost exclusively consisting of' shall be understood to mean that in a consignment of plastic waste or mixtures of plastic waste, classified under entry **B3011**, the content of contamination, other types of wastes or non-halogenated polymers, cured resins or condensation products, or fluorinated polymers, other than the one non-halogenated polymer, cured resin or condensation product, or fluorinated polymer that makes up the bulk of the plastic waste **shall not exceed a total maximum of 2 % of the weight of the consignment**.*"

At the global level, it is worth noting that in the Hong Kong guidelines (EPD-HK, 2020):
"*'**Uncontaminated waste plastics**' mean waste plastics that are clean and contain no more than **0.5% impurities by total weight**. Impurities include other types of waste plastics, waste paper, waste glass, etc.*"

With these notions in mind, the appropriate limit value for the presence of foreign materials in the plastic recyclate has to be determined, as part of the requirements on output materials. The limit should, on the one hand, be sufficiently strict to promote the production of high-quality recyclates, while on the other hand it should not be too strict to facilitate the uptake of recycled plastics in the EU.

Stakeholders suggested limit values between 0.5% and 6%. When looking at **national EoW criteria**, Spain and Portugal impose a single limit of non-plastic components equal to 2%. In the Finnish EoW decree notified to the Commission a different approach is used: there is no threshold for non-plastic components or other foreign materials, but it is required that the melt flow index and the mass fraction of the main polymer and other polymers be determined.

A negative consequence of lowering the threshold of foreign materials below 2%, the strictest limit currently in place in national EoW criteria, could be that few plastic recyclates will be able to achieve EoW status. Hence, the JRC proposes to keep the value of foreign materials to 2%, which is already considerably lower than the value for contamination in entry EU3011 (6%). As such, EoW criteria do not risk bypassing environmental protections for intra-EU shipments of plastic waste under the new Waste Shipment Regulation.

Similarly, EoW criteria should not leave a door open to circumvent the export ban to non-OECD countries established under the new Waste Shipment Regulation. To address this issue, the JRC proposes to adopt a **two-step approach** for the presence of **foreign materials**:

- if the plastic recyclate is intended to be used **within the Union**, the limit of foreign materials shall be 2%;
- if the plastic recyclate is intended to be exported **outside the Union**, the limit of foreign materials shall be 0.5% and the output plastic shall consist of one thermoplastic polymer, except for mixtures of PE, PP and PET.

The value of 0.5% is also considerably lower than the value for contaminations in entry B3011 (2%) and is in line with the value proposed by Hong-Kong.

Self-monitoring requirements

While note is taken of the interest shown by some stakeholders in having clear guidelines on testing, the JRC recommends keeping a risk-based approach. This allows the operator to reduce the frequency of testing if the historical results demonstrate that the non-plastic component threshold is met.

Nonetheless, the sampling frequency should be maintained at a suitable level to detect trends and/or other changes in the input batches, and to identify whether the presence of foreign materials above the thresholds is reoccurring. It is proposed to align with EoW legislation on metal scrap already in force ((EU) No 333/2011 for iron, steel and aluminium scrap, (EU) No 715/2013 for copper scrap) by prescribing an analysis of the output materials at least **every 6 months**.

Aligning with the testing requirements of the Food Contact Regulation, as suggested by stakeholders, is not considered appropriate, as this would result in additional and unnecessary administrative burdens for the operators of the treatment facilities that do not produce plastic materials destined for food contact.

6.4.3.3 JRC proposal

The JRC proposal on the limit for non-plastic components is presented in **Table 20**.

Table 20: EoW criteria on product quality – Criterion 3.3

No.	Proposed EoW criteria on product quality	Self-monitoring requirements
3.3	If the output plastic is intended to be used within the European Union, the total amount of foreign materials shall be ≤ 2% of moisture-free output plastic weight. If the output plastic is intended to be exported to countries outside the EU, the threshold of foreign materials shall be ≤ 0.5% of moisture-free output plastic weight and the output plastic shall consist of one thermoplastic polymer, except for mixtures of polyethylene (PE), polypropylene (PP) and/or polyethylene terephthalate (PET). Foreign materials are polymers other than thermoplastics, non-targeted polymers in the recycling operation and non-plastic components. Components that are bound to the polymer matrix as a result of intentional addition with the purpose of enhancing the properties of the polymer (like fillers, barriers, pigments, additives or any other active ingredients typically used in the compounding of plastics) are not counted as non-plastic components. Examples of non-plastic components are metals, paper, glass, earth, sand, ash, dust, wax, bitumen, ceramics and wood.	Qualified staff shall carry out visual inspection of each batch in the consignment, to detect anomalies in product qualities. At appropriate intervals subject to review if significant changes in the operating process are made, representative samples of the moisture-free output plastic shall be analysed gravimetrically to measure the content and nature of foreign materials. The content of foreign materials shall be analysed by weighing in moisture-free conditions. Complementary analytical techniques may be used in the determination of the foreign materials content, such as chromatography or infrared spectroscopy, especially for the purpose of inspection. When the material has undergone thermal treatment to agglomerate or pelletise it, the content of foreign material has to be determined at the latest stage of reprocessing before thermal treatment is applied to the plastic to agglomerate or pelletise it. The appropriate frequencies of monitoring by sampling shall be established taking into account the following factors: (1) the expected pattern of variability of the output plastic composition (for example as shown by historical results); (2) the inherent risk of variability in the quality of the plastic waste used as input for the recycling operation and any subsequent processing; (3) the inherent precision of the monitoring method; and (4) the proximity of results to the limitation of the foreign materials content. The sampling frequency shall in any case be maintained at a suitable level to detect trends and/or other changes in the input materials and shall not be less than 6 months. The process of determining monitoring frequencies shall be documented as part of the quality management system.

6.4.4 Criterion 3.4: Presence of other contaminants

Villanueva & Eder (2014) proposed to include a criterion to ensure that the output material is free from visible chemical or biological contamination such as oil, solvents, paints, or biodegradable substances that could result in mould growth or off-odours. The presence of those contaminations could consequently have negative effects on the production of new plastic products.

6.4.4.1 Stakeholders' feedback

- **Chemical and biological contaminants**: Only a few stakeholders reacted to this criterion. Those who did agreed to have a specific requirement on the presence of possible organic contaminants in the output materials. In this regard, an aspect that has been flagged as a commercial concern is the presence of volatile organic compounds (VOCs) in the material, as there is a high customer demand for odourless recycled plastics.
- **Additional restrictions**: It was also mentioned that the presence of other contaminants, such as pharmaceuticals and pathogens in the output materials should also be considered a possible concern.

6.4.4.2 JRC assessment of feedback

Chemical and biological contaminants

When looking at **national EoW criteria**, in the Spanish and Portuguese EoW decrees there is a requirement for output materials to be free of oils, solvents, paints or liquid/fatty food residues, based on the proposal by Villanueva & Eder (2014).

Villanueva & Eder (2014) acknowledged that the presence of those contaminants could affect the quality of the recyclate and its suitability for specific applications. It was therefore considered worthwhile to include a specific requirement on the presence of chemical contaminants (e.g. solvents, glues, paints) and biological contaminants (e.g. food residues). Cabanes, Valdés, et al. (2020) developed an inventory of around 440 VOCs emitted from virgin and recycled plastics, 80 of which are identified as odour-causing substances. Most of those compounds are classified as volatile or semi-volatile[75] and can remain in the polymer matrix after conversion, lowering the quality of the final product. Cabanes, Valdés, et al. (2020) recognised that the detection and removal of VOCs in recycled plastic is a technical challenge for mechanical recycling.

Similarly, a requirement on the absence of other chemical contaminants or biological contaminants would be difficult to enforce. Given the current state of technology, it does not seem appropriate to prescribe requirements to eliminate chemical and biological contaminants during the recycling process or to prescribe testing of those contaminants in the output materials, unless specifically requested by the customer in the related customer specifications (Criterion 3.2).

Additional restrictions

Plastic wastes that could be linked to possible contamination of pathogens and pharmaceuticals have been excluded as possible input materials (Criterion 1.2). Hence it does not seem necessary to include additional sets of limit values or testing requirements for pathogens or pharmaceuticals for the output materials. This is in line with **national EoW criteria**.

[75] According to the World Health Organization (WHO), VOCs are classified into: very volatile organic compounds (VVOCs) - boiling point <100 °C; volatile organic compounds (VOCs) - boiling point 100-260 °C; semi-volatile organic compounds (SVOCs) - boiling point 260-400 °C.

6.5 Requirements on quality assurance procedures

Quality assurance is a key element of EoW criteria, to assure reliability and verify compliance.

Villanueva & Eder (2014) proposed that the operator of the treatment facility should implement a quality management system (QMS) to demonstrate compliance with the EoW criteria. The QMS shall include documented procedures to monitor the input materials, the treatment steps and the quality of the output materials. It should also serve to record the results of the self-monitoring requirements of each criterion and feedback from customers on the quality of the output material. The QMS should also be certified by a conformity assessment body and be verified every 3 years. Villanueva & Eder (2014) did not make reference to specific international standards on quality management.

6.5.1 Criterion 4.1: Quality management system

6.5.1.1 Stakeholders' feedback

The comments received from stakeholders on the requirements on quality assurance procedures are summarised below.

— **Implementation of a QMS with documented procedures**: The majority of stakeholders agreed that the operator should implement a QMS suitable to demonstrate compliance with the EoW criteria with a given set of documented procedures, including self-monitoring requirements. The proposed approach should ensure reliable data on the quality management system along the whole supply chain. Some stakeholders argued, however, that a mandatory QMS would represent a disproportionate burden for small and medium-sized recyclers and suggested to make it mandatory only for sensitive applications, such as food contact materials.

— **Application of international standards**: There were diverging opinions:

- Certain stakeholders argued that it should not be mandatory to implement international standards, in line with other EoW legislation in place. However, the quality procedures included in the EoW criteria should be compatible with international standards (e.g. EN ISO 9001, EN ISO 14001), to avoid the administrative burden of adapting the QMS, if the operator already implemented international standards. Stakeholders also argued that applying a mandatory standard could limit small and medium-sized enterprises from reaching EoW status, due to the high costs. Other arguments against a specific reference to standards are that those are updated regularly and new standards may become available in the future.
- Some stakeholders suggested to make specific reference to international standards, arguing that EN ISO 9001 is already widely used by recyclers, so this should be a minimum requirement.
- Other stakeholders commented that existing (QMS) standards were not specifically developed for EoW criteria. Therefore, it was suggested to develop a quality procedure specifically targeted to EU-wide EoW criteria, instead of adopting existing standards. Possible references that were mentioned are EN ISO 9001:2015, ISO 14001:2015, EN 15343, ISO/IEC 17021-1:2015, and ISO/IEC 17021-3:2015.

— **Self-monitoring requirements:** As mentioned above, self-monitoring requirements for the individual criteria were criticised in the consultations by a large group of stakeholders. In particular, it was argued that the formulation could lead to different interpretations by operators and verifiers. Another group of stakeholders suggested not to impose too strict and too frequent testing requirements. A few stakeholders suggested that the QMS should also include procedures for monitoring the traceability of chemical compounds.

— **Certification**:

- As regards certification of the QMS itself, it was suggested that only a conformity assessment body which is accredited by an accreditation body successfully peer-evaluated for this activity by the body recognised in Article 14 of Regulation (EC) No 765/2008 should be a certifier. Environmental verifiers should be excluded. Those bodies shall also be in charge of performing inspections.
- Certain stakeholders argued that third-party certification is key to enabling transparency and reliability. Certain certification schemes are becoming a common reference for quality management amongst plastic recyclers (e.g. EuCertPlast, European PET Bottle Platform (EPBP), RecyClass) and could be considered viable options. Other stakeholders would be against the requirement to adhere to third-party certification schemes.

— **Verification of the QMS**:

- Some stakeholders suggested establishing third-party audits for the EoW criteria, including for instance verification of the testing methods used to generate data for monitoring and a characterisation of the quality of the output plastic. It was proposed that these verification procedures could be integrated in regular audits already conducted by a recycler, rather than imposing a separate audit dedicated to verification of EoW compliance only. It was mentioned that Member States should not be entitled to impose separate audits for EoW compliance.
- Some stakeholders commented that verification of the QMS every 3 years may be too long an interval. Other stakeholders argued that, if the QMS were to be based on EN ISO 9001, it would be challenging to carry out an annual verification, as this would increase administrative costs greatly, especially for small and medium-sized enterprises.

6.5.1.2 JRC assessment of feedback

Implementation of a QMS with documented procedures

From the feedback received from stakeholders, there seems to be an overall agreement that the implementation of a QMS should be demanded. Only a few stakeholders were against and suggested imposing it only for sensitive applications. However, considering that EoW plastics should be suitable for the production of various plastic products or articles containing plastic parts, it is not meaningful to make a distinction based on the application. The JRC recognises that quality assurance is key to ensuring a certain level of confidence in the quality of the output materials. It is also important to be able to distinguish consignments meeting EoW criteria from consignments that have not applied for, or do not meet, EoW criteria. Hence, the JRC proposes that **the operator of the treatment facility should be required to implement a QMS** to keep track of the relevant procedures and to demonstrate compliance with the EoW criteria. This is in line with the approach adopted in **national EoW criteria**.

In many aspects **national EoW criteria** show similarities when it comes to the required **documented procedures** (e.g. monitoring of the process and treatment requirements, training of personnel, control of the acceptance of waste undergoing recovery treatment or review and improvement of the quality management system). Member States have implemented some additional country-specific documented procedures though (further details are provided in Annex 2). The JRC suggests to keep the set of documented procedures proposed by Villanueva & Eder (2014), mostly in line with those of Member States. Taking inspiration from the ISO 9001 standard, it is additionally suggested to include procedures to keep track of possible actions taken to improve the performance of the treatment operation, in the event of not fulfilling one of the EoW criteria.

It is clarified that if a QMS system is already in place, the operator of the treatment facility should be allowed to integrate the relevant procedures related to process monitoring and EoW compliance into the existing system.

Application of international standards

National EoW criteria do not mandate an ISO-type procedure for the quality management system. After a careful evaluation of the feedback received, the JRC proposes not to mandate the application of specific standards. This decision is primarily driven by the fact that the implementation of a standardised QMS entails additional costs, which can pose a financial burden, particularly on small and medium-sized companies.

Besides, as mentioned by stakeholders, standards are reviewed periodically and independently, hence a direct reference to standards would lead to the need for amendments. This approach is in line with the EU-wide EoW criteria already in place (e.g. glass cullet or iron and steel scrap) and with **national EoW criteria** (see Annex 2).

A non-exhaustive list of standards for QMS is reported in Section 5.1.2.

Self-monitoring requirements

Self-monitoring requirements have been duly updated in the individual categories of criteria, to address the concerns raised by stakeholders (see also Sections 6.2, 6.3 and 6.4).

Certification

No major changes are proposed regarding the certification of the QMS by a conformity assessment body or an environmental verifier, also in accordance with **national EoW criteria**.

Adherence to the proposed third-party schemes (e.g. EuCertPlast, EPBP, RecyClass) to certify the quality of the output materials should remain voluntary. Hence no explicit reference to those schemes is made in the EoW criteria. This is in line with the **national EoW criteria** for plastic waste.

Verification of the QMS

The JRC agrees in general that an external inspection of the treatment facility could provide additional confidence to the buyer of the output material. It is clarified that conformity assessment bodies will perform relevant inspections, as appropriate, when certifying and verifying the QMS. It is then up to competent authorities designated by the Member States to verify EoW compliance and to perform additional inspections.

The JRC proposes to keep the interval of verification of the QMS procedures to **3 years**, to avoid imposing an additional economic burden on the operators of the treatment facilities. When comparing the JRC approach with **national EoW criteria**, one can conclude that it aligns with Portugal, the only Member State defining the interval for verification. Spain and Finland do not specify an interval for verification of the QMS.

6.5.1.3 JRC proposal

The JRC proposal on the quality management system is presented in **Table 21**.

Table 21: EoW criteria on quality assurance procedures – Criterion 4.1

No.	Proposed EoW criteria on quality assurance procedures
4.1	1. The operator of the treatment facility shall implement a quality management system suitable to demonstrate compliance with the end-of-waste criteria.

	2. The quality management system shall include a set of documented procedures concerning each of the following aspects: (a) monitoring of waste used as input material for the recycling operation and acceptance control (including risk management and control measures); (b) monitoring of the treatment processes and techniques; (c) monitoring of the quality of the output plastic resulting from the recycling operation (including instructions for sampling and analysis and frequency of verification); (d) feedback from customers concerning the quality of the output plastic; (e) record-keeping of the results of monitoring conducted under points (a) to (c); (f) record-keeping of the actions taken to improve the performance of the recycling operation, in the case of non-conformity with the end-of-waste criteria; (g) review and improvement of the quality management system; and (h) training of staff. 3. The quality management system shall also prescribe the specific self-monitoring requirements set out in the end-of-waste criteria for each criterion. 4. The quality management system shall be certified by a conformity assessment body which is accredited by an accreditation body successfully peer-evaluated for this activity by the body recognised in Article 14 of Regulation (EC) No 765/2008[76], or by an environmental verifier which is accredited or licensed by an accreditation or licensing body, as defined respectively in Article 2(30) and 2(31) of Regulation (EC) No 1221/2009[77], which is also subject to peer-evaluation according to Article 31 of Regulation (EC) No 1221/2009. Verifiers who want to operate in third countries must obtain a specific accreditation or licence, in accordance with the specifications laid down in Regulation (EC) No 765/2008 or Regulation (EC) No 1221/2009, the latter together with Commission Decision (EU) No 2011/832[78]. 5. The importer of plastic material resulting as output of treatment facilities based in third countries shall require third-country suppliers to implement a quality management system which complies with the requirements of points 1, 2 and 3 of this criterion and which has been verified by an independent external verifier. 6. A conformity assessment body, as defined in Regulation (EC) No 765/2008, which has obtained accreditation in accordance with that Regulation, or an environmental verifier, as defined in Article 2(20)(b) of Regulation (EC) No 1221/2009, which is accredited or licensed in accordance with that Regulation, shall verify that the quality management system fulfils the requirements on quality assurance procedures. The verification shall be carried out every 3 years. 7. Only verifiers with the following scopes of accreditation or licence based on the NACE Codes as specified in Regulation (EC) No 1893/2006[79] are regarded as having sufficient specific experience to perform the verification mentioned in this Regulation: – NACE Code 20 (Manufacture of chemicals and chemical products); or – NACE Code 22 (Manufacture of rubber and plastic products); or – NACE Code 38 (Waste collection, treatment and disposal activities; material recovery); 8. The operator of the treatment facility shall give competent authorities, as defined in Article 2(26) of Regulation (EC) No 1121/2009, access to the quality management system upon request.

[76] Regulation on setting out the requirements for accreditation and market surveillance relating to the marketing of products and repealing Regulation (EEC) No 339/93.

[77] Regulation on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS), repealing Regulation (EC) No 761/2001 and Commission Decisions (EC) No 2001/681 and (EC) No 2006/193.

[78] Commission Decision concerning a guide on EU corporate registration, third country and global registration under Regulation (EC) No 1221/2009 of the European Parliament and of the Council on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS).

[79] Regulation on establishing the statistical classification of economic activities NACE Revision 2 and amending Council Regulation (EEC) No 3037/90 as well as certain EC Regulations on specific statistical domains. Text with EEA relevance.

6.6 Requirements on provision of information

The requirements on provision of information are complementary to quality criteria. In order to minimise the risk that EoW plastics are diverted to uses different from production of plastic products or articles containing plastic parts, additional requirements are needed, specifically on the statement of conformity.

6.6.1 Criterion 5.1: Statement of conformity

Villanueva & Eder (2014) proposed to include a statement on compliance with the CLP, REACH and POP Regulations and that each consignment should be labelled with the intended use.

6.6.1.1 Stakeholders' feedback

The comments on these requirements received from stakeholders can be summarised as follows:

— **Issuing a statement of conformity**: Stakeholders argued that the mandatory delivery of a statement of conformity is associated with a financial and administrative burden. Larger plastic recyclers should be able to cope with the requirement, but smaller recyclers could face challenges to provide the documentation.

— **Labelling plastic consignments**: While some stakeholders supported the idea of labelling each consignment to increase traceability, other stakeholders argued that recycled plastic is often stored and transported in silos and therefore labelling is not always feasible. Labelling the recycled plastics would pose a considerable burden for the plastic recycler if each batch has to be labelled separately for each sold consignment.

— **Intended use**:

- Stakeholders generally agreed to include a statement on use for production of plastics or articles containing plastic parts. However they argued that the buyer of a plastic recyclate should not be obliged to disclose any information on the use of the acquired good. Besides, in the event that the recycled material is sold to a trader, who in turn resells it to one or more manufacturers, the consignment can be used for the production of different plastic products or articles containing plastic parts. Hence the specific use or application should not be included in the statement of conformity. A mandatory supply-chain certification system was suggested as a possible alternative to trace the end-use of the output material.
- One stakeholder suggested, on the other hand, to include a statement on the type of products to be produced, particularly in the case of food contact material.
- A few stakeholders indicated that the recycler cannot be held responsible for the final use of the recyclate and this should be specified in the statement of conformity.

— **Template for the statement of conformity:** Stakeholders recommended providing a template for the statement of conformity, in line with EU-wide EoW legislation in place. The statement of conformity should include information on weight/volumes.

6.6.1.2 JRC assessment of feedback

Issuing a statement of conformity

The JRC is of the opinion that certain information should be passed on when the plastic recyclate is handed over to the buyer, to ensure traceability. Hence it is proposed to require the producer of the plastic EoW material to issue a statement of conformity. This is in line with the approach followed by all Member States with **national EoW criteria** (see Annex 2).

As regards the retention of copies, **national EoW criteria** require records to be kept for different lengths of time (between 3 years (Spain) and 10 years (Finland), see Annex 2). The JRC proposes to adopt a timeframe of 3 years.

Labelling plastic consignments

The JRC does not propose mandatory labelling of each consignment. It is sufficient that the plastic recycler provides a signed statement of conformity to the next holder of the recycled material. This is in line with **national EoW criteria** (see Annex 2).

Intended use

The suggestion by some stakeholders to prescribe a mandatory supply-chain certification system for the EoW plastic is difficult to implement and is ruled out.

The JRC agrees that the buyer of a plastic recyclate should not be obliged to disclose information on the use of the recycled plastic, in terms of the type of plastic product that is to be produced, considering that this is not always clear, especially when the material is sold to a trader. However, there should be a general clause in the statement of conformity, to avoid the EoW material being diverted to other uses and to ensure that correct reporting of the actual level of plastic recycling is not jeopardised.

The Waste Framework Directive (EU 2018/851, amending Directive 2008/98/EC) and the Packaging and Packaging Waste Directive (EU 2018/852, amending Directive 94/62/EC) lay down recycling targets for municipal waste and for packaging waste, respectively, including for plastic waste.

Commission Implementing Decision (EU) 2019/1004[80] and Commission Implementing Decision (EU) 2019/665[81] lay down rules for calculation, verification and reporting of data. Notably, they establish the calculation points for recycling[82].

Recital 2 of Implementing Decision (EU) 2019/1004 reads: "*The rules set out in Article 11a of Directive 2008/98/EC specify that, as regards recycling, waste that enters a recycling operation or* ***waste that has achieved end of waste status*** *is to be used for the calculation of the targets for 2025, 2030 and 2035.*"

Article 3(3) of that Decision establishes that waste that has ceased to be waste at the calculation point specified in Annex I (namely for plastics: "*plastic separated by polymers that does not undergo further processing before entering pelletisation, extrusion, or moulding operations. Plastic flakes that do not undergo further processing before their use in a final product.*") shall be included in the amount of recycled municipal waste.

Similarly, Recital 3 of Implementing Decision (EU) 2019/665 reads: "*The calculation rules for the attainment of the packaging and packaging waste targets for 2025 and 2030 established in Article 6a(1) and (2) of Directive 94/62/EC clarify that only waste that enters a recycling operation or* ***waste that has achieved end of waste status*** *should be used for the calculation of the recycling target […].*"

Hence, as soon as the plastic recyclates obtain EoW status they can be counted as recycled. It is important to avoid possible double counting on recycling. Therefore, if the material is used for

---

80 Commission Implementing Decision (EU) 2019/1004 of 7 June 2019 laying down rules for the calculation, verification and reporting of data on waste: https://eur-lex.europa.eu/eli/dec_impl/2019/1004/oj

81 Commission Implementing Decision (EU) 2019/665 of 17 April 2019 amending Decision 2005/270/EC establishing the formats relating to the database system pursuant to European Parliament and Council Directive 94/62/EC on packaging and packaging waste: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019D0665

82 'Calculation point' means the point where municipal waste materials enter the recycling operation whereby waste is reprocessed into products, materials or substances that are not waste or the point where waste materials **cease to be waste** as a result of a preparatory operation before being reprocessed.

purposes other than those allowed in the current proposal (i.e. production of plastic products or articles containing plastic parts), the material should revert to waste status and the recycler should be informed of this, in order to be able to report correct EoW volumes. This is particularly relevant with regard to waste statistics and to the plastics own resource mechanism[83]. The latter consists of a national contribution based on the amount of non-recycled plastic packaging waste. For plastics, Member States will have to pay a sum of EUR 0.80 for every kg of plastic packaging waste that is not recycled. The contributions are calculated based on Eurostat data, which Member States already collect and provide under existing reporting obligations for plastic packaging waste generation and recycling.

To address this issue, the JRC proposes to include the following paragraph in the statement of conformity: "*The material in this consignment is intended to be used exclusively for the manufacture of plastic products or articles containing plastic parts. It must not be converted directly or indirectly to energy or non-plastic materials or used for any other purpose. Where these conditions are not met, the user of the plastic material shall handle it as waste and shall inform the producer, for the purpose of maintaining and reporting correct information on end-of-waste volumes*".

It is also proposed to add a unique identifier code, to easily identify EoW consignments which may have been used for other purposes.

Template for the statement of conformity

The JRC welcomes the proposal made by stakeholders to provide a template for the statement of conformity in the JRC report. The template for the statement of conformity enhances traceability of the recycled plastic.

Terminology

The JRC proposes to use the term 'output plastic' to refer to the candidate EoW material and the term 'plastic recyclate' to refer to the recycled plastic material that has achieved EoW status.

6.6.1.3 JRC proposal

The JRC proposal on the statement of conformity is presented in **Table 22**.

Table 22: EoW criteria on provision of information – Criterion 5.1

No.	Proposed EoW criteria on provision of information
5.1	The producer or the importer shall issue, for each consignment of output plastic complying with end-of-waste criteria, a statement of conformity as set out in the template. The producer or the importer shall transmit the statement of conformity to the next holder of the consignment. They shall retain a copy of the statement of conformity for at least 3 years after its date of issue and shall make it available to competent authorities upon request. The statement of conformity is preferably issued in electronic form.

Table 23 contains the proposal for the statement of conformity to be used by the producer/importer of the plastic EoW material.

Table 23: JRC technical proposal for the statement of conformity template

1.	Unique identification code of the consignment:

[83] Plastics own resource: https://commission.europa.eu/strategy-and-policy/eu-budget/long-term-eu-budget/2021-2027/revenue/own-resources/plastics-own-resource_en

	Producer/importer of the plastic recyclate: Name: Address: Contact person: Tel.: E-mail:
2.	Quantity of the consignment in tonnes:
3.	a) Name or code of the plastic recyclate category in accordance with a customer specification, an industry specification or standard: b) Main technical provisions of the customer specification, industry specification or standard, including compliance with end-of-waste product quality requirements for foreign materials:
4.	The plastic recyclate consignment complies with a customer specification, industry specification or a standard referred to in point 3.
5.	The plastic recyclate consignment meets the criteria on input materials (1.1, 1.2 and 1.3), on treatment processes and techniques (2.1, 2.2 and 2.3), and on product quality (3.1, 3.2 and 3.3).
6.	The plastic recyclate in this consignment is not classified as hazardous pursuant to Article 3 of and Annex I to Regulation (EC) No 1272/2008 (CLP); The substances contained within the plastic recyclate in this consignment comply with Regulation (EC) No 1907/2006 (REACH), including but not limited to compliance with Article 56 setting out authorisation provisions for uses of substances listed in Annex XIV to REACH and for their placing on the market as well as the conditions laid down in Article 67 for the manufacture, placing on the market and use of substances restricted in Annex XVII[84] to REACH; and The substances contained within the plastic recyclate in this consignment meet the provisions limiting the manufacturing, placing on the market and use of persistent organic pollutants (POPs) pursuant to Article 3 of and Annex I to Regulation (EU) No 2019/1021.
7.	The producer of the plastic recyclate applies a quality management system verified by an accredited conformity assessment body or by an environmental verifier or, where plastic waste which has ceased to be waste is imported into the customs territory of the European Union, by an independent external verifier.
8.	The material in this consignment is intended to be used exclusively for the manufacture of plastic products or articles containing plastic parts. It must not be converted directly or indirectly to energy or non-plastic materials or used for any other purpose. Where these conditions are not met, the user of the plastic recyclate shall handle it as waste and shall inform the producer, for the purpose of maintaining and reporting correct information on end-of-waste volumes.
9.	Declaration of the producer/importer of the plastic recyclate: I certify that the above information is complete and correct to the best of my knowledge: Name: Date: Signature:

[84] Including the latest amendment of Annex XVII (Regulation (EU) No 2023/923).

6.7 Comparison of JRC proposals for EU-wide EoW criteria with national EoW criteria

As mentioned in Section 5.4, only two Member States (Portugal and Spain) have implemented a national EoW decree for plastic waste. Finland notified a draft EoW decree to the Commission.

The JRC proposals for EU-wide EoW criteria presented above are compared with the national EoW criteria of these three Member States, in line with the requirements laid down in Article 6(2) of the Waste Framework Directive, to take account of existing national EoW criteria and to use as a starting point the most stringent and environmentally protective of those criteria.

An overall comparison aims at justifying possible deviations from national EoW provisions and at showcasing the robustness of the JRC proposals.

It is to be anticipated that, in some cases, the comparison is not straightforward, as different approaches are used. For example, stricter requirements on input materials can lead to less stringent requirements on processes and techniques or on output materials.

6.7.1 Comparison with EoW criteria implemented in Portugal

It may be noticed that Portugal used as a basis the proposals for EU-wide EoW criteria for plastic waste for conversion by Villanueva & Eder (2014).

The scope of plastic polymers and recycling technologies as well as the criteria are in fact mostly in line with the JRC proposals from 2014. Considering that the JRC proposals presented in this document differ in some instances from the JRC proposals made in 2014, some differences are identified in the Portuguese EoW criteria when comparing them with the latest JRC proposals, notably:

- bio-waste and used personal hygiene products are restricted as input materials;
- different types of plastic waste to be used as input have to be stored separately;
- plastic waste to be used as input must be subject to a pre-treatment to remove as many contaminants as possible, such as non-plastic components and hazardous substances;
- the output material must be free of fluids and leachables, namely oils, solvents, glues, paints and aqueous and/or fatty foodstuffs that can be detected by visual inspection and/or olfactory test, with the exception of trace amounts that are not enough for droplets to form[85].

As explained above (see Section 6.2.2), the JRC does not deem it necessary to explicitly mention bio-waste as a restricted source, as there are safe cleaning techniques able to separate plastic waste from bio-waste. The restriction of personal hygiene products proposed by Villanueva & Eder (2014) has been narrowed down to the stream of absorbent hygiene products. The slightly more lenient requirements on input materials proposed by the JRC compared to Portugal are justified by the arguments provided by stakeholders and the state-of-the-art technology for sorting and recycling.

As discussed in Section 6.3.1, the requirement on separate storage of different types of plastic waste seems too onerous for the recycler and it does not reflect common practices in the industry.

The JRC proposes to request a mandatory pre-treatment of input materials only if mandated by the legislation, as in the case of plastic waste containing POPs (see Section 6.2.1) or plastic waste originating from WEEE and ELVs (see Section 6.2.3). The recycler will have to make sure that the output materials comply with the relevant provisions of the CLP, REACH and POP Regulations,

[85] This criterion also defines corresponding self-monitoring criteria such as visual inspection, training of personnel and recording in the QMS.

including relevant limit values for the presence of various substances. Overall, stricter requirements on the output materials are considered to balance more lenient requirements on input materials, while avoiding cost- and time-intensive testing on the input materials.

The requirement for the output materials to be free of fluids and leachables was part of the proposals by Villanueva & Eder (2014) and it was not retained in the current JRC proposal, as it is difficult to enforce (see Section 6.4.4).

Further details on the Portuguese EoW criteria are given in Annex 2.

6.7.2 Comparison with EoW criteria implemented in Spain

As in the case of Portugal, Spain used the proposals by Villanueva & Eder (2014) as the basis for the development of EoW criteria. Consequently, the Spanish EoW criteria are mostly in line with the JRC proposals made in 2014. Few differences are identified when comparing them with the latest JRC proposals presented in this document.

The main difference with regards to input material requirements is that in the Spanish EoW decree there is a positive list of input materials that can be used as input (listed by waste codes). The JRC proposes a different approach, namely a negative list of input materials that cannot be used as input (see Section 6.2.2), complemented by additional requirements for specific waste streams that are considered to be potentially harmful (see Sections 6.2.1 and 6.2.3). Thus, overall, the criteria for input materials proposed by the JRC cannot be considered more lenient; they are instead more targeted and also future-proof (a positive list of plastic waste could possibly require an amendment of the EoW criteria to add new entries).

With regard to POPs waste, Spain is more stringent, as plastic wastes exceeding the limit values defined in Annex IV to the POP Regulation are not allowed as input, whereas in the current proposal POPs waste is allowed as input as long as it is pre-treated to meet the limit values of Annex IV to the POP Regulation and the output material meets the concentration limits in Annex I to the POP Regulation (see Section 6.2.1). The JRC approach aims at stimulating the recycling market, while remaining open to technological advancements. Both current and emerging technologies have the potential to effectively eliminate POPs from plastic waste, such as through physical recycling.

In the Spanish EoW decree additional requirements are defined for output materials intended for food contact applications, namely the absence of non-plastic components, the absence of foreign bodies and the absence of plastic textile fibres. In contrast, the JRC proposes not to list the requirements mandated by Regulation (EC) No 2022/1616, as those apply only to output materials intended to be used for food contact (see Section 6.4.1). The omission of this requirement is not considered to be less lenient, as plastic recyclates to be used for food contact applications will have to comply with the relevant provisions for food contact.

When it comes to the requirements on processes and techniques, Spain lists certain minimum treatment steps that have to be completed (sorting and shredding) and additional treatment steps depending on the plastic type and intended use. In the JRC proposals there is no given sequence of treatment steps, justified by the fact that a wider range of input materials are allowed as input and also considering that the JRC proposals cover not only mechanical recycling but also physical recycling, making it hence unfeasible to request specific treatment steps (see Section 6.3.2).

In the Spanish EoW criteria there is explicit reference to the standards to be applied for the characterisation of the output material as well as for sampling (in line with the proposals by Villanueva & Eder (2014)). As discussed in Section 6.4.2, the JRC generally refrains from making reference to specific standards, as current standards do not cover all polymers under the scope and are updated periodically.

Similarly to in the Portuguese EoW criteria, the Spanish EoW criteria include a requirement on the absence of oils and fatty foodstuffs, notably if signs of absorption of fluids that may lead for example to mould growth or odours are identified by visual inspection, that the batch should be

considered waste. As stated above, the requirement for the output materials to be free of fluids and leachables was not retained in the current JRC proposal, as it is difficult to enforce (see Section 6.4.4).

Further details on the Spanish EoW criteria are given in Annex 2.

6.7.3 Comparison with EoW criteria proposed by Finland (notified)

Finland follows an approach similar to the one used by Spain as regards restriction of sources, namely the definition of a positive list of plastic waste allowed as input (plastic waste from the manufacture of plastics and plastic products, plastic construction waste, other separately collected plastic waste and plastic waste separated from mixed waste). Only non-hazardous plastic waste is allowed as input material. Furthermore, plastic waste used for packaging and storage of substances with hazardous properties and plastic waste which may substantially impair the output material are also restricted. The requirements on input materials imposed by Finland are stricter than the ones proposed by the JRC. As explained above, the JRC approach of adopting a negative list is considered more targeted and future-proof.

As regards treatment requirements, in the Finnish EoW decree separate transport and storage of the different materials allowed as input is mandated and pre-processing of plastic waste is demanded, in order to remove non-plastic waste or plastic waste containing significant quantities of impurities.

When looking at the requirements on product quality applicable to output materials, the Finnish approach can be considered more lenient than the JRC approach. In fact, no limit values for foreign materials are defined for the output materials; the operator has to determine certain parameters such as the melt flow index and the fraction of the main polymers.

The JRC proposals strive to find a balance to promote an increase in recycling rates on the one hand and to minimise potential negative effects on human health and environment on the other hand. Overall, it can be concluded that, despite having less strict requirements on input materials, potential impacts that could result from the use of the plastic recyclate are controlled through stricter requirements on output materials, including testing and compliance with chemicals legislation.

Further details on the EoW criteria proposed by Finland are given in Annex 2.

7 Conclusions and recommendations

The objective of this work was to provide technical recommendations for EU-wide end-of-waste criteria for plastic waste, in accordance with Article 6 of Directive 2008/98/EC. The selection of plastic waste as the focus of this study was based on the results of a scoping exercise conducted by Orveillon et al. (2022) to identify top-priority streams for the development of EU-wide end-of-waste or by-product criteria, with plastic waste being identified as the highest priority stream for end-of-waste criteria.

The report provides background information on plastics, plastic waste and the recycling value chain, along with additional pertinent details for the development of end-of-waste criteria. Specifically, it covers market-related aspects, technical requirements and standards, relevant legislation, as well as environmental and human health impacts. Additionally, it offers an overview and in-depth analysis of national end-of-waste criteria in EU Member States.

The JRC has developed the technical recommendations presented in this report based on input from key stakeholders in the plastic value chain. The JRC organised a total of three stakeholder events and carried out two written consultations to collect additional evidence for the development of EoW criteria, as well as to receive feedback on the initial proposals by Villanueva & Eder (2014) and subsequently on the preliminary proposals by the authors of this report. Site visits and bilateral meetings were also key to getting a better overview of the state of technology for plastic recycling across Europe and to understanding possible implications of EoW criteria.

In adherence to the requirements of Article 6(2), the proposed criteria have been carefully pondered, by drawing a thorough comparison of the JRC approach with national EoW criteria for plastic waste in Member States.

The technical proposals consist of a single set of end-of-waste criteria, applicable to **recycling processes that are able to treat thermoplastic polymer waste and blends of thermoplastic polymer waste without deliberately altering the molecular structure of the polymers**[86], with the exception of damage that is repaired within the process[87].

In line with the JRC methodology by Delgado et al. (2009) (cf. Article 6(2) of Directive 2008/98/EC), the EoW criteria encompass five main categories, namely **input materials**, **treatment processes and techniques**, **product quality**, **quality assurance** and **provision of information**.

Criteria on input materials include restrictions on feedstock or conditional requirements for specific plastic waste streams to be used as feedstock for the recycling operation.

Criteria on treatment processes and techniques lay down requirements for separate storage of input and output materials, on the recycling operation itself and specifically on the treatment of problematic waste streams.

Criteria on product quality include requirements to comply with product legislation, standards and technical specifications and establish limit values for foreign materials in the plastic recyclate.

Criteria on quality procedures establish the mandatory implementation of a quality management system with a given set of documented procedures. They also encompass self-monitoring requirements for each criterion.

Criteria on provision of information lay down a requirement for the producer (or importer) of plastic EoW to issue a statement of conformity.

The proposed EU-wide end-of-waste criteria for plastic waste are summarised in **Table 24**.

---

[86] Including mechanical recycling and physical recycling using solvent, among others.

[87] For example through solid-state polycondensation (SSP).

Table 24: JRC technical proposals for EU-wide end-of-waste criteria and self-monitoring requirements for plastic waste

No	Proposed end-of-waste criteria	Proposed self-monitoring requirements
Requirements on input materials		
1.1	Hazardous plastic waste and plastic waste containing hazardous substances shall not be used as input, unless it can be treated to the extent that the output plastic[88], resulting from the recycling operation are not classified as hazardous pursuant to Article 3 of and Annex I to Regulation (EC) No 1272/2008 (CLP). Plastic waste containing substances restricted under Regulation (EC) No 1907/2006 (REACH) shall not be used as input, unless it can be treated to the extent that substances on their own or in mixtures, resulting from the recycling operation comply with that Regulation, including but not limited to compliance with Article 56 setting out authorisation provisions for uses of substances listed in Annex XIV to REACH and for their placing on the market as well as the conditions laid down in Article 67 for the manufacture, placing on the market and use of substances restricted in Annex XVII[89] to REACH. Plastic waste containing POP concentrations above the limit values pursuant to Annex IV to Regulation (EU) No 2019/1021[90] on persistent organic pollutants (POPs) shall not be used as input, unless: (a) a (pre-)treatment step is in place that is able to generate an input fraction for the recycling operation with POP concentrations below the limit values defined in Annex IV to that Regulation; and (b) the applied treatment processes and techniques are able to treat this input fraction, to the extent that substances on their own or in mixtures , resulting from the recycling operation meet the provisions limiting the manufacturing,	Acceptance control by visual inspection of all plastic waste received and of the accompanying documentation shall be carried out by qualified staff. In particular, the operator shall request documentation on the origin of the material. The operator of the treatment facility shall apply appropriate control measures to detect hazardous waste and waste containing hazardous substances or other substances restricted under the REACH and POP Regulations. The control measures shall be documented under the quality management system. Particular attention shall be paid to plastic material input originating from waste electric and electronic equipment (WEEE), end-of-life vehicles (ELVs), construction and demolition waste (CDW) as well as waste batteries, which are more likely to contain those substances. For plastic waste containing POPs, the (pre-)treatment steps to separate the POPs content shall be documented under the quality management system.

[88] The output of a recovery operation can result: i) in a substance on its own, ii) in a mixture (e.g. plastics, rubber) or, iii) potentially, in an article recovered directly from waste, as referred to in the Guidance on Waste and Recovered Substances (ECHA, 2010). It is to be noted that the CLP Regulation does not cover the hazard classification of articles (except for explosive and pyrotechnic articles). Nonetheless, the system boundaries of the present technical proposals for the EoW criteria exclude the point at which articles are formed (see section 6.1.3). In line with this, the reference to hazardousness should apply to the classification of the material as a mixture, if the operator considers the output to be a mixture, or otherwise, as a substance (including a UVCB substance). As indicated in the referred guidance, it is up to the relevant operator to decide which of the two options best fits the characteristics of the material.

[89] Including the latest amendment of Annex XVII (Regulation (EU) No 2023/923).

[90] Including the last amendment of Annexes IV and V (Regulation (EU) 2022/2400).

	placing on the market and use of persistent organic pollutants (POPs) pursuant to Article 3 of and Annex I to Regulation (EU) No 2019/1021.	
1.2	Plastic waste to be used as input may originate from any source of waste containing plastics. The following materials shall not be used as input: (a) healthcare waste, except non-hazardous plastic healthcare waste that has been segregated at source; and (b) used absorbent hygiene products.	The operator of the treatment facility shall define appropriate risk management measures to identify and remove contaminated batches. Acceptance control by visual inspection and analysis of accompanying documentation of all plastic-containing waste received shall be carried out by qualified staff who are trained on how to recognise plastic-containing input restricted under this criterion. The operator of the treatment facility shall apply appropriate control measures to ensure that plastic healthcare waste used as input does not present hazardous properties. Specifically, the operator shall request documentation on the origin, segregation, storage and transport of this waste stream. The control measures shall be documented under the quality management system. The operator of the treatment facility shall keep track of the plastic waste used as input material (date of receipt, supplier, origin, type and quantity of plastic waste received) and the plastic waste streams that have been rejected (date of rejection, supplier, origin, type, quantity of plastic waste and reason for rejection). The data shall be recorded under the quality management system.
1.3	Additional treatment requirements shall apply to input materials originating from selected sources: (a) input materials that originate from waste electrical or electronic equipment shall have undergone all treatments[91] required by Article 8 of and Annex VII to Directive (EU) No 2012/19 (WEEE); and (b) input materials that originate from end-of-life vehicles shall have undergone all treatments required by Article 6 of and Annex I to Directive (EU) No 2000/53 (ELVs).	When accepting input materials originating from WEEE and ELVs, the operator of the treatment facility shall request the previous holder to provide documentation of compliance with the relevant treatment requirements for WEEE and ELVs. This documentation shall be recorded under the quality management system.
Requirements on treatment processes and techniques		
2.1	Plastic waste eligible to be used as input material shall, once received by the operator of	The procedures carried out to fulfil the separate storage requirements for input and output

[91] The removal of plastic containing brominated flame retardants from separately collected WEEE can be seen as an integral part of the plastic recycling process.

	the treatment facility, be stored separately from non-eligible input materials, to avoid contamination. Output materials that comply with the EoW criteria shall be stored separately from any waste material not complying with the EoW criteria.	materials laid down in this criterion shall be documented under the quality management system.
2.2	The recycling operation shall be able to treat plastic waste without deliberately altering the molecular structure of the polymers, with the exception of damage that is repaired within the process. The recycling operation shall include all treatment steps needed to prepare the output plastic to be used as input for the production of plastic products or articles containing plastic parts.	The sequence of treatment steps shall be documented under the quality management system.
2.3	Materials originating from any source that are eligible to be used as input (cf. Criteria 1.1, 1.2 and 1.3) shall be treated to the extent that: (a) the output plastic[92] is not classified as hazardous pursuant to Article 3 of and Annex I to Regulation (EC) No 1272/2008 (CLP); (b) substances on their own or in mixtures, resulting from the recycling operation comply with Regulation (EC) No 1907/2006 (REACH), including but not limited to compliance with Article 56 setting out authorisation provisions for uses of substances listed in Annex XIV to REACH and for their placing on the market as well as the conditions laid down in Article 67 for the manufacture, placing on the market and use of substances restricted in Annex XVII[93] to REACH; and (c) substances on their own or in mixtures, resulting from the recycling operation meet the provisions limiting the manufacturing, placing on the market and use of persistent organic pollutants (POPs) pursuant to Article 3 of and Annex I to Regulation (EU) No 2019/1021. As per Article 18(1) of Directive 2008/98/EC, hazardous plastic waste used as input shall not be mixed with the sole purpose of dilution. The derogations established in Article 18(2) shall	Particular attention shall be paid to the processing of hazardous waste and plastic waste that may contain hazardous substances or other substances restricted under the REACH and POP Regulations, as indicated in the criterion. The procedure and method used to comply with the substance concentration requirements of the CLP, REACH and POP Regulations shall be documented under the quality management system.

[92] See footnote 88.

[93] Including the latest amendment of Annex XVII (Regulation (EU) No 2023/923).

	apply. The same restrictions shall apply to plastic waste with POP concentrations above the limit values established in Annex IV to Regulation (EU) No 2019/1021.	
Requirements on product quality		
3.1	The following conditions shall be fulfilled: (a) the output plastic[94] resulting from the recovery operation shall not be classified as hazardous pursuant to Article 3 of and Annex I to Regulation (EC) No 1272/2008 (CLP); (b) substances on their own or in mixtures, resulting from the recycling operation shall comply with Regulation (EC) No 1907/2006 (REACH), including but not limited to compliance with Article 56 setting out authorisation provisions for uses of substances listed in Annex XIV to REACH and for their placing on the market as well as the conditions laid down in Article 67 for the manufacture, placing on the market and use of substances restricted in Annex XVII[95] to REACH; and (c) substances on their own or in mixtures, resulting from the recycling operation shall meet the provisions limiting the manufacturing, placing on the market and use of persistent organic pollutants (POPs) pursuant to Article 3 of and Annex I to Regulation (EU) No 2019/1021.	The assessment of compliance with Regulation (EC) No 1272/2008 (CLP), Regulation (EC) No 1907/2006 (REACH) and Regulation (EU) No 2019/1021 (POPs) has to be concluded from a qualitative and quantitative characterisation of the output plastic in the consignment. Relevant exemptions laid down in the REACH, CLP and POP Regulations shall apply. At appropriate intervals subject to review if significant changes in the operating process are made, representative samples of the output plastic shall be analysed to measure the concentration and nature of hazardous substances and substances restricted under the REACH and POP Regulations, as indicated in the criterion. The appropriate frequencies of monitoring by sampling shall be established taking into account the following factors: (1) the expected pattern of variability of the output plastic composition (for example as shown by historical results); (2) the inherent risk of variability in the quality of the waste used as input for the recycling operation and any subsequent processing, for instance the higher average content of plastics containing hazardous substances and substances restricted under the REACH and POP Regulations; (3) the inherent precision of the monitoring method; and (4) the proximity of results to the concentration thresholds that render the material hazardous or restrict its commercialisation. The process of determining monitoring frequencies shall be documented as part of the quality management system.
3.2	The output plastic shall demonstrably fulfil all legal requirements and shall comply with customer specifications, industry specifications	Qualified staff shall verify that each batch in the consignment complies with the legal requirements and appropriate specifications or

[94] See footnote 88.
[95] Including the latest amendment of Annex XVII (Regulation (EU) No 2023/923).

	or standards for the use of the material in the production of plastic products or articles containing plastic parts.	standards. The frequency of verification shall be defined in accordance with the characteristics of the plastic waste stream treated.
3.3	If the output plastic is intended to be used within the European Union, the total amount of foreign materials shall be ≤ 2% of moisture-free output plastic weight. If the output plastic is intended to be exported to countries outside the EU, the threshold of foreign materials shall be ≤ 0.5% of moisture-free output plastic weight and the output plastic shall consist of one thermoplastic polymer, except for mixtures of polyethylene (PE), polypropylene (PP) and/or polyethylene terephthalate (PET). Foreign materials are polymers other than thermoplastics, non-targeted polymers in the recycling operation and non-plastic components. Components that are bound to the polymer matrix as a result of intentional addition with the purpose of enhancing the properties of the polymer (like fillers, barriers, pigments, additives or any other active ingredients typically used in the compounding of plastics) are not counted as non-plastic components. Examples of non-plastic components are metals, paper, glass, earth, sand, ash, dust, wax, bitumen, ceramics and wood.	Qualified staff shall carry out visual inspection of each batch in the consignment, to detect anomalies in product qualities. At appropriate intervals subject to review if significant changes in the operating process are made, representative samples of the moisture-free output plastic shall be analysed gravimetrically to measure the content and nature of foreign materials. The content of foreign materials shall be analysed by weighing in moisture-free condition. Complementary analytical techniques may be used in the determination of the foreign materials content, such as chromatography or infrared spectroscopy, especially for the purpose of inspection. When the material has undergone thermal treatment to agglomerate or pelletise it, the content of foreign material has to be determined at the latest stage of reprocessing before thermal treatment is applied to the plastic to agglomerate or pelletise it. The appropriate frequencies of monitoring by sampling shall be established taking into account the following factors: (1) the expected pattern of variability of the output plastic composition (for example as shown by historical results); (2) the inherent risk of variability in the quality of the plastic waste used as input for the recycling operation and any subsequent processing; (3) the inherent precision of the monitoring method; and (4) the proximity of results to the limitation of the foreign materials content. The sampling frequency shall in any case be maintained at a suitable level to detect trends and/or other changes in the input materials and shall not be less than 6 months. The process of determining monitoring frequencies shall be documented as part of the quality management system.
Requirements on quality assurance procedures		
4.1	1. The operator of the treatment facility shall implement a quality management system suitable to demonstrate compliance with the end-of-waste criteria.	

	2. The quality management system shall include a set of documented procedures concerning each of the following aspects: (a) monitoring of waste used as input material for the recycling operation and acceptance control (including risk management and control measures); (b) monitoring of the treatment processes and techniques; (c) monitoring of the quality of the output plastic resulting from the recycling operation (including instructions for sampling and analysis and frequency of verification); (d) feedback from customers concerning the quality of the output plastic; (e) record-keeping of the results of monitoring conducted under points (a) to (c); (f) record-keeping of the actions taken to improve the performance of the recycling operation, in the case of non-conformity with the end-of-waste criteria; (g) review and improvement of the quality management system; and (h) training of staff. 3. The quality management system shall also prescribe the specific self-monitoring requirements set out in the end-of-waste criteria for each criterion. 4. The quality management system shall be certified by a conformity assessment body which is accredited by an accreditation body successfully peer-evaluated for this activity by the body recognised in Article 14 of Regulation (EC) No 765/2008[96], or by an environmental verifier which is accredited or licensed by an accreditation or licensing body, as defined respectively in Article 2(30) and 2(31) of Regulation (EC) No 1221/2009[97], which is also subject to peer-evaluation according to Article 31 of Regulation (EC) No 1221/2009. Verifiers who want to operate in third countries must obtain a specific accreditation or licence, in accordance with the specifications laid down in Regulation (EC) No 765/2008 or Regulation (EC) No 1221/2009, the latter together with Commission Decision (EU) No 2011/832[98]. 5. The importer of plastic material resulting as output of treatment facilities based in third countries shall require third-country suppliers to implement a quality management system which complies with the requirements of points 1, 2 and 3 of this criterion and which has been verified by an independent external verifier. 6. A conformity assessment body, as defined in Regulation (EC) No 765/2008, which has obtained accreditation in accordance with that Regulation, or an environmental verifier, as defined in Article 2(20)(b) of Regulation (EC) No 1221/2009, which is accredited or licensed in accordance with that Regulation, shall verify that the quality management system fulfils the requirements on quality assurance procedures. The verification shall be carried out every 3 years. 7. Only verifiers with the following scopes of accreditation or licence based on the NACE Codes as specified in Regulation (EC) No 1893/2006[99] are regarded as having sufficient specific experience to perform the verification mentioned in this Regulation: – NACE Code 20 (Manufacture of chemicals and chemical products); or – NACE Code 22 (Manufacture of rubber and plastic products); or – NACE Code 38 (Waste collection, treatment and disposal activities; material recovery); 8. The operator of the treatment facility shall give competent authorities, as defined in Article 2(26) of Regulation (EC) No 1121/2009, access to the quality management system upon request.

[96] Regulation on setting out the requirements for accreditation and market surveillance relating to the marketing of products and repealing Regulation (EEC) No 339/93.

[97] Regulation on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS), repealing Regulation (EC) No 761/2001 and Commission Decisions (EC) No 2001/681 and (EC) No 2006/193.

[98] Commission Decision concerning a guide on EU corporate registration, third country and global registration under Regulation (EC) No 1221/2009 of the European Parliament and of the Council on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS).

[99] Regulation on establishing the statistical classification of economic activities NACE Revision 2 and amending Council Regulation (EEC) No 3037/90 as well as certain EC Regulations on specific statistical domains. Text with EEA relevance.

Requirements on provision of information	
5.1	The producer or the importer shall issue, for each consignment of output plastic complying with end-of-waste criteria, a statement of conformity as set out in the template. The producer or the importer shall transmit the statement of conformity to the next holder of the consignment. They shall retain a copy of the statement of conformity for at least 3 years after its date of issue and shall make it available to competent authorities upon request. The statement of conformity is preferably issued in electronic form.

Table 25 contains the proposal for the statement of conformity to be used by the producer/importer of the plastic EoW material, already presented in Section 6.6.

Table 25: JRC technical proposal for the statement of conformity template

1.	Unique identification code of the consignment: Producer/importer of the plastic recyclate: Name: Address: Contact person: Tel.: E-mail:
2.	Quantity of the consignment in tonnes:
3.	a) Name or code of the plastic recyclate category in accordance with a customer specification, an industry specification or standard: b) Main technical provisions of the customer specification, industry specification or standard, including compliance with end-of-waste product quality requirements for foreign materials:
4.	The plastic recyclate consignment complies with a customer specification, industry specification or a standard referred to in point 3.
5.	The plastic recyclate consignment meets the criteria on input materials (1.1, 1.2 and 1.3), on treatment processes and techniques (2.1, 2.2 and 2.3), and on product quality (3.1, 3.2 and 3.3).
6.	The plastic recyclate in this consignment is not classified as hazardous pursuant to Article 3 of and Annex I to Regulation (EC) No 1272/2008 (CLP); The substances contained within the plastic recyclate in this consignment comply with Regulation (EC) No 1907/2006 (REACH), including but not limited to compliance with Article 56 setting out authorisation provisions for uses of substances listed in Annex XIV to REACH and for their placing on the market as well as the conditions laid down in Article 67 for the manufacture, placing on the market and use of substances restricted in Annex XVII[100] to REACH; and The substances contained within the plastic recyclate in this consignment meet the provisions limiting the manufacturing, placing on the market and use of persistent organic pollutants (POPs) pursuant to Article 3 of and Annex I to Regulation (EU) No 2019/1021.

[100] Including the latest amendment of Annex XVII (Regulation (EU) No 2023/923).

7.	The producer of the plastic recyclate applies a quality management system verified by an accredited conformity assessment body or by an environmental verifier or, where plastic waste which has ceased to be waste is imported into the customs territory of the European Union, by an independent external verifier.
8.	The material in this consignment is intended to be used exclusively for the manufacture of plastic products or articles containing plastic parts. It must not be converted directly or indirectly to energy or non-plastic materials or used for any other purpose. Where these conditions are not met, the user of the plastic recyclate shall handle it as waste and shall inform the producer, for the purpose of maintaining and reporting correct information on end-of-waste volumes.
9.	Declaration of the producer/importer of the plastic recyclate: I certify that the above information is complete and correct to the best of my knowledge: Name: Date: Signature:

Finally, the JRC would like to mention that, following publication of the present document and its technical proposals for EoW criteria, DG Environment may decide to initiate the process towards the potential adoption of an implementing act. Nonetheless, it should be stressed that the drawing up of technical recommendations by the JRC does not imply any commitment whatsoever by the Commission to adopt EoW criteria for plastic waste. Moreover, the Commission, should it decide to proceed with adopting EoW criteria, is not bound by the proposals in this document and is free to introduce further changes to the proposals.

References

ACE. (2024). *Beverage carton - Recycling facts & figures. Alliance for beverage cartons and the environment. ACE aisbl and EXTR:ACT*. https://www.beveragecarton.eu/wp-content/uploads/2023/10/JAN2024_ACE-Recycling_BROCHURE-copy.pdf

Albizzati, P. F., Antonopoulos, I., Caro, D., CRISTOBAL GARCIA, J., Egle, L., Gaudillat, P., Manfredi, S., Marschinski, R., MARTINEZ TUREGANO, D., & Pierri, E. (2023). Development of an EU harmonised model for separate municipal waste collection and related policy support: literature review. In *Publications Office of the European Union* (Issue JRC130419). https://doi.org/10.2760/158073

Albizzati, P. F., Tonini, D., & Gaudillat, P. (2024). *Impacts of the collection and treatment of dry recyclables*. https://doi.org/10.2760/4532

Amadei, A. M., & Ardente, F. (2022). *Modelling plastic flows in the European Union value chain*. https://doi.org/10.2760/66163

Anuar Sharuddin, S. D., Abnisa, F., Wan Daud, W. M. A., & Aroua, M. K. (2016). A review on pyrolysis of plastic wastes. *Energy Conversion and Management*, *115*, 308–326. https://doi.org/10.1016/j.enconman.2016.02.037

Azzopardi, B., Hapid, A., Kaleg, S., Onggo, D., & Budiman, A. C. (2023). Recent Advances in Battery Pack Polymer Composites. *Energies*, *16*(6223). https://doi.org/https://doi.org/10.3390/en16176223

Bill, A., Gasser, M., Haarman, A., & Böni, H. (2019). *Processing of WEEE plastics - A practical handbook*. https://www.sustainable-recycling.org/wp-content/uploads/2019/12/Plastic-Handbook-Final.pdf

Bouwmeester, H., Hollman, P. C. H., & Peters, R. J. B. (2015). Potential Health Impact of Environmentally Released Micro- and Nanoplastics in the Human Food Production Chain: Experiences from Nanotoxicology. *Environmental Science & Technology*, *49*, 8932–8947. https://doi.org/10.1021/acs.est.5b01090

BSEF. (2023). *Brominated Flame Retardants and the Circular Economy of WEEE Plastics State of Play*. https://www.bsef.com/wp-content/uploads/2023/09/Brominated-Flame-Retardants-and-the-Circular-Economy-of-WEEE-Plastics-online-final.pdf

Cabanes, A., Strangl, M., Ortner, E., Fullana, A., & Buettner, A. (2020). Odorant composition of post-consumer LDPE bags originating from different collection systems. *Waste Management*, *104*, 228–238. https://doi.org/10.1016/j.wasman.2020.01.021

Cabanes, A., Valdés, F. J., & Fullana, A. (2020). A review on VOCs from recycled plastics. *Sustainable Materials and Technologies*, *25*. https://doi.org/10.1016/j.susmat.2020.e00179

Chartier, Y., Emmanuel, J., Pieper, U., Pruess, A., Rushbrook, P., Stringer, R., Townend, W., Wilbum, S., & Zghondi, R. (2014). Safe Management of Wastes from Health-Care Activities. In *World Health Organization Press* (Issue Geneva).

Cimpan, C., Maul, A., Jansen, M., Pretz, T., & Wenzel, H. (2015). Central sorting and recovery of MSW recyclable materials : A review of technological state-of-the-art , cases , practice and implications for materials recycling. *Journal of Environmental Management*, *156*, 181–199. https://doi.org/10.1016/j.jenvman.2015.03.025

CIRC-ELV. (2022). *State-of-the-art and current situation in ELV management. Deliverable D_A1.1 of Life Project [LIFE17 ENV/ES/000438] Boosting Circular Economy of Plastics from End-of-Life Vehicles through recycling into high added-value applications.*

Clark, R. A., & Shaver, M. P. (2024). Depolymerization within a Circular Plastics System. *Chemical Reviews*, *124*(5), 2617–2650. https://doi.org/10.1021/acs.chemrev.3c00739

Cossu, R., & Lai, T. (2015). Automotive shredder residue (ASR) management : An overview. *Waste Management*, *45*, 143–151. https://doi.org/10.1016/j.wasman.2015.07.042

CPA. (2020a). *Agriculture Working Group Collection & Sorting Workshop – European State of Play Preliminary Report* (Issue July). https://ec.europa.eu/docsroom/documents/43694

CPA. (2020b). *Automotive WG input for Deliverable 2: Work plan on State of Play collection and sorting (C&S)*. https://ec.europa.eu/docsroom/documents/43694

CPA. (2020c). *Plastic Packaging Collection and Sorting – State of play report for the Circular Plastics Alliance*

(Issue November). https://ec.europa.eu/docsroom/documents/43694

CPA. (2020d). *State of play for collected and sorted plastic waste from construction* (Issue June). https://ec.europa.eu/docsroom/documents/43694

CPA. (2020e). *State of play on collected and sorted plastic waste (WEEE)*. https://ec.europa.eu/docsroom/documents/43694

CPA. (2021a). *Circular Plastics Alliance Roadmap to 10 Mt – Untapped Potential Report*.

CPA. (2021b). *Guidance on Waste Definitions* (Issue September).

CPA. (2022). *Supporting greater uptake of recycled plastics: Circular Plastics Alliance assessment of legal, economic and technical requirements and solutions across major plastics using sectors (Draft version)*. *February*, 1–21.

CreaSolv. (2024). *The CreaSolv Process*. https://www.ivv.fraunhofer.de/en/recycling-environment/recycling-plastics-creasolv.html

Dai, L., Zhou, N., Lv, Y., Cheng, Y., Wang, Y., Liu, Y., Cobb, K., Chen, P., Lei, H., & Ruan, R. (2022). Pyrolysis technology for plastic waste recycling: A state-of-the-art review. *Progress in Energy and Combustion Science*, *93*(August), 101021. https://doi.org/10.1016/j.pecs.2022.101021

Delgado, L., Catarino, A. S., Eder, P., Litten, D., Luo, Z., & Villanueva, A. (2009). End of waste criteria, final report. In *JRC Scientific and Technical Reports* (Vol. 14, Issue 3). https://doi.org/10.2791/28650

Dey, S., Purdon, M., Kirsch, T., Helbich, H. M., Kerr, K., Li, L., & Zhou, S. (2016). Exposure Factor considerations for safety evaluation of modern disposable diapers. *Regulatory Toxicology and Pharmacology*, *81*, 183–193. https://doi.org/10.1016/j.yrtph.2016.08.017

ECHA. (2010). *Guidance on waste and recovered substances* (Issue May). http://echa.europa.eu/

ECHA. (2023). *Guidance for monomers and polymers* (Issue November). https://echa.europa.eu/documents/10162/2324906/polymers_en.pdf/9a74545f-05be-4e10-8555-4d7cf051bbed?t=1676975081896

EFSA. (2024). *Brominated flame retardants*. European Food Safety Authority (EFSA). https://www.efsa.europa.eu/en/topics/topic/brominated-flame-retardants

EPD-HK. (2020). *ENVIRONMENTAL PROTECTION DEPARTMENT GUIDELINES ON IMPORT AND EXPORT CONTROL OF WASTE PLASTICS GUIDELINES ON IMPORT AND EXPORT CONTROL OF WASTE PLASTICS*. https://www.epd.gov.hk/epd/english/environmentinhk/waste/guide_ref/guide_wiec_tcs6.html

EURIC. (2020). *Position paper - Call for recycled plastic content plastic in cars*. https://euric.org/resource-hub/position-papers/euric-call-for-recycled-plastic-content-in-cars

European Commission. (2003). *Reference Document on the General Principles of Monitoring* (Issue July). https://eippcb.jrc.ec.europa.eu/sites/default/files/2020-03/superseded_mon_bref_0703.pdf

European Commission. (2020). *Plastic waste shipments: new EU rules on importing and exporting plastic waste*. https://environment.ec.europa.eu/news/plastic-waste-shipments-new-eu-rules-importing-and-exporting-plastic-waste-2020-12-22_en

Garcia-Gutierrez, P., Amadei, A. ., Klenert, D., Nessi, S., Tonini, D., Tosches, D., Ardente, F., & Saveyn, H. (2023). *Environmental and economic assessment of plastic waste recycling. A comparison of mechanical, physical, chemical recycling and energy recovery of plastic waste. EUR 31423 EN, Publications Office of the European Union, Luxembourg, 2023, ISBN 978-92-76-9952*. https://doi.org/10.2760/0472

Geueke, B., Groh, K. J., Maffini, M. V, Martin, O. V, Boucher, J. M., Chiang, Y.-T., Gwosdz, F., Jieh, P., Kassotis, C. D., Łańska, P., Myers, J. P., Odermatt, A., Parkinson, L. V, Schreier, V. N., Srebny, V., Zimmermann, L., Scheringer, M., & Muncke, J. (2022). Systematic evidence on migrating and extractable food contact chemicals: Most chemicals detected in food contact materials are not listed for use. *Critical Reviews in Food Science and Nutrition*, *63*(28), 9425–9435. https://doi.org/10.1080/10408398.2022.2067828

Geueke, B., Inostroza, P. A., Maffini, M., Backhaus, T., Carney-Almroth, B., Groh, K. J., & Muncke, J. (2018). *Prioritization approaches for hazardous chemicals associated with plastic packaging. Food Packaging Forum.* https://doi.org/10.5281/zenodo.1436442

Groh, K. J., Backhaus, T., Carney-almroth, B., Geueke, B., Inostroza, P. A., Lennquist, A., Leslie, H. A., Maf, M., Slunge,

D., Trasande, L., Warhurst, A. M., & Muncke, J. (2019). Overview of known plastic packaging-associated chemicals and their hazards. *Science of the Total Environment*, *651*, 3253–3268. https://doi.org/10.1016/j.scitotenv.2018.10.015

Groh, K. J., Backhaus, T., Carney-Almroth, B., Geueke, B., Inostroza, P. A., Lennquist, A., Leslie Heather, A., Maffini, M., Slunge, D., Trasande, L., Warhurst, M. A., & Muncke, J. (2018). Database of Chemicals associated with Plastic Packaging (CPPdb), updated Oct 9, 2018. *Science of the Total Environment*. https://doi.org/https://doi.org/10.5281/zenodo.1287773

Haarman, A., Magalini, F., & Courtois, J. (2020). *Study on the Impacts of Brominated Flame Retardants on the Recycling of WEEE plastics in Europe.* https://www.bsef.com/publications/study-on-the-impacts-of-brominated-flame-retardants-on-the-recycling-of-weee-plastics-in-europe/

Hahladakis, J. N., Velis, C. A., Weber, R., Iacovidou, E., & Purnell, P. (2018). An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling. *Journal of Hazardous Materials*, *344*, 179–199. https://doi.org/10.1016/j.jhazmat.2017.10.014

Hann, S., Bapasola, A., Fletcher, E., Lee, T., & Long, L. (2022). *Study to Develop Options for Rules on Recycled Plastic Content for the Implementing Act Related to Single-Use Plastic Bottles Under Directive (EU) 2019/904*. https://data.europa.eu/doi/10.2779/13133

Hermabessiere, L., Dehaut, A., Paul-Pont, I., Lacroix, C., Jezequel, R., Soudant, P., & Duflos, G. (2017). Occurrence and effects of plastic additives on marine environments and organisms: A review. *Chemosphere*, *182*, 781–793. https://doi.org/10.1016/j.chemosphere.2017.05.096

Hernandez, G., Low, J., Nand, A., Bu, A., Wallis, S. L., Kestle, L., & Berry, T. (2023). *Quantifying and managing plastic waste generated from building construction in Auckland , New Zealand*. https://doi.org/10.1177/0734242X221105425

Jordan Gantt, I., & Refalo, P. (2022). Reusability and recyclability of plastic cosmetic packaging: A life cycle assessment. *Resources, Conservation & Recycling Advances*, *15*(June). https://doi.org/10.1016/j.rcradv.2022.200098

Jung, H., Shin, G., Kwak, H., Hao, L. T., Jegal, J., Kim, H. J., Jeon, H., Park, J., & Oh, D. X. (2023). Review of polymer technologies for improving the recycling and upcycling efficiency of plastic waste. *Chemosphere*, *320*(November 2022), 138089. https://doi.org/10.1016/j.chemosphere.2023.138089

Kalverkamp, M., & Raabe, T. (2018). Automotive Remanufacturing in the Circular Economy in Europe: Marketing System Challenges. *Journal of Macromarketing*, *38*(1), 112–130. https://doi.org/10.1177/0276146717739066

Klotz, M., Oberschelp, C., Salah, C., Subal, L., & Hellweg, S. (2024). The role of chemical and solvent-based recycling within a sustainable circular economy for plastics. *Science of the Total Environment*, *906*(October 2023), 167586. https://doi.org/10.1016/j.scitotenv.2023.167586

Kunwar, B., Cheng, H. N., Chandrashekaran, S. R., & Sharma, B. K. (2016). Plastics to fuel: a review. *Renewable and Sustainable Energy Reviews*, *54*, 421–428. https://doi.org/10.1016/j.rser.2015.10.015

Lange, J. (2021). Managing Plastic Waste - Sorting, Recycling, Disposal, and Product Redesign. *Sustainable Chemistry & Engineering*, *9*, 15722−15738. https://doi.org/10.1021/acssuschemeng.1c05013

Lase, I. S., Tonini, D., Caro, D., Albizzati, P. F., Cristóbal, J., Roosen, M., Kusenberg, M., Ragaert, K., Van Geem, K. M., Dewulf, J., & De Meester, S. (2023). How much can chemical recycling contribute to plastic waste recycling in Europe? An assessment using material flow analysis modeling. *Resources, Conservation and Recycling*, *192*(March). https://doi.org/10.1016/j.resconrec.2023.106916

Li, M., Liu, J., & Han, W. (2016). *Recycling and management of waste lead-acid batteries : A mini-review*. https://doi.org/10.1177/0734242X16633773

Lopez, G., Artetxe, M., Amutio, M., Alvarez, J., Bilbao, J., & Olazar, M. (2018). Recent advances in the gasification of waste plastics. A critical overview. *Renewable and Sustainable Energy Reviews*, *82*(May 2017), 576–596. https://doi.org/10.1016/j.rser.2017.09.032

Mantia, F. P., & Mistretta, C. (2020). *Polymers. Polymer Recycling: Degradation, Processing, Applications. ISSN 2073-4360*.

Martín-lara, M. A., Moreno, J. A., Garcia-garcia, G., Arjandas, S., & Calero, M. (2022). Life cycle assessment of

mechanical recycling of post-consumer polyethylene flexible films based on a real case in Spain. *Journal of Cleaner Production*, *365*(April), 132625. https://doi.org/10.1016/j.jclepro.2022.132625

Martinez Sanz, V., Morales Serrano, A., & Schlummer, M. (2022). A mini-review of the physical recycling methods for plastic parts in end-of-life vehicles. *Waste Management and Research*, *40*(12), 1757–1765. https://doi.org/10.1177/0734242X221094917

Muchova, L., & Eder, P. (2010a). *End-of-waste Criteria for Aluminium and Aluminium Alloy Scrap: technical proposals*. Publications Office of the European Union. https://publications.jrc.ec.europa.eu/repository/handle/JRC58527

Muchova, L., & Eder, P. (2010b). End-of-waste Criteria for Iron and Steel Scrap: Technical Proposals. In *European Commission, Joint Research Centre*. https://doi.org/10.2791/43563

Muchova, L., Eder, P., & Villanueva, A. (2011). End-of-waste criteria for copper and copper alloy scrap: Technical Proposals. In *JRC Scientific and Technical Report, Scientific and Technical Research series*. https://doi.org/10.2791/57777

Naderi Kalali, E., Lotfian, S., Entezar Shabestari, M., Khayatzadeh, S., Zhao, C., & Yazdani Nezhad, H. (2023). A critical review of the current progress of plastic waste recycling technology in structural materials. *Current Opinion in Green and Sustainable Chemistry*, *40*, 100763. https://doi.org/10.1016/j.cogsc.2023.100763

Net, S., Sempe, R., Delmont, A., Paluselli, A., & Ouddane, B. (2015). Occurrence, Fate, Behavior and Ecotoxicological State of Phthalates in Di ff erent Environmental Matrices. *Environmental Science & Technology*, *49*, 4019–4035. https://doi.org/10.1021/es505233b

OECD. (2018). *Improving Markets for Recycled PlasticsPlastics: Trends, Prospects and Policy Responses*. https://doi.org/10.1787/9789264301016-en

OECD. (2022). Global Plastics Outlook: Economic drivers, environmental impacts and policy options. In *Global Plastics Outlook*. https://doi.org/10.1787/de747aef-en

Orveillon, G., Pierri, E., Egle, L., Gerbendahl, A., Wessman, P., Garcia John, E., & Saveyn, H. G. M. (2022). *Scoping possible further EU-wide end-of-waste and by-product criteria* (Issue March). https://doi.org/10.2760/067213

Pérez-Camacho, M. N., Faraca, G., Pérez Arribas, Z., Kowalska, M. A., & Wolf, O. (2023). *Revision of EU Ecolabel criteria for Absorbent Hygiene Products and Reusable Menstrual Cups (previously Absorbent Hygiene Products) - Preliminary Report* (Issue November). https://doi.org/10.2760/467041

Plastics Europe. (2013). *Automotive - The world moves with plastics. Plastics Europe AISB*. https://plasticseurope.org/knowledge-hub/automotive-the-world-moves-with-plastics-brochure/

Plastics Europe. (2024). *The Circular Economy for Plastics – A European Analysis*. https://plasticseurope.org/wp-content/uploads/2024/05/Circular_Economy_report_Digital_light_FINAL.pdf

Plastigram. (2024). *Technical data sheet. aluLDPE regranulate. Plastigram Industries*. https://plastigram.eu/wp-content/uploads/Technical-data-sheet-aluLDPE-2024-04.pdf

Regulski, R., & Dariusz, S. (2020). Assessment of the Electrostatic Separation Effectiveness of Plastic Waste Using a Vision System. *Sensors*. https://doi.org/10.3390/s20247201

Rey, L., Conesa, J. A., Aracil, I., Garrido, M. A., & Ortuño, N. (2016). Pollutant formation in the pyrolysis and combustion of Automotive Shredder Residue. *Waste Management*, *56*, 376–383. https://doi.org/10.1016/j.wasman.2016.07.045

Rodriguez Vieitez, E., Eder, P., Villanueva, A., & Saveyn, H. (2011). End-of-waste criteria for glass cullets: Technical proposals. In *JRC Scientific and Technical Reports*. https://doi.org/10.2791/7150

Rosato, D. V., & Rosato, M. V. (2004). Plastic Product Material and Process Selection Handbook. *Oxford: Elsevier Advanced Technology*. https://doi.org/https://doi.org/10.1016/B978-1-85617-431-2.X5000-2

RVIM. (2019). *Assessment of recycling of diapers and incontinence materials - Step-by-step plan and risk assessment framework for potential risks of substances and pathogens in products*. https://www.rivm.nl/bibliotheek/rapporten/2019-0111.html

Saebea, D., Ruengrit, P., Arpornwichanop, A., & Patcharavorachot, Y. (2020). Gasification of plastic waste for synthesis gas production. *Energy Reports*, *6*, 202–207. https://doi.org/10.1016/j.egyr.2019.08.043

Santini, A., Herrmann, C., Passarini, F., Vassura, I., Luger, T., & Morselli, L. (2010). Resources , Conservation and Recycling Assessment of Ecodesign potential in reaching new recycling targets. *Resources, Conservation & Recycling*, *54*(12), 1128–1134. https://doi.org/10.1016/j.resconrec.2010.03.006

Santos, G., Esmizadeh, E., & Riahinezhad, M. (2023). Recycling Construction, Renovation, and Demolition Plastic Waste: Review of the Status Quo, Challenges and Opportunities. *Journal of Polymers and the Environment*, 479–509. https://link.springer.com/article/10.1007/s10924-023-02982-z

Saveyn, H., & Eder, P. (2014). Final report on End-of-waste criteria for biodegradable waste subjected to biological treatment (compost & digestate): Technical Proposals. In *JRC Scientific and Policy Reports*. https://doi.org/10.37307/j.1863-9763.2014.04.07

Schleier, J., Simons, M., Greiff, K., & Walther, G. (2022). End-of-life treatment of EPS-based building insulation material – An estimation of future waste and review of treatment options. *Resources, Conservation and Recycling*, *187*(March), 106603. https://doi.org/10.1016/j.resconrec.2022.106603

Schlummer, M., Fell, T., Mäurer, A., & Altnau, G. (2020). The role of chemistry in plastics recycling: A Comparison of Physical and Chemical Plastics Recycling. *Kunststoffe International*.

Schyns, Z. O. G., & Shaver, M. P. (2021). Mechanical Recycling of Packaging Plastics: A Review. *Macromolecular Rapid Communications*, *42*(3), 1–27. https://doi.org/10.1002/marc.202000415

Shah, H. H., Amin, M., Iqbal, A., Nadeem, I., Kalin, M., Soomar, A. M., & Galal, A. M. (2023). A review on gasification and pyrolysis of waste plastics. *Frontiers in Chemistry*, *10*(February), 1–38. https://doi.org/10.3389/fchem.2022.960894

Souder, J., Kennedy, E., Xu, C., Gruber, B., Paes, C., Hu, R., & Al, E. (2024). *Modelling plastic product flows and recycling in the EU*. https://doi.org/https://doi.org/10.2760/69492

Stubbe, B., Vrekhem, S. Van, Huysman, S., Tilkin, R. G., Schrijver, I. De, & Vanneste, M. (2024). *White Paper on Textile Fibre Recycling Technologies*.

UNEP. (2003). *Technical Guidelines on the Environmentally Sound Management of Biomedical and Healthcare Waste. Basel (Y1; Y3). Convention series/SBC No. 2003/3. Secretariat of the Basel Convention.* https://www.basel.int/Portals/4/Basel Convention/docs/pub/techguid/tech-biomedical.pdf

UNEP. (2019a). *Basel Convention on the control of transboundary movements of hazardous waste and their disposal. Protocol on liability and compensation for damage resulting from transboundary movements of hazardous wastes and their disposal. Texts and Annexex. Revised i*.

UNEP. (2019b). *Updated general technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (POPs).* https://www.basel.int/Portals/4/Basel Convention/docs/pub/techguid/tg-POPs.pdf

UNEP. (2020). *Healthcare or Medical Waste - Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal* (Issue 4). https://unece.org/fileadmin/DAM/RCM_Website/UNEP-CHW-PUB-Factsheets-Healthcare-MedicalWaste-2020.English.pdf

UNEP. (2022a). *End Plastic Pollution: Towards an International Legally Binding Instrument - Resolution adopted by the United Nations Environment Assembly on 2 March 2022*. https://wedocs.unep.org/handle/20.500.11822/40597

UNEP. (2022b). *FROM POLLUTION TO SOLUTION - A global assessment of marine litter and plastic pollution*. https://www.unep.org/resources/pollution-solution-global-assessment-marine-litter-and-plastic-pollution

UNEP. (2023a). *Chemicals in plastics: a technical report*. https://www.unep.org/resources/report/chemicals-plastics-technical-report

UNEP. (2023b). *Technical guidelines on the environmentally sound management of plastic wastes*. https://www.basel.int/Portals/4/Basel Convention/docs/plastic waste/UNEP-CHW.16-6-Add.3-Rev.1.English.pdf

Velásquez, E., López-de-Dicastillo, C., Tapia, A., Garrido, L., Catalán, L., Valenzuela, X., Guarda, A., & Galotto, M. (2024). Repetitive mechanical recycling of post-consumer high impact polystyrene from yogurt cups: A pilot-scale performance assessment at different reprocessing cycles. *Resources, Conservation and Recycling*, *202*(December 2023). https://doi.org/10.1016/j.resconrec.2023.107368

Vencovsky, D., Shapland, I., Vencovska, J., Garrett, S., Webb, S., Upson, S., Vedrine, M. La, & Rpa, L. W. (2021).

Study to support the assessment of impacts associated with the review of limit values in waste for POPs listed in Annexes IV and V of Regulation (EU)n 2019/1021 (Issue April). https://op.europa.eu/en/publication-detail/-/publication/c7c70b73-3798-11ec-8daf-01aa75ed71a1/language-en

Veolia. (2018). *Tetra Pak and Veolia partner to get all beverage carton comnponents recycled*. https://www.veolia.com/en/newsroom/news/tetra-pak-recycling-beverage-carton-packaging

Villanueva, A., & Eder, P. (2014). End-of-waste criteria for waste plastic for conversion. In *Luxemburg*. https://doi.org/10.2791/13033

Wagner, M., Monclús, L., Arp, H. P. H., Groh, K. J., Løseth, M. E., Muncke, J., Wang, Z., & Wolf, R. (2024). *State of the science on plastic chemicals - Identifying and addressing chemicals and polymers of concern*. https://doi.org/http://dx.doi.org/10.5281/zenodo.10701706

Wahlström, M., Bergmans, J., Teittinen, T., Bachér, Smeets, A., & Paduart, A. (2020). Construction and Demolition Waste : challenges and opportunities in a circular economy. *European Topic Centre on Waste and Materials in a Green Economy*, *January*.

WHO. (2016). *Protecting Health Through Healthcare Waste Management* (Vol. 4, Issue 4, pp. 379–388). https://www.who.int/docs/default-source/wpro---documents/hae---regional-forum-(2016)/hcwmanagement-factsheet-rfhe.pdf?sfvrsn=6d59d7e_2

WHO. (2017). *Recycling used lead-acid batteries: Brief information for the health sector. World Health Organization (WHO)*. https://www.who.int/publications/i/item/WHO-FWC-PHE-EPE-17.02

WHO. (2018). *Health-care waste*. https://www.who.int/news-room/fact-sheets/detail/health-care-waste

Wilts, H., Garcia, B. R., Garlito, R. G., Saralegui, L., & Gonz, E. (2021). Artificial Intelligence in the Sorting of Municipal Waste as an Enabler of the Circular Economy. *Resources*, 1–9. https://doi.org/https://doi.org/10.3390/resources10040028

Wu, H., Wang, B., Li, T., Wu, Y., Yang, R., Gao, H., & Nie, Y. (2023). Efficient recycle of waste poly-cotton and preparation of cellulose and polyester fibers using the system of ionic liquid and dimethyl sulfoxide. *Journal of Molecular Liquids*, *388*(August), 122757. https://doi.org/10.1016/j.molliq.2023.122757

Yli-Rantala, E., Bachér, J., Kaartinen, T., Vincenti, N., & Zhan, M. (2020). Pre-treatment and characterisation of WEEE , ELV and C & DW plastics , regional perspectives on their recycling , and testing of recyclates. *Deliverable D1.1 of NONTOX Project [Horizon 2020 Grant Agreement No: 820895]. Project Full Title: Removing Hazardous Substances to Increase Recycling Rates of WEEE, ELV and C&DW Plastics.*, *820895*, 1–89.

List of abbreviations

ABS	Acrylonitrile Butadiene Styrene
AHP	Absorbent Hygiene Products
ASTM	American Society for Testing and Materials
ASR	Automotive Shredder Residue
ATF	Authorised Treatment Facilities
APEO	Alkylphenols and alkylphenol ethoxylate
BBP	Benzyl butyl phthalate
BFR	Brominated Flame Retardant
BPA	Bisphenol A
CPPdb	Chemicals associated with Plastic Packaging
CEAP	Circular Economy Action Plan
CEN	European Committee for Standardisation
C&I	Commercial and industrial
CDW	Construction and Demolition Waste
CLP	Classification, Labelling and Packaging
DBP	Dibutyl phthalate
DCHP	Dicyclohexyl phthalate
DiBP	Diisobutyl phthalate
DDT	1,1,1-trichloro-2,2-bis (4-chlorophenyl)ethane
decaBDE	Decabromodiphenyl Ether
DEHP	Di(2-ethylhexyl) phthalate
DG ENV	Directorate-General for Environment
DIBP	Diisobutyl phthalate
DIN	Deutsches Institut für Normung
DRS	Deposit-Refund System
EC	European Commission
ECHA	European Chemicals Agency
EEA	European Economic Area
EEE	Electrical and Electronic Equipment
EL	Elastane
ELV	End-of-Life Vehicle
EN	European Norm
EoW	End-of-Waste
EPS	Expanded Polystyrene
EU	European Union
FCM	Food Contact Material
HBCD	Hexabromocyclododecane
HDPE	High-Density Polyethylene
HIPS	High-Impact Polystyrene
JRC	Joint Research Centre

ISO	International Organization for Standardization
IVH	Industrieverband Hartschaum e.V. (Rigid Foam Industry Association)
LCA	Life Cycle Assessment
LDPE	Low-Density Polyethylene
MEP	Monoethylene glycol
MF	Melamine Formaldehyde
MFI	Melt Flow Index
MRF	Material Recovery Facility
MS	Member State(s) of the EU
MSW	Municipal solid waste
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne (statistical classification of economic activities in the European Community)
NIAS	Non-Intentionally Added Substances
NIR	Near Infrared
OECD	Organisation for Economic Cooperation and Development
octaBDE	Octabromodiphenyl ether
PA	Polyamide
PAC	Acrylic
PAHs	Polycyclic aromatic hydrocarbons
PC	Polycarbonates
PCB	Polychlorinated Biphenyls
PCDD/PCDF	Polychlorinated dibenzo-p-dioxins and dibenzofurans
PE	Polyethylene
PES	Polyester Sulphone
PET	Polyethylene Terephthalate
PFAS	Per- and polyfluoroalkyl substances
PFOS	Perfluorooctane sulphonic acid and its derivatives
PF	Phenol Formaldehyde
PMMA	Polymethyl Methacrylate
POM	Polyoxymethylene
POP	Persistent Organic Pollutant
PP	Polypropylene
PPWD	Packaging and Packaging Waste Directive
PRO	Producer Responsibility Organisation
PS	Polystyrene
PUR	Polyurethane
PVC	Polyvinyl Chloride
QMS	Quality Management System
RDF	Refuse-Derived Fuel
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RoHS	Restriction of Hazardous Substances

SAN	Styrene acrylonitrile
SCCP	Short-chain chlorinated paraffins
SCIP	Substances of Concern In articles as such or in complex objects (Products)
SoC	Substance of Concern
SUP	Single-Use Plastic
SVHC	Substance(s) of Very High Concern
TC	Technical Committee
TPA	Thermoplastic polyamide elastomers
TR	Technical Report
TS	Technical Specification
UVCB	Substance of unknown or variable composition, complex reaction products or biological materials
UF	Urea Formaldehyde
UNEA	United Nations Environment Assembly
UV	Ultraviolet
VIS	Visual Spectrometry
VOC	Volatile Organic Compound
WEEE	Waste Electrical and Electronic Equipment
WFD	Waste Framework Directive
WSR	Waste Shipment Regulation
w/w	Weight in weight
XRF	X-ray Fluorescence
XRT	X-ray Transmission

List of figures

List of tables

Annexes

Annex 1. Glossary

Absorbent Hygiene Products (AHP) (follows the definition in Commission Decision (EU) 2023/1809 establishing EU Ecolabel criteria for absorbent hygiene products and for reusable menstrual cups): any article whose function is to absorb and retain human fluids such as urine, faeces, sweat, menstrual fluid or milk, excluding textile products.

Additives: substances added to a polymer in the manufacturing of plastics to improve specific properties of the end product (e.g. hardness, softness, UV resistance, flame formation resistance) or improve its behaviour during manufacturing. Additives that are included in plastics can be divided into four categories:

- **functional additives** (stabilisers, antistatic agents, flame retardants, plasticisers, lubricants, slip agents, curing agents, foaming agents, biocides, etc.) influence specific properties such as stability against UV light and heat, resistance to microbes, flame retardancy, durability, softness, hardness, aesthetics, etc.;
- **colourants** (pigments, soluble azocolourants, etc.) impart colour to the final plastic product;
- **fillers** (mica, talc, kaolin, clay, calcium carbonate, barium sulphate) improve specific properties (e.g. tensile strength, electrical conductivity, surface gloss); they replace expensive resins to reduce costs;
- **reinforcements** (e.g. glass fibres, carbon fibres) are used to enhance mechanical properties such as the strength and elasticity of plastics.

Agglomeration: the process of combining and compressing small plastic particles or granules obtained from recycling into larger, cohesive pieces. This process typically involves melting the plastic granules and then allowing them to cool and solidify into larger agglomerates.

Article (follows the REACH Regulation (1907/2006/EC) definition): an object which during production is given a special shape, surface or design which determines its function to a greater degree than does its chemical composition.

Bale: it can be produced from (plastic) waste collected separately or commingled with other streams and from sorted plastic waste (e.g. PET-bottle bale, polyolefin mix bale).

Biodegradable plastics: plastics that can be degraded under specific conditions, such as temperature, UV radiation, humidity, oxygen content and pH, by microorganisms in nature or controlled conditions, such as bacteria and algae, and turn into carbon dioxide and other small molecules.

Chemical recycling (or **feedstock recycling**)[101]: within this study[102] different technologies that mainly include pyrolysis and gasification and solvent-based depolymerisation.

Collection (follows the Waste Framework Directive (2008/98/EC) definition): the gathering of waste, including the preliminary sorting and preliminary storage of waste for the purposes of transport to a waste treatment facility.

Collection rate: share of plastic waste collected over the total plastic waste generated. Plastic waste collected in a country but exported for recycling to another country is included. Plastic waste imported from other countries and recycled in the country in question is not included.

---

[101] Processes where the input material is used for energy recovery or the reprocessing into materials that are to be used as fuels are not considered recycling according to Article 3(17) of the Waste Framework Directive 2008/98/EC.

[102] Please note that there is no legal definition for chemical recycling in EU legislation at this stage.

Commingled collection: the collection of two or more recyclable waste streams (e.g. plastic and metals) in a single container which does not impede subsequent high-quality recycling or other recovery of waste, in line with the waste hierarchy (Directive (EU) 2018/851) (Albizzati et al., 2024).

Compounding/Re-compounding: the process of combining two or more types of plastics with additives, fillers and pigments to create a new composite material with specific properties.

Conformity assessment body (follows the definition of Regulation (EC) No 765/2008): a body that performs conformity assessment activities including calibration, testing, certification and inspection.

Consignment: a batch of output plastic which is intended for delivery from a recycler to another holder and may be contained in either one or several transport units, such as containers.

Contaminants (or **impurities**): substances which are present in plastic waste or materials and may pose a risk to human health and the environment (e.g. hazardous substances, persistent organic pollutants, substances of concern).

Converter: manufacturer of semi-finished or finished products by a number of operations involving pressure, heat and/or chemical addition, converting output plastic, usually in the form of powder, flakes, regrind, pellets (regranulates), agglomerates or profiles. The process involves the remelting of the plastic, and often also extrusion and filtering.

Disposal (follows the Waste Framework Directive (2008/98/EC) definition): any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy. Annex I to the Directive sets out a non-exhaustive list of disposal operations.

Energy recovery: i the use of waste principally as a fuel (e.g. refused-derived fuel (RDF)) or other means to generate energy.

Flake: a small, thin piece of plastic material that has been shredded or broken down from larger plastic items. Flakes are often directly used as feedstock in the manufacturing of new plastic products.

Foreign materials: within this study polymers other than thermoplastics, non-targeted polymers in the recycling operation and non-plastic components:

- **Non-targeted polymers**: a polymer present in the output material, which is not targeted in the recycling operation.
- **Non-plastic components**: materials other than plastics that are present in the output material of the recycling operation. Examples are metals, paper, glass, earth, sand, ash, dust, wax, bitumen, ceramics and wood. Components that are bound to the polymer matrix as a result of intentional addition with the purpose of enhancing the properties of the polymer (like fillers, barriers, pigments, additives or any other active ingredients typically used in the compounding of plastics) are not considered non-plastic components.

Granulates: plastic material that has been processed and shredded into small, granular pieces as part of the recycling process. Granules are typically created by shredding and grinding post-consumer or post-industrial plastic waste into particles of uniform dimension.

Hazardous substance: a substance fulfilling the criteria relating to physical hazards, health hazards or environmental hazards, laid down in Parts 2 to 5 of Annex I to Regulation (EC) No 1272/2008.

Hazardous waste (follows the Waste Framework Directive (2008/98/EC) definition): waste which displays one or more of the hazardous properties listed in Annex III to the WFD (e.g. explosive, acute toxic).

Healthcare waste (or **clinical waste**) (follows the Waste Shipment Regulation ((EU) No 2024/1157) definition): wastes arising from medical, nursing, dental, veterinary, or similar practices, and wastes generated in hospitals or other facilities during the investigation or treatment of patients, or research projects.

Holder: means the natural or legal person who is in possession of the plastic waste or the plastic recyclate.

Importer (follows the REACH Regulation (1907/2006/EC) definition): any natural or legal person established within the European Union who introduces the plastic recyclate which has ceased to be waste into the customs territory of the EU.

Industry specifications: specific requirements and guidelines set by the recycling industry on the quality of the output materials and the processing methods.

Input material: plastic waste used as input to the recycling operation.

Intermediate (follows the REACH Regulation (1907/2006/EC) definition): a substance that is manufactured for and consumed in or used for chemical processing in order to be transformed into another substance.

Lump: plastic fraction separated by the extruder screen, containing small particles of foreign materials.

Marine litter (or **marine debris**): any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment. It consists of items that have been deliberately discarded into the sea or rivers or on beaches and shores; brought indirectly to the sea with rivers, sewage, storm water or winds; accidentally lost, including material lost at sea in bad weather (fishing gear, cargo) (UNEP, 2022b).

Material recovery (follows the Waste Framework Directive (2008/98/EC) definition)**:** any recovery operation, other than energy recovery and the reprocessing into materials that are to be used as fuels or other means to generate energy. It includes, inter alia, preparing for reuse, recycling and backfilling.

Material recovery facility (MRF): specialised plant that receives, separates and prepares waste for further processing (e.g. mechanical recycling). MRFs are either designed to accept dry fractions that have already been separated at source from municipal solid waste or to accept mixed municipal solid waste to separate out designated fractions (e.g. plastics) through a combination of mechanical sorting steps.

Mechanical recycling: for plastics it refers to the recycling of pre-sorted plastic waste through mechanical processes such as sorting, grinding, washing, drying, re-granulating and compounding. Mechanical recycling does not change the chemical structure of the polymer.

Melting/Remelting: in plastic production it refers to the process of heating virgin or recycled plastics to a specific temperature until they reach a molten state. This molten plastic can then be formed into various shapes and products using different manufacturing processes, such as injection moulding, extrusion, or blow moulding.

Micronised plastic: plastic materials that have been processed into very fine particles with a size of less than one millimeter. The process of micronisation involves grinding or pulverising the plastic into tiny particles.

Monomer (follows the REACH Regulation (EC) 1907/2006 definition): a substance which is capable of forming covalent bonds with a sequence of additional like or unlike molecules under the conditions of the relevant polymer-forming reaction used for the particular process

Mixed municipal solid waste (MSW) (also known as **residual waste**): unsorted, mixed waste from households and commercial activities, collected together. This waste flow excludes the waste fractions separately collected, be they single-material flows or multi-material (commingled) flows.

Mixture: (follows the REACH Regulation (EC) 1907/2006 definition): a mixture or solution composed of two or more substances.

Output plastic: plastic material obtained in the form of a polymer from a recycling operation (e.g. mechanical or physical recycling).

Physical recycling (e.g. **solvent-based recycling** or **dissolution**): process that uses heat and solvents to dissolve plastic waste into a solution of polymers and additives. In the following step the additives are separated from the polymers before recovering the polymers from the solution. No chemical degradation reaction takes place and the polymer chains remain unaltered.

Pellet: small granules, having relatively uniform dimensions. Pellets are used as the feedstock to create plastic products.

Plastic (follows the SUP Directive (EC) No 2019/904 definition): a material consisting of a polymer (as defined in point 5 of Article 3 of Regulation (EC) No 1907/2006[103]), to which additives or other substances may have been added, and which can function as a main structural component of final products, with the exception of natural polymers that have not been chemically modified.

Plastic recyclate: output plastic material of a recycling operation which has been recovered from plastic waste, has achieved EoW status and can be used as secondary raw material for the production of new plastic products or articles containing plastic parts.

Plastic waste: waste, which the holder discards, intends to discard or is required to discard, and contains plastic polymers with possible additives. Plastic waste can originate from different sectors: packaging, building and construction, automotive, electrical & electronic equipment, households, and agriculture, among others. The plastic waste can be derived from separate collection systems (e.g. separate collection of plastic packaging from households) but also from more complex waste mixtures (e.g. mixed municipal waste) after a sorting step. Plastic waste can be classified into two main categories:

- **pre-consumer plastic waste**: plastic waste generated during conversion or manufacturing processes and that is discarded;
- **post-consumer plastic waste**: plastic waste that has been generated from plastic products that have been supplied for distribution, consumption or use and placed on the market of a Member State or of a third country.

Polymer (follows the REACH Regulation (EC) No 1907/2006 definition): a substance consisting of molecules characterised by the sequence of one or more types of monomer units. Such molecules must be distributed over a range of molecular weights, wherein differences in the molecular weight are primarily attributable to differences in the number of monomer units.

---

[103] Article 3(5): polymer means a substance consisting of molecules characterised by the sequence of one or more types of monomer units. Such molecules must be distributed over a range of molecular weights wherein differences in the molecular weight are primarily attributable to differences in the number of monomer units. A polymer comprises the following: (a) a simple weight majority of molecules containing at least three monomer units which are covalently bound to at least one other monomer unit or other reactant; (b) less than a simple weight majority of molecules of the same molecular weight. In the context of this definition a 'monomer unit' means the reacted form of a monomer substance in a polymer. Article 3(6): monomer means a substance which is capable of forming covalent bonds with a sequence of additional like or unlike molecules under the conditions of the relevant polymer-forming reaction used for the particular process (Regulation (EC) No 1907/2006).

Post-consumer waste: waste generated by a business or consumer containing substances or objects that have served their intended end use and are discarded.

Primary raw material (or **virgin material**): material which has never been processed into any form of end-use product.

Producer (of EoW): the operator of the recycling facility who transfers the plastic recyclate to another holder for the first time as plastic which has ceased to be waste.

Qualified staff: the staff who are qualified by experience or training to carry out the control measures defined under the self-monitoring requirements as part of the quality management system.

Recovery (follows the Waste Framework Directive (2008/98/EC) definition): any operation generating waste serving a useful purpose by replacing other materials which would have been otherwise used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy. Annex II to the Directive sets out a non-exhaustive list of recovery operations.

Recycling (follows the Waste Framework Directive (2008/98/EC) definition): any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of the material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

Recycling rate: a quotient of mass between the output stream from a recycling plant and the total mass of waste material generated (Albizzati et al., 2024).

Repolymerisation: the process of converting monomers recovered from plastic waste back into polymers.

Secondary raw materials: materials recovered from waste or end-of-life products as a result of a recycling operation. They can be used in manufacturing processes to substitute (or in combination with) virgin raw materials.

Separate collection (follows the Waste Framework Directive (2008/98/EC) definition): collection where a waste stream is kept separated by type and nature so as to facilitate a specific treatment.

Source-segregated collection (or **mono-material collection**): a collection system where the material is collected separately in a single-stream.

Substance (follows the REACH Regulation (EC) No 1907/2006 definition): a chemical element and its compounds in the natural state or obtained by any manufacturing process, including any additive necessary to preserve its stability and any impurity deriving from the process used, but excluding any solvent which may be separated without affecting the stability of the substance or changing its composition.

Targeted plastic: a polymer or resin present in plastic waste, including integral parts of the input material, which is collected and recycled.

Thermoplastics: polymers that have the ability to soften with the application of heat and can solidify again upon cooling, allowing them to be remoulded and recycled. This process can be repeated several times. Examples of thermoplastics are polyethylene (PE), polypropylene (PP) and polystyrene (PS), which constitute the most common consumer plastics, also referred to as commodity plastics.

Thermosets: polymers that are shaped into the desired form under heat and pressure, normally with a chemical reaction taking place, and cannot be resoftened or reshaped again. Examples of

thermosets include urea formaldehyde (UF) resins, phenol formaldehyde (PF) resins, and melamine formaldehyde (MF) resins.

Treatment (follows the Waste Framework Directive (2008/98/EC) definition): recovery or disposal operations, including preparation prior to recovery or disposal.

Used products of personal hygiene: a wide variety of products used for personal care, such as soap, shampoo, toothpaste and deodorant, which have been discarded by the consumer.

Verifier (follows the definition of Regulation (EC) No 1221/2009):

— a conformity assessment body as defined in Regulation (EC) No 765/2008 or any association or group of such bodies which has obtained accreditation in accordance with that Regulation; or

— any natural or legal person, or any association or group of such persons which is accredited or licensed by an accreditation or licensing body, as defined respectively in Article 2(30) and 2(31) of Regulation (EC) No 1221/2009.

Virgin polymer: a new polymer, directly produced from the petrochemical feedstock (e.g. natural gas or crude oil) which has never been used or processed before.

Visual inspection: inspection of consignments using either one or several human senses such as vision, touch and smell and any non-specialised equipment. Visual inspection shall be carried out in such a way that all representative parts of a consignment are covered. This may often be best achieved in the delivery area during loading or unloading and before packing. It may involve manual manipulations such as the opening of containers, other sensorial controls (feel, smell) or the use of appropriate portable sensors.

Annex 2. Assessment of EoW criteria in Member States

The JRC performed a mapping exercise to identify EoW criteria (for plastics) implemented or under development in Member States (see **Table 11** in Section 5.4). The national EoW criteria for plastic waste have been analysed in depth to extract key elements that can serve as a starting point for the development of EU-wide EoW criteria.

It is important to remark that Member States have no obligation to report case-by-case decisions to the Commission (cf. Article 6(4) of the Waste Framework Directive) and the Commission shall take account only of national criteria established by Member States. Case-by-case decisions have been listed in the table for the sake of completeness,; however, these criteria are not contained in the summary below and are not taken as a starting point.

In total, two national EoW decrees for plastic waste have been implemented at the time of the preparation of this report, namely by Spain (ES) and Portugal (PT). The national EoW criteria for plastic waste from Finland (FI) were notified to the Commission on 8 December 2023. Flanders (Belgium) and France have developed EoW criteria for all wastes, with certain exceptions, but not specific for plastic waste. It is difficult to make a comparison between criteria applicable to all wastes and criteria developed by the JRC exclusively for plastic waste. The EoW criteria of Belgium and France are therefore not considered in the assessment.

The analysis of the national EoW criteria was focused on: (1) polymers and recycling technologies under the scope, (2) intended use of EoW plastics, (3) requirements on input materials, (4) requirements on processes and techniques, (5) requirements on output quality, (6) requirements on quality assurance and (7) requirements on provision of information.

A non-exhaustive summary of those elements is given below.

1) Polymers and recycling technologies under the scope

Member States exclusively consider **mechanical recycling** and, as a consequence, only **thermoplastics** are under the scope. While ES and PT expliclity mention that all thermoplastics are under the scope, FI does not explicitly state that all thermoplastics are under the scope.

2) Intended use

- ES, PT and FI state that EoW plastic can only be used for the production of new plastic products or articles containing plastic parts.
- PT has imposed prohibitions on the use of EoW plastics for applications such as combustion, pyrolysis, plasmolysis, gasification or similar technologies, landfilling and reprocessing into materials.
- FI has established a list of plastic products or articles containing plastics for which recycled plastics can be used[104]. It also refers to other legislation (e.g. food contact) or product standards that may prohibit the use of recycled plastics (e.g. product standard for pressurised water pipes does not allow the use of recycled plastic).

3) Requirements on input materials

Restrictions on feedstock

[104] 1) Rods, bars, profiles; 2) pipes, hoses; 3) plates, sheets, foil, panel wrap and tape; 4) sacks, bags, pouches and cones; 5) cases, boxes, crates, containers and similar products for the transport or packing of goods; 6) carboys, bottles and similar products for the transport or packing of goods; 7) reservoirs, tanks, vats and similar containers; 8) household, hygiene and toilet products; 9) construction materials and parts for construction.

— PT has adopted an open approach by allowing all thermoplastic waste as input material, while ES[105] and FI[106] specifically restrict the use of thermoplastic waste allowed as input material by waste codes from the European List of Waste.

— National EoW criteria define specific (plastic) waste streams that are not allowed as input material to a recycling process. Restricted (plastic) waste or waste streams are for instance:

- bio-waste (PT);
- hazardous healthcare waste (PT);
- used products of personal hygiene (including AHP) (ES, PT);
- thermosets (ES, PT);
- plastic waste used for the packaging or storage of a hazardous substance or mixture which meets one or more of the definitions and criteria for hazardous classification (FI);
- plastic waste which may substantially impair the recycled plastic (FI).

Hazardous waste, waste containing hazardous substances or other restricted substances

— ES and PT allow the use of hazardous waste, on the condition that the process is able to remove hazardous substances.

— FI has adopted a strict approach, listing only non-hazardous waste as allowed input.

---

105 Thermoplastic wastes accepted for final recovery treatment: a) pre-consumer: 07 02 13 (waste plastic), 12 01 05 (plastics shavings and turnings); b) post-consumer: 02 01 04 (waste plastics (except packaging)), 15 01 02 (plastic packaging), 15 01 10* (packaging containing residues of or contaminated by hazardous substances), 16 01 19 (plastic), 17 02 03 (plastic), 19 12 04 (plastic and rubber), 20 01 39 (plastic); c) With regard to chapters 18 01 and 18 02, it should be clarified that plastic wastes with codes 18 01 03* and 18 02 02* as well as 18 01 02, 18 01 04, and 18 02 03 could also be considered as admissible waste.

106 Annex 1: Plastic waste types allowed to be used as an input for the recycling operation and their waste codes

1) Plastic waste from the manufacture of plastics and plastic products: a) plastic waste from the manufacture and use of plastics (07 02 13; waste plastic), b) waste from unmarketable plastic products resulting from the manufacture of plastic products (16 03 04: inorganic wastes other than those mentioned in 16 03 03), c) plastic waste resulting from the moulding of plastics (12 01 05: plastics shavings and turnings), d) pre-processed plastic waste resulting from mechanical processing of plastic waste referred to in points (a) to (c) (19 12 04: plastic and rubber).

2) Plastic construction waste: a) plastic waste resulting from construction (17 02 03: plastic), b) Plastic insulation material waste resulting from construction (17 06 04: insulation materials other than those mentioned in 17 06 01 and 17 06 03), c) pre-processed plastic waste resulting from the mechanical processing of plastic waste referred to in points (a) to (b) (19 12 04: plastic and rubber).

3) Other separately collected plastic waste: a) Separately collected plastic waste from agriculture, horticulture and forestry (02 01 04: waste plastics (except packaging)), b) Separately collected plastic packaging waste and other plastic waste from households (15 01 02: plastic packaging and 20 01 39: plastics), c) plastic bottles collected separately collected via the deposit system (15 01 02: plastic packaging), d) plastic packaging waste and other plastic waste separately collected or sorted at source from industry, trade and services (15 01 02: plastic packaging), e) pre-processed plastic waste from the mechanical processing of plastic waste referred to in points (a) to (d) (19 12 04: plastic and rubber).

4) Plastic waste separated from mixed waste: a) Plastic film waste separated from mixed construction and demolition waste (17 09 04) (19 12 04: plastic and rubber), b) plastic packaging waste separated from energy waste separately collected separately from industry, trade and services (20 01 99) (19 12 04: plastic and rubber).

— ES has adopted a restriction for waste with POPs above the limit values of Annex IV to the POP Regulation ((EU) No 2019/1021). FI and PT do not explicitly restrict POPs-containing plastic waste.

— The approach of ES and FI to exclude certain plastic waste streams by a positive list of allowed input material can be seen as a way to avoid plastic waste potentially containing hazardous substances or other substances of concern.

Plastic waste from Waste Electric and Electronic Equipment (WEEE) and End-of-Life Vehicles (ELVs)

— FI does not allow the use of WEEE/ELV plastics as input (not included in the positive list).

— ES and PT allow its use if pre-treatment steps are applied and refer to the treatment requirements of the WEEE Directive (EU) No 2012/19 and ELV Directive (EU) No 2000/53.

4) Requirements on processes and techniques

Separate storage

— ES, PT and FI require that input plastic waste be stored separately from any other type of waste.

— In PT plastic waste has to be stored separately by type.

— In addition, FI requests that plastic waste intended to come into contact with food be stored separately from other plastic waste and that plastic waste from construction is kept separate from demolition waste.

— FI and PT demand separate storage of EoW output plastic materials intended for different uses (e.g. for food contact).

Treatment steps

— Member States follow a neutral approach when it comes to the necessary treatment processes. They request that all necessary treatment steps shall have been completed to produce an output material that is suitable for direct use in the manufacture of new plastic products. Only a few examples of basic recycling processes are mentioned (e.g. sorting and shredding).

— ES mentions that further mechanical treatments may be carried out depending on the type of plastic waste and the further application for which it is intended. Mechanical treatment steps may include size reduction by rolling or micronising, washing, centrifuging, drying, filtering, agglomerating, extruding and pelletising.

Treatment of hazardous waste and waste containing hazardous substances or other restricted substances

— FI requires that non-plastic waste, plastic waste high in material impurities and contaminants be removed to the greatest extent possible.

— PT demands the removal of as many contaminants as possible (non-plastic components and hazardous materials) in a pre-treatment step.

Mixing hazardous waste and POPs waste

— ES states that it shall be ensured that plastic waste potentially containing hazardous substances or POPs shall be treated separately and shall not be mixed with other plastic waste. This also allows maximum traceability, when dealing with these sources of plastic waste.

5) Requirements on product quality

Compliance with product legislation

— In two of the national EoW criteria (ES, PT) it is defined that the output plastic has to comply with relevant product legislation, namely the CLP, REACH, and POP Regulations.

— FI does not explicitly mention any product legislation. The JRC was informed in bilateral discussions that compliance with product legislation is a basic requirement for any output material to be traded in Finland, and therefore FI does not see the necessity to explicitly mention it in their national EoW criteria.

Compliance with legal requirements and specifications

— ES and PT specify that the output material needs to be characterised according to defined standards such as EN 15342 (PS), EN 15344 (PE), EN 15345 (PP), EN 15346 (PVC), and EN 15348 (PET).

— ES further defines that, if no standard is available for a certain polymer, the output material shall comply with customer specifications.

— FI does not refer to standards, but states that recyclates shall meet market specifications.

Threshold of foreign materials

— ES and PT have established a threshold of 2% for non-plastic components (excluding moisture).

— FI does not apply a threshold for non-plastic components, but it is requested to determine the Melt Flow Index (MFI[107]) and the mass fraction of the main polymer for output requested and other polymers.

Presence of other contaminants

— ES and PT state that the recycled plastic shall not contain leachable fluids such as oil, solvents, glues, paints and aqueous/fatty foodstuffs that can be detected by visual inspection and olfactory tests.

6) Requirements on quality assurance

Documented procedures in the QMS

— All national EoW criteria (ES, PT, FI) impose the implementation of a QMS with specific procedures.

— Reference to standards is made in some cases (e.g. for sampling procedures or certifications).

— The analysis of the national EoW criteria reveals that the EoW criteria proposed by Villanueva & Eder (2014) were taken as the basis for the development of national EoW criteria. However, there are differences in how detailed the QMS should be and what set of documented procedures shall be included. The following list provides an overview of elements typically defined by Member States:

  (a) monitoring of the process and treatment requirements;

  (b) training of personnel;

  (c) control of the acceptance of waste undergoing recovery treatment;

  (d) control of the quality of the material obtained (including sampling and analysis);

  (e) recording of the results of the monitoring;

  (f) review and improvement of the quality management system;

  (g) comments from the next holder on the compliance of the resulting material with the requirements;

[107] The MFI is a measurement used to assess the flowability or melt viscosity of a polymer. It provides an indication of how easily a polymer can be processed through different processes.

(h) control of plastic waste used as input and description of the path taken by plastic waste from its integration into the treatment processes, including storage;

(i) identification of chemical substances incorporated in the process;

(j) description of the fate of waste generated in the treatment process;

(k) description of the fate of recycled plastic;

(l) description of the methodology for evaluating customer satisfaction regarding the quality of the recovered product**;**

(m) identification of the person responsible for the QMS;

(n) identification of the persons responsible for each phase of the process and the models for the technical sheet, labels and declaration of conformity;

(o) compliance with relevant standards, legislative requirements and customer specifications;

(p) use and maintenance of testing equipment;

(q) sampling design and sampling methodology in accordance with UNE-CEN/TS 16011 EX standards and the PD standard CEN/TS 16010, in its most updated and current version.

Certification and verification

Regarding the certification and verification of the QMS, Member States follow different approaches:

— In ES, the QMS shall be certified by a conformity assessment body accredited to carry out such certification in accordance with Regulation (EC) No 765/2008. No information is provided on the verification of the QMS.

— In FI, the recycler has to submit a notification of the implementation of the criteria in accordance with the national EoW decree to the authority supervising the environmental permit, including a report on the recyclers' quality assurance system and a document certifying that the system has been authorised by a third party. The compliance of the quality assurance system should be verified by an independent party[108].

— In PT, it is up to the conformity assessment body to check whether the management system complies with the EoW criteria. Verification shall be carried out every 3 years or whenever there are significant changes in the production process.

— In ES, PT and FI the recycler shall provide the competent authorities access to the management system and to the relevant records upon request.

Self-monitoring requirements

— In ES and PT the appropriate frequencies of monitoring shall be established taking into account the following factors:

- the predicted variability, based for example on historical results;
- the inherent risk of variations in the quality of the input material and the recycling process and in particular of the high average content of plastics containing harmful substances;
- the precision of the monitoring method;
- the proximity of the results to the concentration thresholds established in the criteria.

[108] Independent party would refer to an entity that would verify the compliance of the quality assurance system and who has been granted accreditation for this task by the Finnish Safety and Chemicals Agency's Accreditation Service (FINAS). FINAS publishes all its accredited certifiers and verifiers and their areas of competence on its website.

— In FI the recycler shall draw up instructions for sampling and testing and shall record them in the QMS. The instructions include:

  - the person collecting samples and their qualifications, the sampling site, the method of sampling including date and time;
  - the methods to determine the melt index and other characteristics;
  - deviations observed during sampling;
  - the use, calibration and maintenance of the sampling, measurement or testing equipment used.

7) Requirements on provision of information

— ES, PT and FI include a clause on the intended use in the statement of conformity. They require that the recycler issue a statement of conformity (possibly in electronic form) for each consignment that is transferred to the next holder. The information to be included is:

  - name of the manufacturer, contact details and basic information on the material;
  - date of supply and quantity supplied by weight/volume;
  - product description (including the origin of the material by waste entry);
  - specific additional information, e.g. on the melt index and the standards used for its determination and the material distribution;
  - specification of non-plastic component content;
  - statement of compliance with the CLP, REACH and POP Regulations (only in ES and PT);
  - statement of non-hazardousness;
  - statement of compliance with relevant technical standard(s) and customer specifications, including details on the standard(s) and specification(s) applied;
  - intended use and restrictions on uses;
  - declaration of the implementation of a QMS verified by an accredited conformity assessment body;
  - signed declaration by the recycler which accredits that the material has achieved EoW status (statement of compliance) and that the information provided is accurate.

— Member States require that the recycler and next holder keep a copy of the statement of conformity for a defined timeframe after its issuance, ranging from 3 years (ES) to 10 years (FI).

— In ES and PT the recycler shall present the statement of conformity to competent authorities upon request.

— In FI, the recycler shall submit a declaration of compliance to the national 'Safety and Chemicals Agency' upon request.

Getting in touch with the EU

In person

All over the European Union there are hundreds of Europe Direct centres. You can find the address of the centre nearest you online (european-union.europa.eu/contact-eu/meet-us_en).

On the phone or in writing

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

— by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),

— at the following standard number: +32 22999696,

— via the following form: european-union.europa.eu/contact-eu/write-us_en.

Finding information about the EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website (european-union.europa.eu).

EU publications

You can view or order EU publications at op.europa.eu/en/publications. Multiple copies of free publications can be obtained by contacting Europe Direct or your local documentation centre (european-union.europa.eu/contact-eu/meet-us_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex (eur-lex.europa.eu).

EU open data

The portal data.europa.eu provides access to open datasets from the EU institutions, bodies and agencies. These can be downloaded and reused for free, for both commercial and non-commercial purposes. The portal also provides access to a wealth of datasets from European countries.

Science for policy

The Joint Research Centre (JRC) provides independent, evidence-based knowledge and science, supporting EU policies to positively impact society

EU Science Hub
Joint-research-centre.ec.europa.eu

Publications Office
of the European Union