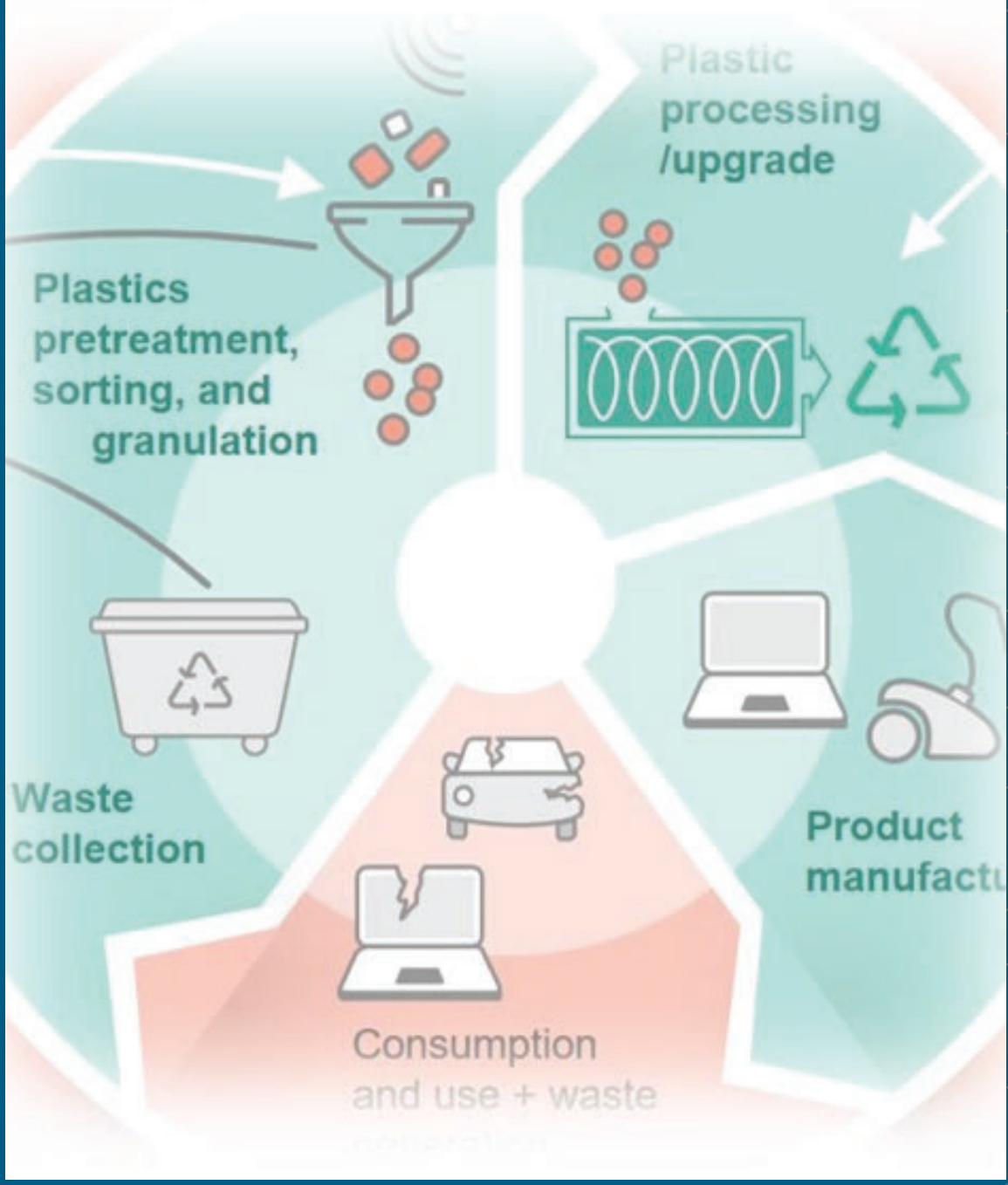

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Review of the European Legislative and Policy Framework Affecting the Recycling of Hazardous Plastics from ELV, WEEE and C&DW

Malin zu Castell-Rüdenhausen | Anna Tenhunen | Mathilde Taveau | Lotta Marjamäki | Nazarena Vincenti | Tatu Marttila | Margareta Wahlström | Paola Colzani

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Preface

This report is an output of the NONTOX EU project, Work Package 5, Task 5.1 'Mapping of the regulatory and standardisation framework'. The objective of the task was to review the regulatory framework and operational environment in the EU, based on relevant existing directives, standards and international agreements, with a special focus on the criteria and requirements for the recycling of plastic waste containing hazardous substances.

When developing recycling technologies, it is important to understand the limits set by the operational environment. This study is conducted by a multidisciplinary team of experts from four organisations, all contributing with strong expertise related to plastics recycling. The diverse expertise of this group has been a true asset for depicting the activities throughout the value chain, forming a basis for understanding the operational environment. This enabled us to draw the policy framework across the circular value chain and create a good overview of the policy drivers for the recycling of plastics containing hazardous substances.

This report is the first deliverable (D5.1) of the Work Package 5 of the NONTOX EU project. The NONTOX project has received funding from the European Union's Horizon 2020 research and innovation programme. The work in this report will be followed up by another deliverable of the NONTOX project, D5.3, which will build on the findings related to the legislative framework presented in this report to further propose recommendations for actions and instruments to improve circularity in order to achieve the targets of the plastic strategy.

Contents

Annexes

List of abbreviations

ABS	Acrylonitrile butadiene styrene
BFR	Brominated flame retardant
C&DW	Construction and demolition waste
CE	Circular economy
CEAP2015	The first European circular economy action plan from 2015
CEAP2020	The second European circular economy action plan from 2020
CLP	Regulation on classification, labelling and packaging of substances and mixtures
CPR	Construction Product Regulation
CRT	Cathodic Ray Tube
EC	European Commission
EEE	Electrical and Electronic Equipment
EGD	The European Green Deal
EPR	Extended producer responsibility
EU	European Union
EU-27	The 27 Member States of the European Union – as of 2020
EU-28	The 28 Member States of the European Union – up to 2020
ELV	End-of-life-vehicle
EoW	End-of-waste
EoL	End-of-life
GCMS	Gas Chromatography Mass Spectroscopy
GHG	Greenhouse gas
HBCDD	Hexabromocyclododecane

HIPS	High-impact polystyrene
JRC	Joint Research Centre
LCMS	Liquid Chromatography Mass Spectroscopy
LoW	European List of Waste, Commission Decision 2000/532/EC
MODIX	Modular extrusion mixer
PBDE	Polybromobiphenyl ethers
PC	Polycarbonate
PCB	Polychlorinated biphenyl
POP	Persistent Organic Pollutant
PRE	Plastics Recyclers Europe
PRO	Product responsibility organisation
PS	Polystyrene
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
SRF	Shredder Light Fraction
SVHC	Substance of very high concern
TRL	Technology readiness level
WEEE	Waste Electrical and Electronic Equipment
WFD	Waste Framework Directive
XRF	X-Ray fluorescence
ZPA	Zero Pollution Ambition – the EC's strategy for a non-toxic environment

Executive summary

In the NONTOX project, the focus is on the recycling of plastics contained in three specific waste streams, namely ELV, WEEE and C&DW, and especially on the recycling of plastic waste with heritage hazardous compounds, such as brominated flame retardants. For the recovery of such materials, the treatment processes need to be adapted to safely remove the compounds of concern in order to produce recovered material that is safe to use in new products.

When aiming to promote recycling, it is important to understand the relationship between the waste and chemical regulations and the different driving forces behind them. While the legislative framework on waste[1] aims to increase recycling, the legislative framework on chemicals[2] aims to prevent the circulation of harmful and potentially harmful substances.

Increasing recycling rates and creating well-functioning markets for secondary raw materials are crucial for the implementation of a circular economy, which is also highlighted in the European Green Deal (EC, 2019), the circular economy action plan (EC, 2020a) and the plastic strategy (EC, 2018), for example. The promotion of a circular economy and the recent revision of several waste directives has resulted in increased pressure for the recycling of waste in the EU. The target waste streams of NONTOX fall in the domain of waste directives, which set requirements for the annual collection and recycling of waste:

- The ELV Directive[3] sets minimum requirements for the treatment of ELV, more specifically for the collection of all end-of-life vehicles at authorised treatment facilities and for the processes of depollution of fluids and specific components. It sets targets for 85 % recycling and 95 % recovery for end-of life vehicles, by an average weight per vehicle and year.

- The WEEE Directive[4] sets quantitative requirements for the collection of WEEE; 65 % collection of the average weight of EEE placed on the market in the three preceding years, or alternatively 85 % of WEEE generated in

[1] In this report the WFD, WEEE and ELV directives as well as the Waste Shipment Regulation are reviewed
[2] In this report the REACH and POP regulations are reviewed
[3] 2000/53/EC
[4] 2012/19/EU

that same year. The recycling targets for WEEE are set per category at 75–85 % recovery and 55–80 % recycling.

- The Waste Framework Directive (WFD)[5] promotes selective demolition and site sorting for construction and demolition waste, and a target of recycling 70% (by weight) of non-hazardous construction and demolition waste. The Commission shall consider material-specific targets for key C&DW streams by 2024.

Simultaneously, the regulatory framework[6] in the EU has set recommendations and limitations for a number of hazardous substances, with the aim of preventing the circulation of these materials, and finally, eliminating their existence and providing recommendations for regulations and standards that address the removal of contaminants.

The European legislative framework for products sets limits for the use of specific compounds and materials in products, and the European legislative framework for chemicals and waste also for the treatment of waste containing hazardous compounds. The chemical legislation in Europe strives to eliminate hazardous substances in new and used products. However, some hazardous substances play an important role in product safety, such as flame retardants in construction materials, vehicles, and electronics. Thus, it is sometimes interpreted that the use of these substances is crucial for the production and use of the products. If there are no less hazardous alternatives serving the same purpose, the chemical legislation may give exemptions allowing the use of chemicals within specifically defined limitations.

The waste management directives[7] frame the operational environment of waste collection and treatment. The directives stipulate how waste can or must be collected, how to transport the waste, and the requirements on facilities and processing, and also on recovery and recycling targets. The WFD sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling, recovery and end-of-waste criteria. The WFD and the List of Waste[8] (LoW) defines whether waste is considered hazardous or not and the treatment requirements for such waste. Furthermore, the LoW provides an EU-wide common terminology for waste classification to ease waste management, including for hazardous waste, and the Waste Shipment Regulation restricts international shipments of waste, with specific requirements and prohibitions for hazardous waste.

The definition of waste as hazardous/non-hazardous enables stakeholders in the waste management chain to define which regulatory framework to comply with in treatment and recycling. If the plastic waste of the target waste streams satisfy the limit values set in the above-mentioned regulations, the waste is typically not classified as hazardous and can generally be treated without any processes that aim to eliminate the hazardous substances.

[5] 2008/98/EC
[6] Such as the REACH and POP regulations and the RoHS directive
[7] In this report, the WFD, WEEE and ELV directives and the Waste Shipment Regulation are reviewed
[8] 2000/532/EC

Standards aim to set a case for best recycling and trading practices. The standards enable recyclers to demonstrate compliance with specific treatment operations. Standards also facilitate the fulfilment of requirements of the specific waste directive and also compliance with a certain quality of product. The standards link to supporting technical specifications (TS), which provide technical details, such as sampling protocols, analysis methodologies, and so on. The use of standards is voluntary, while laws and regulations developed by each Member State may refer to standards.

Once the waste plastic is treated in a recycling process, the aim is to have a clean plastic product. The aim of REACH[9] is to ensure that all substances are manufactured and used safely. REACH concerns the use of substances in products manufactured in the EU or imported to the EU. REACH is implemented in the production, import and use of substances. In the case of recycling operators, REACH applies after the recycling process, when the plastic has ceased to be waste. The aim of REACH is to ensure that all substances are manufactured and used safely.

The most important conditions for the end-of-waste status of recovered plastics should relate to the secondary material being an adequate alternative to primary raw materials and being used as direct input to the manufacture of plastic products. Today, there is no EU-wide end-of-waste status for recovered plastics, although some Member States have a national end-of-waste status.

In manufacture, the product regulation also limits the use of certain hazardous substances. The RoHS Directive[10] sets limits for the use in electrical and electronic equipment and the ELV Directive for the use in vehicles. It is important to note that not all hazardous bromine-based substances are regulated under the specific product directives, but if they are subject to restriction under REACH, they must comply with these restrictions.

Concluding remarks

This report presents a review of the operational framework, and the different policies and legislation that different actors in the value chain need to comply with. The framework consists of several interconnecting pieces of policy and legislation that are presented independently, but it refers to the interdependencies. This report uses a circular value chain approach, from waste collection to recycling and upgrading, to finally ending in the use in production of a new product.

In conclusion, it can be stated that the responsibilities of the actors in the value chain are well stated in the legislative framework. However, due to the breadth and intricacy of European legislation, as well as differing legislation between Member States, knowledge of the explicit responsibilities and requirements is hard to accomplish for a single actor in the plastics recycling value chain.

[9] 1907/2006/EC
[10] 2011/65/EU

1. Scope and objective

This report (D5.1) is an output of the NONTOX EU project[11], Work Package 5, Task 5.1 'Mapping of the regulatory and standardisation framework'. The objective of the task is to review the regulatory framework and operational environment in the EU, based on relevant existing directives, standards, and international agreements, with a special focus on criteria and requirement for the recycling of plastic waste containing hazardous substances. The legislative framework includes key waste, product, and chemical legislation, as well as standards on recycling and end-of-life products. The suitability of the NONTOX concept for end-of-waste criteria is elaborated based on the methodology work on end-of-waste criteria by the Joint Research Centre. The focus is on plastic waste originating from three specific waste streams, namely construction and demolition waste (C&DW), end-of-life vehicles (ELV), and waste electronic and electrical equipment (WEEE).

The NONTOX team is comprised of a multidisciplinary consortium including internationally renowned RTOs, universities, key industrial partners and recyclers, as well as product design experts. The overall objective of the NONTOX project is to increase the recycling rates of plastic waste containing hazardous substances by developing and optimising recycling processes to produce safe and high-quality secondary plastic materials and by optimising the overall process economics. The project firstly considers sorting and pre-treatment techniques applied to feedstocks. NONTOX will further develop two technologies (Extruclean and CreaSolv®) to remove hazardous substances allowing for increased recycling rates. The thermochemical conversion of non-target plastics and side streams from the main recycling processes will be investigated to increase system efficiency by integration and to widen the range of final products and applications. Furthermore, the recyclates are to be upgraded to be used in high-value applications. NONTOX focuses especially on brominated flame retardants, from plastic waste of C&DW, ELV and WEEE. A non-exhaustive process scheme of NONTOX is illustrated in Figure 1.

[11] http://NONTOX-project.eu/

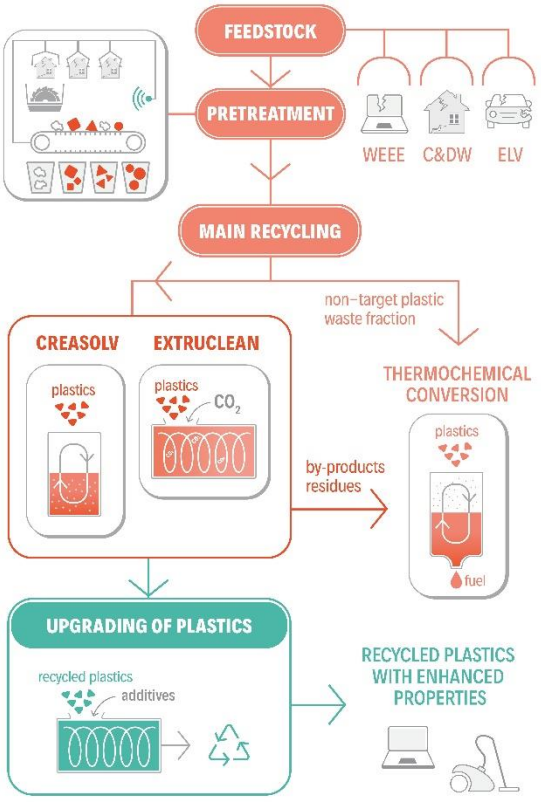

Figure 1. Process scheme of the NONTOX concept

1.1 The NONTOX process

NONTOX target plastic fractions are all part of metal-rich waste streams, the management of which is common with mixed treatment with other metal-containing wastes, such as between the three target streams, but also with mixed metal scrap from industries and municipalities. The main target of the recycling activities is the recovery of metals. The plastics containing fractions from shredding are often heterogeneous and contaminated, which is why the main routes for treatment of the plastic fractions of the target waste streams today in the EU are incineration or landfilling.

The NONTOX process targets only the plastic fractions from C&DW, ELV and WEEE, or more specifically ABS, PS and PC with high levels of brominated flame retardants (BFRs). The NONTOX process aims for the removal of hazardous and undesired substances, with a particular focus on the BFRs, from the target plastic waste streams. Hazardous waste can only be used as an input if proof is provided that the processing techniques removes all hazardous properties; the processing

must comply with treatment requirements of the relevant waste legislation, such as the Waste Framework Directive (WFD), the WEEE Directive and the ELV Directive.

The aim of the NONTOX process is to remove hazardous compounds to a level that is in compliance with the relevant product legislation or that exceeds the requirements. After the required treatment operations, the material should be suitable for direct input to the manufacture of plastic products. The NONTOX process will lower the bromine content and increase the margin of safety and the value of the recovered materials. The final products can be utilised in demanding high-value applications within non-food packaging, consumer goods, transportation, electronics, building and construction.

The main units of the NONTOX concept include sorting, CreaSolv®, Extruclean, thermochemical conversion and recycled plastic upgrading, and the products are upgraded monomaterial streams of ABS, HIPS, PC and pyrolysis oil.

The NONTOX processing has two major feedstocks:

- A heavy fraction (density above 1.1 kg/l) with high levels of brominated flame retardants (BFRs), from which the clean plastics are removed with density sorting. This stream is directed to the CreaSolv® process.
- A recovered ABS and PS polymer, containing acceptable but high levels of bromine (600-1000 ppm Br), which is currently on the market. These streams are processed with Extruclean to lower the bromine content.
- In addition, non-target plastics and residues from the recycling processes are sent directly to thermochemical conversion.

The NONTOX processing is based on two technologies for the removal of contaminants from target polymers:

- The stream directed to CreaSolv® is first sorted to separate the target polymers of the CreaSolv® process (ABS, PS, PC/ABS). The CreaSolv® is based on dissolution, allowing efficient and selective separation of polymers and contaminants.
- The contaminated but accepted ABS and PS polymer streams are processed with Extruclean to lower the bromine content. Extruclean is based on extrusion with simultaneous extraction, to remove hazardous compounds using supercritical carbon dioxide.

The clean ABS, PS and PC are directed to plastics upgrading to improve the properties of purified recyclates and convert them into products to be utilised in demanding high-value applications. The rejected material from optical sorting, from CreaSolv® and Extruclean, as well as dust, sludge and fines from current WEEE pre-treatment processes, are sent to thermochemical conversion to remove remaining bromine compounds and to produce pyrolysis oil. MODIX, a unique modular extrusion mixer, is planned to serve as a pre-treatment and decontamination unit before the thermochemical conversion.

1.2 Objective

The aim of D5.1 is to create a review of the operational framework related to the management of plastic waste, possibly containing hazardous substances, as well as to elaborate the regulatory framework and limit values of some relevant compounds of concern. This report can be used to guide relevant plastic value chain stakeholders to formulate an overview of the framework affecting operations and further support the familiarisation of the actual legislative documents. The framework that is reviewed includes the following regulation, directives, international agreements and standards:

1. Related to vehicles and ELV
    - Directive 2000/53/EC (the ELV Directive)
2. Related to electronics and WEEE
    - Directive 2012/19/EU on waste electrical and electronic equipment (WEEE)
    - CENELEC standards
    - WEEELABEX
3. Related to construction products and C&DW
    - Directive 2008/98/EC on waste (Waste Framework Directive)
    - Construction Products Regulation (305/2011/EU)
4. Related to recycling of plastics
    - European plastics recyclers' specification: PRE1000-1
    - EoL (End-of-Life) material standards like EUCertPlast (European Certification of Plastics Recyclers) and EN15343 with linked standards
5. General legal framework
    - Directive 2008/98/EC on waste (Waste Framework Directive)
    - Waste shipment regulation 1013/2006/EC
    - Regulation 1907/2006/EC concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals, REACH
    - Restriction of Hazardous Substances (RoHS) Directive 2011/65/EU for EEE
    - Regulation 2019/1021/EU on Persistent Organic Pollutants and Stockholm Convention for POPs
    - Ecodesign Directive (2009/125/EC)

The above listed documents are chosen based on the responsibilities of the actors in the value chain, to cover the key interests and obligations of the relevant stakeholders. This report aims to follow a circular value chain approach, following the material from waste collection via recycling and upgrading to the use in production of a new product.

The aim of this report is to present the key areas of interest of the legislative documents. The key stakeholders targeted are recyclers and manufacturers utilising recovered materials for the production of plastic products in vehicles, electronics and construction products, thus excluding food contact materials. The legislative framework is reviewed to show stakeholders which legislative documents they are required to comply with in their activities. The review of the legislative documents

presents merely an overview of the document. Due to the nature of the documents, they cannot be summarised without losing a significant proportion of important content.

1.3 Guidance to the reader

This report presents a review of the operational framework, with the different pieces of policy and legislation to comply with for different actors in the value chain. The framework consists of several interconnecting pieces of policy and legislation, which are presented independently, but which refer to the interconnected documents. This report uses a circular value chain approach, from waste collection to recycling and upgrading, to finally ending in the use in production of a new product.
The value chain of the NONTOX process is illustrated in Figure 2, where the European waste, chemical and product legislation, as well as standards, and their impact on the stages of the value chain are presented. Different legislation applies in different sections of the value chain. In this document, the value chain is divided into four sections – 1) plastic processing and upgrades, 2) product manufacture, 3) consumption and use, as well as waste generation, and 4) collection of waste and plastic pre-treatment, sorting and granulation.

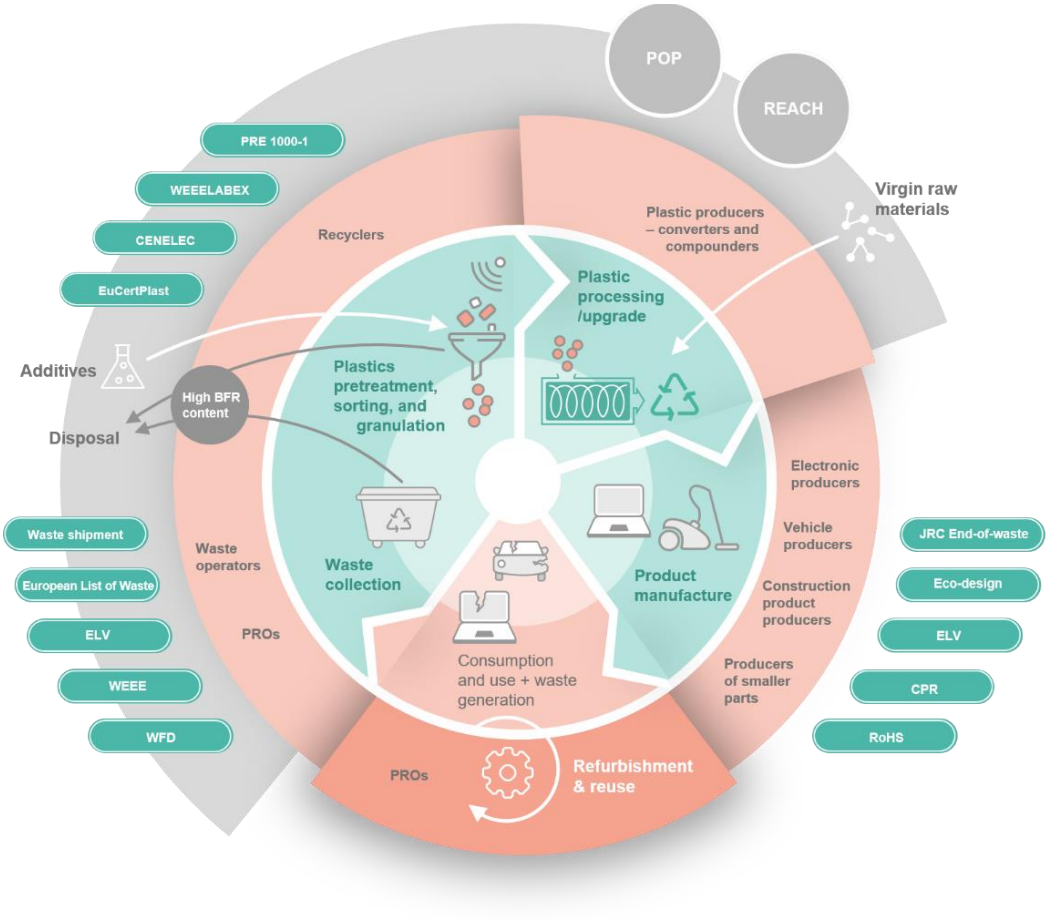

Figure 2 The value chain of the NONTOX process, indicating the impact of the European waste, chemical and product legislation, as well as standards on the different stages of the value chain

Chapter 2 gives an introductory overview of and background to the relevant EU policies and strategies for the recycling of plastic waste with hazardous substances. The value chains of the focus waste streams are presented in Chapter 3 to give a general overview of the material streams. Then the regulatory and policy framework presents the general and stream-specific waste legislation in sections 4.1–4.4. The regulatory framework on waste is directed towards stakeholders in the waste management and recycling sector. Sections 4.5–4.8 are directed towards recyclers, presenting the standards for recycling of plastic waste and plastic waste with hazardous content. Following the recycling standards, in sections 4.9 and 4.10, the REACH Regulation and the POP Regulation with related international agreements is

directed towards all actors of waste management, recycling and plastic upgrading. For product manufacturers, the Ecodesign Directive in section 4.11 is of interest to all stakeholders, whereas the RoHS directive in section 4.12 is of interest in the EEE sector, the CPR in section 4.13 in the construction sector, and the ELV directive presented in section 4.2 is of interest in the vehicles sector. Finally, section 4.13 presents a list of the limit values for the substances of concern in the NONTOX scheme. The basic methodology for setting end-of-waste criteria is presented in Chapter 5, together with an analysis of the suitability of the NONTOX process scheme for end-of-waste status. Finally, the findings of the report are summarised in Chapter 6, together with some concluding remarks on the roles and responsibilities of the stakeholders in the NONTOX circular value chain.

2. Introduction

2.1 EU strategies/policies

The first European circular economy action plan from 2015, CEAP2015 (CE, 2015), includes the revision of the European waste legislation, presenting substantially higher targets for recycling, among other things. In order to provide operators with more certainty and a level playing field, the revised waste legislation aims to establish more harmonised rules to determine when a secondary raw material should no longer be legally considered 'waste', by clarifying existing rules on 'end-of-waste'. The CEAP2015 includes comprehensive commitments on ecodesign and the development of strategic approaches on plastics and chemicals. The CEAP15 acknowledges that increasing plastic recycling is essential for the transition to a circular economy and launched the preparation of the European plastic strategy.

The EU Strategy for Plastics in the Circular Economy (EC, 2018) aims to increase uptake of recycled plastics and contribute to the more sustainable use of plastics. The Commission plans to propose mandatory requirements for recycled content (in 2021–2022) for key products such as packaging, construction materials and vehicles. The strategy acknowledges construction and the automotive and electronics sectors as significant sources of plastics waste that could be recycled. The plastic strategy also acknowledges that a lack of information regarding the possible presence of chemicals of concern (e.g. flame retardants) creates a significant obstacle to achieving higher recycling rates; a problem the NONTOX project aims to solve.

The European Green Deal is the European Commission's plan to make the EU's economy sustainable. It presents Europe's commitment to tackling climate and environmental-related challenges. The European Green Deal provides an action plan to boost the efficient use of resources by moving to a clean, circular economy as well as to restore biodiversity and cut pollution. The action plan includes the publication of several important policy documents, such as the Circular Economy Action Plan (2020), the industrial strategy (2020) and the zero pollution action plan (2021).

All three target waste streams stem from key product value chains presented in the current circular economy action plan, CEAP2020, (i.e. electronics, vehicles, and construction and buildings). The CEAP2020 guides the transition to a CE and presents policies for key product value chains to support circular design, prioritising reducing and reusing materials before recycling them. (EC, 2020a)

The European Green Deal mentions the Zero Pollution Ambition (ZPA) for a toxic-free environment which is a follow-up action to the EU strategy for non-toxic environment mentioned in the 7th Environment Action Plan (7EAP). The 7EAP mandated the European Commission to develop 'a Union strategy for a non-toxic environment that is conducive to innovation and the development of sustainable substitutes including non-chemical solutions' by 2018, but was postponed to 2020. The ZPA especially addresses a need to rapidly address the risks posed by hazardous chemicals and, more specifically, very persistent chemicals, and encourages initiatives that ensure that products are designed to be safe – free from hazardous

chemicals – and circular/sustainable by design and that support actions for clean material loops.

The European product legislation sets limits for the use of specific hazardous compounds and materials in products, and also the chemical legislation for the treatment of waste containing hazardous compounds. Simultaneously, the European plastic strategy and waste legislation sets targets for the recycling of plastics[12] and the European Green Deal and the Circular Economy Action Plan sets targets for the use of recovered materials in new products and ZPA emphasises the non-toxicity. Standards for the treatment and recycling of plastic waste enable the safe recovery of materials with heritage hazardous compounds.

Increasing recycling rates and well-functioning markets for secondary raw materials are crucial for the implementation of a circular economy, which is also highlighted in the European Green Deal, the Circular Economy Action Plan and the plastic strategy. The promotion of a circular economy and the recent revision of several waste directives has resulted in an increasing pressure for the recycling of waste in the EU. Strict targets for the recycling of different waste streams are set in waste-specific directives. These new recycling targets are posing new challenges for the coordination of the different objectives on waste, product and chemicals legislation.

2.2 Presence of hazardous substances

The focus of the NONTOX project is on hazardous substances regulated by EU or international agreements or national legislation. Hazardous substances are substances that have a negative impact on the environment or human health (e.g. consumers, workers) during the use phase, post-use phase (i.e. recycling/reuse of materials) or at the end-of-life phase (landfilling/incineration). NONTOX has a special focus on hazardous brominated flame retardants, e.g. hexabromocyclododecane (HBCDD), octabromodiphenyl ether (c-OBDE) including also hexa-, hepta- and pentabromodiphenyl ethers, hexabromodiphenyl (HBB) and decabromodipheyl ethane (BDBPE). c-OBDE refers to a commercial mixture of different polybrominated dipheyl ethers (like penta, deca-bromodiphenyl ethers). It is regulated by POP Regulation, listed in the RoHS Directive and on the restriction list of REACH Regulation for certain uses. c-OBDEs have been used as flame retardants in plastics in products like computer monitors, televisions, textiles and plastic foams. It has been used with acrylonitrile-butadiene-styrene (ABS) (70%), but also on a smaller scale in high-impact polystyrene (HIPS), polybutylene terephthalate (BPT) and polyamides. In ABS-based products, there is typically 12–18 % c-OBDE. The polyborminated biphenyls have been shown to migrate from plastics and enter the environment and are classified as health hazards. c-OBDE has toxic properties and has been shown to be both persistent and bioaccumulative and pose a potential risk to health. They

[12] None of the waste directives specifies a target for the plastic fraction. Targets for recycling of construction waste are set in the Waste Framework Directive (2008/98/EC), targets for recycling of WEEE in the WEEE Directive (2012/19/EU) and for ELV in the ELV directive (2000/53/EC). The plastic strategy sets the target to recycle more than half of all generated plastic waste by 2030 (EC, 2018)

have been highlighted to be especially potentially hazardous to unborn children and fertility. The EU has conducted comprehensive chemical risk assessments of the chemical and it was banned in 2004. Due to the EU and other governmental restrictions, it was estimated in 2004 that OBDE is no longer produced for example in the EU, the US, Canada or Japan. There are alternatives to the OBDE like tetrabromobisphenol A (TBBPA) or triphenyl phosphate, but it needs to be noted that they might also have negative effects but are not currently restricted.[13]

Information about toxicity and hazardous properties of different substances is, however, constantly updated and revised and later introduced in legislation. Therefore, the list of hazardous substances will never be complete, but requires constant follow-up. Hazardous substances can also enter the waste streams as contaminants from the use phase (e.g. spills, chemical used, surrounding materials, fire).

In the target waste streams (WEEE, ELV and C&DW) of the NONTOX process, hazardous substances may be present in plastics. The main use of hazardous substances in all the three target waste streams are as flame retardants, but also as plasticisers.

2.3 Regulatory framework

Only the key areas of interest of the relevant legislative documents are reviewed in this report. Due to the width and intricacy of European legislation, the review of the legislative documents presents merely an overview of the document from the perspective of the average stakeholder. Due to the nature of the documents, they cannot be summarised without losing a significant proportion of important content. This report can be used to guide relevant plastic value chain stakeholders to formulate an overview of the framework affecting operations and to further support the familiarisation of the actual legislative documents.

EU legislation is divided into layers, depending on how decisions are made. In this document we investigate the implementation of EU legislation via regulations and directives. Regulations have binding legal force throughout every Member State and enter into force on a set date in all Member States. Directives lay down certain results that must be achieved but each Member State is free to decide how to transpose directives into national laws. The directives set only minimum requirements and allow for adaptation to the regulatory requirements of the European Member States. Thus, implementation may differ slightly around Europe.

Current waste management restrictions formulated in the Waste Framework Directive (WFD), ELV Directive and WEEE Directive set minimum requirements for the treatment of the C&DW, ELV and WEEE respectively, such as requirements on collection systems, treatment facilities, and targets for reuse, recycling and recovery. The European waste management directives set targets for the collection and recycling of the NONTOX waste streams. Figure 3 illustrates the current recycling rates and targets for recycling of the NONTOX target waste streams.

[13] Stockholm Convention on Persistent Organic Pollutants - Persistent Organic Pollutants Review Committee

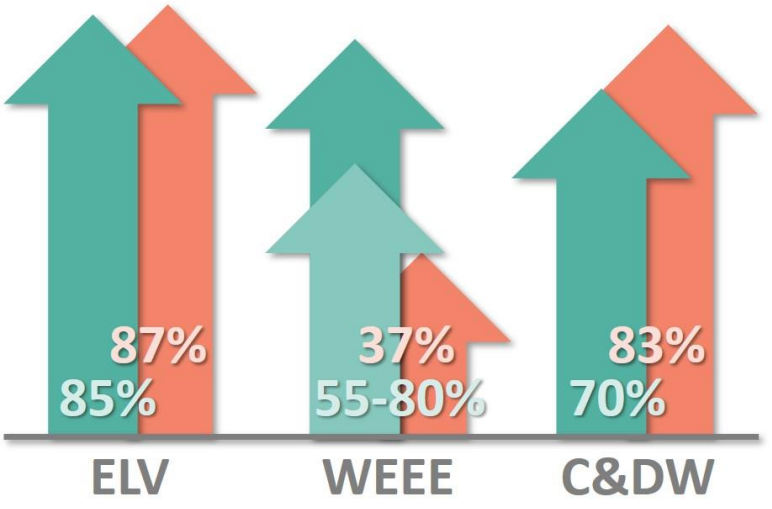

Figure 3 Current recycling requirements (in green) and performance (in red) for the NONTOX target waste streams (Eurostat, 2020b; 2020c; 2020c; 2020d[14]; and directives (2008/98/EC); (2000/53/EC); (2012/19/EU))

The WFD and the LoW defines whether a waste is considered hazardous or not and the treatment requirements for such waste. The Waste Shipment Regulation restricts international shipments of waste, with specific requirements and prohibitions for hazardous waste. Furthermore, the POP Regulation defines treatment requirements for wastes classified as POP waste. Limits for POP and hazardous waste classification differ, meaning that POP waste may be hazardous or non-hazardous depending on whether the hazardous waste limit is exceeded or not. For example, textiles containing POP substances might be circulated for recycling if not identified and removed by skilled personnel at the waste sorting centre.

The definition of waste as hazardous/non-hazardous[15] enables stakeholders in the waste management chain to define which regulatory framework to comply with in treatment and recycling. If the plastic waste of the target waste streams satisfies the limit values set in the above-mentioned regulations, the waste is typically not classified as hazardous and can generally be treated without any processes aiming at eliminating the hazardous substances.

The WFD states that it is forbidden to dilute waste in an attempt to satisfy the limit values. The Stockholm Convention and the EU POP Regulation emphasises the

[14] Recycling rate for WEEE is calculated as the ratio of waste recycled per products put on the market.

[15] The classification is primarily based on the European List of Waste (2014/955/EU). In some cases, a particular type of waste on the list can be either hazardous or non-hazardous depending on the specific properties of the waste and in these cases the waste status has to be assessed based on its hazardous properties.

identification and removal of POP waste. In the Basel Convention, it is stated that POP waste should be treated separately from non-hazardous waste streams.

Once the waste plastic is treated in a recycling process, the aim is to have a clean plastic product. The aim of REACH is to ensure that all substances are manufactured and used safely. REACH concerns the use of substances in products manufactured in or imported to the EU. In REACH, certain substances are listed as Substances of Very High Concern (SVHC) and published on the web page of the European Chemical Agency ECHA. The list is constantly updated, and new hazardous substances are introduced. When using the recovered material in a product, it must comply not with only REACH, but also other relevant product legislation, such as the ELV, RoHS and CPR directives and regulations.

The revised WFD defines the criteria for end-of-waste; the most important requirements being that the secondary material should be an adequate alternative to primary raw materials and used as direct input to the manufacture of plastic products. However, there is no general end-of-waste status for plastic in the EU. Still, the recovered material can be used in the production of new products, again in compliance with product legislation. The methodology for evaluating end-of-waste compliance formulated by the Joint Research Centre is presented in section 4.9.

2.4 Economic and environmental benefits of plastics recycling

2.4.1 Economic challenges of the current system and benefits of recycling and circular plastics

Plastics bring benefits through their functionality and high performance; however, the current linear plastic economy with low recycling rates has unintended drawbacks, like loss of materials and subsequent environmental challenges. It is estimated that currently the value of global material losses amount to EUR 70 to 105 billion. Agriculture, fishery and other livelihoods are particularly vulnerable to losses due to direct and in indirect effects of plastic pollution in the environment. Transforming the current system to circular models is expected to result in both environmental and economic gains. The economic impact of the circular economy is expected to reach out to the employment sector; it is estimated that by 2030 the circular plastics economy will create 200 000 new jobs across the EU. (Crippa, et al., 2018)

The economic benefits of plastics recycling and a circular plastics economy have been assessed in the NONTOX project through a preliminary NONTOX concept technoeconomic assessment on WEEE streams in Europe. The results of this preliminary assessment indicate that approximately 93 % WEEE-derived waste material currently incinerated or landfilled could be converted into products via the NONTOX concept. The NONTOX concept could produce around 376 200 tonnes/year of recycled polymers, pyrolysis oil and char at a European level. In addition, the currently recycled ABS and PS polymers containing

acceptable but high levels of bromine (600–1000 ppm) could be further processed to decrease the bromine content and thus increase their value. At a European level this would mean up to 29 700 tonnes/year of value-added, higher-quality recycled plastics. The economic potential of the NONTOX plant concept at the European level was estimated by contribution margins, defined as the variable operating costs subtracted from revenues. Variable operating costs are based on raw materials, chemicals and utilities, and revenues are obtained from the waste stream-specific gate fees, recycled monotype polymers, oil and char. Based on the variable operational costs and revenues, the contribution margin was determined to be approximately EUR 400 million/year. Strongly positive contribution margins indicate that there is potential to also cover variable costs, which were not yet included due to lack of data, as well as fixed costs (total capital investment, labour and maintenance).

In conclusion, the contribution margin of the NONTOX concept is strongly positive, when converting hazardous waste from WEEE sorting via the NONTOX concept to valuable products at the European level. The estimated contribution margin is almost 80% of the revenues. The preliminary results indicate that the NONTOX concept has the potential for economically feasible operation.

2.4.2 Environmental challenges of the current system and the benefits of recycling and circular plastics

The major environmental issues of the current plastic waste management include plastic pollution and contribution to climate change through GHG emissions. It is estimated that annually, 75 000–300 000 tonnes of microplastics are released into the environment (Crippa et al., 2018). It is also estimated that annually 1.5–4 % of the global plastic production ends up in the oceans. It takes hundreds of years for plastics to decompose, which constitutes a grave threat to the marine environment.

Currently, on average, 27 million tonnes of plastics waste (PlasticsEurope, 2018) are generated in Europe per year. In 2016, 31 % of this was effectively recycled, 41.7 % was sent to energy recovery, and the remaining 27.3 % was landfilled. Over the past decade, recycling and energy recovery rates have steadily increased, which has significantly reduced landfilling. Worldwide, the amount of plastics ending up in landfill is almost half of the produced amount, being 150 Mt annually. As recycling rates for plastics are increasing, a worldwide market for recycled plastics is developing.

As well as economic benefits, using recycled plastic avoids emissions of an amount equivalent to that generated through the production of virgin plastics, leading to a significant reduction in CO_2 emissions.

3. Value chains of target waste streams

The overall objective of the NONTOX project is to increase the recycling rates of plastic waste containing hazardous substances by developing and optimising recycling processes to produce safe and high-quality recovered plastics, focusing on the plastic fractions of C&DW, WEEE and ELV. The project is targeting the removal of hazardous and undesired substances, with a focus on especially brominated flame retardants (BFRs).

The three target waste streams have very different characteristics and magnitudes. The waste streams share the fact that end-of-life comes with a delay from being put on market – in buildings it can be up to 50 or 100 years, for vehicles it is closer to a decade, and for electronics the life span varies between appliances from a year or two to a decade or two. For ELV, the first treatment steps are solely for one vehicle, and mixing with other vehicles is done at later processing stages, whereas the C&DW is mixed already at waste generation and WEEE is collected as a mix of different WEEE, commonly with some differentiation between categories of material characteristics.

C&DW waste is the largest waste stream in the EU-27, with an annual generation of approximately 330 million tonnes, while annual ELV generation is less than 7 million tonnes, and WEEE generation is somewhat unknown due to the loss of WEEE in the value chain, varying between the 8.7 million tonnes of EEE placed on the market to the 3.5 million tonnes of WEEE collected in 2018.

All three waste streams have a similar magnitude of plastic content, approximately 1 million tonnes of plastic waste annually generated in the EU in each waste stream. WEEE has the highest average plastics content of about 30%, for C&DW, plastic accounts for only 0.2 % of the total waste generation and for ELV the corresponding number is estimated to be 15 % (Kaartinen et al., 2020).

Today, many WEEE streams are treated separately from other waste streams. That is not the case for the other two target waste streams, which are commonly mixed with waste with similar properties, such as mixed metal scrap from industries and municipalities. The ELV and WEEE streams in particular contain a high proportion of metals, which have a high value as recovered metal scrap. Thus, the primary processes for treatment of these target waste streams are developed for metal recovery, and the plastic fraction is a side stream from primary sorting and shredding.

The plastic waste fractions are very heterogeneous in nature, which poses a challenge for efficient plastics recycling. Recycling different polymers together typically result in poor plastic recyclate quality. Efficient sorting is needed to achieve high-quality recyclates. Today, the main route for collected plastics in the target waste streams in the EU is incineration and landfill.

Between the NONTOX target waste streams, most plastics recycling is applied for WEEE, partly because of the polymer types used and partly because many WEEE streams are treated as mono streams for metal recovery purposes, making the resulting non-metallic fractions less complex in nature. Also, the large volumes of plastics in WEEE streams enable economically feasible plastic recovery and

supports the reaching of recycling targets for this waste stream. An overview of current plastic recycling treatment methods and process chains are further explained in Deliverable D1.1 of the NONTOX project (Yli-Rantala et al., 2020).

3.1 End-of-life vehicles, ELV

Every year, between 5 and 6 million tonnes of ELV waste are generated in the EU-27 (Eurostat, 2020a). The ELV Directive (2000/53/EC) sets targets for 85 % recycling and 95 % recovery for end-of life vehicles, by an average weight per vehicle and year. The directive further states that all ELVs must be collected via an authorised collection scheme. The recycling rate in the EU-27 was 87 % in 2018, thus exceeding the target.

The average weight of an ELV is approx. 1 100 kg (Eurostat, 2020e), but it is estimated that this will increase in the future due to the higher average weight of vehicles currently being produced. GHK (2006) estimates the average vehicle life span to be 13 years. The average content of an ELV changes over time, depending on the typical composition of vehicles produced on average 13 years ago. Plastics content of ELV is increasing, from approximately 10 % in 2003 to 12 % in 2012, and is expected to reach around 15 % within a few years (GHK, 2006). Figure 4 illustrates the average composition of a vehicle in 2012.

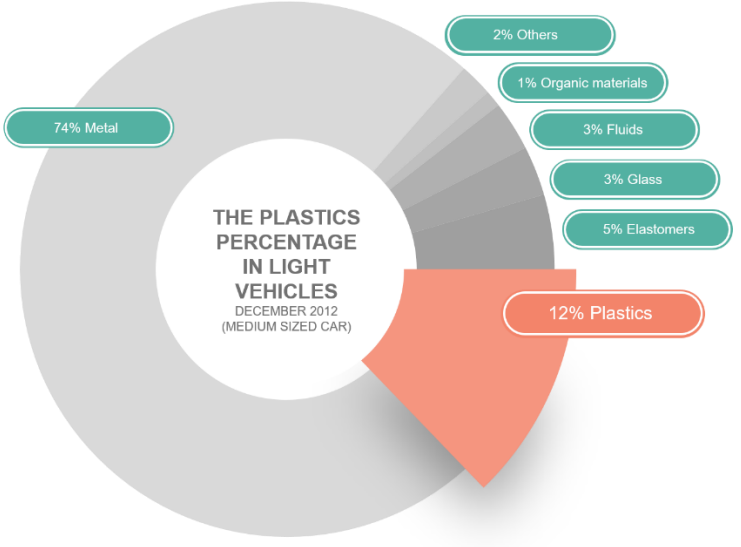

Figure 4 The composition of vehicles in 2012, which are expected to reach end-of-life within a few years. (Plastics Europe, 2013)

Cars produced today are heavier than current ELVs. With increasing ELV weight and increasing plastic content, the future ELV plastic streams are bound to increase. In cars that will become ELV within a few years, the most common plastics are (Plastics Europe, 2013):

- PP (28.6 %)
- PUR (17.4 %)
- PA (11.9 %)
- Other engineering materials (10.9 %)
- PE (LD/LLD/HD/MD) (9.7 %)
- Other plastics (9.5 %)
- ABS, ASA and SAN (5.3 %)
- PVC (3.8 %), PCS (1.6 %)
- PMMA (1.3 %)

The use of plastics in vehicles is divided into exterior 21 %, under the bonnet 14.5 %, interior 52.5 % and electric/lighting 12 % use (Plastics Europe, 2013). In the NONTOX project in Deliverable 1.6, an estimation was made that 1.1 million tonnes of ELV plastics were generated in the EU-28 countries in 2020 (Kaartinen, et al., 2020).

The ELV Directive aims at making the dismantling and recycling of ELVs more environmentally friendly. In the EU, extended producer responsibility (EPR) is mandatory within the ELV Directive, which puts the responsibility for the financing of collection, recycling and end-of-life disposal of vehicles on the producers. The EPR obligates the producers to arrange for the collection and treatment of ELVs, but it also allows for the producer to for example join a collective system to take them back. The collection system needs to have adequate coverage and should be at no cost to the last owner.

There are different types of collection systems in all markets in the EU. The most common systems are based on either reception points where the owner can take the ELV or collection services that pick up the vehicle at end-of-life. At collection, the vehicle is commonly registered as collected ELV and the PRO is responsible for the storage and treatment according to national legislation.

The ELV Directive sets minimum requirements for the collection of vehicles at suitable treatment facilities; the minimum technical requirements are related to preventing harm to health or the environment. The minimum technical requirements for storage and treatment facilities are related to preventing fluids from being released into soil, and to preventing any other harm to health or the environment. The directive also describes requirements for the physical treatment procedure of vehicles, including operations for depollution and treatment operations aiming to promote reuse and recycling.

In order to ensure safe storage and treatment of ELVs, it is necessary to drain them of all fluids and remove components with hazardous content (e.g. components containing mercury), and explosive components (e.g. seatbelt tensioners or air bags). In order to maximise the reuse and recycling rates, certain components are removed before shredding the vehicle, such as catalytic converters, tyres, glass,

and other metal parts containing copper, aluminium or magnesium, and large plastic components if these materials are not segregated in the shredding process. After this pre-treatment the waste is no longer classified as hazardous. Any materials or parts with a market value are commonly removed before shredding. The value of the ELV is determined by its material content and the value of extracted spare parts; the markets for reused spare parts differ between EU Member States.

In the shredding process, ELVs can be combined with other material streams. They are commonly treated together with large WEEE, and fractions from the industry and construction and demolition activities.

With increasing ELV weight and increasing plastic content, future ELV plastic streams are bound to increase. The shredder light fraction (SLF) includes plastics containing hazardous substances such as POPs and BFRs. Several different BFRs are commonly used as flame retardants in plastic vehicle components such as dashboards, and also in textiles. The increasing volumes of contaminated plastics will complicate the attaining of the recycling targets set by the ELV Directive, as the POP Regulation prohibits the reuse and recycling of waste exceeding the concentration levels of certain substances.

3.2 Waste electronic and electric equipment, WEEE

WEEE is the fastest-growing waste stream in the world; some forms of it have been growing exponentially. It was estimated that the WEEE stream reached 50 million tonnes in 2018 and is expected to double if nothing changes; by 2021 the annual total volume is expected to surpass 52 million tonnes. (WEForum, 2019)

WEEE is a complex, heterogeneous waste stream, comprising products manufactured from many different components and materials. In some cases, it contains hazardous chemicals, such as flame retardants and POPs. Because of the hazardous content of WEEE, there are special end-of-life requirements for the treatment processes set out in the WEEE Directive. Handling and treating WEEE is further complicated by the way the waste is dispersed amongst consumers and business users and the diverse range of collection methods across WEEE categories and across Europe. WEEE recycling focuses on the recycling of metals, whereas the residues – mainly plastics laced with metals and chemicals – pose a tougher problem. In the shredding process, WEEE can be combined with other material streams. Large WEEE is commonly treated together with ELV, and fractions from the industry and construction and demolition activities.

Traditionally, WEEE has been divided into 10 categories;[16] as of 2018, all EEE is classified within the six categories set out in Annex III of the WEEE Directive.

[16] The 10 categories of the old system are as follows:

1. Large household appliances, e.g. fridges, radiators and air conditioning appliances
2. Small household appliances, e.g. sewing machines, toasters and clocks
3. IT and telecommunications equipment, e.g. computers and their accessories, calculators and phones
4. Consumer equipment, e.g. TVs, radios and musical instruments
5. Lighting equipment, e.g. fluorescent lamps and non-household luminaires

1. Temperature Exchange Equipment (TEE) – includes refrigerators, air conditioning equipment and heat pumps
2. Monitors and equipment with large screens – includes monitors, televisions, laptops, tablets, e-book readers with screens greater than 100 cm^2 and whose primary focus is displaying information
3. Light bulbs – includes fluorescent, LED, HID and LPS lamp bulbs and tubes
4. Large equipment – includes any EEE not included in categories 1, 2 or 3 that has at least one external dimension (L, W, H) greater than 50 cm. This typically includes washing machines, dryers, electric stoves, large medical equipment, photovoltaic panels, large light fixtures, etc.
5. Small equipment – includes any EEE not included in other categories with all external dimensions (L, W, H) less than 50 cm and that is not IT equipment (Category 6). This typically includes vacuum cleaners, microwaves, small kitchen appliances and consumer electronic equipment
6. Small IT/computer/communications equipment – includes any EEE not included in other categories with all external dimensions (L, W, H) less than 50 cm and that is used for IT, computing or communications. This typically includes smartphones, desktop computers, GPS equipment, printers, routers and fax machines.

The presence of hazardous substances in electrical and electronic equipment (EEE) is restricted by the RoHS Directive, with impacts on the presence of these substances in WEEE as well, with a delay. The RoHS Directive aims at preventing harm to health and the environment through the restriction of hazardous substances in EEE. RoHS restricts the use of the ten substances listed below. In general, the maximum permitted concentrations in products are 0.1% (except for cadmium, which is limited to 0.01% or 100 ppm) by weight. The restrictions are on each homogeneous material in the product:

- Lead (Pb)
- Mercury (Hg)
- Cadmium (Cd)
- Hexavalent chromium (Cr6+)
- Polybrominated biphenyls (PBB)
- Polybrominated diphenyl ether (PBDE)
- Bis(2-ethylhexyl) phthalate (DEHP)
- Butyl benzyl phthalate (BBP)
- Dibutyl phthalate (DBP)

6. Electrical and electronic tools, e.g. drills, welding equipment and lawnmowers
7. Toys, leisure and sports equipment, e.g. electric train sets, video games and slot machines
8. Medical devices, e.g. dialysis machines, ventilators and radiotherapy equipment
9. Monitoring and control instruments, e.g. smoke detectors, thermostats and other instruments used in industrial installations
10. Automatic dispensers, e.g. drinks, food and cash dispensers

- Diisobutyl phthalate (DIBP)

Today, when EEE reaches end-of-life and becomes WEEE, it should be collected and handled according to the descriptions in the WEEE Directive. The directive sets targets for the collection and preparation for reuse or recycling of WEEE. The WEEE Directive sets a target of 65 % collection of the average weight of EEE placed on the market in the three preceding years, or alternatively 85 % of WEEE generated in that same year. Minimum annual targets for recycling of the six categories in Annex III of the WEEE Directive are:

- WEEE category 1 and 4
  - 85 % recovery
  - 80 % recycling and preparation for reuse
- WEEE category 2
  - 80 % recovery
  - 70 % recycling and preparation for reuse
- WEEE category 3
  - 80 % shall be recycling
- WEEE category 5 and 6
  - 75 % recovery
  - 55 % recycling and preparation for reuse

In the EU, extended producer responsibility (EPR) is mandatory within the WEEE Directive, which put the responsibility for the financing of collection, recycling and end-of-life disposal of WEEE on the producers of EEE. The EPR obligates the produces to arrange for the collection and treatment of the WEEE, but it also allows for the producer to join a collective system to take back the WEEE, for example. In the EU, WEEE is mainly collected through community waste collection sites or taken back by retailers.

Reporting on the collection and treatment of WEEE is regulated in the WEEE Directive. The data on officially collected and recycled WEEE is reported to national registers by EEE producers and producer responsibility organisations (PROs). According to the ProSUM (2020) and CWIT (2013) projects, only one third of WEEE is being reported as separately collected and appropriately managed. In 2015 only 3.8 million tonnes of WEEE ended up in the officially reported amounts of collection and treatment (Huisman et al. 2017). According to Eurostat, in 2018 3.5 million tonnes of WEEE was collected in the EU-27, of which 3.3 million tonnes was recycled (Eurostat, 2020d).

WEEE generation is much larger than the statistical amount of WEEE generated in the EU. WEEE disappears into other waste streams, such as in municipal solid waste (MSW), it is hoarded and also illegally shipped abroad, which is not considered in the statistics. According to Huisman et al. (2015), for the EU-28 plus Norway and Switzerland (EU28+2), the total amount of WEEE generated in 2012 was 9.45 million tonnes, of which 3.3 million tonnes was reported by Member States as collected and recycled, 0.75 million tonnes was estimated to end up in the waste bin

and 2.2 million tonnes of WEEE was mixed with metal scrap, leaving 3.2 million tonnes of WEEE missing.

Overall data on the collection and recycling of WEEE is generally more comprehensive than data on WEEE plastics. Baxter et al. (2014) estimates the plastic content of the WEEE stream to be approx. 17–20 %. Analysis of the plastic content on a product group-by-group basis for the grouping of WEEE according to the old system (Dimitrakakis et al., 2009) gives the WEEE plastic composition as illustrated in Table 1.

Table 1. Analysis on a product group-by-group basis for the grouping of WEEE according to previous categories 1–10 (Dimitrakakis et al., 2009)

	1	2	3	4	5	6	7	8	9	10
ABS	40 %	35 %	15 %	42 %	15 %	15 %	42 %	15 %	15 %	15 %
PP	35 %	35 %	0 %	3 %	15 %	15 %	48 %	15 %	15 %	15 %
PS	0 %	10 %	40 %	35 %	50 %	50 %	0 %	50 %	50 %	50 %
PC	15 %	3 %	10 %	0 %	20 %	20 %	0 %	20 %	20 %	20 %
PVC	0 %	10 %	0 %	15 %	0 %	0 %	1 %	0 %	0 %	0 %
PBT	8 %	3 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
PA	0 %	2 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
Other	2 %	2 %	35 %	5 %	0 %	0 %	9 %	0 %	0 %	0 %

The EEE case – mechanical recycling at Coolrec

Coolrec Plastics is one of the largest recyclers of waste plastics in Europe. Having three high-tech production plants, Coolrec Plastics recycles about 50 thousand tonnes of plastic materials into valuable raw materials annually, from shredded plastic of WEEE, to regranulate enhanced to the specification for the production of new (components of) products. The case below is a good practice example of how the regulations are involved in the daily life of a recycler and producer of secondary raw materials.

- Collection, transport and EEE recovery

Discarded electronic and electrical equipment (EEE) is collected according to the country legislation and collection scheme. The EEE is transported from the container park to the treatment facilities.

EEE is depolluted from hazardous gas and liquid. The sorting starts with the separation of ferrous and non-ferrous metals. The remainder consists of the light fraction that is sent to the plastics recovery facility.

Involved regulation in this section: **Waste Shipment regulation, WEEE Directive, WEEELabex CENELEC (EN-50625), Waste Framework Directive, POP Regulation**

- Plastics sorting

The plastics-rich fraction is separated by polymer types through a combination of wet and dry sorting technologies. The sorted output fraction is characterised according to the **EN 15343** standard and a technical data sheet is established. To ensure compliancy with **REACH** and **POP** Regulation Annex I, the **PRE-1000-1** specification is used.

The output material can apply to the **End-of-Waste criteria** if such is available in the country of treatment.

- Back to the market

A granulation or compounding step is performed on the sorted material to form a ready-to-use product for the manufacturer. If the material is intended for use in the electronics market, compliance to **RoHS** has to be established. To ease the integration of recycled plastics into new products, the designer can modify the product structure according to the **Ecodesign Directive**.

The loop is complete!

3.3 Construction and demolition waste, C&DW

C&DW is the largest waste stream in the EU, generating approx. 35 % of the annual waste[17] in the region. Construction and demolition waste generation in the EU27 in 2018 was 400 million tonnes (excluding waste soils and dredging waste), of which the mineral content formed the biggest fraction, approximately 90 % of the total volume. The plastics content is 0.2 % of the total waste stream, in total approximately 1 million tonnes (in comparison: plastics from households is approximately 3 million tonnes in total). (Eurostat, 2020b) The C&DW composition of the EU-27 is illustrated in Figure 5.

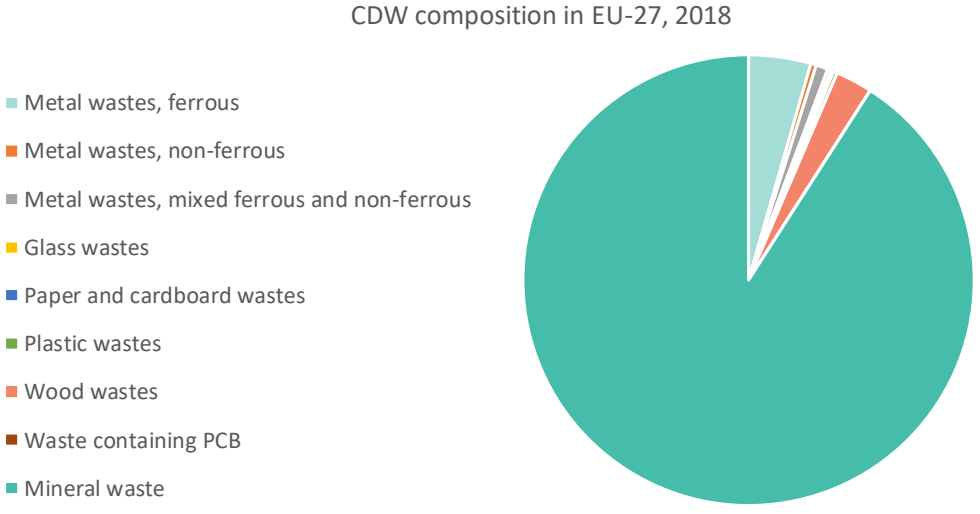

Figure 5. C&DW composition (Eurostat, 2020b)

Generally, around one fifth of all plastics are used in construction. The most typical end uses of plastics include insulation materials, moisture and damp-proofing materials, floor coverings and window frames. Plastics are commonly also used as different kinds of profiles and items related to electrical systems, plumbing, as well as heating, ventilation, and air conditioning (HVAC) systems. Furthermore, most paints, glues, boards, roof coverings, mineral material-based insulations and laminated surfaces include plastics in the form of raw materials or resins. Plastics can

[17] Eurostat. 2020b. Generation of waste by waste category, hazardousness and NACE Rev. 2 activity [env_wasgen]. The amount of C&DW generated is calculated as the sum of waste categories W061 ferrous metal wastes, W062 non-ferrous metal wastes, W063 mixed ferrous and non-ferrous metal-wastes, W071 glass wastes, W072 paper and cardboard wastes, W074 plastic wastes, W075 wood wastes, W077 waste containing PCB, and W121 mineral waste from construction and demolition, all generated by the statistical classification of economic activities in the European Community (NACE) Rev. 2 Section F (construction sector).

help to achieve many essential technical and functional properties that are vital for modern buildings. (Häkkinen et al. 2019)

Construction and demolition are defined as priority areas in the EU according to the first Circular Economy Action Plan (EC, 2015) for closing the loop, and have since remained key areas of interest in the European Green Deal (EC, 2019) and the new Circular Economy Action Plan (EC, 2020A). The WFD sets a target of recycling 70% (by weight) of non-hazardous construction and demolition waste. The Commission shall also consider by 2024 material-specific targets for key streams. As calculated from Eurostat (2020b and 2020c), the average recovery rate of C&DW in the EU was 83 % in 2018[18], with the remainder being incinerated or landfilled. The recovery rate is very much dominated by the mineral part of C&DW.

A typical feature of C&DW is that it is not continuously generated, and its characteristics vary due to site-specific conditions. C&DW is commonly very heterogeneous and contaminated. C&DWs are generated at three types of construction sites: construction, renovation and demolition, demolition waste being the dominant waste stream. Each of these sites produces waste with a different composition and characteristics. The waste streams of construction sites are mostly clean material surpluses and leftovers. Demolition and renovation waste, on the other hand, is mixed and contaminated and thus also more difficult to recover.

Even though the vast majority of C&DW is recyclable, one common barrier to recycling and reusing C&DW in the EU is the lack of confidence in the quality of the recovered materials. Construction products containing recovered material need to comply with requirements for products produced from virgin materials, since the CPR and standards often exclude the use of recovered materials in products.

The delay of waste generation from the time of construction of buildings or production of materials is often of several decades. Reservations linked to past or current building practices and the utilisation of hazardous substances currently known to be of harm to the health or environment create the main bottleneck for recycling. Products imported from outside Europe may also contain hazardous substances which are regulated in the EU.

Chemicals that are classified as hazardous have been added to achieve a certain function or property in the product (e.g. flame retardants). Especially flooring, carpets and panel materials may contain hazardous substances. In plastic products, brominated flame retardants and phthalates as plasticisers have been used quite commonly. Hazardous substances commonly found in plastic C&DW are (Wahlström et al., 2019):

- PCBs
- Flame retardants containing bromine or chlorine

[18] Statistics on treatment of waste by waste category, hazardousness and waste management operations [env_wastrt] and generation of waste by waste category, hazardousness and NACE Rev. 2 activity [env_wasgen]. Generation data based on classification of economic activities in the European Community (NACE) Rev. 2 Section F (construction sector). C&DW treatment and generation data is only based on mineral C&DW (W121 code), because no data is available on the treatment of other C&DW in Eurostat.

- Heavy metals as additives in paint (cadmium (Cd), chrome (Cr), copper (Cu), lead (Pb) and zinc (Zn))

Flame retardants containing bromine or chlorine can be found in plastics, furniture and carpeting. The main concern of brominated flame retardants in C&DW relates to the presence of HBCDD (hexabromocyclododecane). The main part (90 %) of HBCDD is used as a flame retardant in polystyrene (PS) (Wahlström et al. 2019).

Hazardous substances in construction products are predominantly regulated through the REACH Regulation and national regulations (e.g. asbestos, lead, arsenic, creosote, etc). The CPR makes references to REACH. The CPR lays down harmonised rules for the marketing of construction products in the EU, ensuring that reliable information is available and enabling a comparison of the performance of products from different manufacturers in different countries. Some examples of different brominated flame retardants and what their situation is under REACH are described in Table 2.

Table 2. Examples of brominated flame retardants that can occur or are used in C&DW plastics[19][20][21]

Substance	CAS no.	Substance group	Substance description in C&DW applications	Plastic type	REACH (by 10/2019)	POP Regulation (by 10/2019)
Decabromodiphenyl ether (DBDE)	1163-19-5	Flame retardants	Used in furniture, textiles, carpets, roofing, insulation, piping, ducting, hoses, cables	Typically used in HIPS. ABS+HIPS, HIPS, PP	Use is restricted under authorisation, candidate list. If concentration is below 0.1 %, no authorisation is required.	Sum of tetra-, penta-, hexa-, hepta- & decabromodiphenyl ether 1000 mg/kg (2010 POP). 500 mg/kg limit under review (2019 POP).
Decabromodiphenyl ethane (DBDPE)	84852-53-9	Flame retardants	Used in furniture, construction materials, plasters, polishes and waxes, binding agents in paints, emulsions and coatings, adhesive, sealants	Typically used with HIPS, PE, PP, thermosets, engineering thermoplastics	CoRAP – substance is being evaluated. No limit values since not on Authorisation or Restriction list.	Not on the list.

[19] Stockholm Convention on Persistent Organic Pollutants: ECHA proposes a restriction on decaBDE, a brominated flame retardant used in plastics and textiles.
[20] ECHAa: Substance infocard: 1,1'-(ethane-1,2-diyl)bis[pentabromobenzene]
[21] ECHAb: Substance infocard: Hexabromocyclododecane

Hexabromocyclododecane (HBCDD)	25637-99-4		Construction waste, insulation	XPS, EPS, HIPS	Candidate list for SVHC, Authorisation list.	Annex 1 & 2: 100 mg/kg (0.01 % by weight); Lower value 1000 mg/kg, higher value 1000 mg/kg (2010 POP). 500 mg/kg limit under review (2019 POP).

The WFD encourages Member States to promote selective demolition in order to enable the removal and safe handling of hazardous substances and facilitate reuse and high quality, and to establish sorting systems for C&DW at least for wood, mineral fractions, metal, glass, plastic and plaster. Furthermore, it is suggested that by 31 December 2024 the Commission should consider setting targets for material-specific fractions of C&DW.

Waste audits and selective demolition are expected to increase in Europe. Selective demolition is the key to efficient site sorting of C&DW, which enables recycling and the production of safe and high-quality recovered materials. Hazardous, reusable and recyclable materials should be identified prior to demolition in a waste audit, and actions can be planned for securing high-quality materials during the selective demolition. The quality of the waste is influenced by the performance/specifications/requirements of selective demolition. The C&DW is commonly transported to the treatment facilities directly from the construction site by the contractor.

The plastic material in C&DW contains a wide range of polymer types, and its composition within C&DW is generally seen as unclear (e.g. Lahtela et al. 2019). As an example, the estimated shares of different polymers in building and demolition waste in Finland in 2017 were as follows (Häkkinen et al. 2019).

- PVC 50–55 %
- PS 14–19 %
- PU 3–8 %
- PE-HD 4–9 %

4. The regulatory and policy framework

This chapter focuses on how different legislation applies to the different actors in different phases of the value chain. The key stakeholders targeted are recyclers and manufacturers utilising the recovered materials for the production of plastic products.

The legislative framework is reviewed to show its impact in the different sectors of the value chain and to show the stakeholders which legislative documents to comply with in their activities. In this report, the review on regulation and directives aims to follow a unified concept:

1. Scope, definition and general requirements of the directive
   Coverage, background and purpose
2. Content of key interest for recycling of plastics with undesired legacy substances
   Issues related to the topic, e.g. products, polymers and limit values
3. Reporting and controlling measures
   Methods for reporting and controlling

Standards aim at setting requirements for best recycling and trading practices. The purpose of standards is to provide additional guidelines and assist actors in fulfilling the requirements of the legislative documents. The use of standards is voluntary, but the legislation of specific Member States may refer to standards. In this report, the review of standards follows the treatment process and material fractions presented via a unified concept:

1. Purpose of the standard
   Why is this standard developed, what are the target groups to use this standard
2. Basis for the standard
   Background, prerequisites, other relevant information
3. Methods and materials
   What is done, how is it done, etc.

4.1 The Waste Framework Directive 2008/98/EC

4.1.1 Scope, definition and general requirements of the directive

Directive 2008/98/EC[22] sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling, recovery, end-of-waste

[22] Amended by
- Commission Regulation (EU) No 1357/2014 of 18 December 2014
- Commission Directive (EU) 2015/1127 of 10 July 2015
- Council Regulation (EU) 2017/997 of 8 June 2017
- Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018

criteria, and how to distinguish between waste and by-products. The directive lays down measures to protect the environment and human health via two key objectives: to prevent and reduce the negative impacts caused by the generation and management of waste and to improve resource efficiency through reuse, recycling and recovery. The directive also defines the waste hierarchy (Figure 6), and states in Article 10(1) that:

> *Member States shall take the necessary measures to ensure that waste undergoes preparing for reuse, recycling or other recovery operations.*

And in Article 13 that:

> *Member States shall take the necessary measures to ensure that waste management is carried out without endangering human health, without harming the environment and, in particular:*
> *(a) without risk to water, air, soil, plants or animals;*
> *(b) without causing a nuisance through noise or odours; and*
> *(c) without adversely affecting the countryside or places of special interest.*

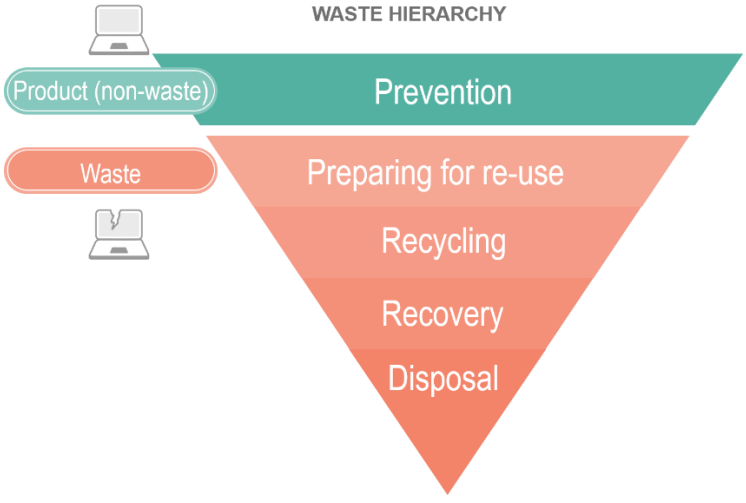

Figure 6 Waste hierarchy according to the European Commission and the WFD (EC, 2020b).

According to the WFD (Article 23), all establishments that carry out waste treatment operations must have a permit from a competent authority for the types and quantities of waste that can be treated, including the processes for treatment. According to the WFD (Article 34), these establishments shall be subject to appropriate periodic inspections by the competent authorities.

4.1.2 Content of key interest for recycling of plastics with undesired legacy substances

Collection and treatment of construction and demolition waste

The WFD promotes selective demolition to enable the removal and safe handling of hazardous substances and facilitate reuse and high-quality recycling. Selective demolition facilitates selective removal of materials, and the establishment of sorting systems for construction and demolition waste.

Waste classification and the European List of Waste

The European List of Waste (LoW) provides an EU-wide common terminology for waste classification[23] to ease waste management, including hazardous waste. The classification of waste as hazardous includes references to other directives for limit values of concentration of hazardous substances. The assignment of LoW codes[24] serves a broad variety of activities, including the transport of waste. The technical guidance on the classification of waste (2018/C 124/01) provides guidance on the interpretation and application of EU legislation on the classification of waste.

The WFD states in Article 7(1)–7(4) that:

> *The list of waste shall include hazardous waste and shall take into account the origin and composition of the waste and, where necessary, the limit values of concentration of hazardous substances.*
> *A Member State may consider waste as hazardous waste where, even though it does not appear as such on the list of waste, it displays one or more of the properties listed in Annex III.*
> *Where a Member State has evidence to show that specific waste that appears on the list as hazardous waste does not display any of the properties listed in Annex III[25], it may consider that waste as non- hazardous waste.*
> *The reclassification of hazardous waste as non-hazardous waste may not be achieved by diluting or mixing the waste with the aim of lowering the initial concentrations of hazardous substances to a level below the thresholds for defining waste as hazardous.*

[23] The classification of waste is based on:
- the European List of Waste (Commission Decision 2000/532/EC – consolidated version) and
- Annex III to Directive 2008/98/EC

[24] The NONTOX polymers are classified under the following codes: ELV 1601, in specific ELV plastics 160119; WEEE 1602; C&DW 17, in specific C&DW plastics 170203.

[25] Annex III of the WFD includes a list of properties of waste that render it hazardous.

Treatment and shipment of hazardous waste

Hazardous waste poses a greater risk to the environment and human health than non-hazardous waste and thus requires a stricter control regime. For hazardous waste, the WFD provides additional labelling, record keeping, monitoring and control obligations from the 'cradle to the grave', i.e. from waste production to final disposal or recovery. In addition, mixing of hazardous waste is banned to prevent risks to the environment and human health.

The WFD states in Article 17:

> *Member States shall take the necessary action to ensure that the production, collection and transportation of hazardous waste, as well as its storage and treatment, are carried out in conditions providing protection for the environment and human health in order to meet the provisions of Article 13, including action to ensure traceability from production to final destination and control of hazardous waste.*

And in Article 18:

> *Member States shall take the necessary measures to ensure that hazardous waste is not mixed, either with other categories of hazardous waste or with other waste, substances or materials. Mixing shall include the dilution of hazardous substances.*

And in Article 19:

> *Member States shall take the necessary measures to ensure that, in the course of collection, transport and temporary storage, hazardous waste is packaged and labelled in accordance with the international and Community standards in force.*

The requirements on treatment facilities for hazardous waste is furthermore stated in the Industrial Emissions Directive (2010/75/EU) for the incineration of hazardous wastes, and in the Landfill Directive (1999/31/EC) and Council Decision for the acceptance of waste at landfills (2003/33/EC) on the landfilling of hazardous wastes. In addition, national legislation restricts the incineration and landfilling of hazardous waste, where some Member States has a ban on landfilling combustible waste or has set a limit value for total organic carbon (European Environment Agency, 2016).

End-of-waste criteria

The end-of-waste criteria specifies when certain waste ceases to be waste and obtains a status of a product (or a secondary raw material). According to Article 6 (1) and (2) of the WFD, certain specified waste shall cease to be waste when it has undergone a recovery (including recycling) operation and complies with specific criteria, in particular:

- the substance or object is commonly used for specific purposes;
- there is an existing market or demand for the substance or object;

- the use is lawful (substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products);
- the use will not lead to overall adverse environmental or human health impacts.

The Commission monitors the development of national end-of-waste criteria in Member States and assesses the need to develop Union-wide criteria. The implementing act 2019/1004/EC establishes detailed criteria on the uniform application of conditions for end-of-waste criteria.

Where criteria have not been set at Union level, Member States may under certain conditions establish detailed national criteria or decide on a case-by-case basis to take appropriate measures to verify that certain waste has ceased to be waste. Those detailed criteria shall take into account any possible adverse environmental and human health impacts of the substance or object and shall satisfy the requirements laid down in the WFD Article 6(2) and taking into account limit values for pollutants and any possible adverse environmental and human health impacts.

4.1.3 Reporting and controlling measures

According to the WFD (Article 35), all establishments that carry out waste treatment operations shall keep a chronological record of the quantity, nature and origin of that waste and the quantity of products and materials resulting from preparing for reuse, recycling or other recovery operations; and where relevant, the destination and mode of transport foreseen in respect of the waste. For hazardous waste, the records shall be preserved for at least three years except in the case of establishments and undertakings transporting hazardous waste, which must keep such records for at least 12 months.

4.2 The ELV Directive 2000/53/EC

4.2.1 Scope, definition and general requirements of the directive

Directive 2000/53/EC[26] sets the basic concepts and definitions related to management of end-of life vehicles. The directive lays down measures to protect the

[26] Amended by:
- Commission Decision 2002/525/EC of 27 June 2002
- Commission Decision 2005/63/EC of 24 January 2005
- Commission Decision 2005/438/EC of 10 June 2005
- Council Decision 2005/673/EC of 20 September 2005
- Directive 2008/33/EC of the European Parliament and of the Council of 11 March 2008
- Commission Decision 2008/689/EC of 1 August 2008
- Directive 2008/112/EC of the European Parliament and of the Council of 16 December 2008

environment and human health by preventing and reducing the generation of ELV, and the adverse impacts of the generation and management of ELV. The ELV Directive sets minimum requirements for the treatment of ELV, more specifically for the collection of vehicles at suitable treatment facilities and for the processes of depollution of fluids and specific components. It sets clear quantified targets for the reuse, recycling and recovery of the ELVs and their components.

The directive covers all vehicles and end-of life vehicles, including their components and materials. Not only does it cover the treatment of ELV, but also the production of vehicles. For example, in Article 4, the directive encourages producers to manufacture new vehicles without hazardous substances[27], thus promoting the reuse, recyclability and recovery of waste vehicles. Furthermore, it also pushes for the integration of an increasing quantity of recycled material in vehicles and other products, in order to develop the markets for recycled materials.

Article 5 on the collection states that Member States must ensure that there is a system for the collection of all end-of life vehicles and that all end-of life vehicles are transferred to authorised treatment facilities. Article 5 further introduces a mandatory extended producer responsibility (EPR) scheme, which puts the responsibility for the financing of collection, recycling and end-of-life disposal of vehicles on the producers[28]. The delivery of the vehicle to the treatment centre must be at no cost to the owner as a result of the vehicle's having no or negative market value.

4.2.2 Content of key interest for the recycling of plastics with undesired legacy substances

Treatment of ELVs

The ELV Directive (Article 7) encourages the reuse of components that are suitable for reuse, the recovery of components that cannot be reused, and recycling when environmentally viable.

Member States shall ensure that all end-of life vehicles are stored (even temporarily) and treated in compliance with the minimum technical requirements, and at treatment facilities complying with the requirements as set out in Annex I. Treatment operations for the depollution of end-of life vehicles as referred to in Annex I shall be carried out as soon as possible. Regarding the treatment operations, Annex I sets out minimum requirements and Article 6 states the following:

- End-of life vehicles shall be stripped before further treatment.

- Commission Decision 2010/115/EU of 23 February 2010
- Commission Directive 2011/37/EU of 30 March 2011
- Commission Directive 2013/28/EU of 17 May 2013

[27] In particular lead, mercury, cadmium and hexavalent chromium

[28] The delivery of end-of life vehicles need not be fully free of charge if the end-of-life vehicle does not contain the essential components of a vehicle, in particular the engine and the coachwork, or contains waste that has been added to the end-of life vehicle.

- Hazardous materials and components shall be removed and segregated in a selective way so as not to contaminate subsequent shredder waste from end-of life vehicles.
- Stripping operations and storage shall be carried out in such a way as to ensure the suitability of vehicle components for reuse and recovery, and in particular for recycling.

Design and production requirements

According to Article 8, producers and manufacturers must use component and material coding standards to facilitate the identification of components and materials that are suitable for reuse and recovery. Manufacturers of components must make the appropriate information available concerning the dismantling, storage and testing of components to authorised treatment facilities. Producers must also provide dismantling information for new vehicles put on the market, with data on different vehicle components and materials, and the location of all hazardous substances in the vehicles.

The producers must make relevant information related to design, recovery and recycling accessible in the marketing of a new vehicle. Article 9 lists the following relevant information:

- the design of vehicles and their components with a view to their recoverability and recyclability,
- the environmentally sound treatment of end-of life vehicles, in particular the removal of all fluids and dismantling,
- the development and optimisation of ways to reuse, recycle and recover end-of life vehicles and their components,
- the progress achieved with regard to recovery and recycling to reduce the waste to be disposed of and to increase recovery and recycling rates.

The use of hazardous substances in vehicles

Specific exemptions to the prohibition of the use of hazardous substances in vehicles are listed in Annex II and are subject to regular reviews according to technical and scientific progress. Article 4(2) states that Annex II shall be reviewed and updated on a regular basis, in order to establish maximum concentration values for lead, mercury, cadmium and hexavalent chromium, and to define exemptions if the use of these substances is unavoidable. Furthermore, Annex II designates materials and components of vehicles that can be stripped before further treatment; they shall be labelled or made identifiable by other appropriate means.

4.2.3 Reporting and controlling measures

According to Article 6, any establishment carrying out treatment operations must be authorised and have a permit from the competent authorities, including all conditions necessary for compliance with the requirements of Annex I. A certificate of destruction must be issued to the holder and/or owner when the end-of life vehicle is transferred to an authorised treatment facility, and the certificate must be a condition for deregistration of the end-of life vehicle (Article 5). Member States must collect data and report to the European Commission on end-of life vehicles and their treatment (Article 9).

4.3 The WEEE Directive 2012/19/EU

4.3.1 Scope, definition and general requirements of the directive

Directive 2012/19/EU[29] on waste electrical and electronic equipment (WEEE) sets the basic concepts and definitions related to the management of waste of electrical and electronic equipment (WEEE) such as computers, TV sets, fridges and mobile phones. The directive aims to increase the recycling and reuse of WEEE and also to protect the environment and human health by preventing or reducing the generation of WEEE, and the adverse impacts of the generation and management of WEEE.

The first WEEE Directive (Directive 2002/96/EC) entered into force in 2003, providing for the creation of collection schemes where consumers return their WEEE free of charge. These schemes aim to increase the recycling and/or reuse of WEEE. The Directive was revised in order to tackle the rapidly increasing waste stream; the new WEEE Directive (2012/19/EU) entered into force in 2012 and became effective in 2014.

The Directive (Article 5) pushes for the creation of collection schemes where consumers return their WEEE free of charge. These schemes aim to increase the recycling and reuse of WEEE. An extended producer responsibility (EPR) is mandatory for EEE, as stated in (Article 7). An EPR puts the responsibility for the financing of collection, recycling and end-of-life disposal on the producers.

The WEEE Directive defines electrical and electronic equipment (EEE) as equipment which is dependent on electricity in order to work properly. Furthermore, WEEE is defined as the waste of EEE, including all components, sub-assemblies and consumables, which are part of the product at the time of discarding. The Directive defines six categories for the classification of WEEE (Annex III) and also provides a list of examples on the classification of WEEE into these categories (Annex IV).

The six categories of WEEE as defined by WEEE Directive Annex III

[29] Amended by Directive (EU) 2018/849 of the European Parliament and of the Council of 30 May 2018

1. Temperature exchange equipment
2. Screens, monitors and equipment containing screens having a surface greater than 100 cm^2
3. Lamps
4. Large equipment (any external dimension more than 50 cm)
5. Small equipment (no external dimension more than 50 cm)
6. Small IT and telecommunication equipment (no external dimension more than 50 cm)

The WEEE Directive requires Member States to adopt measures to maximise the separate collection of WEEE, to minimise the disposal of WEEE in the residual municipal waste, and to ensure the correct treatment of all collected WEEE and also to prohibit the disposal of separately collected WEEE.

In Article 8, the WEEE Directive states that:

> *Member States shall ensure that all separately collected WEEE undergoes proper treatment. Proper treatment, other than preparing for reuse and recovery or recycling operations shall, as a minimum, include the removal of all fluids and a selective treatment in accordance with Annex VII.*

4.3.2 Content of key interest for recycling of plastics with undesired legacy substances

Extended producer responsibility

An extended producer responsibility (EPR) is mandatory for EEE, as stated in Article 7. The EPR puts the responsibility for the financing of collection, recycling and end-of-life disposal on the producers. According to Article 12, producers should provide at least for the financing of the collection, treatment, recovery and environmentally sound disposal of WEEE from private households, and also from users other than private households (Article 13).

Technical requirements

In Article 8, the WEEE Directive states that Member States shall ensure that all separately collected WEEE undergoes proper treatment. The minimum requirements listed in Annex VII are the following:

1. Sites for storage (including temporary storage) of WEEE prior to its treatment:
    - impermeable surfaces for appropriate areas with the provision of spillage collection facilities and, where appropriate, decanters and cleanser-degreasers,

- weatherproof covering for appropriate areas.

2. Sites for treatment of WEEE:
   - scales to measure the weight of the treated waste,
   - impermeable surfaces and waterproof covering for appropriate areas with the provision of spillage collection facilities and, where appropriate, decanters and cleanser-degreasers,
   - appropriate storage for disassembled spare parts,
   - appropriate containers for storage of batteries, PCBs/PCTs containing capacitors and other hazardous waste such as radioactive waste,
   - equipment for the treatment of water in compliance with health and environmental regulations.

Requirements for shipment

Article 10 states that treatment operations may also be undertaken in another EU Member State or outside the EU. However, the shipments must be compliant with EU regulations[30] concerning the export for recovery of certain waste. WEEE exported outside of the EU is allowed when aiming to reach the fulfilment of treatment obligations and recovery targets stated in this directive, but the exporter must be able to prove that the treatment took place in conditions compliant wih the requirements of this directive.

In order to divert WEEE from being shipped out of Europe for treatment not compliant with Article 8 and related annexes of the WEEE Directive, the holder of the object (allegedly EEE) intending to be shipped must provide proper documentation as evidence for this claim (Listed in Annex VI) (1). If the EEE is sent back to the producer for repair under warranty with the intention of reuse, this evidence is not needed. However, to demonstrate the object is EEE, testing and record keeping should be required by authorities following the steps in Annex VI (3).

4.3.3 Reporting and controlling measures

According to the WEEE Directive (Article 9), Member States shall ensure that any establishments that carry out treatment operations must have a permit from a competent authority for the types and quantities of waste that may be treated, including the methods and operation for treatment, in compliance with Article 23 of Directive 2008/98/EC.

Article 23 states that Member States shall carry out appropriate inspections and monitoring of the shipments, in particular exports of WEEE outside the Union.

According to Article 16, Member States shall draw up a register of producers, including producers supplying EEE by means of distance communication. Upon

[30] Regulation (EC) No 1013/2006 and 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.

registering, each producer provides the information set out in Annex X, Part A. That register shall serve to monitor compliance with the requirements of the Directive. The directive also states that the producers must have the possibility of entering online all relevant information on their activities in that Member State.

Information submitted for reporting includes:

- the quantity of EEE placed on the national market;
- the quantity, by weight, of waste of EEE separately collected, recycled (including prepared for reuse), recovered and disposed of within the Member State or shipped within or outside the EU.

All information must be given by WEEE category (as set out in Annex III).

In order to ensure uniform conditions for the reporting, the Commission has adopted Implementing Regulation 2019/290/EU, establishing the format for registration and reporting and the frequency of reporting to the register.

4.4 Waste Shipment Regulation 1013/2006/EC

4.4.1 Scope, definition and general requirements

Regulation 1013/2006/EC[31] on shipments of waste lays down procedures for the transboundary shipments of waste, excluding radioactive wastes. This regulation implements into EU law the provisions of the Basel Convention[32] as well as the

[31] Amended by:

- Commission Regulation (EC) No 1379/2007 of 26 November 2007
- Commission Regulation (EC) No 669/2008 of 15 July 2008
- Regulation (EC) No 219/2009 of the European Parliament and of the Council of 11 March 2009
- Commission Regulation (EC) No 308/2009 of 15 April 2009
- Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009
- Commission Regulation (EU) No 413/2010 of 12 May 2010
- Commission Regulation (EU) No 664/2011 of 11 July 2011
- Commission Regulation (EU) No 135/2012 of 16 February 2012
- Commission Regulation (EU) No 255/2013 of 20 March 2013
- Regulation (EU) No 1257/2013 of the European Parliament and of the Council of 20 November 2013
- Regulation (EU) No 660/2014 of the European Parliament and of the Council of 15 May 2014
- Commission Regulation (EU) No 1234/2014 of 18 November 2014
- Commission Regulation (EU) 2015/2002 of 10 November 2015

Corrected by:

- Corrigendum, OJ L 299, 8.11.2008
- Corrigendum, OJ L 318, 28.11.2008
- Corrigendum, OJ L 334, 13.12.2013
- Corrigendum, OJ L 277, 22.10.2015

[32] The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal http://www.basel.int/default.aspx

OECD Decision[33]. The regulation includes a ban on the export of hazardous wastes to non-OECD countries as well as a ban on the export of waste for disposal. Furthermore, Regulation 1418/2007 concerning the export for recovery of certain waste to certain countries to which the OECD Decision does not apply sets out a list of countries and wastes that can be exported for recovery.

Different regimes apply to shipments of wastes for disposal and for recovery, as well as to hazardous and 'green-listed' non-hazardous wastes:

- The shipment of hazardous wastes and of wastes destined for disposal is generally subject to notification procedures with the prior written consent of all relevant authorities of dispatch, transit and destination.
- The shipment of 'green-listed' wastes for recovery within the EU and OECD does not require the consent of the authorities.

The Waste Shipment Regulation establishes procedures for the shipment of waste, depending on the route of the shipment, the type of waste and the intended treatment. The regulation applies to shipments imported into and exported from the EU, between Member States and in transit through the EU.

4.4.2 Reporting and controlling measures

Article 16 lays down the order and required documents needed for waste shipments. A written notification and consent are required for all waste when destined for disposal operations and for non-'green-listed' waste when destined for recovery. A notification document (as set out in Annex IA) must be submitted, the competent authorities of destination assess the notifications, which can then be consented to without conditions, or with conditions in accordance with Article 10, or objected to in accordance with articles 11 and 12. After consent, signed copies of the movement document (as set out in Annex IB) must be submitted to the competent authorities concerned. The movement document and copies of the notification document containing the written consents and the conditions of the competent authorities concerned shall accompany each transport. The facility of destination must provide confirmation in writing that the waste has been received. Article 18 further states that these shipments must be accompanied by a contract (contained in Annex VII), signed by the person who arranges the shipment.

Article 19 lays down that waste shipments shall not be mixed with other waste during shipment.

All documents in relation to a notified shipment shall be kept for at least three years by the competent authorities, the notifier, the person who arranges for the shipment, the consignee and the facility that receives the waste (Article 20).

[33] The OECD Decision Concerning the Control of Transboundary Movements of Wastes Destined for Recovery Operations https://www.oecd.org/environment/waste/30654501.pdf

4.4.3 Content of key interest for recycling of plastics with undesired legacy substances

Shipments within the EU

Shipments of waste are subject to a written notification and consent when destined for disposal operations. Wastes destined for recovery operations can be subject to either written notification and consent, or to a general information requirement. The general notification can cover several shipments that have essentially similar physical and chemical characteristics, the waste is shipped to the same facility and the route of the shipment is the same. Specific requirements for certain waste streams are laid down in Article 18 and Article 58, supplemented by listings of wastes in annexes III, IIIA, IIIB, IV and IVA.

According to Article 4, when intending to ship non-green-listed waste, a notification document and, where relevant, a movement document must be submitted via the competent authority. Alternatively, a general notification can be submitted in compliance with Article 13. Where a shipment of waste is destined for an interim recovery or disposal operation, all the facilities for interim as well as final recovery and disposal operations must be indicated in the notification documents (Article 15).

According to Article 5, shipments of non-green-listed waste are also required to have a valid contract between the notifier and the consignee for the recovery or disposal of the waste. Furthermore, Article 6 lays down that these are also subject to the requirement of a financial guarantee, covering costs of transport, recovery and/or disposal, and costs of storage for 90 days. The financial guarantee is intended to cover costs if the recovery or disposal cannot be completed as intended, and in cases where a shipment or the recovery or disposal is illegal as referred to in Article 24.

Take-back obligations

Article 22 specifies that if a shipment of waste cannot be completed as intended, the competent authority of dispatch must be informed. If a recovery or disposal facility rejects a shipment, the competent authority of destination must be informed. Unless the competent authorities agree that the waste can be recovered or disposed of in an alternative way in the country of destination or elsewhere, the competent authority of dispatch shall ensure that the waste is taken back to its area of jurisdiction. Costs arising from the return of waste are preferably charged on the notifier (Article 23).

Illegal shipments

Article 24 states that if they become aware that a shipment of waste is illegal, the competent authorities concerned must be informed. The competent authority with

jurisdiction over the area where the waste was discovered shall arrange for safe storage of the waste pending its return, recovery or disposal.

- If an illegal shipment is the responsibility of the notifier, the competent authority of dispatch shall ensure that the waste is taken back to its area of jurisdiction, with costs charged to the notifier. If the competent authorities are satisfied that the waste can be recovered or disposed of in the country of destination or elsewhere, this is also a viable option.
- If an illegal shipment is the responsibility of the consignee, the competent authority of destination shall ensure that the waste in question is recovered or disposed of in an environmentally sound manner, and that costs are charged to the consignee.
- If the responsibility for the illegal shipment cannot be imputed to either the notifier or the consignee, the competent authorities concerned shall cooperate to ensure that the waste in question is recovered or disposed of.

Exports from the EU

Export for disposal

All exports of waste from the EU are prohibited if they are destined for disposal, unless exported to EFTA countries that are also parties to the Basel Convention and that have not prohibited imports of such waste. Exports to EFTA countries are also prohibited if the competent authority of dispatch has reason to believe that the waste will not be managed in an environmentally sound manner, as referred to in Article 49.

A shipment may take place only if the notifier has received written consent from the competent authorities of dispatch and destination, a contract between the notifier and consignee is effective, a financial guarantee is effective, and environmentally sound management, as referred to in Article 49, is ensured (Article 35).

Export for recovery to non-OECD Decision countries

Article 37 lays down that waste listed in Annex III or IIIA is not prohibited for export to non-OECD countries. Exported waste shall be destined for recovery operations within a facility that is operating or is authorised to operate in the country of destination. If waste shipments are not subject to any control in the receiving country, Article 37 still requires certain documents to be accompanied, in compliance with Article 18. Article 36 lists wastes for which exports for recovery from the EU to non-OECD Decision countries is prohibited:

- wastes listed as hazardous in Annex V, as well as hazardous wastes and mixtures including hazardous wastes not classified under one single entry in Annex V

- wastes listed in Annex V, Part 3
- if the country of destination has prohibited import of a specific waste or considers the waste hazardous
- wastes which the competent authority of dispatch has reason to believe will not be managed in an environmentally sound manner, as referred to in Article 49, in the country of destination concerned.

Export for recovery to OECD Decision countries

The shipment of green-listed wastes for recovery to OECD Decision countries does not require the consent of the authorities. Where waste listed in annexes III, IIIA, IIIB, IV and IVA, waste not classified or mixtures of wastes not classified under one single entry in either Annex III, IV or IVA are exported from the EU and are destined for recovery in countries to which the OECD Decision applies, the provisions of the same documents applies as for shipments within the EU. The shipment may take place only if the notifier has received written consent from the competent authorities of dispatch and destination. Exported waste shall be destined for recovery operations within a facility which is operating or is authorised to operate in the country of destination. (Article 38)

Imports of waste to the EU for recovery

Article 43 states that all imports of waste destined for recovery shall be prohibited except from countries to which the OECD Decision applies or which are parties to the Basel Convention, or if the EU or a single Member State have concluded bilateral or multilateral agreements compatible with EU legislation and in accordance with Article 11 of the Basel Convention.

Where waste destined for recovery is imported from countries to which the OECD Decision applies, the provisions of the same documents apply as for shipments within the EU (Article 44). The shipment may take place only if the notifier has received written consent from the competent authorities of dispatch and destination, a contract between the notifier and consignee is effective, a financial guarantee is effective, and environmentally sound management, as referred to in Article 49, is ensured (Article 44).

4.5 CENELEC standards

4.5.1 Purpose of the standard

In 2013, the European Commission requested the European standardisation organisations (ESOs) to develop European Standards (ENs) for the collection, logistics and treatment of waste electrical and electronic equipment (WEEE). The purpose

of the European Commission was to develop a series of standards reflecting the state of the art.

According to the request of the European Commission, the European standardisation organisations (the three of which are officially recognised as competent in the area of voluntary technical standardisation: CEN, CENELEC and ETSI) had the opportunity to develop a single standard or a set of standards to properly cover the treatment (including recovery, recycling and preparing for reuse) of WEEE. Moreover, the commission has requested the standardisation organisations to appropriately utilise the standards already existing or under development.

The standards have been required to cover the treatment of all products in accordance with the extended scope of the WEEE Directive (2012/19/EU). Moreover, the European Commission has asked to include in the development of the standards the treatment of batteries that are frequently disposed of together with WEEE considering, also in this case, standards already developed or under development, in order to ensure compliance with the Battery Directive (2006/66/EC).

Finally, the standardisation organisations have been required to include in the documents under development provisions on data protection where relevant for the treatment of WEEE and to cover the collection of WEEE where crucial in order to allow for proper treatment.

4.5.2 Basis for the standard

The standards have been developed by CENELEC, the European Committee for Electrotechnical Standardization, under the mandate M/518 (EC, 2013) covering the treatment of waste from all products within the extended scope of the WEEE Directive and addressing collection, transport and treatment. The standards have been developed following a transparent and consensus-based process.
Two types of documents have been developed:

1. standards (ENs), provide general requirements and need a higher consensus for approval and publication
2. technical specifications (TS), support EN standards and provide technical details, such as sampling protocols, analysis methodologies, etc.

The process foresees that European Standards (ENs) are reviewed every five years and the Technical Specifications (TS) every three years, in order to reflect the state-of-the-art of technologies and market needs and to support the legislation adequately.

The purpose of the standards is to:

- assist treatment operators in fulfilling the requirements of the WEEE Directive without placing unnecessary administrative burdens on operators of any size, including SMEs;
- provide operators with additional guidelines;
- cover the treatment of waste from all products within the extended scope of the WEEE Directive;

- cover the collection and logistics of WEEE to allow proper treatment.

The use of standards is voluntary, and laws and regulations developed by each Member State may refer to them. The users of standards can demonstrate compliance with them through a third-party conformity assessment performed by an independent accredited certification body (such as WEEELABEX) or by means of self-declaration.

4.5.3 Methods and materials

A list of European standards and related technical specifications (TS) relevant for WEEE are listed in Annex 3. The standards selected as relevant for the NONTOX process are:

- EN 50625-1 Collection, logistics & Treatment requirements for WEEE - Part 1: General treatment requirements;
- TS 50625-3-1 Collection, logistics & treatment requirements for WEEE - Part 3-1: General Technical Specification.

These standards will be further described in the following section.

4.5.4 EN 50625-1 Collection, logistics & Treatment requirements for WEEE – Part 1: General treatment requirements

EN 50625-1 has been analysed and scrutinised to identify content of key interest for recycling of plastics with undesirable legacy substances.

In section 5.5 Depollution, operators are required to have procedures dedicated to the identification of WEEE containing substances, mixtures and/or components listed in the related annex (Annex F).

Moreover, in the above-mentioned section, if it is uncertain whether WEEE contains substances, mixtures or components as listed in the annex, it shall be treated as though it does.

In the list reported in Annex F, **plastics containing brominated flame retardants,** without specific reference to **'restricted'** flame retardants, are listed as components/mixtures to be removed from any separately collected WEEE.

More information on substances, mixtures and components to be removed from WEEE according to the list reported in Annex F are given in Annex A.

In Annex A, it is highlighted that substances, mixtures and components such as plastics **containing brominated flame retardants** contained in an identifiable stream or part of a stream shall be removed during the treatment process. Moreover, in part A.3 'Printed circuit boards' is pointed out the possibility to have plastic parts, mounted on printed circuit boards, that can contain restricted brominated flame retardants.

Finally, A.6 of Annex A is dedicated to plastics, in detail: (i) a flow diagram for plastic fractions is depicted; (ii) instruction to manage plastic streams containing brominated flame retardants are described.

The flow diagram reported in Annex A shows the input and various output streams related to the treatment of plastics containing brominated flame retardants (BFRs), as illustrated in Figure 7.

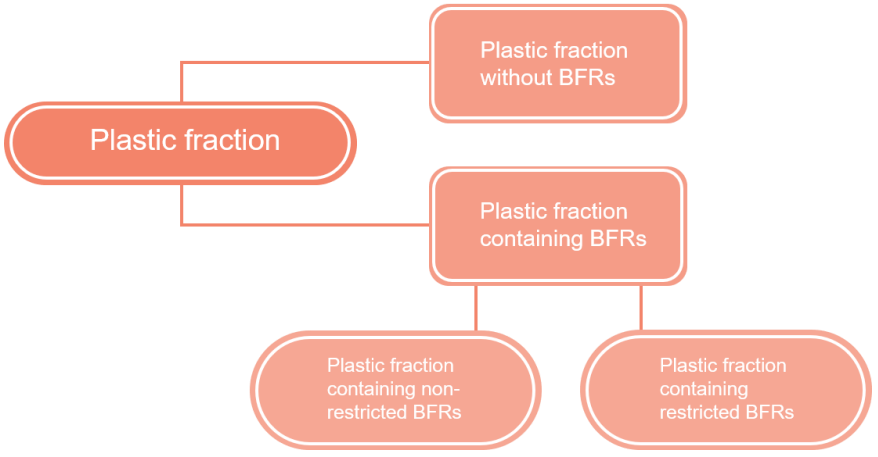

Figure 7 Flow diagram showing the input and various output streams related to the treatment of plastics containing brominated flame retardants (BFRs) (source: EN 50625-1, Annex A).

As depicted in the flow diagram, the plastic fraction is firstly classified into two different streams:

1. plastic fraction without BFRs
2. plastic fraction containing BFRs.

Then, the plastic fraction containing BFRs is further analysed and classified into two different streams:

1. plastic fraction containing non-restricted BFRs
2. plastic fraction containing restricted BFRs (POP Regulation).

For each stream identified in the flow diagram, specific requirements are foreseen. According to Annex A, plastic fractions separated from temperature exchange equipment streams and large household appliances streams shall be deemed free of BFRs and may be recycled without further requirements.

Plastics extracted from other streams shall be deemed to contain BFRs except if there is evidence to the contrary (e.g. report). Plastics containing BFRs have to be segregated and treated according to the appropriate legislation (e.g. Directive 2012/19/EU, Regulation 850/2004).

Regarding the monitoring of the depollution activities, Annex B specifies the rules of monitoring depollution performance for plastics. Details are contained in the Technical Specification TS 50625-3-1, described below.

4.5.5 TS 50625-3-1 Collection, logistics and treatment requirements for WEEE – Part 3-1: General Technical Specification

Technical Specification TS 50625-3-1 is intended to be used in conjunction with the WEEE Treatment Standard EN 50625-1 for most types of WEEE.

In the document, the methodology for the depollution monitoring of WEEE streams (large appliances; cooling and freezing appliances; CRT/FPD appliances; small appliances; lamps) is given and a sampling protocol for plastics is defined.

Generally, for plastic fractions that may contain brominated flame retardants (plastics separated from all categories of WEEE excluded cooling and freezing appliances and large appliances) the segregation should be guaranteed according to specific criteria: (i) the total concentration of bromine is above 2,000 ppm; (ii) the total concentration of bromine is assumed to be above 2,000 ppm; (iii) if there is no declaration related to the content of BFRs, the plastic fraction shall be treated in accordance with the appropriate legalisation and any plastic fraction that is not separated shall be considered to contain BFRs. If the total concentration for bromine is below 2,000 ppm, the operator complies with the depollution requirement for BFRs.

Moreover, for plastic fractions not containing segregated BFRs, a specific sampling protocol is described in Annex B. In particular, in Annex B, it is highlighted that analysis of plastics have to be performed on plastics generated from two specific streams: display appliances and small appliances. The number, size of samples and other information such as the principle of sampling is detailed in Annex B.

4.6 WEEELABEX

4.6.1 Background and purpose of the certification

WEEELABEX ('WEEE label of excellence') is the acronym of a project (2009–2012) co-financed by LIFE, the environmental programme of the European Union (LIFE07 ENV/B/000041). The aim of the project was to improve and harmonise WEEE management in the EU by developing a set of standards in collection, logistics and treatment; and establishing a conformity verification process and auditors' pool.

In 2013, at the culmination of the project, the WEEELABEX organisation was created as a stand-alone accredited legal entity. Nowadays, the WEEELABEX organisation acts as a scheme for operational issues related to WEEE management. It is an accredited body for certifying auditors and WEEE treatment operators according EN ISO/IEC 17065:2013. The WEEELABEX governance is organised as illustrated in Figure 8.

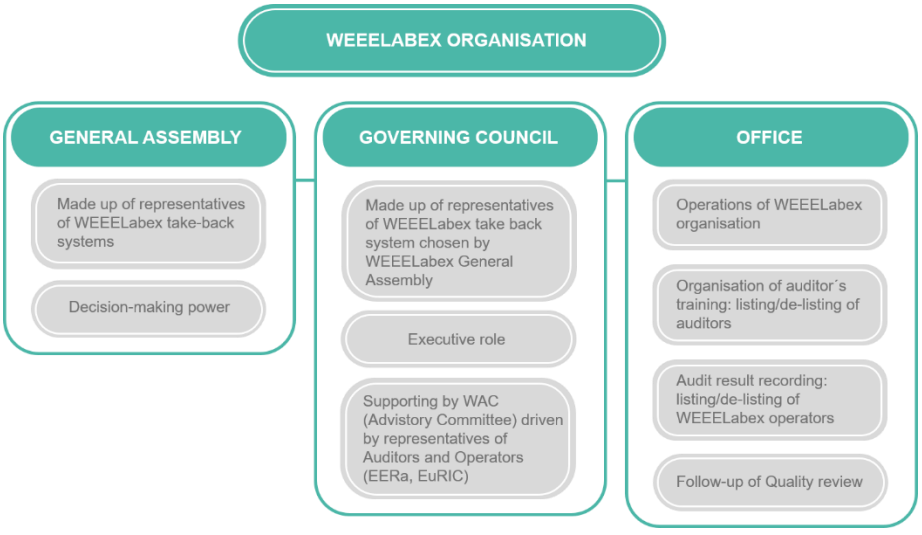

Figure 8 Governance of WEEELABEX (WEEELABEX, 2020a)

As a result of the request of the European Commission to develop a set of standards on treatment, WEEELABEX standards were used as the starting point for writing the CENELEC 50625 series.

The project mapped the following:

- WEEELABEX Documentation to measure depollution
- WEEELABEX Collection
- WEEELABEX Logistic
- WEEELABEX Treatment

4.6.2 Methods and materials

The project successfully developed and harmonised normative standards covering:

- General and specific technical aspects of WEEE
- Management and reporting practices
- Gas discharge lamps, temperature exchange equipment, CRT displays and flat panel displays
- Collection and transportation.

The eligible treatment types for the WEELABEX certification are the following (see scheme below):

- Type 0: Manual cannibalisation of appliances (no depollution)
- Type 1: Manual treatment, including all or some depollution.
- Type 2: Mechanical treatment (pre-treatment and intermediate treatment), or specific manual treatment, including some or all depollution (where indicated).

- Type 3: Advanced mechanical treatment, including some or all depollution (where indicated).
- Type 4: End-processing (pure fractions), or incineration/energy from waste facilities

Types 1, 2 and 3 are included in the certification, but type 4 is not part of it. The plastics sorting is included in type 3.

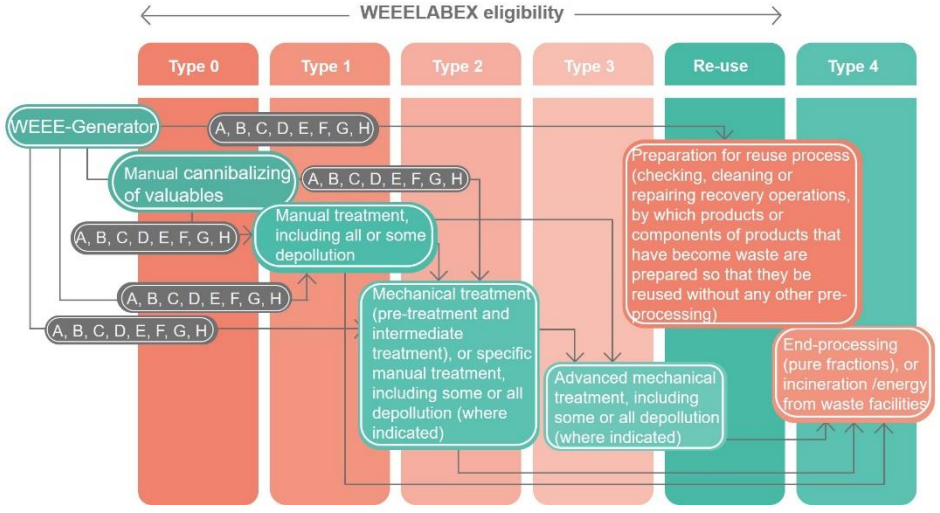

Figure 9 Eligible treatment types for Types 0–4 (WEEELABEX, 2020b)

Eligible treatment for WEEELABEX (B02TR Eligibility of Treatment Operators – DEFREV11_version 1–4 August 2020) where A: Large appliance; B: Mixed equipment; C Temperature exchange equipment; D: CRT display appliances and cathode ray tubes; E: Flat panel display equipment and flat panel displays; F: Gas discharge lamps; G: Photovoltaic panel; H: Other

In order to obtain the certification for one type mentioned above, an audit must be organised to make sure the treatment recovery processes are compliant with CENELEC standards. Obtaining the certification allows recyclers to position themselves as parties that take corporate responsibility as core action. The scheme illustrated in Figure 10 explains the procedure to obtain the certification as well as the interaction between the different parties.

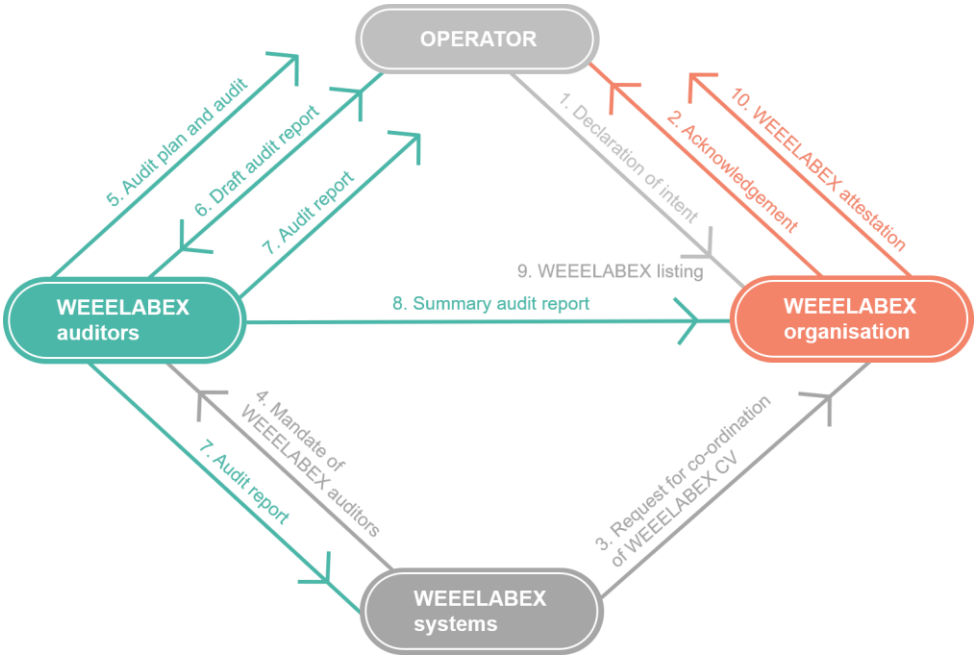

Figure 10 Steps and interaction in obtaining the WEEELABEX certification (WEEELABEX, 2012)

4.7 European plastics recyclers' specification: PRE1000-1

4.7.1 Purpose of the specification

This standard was created to enhance a cost-effective harmonisation across the industry for reporting to customers on the presence of substances of concern (SoC). The aim is also to monitor SoC through time using an accurate method to state the compliancy of recyclates with the regulations in place. This method is developed for plastics recyclers.

4.7.2 Basis of the specification

Principles

The method is split in two analyses: XRF screening and a chemical analysis (if necessary).

The method covers the following regulations:

- REACH Candidate List
- REACH Authorisation List
- REACH Restriction List

- POP Regulation
- RoHS Directive

A list of SoC was compiled as defined in the legislation above and for each of the substances, where it is determined if they can be present in the analysed recycled material. The determination is based on a comparison between the substance limit as in the legislation and the value obtained after XRF screening (after conversion in substance concentration).

Example of conversion from elemental concentration to substance concentration

DecaBDE (decabromobiphenyl ether) is an SVHC and is restricted under REACH. The threshold for this substance is 0.1% (i.e. 1000 ppm) in solid material. The molecular formula for the substance is $C_{12}Br_{10}O$, and the mass percentage of bromine in this molecule is:

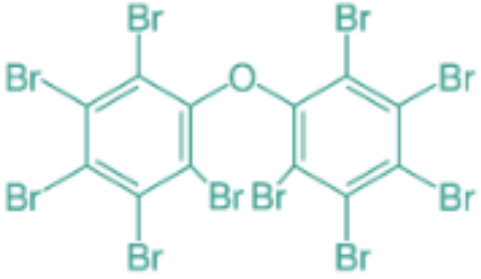

Figure 11 Molecular structure of DecaBDE

XRF provides the elemental composition of a material and thus will provide the concentration of Br atoms in ppm. If the concentration of Br atoms is < 833 ppm it can be concluded that it is not possible for DecaBDE to be present in a concentration of more than 1000 ppm in the material, as this would result in a higher concentration of bromine.

List of the relevant SoC

In order to compare with the relevant substances, some SoC can be excluded based on:

- the evaluation if the physical/chemical properties of the substance allow it to be used in plastics (e.g. if a substance has a boiling point of 135 °C such as 2-ethoxyethanol, it cannot be used in plastics due to it boiling out of the material during processing at temperatures observed in plastics compounding and converting processes)

- the determination of whether a substance can be present in recyclate based on the technical function (e.g. monomers are only expected to be present at trace levels, similar to virgin products)
- the assessment whether the typical additivation rate in virgin production would result in noteworthy concentrations in mixed plastics waste (e.g. UV-stabilisers are legion and added to articles in very low concentrations, no mixes would contain any individual UV-stabiliser in any noteworthy concentration)
- the review of whether the substance has any known historical use in plastics
- the appraisal of whether the additives are specific to a polymer

4.7.3 Methods and materials

Sampling and preparation

The material tested should be flakes or granulates that underwent a sorting process. Special attention is brought to the accurate sampling of material. As the focus is on recycled material, the sample must contain items of all sizes expected to be included in the output stream and it shall be representative of the population. The sample is injection-moulded to ensure proper homogenisation of the material.

Method

Both analyses are performed on the moulded specimens.

XRF screening

- An X-ray fluorescence (XRF) screening is performed to eliminate SoC that could not be present within the material based on the above calculation.

Chemical analysis

- If some SoC cannot be excluded based on the XRF screening, a combination of chemical analysis must be done. This includes:
    - A triple quad liquid chromatography – mass spectroscopy (LCMS) screening
    - Thermal extraction gas chromatography – mass spectroscopy (GCMS)

4.8 EoL (End-of-Life) material standards like EUCertPlast (European Certification of Plastics Recyclers) and EN15343 with linked standards

4.8.1 Purpose of the certification

The standard focuses on the traceability of plastic materials (throughout the entire recycling process and supply chain), and on the quality of recycled content in the end product. The purpose is to increase the transparency of the European plastics industry, and to merge a variety of auditing schemes into one. This standard is setting a case for best recycling and trading practices. The final goal is to create a transparent, efficient and harmonised recycling plastic industry. The certification scheme itself works according to the European Standard EN 15343:2007.

4.8.2 Basis of the certification

The certification covers the following areas:

- Operating and environmental permits required for the country of operation
- Staff training, qualifications and organisation
- Incoming material procedures and controls
- Stock management
- Recycling process and associated mass balance calculation
- Control on recycled outputs
- Environmental protection
- Subcontracting
- Quality management and traceability

The certification also includes a subchapter on food contact material where stricter requirements have to be complied with.

4.8.3 Methods and materials

Tested parameters to obtain the certification

To obtain the certification, three audits are performed on-site (initial, monitoring and change in the recycling process audit). Three levels of traceability can be awarded to the recycler up to the extent of a full traceability system, including a control of input and output material as well as a control during the production process.

Data from the last 12 months is analysed by the auditor, including recycling statistics (water, energy consumption, etc.), process inputs and outputs, mass balances, yield and production records.

The recycled outputs must be controlled and solutions for the by-products must be presented. Environmental protection is also covered in the certification tackling the topics of wastewater, contamination of the local environment and solid wastes.

The EUCertPlast has a section dedicated to the characterisation of the output fraction as recyclates according to EN standards EN 1534 –2,4,5,6,8 (depending on the polymer types). The output material needs to be compliant with REACH; therefore a procedure must be in place in the audited company to test those substances. Rejection and acceptance procedures are implemented to comply with the above.

Materials

All the input and output materials processed by the audited recycler are studied in the audit and therefore included in the certification. The by-products, such as waste fractions, are also taken into account in the certification.

4.9 REACH Regulation 1907/2006/EC

4.9.1 Scope, definition and general requirements

Regulation (EC) No 1907/2006 is enforced through REACH procedures, which are the registration, evaluation, authorisation and restriction of chemicals. REACH aims to improve the protection of human health and the environment from risks that can be posed by chemicals, while enhancing the competitiveness of the EU chemicals industry as well as promoting alternative methods for animal testing. It is implemented in the production, import and use of substances. (European Chemicals Agency, 2020a) In the case of recycling operators, REACH applies after the recycling process when the plastic has ceased to be waste (European Chemicals Agency, 2016). Since the decomposition of BFRs makes it hard to link compounds in the recyclate to the original BFRs, the term 'bromine compound' is used to better describe these unwanted legacy compounds. Key terms for REACH are presented in Table 3.

Table 3 Key terminology for REACH

Key terms	Definitions
Substance	A chemical element and its compounds in natural state or obtained by any manufacturing process, including stabilisers and impurities, but not additives. E.g. PVC pellets.
Article	An object which during production is given a special shape, surface or design that determines its function to a greater degree than does its chemical composition, e.g. a toothbrush.
Mixture	A mixture or solution composed of two or more substances, e.g. plastic and additives.
Impurity	An unintended constituent present in a substance as manufactured. It may originate from the starting materials or be the result of secondary or incomplete reactions during the manufacture process. While it is present in the final substance it was not intentionally added. E.g. unwanted legacy substances in recycled material.

UVCB	Substances of unknown or variable composition, complex reaction products or biological materials. They cannot be sufficiently identified by their chemical composition because of the large number of constituents, unknown composition or large or poorly predictable variability of the composition. E.g. natural oils, petroleum substances, antibiotics.
SVHC	Substances of very high concern, which meet the criteria in Article 57 and are identified and added to the Candidate List for eventual inclusion to the Authorisation List.

Registration

When evaluating whether the substance has a registration obligation, manufacturers and importers should carefully analyse the chemical composition of the substance. The recycling operator should also define whether their recyclate is a substance or an article. According to the definitions of a substance and an article in REACH, the recyclate is a substance if its chemical composition defines its use rather than its shape, use or design. Bromine compounds in the recyclate are either impurities or substances, since under REACH only stabilisers are considered additives. The definition of an impurity is 'An unintended constituent present in a substance as manufactured. It may originate from the starting materials or be the result of secondary or incomplete reactions during the manufacture process. While it is present in the final substance it was not intentionally added.' The bromine compounds are most likely considered impurities, and therefore they are a part of the monomer substance(s). However, if the substance has an unknown or variable composition, complex reaction products or biological materials (UVCB), the concept of impurities does not apply. (European Chemical Agency, 2017) If that is the case, then the bromine compounds are regarded as substances in a mixture.

When bromine compounds are considered impurities, it is reasonable to only regard Article 6 paragraph 3 of REACH as relevant for registration when it comes to the **polymer substance**. The polymer itself does not require a registration, but monomers or substances in it do. A monomer or a substance in a polymer needs to be registered if the polymer consists of 2% weight by weight (w/w) of it, and the total quantity of the monomer or the substance is one tonne or more per year. If the monomer substance has been registered before, it does not require registration. This exemption from registration applies even if the registration was made in another supply chain. Polymers are exempted from the provisions on registration of Title II of REACH under Article 2 paragraph 9, and therefore the recycle operator is generally not required to submit any information related to the intrinsic properties **of the polymer itself**. (European Chemicals Agency, 2012)

When bromine compounds are considered substances instead of impurities, they are to be separately registered as substances in a mixture. Article 6(1) requires that substances in mixtures must be registered if they are produced in quantities of one tonne or more per year. If the quantity of a specific bromine compound is less than one tonne per year, it is also then exempt from registration. There seems to be no

conditions under which substances of less than one tonne per year manufactured or imported could be required to register. This does not apply to substances in articles, which are addressed later. Since **typically the permitted concentration of a BFR is 0.1 % w/w, in tonnes this would mean that less than 1 tonne of a specific BFR is exempt from registration in 1 000 tonnes of recycled plastic.**

Article 2 paragraph 7(d) can exempt the bromine compounds on their own (as substances), in mixtures or in articles from Title II: Registration of substances, Title V: Downstream users and Title VI: Evaluation. Substances that have been registered and are recovered in the community are exempt from registration if

- the substance that results from the recovery process is the same as the substance that has been registered in accordance with Title II; and
- the information required by articles 31 or 32 relating to the substance that has been registered in accordance with Title II is available to the establishment undertaking the recovery.

The sameness of the substance should be examined carefully. For a BFR substance, the decomposition during the recovery process may result in a different bromine compound that was originally registered in the waste material, and the exemption of Article 2(7)(d) will not apply to that specific bromine compound.

If the recycling process results in **an article**, where the design, shape or surface defines its function more than its chemical properties, **the substances in that article have to be registered** if both conditions are met:

- the substance is present in those articles in quantities totalling **over one tonne per producer or importer per year**;
- The substance is intended to be released under normal or reasonably foreseeable conditions of use (Article 7(1)).

This most likely does not apply, since the bromine substances are not meant to be released from the articles. Substances in articles can be exempt from registration by Article 2(7)(d).

Any producer or importer of articles has to notify the agency if the substance meets the criteria in Article 57 (criteria for SVHC), and if it is present in those articles in quantities of over one tonne per producer or importer annually, and the substance is above a concentration of 0.1 % w/w. The notification is not needed if the producer or importer can exclude the exposure to humans or the environment during normal or foreseeable conditions. This also includes disposal. The producer or importer must then supply appropriate instructions according to Article 7(3). Notification is most likely not needed in the case of NONTOX, as the exposure can be excluded.

According to Article 7(6), registration and notification duties do not apply if the substance has been registered before for the same use. Decabromodiphenylether has a PBT (persistent, bioaccumulative and toxic) status matching the Article 57 criteria, and it must be notified to ECHA if over one tonne of it is produced per year, unless the exposure is excluded. However, if more decabromodiphenylether was added to the article to serve as a flame retardant, and it has been previously

registered as a flame retardant, it can then be exempt from registration and notification duties.

If registration is required, an inquiry needs to be sent to ECHA on whether a valid registration has already been summited by another registrant. This is to ensure that the data is shared by the relevant parties. After sufficient information is gathered, a registration dossier shall be submitted. This consists of two main components: a technical dossier required for all substances subject to the registration obligations, and **a chemical safety report required for a substance manufactured/imported in quantities of 10 tonnes or more annually**. If the substance is considered to be hazardous or PBT or vPvB, the chemical safety report has to include exposure scenarios for all identified uses of the registrant.

Evaluation

The ECHA examines all submitted dossiers along with Member States. Evaluation covers two areas: dossier evaluation and substance evaluation. In dossier evaluation, the ECHA checks that registration dossiers contain the information on chemicals required by the legislation. In substance evaluation, the Member States evaluate substances after they have identified specific concerns. (European Chemicals Agency, 2020b) The dossier evaluation process in demonstrated in Annex 1.

Authorisation

The aim of authorisation is to ensure the effective functioning of the internal market while assuring that the risks from substances of very high concern are properly controlled. Authorisation is applicable when bromine compounds are considered substances. Polymers rarely require authorisation. Impurities most likely do not require authorisation, unless the authorisation requirement is specified in the Annex XIV (Authorisation list) entry (e.g. substance W and substances X, Y and Z containing substance W in a concentration ≥ x %) (ECHA, 2018b). Some BFRs may be included in the authorisation list. Substances included in the authorisation list cannot be used or placed on the market on their own, in a mixture or in articles, unless they have been authorised. More conditions for when a substance on the authorisation list can be used can be found from Article 56(1). Substances referred to in Article 56(1) are subject to authorisation unless they are present in mixtures below a concentration limit of 0.1 % w/w (for substances referred to in Article 57(d), (e), (f)), or in the values specified in Article 11(3) of Regulation (EC) No 1272/2008 (which result in the classification of the mixture as hazardous) for other substances.[34]

The Commission is responsible for making decisions for applications for authorisations and granting authorisation. According to Article 60 paragraph 2, an authorisation is granted if the risks to human health or environment arising from the intrinsic properties of the substance are adequately controlled, taking the opinion of the

[34] REACH Article 56 (6)

Committee of Risk Assessment into account. However, if the bromine substance meets any criteria in Article 57, authorisation may only be granted if it is shown that socio-economic benefits outweigh the risk to human health or the environment arising from the use of the substance and if there are no suitable alternative substances or technologies.[35]

A downstream user (the user of recycled material) may use a substance subject to Article 56 paragraph 1, if the use is in accordance with the conditions of an authorisation granted to an actor up the supply chain for that use. In practice, a downstream user (e.g. a plastic product manufacturer) does not need authorisation if the supplying recovery operator has one for that use. Downstream users have to notify the agency within three months of the first supply of the substances and include the authorisation number on the label before placing the substance or a preparation containing it on the market.[36]

Restrictions

REACH articles 68(1) and 67(1) state that the restriction process starts when there is 'an unacceptable risk to human health or the environment, arising from the manufacture, use or placing on the market of substances, which needs to be addressed on a Community-wide basis'. Annex XVII, which is the list of restricted substances, will then be amended accordingly. When deciding, socio-economic impacts of the restriction will be taken into account, as well as the availability of alternatives. Substances listed in Annex XVII cannot be placed on the market or produced, unless they comply with the conditions of restriction. This also applies to impurities, meaning that the impurities must comply with the conditions of restriction. For most BFRs, this means that they must be under a specific concentration limit. For example, both penta- and octabromodiphenylethers can be placed on the market if their concentrations as a substance, a constituent of a mixture or in articles are 0.1 % or less.

If the Commission, ECHA or a Member State considers a need for a restriction of a substance, a dossier is prepared, unless the substance is already on the candidate list. The dossier is checked by the Committee for Risk Assessment and the Committee for Socio-economic Analysis. All dossiers, including the restrictions suggested, are published on the ECHA website. All the registrants of the substance are informed. All interested parties are invited to comment or submit a socio-economic analysis or information which can contribute to one. Both committees will comment on the appropriateness of restrictions, and their opinions are passed to the Commission. The Commission prepares a draft amendment, which is sent to the Member States at least 45 days before voting and the final decision being made.[37]

[35] REACH Article 60 (4)
[36] REACH Article 56 (2), Article 65, Article 66 (1)
[37] REACH Articles 69-73

Informing in the supply chain

REACH requires companies to collect and communicate information for the safe use of substances. Information requirements in articles 31 and 32 are also required to benefit from Article 2(7)(d). A recovery operator that can rely on exemption from Article 2(7)(d) and has the required information available does not need to perform a chemical safety assessment or complete a chemical safety report. They should take into account the existing information and must provide appropriate risk management measures for safe use. Although a recipient of recovered substances will receive either an SDS or safe use information, they do not usually receive a registration number or an exposure scenario for the subsequent uses within the new life cycle chain from the manufacturer of the recovered substance. (European Chemicals Agency, 2010)

Safety Data Sheets

REACH requires suppliers to provide Safety Data Sheets, when a substance on its own or in a mixture falls under the criteria given in Article 31(1). This includes dangerous, candidate list, PBT and vPvB substances. An SDS must be updated and provided free of charge. Upon request, the supplier must provide the recipient with a safety data sheet when a mixture does not meet the criteria for classification as hazardous in accordance with Titles I and II of Regulation (EC) No 1272/2008, but it fulfils one of the criteria given in Article 31(3).

The regulation does not define how an SDS should be acquired; it can be received from an actor in the supply chain or created. The recovery operator must take care that the data on a received SDS is adequate for the recovered substance, since any difference in the impurity profile might change the substance's hazard profile. If data is inadequate, the recovery operator must fix it to prevent liability issues. Impurities over the legal cut-off values should be addressed in the SDS or safe use information. (European Chemicals Agency, 2010)

When BFRs are considered a substance instead of an impurity, they typically require an SDS. When BFRs are treated as impurities, they are not subject to Article 31(1) and the recovery operator is not obliged to provide an SDS unless the substance (recyclate) requires it. However, Article 31(2) could trigger that obligation. (European Chemicals Agency, 2010) An SDS does not need to be supplied where dangerous substances or preparations are offered or sold to the general public, if sufficient information is given to users to take necessary safety measures, unless requested by a downstream user or distributor. Any actor in the supply chain who is required to prepare a chemical safety report must place the relevant exposure scenarios in an annex to the SDS.

Any downstream user must include relevant exposure scenarios and other useful information from the SDS supplied to them when compiling their own SDS for identified uses. Distributors must pass on relevant exposure scenarios and other useful information from the safety data sheet when compiling their own SDS.

Information requirements when a Safety Data Sheet is not required

REACH requires the supplier to communicate information down the supply chain when a safety data sheet is not required. If a substance is not subject to Article 31, information in Article 32 paragraph 1 is required. It is also required to benefit from Article 2(7)(d). According to Article 32(2) and (3), this information is also to be provided free of charge and kept updated.

REACH Article 33 (1), (2) states that any supplier of an article containing a substance meeting the criteria in Article 57 (a SVHC) in a concentration above 0.1 % w/w shall provide the recipient of the article with sufficient information, available to the supplier, to allow safe use of the article including, as a minimum, the name of that substance. On request by a consumer, any supplier of an article containing a substance meeting the criteria in Article 57 (a SVHC) in a concentration above 0.1 % w/w shall provide the consumer with sufficient information, available to the supplier, to allow safe use of the article including, as a minimum, the name of that substance. The relevant information shall be provided, free of charge, within 45 days of receipt of the request.

According to Article 34, any actor in the supply chain of a substance or mixture is required to communicate the following information to the next actor or distributor in the supply chain:

- new information on hazardous properties, regardless of the uses concerned;
- any other information that might call into question the appropriateness of the risk management measures identified in a safety data sheet supplied to them, which shall be communicated only for identified uses.

REACH articles 34, 35 and 36(1) state that distributors shall pass on that information to the next actor or distributor up the supply chain. The employer must give access to information of substances or mixtures used or possibly exposed to, to workers and their representatives. Manufacturers, importers, downstream users and distributors are obliged to assemble and keep available information required under REACH for at least 10 years after they last manufactured, imported, supplied or used the substance or mixture.

The SCIP Database

SCIP is a database for information about substances of concern in articles as such or in products (complex objects). It was established under the Waste Framework Directive, and it applies from January 2021. It aims to increase the knowledge of hazardous chemicals in articles and products throughout their life cycle, and all information in it is made publicly available. (European Chemicals Agency, 2020c) This is beneficial for NONTOX, because it provides better information about the chemicals in the waste and could support better segregation and sorting of waste.

Suppliers need to notify the SCIP database if the articles they produce contain substances of high concern from the candidate list in a concentration above 0.1 % weight by weight. This affects suppliers that produce, assemble, import or distribute the articles. If the recycling process results in an article, it may be subject to notification. If the recycling process results in a substance (as often is the case), it is not subject to notification. Suppliers need to submit information about the identification of the article, the name, location and concentration range of the substance in the article and other information that allows its safe use.

4.9.2 Reporting and controlling measures

The first control measures are taken before the substance is placed on the market. A substance cannot be manufactured or placed onto the market unless it has been registered accordingly or is exempt from registration. The registration dossier must comply with information requirements. If the dossier is non-compliant, the ECHA requires the registrant to provide more information to bring the dossier up to compliancy. Non-compliance in the registration phase may extend the evaluation process considerably, so it is recommended to prepare the dossier with due care. The ECHA will not accept the substance as registered if the registration dossier is non-compliant, and the competent authorities of the registrant's country can use enforcement methods on the registrant. If the substance is exempt from registration, it must comply with the conditions of that exemption. If the substance does not comply with the conditions, it must be registered. In any case, the registrant must submit an inquiry to the ECHA to see if the same substance has been registered before.

The use of hazardous or harmful chemicals is controlled with authorisation or restrictions. Authorisation can only be granted for substances listed in Annex XIV if the risks to human health and the environment are adequately controlled and documented, and if risks cannot be adequately controlled, only if the socio-economic benefits outweigh the risks. Some substances under a specific concentration limit are exempt from authorisation. Substances listed in Annex XVII contain restrictions. These substances cannot be manufactured or placed on the market unless they comply with the conditions of restriction.

REACH Article 22(1), (5) states that a registrant is responsible on their own initiative for updating their registration without undue delay. REACH identifies nine cases in Article 22 where update without delay is required. These include any changes to the registrant's status, changes in substances, quantities, uses and safety information, etc. Updates are subject to a fee.

National authorities are responsible for enforcing REACH, which causes considerable variation between different countries. Enforcement measures typically includes inspections, investigations, formal enforcement actions such as enforcement notices and compliance promotion.[38] The Member States' authorities have a Forum

[38] Forum for Exchange of Information on Enforcement, 2011. Strategies for enforcement of Regulation (EC) no. 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and of Regulation (EC) no. 1272/2008 on the classification, labelling and packaging of substances and mixtures (CLP), p. 10.

for Exchange of Information on Enforcement (Forum) to facilitate the exchange of information on and coordination of the activities related to the enforcement of chemicals legislation. According to Milieu Ltd (2011), all countries except Denmark have adopted specific legislation or amended their legislation to deal with REACH. In Annex 2 differences between countries are demonstrated in the areas of authorities and penalties. For example, in Finland and Portugal, several authorities are responsible for REACH, while Italy has one responsible authority with regional enforcing authorities.

The level of penalties and methods of enforcement vary quite a lot. The most commonly used sanction is a fine. In common law countries, enforcement is mostly based on criminal law. In the Nordic Countries enforcement policy is based on coercive measures. Countries using the continental system enforce their legislation through administrative and criminal laws or only through administrative law. Most countries administer fines between EUR 50 000 and 1 000 000 maximum for the first infringement. (Milieu, 2011)

4.9.3 Content of key interest for recycling of plastics with undesired legacy substances

When bromine compounds are considered impurities, the registration applies only to the monomer substance(s) they are part of. Most monomers and other substances are registered already, and those are exempt from registration according to Article 6(3). Monomers and other substances that have not been registered by anyone in any supply chain have to registered. Polymers do not have be registered in articles, since they are not meant to be released from articles. When BFRs are impurities in a substance, they usually do not require an authorisation unless it is specified in the substance entry in the Annex XIV. BFR substances require an authorisation if they are listed in the authorisation list. If the substance or impurity is restricted, it must comply with the conditions of restrictions.

If BFRs are considered substances, Article 2(7)(d) may exempt them from registration, even in articles. To benefit from Article 2(7)(d), the same substance has to be registered in advance and adequate information (a SDS or safe use information) has to be available. The sameness of the substance should be evaluated particularly carefully, since the decomposition may happen in the recycling process and result in different bromine compounds, leading to Article 2(7)(d) not being applicable. If Article 2(7)(d) is not applicable, the substance must be registered if it is produced over quantities of one tonne or more annually. For BFR substances in articles, they most likely do not have to be registered, since they are not meant to be released from articles and are below a concentration of 0.1 % w/w. The agency may decide to require registration if it suspects that the substance is released from articles and it poses a risk to human health or environment. Even if BFR substances are not obliged to register, they might be subject to notification to the agency. BFRs as substances are typically subject to authorisation. The conditions of restriction must be met to place the recyclate on the market.

The supplier must provide adequate safety information to the recipient of the substance. This may be in the form of a safety data sheet. The recovery operator should check that the information in a received SDS is adequate to prevent liability issues. If the recovery operator is relying on Article 2(7)(d), the recipient will not typically receive a registration number or an exposure scenario for the subsequent uses within the new life cycle chain from the manufacturer of the recovered substance.

If the substance is considered to be hazardous, PBT or vPvB, the chemical safety report must include exposure scenarios for all identified uses of the registrant. Significant costs may arise if the recycler must buy the rights for the exposure scenarios included in the registration dossier, which are required for hazardous substances.

4.10 POP Regulation 2019/1021/EC and related international agreements

Persistent organic pollutants (POPs) are toxic chemical substances that globally affect human health, animals and the environment. They persist in the environment for a long time, bioaccumulate in human and animal tissue, biomagnify in food, degrade slowly and are transported by wind and water, even far from the originating pollution source. Exposure to POPs can result in serious health issues such as cancer, birth defects, dysfunctional immune and reproductive systems, and higher susceptibility to illness and disease. (Ministry of the Environment, 2016)

The POP Regulation (EU) 2019/1021 is the recast of and repeals Regulation (EC) No 850/2004 on Persistent Organic Pollutants. It is the EU tool for limiting substances listed in the Stockholm Convention and the POPs Protocol of the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP). The Stockholm Convention is an international agreement to protect human health and the environment from POPs. The treaty is aimed at reducing and eliminating the production, use and release of POPs. The Stockholm Convention on POPs is built on the Aarhus Protocol on Persistent Organic Pollutants (Denmark, 1998), initially in 2001. The convention was adopted in 2001 and entered into force in 2004. In 2009, seven substances were added to the POPs which entered into force in 2010.[39] Another update to the POPs was made in 2014 and 2017. The 2017 Stockholm Convention has been ratified by 181 parties globally. The Convention is supported by POPs Review Committee (POPRC), which composes of 31 government-designated experts from all UN regions. The parties can submit proposals for new chemicals to be listed in the Convention, which are then reviewed by chemistry assessment and management experts in the POPRC. (Stockholm Convention Secretariat, 2017)

4.10.1 Scope, definition and general requirements

Initially, there were 12 POP chemicals under the Stockholm Convention. In 2017, 16 new POPs were added. The POP in Regulation (EU) 2019/1021 has been

[39] UNECE: Protocol on Persistent Organic Pollutants (POPs)

divided into three annexes (I–III) and in the Stockholm Convention in the three same annexes (A-C);

I. Elimination (A)
II. Restriction (B)
III. Unintentional production/release reduction provisions (C)

In Annex A, parties must take measures to eliminate the production and use of chemicals that are listed. This means that the chemicals must be removed from circulation and destroyed permanently in waste management. In addition, specific exemptions are listed in the annex that parties can apply and register for. The chemicals listed in Annex B are chemicals that the parties must take measures against to restrict the production and use of. Acceptable purposes and specific exemptions are also listed in Annex B. In Annex C, actions must be taken to reduce unintentional release of chemicals, and substances listed there are subject to so-called release reduction provisions. The goal needs to be to continuously minimise and where feasible, eliminate permanently. A summary of the restricted substances in the different annexes are listed in Table 4 with bromine-containing substances highlighted. (Stockholm Convention Secretariat, 2017)

Table 4 An overview of restricted substances in Annexes A, B and C. The bromine-containing substances are in bold (Stockholm Convention Secretariat, 2017).

Elimination: Annex A	Restriction: Annex B	Unintentional production: Annex C
• Adlrin (2004), • Alpha hexachlorocyclohexane (2017), • Beta hexachlorocyclohexane (2017), • Chlordane (2004), • Chlordecone (2017) • Dieldrin (2004), • Endrin (2004), • Heptachlor (2004), • **Hexabromobiphenyl** (2017) • **Hexabromocyclododecane HBCDD** (2017, some exemptions) • **Hexabromodiphenyl ether** and **heptabromodiphenyl ether (commercial octabromodiphenyl ether**, (2017)) • Hexachlorobutadiene, (2017) • Hexachlorobenzene (2004), • Lindane (2017) • Mirex (2004), • Toxaphene (2004), • PCB (2004) • Pentachlorobenzene (2017)	• DDT (2004) • Perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride (PFOSF) (2017)	• Polychlorinated dibenzo-p-dioxins and dibenzofurans (2004) • Hexachlorobenxene (2004) • Hexachlorobutadiene, (2017) • PCB (2004) • Pentachlorobenzene (2017) • Polychlorinated naphthalenes (2017)

• Pentachlorophenol and its salts and esters (2017) • Polychlorinated naphthalenes (2017) • Technical endosulfan and its related isomers (2017) • **Tetrabromodiphenyl ether** and **pentabromodiphenyl ether (commercial pentabromodiphenyl ether**) (2017) • **Decabromodiphenyl ether (Commercial mixtures, c-DecaBDE**) (2017) • Short-chain chlorinated paraffins (SCCPs) (2017)		

For the NONTOX project, the brominated compounds are in specific focus. Decabromodiphenyl ether (commercial mixture, c-decaBDE. CAS No: 1163-19-5) was listed in Annex A in 2017, but it has various specific exemptions listed as well. The decaDBE is highly persistent and has high potential for bioaccumulation and biomagnification. It also has high potential for long-range transport. DecaBDE is used a flame retardant, especially in plastic applications. Some typical examples are in electronics and electrical equipment like household computers, TVs, wires, cables, pipes, carpets, textiles and so on. C-decaBDE is widely used globally, but the peak in use for decaBDE was in the early 2000s. There are replacements available like non-POP chemical alternatives for plastics and textiles. Also, non-chemical alternatives and technical solutions are available, such as non-flammable materials and higher physical barriers. (Stockholm Convention Secretariat, 2017)

Another brominated flame retardant included in Annex A is hexabromodiphenyl (CAS No: 36355-01-8) and it is listed without specific exemptions. In addition to being highly persistent in the environment, highly bioaccumulative and having strong potential for long-range transport, it is also classified as a possible human carcinogen and has other chronic toxic effects as well. Hexabomodiphenyl was mostly used in the 1970s and has largely been restricted in different countries. There seems to be no production of it anymore (according to available information), and there are alternatives for replacement. (Stockholm Convention Secretariat, 2017)

Also, hexabromocyclododecane (HBCD, CAS Nos: 25637-99-4, 3194-55-6) has been listed in Annex A with specific exemptions for EPS and extruded PS in construction. It was widely used as a BFR with PS in constructions and vehicles in the 1980s as it was part of common safety regulations. Alternatives exists for HBCD. Hexa- and heptabromodiphenyl ethers (hexaBDE and heptaBDE, CAS Nos: 68631-49-2, 207122-15-4, 446225-22-7, 207122-16-5) are main components for octaBDEs and were also added to Annex A in 2017. They are listed with a few exemptions for use, for example for recycling articles that contain these chemicals. For octaBDEs,

the only degradation pathway is debromination and production of other less toxic bromodiphenyl ethers. It is reported that many articles in use still contain these chemicals, even though alternatives do exist. (Stockholm Convention Secretariat, 2017)

Finally, from brominated flame retardants, tetrabromodiphenyl ether and pentrabromodiphenyl ether (CAS No: 5436-43-1, 60348-609) were also listed in Annex A in 2017. Polybromodiphenyl ethers include tetra-, penta-, hexa- and heptaBDEs. At least the production of tetra- and pentaBDEs seem to have stopped and no reports have been made on the production of hexa- and heptaBDEs according to available reports. Alternatives also exists for these substances, but those alternatives might also have harmful effects, so they might show up under the REACH regulation, for example, but they are not listed under the elimination list of Annex A of the Stockholm Convention. (Stockholm Convention Secretariat, 2017)

4.10.2 Treatment of POP waste

The POP Regulation sets prohibitions and restrictions of intentionally produced substances (substances listed in Annex I and II) and measures for release reduction (Annex III). The POP Regulation prohibits the disposal and recovery operations that may cause POPs to be recovered, recycled, reclaimed or reused. Also, the dilution of waste is not allowed according to the Waste Framework Directive (2008/98/EC) and the Technical Guidelines of the Basel Convention.

The concentration of POPs in plastic waste determines how the waste needs to be processed based on whether certain concentration limits are exceeded or not. Two concentration limits are used for waste plastics and possible treatment/handling methods are described in the regulation. It is important to note that if the higher limit is exceeded, there are additional restrictions. If the concentration is lower than the lower limit, the waste can also be treated using methods in which the POPs are not completely destroyed or irreversibly transformed. Also, whether the POP waste is classified as hazardous or non-hazardous waste affects how the POP waste needs to be treated, what kind of environmental permit is needed for the handling, packaging and marketing of the waste, what kind of records need to be kept, and so on. The classification of waste as hazardous or non-hazardous is based on the Waste Framework Directive (2008/98/EC) and the European List of Waste (Commission Decision 2014/955/EU).

Waste consisting of, containing or contaminated by any substances listed in Annex IV as well as waste that has exceeded concentration limits of substances specified in Annex IV shall be disposed of or recovered in accordance with Annex V (Waste Management) in such a way as to ensure that the persistent organic pollutant content is destroyed or irreversibly transformed. These accepted methods are:

- Physico-chemical treatment (Disposal method code D9)
- Incineration without energy recovery/incineration on land (Disposal method D10)
- Incineration with energy recovery (Recovery method R1)

- Recycling and reclamation of metals and metal compounds under certain conditions (R4)

In exceptional cases, permits for permanent storage, such as in inside deep, safe bedrock, salt mines or landfill for hazardous waste might be permitted if it can be proven that removing the POPs from the waste is not possible or the destruction or transformation of POPs is not environmentally a good option. Also, the POP waste must be solidified or partly stabilised according to Annex V of the regulation.

Physico-chemical treatments entail methods like alkali metal reduction, base catalysed decomposition, catalytic dehydrogenation, super- and subcritical water oxidation, gas phase chemical reduction, and so on. Suitable physico-chemical treatments are described further in the technical guidelines on POP waste in the Basel Convention Technical Guidelines (2013). It is common for physico-chemical treatments that they are typically suitable for only some of the POPs and can have further limitations like Br-concentration limits, composition, or state requirements for the waste.

For substances that need to be totally destroyed or irreversibly transformed, the regulation does not define the concepts specifically. The Basel Convention (2015a) proposes that the efficiency of destruction or irreversibility of transformation of POPs of a treatment method needs to be 99.999 % to be considered environmentally sound. Important aspects to take into consideration are that waste containing, consisting or that is contaminated by POPs must be disposed of or recovered without any delay. The owner of the waste must prevent the contamination of waste with POPs, which entails the POPs waste treatment chain having to be organised so that the risk of contamination of other wastes being treated is not possible.

The instructions of the Basel Convention on POP waste (2015a) evaluate what kind of incineration processes are suitable. For example, an incineration plant must fulfil requirements set by the EU Industrial Emission Directive (2010/75/EU) to treat POP waste. For hazardous halogenated POPs (indicated as fluorine, chlorine or bromine), and if the upper limit concentration is exceeded, the incineration process must reach temperatures of 1100 °C for at least two seconds. If it is below that or the halogenated POPs are non-hazardous, a temperature of 850 °C is sufficient.

Material recycling of POP waste is only allowed for certain types of metal-containing wastes from the metal industry; other POP waste recycling is prohibited. However, for example for hexaBDE and heptaBDE, specific exemptions have been applied by Brazil, Japan, Cambodia and the Republic of Korea to recycle plastic waste containing these substances. The European Union had an exemption for recycling articles that might contain these substances due to their production and use before the ban, but it was withdrawn in November 2019. (Secretariat of the Stockholm Convention, 2020a)

The POP Regulation allows pre-treatment of POP waste before destruction or irreversible transformation, e.g. to ensure that the waste treatment method is optimum. Pre-treatments can be methods such as separation (mechanical, adsorption, absorption, desorption, membrane filtration, solvents), shredding, mixing, pH adjustment, vaporisation, removing water from waste, disassembling and so on. If only

a part of the waste contains POPs, if possible, that part must be separated from the other waste and handled separately. If POPs are separated during pre-treatment, they must be treated using the allowed methods. It is important to note that the pre-treatments cannot be used to dilute or mix POPs with other waste for the purpose of lowering the concentration under the POPs concentration limit (Basel Convention, 2015a; JRC, 2015). Pre-treatment of POP waste on a professional basis requires an environmental permit.

4.10.3 Reporting and controlling measures

Monitoring of the POP Regulation is done via the Commission with the support of the European Chemicals Agency and the Member States are obligated to establish and maintain appropriate programmes and mechanisms on a regular basis to provide comparable monitoring data on the presence of listed substances in Part A of Annex III. The Commission will also regularly assess the need to include substances from Part B of Annex III to the mandatory monitoring scope. The monitoring of the implementation is the responsibility of the Member States and they need to annually put together and publish reports containing information on the application and implementation of the Regulation. Member States also provide annual monitoring and statistical data on the actual or estimated manufacturing and placing on the markets of any substances listed in annexes I or II, including relevant indicators, overview maps and reports. The substances listed in the Convention are also reported by the Commission with the support of the European Chemicals Agency. The European Chemicals Agency will also compile and publish the EU's overview report every six months. Penalties are set by Member States in case there are infringements of the Regulation. (POP Regulation 2019/1021)

Exemptions

In cases where there are no alternatives (yet) to the POPs from intentional production and use, the Convention allows parties to register specific exemptions for a specific period. In annexes A and B, specific exemptions as well as acceptable purposes are described. (Stockholm Convention Secretariat, 2017)

Proposals for new chemicals

Parties can propose new chemicals to be amended into the Convention. The proposals are reviewed by the POPRC. The POPRC thoroughly evaluate the chemicals in Risk Profiles and Risk Management Evaluation documents, which are available on the Convention's website. (Stockholm Convention Secretariat, 2017)

Addition of new chemicals

The newly listed chemicals require actions from the parties. The necessary action points affect control measures, require the development and implementation of action plans and inventories, and affect the reporting measures. More specifically the following need to be taken into consideration when new chemicals are added to the POPs. (Stockholm Convention Secretariat, 2017)

- Implement control measures for each added chemical (according to articles 3 & 4 of the Convention)
- Develop and implement action plans for unintentionally produced chemicals (according to Article 5 of the Convention)
- Develop inventories of the chemical stockpiles (according to Article 6 of the Convention)
- Review and update the National Implementation Plan (according to Article 8 of the Convention)
- Include the new chemicals in the reporting (according to Article 15 of the Convention)
- Include the new chemicals in the programme for the effectiveness evaluation (according to Article 16 of the Convention)

New chemicals are constantly added to the Convention based on the proposals of parties. The chemicals are added to the Convention with possible exemptions based on negotiations between the Convention's parties at the Conference of the Parties. After the addition is made, the countries have one year to include it in their national legislation. In the EU, the changes to the Convention are made by adding the substances to the EU POP Regulation.

4.10.4 Content of key interest for recycling of plastics with undesirable legacy substances

Disposal or recovery operations that may lead to recovery, recycling, reclamation or reuse of the restricted substances listed in Annex IV of POP Regulation 2019/1021 are prohibited. Figure 12 can be used to help assess if and how the POP Regulation affects the treatment of waste that has compounds of concern, and what the accepted waste treatment options are.

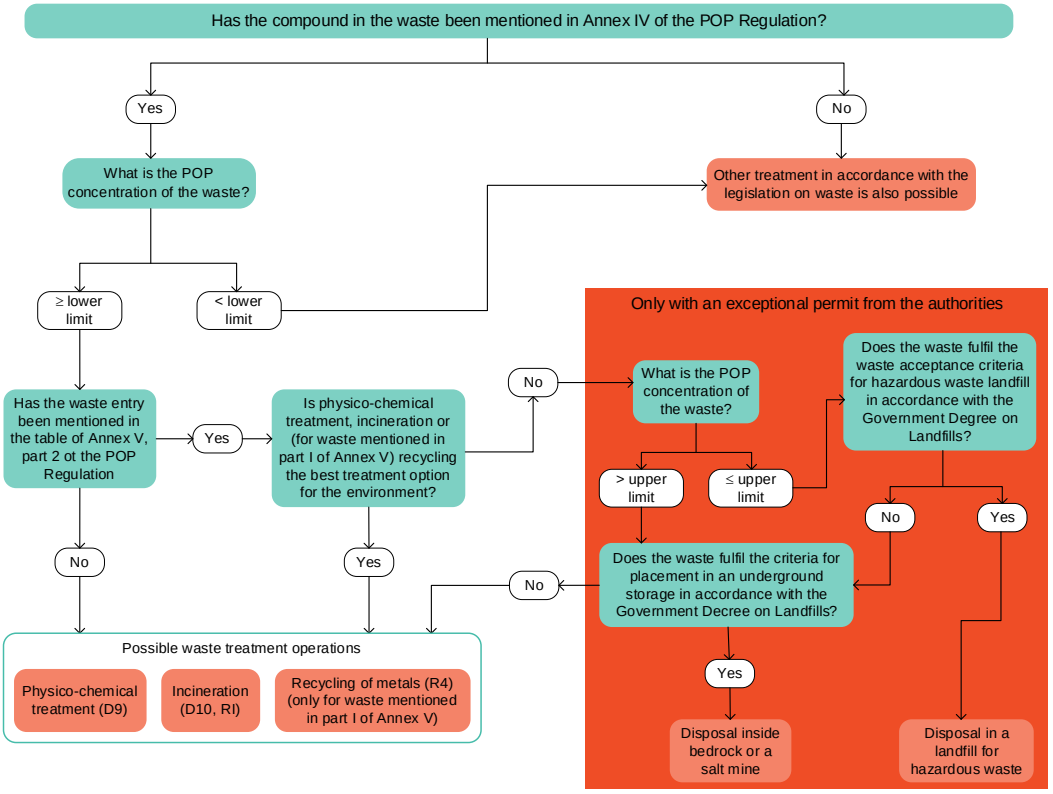

Figure 12. An overview to help assess the applicability of the POP Regulation (modified from Ministry of the Environment, 2016)

4.11 The directive on ecodesign requirements for energy-related products 2009/125/EC

4.11.1 Scope, definition and general requirements of the directive

The aim of EU legislation on ecodesign for energy-related products has been to improve the environmental performance of products by setting mandatory minimum standards for their energy efficiency. The overall aim is to eliminate the worst performing products from the market, contributing to the EU's energy-efficiency objective. (EC, 2020c) The directive connects with the energy performance of products, with varying product-related performance categories (for example between A–G). As such, the Ecodesign Directive on energy-related products in the EU is inherently connected with directives and communications on energy labelling, in which selected performance metrics can be communicated to consumers:

> *In order to maximise the environmental benefits from improved design, it may be necessary to inform consumers about the*

> *environmental characteristics and performance of energy-related products and to advise them on how to use products in a manner which is environmentally friendly.*
> (Article 12; OJ L285/11 31.10.2009)

The directive was originally devised in 2005, and then expanded with new product categories and regularly revised. Product categories that currently connect with EU ecodesign legislation for energy-related products are for example computers and servers, TVs and displays, washing machines, driers and dishwashers, refrigerators, light sources, power supplies and transformers, motors, heaters and welding instruments. Energy performance during use phase has been the main focus. Most of the product-related guidelines will be updated again in 2020–2021. (EC, 2020d)

Both ecodesign for energy-related products and energy labelling directives are a part of the Integrated Product Policy (IPP) toolbox. IPP is an EU-level initiative aimed at reducing the environmental impacts of products and services throughout their life cycles by using a toolbox of (policy) instruments to improve both the demand side (consumption) and the supply side (product development). Integrated Product Policy (IPP) seeks to minimise the environmental degradation resulting from their manufacturing, use or disposal, by looking at all phases of a products' life cycle and planning effective interventions. (EC, 2020e)

> *The approach set out in the Commission's Communication of 18 June 2003 entitled 'Integrated Product Policy — Building on Environmental Life-Cycle Thinking' […] aims to reduce the environmental impacts of products across the whole of their life cycle, including in the selection and use of raw materials, in manufacturing, packaging, transport and distribution, installation and maintenance, use and end-of-life.*
> (Article 13)

The ecodesign of the energy-related products directive connects with product suppliers (manufacturers, importers or authorised representatives) and product design. As the directive notes in Article 7, '[a]ction should be taken during the design phase of energy-related products, since it appears that the pollution caused during a product's life cycle is determined at that stage, and most of the costs involved are committed then.' According to Article 10, improvement in the energy and resource efficiency of products 'contributes to the security of the energy supply and to the reduction of the demand on natural resources.'

In the directive, in Article 9 it is mentioned that 'ecodesign requirements should also be set taking account of the goals and priorities of the Sixth Community Environment Action Programme' (2002–2012) and its subsequent programmes on sustainable development (EC, 2011). This means connections to the broad priority areas of climate change; nature and biodiversity; environment and health; and natural resources and waste. On a broader scale, the EU ecodesign policy also supports industrial competitiveness and innovation by promoting better environmental performance of products throughout their product life, and over the whole value chain, with a focus on the internal EU market.

This has been also addressed clearly in the newest revision of the directive (currently being revised), which puts novel emphasis on 'the inclusion of elements to further enhance the reparability and recyclability of appliances' with measures that include 'requirements for repairability and recyclability, contributing to circular economy objectives by improving the life span, maintenance, reuse, upgrade, recyclability and waste handling of appliances' (EC, 2019b).

The Directive is complementary to other EC instruments such as:

- Council Directive 92/75/EEC of 22 September 1992 on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances,
- Regulation (EC) No 1980/2000 of the European Parliament and of the Council of 17 July 2000 on a revised Community eco-label award scheme,
- Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment (WEEE),
- Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment,
- Directive 2006/121/EC of the European Parliament and of the Council of 18 December 2006 amending Council,
- Directive 67/548/EEC on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances,
- Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and establishing a European Chemicals Agency,
- Regulation (EC) No 106/2008 of the European Parliament and of the Council of 15 January 2008 on a Community energy-efficiency labelling programme for office equipment.

(Article 35)

4.11.2 Content of key interest for the recycling of plastics with undesirable legacy substances

Acknowledging the environmental impacts of several energy-related products in the Community, this EU directive encourages continuous improvement in the overall environmental impact. Currently, however, the ecodesign criteria in the directive and its related product categories focuses almost solely on the use phase, with a focus on energy and water consumption.

The directive connects well with WEEE products, which are important waste feedstock in the NONTOX project. However, it does not discuss material choices or recycling aspects, but simply use-phase-related aspects of consumption and

efficiency. Furthermore, it seems that this specific EU ecodesign policy connects with ELV and C&DW even more poorly.

In this respect, the current EU ecodesign criteria on energy-related products does not connect well with the NONTOX focus in plastics and recycling, or with material considerations or the EU aim for a circular economy in general. Even its soon-to-be-updated product-related guidelines seem to omit material and manufacturing impacts (mainly if not completely), although some aspects for repairability and recycling might be introduced. However, it is important to remember that in the NONTOX context, the scope is also expanded to design choices regarding material considerations, manufacturing and different phases of recycling. This connects to the IPP toolbox more broadly, to directives related to chemicals and waste, and also to considerations in relation to extended producer responsibility (Bio by Deloitte, 2014). Overall, more relevant material and ecodesign considerations related to end-of-life are communicated in a wide range of other directives and guidelines.

4.11.3 Reporting and controlling measures

The EU Ecodesign Directive includes mandatory guidelines for different product categories to test and communicate energy performance. The information that needs to be communicated in the label, and the measurements that are needed in this process, are described in the product-related guidelines.

Currently, suppliers that introduce products that require an energy label for EU markets need to register their appliances in the European Product Database for Energy Labelling (EPREL) before sales. As of the end of 2020, consumers can also browse this database. (EC, 2020f)

4.12 RoHS directives for EEE 2011/65/EU

The RoHS Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electronic and electric equipment (recast) restricts the use of hazardous substances in electrical and electronic equipment (EEE) and promotes the collection and recycling schemes of the WEEE Directive. There has been an evolution of the directive from RoHS 1 and RoHS 2. EEEs are generally defined as all equipment that have at least one intended function that is dependent on electric current or electromagnetic fields to enable at least one function, or that generates or transfers or measures current and fields. There are more specific definitions in Article 3(1) and (2). (Directive 2011/65/EU)

The objective of the collection and recycling schemes is to promote recycling and/or reuse of EEE products and decrease the amount of landfilling or incineration. The directive requires the substitution of safer alternatives to certain hazardous substances as the WEEE has environmental and health risks if mismanaged at end-of-life.

The RoHS was recast, repealing the old RoHS Directive (2002/95/EC) in 2011 due to the rapid increase in the waste stream. In the update, the scope was clarified

and the requirements for all EEEs, cables and spare parts were gradually extended for full compliance; the methodology was updated to cover restrictions mainly based on waste-related criteria for the assessment of new substances in EEEs; the exemption rules for granting, renewing and deleting were made clearer and more transparent, and also the obligation of manufacturers for applying for exemptions and carrying out necessary assessments was updated in RoHS 2. Extensions to new application categories were phased between 2014–2019.

4.12.1 Scope, definition and general requirements

The RoHS Directive restricts the use of certain hazardous substances in EEE, and it is effective when new EEE products are put on the market as it specifically addresses the hazardous substances concern at the point of manufacture. Even though the recycled plastics might originate from WEEE, the RoHS Directive only applies when recycled plastics return to the electrical and electronic equipment markets. It is also important to note that for EEEs, not all hazardous brominated-based substances are regulated under the RoHS Directive. (Directive 2011/65/EU; Groß et al., 2008)

The RoHs directive limits the use of hazardous substances in electrical and electronic equipment with the aim of contributing to the protection of human health and the environment. The first RoHS Directive came into force in 2006 and it applies to EEE put on the market in the EU – both domestically manufactured and imported products. Since June 2006, producers have not been allowed to put new EEEs on the market that contain substances listed under RoHS. The restricted substances under RoHS with limit values are listed in Table 5. The maximum concentration values for restricted substances are listed in Article 4(2) in Annex II. The concentration is calculated based on weight percentage in all homogeneous materials in the EEE, meaning that the maximum concentration is applied to the different homogeneous materials in EEEs individually. (Directive 2011/65/EU)

Table 5 Restricted substances and their limit values under RoHS

Substance	Limit value
Lead	0.1 %
Mercury	0.1 %
Cadmium	0.01 %
Hexavalent chromium (all heavy metals)	0.1 %
Polybrominated biphenyls (PBB)	0.1 %
Polybrominated diphenyl ethers (PBDEs, both groups of BFRs)	0.1 %
Bis(2-Ethylhexyl) phthalate (DEHP)	0.1 %
Benzyl butyl phthalate (BBP)	0.1 %
Dibutyl phthalate (DBP)	0.1 %

4.12.2 Reporting and controlling measures

Placing products on the market

Manufacturers or authorised representatives established in the EU are obligated to file a Declaration of Conformity (DoC) when placing products on the market. The DoC is part of a conformity assessment procedure and ensures that the product is compliant with the directive. Article 7(b) of RoHS sets out the specifications for technical documentation and internal production control procedures that must also be carried out. For example, CENELEC has produced a Harmonised European Standard for the technical documentation requirements that is compliant with the requirements. Also, all EEE products in the RoHS scope must be CE-marked; however, exemptions can apply e.g. for components. (Directive 2011/65/EU)

Exemptions

Exemptions to the use of these hazardous substances in EEE products are only approved if there is no alternative substance to be used. Exemptions are granted for the specific substance used in a specific application(s), not the whole EEE or for a company. Anyone who uses the substances in the specific application can use the exemption to their benefit and the exemptions are listed on the EC's RoHS website. As an example, an exemption can apply to the tailored and specialised equipment used for research and scientific purposes. Examples of possible exemptions are listed in Article 2(4). (Directive 2011/65/EU)

Collection and recycling

WEEE must be separately collected from household waste and recycled. Collection targets have been set out in the WEEE Directive (2012/19/EU). The WEEE Directive also sets out that BFRs have to be removed separately from collected WEEE plastics (Annex VII). BFRs containing plastics have to be removed from separately collected WEEE and that BFRs containing plastic fractions need to be disposed of or recovered in compliance with the Waste Framework Directive (2008/98/EC). (Directive 2011/65/EU)

The Member States of the European Commission transpose the RoHS Directive and WEEE Directive into their national legislation. Member States are obligated to ensure that there is a network of collection points and funding for the collection, treatment and recovery of WEEE. Member States are also responsible for ensuring that retailers offer 1:1 take-back to consumers. Producers are obligated to consider the recycling and reuse of their designed products. They must also take part in collectively or individually financing the collection, treatment and recovery of their products when they become waste. Consumers must have the option to return used

EEEs free of charge. The Commission is responsible for monitoring Community law and can take actions against a Member State if it is not fulfilling the obligations set in the directives. (Directive 2011/65/EU)

4.12.3 Content of key interest for recycling of plastics with undesirable legacy substances

Figure 13 helps to assess and understand whether the new product is compliant under RoHS. It is important to also note that even though restrictions might not apply under RoHS, other regulations might impose restrictions that need to be taken into consideration. Also, if a substance is restricted in other regulations and it is stricter, that restriction limit must be complied with.

It is also good to note that *making available on the market* includes all actions in placing on the market, first making available on the market and all secondary market operations like resale. Since June 2019, all products have had to comply with the RoHS Regulation including products in categories that earlier benefited from Article 2(2). This means that all products must comply with the maximum concentration values. The maximum concentration values tolerated by weight in homogeneous materials is 0.1 %, except for cadmium, whose maximum concentration value is 0.01 %.

EEE has to comply with the substance restrictions and can only do so if the different components used to make it comply with the restrictions according to Article 4 even if not in the scope of RoHS, but then they do not necessarily need to have the CE marking. Other legislation may require the CE marking.

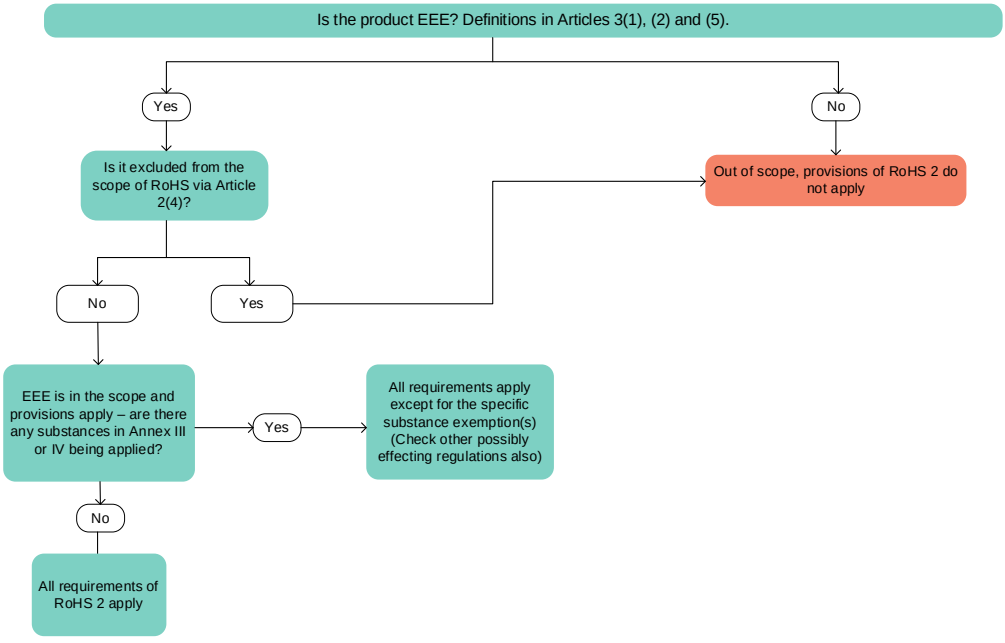

Figure 13. An overview of assessing whether an EEE product is subject to RoHS (Directive 2011/65/EU)

4.13 Construction Products Regulation 305/2011/EU

4.13.1 Scope, definition and general requirements of the directive

Construction works and products must be fit for their intended use, considering in particular the health and safety of persons involved throughout their life cycle. The Construction Products Regulation (305/2011/EU)[40], CPR, sets out the conditions for the marketing of construction products. It sets out harmonised methods and criteria for assessing and expressing the performance of construction products, and the conditions for the use of CE marking in construction products. The regulation aims to remove trade barriers between Member States to improve the EU's internal markets for construction products by providing a common technical language and also by laying down uniform rules for marketing.

The CPR refers to other pieces of legislation (such as the CLP Regulation, 1272/2008, and REACH, 1907/2006) and does not itself set legal requirements on construction products; only on the reporting of performance. It also requires that harmonised test methods are used in the performance declarations.

[40] Amended by:

- Commission Delegated Regulation (EU) No 568/2014 of 18 February 2014
- Commission Delegated Regulation (EU) No 574/2014 of 21 February 2014

The Declaration of Performance is a key part of the Construction Products Regulation. It provides information on the performance of a product. Each construction product covered by a European harmonised standard or a European Technical Assessment needs this declaration and must be CE-marked. The CE marking indicates that a construction product is in conformity with its declared performance.

4.13.2 Content of key interest for recycling of plastics with undesirable legacy substances

Obligations of manufacturers

Manufacturers are responsible for preparing the technical documentation, drawing up a Declaration of Performance and affixing a CE mark to the product. Furthermore, the manufacturer must ensure that the product maintains its conformity with the Declaration of Performance. Where manufacturers consider that the product no longer conforms with the Declaration of Performance, they must immediately take the necessary corrective measures or withdraw or recall the product from the market.

Essential characteristics of construction products

The essential characteristics of construction products are defined in harmonised technical specifications. For specific families of construction products, harmonised standards lay out the basic requirements for the essential characteristics for which the manufacturer shall declare the performance of the product when it is placed on the market. (Article 3) If a construction product is not covered or not fully covered by a harmonised standard, manufacturers may request a European Technical Assessment. The European Technical Assessment is a documented assessment of the performance of a construction product, in relation to its essential characteristics.

Harmonised technical specifications

Harmonised technical specifications include harmonised standards and European Assessment Documents are established by the European standardisation bodies. These create a common technical language used by all players in the construction sector and enable manufacturers to draw up the Declaration of Performance and affix the CE marking. Harmonised standards provide the methods and the criteria for assessing the performance of the construction products, the specific conditions of the manufacturing process and factory production control. The harmonised standard includes technical details for the assessment and verification of constancy of performance.

Declaration of performance

If a manufacturer aims to market a construction product that is covered by a harmonised standard or has been issued a European Technical Assessment, a Declaration of Performance must be made. Derogations from the Declaration of Performance is allowed for construction products that are custom-made either to order or on-site, or if the product is manufactured in a traditional manner (non-industrial process) aimed for adequately renovating protected heritage constructions (Article 5). The Declaration of Performance is drawn up using the model set out in Annex III, containing, among other things, the following information:

- The intended use of the product
- A list of essential characteristics, as determined in the harmonised technical specification for the declared intended use or uses
- The systems of assessment and verification of consistency of performance of the product, as set out in Annex V
- Declared performance based on the assessment according to the applicable harmonised standard or European Technical Assessment
- If the product contains substances regulated by REACH[41], information on these substances must be provided together with the Declaration of Performance in compliance with the REACH Regulation.

Once the Declaration of Performance has been drawn up, the manufacturer must affix a CE marking to the product. The CE marking indicates that the performance of the product has been assessed and that it remains constant. The CE marking enables a construction product to be placed legally on the market in any EU country and then be traded on the EU's single market. (Art 8 & 11)

The technical documentation and the Declaration of Performance must be kept for 10 years after the placing on the market. Manufacturers may have to demonstrate the conformity of the construction product to the national authority. A manufacturer may appoint an authorised representative who can be responsible for the communication and cooperation with the national authorities regarding the Declaration of Performance and the technical documentation. (Art 11 & 12)

4.13.3 Reporting and controlling measures

The product must be accompanied by instructions and safety information in the national language, and they must contain an element for identification either on the product itself or on the packaging. (Art 11)

Manufacturers must ensure that production maintains the declared performance, and, if necessary, keep a register of complaints, of non-conforming products and of product recalls, and keep distributors informed of any such monitoring. If a product

[41] Regulation (EC) No 1907/2006

fails to comply, it must be withdrawn or recalled. If the product presents a risk, the competent national authorities must be informed. (Art 11)

Micro-enterprises manufacturing construction products covered by a harmonised standard may replace the standard type-testing for demonstration of compliance with simplified procedures, as set out in Annex V.

If the product is covered by a harmonised standard but is individually manufactured or custom-made in a non-series process, and which are installed in a single identified construction work, the performance assessment may be replaced by Specific Technical Documentation demonstrating compliance with the harmonised standards.

4.14 Limit values for substances of concern

The regulatory framework in the EU has set recommendations and limitations for a number of hazardous substances aiming to prevent the circulation of these materials and finally, capturing them and eliminating their existence and providing recommendations for regulations and standards that address the removal of contaminants. For the operational framework analysis, an analysis regarding the limit values for the plastics value chain was also carried out based on the affecting existing directives, standards and international agreements affecting the recycling and utilisation of recyclates from WEEE, ELV and C&DW streams with a focus on flame retardants and plasticisers. Their limit values under different regulations in the target waste streams were studied. An overview of regulations that have limit values are presented in Table 6.

Table 6 An overview of limit values for different substances relevant for the plastics value chain

Regulation	Substances restricted or scope	General limit value or restriction	Further notes to consider
RoHS Directive (Directive 2011/65/EC)	Lead, mercury, hexavalent chromium, polybrominated biphenyls (PBB), polybrominated diphenyl ethers (PBDE), bis(2-Ethylhexyl) phthalate (DEHP), benzyl butyl phthalate (BBP), dibutyl phthalate (DBP), diisobutyl phthalate (DIBP).	0.1 %	Only applicable to EEEs that are manufactured and put on the market. Calculated as maximum concentration for homogeneous materials. Specific exemptions are possible.
	Cadmium	0.01 %	
ELV Directive (2000/53/EC)	Lead, mercury,	Prohibits use of these substances in vehicle	Only applicable to the new

	cadmium, hexavalent chromium	materials and components.	vehicle manufacturing. Specific exemptions are possible.
POP Regulation (EU No 850/2004) (and Stockholm Convention and the POPs Protocol of the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP))	See Table 4 for full list (26 substances in total). A summary of the bromine-containing substances in Annex A Elimination: Hexabromobiphenyl, hexabromocyclododecane HBCDD (some exceptions), hexabromodiphenyl ether and heptabromodiphenyl ether (commercial octabromodiphenyl ether), tetrabromodiphenyl ether and pentabromodiphenyl ether (commercial pentabromodiphenyl ether), decabromodiphenyl ether (commercial mixtures, c-decaBDE).	Substance specific limits: lower limit; higher limit. For tetra-, penta-, hexa-, hepta-, and decabromodiphenyl: 1000 mg/kg; 10 000 mg/kg. Review for lower limit of 500 mg/kg ongoing (EU 2019/1021). Hexabromobiphenyl 50 mg/kg; 5000 mg/kg (EU 2019/1021). Hexabromocyclododecane 1000 mg/kg; 1000 mg/kg (EU 2019/1021).	Lower and higher limits given which determine e.g. possible treatment methods for the waste.
REACH	Chemicals in general, applies for when waste becomes non-waste. Substances further divided into candidate lists, authorisation and restriction lists based on level of hazardousness.	Authorisation and restrictions apply if concentrations are higher than 0.1 %.	Substance registration obligations, evaluation procedures.
Hazardous waste limit (WFD 2008/98/EC Annex III)	Classified hazardous substances	Limit value is dependent on the assigned hazard statement code. Concentration values vary between 0.1 % to 25 %.	

5. End-of-waste candidate streams

5.1 End-of-waste criteria for waste plastic for conversion

The current waste status of recovered plastics can create some administrative and economic burdens, especially related to storage and shipment. There is a legal uncertainty in keeping a material that in practice is perceived and treated as a product, under waste legislation. The practices vary between different MS: while recyclates are still waste in some MS, they have a non-waste status in others. These differences have raised some cases of conflict in transboundary movement, but according to stakeholders, have so far been solved on a case-by-case basis. Therefore, however well-functioning, the legislative playing field is uneven in the EU, and may clearly benefit from harmonisation. (Villanueva and Eder, 2014)

The Waste Framework Directive (2008/98/EC), WFD, defines the process and general conditions for the criteria of end-of-waste (see section 4.1). Waste streams that are candidates for the EoW procedure must have undergone a recovery operation, and comply with a set of specific criteria, to be defined specifically for each waste stream.

The aim of the introduction of an end-of-waste criteria for plastics is a certificate for product quality. It would thus provide a clear differentiation between the quality-assured product and the non-quality-assured waste plastic. The end-of-waste criteria should identify where waste plastic has attained a quality where the administrative control that is related to waste processing, trade and shipment can be withdrawn. (Villanueva and Eder, 2014)

Two basic distinct ranges of recyclate outputs are currently marketed in the EU (Villanueva and Eder, 2014):

1. High quality, most often washed, melt-filtered and granulated/pelletised recycled plastic with a non-plastic component content of between 0.1 and 1 %. They often are able to substitute virgin resins in their applications. These recyclates currently represent some 70–80 % of the EU market of recycled plastics. Input materials are pre-consumer flakes or post-consumer washed flakes.

2. Agglomerates and regrinds from mixed origin (mostly from post-consumer plastic waste), with a non-plastic content of 5–15 %, sometimes more. They have a significantly lower value than the higher-quality recyclates, and currently represent approximately 15 % of the EU market. Another common grade is an unwashed regrind or agglomerate with 10–15 % impurities (mostly paper, but also other plastics such as PET and PVC, and 3–4 % ash content from glass, ceramics, metal and stones).

The expense of the input material and/or processing restricts the market for the recyclate to buyers willing to pay for quality suitable for plastic manufacturing. Currently, only high-grade plastic recyclate is used for recycling of polymers, and as the percentage of non-plastics increases, the price also decreases proportionally, and

the recyclates become attractive for other alternative applications. (Villanueva and Eder, 2014)

This latter material is not suited for the substitution of equivalent virgin polymers and is currently only used in applications with high tolerance to physical impurities, substituting other materials than virgin plastic, such as cement and wood for outdoor furniture and civil works applications. In addition, non-washed material with 20% impurities or above is frequently marketed in some regions of the EU as fuel (cement kilns, metal foundries) and not for mechanical recycling. (Villanueva and Eder, 2014)

5.2 Compliance and end-of-waste criteria for the NONTOX process

A methodology guideline to develop end-of-waste criteria has been elaborated by Villanueva and Eder (2014) at the Joint Research Centre's Institute for Prospective Technological Studies (JRC-IPTS) as part of the so-called 'End-of-Waste Criteria' report. The aim of the introduction of an end-of-waste criteria for plastics is a certificate for product quality. As there is no EU-wide end-of-waste status for plastic waste, compliance with the JRC criteria is here considered as compliance with end-of-waste criteria for plastic waste.

Feedstock (chemical) recycling is excluded from the scope of the JRC methodology[42]. This is based on the fact that there is no evidence that the products of feedstock recycling would not be recognised as products. In feedstock recycling, both the use of the product gas or oil as refined fuels and as chemical transformation feedstock are possible. Only use as transformation feedstock is considered recycling, while use as fuel is waste recovery. (Villanueva and Eder, 2014)

In the JRC EoW methodology, the following elements formulate the set of end-of-waste criteria (Villanueva and Eder, 2014):

1. Product quality requirements
2. Requirements on input materials
3. Requirements on treatment processes and techniques
4. Requirements on the provision of information (e.g. documentation of end use, traceability systems, labelling)
5. Requirements on quality assurance procedures

[42] The outputs are on one side refined gas or liquid hydrocarbons (syngas, ethylene, etc.) used as chemical feedstock or as fuels, and on the other side heavy fractions (tar, oils) that are normally considered waste due to the presence of mixtures of high molecular mass aromatic compounds. This route has so far faced no barriers in the recognition of the refined output materials (and only these) as non-waste, meeting consistently product standards, and therefore their inclusion would be redundant.

5.2.1 Product quality requirements

Product quality criteria verify that there are no direct environmental and health risks, and that the product is suitable as direct input to recycled plastic production. The secondary material must form an adequate alternative to primary raw materials, and components limiting use have been effectively separated. The quality criteria should include at least quantitative limits on non-plastic components, hazardous substance content, and the content of erroneous plastic types should not prevent the use as direct input to the manufacture of plastic products. (Villanueva and Eder, 2014)

The quantitative limits of non-plastic content relate to the recyclability of the material, contributing to the circularity of the plastic and also minimising environmental impacts of the material loop. The JRC proposes a threshold of 2% of non-plastic impurities, valid for all polymer types. This requirement on non-plastic content would hinder the EoW for some currently recycled waste streams with higher grades of impurities, and thus recycling of these materials would remain under the waste regime. (Villanueva and Eder, 2014)

The material qualifying for EoW must not contain hazardous substances[43]. The JRC proposes that that recyclates meet the same requirements as virgin plastic, including the same knowledge of material composition, and the communication of this data in the supply chain. The determination of hazardousness should be done based on the concentration of the hazardous substance, and in compliance with REACH, CLP and POP regulations. Three options are presented by JRC to control the risks derived from hazardousness content in feedstock and secondary raw materials (Villanueva and Eder, 2014):

1. a direct criterion on the quality of the material, which shall not display any hazardous properties
2. a criterion on the exclusion of the use of hazardous material as input
3. a criterion on the processing for the removal of hazardous material.

For the NONTOX scheme, option 2 would prevent the recycling of the target materials, whereas options 1 and 3 would support the processing for removal of the hazardous compounds according to the NONTOX process.

Alternative 1 is a prerequisite for compliance with chemical and product regulation, although exemptions exist, where certain hazardous compounds are allowed until a limit value, as elaborated in section 4.14.

Alternative 3 is currently a standard method, where the first items known to contain hazardous substances are removed manually, and then plastics containing BFRs, for example, are separated based on density, for example. The NONTOX project aims for the development of a process to safely remove hazardous compounds.

[43] The material must not have any hazardous properties, as listed in Annex III to Directive 2008/98/EC, and must also comply with the concentration limits laid down in Commission Decision 2000/532/EC ('List of wastes').

- Compliance with **product quality criteria is reached** when the content of erroneous plastic types in the recyclate does not prevent the use as direct input to the manufacture of plastic products, the material contains less than 2% of non-plastic impurities, and complies with limit values set in product[44] and chemical regulations. This should verify that there are no direct environmental and health risks, and that the product is suitable as an adequate alternative to primary raw materials.

5.2.2 Requirements on input materials

The end-of-waste criteria should restrict input waste streams to only plastics that can be processed for the production of new plastic in compliance with the product quality requirements. Once the foreign plastics, non-plastic materials and hazardous substance have been restricted, the remaining substances of concern are part of the plastic structure, i.e. they are additives. The control of the substances still in the plastics is done through compliance with REACH/CLP/POPs. (Villanueva and Eder, 2014)

JRC also proposes excluding bio-waste, health care waste, and used products of personal hygiene as input materials for EoW recycling. During waste management, the material should not have been in contact with certain waste types, e.g. biowaste, oil waste, waste solvents, health care waste or mixed municipal solid waste, due to the risk of cross-contamination. (Villanueva and Eder, 2014) This may be an issue for the NONTOX waste input fractions, since many of them are treated in metal shredding and mixed with several other fractions, including ELV. End-of-life vehicles have a high risk of contamination with waste oils.

Hazardous waste can only be used as an input if proof is provided that the processing techniques remove all hazardous properties. The procedure of recognising hazardous materials should be documented under the management system and particular attention should be placed on plastic waste originating from electric and electronic equipment waste, construction and demolition waste, and end-of-life vehicles – the target waste streams of the NONTOX project.

- Compliance with **input material requirements** is reached when contamination and cross-contamination risks can be excluded. For ELV, this poses a risk related to the nature of the waste. However, the ELV Directive states specific requirements for the safe treatment of ELV, and via compliance with this directive, the recovery of the ELV plastics should comply with EoW requirements.

[44] Depending on end use of recovered material, different regulations apply for different products.

5.2.3 Requirements on treatment processes and techniques

The purpose of the process requirements is to define conditions known to result in the quality required for EoW. Treatment operations are based on a specific need, and are not standard for all feedstock fractions. When reaching end-of-waste status, the material must be suitable for direct input to the manufacture of plastic products. The criteria on processes and techniques can include (Villanueva and Eder, 2014):

- Basic general process requirements, such as the avoidance of cross-contamination, diluting and after-mixture with waste
- Specific process requirements for specific types of waste plastic, such as key unit operations (sorting, cleaning, etc.) that provide the essential reduction/removal of environmental and health risks for waste plastics.

The minimum processing requirement is sorting and size reduction. Additional cleaning may be needed for the removal of impurities to make the material suitable for pelletising. However, for some clean fractions, such as pre-consumer waste, washing can be unnecessary. (Villanueva and Eder, 2014)

In addition to the choice of equipment installed at sorting plants, key factors affecting the quality of the output include (Villanueva and Eder, 2014):

- Speed of throughput (e.g. at manual sorting cabins, mechanical screens)
- Staffing levels within sorting cabins
- Management of quality of the input streams (e.g. via communication with waste producers and collectors)
- The existence of a wet cleaning phase (washing) for removal or fluid residues (oils, detergents, solvents, paints, foodstuffs, etc.), versus dry cleaning, which does not remove them if they are attached or adsorbed to the plastic surface
- The existence of a filter mesh for impurity removal in the melted phase (extrusion), and size requirements.

Hazardous waste can only be used as an input if proof is provided that the processing techniques remove all hazardous properties. The purpose of the process requirements is to define conditions known to result in the quality required for EoW. The JRC proposes the following criteria for the treatment processes (Villanueva and Eder, 2014):

- The input fraction must be stored separately from contact with any other waste;
- Required treatment operations prepare the material to be suitable as input to manufacturing of plastic products. Treatment operations are based on a specific need, and is not standard for all feedstock fractions, and;

- Hazardous components must be removed before shredding in order to prevent mixing of these substances into clean fractions. For waste containing hazardous components, the product must comply with treatment requirements of the WFD, WEEEDir and ELVDir. If not mentioned in these directives, the hazardous substances must be efficiently removed in the processing of the plastic waste.

➢ The **requirements on treatment processes** cannot be standard for all feedstock but vary according to need. The basic general process requirements include the avoidance of cross-contamination, diluting and after-mixture with waste, while specific process requirements for the NONTOX feedstock are presented in the NONTOX process. The NONTOX process uses hazardous waste as an input and must thus provide proof that the processing techniques remove all hazardous properties.

5.2.4 Requirements on the provision of information

The end-of-waste criteria should not aim to increase the administrative burden of plastic recycling by setting high requirements on labelling and the provision of information (Villanueva and Eder, 2014). Labelling is needed only in specific cases, e.g. to support the use for a specific purpose (criteria 1 of the WFD general conditions of EoW, as stated in Art. 6(a)).

The JRC suggests that EoW plastic consignments shall be specifically labelled with a statement that the material is intended exclusively for the manufacture of plastic products through conversion processes. This is to ensure compliance with the WFD regarding the use for a specific purpose. If an EoW plastic labelled as EoW for recycling is not destined for plastic manufacture, it cannot be referred to as EoW, but waste, and becomes an illegal shipment of waste. (Villanueva and Eder, 2014)

➢ Compliance with the **requirements on provision of information** would include that the recovered plastic from the NONTOX processing would be accompanied with a statement that the material that has ceased to be waste is within the scope of REACH, POP and CLP Regulations and that the material is intended exclusively for the manufacture of plastic products.

5.2.5 Requirements on quality assurance procedures

Quality assurance is of importance to establish confidence in the end-of-waste status and also as it is required for compliance with REACH. The owner of the material applying the end-of-waste status will be responsible for quality assurance and must be able to demonstrate and document compliance with all the end-of-waste criteria. (Villanueva and Eder, 2014)

There should be a management system in place assuring the quality of the end product, covering the key areas of operation where compliance with end-of-waste criteria has to be demonstrated, and that includes a certified external verification

process to assess if the management system is effective and suitable for demonstrating compliance with the end-of-waste criteria. The system should also have documented procedures and monitoring requirements concerning, e.g. the following (Villanueva and Eder, 2014):

- monitoring of the quality of waste plastic (including sampling and analysis)
- monitoring of the treatment processes and techniques
- acceptance control of feedstock waste
- feedback from customers concerning the product quality.

➢ For compliance with **requirements on quality assurance procedures**, the NONTOX recyclers should adapt documented procedures and monitoring requirements concerning e.g. the following:
  - acceptance control of feedstock waste (possibly including proof of traceability for the origin of the waste)
  - monitoring of the quality of the waste plastic stream via sampling and analysis
  - monitoring of the treatment processes and techniques
  - monitoring of product quality via sampling and analysis
  - feedback from customers concerning the product quality

➢ Compliance with requirements on quality assurance aims to provide the required information on product quality, verifying that there are no direct environmental and health risks, and that the product is suitable for use as direct input to the manufacture of plastic products.

6. Summary and conclusions

Increasing recycling rates and well-functioning markets for secondary raw materials are crucial for the implementation of a circular economy, which is also highlighted in the Green Deal, the Circular Economy Action Plan, and the Zero Pollution Ambition for a non-toxic environment and plastic strategy. The recycling targets set in the waste-specific directives pose new challenges for the coordination of the different objectives on waste, product and chemicals legislation, as the European product legislation sets limits for the use of specific compounds and materials in products, and the chemical legislation also for the treatment of waste containing hazardous compounds.

Different legislation applies in different sections of the value chain. In this report, the value chain is divided into four sections: 1) plastic processing and upgrade, 2) product manufacture, 3) consumption and use, as well as waste generation, and 4) collection of waste and plastic pre-treatment, sorting and granulation. The value chain of the NONTOX process is illustrated in Figure 2, where the European waste, chemical and product legislation, as well as standards, and their impact on the stages of the value chain are presented.

6.1 Waste management

The WFD[45] sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling, recovery and end-of-waste criteria. It further states that waste treatment operators must have a permit and have regular inspections by the authorities.

The LoW[46] provides an EU-wide common terminology for waste classification to ease waste management, including for hazardous waste. The classification of waste as hazardous includes limit values of concentration of hazardous substances.

The waste directives set targets and requirements for the collection of waste and for recycling:

- The ELV Directive[47] sets minimum requirements for the treatment of ELV, more specifically for the collection of all end-of-life vehicles at authorised treatment facilities and for the processes of depollution of fluids and specific components. It sets targets for 85 % recycling and 95 % recovery for end-of life vehicles, by an average weight per vehicle and year.

- The WEEE Directive[48] sets quantitative requirements for the collection of WEEE; of 65 % collection of the average weight of EEE placed on the market in the three preceding years, alternatively 85 % of WEEE generated

[45] 2008/98/EC
[46] 2000/532/EC
[47] 2000/53/EC
[48] 2012/19/EU

in that same year. The recycling targets for WEEE is set per category at 75–85 % recovery and 55–80 % recycling.

- The WFD promotes selective demolition and site sorting for construction and demolition waste, and a target of recycling 70% (by weight) of non-hazardous construction and demolition waste. The Commission shall consider by 2024 material-specific targets for key streams.

An extended producer responsibility (EPR) is mandatory for vehicles and EEE, as stated in the WEEE Directive and the ELV Directive. The EPR puts the responsibility for the financing of collection, recycling and end-of-life disposal on the producers.

The Waste Shipment Regulation[49] establishes procedures for the shipment of waste, depending on the route of the shipment, the type of waste and intended treatment. There is a ban on the export of hazardous wastes to non-OECD countries and on the export of waste for disposal. The shipment of 'green-listed' wastes for recovery within the EU and OECD does not require permission, whereas the shipment of hazardous wastes and of wastes destined for disposal requires a permit from all relevant authorities of dispatch, transit and destination.

- Waste management directives frame the operational environment of waste collection and treatment. The directives stipulate how waste can or must be collected, how to transport the waste and also the requirements on facilities, processing and recovery and recycling targets.
- In cases where the waste stream is covered by an extended producer responsibility, the producers are responsible for arranging and financing waste collection and treatment, as well as achieving set targets for collection, recovery, recycling and proper disposal of the end-of-life products. Producers can outsource the waste management to waste operators and recyclers.
- Waste operators and recyclers must have adequate waste treatment permission, which differs between green-listed and hazardous waste.
- Waste operators are responsible for the collecting of waste in compliance with relevant waste legislation. If the waste is classified as hazardous, proper collection and storage infrastructure is compulsory. Furthermore, recyclers must accompany waste consignments with relevant documentation on properties.
- Recyclers are responsible for the screening of incoming waste materials, separating hazardous waste from green-listed, and waste of different origin in storage to avoid cross-contamination.
- Recyclers are responsible for adequate treatment of feedstock depending on its properties and requirements on quality of the recovered material. Hazardous waste can be recycled if the recovered material complies with relevant product legislation.

[49] 1013/2006/EC

- Recyclers are responsible for accompanying recovered materials with relevant documentation on properties.

6.2 Recycling, recovered materials and products

Standards aim to set a case for best practices in recycling and trading. The standards have linked supporting technical specifications (TS) to provide technical details, such as sampling protocols, analysis methodologies, etc. The use of standards is voluntary, but laws and regulations developed by each Member State may refer to standards. The purpose of the standards is to provide the operators with guidelines and assist treatment operators in fulfilling the requirements of the waste directives without placing unnecessary administrative burdens on operators of any size, including SMEs.

The current waste status of recovered plastics can create some administrative and economic burdens, especially when related to storage and shipment. The practices vary between different Member States: while recyclates are still waste in some, they have a non-waste status in others. These differences have raised some cases of conflict in transboundary movement, but according to stakeholders, they have so far been solved on a case-by-case basis.

Today, there is no general end-of-waste status for recovered plastic in the EU. Some Member States have a national end-of-waste status. Harmonising the rules related to quality verification differences between the recovered product and the waste plastic would reduce the administrative burdens related to trade. The different categorisation in different Member States of the product-waste status results in distortion in the single market due to different administrative requirements for shipment, transport and permits of the recyclers.

The revised WFD defines the process and general conditions for the criteria of end-of-waste, where the most important conditions for recovered plastics would relate to the use of the secondary material as an adequate alternative to primary raw materials to be used as direct input to the manufacture of plastic products. The JRC methodology explicitly defining end-of-waste for plastic waste for conversion defines five conditions for the EoW status: product quality, feedstock features, requirements on treatment, provision of information and quality assurance. Relevant standards examined in this report (sections 4.5–4.8) respond to the same requirements as the EoW criteria.

REACH is implemented in the production, import and use of substances. In the case of recycling operators, REACH applies after the recycling process when the plastic has ceased to be waste. The aim of REACH is to ensure that all substances are manufactured and used safely.

Persistent organic pollutants (POPs) are toxic chemical substances that globally affect human health, animals and the environment. They persist in the environment for a long time and transfer far from the originating pollution source. The Stockholm Convention is an international agreement that aims at reducing and eliminating the

production, use and release of POPs, and the POP Regulation[50] is the EU tool for limiting POP substances.

In the production of specific products, the product regulation limits the use of certain hazardous substances. The RoHS Directive sets limits for the use in electrical and electronic equipment and the ELV Directive for the use in vehicles. It is important to note that not all hazardous brominated-based substances are regulated under the specific product directives, but if they are subject to restriction under REACH, they must comply with these restrictions.

- By using standards, recyclers can demonstrate compliance with specific treatment operations, assisting in fulfilling the requirements of the specific waste directive and also compliance with a certain quality of product. The final goal of standardisation is to create a transparent, efficient and harmonised plastics recycling industry.
- Recyclers are responsible for having adequate treatment for the feedstock depending on its properties and requirements on quality of the recovered material. Hazardous waste can be recycled if the recovered material complies with relevant product legislation.
- Recyclers are responsible for accompanying recovered materials with relevant documentation on properties.
- Today, there is no general end-of-waste status for recovered plastic in the EU. Standards respond to the same requirements as the EoW criteria including documentation and verification. By using standards, recyclers can verify compliance with waste regulation and quality requirements of the recovered product.
- There are no cross-EU regulation or harmonised systems for when a recovered plastic ceases to be a waste. Recovered plastics that have not received an official EoW status is commonly marketed as a product and used in production.
- Product regulation, REACH and the POP Regulation list chemicals and their limit values for use in products. Recyclers must ensure that the recovered plastics comply with these limit values.
- Not all recycled plastics have to comply with all product regulation; compliance is relevant only for end-use purposes, e.g. even though the recycled plastics might originate from WEEE, the RoHS Directive only applies when recycled plastics go back into the electrical and electronic equipment markets; if the plastic ends up in a construction product, it must comply with the CPR.

6.3 Concluding remarks

When aiming to promote recycling, it is important to understand the relationship between waste and chemical regulation and the different driving forces behind

[50] 850/2004/EU

them. While the waste legislation aims to increase recycling, the chemical regulation aims to prevent the circulation of harmful and potentially harmful substances.

As the chemical content and harmfulness of waste materials is uncertain due to the nature of waste generation and collection, where not all items are reported or controlled, the chemicals regulation aims to prevent the circulation of some waste materials. In CEAP2015 (COM, 2015), the importance of the link between the chemicals and waste regulation is stressed in order to create markets for recovered raw materials.

The chemical legislation in Europe is highly based on proactive principles, based on the idea that as long as the safety of chemicals are uncertain and have not been proven safe, they are considered not to be safe. The approach aims to minimise all potential hazards, which can be either direct due to the unknown hazardousness of the chemical, or indirect due to different types of misuse, long-term impacts and combined impact with other substances.

The chemical legislation in Europe strives to eliminate hazardous substances in products and prevent hazardous substances from being used. However, some hazardous substances play an important role in product safety, such as flame retardants in construction materials, vehicles and electronics. Thus, it is sometimes interpreted that the use of these substances is crucial for the production and use of the products. If there are no less hazardous alternatives serving the same purpose, the chemical legislation may give exemptions allowing to use the chemicals within specific limitations.

6.4 Discussion

This report is a review of the regulatory framework and operational environment in the EU. The focus is on the plastics contained in three specific waste streams, namely C&DW, WEEE and ELV, especially plastics containing brominated flame retardants and other hazardous substances.

In general, it can be concluded that the plastic fractions from the three waste streams are quite different. Although C&DW and ELV are to some extent treated together, this is only due to the high metal content of the waste fraction and the metal recycling processes of today. The three plastic fractions have different impacts on their respective waste streams; with WEEE containing up to 30 % plastic, the recycling of WEEE plastics is essential for reaching the recycling targets of the waste stream. For C&DW, the plastic content is extremely heterogeneous and stands for only approximately 0.2 % of the waste stream, therefore the recycling of plastics will not have an impact on the total recycling rate of this waste stream.

By the end of 2024, the Commission shall consider material-specific targets for key streams of C&DW. As of now, a recycling target for the entire industry creates incentives to recycle materials that have a large impact on the target. Currently, there are no incentives to recycle the plastic fraction of the C&DW, as the impact on the total recycling rate is not essential. A recycling target for the plastic fraction

would heavily incentivise plastics recycling from C&DW, which after all is a significant plastic stream in the EU.

Both ELV and WEEE are covered by an extended producer responsibility (EPR), and a discussion is needed on the possibilities to demand an (EPR) for some construction products and/or materials. PVC pipes would be a good alternative for a specific plastic product in C&DW. In practice, EPR schemes work in the way that the producers are responsible for the waste management of their products, and also for reaching set recycling targets. EPR schemes are seen as very efficient means of reaching recycling targets as the costs for recycling are embedded in the cost of the product instead of forming a separate waste management fee for the consumer.

On the product side, there is a legal uncertainty in keeping a material that in practice is perceived and treated as a product, under waste legislation. The practices vary between different Member States: while recyclates are still waste in some, they have non-waste status in others. Therefore, however well-functioning it is, the legislative playing field is uneven in the EU, and may clearly benefit from harmonisation.

The introduction of an end-of-waste criteria for plastics as a certificate for product quality would provide a clear differentiation between product and waste. Harmonising the rules would also facilitate improved functioning of the internal and external markets of the EU and also reduce the administrative burdens related to shipment, transport and trade; and minimise distortion in the single market due to different administrative requirements for shipment, transport and permits of the recyclers.

In conclusion, it can be stated that the responsibilities of the actors in the value chain are well stated in the legislative framework. However, due to the breadth and intricacy of the European legislation, as well as differing legislation between Member States, knowledge of the explicit responsibilities and requirements is hard to accomplish for a single actor in the plastics recycling value chain.

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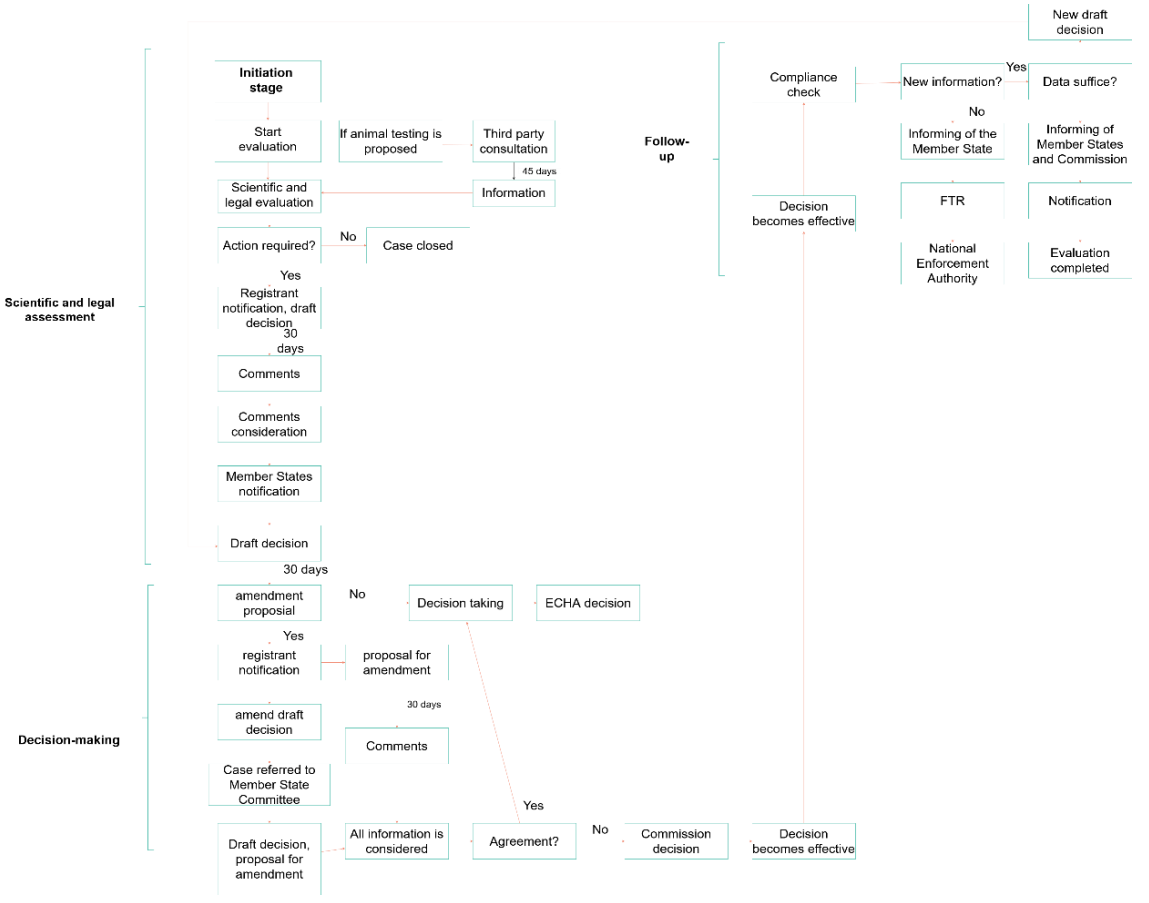
Annex 1: Dossier evaluation process (modified from ECHA's 2019 flowchart)



Annex 2: National Enforcement Authorities in Poland, Germany, Italy, Finland and Portugal, and examples of administrative and criminal penalties.

(Sources: ECHA 2020 and Milieu 2011)

Country, the Regime of Enforcement	Competent Authorities and enforcement	Administrative penalties	Criminal penalties
Poland (Administrative and criminal)	The leading enforcement authority is the State Sanitary Inspection, the State Sanitary Inspection of Ministry of Internal Affairs and the Military Sanitary Inspection, which works in the field of public health. Control activities are realised by inspectors at the regional level. They are coordinated/supervised by the Chief Sanitary Inspectorate.	An order by way of an administrative decision to: • stop the manufacture or placing on the market of this substance, preparation or article, or, where necessary, • withdraw this substance, preparation or article from the market.	**Where the administrative decision sideline is violated**: • Fine (from 100 PLN to PLN 720 000 PLN (from 24 EUR to 171 428 EUR), • Restricted freedom or • Imprisonment for up to 2 years. **For a criminal offence of a legal person:** • the penalty of a fine from PLN 1 000 to 20 000 000 (from EUR 221 to 4.25 million); however, not higher than 10 % of the revenue gained in the financial year in which the forbidden act was committed. Forfeiture of: • objects, property or the value equivalent to that of the objects or property benefit which originate at least indirectly from a forbidden act. The following may be prohibited: promotion or publicity of activities, articles or services, use of grants, subsidies, etc. In turn, the penalty for a petty offence is a fine (up to PLN 5 000 – up to EUR 1 190).
Germany (Administrative and criminal)	The Competent Authority for REACH is the Federal Institute for	Fines for intentional or negligent non-	**Intentional/ negligent non-compliance with**

	Occupational Safety and Health (BAuA). Enforcement is under the sole responsibility of the individual states. The regional enforcement authorities conduct regular inspections on companies and products and run focused enforcement projects. BAuA provides them the scientific expertise, informational services and legal support.	compliance: EUR 50 000/25 000 Confiscation and deprivation of objects Negligent violation registration obligations: fine up to EUR 100 000	**enforceable administrative acts targeting the elimination of infringements of registration obligations and fulfilment of aggravating circumstances:** Up to 5 years in prison or up to 360 daily units fine/ Up to 2 years in prison or up to 360 daily units fine, Legal persons: Fine up to EUR 1 000 000/ 500 000. • Intentional violation of registration obligations: Up to 2 years in prison or up to 360 daily units fine, Legal persons: Fine up to EUR 1 000 000 (with aggravating circumstances: Up to 5 years in prison or maximum fine of 360 daily units, Legal persons: Fine up to EUR 1 000 000) • Confiscation and deprivation of objects
Italy (Administrative and criminal)	Ministry of Health, DG Health Prevention is responsible for controls to be conducted by a central pool of inspectors. At local level, surveillance plans involve 21 regional enforcing authorities.	From EUR 10 000 to 60 000. Violation of Articles 60, 65: From EUR 5 000 to 30 000 (breach of Article 66 par.1)	Up to 3 months in prison or a penalty from EUR 40 000 to 150 000 (breach of article 67) • Up to 3 months in prison or a penalty from EUR 40 000 to 150 000 (breach of Articles 56(1–2))
Finland (Administrative and criminal)	Finnish Safety and Chemicals Agency (TUKES) Occupational health and safety authority (AVI) Centre for Economic Development, Transport and Environment (ELY). All competent authorities are responsible for REACH enforcement. AVI and ELY have regional authorities.	Coercive measures, e.g. prohibition to keep on carrying out or repeat a procedure infringing REACH + a coercive fine.	Chemical violation: fine Health offence: fine or up to six months in prison Impairment of environment: fine or up to 2 years in prison. Aggravated impairment of the environment: from 4 months to up to six years in prison
Portugal (Administrative)	The General Inspectorate for Agriculture, the	Very serious offences:	N/A

	Sea, the Environment and Spatial Planning (IGAMAOT) The Authority for the Economy and Food Safety (ASAE) The Tax and Customs Authority (AT) IGAMAOT focuses on producers and formulators. ASAE focuses on distributors, wholesalers and retailers, and AT on importers.	• Natural Persons – Fine from EUR 20 000 to 30 000 (negligence) and from EUR 30 000 to 37 500 (fault) • Legal Persons – Fine from EUR 38 500 to 70 000 (negligence) and from EUR 200 000 to 2 500 000 (fault) For serious and very serious offences the following administrative sanctions may be applicable together with the fine: • Confiscation of the assets (objects used or that were meant to be used)	

Annex 3: European standards and related Technical Specifications (TS) relevant for WEEE

The process of standard development is not yet concluded. Future standards, currently under development, will also cover the preparation for reuse of the WEEE, e.g. EN 50614: Requirements for preparing for reuse of waste electrical and electronic equipment.

European standards and related technical specifications (TS) relevant for WEEE are the following:

- EN 50419 on the marking of electrical and electronic equipment
- EN 50574 on the collection, logistics and treatment requirements for end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons
- TS 50574-2: Collection, logistics and treatment requirements for end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons - Part 2: specification for depollution
- EN 50625-1: Collection, logistics and treatment requirements for WEEE - Part 1: General treatment requirements
- EN 50625-2-1: Collection, logistics and treatment requirements for WEEE – Part 2-1: Lamp requirements
- EN 50625-2-2: Collection, logistics and treatment requirements for WEEE - Part 2-2: Displays requirements
- EN 50625-2-3: Collection, logistics and treatment requirements for WEEE - Part 2-3: Temperature exchange equipment
- EN 50625-2-4: Collection, logistics and treatment requirements for WEEE - Part 2-4: Photovoltaic panels requirements
- TS 50625-3-1: Collection, logistics and treatment requirements for WEEE - Part 3-1: General Technical Specification
- TS 50625-3-2: Collection, logistics and treatment requirements for WEEE - Part 3-2: Lamps Technical Specification
- TS 50625-3-3: Collection, logistics and treatment requirements for WEEE -- Part 3-3: Displays Technical Specification
- TS 50625-3-4: Collection, logistics and treatment requirements for WEEE - Part 3-4: TEE Technical Specification
- TS 50625-3-5: Collection, logistics and treatment requirements for WEEE - Part 3-5: PV panels Technical Specification
- TS 50625-4: Collection, logistics and treatment requirements for WEEE - Part 4: Collection and Logistics requirements
- TS 50625-5: Collection, logistics and treatment requirements for WEEE - Part 5: End processing fractions requirements
- EN 50614. Re-use requirements

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Title	**Review of the European Legislative and Policy Framework Affecting the Recycling of Hazardous Plastics from ELV, WEEE and C&DW**
Author(s)	Malin zu Castell-Rüdenhausen, Anna Tenhunen, Mathilde Taveau, Lotta Marjamäki, Nazarena Vincenti, Tatu Marttila, Margareta Wahlström, Paola Colzani
Abstract	Increasing recycling rates and well-functioning markets for secondary raw materials are crucial for the implementation of a circular economy, which is also highlighted in the EU's Circular economy policies, such as European Green Deal, Circular Economy Action Plan, Zero Pollution Action Plan and Plastic Strategy. When aiming to promote recycling, it is important to understand the policy and legislative framework steering the operational environment. The legislative framework as well as other policy drivers were depicted through a literature review and screening of legislative documents and standards across the circular economy value chain for plastic waste containing hazardous substances from WEEE (Waste Electronic and Electrical Equipment), C&DW (Construction and Demolition Waste) and ELV (End-of-Life Vehicles) streams, creating a good overview of the driving forces framing the operational environment. The study shows that the key waste management directives frame the operational environment of waste collection and treatment, while the product and chemicals legislation can further restrict the recycling of hazardous or potentially hazardous substances. The waste directives stipulate waste collection and treatment practices. By using standardised technologies and methods, recyclers can comply with a certain quality of product. A steady supply and a harmonized quality throughout the plastic recycling industry will contribute to a well-functioning market for secondary plastics. Finally, it can be concluded that the objectives set in the directives are posing some challenges for the coordination of the different objectives on waste, product, and chemicals legislation. While the legislative framework on waste aims at increasing recycling, the legislative frameworks on chemicals and products aims at preventing the use and circulation of harmful and potentially harmful substances.
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Review of the European Legislative and Policy Framework Affecting the Recycling of Hazardous Plastics from ELV, WEEE and C&DW

Increasing recycling rates and well-functioning markets for secondary raw materials are crucial for the implementation of a circular economy, which is also highlighted in the EU's Circular economy policies. When developing recycling technologies, it is important to understand the policy framework steering the operational environment. The legislative framework as well as other policy drivers were depicted through a literature review and screening of legislative documents and standards across the circular economy value chain for plastic waste containing hazardous substances from WEEE (Waste Electronic and Electrical Equipment), C&DW (Construction and Demolition Waste) and ELV (End-of-Life Vehicles) streams, creating a good overview of the driving forces framing the operational environment.
The study shows that the key waste management directives frame the operational environment of waste collection and treatment, while the product and chemicals legislation can restrict the recycling of hazardous or potentially hazardous substances. The waste directives stipulate waste collection and treatment practices. By using standardised technologies and methods, recyclers can comply with a certain quality of product. It can be concluded that the objectives set in the directives are posing some challenges for the coordination of the different objectives on waste, product, and chemicals legislation. While the legislative framework on waste aims at increasing recycling, the legislative frameworks on chemicals and products aims at preventing the use and circulation of harmful and potentially harmful substances.

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