PolyCE

Post-Consumer High-tech Recycled Polymers for a Circular Economy

Project Duration:	**01/06/2017 - 31/05/2021**
Deliverable No.:	**9.5**
Deliverable Title:	**Policy measures, Environmental labelling and standardization input: Summary of policy recommendations**
Submission date:	**31/05/2021**
Lead Beneficiary:	**Fraunhofer IZM**
Lead Authors:	Gergana Dimitrova; Anton Berwald; Max Tippner
Co-Lead Author:	Franziska Maisel (Technische Universität Berlin)
Deliverable Type:	R

R = Document, report
DEM = Demonstrator, pilot, prototype, plan designs
DEC = Websites, patent filing, press & media actions, videos, etc.

Dissemination Level: PU

PU = Public
CO = Confidential, only for members of the consortium, including the Commission Services

Co-Lead Author Contact: Franziska Maisel

TU Berlin

phone +493046403-293

e-mail: franziska.maisel@tu-berlin.de

Contributing Partners:

Stéphane Arditi, European Environmental Bureau
Alessia Accili, ERION
Luca Campadello, ERION
Prof. Kim Ragaert, University Ghent
Gianni Vyncke, University Ghent
Alexander Boudewijn, KU Leuven
Prof. Jef Peeters, KU Leuven
Anne Bonhoff, UL
William Hoffman, UL
Chris Slijkhuis, MGG Polymers
Günther Höggerl, MGG Polymers

Disclaimer

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730308

Glossary

ABS	Acrylonitrile butadiene styrene
BFR	Brominated Flame Retardants
CEAP	Circular Economy Action Plan
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CLP	Classification, Labelling and Packaging
CMR	Carcinogenic, mutagenic, or toxic for reproduction
CPA	Circular Plastics Alliance
ECHA	European Chemicals Agency
EEE	Electrical and Electronic Equipment
EFSA	European Food Safety Authority
EoW	End-of-Waste
ETSI	European Telecommunications Standards Institute
EU	European Union
FPD	Flat Panel Display
FR	Flame Retardants
GPP	Green Public Procurement
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
OEM	Original Equipment Manufacturer
PBB	Polybrominated biphenyls
PBDE	Polybrominated diphenyl ethers
PBT	Persistent, bio-accumulative and toxic
PCR	Post-consumer recycled
PE	Polyethylene
PP	Polypropylene
PEF	Product Environmental Footprint
PET	Polyethylene terephthalate
PO	Polyolefins
POP	Persistent Organic Pollutants
PVC	Polyvinyl chloride
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
RoHS	Restriction of hazardous substances
SHA	Small Household Appliances
SVHC	Substances of very high concern
vPvB	Very persistent and very bio-accumulative
WEEE	Waste Electrical and Electronic Equipment
WFD	Waste Framework Directive

Executive Summary

PolyCE intends to promote the use of recycled plastics from Waste Electric and Electronic Equipment (WEEE) in new Electric and Electronic Equipment (EEE) reducing the use of virgin plastics. During the whole project, practical trials were carried out to elaborate specific solutions for each step of the EEE/WEEE plastic value chain and to demonstrate the technical feasibility of using recycled plastics in new EEE.

The following report provides an overview of current product and waste-related policy framework that has a direct impact on the circularity of high-tech plastics from WEEE. Based on the evidence generated throughout the PolyCE project, the report makes recommendations with the overall aim to bring the value chain a step forward to a coherent and comprehensive legislative framework towards reusing and recycling technical plastics from WEEE.

1 Introduction

PolyCE intends to promote the use of recycled plastics in new electrical and electronic equipment (EEE). During the whole project, several investigations were carried out to elaborate specific solutions for each step of the EEE/WEEE plastic value chain and to demonstrate the technical feasibility of using recycled plastics in new electronic products.

The aim of this deliverable is to provide recommendations to support the development of a coherent and comprehensive legislative framework towards reusing and recycling technical plastics from WEEE and to ensure that evidence generated throughout the PolyCE project in WPs 3 to 8 is replicated in the European product and waste-related framework. In particular, PolyCE will provide direct feedback to the following legislations, green labelling and standardisation initiatives regarding their strengths and limitations to support innovative solutions for the production and uptake of secondary technical plastics in the context of the Circular Economy:

- Waste Framework Directive
- REACh-Regulation
- RoHS-Directives
- Stockholm Convention and POP-Directive
- WEEE-Directive
- Basel Convention and Regulations on shipments of waste
- Food Contact Legislation
- Ecodesign-Directive
- European Green Public Procurement (GPP)
- Ecolabels and voluntary agreements
- CEN/CENELEC Standards
- Additional EU Initiatives such as Green Labelling, Green Claims, Green Taxonomy, Product Environmental Footprint (PEF)

2 Actions of the EU to increase the uptake of PCR plastics in the circular economy

Increasing the uptake of recycled materials and creating the conditions for a more stable and foreseeable market has been an issue for years, but it has gain momentum with the release of the EC' Circular Economy action plans.

2.1 The first Circular Economy Action Plan and the European Strategy for Plastics in a Circular Economy

The European Commission published the European Strategy for Plastics in a Circular Economy in 2018 as part of the first Circular Economy Action Plan of December 2015. The EU Strategy for Plastics aimed to focus on the design and production of plastic products to enhance reuse, repair and recycling and the development and promotion of sustainable materials. Thereby it should help to reduce plastic pollution and prevent the negative impacts on the environment and contribute to deliver greater added value and welfare in Europe and enhance innovation. The strategy also aims to make a concrete contribution to achieve the Sustainable Development Goals in 2030 and the targets set in the Paris Agreement as well as to help EU become a modern, low-carbon, resource and energy-efficient economy. (European Commission 2018)

The strategy contains the following topics:

- Improving the economics and quality of plastics recycling
  - Design for recyclability
  - Boosting demand for recycled plastics
  - Better and more harmonised separate collection and sorting
- Curbing plastic waste and littering
  - Preventing plastic waste in our environment
  - Establishing a clear regulatory framework for plastics with biodegradable properties
  - Addressing the rising problem of microplastics
- Driving innovation and investment towards circular solutions
- Harnessing global action

For this purpose, the European Commission launched the Circular Plastics Alliance (CPA) in December 2018 to support plastics value chains and boost the EU market for recycled plastics to ten million tonnes by 2025.

In the beginning of 2021, 266 companies and business organisations have submitted to the voluntary pledge (European Commission 2021b). The organisations represent the main plastic materials currently recycled in the EU and a wide range of actors along the related supply chains, namely polyolefins (POs), including polyethylene (PE) and polypropylene (PP); polyethylene terephthalate (PET); polyvinyl chloride (PVC); and expanded polystyrene (EPS). (European Commission 2018)

A recent evaluation of the voluntary pledges showed that by 2016 the demand for recycled plastics was at around 3.9 Million tonnes (Mt) per year, meaning that more than 6 Mt were missing to reach the 2025 target (European Commission 2019a). Figure 1 contains all plastics in all sectors. It can be observed that not only the supply and demand for recycled plastics

need to increase significantly, but also that much more plastics that is collected needs to go to recycling in first place.

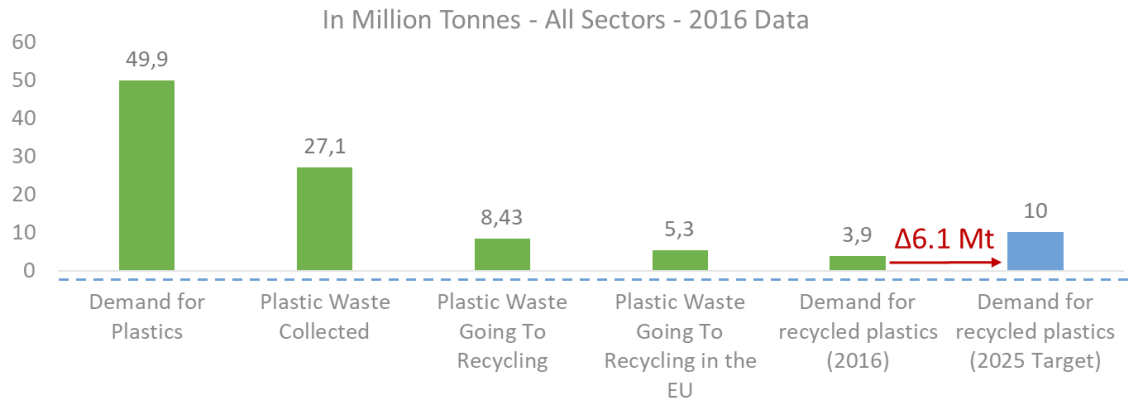

Figure 1: From plastics demand to recycled plastics demand in Europe, 2016, million tonnes (European Commission 2019a)

2.2 The European Green Deal and the second Circular Economy Action Plan

In December 2019, the European Green Deal was announced by the European Commission. It is Europe's new growth strategy and aims for no net emissions of greenhouse gases until 2050 and to decouple the economic growth from resource use (European Commission 2019d). One of the main blocks of the Green Deal is the second Circular Economy Action Plan (CEAP), which was published in March 2020 and provides a future-oriented agenda for achieving a cleaner and more competitive Europe. The Action Plan announces initiatives along the entire life cycle of products, targeting the design of products towards sustainability, promoting circularity in production processes, supporting sustainable consumption and aiming to ensure that the resources used are kept in the EU economy for as long as possible (European Commission 2020). The 2nd EU CEAP puts the emphasis on waste reduction measures and propose that one of the strategies to increase the uptake of recycled plastics and could go along a requirement for minimum recycled content in new products. The Circular Economy Action Plan consists 35 actions summarized in Figure 2:

Figure 2: Circular Economy Action Plan and its key actions (European Commission 2020)

Within the area of "key product value chains", one of the priorities of the second CEAP is to improve the environmental footprint of electrical and electronic equipment as well as Information and Communication Technologies (ICT). To address this sector, the European Commission will present a **'Circular Electronics Initiative'** aiming to extend the lifespan of electronics, prevent premature obsolescence and promote repair, recycling and efficient use of resources with focus on the following topics (Banti 2020; European Commission 2020):

- regulatory measures for electronics and ICT including **mobile phones, tablets and laptops** under the Ecodesign Directive;
- focus on electronics and ICT as a priority sector for implementing the **'right to repair'**, including a right to update obsolete software;
- regulatory measures on chargers for mobile phones and similar devices, including the
- introduction of a **common charger**;
- improving the collection and treatment of WEEE including by exploring options for an **EU-wide take back scheme to return or sell back old mobile phones, tablets and chargers**;
- review of EU rules on **restrictions of hazardous substances in Electrical and Electronic Equipment (EEE)** and provide guidance to improve coherence with relevant legislation, including REACH and Ecodesign.

The European Commission will furthermore present another initiative in late 2021 called the **"Sustainable Product Initiative"** aiming to revise the Ecodesign Directive. The Initiative will propose additional legislative measures as appropriate to make products placed on the EU market more sustainable. Key topics of the Initiative are the following (Banti 2020):

- **extending product lifetime** (durability, reparability, upgradability, counter premature obsolescence, addressing the presence pf hazardous chemicals in products);
- **improving overall 'circularity'** (remanufacturing, recyclability, recycled content, restrict single use);
- **reducing emissions, pollution and waste** (chemicals, carbon/environmental footprint, efficiency, etc);
- **more circular 'handling'** (destruction unsold goods, product-as-a-service, reward sustainable performance).

Current political initiatives are very much in line with such a strategy that supports the integration of recycled plastics in new electrical and electronic appliances. The following Figure 3 summarizes the relationship between the Green Deal, the second CEAP and above-mentioned initiatives.

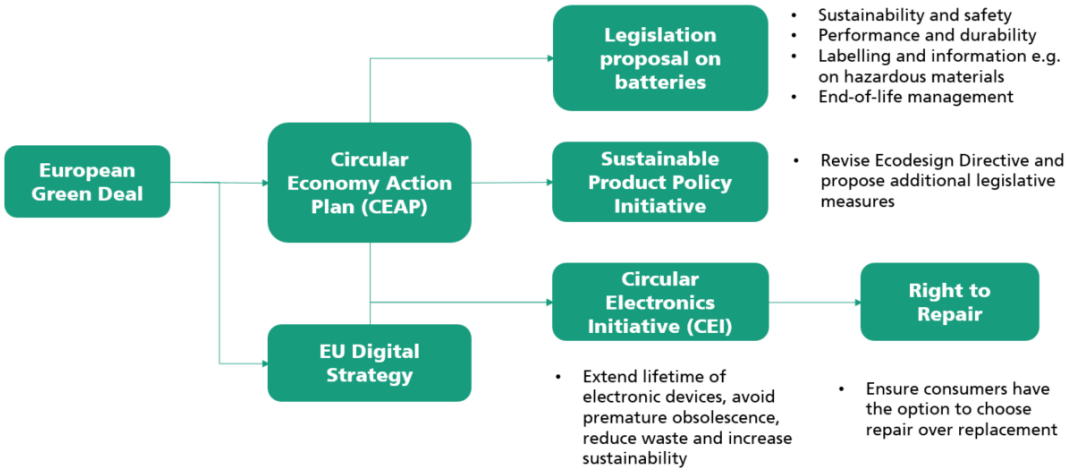

Figure 3: Relationship between the Green Deal, the second CEAP and the initiatives

3 Background of European waste- and product-related framework

3.1 Waste Framework Directive

The Waste Framework Directive (WFD) provides the general hierarchy of waste management and sets the basic waste management definitions.
According to Article 6 (1) and (2) of the WFD, certain specified waste shall cease to be waste when it has undergone a recovery operation and complies with specific criteria to be developed in line with certain legal conditions (European Commission 2008b). Using a comitology procedure, the EC will develop such criteria for specific materials. Waste streams may be subject to exclusion from the waste regime, if the following general End-of-Waste (EoW) criteria apply (European Commission 2008b):

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

IDENTIFIED GAPS REGARDING WEEE PLASTICS CIRCULARITY	
Definition of specific EoW criteria for plastics are necessary	The Waste Framework Directive identifies specific End-of-Waste (EoW) criteria for some materials (e.g. iron, steel and aluminium scrap, glass cullet, copper scrap), but there are no harmonized EoW-criteria applicable for plastics. A technical report led by the Joint Research Centre (JRC) of the European Commission studied the EoW-criteria of plastics in particular (Villanueva und Eder 2014). Among others, the development of EoW-criteria for post-consumer plastics strives to improve the market for recycled plastic in the European Union (EU), to ensure a "recognisable distinction of a quality-assured product to non-quality checked waste plastic" as well as "certainty only high-quality waste plastic destined to recycling will cease to be waste" (Villanueva und Eder 2014). The discussion around the EoW for plastics were not conclusive and consequently, the criteria were never formally adopted at EU level.

3.2 REACH-Regulation

The regulation 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorization and Restriction of Chemicals entered into force on 1st May 2007 and established a European Chemicals Agency (European Commission 2006; Jepsen et al. 2011). The regulation aims to ensure a high level of protection of human health and the environment as well as to ensure the free movement of substances, mixtures or articles, while improving competitiveness and innovation. The development of alternative assessment methods for substance-borne hazards should also be encouraged (article 1, paragraph 1). The principle of the Regulation is that manufacturers, importers and downstream users must ensure that they manufacture, place on the market and use substances that do not adversely affect human health or the environment (article 1, paragraph 3). (European Commission 2006)

REACH provides criteria to identify "substances of very high concern" (SVHC). SVHC are defined as (European Commission 2006):

- Substances meeting the criteria for classification as carcinogenic, mutagenic, or toxic for reproduction (CMR) category 1A or 1B in accordance with the Classification, Labelling and Packaging (CLP) Regulation.
- Substances which are persistent, bio-accumulative and toxic (PBT), or very persistent and very bio-accumulative (vPvB) according to REACH Annex XIII.
- Substances on a case-by-case basis, which cause an equivalent level of concern as CMR or PBT/vPvB substances.

If a substance is identified as a SVHC, it is included in the Candidate List. The European Chemicals Agency (ECHA) regularly assesses the substances on the Candidate List to determine if they should be moved to the Authorisation List (Annex XIV). Once a substance is on an Authorisation List, it can only be used or produced with a specific authorisation and under specified circumstances for defined applications. The Restrictions List (Annex XVII) is also regularly revised. The use of a substance on the Restrictions List is prohibited.

In 2013, the Commission published the first review of REACH. A second review report was performed in 2018 (European Commission 2018b). The Commission works closely with the European Chemicals Agency (ECHA) and national authorities in the implementation of the regulation.

Under certain conditions, REACH offers recyclers an exemption from the obligation to register substances from recycling processes. This recycling privilege follows from Article 2 (7d) that substances registered as such in accordance with Title II, in mixtures or in articles[1] recovered in the community, if (European Commission 2006):

(i) the substance resulting from the recovery process is identical to the substance registered under Title II, and

(ii) the recovery performing companies have the information required under articles 31 or 32 on the substance registered under Title II.(European Parliament 2006)

[1] Article 3(3) of REACH defines "article" as "an object which during production is given a special shape, surface or design which determines its function to a greater degree than does its chemical composition". Based on this definition, if you can unambiguously conclude that the shape, surface or design of an object is more relevant for the function than its chemical composition, the object is an article.

IDENTIFIED GAPS REGARDING WEEE PLASTICS CIRCULARITY	
WEEE plastics under REACH Regulation	For the purposes of REACH, recyclers are manufacturers, as they either manufacture a chemical substance, a mixture or a product containing chemicals. Therefore, they have the same rules as all other substance manufacturers (Jepsen et al. 2011). Recital 11 of the regulation states that waste is not considered to be a substance, mixture or article in order to create incentives for recovery and recycling (European Commission). The scope of REACH is mainly related to the manufacturing and use of the substance. In REACH terms, the life cycle of a substance ends when the substance enters the waste stage. At that point, the regulatory context for the substance is defined by the Waste Framework Directive (Directive 2009/98/EC and amended in 2018 by Directive 2018/851/EC). However, after a recycling or a recovery process, a new substance life cycle can start. This split of both legislations should avoid overlap of regulations and by this avoid any inconsistencies between both regulations (Tandt et al. 2021). It is important for plastic recyclers to determine exactly when and when not to treat waste and to clarify whether handled "raw materials" are waste within the meaning of the Waste Framework Directive or possibly unchanged substances, mixtures or articles within the meaning of REACH (Jepsen et al. 2011).

3.3 RoHS-Directive

The EU legislation restricting the use of hazardous substances in electrical and electronic equipment (RoHS Directive 2002/95/EC) entered into force in February 2003. While REACH is not limited to a specific product group, RoHS explicitly targets electrical and electronic equipment. It bans products from the European market that contain more than the permitted levels of certain substances listed in Annex II of the Directive. The legislation requires heavy metals such as lead, mercury, cadmium, and hexavalent chromium and flame-retardants such as polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE) to be substituted by safer alternatives. In 2008, the Commission proposed to revise the Directive and the RoHS recast Directive 2011/65/EU became effective on 3 January 2013. The third revision of the EU Directive of the European Parliament 2015/863 comes into force on July 22, 2019. This RoHS-3 Directive extends the definition of certain hazardous substances. According to Annex II of the RoHS-3 Directive, the following substance and permissible maximum concentration values apply to homogeneous materials (European Commission 2011b):

- Lead (Pb): 0.1 %
- Mercury: 0.1 %
- Cadmium (Cd): 0.01 %
- Hexavalent chromium: 0.1 %

- Polybrominated biphenyls (PBB): 0.1 %
- Polybrominated diphenyl ethers (PBDE): 0.1 %
- Bis(2-Ethylhexyl) phthalate (DEHP): max 0.1% (Additional substance of EU 2015/863)
- Benzyl butyl phthalate (BBP): max 0.1% (Additional substance of EU 2015/863)
- Dibutyl phthalate (DBP): max 0.1% (Additional substance of EU 2015/863)
- Diisobutyl phthalate (DIBP): max 0.1% (Additional substance of EU 2015/863)

Recycled plastics are considered secondary raw materials and should align with virgin materials requirements, consequently PCR plastics must comply with the maximum concentration values of the RoHS-Directive.

3.4 Stockholm Convention and POP-Directive

The Stockholm Convention on Persistent Organic Pollutants was adopted in 2001 and entered into force in 2004. Currently, it regulates 28 substances that are persistent, bioaccumulative, toxic, and travel long distances. The Convention currently has 182 parties, among others the EU and all its Member States. The Stockholm Convention, together with the Aarhus Protocol are implemented in the EU by the POPs Regulation 2019/1021(EU) and have the same objective to control, reduce or eliminate POPs emission into the environment. The regulation (EC) No. 850/2004 of the European Parliament and of the Council of 29 April 2004 on persistent organic pollutants (POP) and amending Directive 79/117/EEC aims to protect environment and human health from persistent organic pollutants.

Since 2009 several flame retardants have been added to Annex I of the POP-regulation, which may only be used in products with a maximum weight percentage. The latest revision of the POP-Directive entered into force on July 15, 2019. This recast includes the update of the substances listed on Annex I – Part A. Annex I of the Directive defines a **unintentional trace contaminant** (UTC), which means a level of a substance that is incidentally present in a minimum amount, below which the substance cannot be meaningfully used, and above the detection limit of existing detection methods to enable control and enforcement (European Commission 2019c) Annex IV of the Directive defines a "**low POP content**" (LPC) for wastes which requires that POPs wastes be destroyed or irreversibly transformed if substances contain POPs concentration greater this LPC (European Commission 2019c). This value applies to all products that are put on the market, including recycled plastics. The thresholds for all PBDEs are the following:

- UTC threshold for substances (new product): 10 ppm
- UTC threshold for mixtures or articles (recycled products): 500 ppm
- LPC threshold for wastes: 1000 ppm

These different thresholds of UTC and LPC means that different limit values apply to POPs in products. It follows from the different values that WEEE plastics my currently be recycled if they contain up to 1000 ppm and the finally produced plastic granulates must contain less than 500 ppm of the sum of PBDEs. The UTC and LPC thresholds for PBDEs is to be reviewed by the European Commission by July 2021 (European Commission 2019c).

IDENTIFIED GAPS REGARDING WEEE PLASTICS CIRCULARITY	
Alternative flame retardants and their impact on the recycling efficiency of WEEE plastics	Plastic recyclers from WEEE cannot distinguish between different types of flame retardants. A study of SOFIES on the impact of brominated flame retardants on the recycling of WEEE plastics in Europe found out that 98 % of BFR plastics entering the official WEEE recycling are properly disposed of by the plastic recycling facilities. (Haarman et al. 2020) 55 % of all BFR plastics generated are not entering official WEEE recycling channels due to improper sorting of WEEE by consumers or substandard WEEE treatment practices (Haarman et al. 2020). Today's recycling facilities can effectively recycle on average some 50 % of their plastics input material (Slijkhuis 2021). This recycling yield would not be affected by a switch to alternative flame retardants. Furthermore some alternatives could even worsen the recycling yields due to their complexity and presence of various additives (Slijkhuis 2021; Haarman et al. 2020).
Thresholds for DECA-BDE and the group of PBDEs	The technical method how to measure the content of Brominated Flame Retardants is based upon the analysis standard IEC EN 62321–3–1. This standard is validated for 1000 ppm of Bromine as element and there is no other viable test method available to date. As long as this test method is not available for any validated lower values, the WEEE plastics community has called for keeping the maximum low POP content at 1000 ppm for Deca-BDE or for the group of PBDEs. And this has finally been decided in the latest recast of the EU POP Regulation. The consequence of this decision is not that suddenly WEEE plastics above the Low-POP-threshold become classified as hazardous waste. Merely it implies that such wastes need to be monitored to make sure that these are treated in facilities that separate the plastics with the POP BFRs and that these separated plastics are discarded properly (i.e. incinerated for destruction of the POP substances) and this has been the case ever since some BFRs substances have been restricted, which is well over 15 years.

3.5 WEEE-Directive

The WEEE Directive 2012/19/EU has the goal to ensure that waste electrical and electronic equipment is properly treated within the EU. Its purpose is to contribute to sustainable production and consumption by the prevention of WEEE and by the re-use, recycling, and other forms of recovery of the waste stream. The first WEEE Directive (Directive 2002/96/EC) contained the creation of collection schemes where consumers return their old devices free of charge. These schemes aim to increase re-use and recycling of WEEE. In 2008, the EC proposed to revise the Directive. The new WEEE Directive 2012/19/EU entered into force in 2012 and became effective in 2014.

The WEEE Directive implements the principle of extended producer responsibility (EPR), under which producers are expected to take responsibility for the environmental impact of their products, especially when they become waste. It obliges producers of EEE to finance the end-of-life activities. Distributors have responsibilities in terms of the provision of facilities to enable the free take-back of WEEE by consumers and the provision of certain information.

The current scope of the Directive covers the following categories that are defined in Annex III (European Commission 2012):

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) including, but not limited to: Household appliances; IT and telecommunication equipment; consumer equipment; luminaires; equipment reproducing sound or images, musical equipment; electrical and electronic tools; toys, leisure, and sports equipment; medical devices; monitoring and control instruments; automatic dispensers; equipment for the generation of electric currents. This category does not include equipment included in categories 1 to 3.
5. Small equipment (no external dimension more than 50 cm) including, but not limited to: Household appliances; consumer equipment; luminaires; equipment reproducing sound or images, musical equipment; electrical and electronic tools; toys, leisure and sports equipment; medical devices; monitoring and control instruments; automatic dispensers; equipment for the generation of electric currents. This category does not include equipment included in categories 1 to 3 and 6.
6. Small IT and telecommunication equipment (no external dimension more than 50 cm).

The WEEE Directive also sets minimum recovery targets, which are the following (Annex V):

- For WEEE falling within category 1 or 4 of Annex III,
  - 85 % shall be recovered, and
  - 80 % shall be prepared for re-use and recycling.
- For WEEE falling within category 2 of Annex III
  - 80 % shall be recovered, and
  - 70 % shall be prepared for re-use and recycling.
- For WEEE falling within category 5 or 6 of Annex III
  - 75 % shall be recovered, and
  - 55 % shall be prepared for re-use and recycling.
- For WEEE falling within category 3 of Annex III, 80 % shall be recycled.

IDENTIFIED GAPS REGARDING WEEE PLASTICS CIRCULARITY: Availability of improvement options for increased recycling of WEEE plastics	
Setting material specific recovery targets	Several studies estimated that metals and plastics in WEEE account respectively for roughly 60 % by weight and 15 % by weight of the total product material content (Boudewijn et al. 2019). The WEEE-Directive sets strict recycling and recovery targets for the 6 WEEE categories but does not define specific material-based recycling targets. To improve plastic recycling and recovery, a minimum plastics recycling rate from WEEE should be considered (Boudewijn et al. 2019). The definition of the recycling rate needs to take into account the average plastics content used in the specific product group.
Adopting finer clustering strategies within WEEE categories	The metal and plastics fraction from WEEE can cause a challenge for Material Recovery Facilities (MRF) due to the complexity of EEE products' such as EEE design or material content. The WEEE-Directive is divided into six categories for the collection of WEEE. Since the input materials of the WEEE stream are diverse and complex even within each of these six categories, it is suggested to subdivide them into further "clusters" (see chapter 5.3). Clustering strategies based on polymer type dominant in certain EEE, (see clustering parameters in D3.2) can limit the degree of contamination in the streams coming out of shredders and reduce the mixing of difficult to separate and incompatible materials (Boudewijn et al. 2019).

3.6 Basel Convention on shipment of waste

The most relevant UN conventions related to plastics from WEEE are the Basel Convention on the control of transboundary movements of hazardous wastes and their disposal, the Rotterdam Convention on the prior informed consent procedure for certain hazardous chemicals and pesticides in international trade and the Stockholm Convention on persistent organic pollutants (POP). In 2012, the Secretariats of the Basel and Stockholm conventions and the UNEP-part of the Rotterdam Convention Secretariat moved from three individuals to a single secretariat serving the three conventions.

3.6.1 Basel Convention

The Basel Convention on the control of transboundary movements of hazardous wastes and their disposal was adopted in 1989 and entered into force in 1992. It regulates exports and imports of hazardous waste and addresses especially marine litter. It currently has 187 parties, among others the EU and all its Member States. In order to improve the transparency and regulation of the global trade in plastic waste the Basel Convention implemented a plastic waste framework which is effective since 1st January 2021. The main aims of the Basel Convention regarding plastic waste are the minimization and prevention of plastic waste and also the risk reduction from hazardous plastic materials.

In all EU Member States transboundary shipments of waste are regulated by EC Regulation No 1013/2006 on shipments of waste. This regulation is based on the Basel Convention and the decision of the OECD-Council (2001)107 on the control of transboundary movements of wastes destined for recovery operations. The EC regulation transposes the procedural rules of both regulations into directly applicable European legislation.
During the 14th meeting of the COP to the Basel Convention in 2019, one of the main decision was to include most plastic wastes into Annexes II and VIII of the Basel Convention. Consequently, transboundary movements of these plastic wastes (either hazardous or difficult to recycle) will be subject to the control mechanisms of the Convention. These amendments to the Annexes will enter into force in 2021 (Council of the European Union 2019).

The Plastic Waste Amendment for example allows exporting hazardous or difficult to recycle plastic waste only if the importing country has the option to recycle the concerned plastic in environmentally sound manner. The application for this export needs to follow a given procedure, where the importing country has to grant a Prior Informed Consent (PIC) before the exporting country can allow the shipment. Plastics which are defined as non-hazardous, clean and sorted can be treated without following the PIC procedure, if they are destined for recycling in an environmentally sound manner. (UNEP 2020)

3.6.2 Rotterdam Convention

The Rotterdam Convention on the prior informed consent procedure for certain hazardous chemicals and pesticides in international trade was adopted in 1998 and entered into force in 2004. The Convention has the main objective to strengthen the protection of human health and the environment through informed decision-making on the import of certain chemicals (Annex III of the Convention) and by exchanging safety information. It does not ban or restrict trade in chemicals or pesticide formulations. The Convention currently has 161 parties, among others the EU and all its Member States.

In the EU, the Prior Informed Consent Regulation (PIC Regulation (EU) 649/2012) implements the Rotterdam Convention. It administers the import and export of specified hazardous chemicals and puts obligations on enterprises that want to export these chemicals to non-EU

IDENTIFIED GAPS REGARDING WEEE PLASTICS CIRCULARITY	
Complexity of shipment procedures of mixed plastics from WEEE	Due to the plastics delegated act implemented on 1st January 2021 all mixed WEEE plastic need notifications. This notification request for shipments across EU borders takes on average 3 months which leads to the issue that plastic waste shipments have become unplannable for plastic recyclers. In case of delivering to companies producing EEE products, the PCR plastics need to have a plannable production by plastic recyclers, what is prevented by these notifications. (Slijkhuis 2021) For the WEEE plastics recycling industry this could to lead to huge files of 100 pages to get one notification done, many authorities still need original signatures, files have to send by post to all authorities in the different countries involved and there are no harmonized rules and procedures which means every country has different rules and its own interpretation of the rules which is linked to major costs.(Slijkhuis 2021)

3.7 Food contact legislation

Regulation (EC) No 1935/2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC provides a regulatory framework for food contact material (FCM) and set out general principles of safety and inertness for FCMs. The Regulation shall apply material and articles which are already in contact, intended to be brought in contact or can reasonably be expected to be brought into contact with food. The main purpose of the regulation is mentioned in Article 1 (1) (European Commission 2004):

> *"The purpose of this Regulation is to ensure the effective functioning of the internal market in relation to the placing on the market in the Community of materials and articles intended to come into contact directly or indirectly with food, whilst providing the basis for securing a high level of protection of human health and the interests of consumers."*

In addition to that, there is also the Commission Regulation (EC) No 2023/2006 on good manufacturing practice for materials and articles intended to come into contact with food to ensure that the production process is well controlled.

EU legislation on specific materials: Plastic Materials

Regulation (EC) No 10/2011 on plastic materials and articles intended to come in contact with food set out the rules on the composition of plastic FCM. A so-called "Union list" of monomers or other starting substances as well as authorised additives was set up to permit or in reverse conclusion restrict certain materials for the final FCM product. For the substances on the Union list, a risk assessment was performed by the European Food Safety Authority (EFSA) to cover the potential migration under worst foreseeable conditions of use and the toxicity (EFSA 2008). Based on the results of the risk assessment and to ensure the safety of the final material or article, the EFSA set out quantitative restrictions or migration limits, restrictions of use or specifications for the substance. The Regulation provides an Overall Migration Limit (OML) of 60 mg/kg food, or 10 mg/dm^2 of the contact material to ensure the overall quality of the plastic. (European Commission 2011a)

EU legislation on specific materials: Recycled Plastic Materials

Regulation (EC) No 282/2008 on recycled plastic materials and articles intended to come into contact with foods sets out criteria for the composition of new plastic materials. This Regulation is applied when FCM plastics have reached their end of life and have been contaminated with other substances and therefore are no longer subject to the Regulation on plastic materials. (European Commission 2008a)
Recycled plastic materials and articles intended to put on the market have to undergo an authorised recycling process based on an individual case-by-case evaluation by EFSA and in accordance with the Regulation. Each recycling process has to undergo an authorisation process similar to the one under the FCM regulation and must be described by a detailed dossier, which must include a flow chart of key processing steps. Special attention is paid to quality control of input material and the final recycled product, as well as intended final use. The dossier should comprise a special section devoted to decontamination efficiency of the recycling process, especially for materials not originating from product loops, in order to demonstrate the effective reduction of contamination concentrations. Challenge tests are set up to prove the recycling process ability to reduce input contaminations by deliberately contaminating input materials and testing for surrogate substances in the final product proving that no risk for human health is given. (Tandt et al. 2021)

IDENTIFIED GAPS REGARDING WEEE PLASTICS CIRCULARITY	
Beyond PET recycling – food-contact recycled plastics from WEEE?	In the Regulations on FCM there is no strict definition of what a FCM is. The Member State authorities have to define them by themselves. Annex I of Regulation (EC) No 1935/2004 lists some groups of materials and articles which could be used as FCM, but there should be a harmonized definition of what a FCM is. (Tandt et al. 2021) When it comes to plastic recycling, a recycler must take into account the possible use of his recycled waste material, as the regulation affects the entire life cycle of a material or article that comes into contact with food. If the intention of a manufacturer is to produce FCMs, the recycler must comply with certain rules for traceability and the declaration of conformity in accordance with the FCM framework. (Tandt et al. 2021) Achieving the same target properties can be very challenging with recycled plastics, since the collected material can suffer from limitations with respect to mechanical properties, colour, or purity. These limitations can reduce the area of applications for recycled plastics. As it cannot be categorically ruled out for certain waste streams that they contain impurities (incl. substances of concern), they cannot be used in products with food contact, toys, or medical devices. As an example, food contact regulation is currently an important barrier to the increased use of recycled content (except for bottle PET). The main concern of EFSA is an adverse impact on human health or the environment due to the presence of non-intentionally added substances in recycled plastics intended for food contact use. Therefore, it is necessary that the recycled plastics undergo an authorised recycling process to ensure traceability and decontamination efficiency of the process and an evaluation of the quality of the input material. When trying to comply with the requirements of the authorised recycling process, recyclers face several challenges related to traceability and the lack of communication and transparency of the whole plastics value chain due to potential misuse of FCMs or articles and technical challenges such as separating FCM from non-FCM waste. (Tandt et al. 2021)

3.8 Ecodesign-Directive

The Ecodesign Directive (EDD, 2009/125/EC) is a product-oriented policy tool setting mandatory requirements for energy-related products sold in all EU Member States. It has the objective to improve the environmental characteristics of energy-related-products through implementing generic and specific Ecodesign requirements. Initially the scope of the established framework within the previous Ecodesign Directive (EDD, 2005/32/EC) was solely set on energy-using-products (EuP) but was been extended in the last amendment to so called energy-related-products (ErP). The ecodesign requirements for individual product groups are created in a process coordinated by the EC.

Such requirements are open to change over the course of time and with proceeding advances in the technologies and will subsequently be revised and readjusted. Albeit these requirements are legally binding, the possibility of self-regulatory initiatives (SRI) by producers can present an alternative. Nonetheless, these SRIs must still fulfil certain criteria to be accepted as such and are defined in Annex IV. Such criteria include among others verifiable goals and mid goals, representative relevance for the affected branch, monitoring system working efficiently with independent auditors and many more. The usual procedure, if SRIs are not the case, follows certain steps towards the obligatory minimum requirement regulations. These include in set order the assort of background data, setting up a draft by the EC with several revisions if necessary, a draft implementation through voting and lastly a scrutiny by the European Parliament is performed to finally publish the mandatory requirements. A manufacturer or producer must provide information on requirement compliance through a declaration of conformity, where it must be demonstrated the product specifications lie within the amendment limits.

In the past, the main focus of the Ecodesign Directive was on energy efficiency improvements of energy-related products. However, material efficiency criteria have gained in importance in recent years. In the near future, the legislative proposal for a sustainable product initiative (SPI) will suggest revising the Ecodesign Directive to extend its scope beyond energy-related products and make it deliver on circularity. According to the Ecodesign Directive, implementable and enforceable requirements at the product design phase may be appropriate for optimising resource and material efficiency at end of life. The EC agreed to take into account aspects relevant to the circular economy when setting out or revising ecodesign criteria.

Two key publications were developed to investigate the integration of material efficiency criteria in the Ecodesign Directive. These studies are developed by Ardente & Mathieux (2012), analysed methods for assessing circular economy aspects under the Ecodesign Directive and by the Bio Intelligence Service (2013), which looked at strengthening material efficiency in MEErP (Methodology for the Ecodesign of Energy-related Products) and the EcoReport Tool (Mugdal et al. 2013a; Zygierewicz 2017). The MEErP methodology was developed to allow evaluating whether and to which extent various energy-related products fulfil certain criteria according to Article 15 and Annex I and/or II of the Ecodesign Directive that make them eligible for implementing measures (Kemna et al. 2011). The EcoReport Tool is a life cycle assessment tool and facilitates the environmental impact analysis of energy-related products (Kemna et al. 2011).

IDENTIFIED GAPS REGARDING WEEE PLASTICS CIRCULARITY	
Enhancing the way Ecodesign delivers on circularity	From 1 March 2021, material efficiency requirements are set for electronic displays. In the near future, more applications should be added to Ecodesign Directive for optimising resource and material efficiency at end of life. However, the integration of material efficiency requirements in the Ecodesign Directive must be identified in the preparatory study as having substantial improvement potential. When it comes to recycled content and the requirement to define a minimum recycled content of a product, preparatory studies on product level need to be carried out. Also, such a requirement has to be phase in gradually. As a first step, an information provision for recycled content should be introduced.

3.9 European Green Public Procurement (GPP)

At European level, GPP is defined in the public procurement for a better environment as "*a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life-cycle when compared to goods, services and works with the same primary function that would otherwise be procured*". It serves as an important tool to achieve environmental goals related to climate change, resource use and sustainability in production and consumption, in particular given the importance of public sector spending on goods and services. (European Commission 2016a)
At the present moment, the EC has developed GPP criteria for 20 product groups in order to help contracting authorities identify and procure more environmentally friendly products, services and works (European Commission 2016a). With its purchasing power, public procurement can play significant role for the diffusion of environmental aspects, such as Design for Recycling and use of post-consumer recycled plastics (Dimitrova 2017).
For GPP of products, ecolabels can be used as selection criteria to help a purchaser to define the technical requirements of their targeted purchase and/ or to check the compliance with the requirements of the EU Procurement Directive 2014/24/EU (European Commission 2017, 2014). For this the ecolabel schemes described in sections 2.7.2 to 2.7.6 can be used.

The GPP consists of two main approaches to ensure justifiable, verifiable and clear environmental criteria for products and services which shall base on scientific evidence and life-cycle assessments. These are **core and comprehensive criteria.** Core criteria address key environmental impacts of a product or service, such as energy consumption and lifetime of a product and are designed to be used with minimum additional verification effort or cost increases. The comprehensive criteria highlight products on the market, which ensure higher environmental performance. (European Commission 2016a)
These criteria address the following aspects:

- Energy management functions on the hardware itself
- Noise emissions
- The use of mercury in LCD monitor backlighting
- The disassembly of equipment
- **Recycled content and recyclability**
- **The use of flame retardants with certain risk-phrases** (carcinogenic, mutagenic or harmful to reproduction) in plastic parts

According to the agreed voluntary target for GPP, the Commission proposed that by 2010 all public tendering procedures should have been "green" to 50 %, where "green" refers to the defined GPP core criteria (European Commission 2017). There is not yet a robust monitoring in place to precisely assess the percentage of green procurement, but there is no evidence such an indicative target is being met today.

3.10 Ecolabels and voluntary agreements

The International Organization for Standardization (ISO) developed standards for environmental labelling for three different type of voluntary environmental labels (ISO 14021, 14024, 14025): type I, II and III (GEN 2004). The general definitions of these different types are explained in table 1:

Table 1: Definitions of three types of Environmental Performance Labelling according to ISO (GEN 2004)

Type I *Environmental labelling (i.e. ecolabels)*	A voluntary, multiple-criteria based, third party program that awards a license which authorises the use of environmental labels on products indicating overall environmental preferability of a product within a product category based on life cycle considerations
Type II *Self-declaration claims*	informative environmental self-declaration claims
Type III *Environmental declarations (e.g. report cards/information labels)*	Voluntary programs that provide quantified environment data of a product, under pre-set categories of parameter set by a qualified third party and based on life cycle assessment, and verified by that or another qualified thir party

Ecolabels are implemented to identify overall environmental performance of a product based on life cycle considerations within a special product category. It differs from self-styled environmental symbols developed by single manufacturers because the ecolabel is awarded to products based on established environmental leadership criteria by an impartial third party. Eco-labelling is to provide the information about the recognised environmental quality of a product to the consumer. The objectives of Eco-labelling are protecting the environment, encouraging environmentally sound innovation and leadership as well as building consumer awareness of environmental issues. (GEN 2004).

Voluntary Agreements are a form of self-regulation by industry. They exist in different sectors. For EEE, they exist as an alternative to potential eco-design regulations, where industry sectors prefer to develop self-regulations measures in form of voluntary agreements (VA). These VAs are assessed and monitored by the European Commission because they need to fulfil specific criteria of the Ecodesign Directive. (European Commission 2019e).

3.10.1 EU Ecolabel (Eco flower)

The EU Ecolabel was established in the year 1992 and awards a wide range of product groups with the best environmental performance on the market, measured throughout their entire lifecycle (European Commission 2019b). In order to be awarded with an Ecolabel, the product shall comply with the multi criteria defined for each product group (Mugdal et al. 2013b).

For personal and notebook computers as well as for televisions and electronic displays criteria include amongst others the following aspects:

- Energy savings
- Power management
- Mercury in fluorescent lamps
- Hazardous substances and mixtures
- Substances listed in accordance with Article 59(1) of Regulation (EC) No 1907/2006 of the European Parliament and of the Council
- **Plastic parts**
- **Recycled content**
- Reparability
- Design for disassembly
- Lifetime extension

The total plastic content of the product, with the exception of printed circuit boards and visible optical plastic parts, is expected to be on average at least 10 % by weight of post-consumer recycled plastics. If the proportion of recycled material is more than 25 % by weight, a note can be included in the text field for the eco-label. (European Commission 2016b)

3.10.2 EPEAT

The Electronic Product Environmental Assessment Tool (EPEAT) is the leading Type I global ecolabel for the IT sector, currently registering products in more than 42 countries. It is managed by the Green Electronics Council (GEC), a non-profit organisation. The EPEAT program offers independent verification of manufacturers' claims. Furthermore, the EPEAT online registry provides an overview over all labelled products in the following categories:

- Computers & displays
- Imaging equipment
- Mobile phones
- Photovoltaic modules and inverters
- Servers
- TVs

Governments as well as other private and public institutional purchasers use EPEAT as part of their green public procurement (GPP) decisions. EPEAT assesses different lifecycle environmental aspects of devices and ranks them as Gold, Silver, or Bronze, based on a set of performance criteria. Criteria are based on standards (e.g. IEEE, UL, etc.) and address e.g. the elimination of toxic substances, use of recycled and recyclable materials, product longevity, and energy efficiency as well as corporate social performance.

Products that are rated bronze meet all required criteria in each EPEAT product category. Those devices that are silver-rated meet all required criteria and at least 50% of the optional criteria. The highest class are gold-rated products where all the required criteria and at least 75% of the optional criteria are met.

According to the EPEAT labelling scheme, televisions, imaging equipment, and computer and displays have to meet numerous mandatory and optional requirements that are defined in different IEEE standards (IEEE 1680.3-2017; IEEE 1680.2-2017; IEEE 1680.1-2018). For

televisions and imaging equipment the use of post-consumer recycled plastics is optional. For computers and displays, it is mandatory. The following table 2 provides an overview of the EPEAT criteria for recycled plastics for the three device categories televisions, imaging devices (printers, copiers, multifunctional devices, etc.), and computers and displays.

Table 2: EPEAT criteria for PCR plastic content for televisions, imaging equipment and computers & displays

	Television	Imaging Equipment	Computer and Displays
Standard	**IEEE 1680.3**	**IEEE 1680.2**	**IEEE 1680.1**
Required	4.2.1.1 Declaration of the content of post-consumer plastic (including fillers / additives contained), based on the total plastic content of the product (with the exception of circuit boards, cables, connectors, etc.)	4.2.1.1 Declaration of the content of post-consumer plastic (including fillers / additives contained), based on the total plastic content of the product (with the exception of circuit boards, cables, connectors, etc.) 4.2.1.2 Products containing plastic parts with a combined weight >100g shall contain at least 5g of post-consumer recycled plastics. Circuit boards, labels, cables, connectors, etc. can be excluded from the combined weight.	4.2.1.1 At least 2% post-consumer plastic and / or post-consumer plastic content from IT devices and / or bio-based plastic, based on the total plastic content of the product (with the exception of circuit boards, cables, connectors, etc.)
Optional	4.2.1.2 Products with 5kg or less shall contain 10% of post-consumer recycled plastics. Products with a weight >5 kg shall contain on average a minimum of 5% of post-consumer recycled plastics. *(1 point)*	4.2.1.3 Products with 5kg or less shall contain 10% of post-consumer recycled plastics. Products with a weight >5 kg shall contain on average a minimum of 5% of post-consumer recycled plastics. *(1 point)*	4.2.1.2 Higher levels of post-consumer plastic and / or post-consumer plastic made from IT equipment and / or bio-based plastic, graded according to product groups *(1-2 points, see table below)*
	4.2.1.3 At least 25% post-consumer recycled plastic based on the plastic content. *(1 point)*	4.2.1.4 At least 25% post-consumer recycled plastic based on the plastic content. *(1 point)*	4.2.1.3 Two methods are available. Either the external enclosure of the product shall contain a minimum of 10% IT equipment derived post-consumer recycled plastics or the product shall contain a minimum of 10% IT equipment derived post-consumer recycled plastics. *(1 point)*

Below table 3 further specifies possible optional points as a function of the minimum share of post-consumer recycled plastics for different product types.

Table 3: EPEAT criteria for computer and displays - optional points for minimum percent PCR plastics content by product type

Product type	Minimum % content for 1 optional point	Minimum % content for 2 optional points
Desktop computers, workstations, thin clients, portable all-in-one computers, small servers	10	35
Integrated desktop computers	15	40
Notebooks	5	10
Tablets	3	5
Monitors	15	50

Besides promoting the use of recycled plastics, EPEAT also sets end-of-life criteria with respect to plastics recyclability. The following table 4 summarises the criteria for televisions, imaging equipment and computers, and displays.

Table 4: EPEAT criteria related to design for plastics recycling

	Television	Imaging Equipment	Computer and Displays
Standard	**IEEE 1680.3**	**IEEE 1680.2**	**IEEE 1680.1**
Required	4.3.2.2 Plastic markings. Plastic parts >25 g have to be marked with a material code in accordance with ISO 11469 considering ISO 1043. Exceptions apply. 4.3.2.5 Restriction on materials not compatible with reuse and recycling. Plastic parts >25 g shall not contain adhesives, coatings, paints, finishes, or pigments associated with surface coatings that are not compatible with reuse and recycling. PCBs, labels, cables, connectors, etc. are excluded from this requirement.	4.3.2.1. Use of single recyclable plastic type per plastic part. Each plastic part >100g shall consist of only one recyclable plastic type. PCBs, labels, cables, connectors, etc. are excluded from this requirement. 4.3.2.2 Restriction on materials not compatible with reuse and recycling. Plastic parts >100 g shall not contain adhesives, coatings, paints, finishes, or pigments associated with surface coatings that are not compatible with reuse and recycling. PCBs, labels, cables, connectors, etc. are excluded from this requirement. 4.3.2.3 Manual separation and marking of plastics. Plastic parts >100 g shall be manually separable into recyclable plastic streams with commonly available tools. Plastic parts >100 g shall be marked with a material code in accordance with ISO 11469/1043. Exceptions apply.	4.3.2.1 Plastic parts compatible with recycling. All discrete parts >25g have to be market according to ISO 11469/1043 and should not contain a metal insert or fasteners that is moulded in, heat or ultrasonically inserted, or glued in. Some exceptions apply. All discrete parts >100g should not have adhesives, coatings, paints, or finish that is not compatible with recycling. 4.3.2.2 Plastic parts separable for recycling. All discrete plastic parts >25 g have to be composed of a single resin, or a combination of resins (e.g., a blend), that are compatible for recycling, and be separable by hand or with commonly available tools from other plastic parts that are >25 g and not compatible together for recycling.

	4.3.2.1 One recyclable plastic type per rigid plastic part >25 g. Only one recyclable plastic type shall be used in each rigid plastic part >25 g. PCBs, labels, cables, connectors, etc. are excluded from this requirement.	NA	NA
Optional	4.3.2.3 Manual separation of plastics for recycling. All plastic parts >25 g have to be separable into individual or compatible recyclable plastic streams. For products <50 lb this should occur in at most 10 min. For products >50 lb in at most 10 min+1 min per each additional 5 lb. PCBs, labels, cables, connectors, etc. are excluded from this requirement. 4.3.2.4 Moulded/glued-in metal eliminated or removable. Plastic parts shall not contain metal inserts or fasteners that are moulded-in; heat or ultrasonically inserted or glued-in. Exceptions apply.	NA	NA

3.10.3 Blue Angel

Since 1978, the Blue Angel has been the ecolabel of the federal government of Germany, setting standards for environmentally friendly product design. The DE-UZ 30a for “Products made from Recycled Plastics” applies to finished products with a plastics content of over 90% by weight and a minimum PCR content of 80% by weight in these plastics (DE-UZ 30a-2019).

The document defining the basic award criteria provides some examples of finished products, such as office equipment, waste and recycling bins, plastic buckets, garden tables, compost silos, film and sheet products, etc. DE-UZ 30a also specifies that finished products falling within the scope of other product-specific criteria for the award of the Blue Angel may not be labelled with this general eco-label. This is the case for numerous electrical and electronic equipment where other Blue Angel criteria already exist (e.g. vacuum cleaners, coffee machines, printers and multifunction devices, routers, set-top boxes, etc.).

When it comes to verification, DE-UZ 30a refers to the EuCertPlast certification scheme as a method for verifying the use of recycled materials. The requirements for proof are summarized

with reference to EuCertPlast (see **Fehler! Verweisquelle konnte nicht gefunden werden.**): "The applicant shall submit a certificate (including report) pursuant to the EuCertPlast certification scheme (including a calculated and plausibility-checked verification of the post-consumer percentage) to verify the origin and composition of the PCR materials used" (DE-UZ 30a-2019). Furthermore, the applicant needs to specify the qualitative and quantitative composition of the product applied for, i.e. the proportions of plastic recyclates as well as virgin plastics related to every component.

The Blue Angel for Writing Utensils and Stamps according to DE-UZ 200 is currently the only environmental label that sets minimum requirements for the plastic recyclates content of composite products (DE-UZ 200-2016). The plastics used must either consist of at least 80% PCR plastics or at least 60% renewable raw materials. Proof is again provided in accordance with the EuCertPlast certification scheme.

For various product groups, the use of PCR plastics or the declaration of the PCR proportion is a criterion of the Blue Angel requirements, but in many cases, there is no explicit reference to EuCertPlast. One specific example would be the case for printers and multifunction devices (DE-UZ 205-2017) where the requirement of the share of post-consumer recycled plastics being at least 5% of the complete plastic material is only a target requirement.

In other cases, certain material combinations may only be used if they consist of EuCertPlast-certified PCR plastics. As an example, the following applies for routers (DE-UZ 160-2018): „If plastic composites made of PC and ABS are used, their origin and composition must also be proven by means of a certificate (including report) according to the EuCertPlast certification scheme (with calculated and plausible proof of the post-consumer share)".

3.10.4 TCO Certified

TCO certified, managed by the TCO Development Company in Sweden, is a sustainable certification scheme for IT products of 11 product categories that include displays, notebooks, tablets, smartphones, desktops, all-in-One PCs, projectors, headsets, network equipment, data storage and servers. TCO certified support social and environmental sustainability across the entire IT product lifecycle. Compliance is checked independently, both before and after certification. (TCO certified 2019).
The following criteria are designed for driving sustainable development (TCO certified 2019):

- Socially responsible manufacturing
- Environmentally responsible manufacturing
- User health and safety
- Product performance
- Product lifetime extension
- Reduction of hazardous substances
- Material recovery
- Sustainability performance indicators

The TCO Certified Edge specification is a certification scheme offered by the same company, which sets more mandating product specifications. Every TCO Certified Edge product model

has to fulfil the requirements of both TCO Certified for its product category and at least one additional TCO Certified Edge criterion. Accordingly, since April 2014, in displays at least 85 % and in All-in-One PCs at least 50 % of the total weight of all plastic parts used in product have to come from post- consumer recycled materials (TCO certified 2019).

3.10.5 Nordic Ecolabel (Nordic Swan)

The Nordic Ecolabel has been the official Ecolabel for the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden) since 1989, covering more than 60 product groups from a bride spectrum. The Nordic Swan sets strict environmental requirements in all relevant phases of a product's life cycle, for chemicals used in products as well as for goods and services aiming to continuously progress sustainable development. It certifies and verifies that all requirements are met before a product is approved. (Nordic Ecolabel 2019)

Recommendations for TVs and Computers

- Energy and power consumption
- Design (upgradeability and disassembling)
- Plastics and additives, e.g. flame retardants & phthalates
- Recycling of discarded products
- Chlorine-based plastics

The Nordic Swan imposes strict D4R requirements, integrating design specifications and prohibition of use of hazardous materials. Requirements for minimum content of post-consumer recycled plastics are not covered in the current version valid till 2017. Nevertheless, the upcoming version plans to focus on “possibilities to use recycled or bio based plastic” (Nordic Ecolabel 2019).

3.10.6 Voluntary agreements

The European Commission has recognized under Ecodesign policy voluntary agreements to complex set-top boxes (CSTB), imaging equipment and games consoles.
According to Annex B in the VA of CSTB devices, a CSTB has the primary function of the reception, descrambling and processing of data from digital broadcasting streams and related services and is used to allow conditional access by descrambling using dynamically allocated keys. The device may have the ability to provide content via a home network to one or more dedicated Thin-Client/Remote CSTBs and/or video and audio decoding and output capability. (European Commission 2013) The CSTB can be classified in the following types (European Commission 2013):

- Cable CSTB
- Satellite CSTB
- Internet Protocol (IP) CSTB
- Terrestrial CSTB
- Thin-Client/Remote CSTB

The overall objective of the VA to CSTBs is to reduce the energy consumption with the energy consumption targets, but there is no focus on the use of recycled plastics (European Commission 2013).
For imaging equipment, the VA covers the following product categories:

- Copiers
- Multifunction Devices
- Printers
- Fax machines

This VA contents both requirements for design for recycling and for polymer composition including recycled plastics content. Requirements addressing Design for Recycling (for all product models first placed on the EU market after 1 January 2012) (European Commission 2015):

- Plastic parts >100 g shall be manually separable into recyclable plastic streams with commonly available tools
- Product shall utilize commonly used fasteners for joining components, subassemblies, chassis and enclosures
- Non-separable connections (e.g. glued, welded) between different materials shall be avoided unless they are technically or legally required
- Product plastics shall be marked by material type (ISO 11469 referring ISO 1043, resin identification code, SPI, DIN, or country specific). Marking requirement does not apply to plastic parts weighing less than 25 g or with surface area less than 50 cm², tape; plastic protective and stretch wraps and labels; or plastic pieces when due to shape marking is not possible. Exempted are plastic parts contained in reused complex modules.

IDENTIFIED GAPS REGARDING WEEE PLASTICS CIRCULARITY	
Need for the integration of electronic applications and criteria in the ecolabel and GPP criteria as well as voluntary agreements	As can be seen from the table below, recycled content, design for recycling requirements e.g. using less polymer types and other design requirements e.g. design for disassembly are hardly addressed in GPP criteria or ecolabels. Furthermore, many EEE are not yet covered by GPP or Ecolabel schemes, when some product groups like notebooks and printers are covered by both. The PolyCE project investigated the applications of coffee machines, vacuum cleaners, freezers and washing machines which are only addressed in the ecolabels Blue Angel and Nordic Swan (see table 5).

3.10.7 Overview of the criteria of ecolabels, GPP and voluntary agreements

Table 5: Overview of the different labels and criteria according to selected applications

Label	Criteria	TV's	Smart-phones	Note-books	Printers	Coffee machines	Vacuum cleaner	Freezer	Washing Machines
EU GPP	Recycled content Plastic types Design for disassembly	N.A.	N.A.	No No Yes	No No No	N.A.	N.A.	N.A.	N.A.
Blue Angel	Recycled content Plastic types Design for disassembly	N.A.	No No Yes	No Yes Yes	No Yes Yes	No No Yes	Yes No Yes	N.A.	N.A.
TCO Label	Recycled content Plastic types Design for disassembly	N.A.	No No No	No No Yes	N.A.	N.A.	N.A.	N.A.	N.A.
EPEAT	Recycled content Plastic types Design for disassembly	Yes, optional No Yes	No No No	Yes Yes Yes	Yes, optional Yes Yes	N.A.	N.A.	N.A.	N.A.
EU Ecolabel	Recycled content Plastic types Design for disassembly	No Yes Yes	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Nordic Swan	Recycled content Plastic types Design for disassembly	No Yes Yes	N.A.	No Yes Yes	Yes Yes Yes	N.A.	N.A.	No No No	No No No
Voluntary agreements	Recycled content Plastic types Design for disassembly	N.A.	N.A.	N.A.	Yes Yes Yes	N.A.	N.A.	N.A.	N.A.

3.11 CEN/CENELEC/ETSI Standards

In Europe, the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI) are the three officially recognized European Standardization Organizations to develop standards. Every product we buy must comply with certain safety and quality standards. CEN and CENELEC have a close collaboration and provide a platform across a wide range of sectors for the development of European Standards and other technical specifications. For corresponding of the standards with any EU legislation, CEN and CENELEC work closely with the European Commission. To reach agreements on common standards that can be applied throughout the whole world they cooperate with the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC).

European mandates

Mandates, also called standardization requests are the mechanism by which the European Commission and the EFTA Secretariat request the European Standards Organizations (ESOs) to develop and adopt European standards in support of European policies and legislation. This mechanism evolves through several steps (CEN/CENELEC 2021a):

- A **provisional draft mandate** is received at CENELEC for possible comments by a due deadline.
- A **draft mandate**, possibly including the proposed modifications, is sent to the Committee on Standards established under Regulation 1025/2012 on European Standardisation, ensuring a wide consultation of sector authorities at national level.
- A **mandate** is then sent for acceptance to CENELEC, where a Programme Manager coordinates with the relevant Technical Body and ensures feedback to the Technical Board(s).
- The Technical Board Members are invited (not) to accept the given mandate, with or without restrictions, based on the Technical Body and CENELEC feedback.
- Once the Technical Board has taken its decision, CENELEC informs the EC accordingly.

In case of acceptance of the mandate, the Technical Body is entrusted with the task of starting expected standardization work within CENELEC.

3.11.1 European Standards relevant for WEEE treatment

The standards developed under the mandate M/518 cover the treatment of waste from all products within the extended scope of the WEEE Directive and address the collection, transport and treatment, while future standards, which are currently under development, will also cover preparation for reuse of the WEEE. The standards should assist treatment operators in fulfilling the requirements of the WEEE Directive without placing unnecessary administrative burdens on operators of any size, including SMEs. (European Commission 2021a)

European standards relevant for WEEE treatment include the following in table 6:

Table 6: Current European standards relevant for WEEE

Category	Number	Document title	Year of publication
WEEE	EN 50419	Marking of electrical and electronic equipment	2006
	EN 50625-1	Collection, logistics & treatment requirements for WEEE -Part 1: General treatment requirements	2014
	TS 50625-3-1	Collection, logistics & treatment requirements for WEEE --Part 3-1: Specification for de-pollution -General	2015
	TS 50625-4	Collection, logistics & treatment requirements for WEEE --Part 4: Specification for the collection and logistics associated with WEEE	2017
	TS 50625-5*	Collection, logistics & treatment requirements for WEEE --Part 5: Specification for the end-processing of WEEE fractions –copper and precious metals	2017
	TR 50625-6	Collection, logistics & treatment requirements for WEEE --Part 6: Report on the alignment between Directive 2012/19/EU and EN 50625 series standards	2018
	EN 50614	Requirements for the preparing for re-use of waste electrical and electronic equipment	2019
	-	WEEELABEX normative document on Treatment V10.0 (articles: 4.1.1; 4.3.5; 4.6; 4.7.5; 5.9.1; A.2.1)	2013
Household appliances	EN 50574-1	Collection, logistics & treatment requirements for end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons	2012
	TS 50574-2	Collection, logistics & treatment requirements for end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons -Part 2: specification for de-pollution	2014
Lamps	EN 50625-2-1	Collection, logistics & treatment requirements for WEEE --Part 2-1: Treatment requirements for lamps	2015
	TS 50625-3-2	Collection, logistics & treatment requirements for WEEE --Part 3-2: Specification for de-pollution –Lamps	2016
CRT display appliances/ fla panel display equipment	EN 50625-2-2	Collection, logistics & treatment requirements for WEEE --Part 2-2: Treatment requirements for WEEE containing CRTs and flat panel displays	2015
	TS 50625-3-3	Collection, logistics & treatment requirements for WEEE --Part 3-3: Specification for de-pollution -WEEE containing CRTs and flat panel displays	2017
Temperature exchange equipment	EN 50625-2-3	Collection, logistics & Treatment requirements for WEEE -Part 2-3: Treatment requirements for temperature exchange equipment	2017
	TS 50625-3-4	Collection, logistics & treatment requirements for WEEE --Part 3-4: Specification for de-pollution –temperature exchange equipment	2017
Photovoltaic panels	EN 50625-2-4	Collection, logistics & treatment requirements for WEEE --Part 2-4: Treatment requirements for photovoltaic panels	2017
	TS 50625-3-5	Collection, logistics & treatment requirements for WEEE --Part 3-5: Specification for de-pollution -photovoltaic panels	2017

3.11.2 European standards relevant for plastics recycling

The standard EN 15343:2007 Plastics - Recycled Plastics - Plastics recycling traceability and assessment of conformity and recycled content specifies the procedures needed for the traceability of recycled plastics and gives the basis for the calculation procedure for the recycled content of a product. Its main objective is to describe the necessary procedures for mechanical recycling that are required for products that have been manufactured completely or in part from recycled plastics and need proof of traceability.

The methodology and procedures include the control of input material, the control of the recyclate production process, plastics recyclate characterisation, and traceability. The standard defines information to be recorded as appropriate to the end-use application (origins, logistics, tests carried out before processing, process parameters, tests carried out after processing, intended application). The calculation of the recyclates content of a plastic (=product) is carried out as a mass fraction according to:

$$Recycled\ content\ of\ the\ product\ (\%) = \frac{Mass\ of\ recycled\ materials\ in\ the\ product}{Total\ mass\ of\ the\ product} * 100$$

The standard does not differentiate between pre-consumer (post-industrial) and post-consumer components but subsumes both in the recyclates content. EN 15343:2007 is part of a series of CEN publications on plastics recycling that is listed in Table 1, but will not be described here in detail.

Table 1: CEN publications on plastics recycling

Reference	Title
EN 15342:2007	Characterization of polystyrene (PS) recyclates
EN 15344:2007	Characterisation of Polyethylene (PE) recyclates
EN 15345:2007	Plastics recyclate characterisation of PP recyclates
EN 15346:2007	Characterisation of poly(vinyl chloride) (PVC) recyclates
EN 15347:2007	Characterisation of plastics wastes
EN 15348:2007	Characterization of poly(ethylene terephthalate) (PET) recyclates
EN 15353:2007	Guidelines for the development of standards for recycled plastics

The Standard EN 45555:2019 General methods for assessing the recyclability and recoverability of energy-related products was established by CEN/CLC Joint Technical Committee 10 on Energy-related products - Material Efficiency Aspects for Ecodesign, based on mandate M/543 of the European Commission to support the implementation of Directive 2009/125/EC of the European Parliament and of the Council. It provides a general horizontal methodology for:

- Assessing the recyclability of energy-related products
- Assessing the recoverability of energy-related product
- Assessing the ability to access or remove certain components or assemblies from energy-related products to facilitate their potential for recycling or other recovery operations
- Assessing the recyclability of critical raw materials from energy-related products

The standard highlights that a horizontal approach might not be enough and correct assessment can only be performed in a product-specific way, taking into account specific parameters of a product group. For this purpose, the EN 45555:2019 defines a series of parameters that can be used to calculate product specific recycling and recoverability rates.
According to EN 45555:2019, the recyclability and recoverability of a product is a combination of the design characteristics of the product (e.g. structure, material composition, size, weight, etc.) and the techniques, combination, or sequence of techniques used to recycle or recover a given waste stream. For this purpose, the recyclability and recoverability assessment should

be based on a product or product-group specific end-of-life treatment scenario. This scenario shall consider the state-of-the-art treatment and recycling methods and geographical aspects.

The standard EN 45557:2020 General method for assessing the proportion of recycled material content in energy-related products was established by CEN/CLC Joint Technical Committee 10 on Energy-related products - Material Efficiency Aspects for Ecodesign. The standard specifies a general method for assessing the proportion of recycled material in an energy-related product (ErP) or parts of the ErP. It was published in April 2020 and should be applied as a framework to be used for defining the assessment of recycled materials content in specific product groups. This means that it is rather aimed at those who will develop product group-specific standards in the future and not directly the manufacturers. EN 45557 takes into account both pre-consumer (post-industrial) and post-consumer recyclates and basically all types of materials. The proportion of recycled materials in relation to the individual part or device must be calculated separately for pre-consumer (post-industrial) and post-consumer components. The standard states that proof of the recyclates content of the specific product is (currently) not feasible. Evidence must therefore only be provided via documentation and mass balances.

IDENTIFIED GAPS REGARDING WEEE PLASTICS CIRCULARITY	
Need for the integrations of PolyCE investigations in standards	Standards play an important role in the economy by facilitating business interaction, enabling companies to comply with relevant laws and regulations, speeding up the introduction of innovative products to market and providing interoperability between new and existing products, services and processes (CEN/CENELEC 2021b). Standards provide useful tools to facilitate communication, measurement, commerce and manufacturing to organizations (CEN/CENELEC 2021b). However, in the frame of PolyCE investigations where identified some needs in standardization such as: - Implementation of clustering strategies for WEEE devices to facilitate the processes of material separation in WEEE pre-treatment facilities and it is potentially beneficial in terms of PCR plastic quality improvement; - Recommendations for WEEE pre-treatment operators or collection points to obtain high-quality mixed plastics; - Development of a quality management system to increase data transparency, to structure and harmonize the communication in the plastics recycling supply chain and to support the trade and sales of PCR plastics.

3.12 Additional interesting EU initiatives related to disclosure of information

As chemicals pose a challenge in our daily lives and industrial processes, the EU set up an extensive framework, the **"Chemicals Strategy for Sustainability",** comprising 40 legislative instruments such as REACH, CLP and many more. In line with the European Green Deal, these substances must always be updated, adjusted, and re-evaluated to achieve the vision of a toxic free environment. The chemical strategy for sustainability aims for a safe and trustworthy recycled materials market, being notably achieved by a *sustainable-by-design* concept and closing the gap of adequate information on the chemical content of products until downstream stages of the value chains. The nascent SCIP (Substances of Concern in Products) database by ECHA is an iconic initiative in that regard.

The "Green claims" initiative is an initiative announced in the EU green deal of December 2019 and CE action plan of March 2020. It aims to develop an approach how green claims by companies can be substantiated to differentiate from 'greenwashing' and to limit the proliferation of green allegations that lead to a certain mistrust by market actors, being for B2C or B2B. The process to support green claims will most likely rely on PEF methodology, and that is why the two approaches are often presented together. The interest for POLYCE project is to understand how products containing recycled plastics could be differentiated through the Green claims initiative.

"Green taxonomy" is an EU initiative to orient investments towards sustainable activities. The goal is to define criteria for activities that would make them qualify for 'sustainability' and reported as such in the portfolio of investments by financial institutions and business. The main dimension of interest for PolyCE is to see if the green taxonomy can associate the uptake of recycled plastics or recyclable plastics in EEE as a criterion (among others) to qualify a sustainable manufacturing of EEE, as well as the respect of certain standards by plastic recycling processes to ensure the necessary quality of recyclates.

"Product passport" is an idea promoted since 2013, but which gained momentum through the CE action plan of March 2020 and the launch of the sustainable product policy initiative. The objective is to accompany products placed on the market with information accessible digitally and presented according to a standard format. The scope of application and types of information is not fully defined and may evolve over time, but we can expect that it encompasses information on material and chemical contents, on circularity performances (durability, repairability, recyclability etc.) and on environmental profile (notably carbon footprinting to start with). The preliminary thinking is that such a product passport would build on existing information scattered in various databases and enable the consolidation of those information (it should not be set through a brand-new gigantic database). The direction to be explored for POLYCE is how such a product passport could recognise the uptake of recycled plastic and potentially the recyclability of plastics in EEE.

"Product Environmental Footprint (PEF)" is existing since 2012/2013, but is rather a methodology to be injected in various instruments than a policy instrument per se. It is basically a methodology to conduct LCAs and qualify the environmental profile of products. The main dimension of concern for PolyCE is how PEF can capture recyclability and recycled contents of electrical and electronic equipment and how this can be reflected in other policy instruments that may refer to PEF methodology and related profile.

4 PolyCE work within regulatory framework

4.1 PolyCE input to current policy debates

PolyCE partners have been actively engaging policy makers and NGOs at EU and international level during related policy event attendances and conferences. Examples include: WHO's Circular Economy and Health Conference (PolyCE was presented as a circular solution to the e-waste challenge).

Additionally, PolyCE had the following input to current policy debates:

- PolyCE reflection paper on EU's Plastics Strategy (Link)
- PolyCE position paper on the classification of WEEE plastics as "hazardous waste" (Link)
- PolyCE report on the importance of using recycled plastics (Link)
- PolyCE position paper on the recycling of black plastics (Link)

In January 2018 the consortium jointly published a Reflection Paper on EU's Plastics Strategy showcasing our support for the initiative and pointing out how our objectives are in line with the priorities set in the Strategy. In 2019, two position papers were published on the classification of WEEE plastics as "hazardous waste" and on the recycling of black plastics. Furthermore, a report on the importance of using recycled plastics raises awareness among consumers and manufacturers in order to change their attitudes towards recycled plastics and improve their market uptake.

4.2 PolyCE work with Circular Plastic Alliance (CPA)

ERION collaborates with the Circular Plastic Alliance, specifically with the task forces dealing with plastic collection and sorting and with monitoring issues. The results of deliverable 3.1 Quantification of material flows along the entire chain have been shared with CPA members and used as starting point to elaborate the document *Horizontal report for collected and sorted plastic waste*. Overall, PolyCE and CPA works together to elaborate a shared strategy for circular plastic development.

As an initial result of this collaboration, on 06/11/2020 the document Circular Plastic Alliance - State of Play on Collection and Sorting has been published.

4.3 PolyCE work with CEN/CENELEC

In June 2019, CENELEC was contacted (WG6) offering the PolyCE support for standardisation in the CENELEC Technical Committee TC111X. The answer received was that the discussion for 2019 and 2020 was dedicated to the evaluation of an implementing act for making the standard mandatory at EU level.
Since then, ERION followed the CENELEC proceedings supporting the standardization work by attending meetings and providing comments through our association (WEEE Forum) on the topics:

- CENELEC meeting on 5-6 September 2019 to discuss which requirements in EN 50625 and the TS are beyond the Directive;

- WEEE standards workshop | 10 March 2020 – discussion with WEEE Forum, APPLIA and DIGITAL EUROPE about the possibility to get an implementing act for the CENELEC standard;
- July 2020 – Making EN standard an EIC standard – since July ERION is represented in CENELEC for starting the revision of the EN standard to make it EIC standard.

Moreover, ERION contributed to the initial draft of the new IEC global standard on WEEE introducing PolyCE findings on clusterization strategy for WEEE collection and WEEE treatment.

5 Policy recommendations according to findings in the PolyCE project

5.1 Development of Design for- and from Recycling Guidelines

Deliverable 8.1 is the outcome of Task 8.1 and Task 8.2 of the PolyCE project. It brings together different aspects concerning the integration of life cycle thinking into product development and provides concrete guidelines for using post-consumer recycled plastics in new electronic applications. The guidelines target designers and engineers who are already experienced with plastics as well as product engineers that are eager to learn where and how to start applying recycled plastics. (Berwald et al. 2020)
The “design for recycling” strategy shows best practices during the product development process, following the sequential design phases of material selection, part, and product design. The “design from recycling” strategy looks to what extent new products can be manufactured using recycled plastics. The new Drop-In Approach™ provides a practical tool for product developers to start designing with recycled plastics. A complexity flowchart helps designers to focus on priority parts and a six-step material approval approach allows them to gradually reduce the risk that is linked to using recycled plastics. (Berwald et al. 2020)

While these strategies are usually followed separately, this report combines them in comprehensive guidelines that are presented on a product and on a part level. On both levels of the guidelines are subdivided into (Berwald et al. 2020):

1. Avoidance of hazardous substances
2. Enabling easy access and removal of hazardous or polluting components
3. Using of recyclable materials that will be recycled by WEEE recyclers
4. Using of material combinations and connections that allow easy liberation
5. Using of recycled materials

PolyCE findings 	*EEE producers can influence the market by choosing the materials to use in their products. The guidelines allow optimising the design of a product in such a way that valuable materials are effectively recovered with current recycling technologies at the end of life.*
Policy instruments 	*Ecodesign Directive, Ecolabels, GPP, Voluntary agreements, WEEE Directive*
Policy recommendations	
R1	*The following adjustments should be made to the **Ecodesign Directive** to strengthen the use of PCR-plastics and to enhance circularity of EEE such as:* *1. Producers should use polymers which are recyclable. If the application requires polymers not recyclable with current technologies, then the recycling process should be capable of separate them in a way they don't affect or hamper the recyclability of the other fractions.* *2. Information on plastics recycled content in new electronic products.*
R2	*Producers that put on the market products not designed for circularity can be sanctioned by fee modulation (e.g. malus fees) defined under EPR schemes that have to be implemented according to the **WEEE Directive.***
R3	***GPP and Ecolabels** can set out criteria to make plastics more circular based on the Design Guidelines developed in Deliverable 8.1.*

5.2 Plastics recycled content in new electronic products

The PolyCE project developed several case studies showing the technical feasibility of producing new electronic products with recycled plastics. A recycled content is mandatory requirement in some green labels and has been addressed in the preparatory study for smartphones for the Ecodesign directive. Since labels are voluntary, a minimum recycled content can be a requirement within the green labels, but it remains challenging to define such criteria under EU legislation, which is mandatory.
Through a number of five demonstrators, the project showed the technical feasibility of using recycled plastics in new EEE shown in table 7:

Table 7: Demonstrator products of PolyCE case studies and their recycled content

Project partner	Product	Material type	Material source	Recycled content	Status
The imagination factory	Fundwaste smart waste management sensor housing	PCR PC/ABS	WEEE	100%	Successful production, product in review with client
ONA	LED lighting fixture	PCR and PIR PC	Packaging and other (unknown)	100%	Product release ongoing
Pezy	Wisensys wireless sensor housing	PCR ABS	WEEE	Wisensys M: 86.5% Wisesnsys S: 85%	Product released to market
Philips	Vacuum cleaner	PCR ABS	WEEE	75%	Product release ongoing
	Senseo eco	PCR ABS and PIR PC	WEEE	75%	Product released to market
	Shaver frame	PCR PC/ABS	WEEE	100%	Optimization of production ongoing
Whirlpool	Fridge liners	PCR PS	WEEE	100%	Successful on technical level, due to its food-contact application further tests have not been proceeded
	Washer tubs	PCR PP filled	WEEE	100%	Successful trials, investigating new business cases

PolyCE findings 	*The demonstrator trials show that it is technically feasible to use PCR-plastics in new electronic products with today's technologies up to 100%.*
Policy instruments 	*Ecodesign Directive, Ecolabels, GPP, Voluntary agreements*
Policy recommendations	
R4	*A requirement for recycled content needs to take at least the following aspects into account:* *1. A mandatory threshold of recycled plastics content as a horizontal measure under Ecodesign cannot be implemented due to the very different technical requirements for the various EEE products.* *2. A product-specific plastics recycled content can be defined after careful analysis taking into account the mass flows and qualities of recycled plastics required for the respective applications over time.* *3. Applications with specific requirements - there are applications, which cannot be made out of recycled plastics currently available on the market. These include, for instance, the use of recycled plastics in medical, toys and food-contact applications. Achieving specific material properties such as transparent, high-gloss or colour freedom are difficult with current grades of PCR plastics from WEEE.* *4. Enhancing the way Ecodesign delivers on circularity through Design for Recycling measures. Setting minimum information requirements with regard to recycled plastic content.*

5.3 Product collection and clustering for maximum sorting and recycling efficiency

Separated plastic particles have a higher resale value than a mixed plastic waste stream. Sorting is, therefore, an important step in plastic value recovery. A technique that can be used to isolate a plastic from a waste stream is referred to as a sorting process. Proper clustering strategies can limit the degree of contamination in output streams. Furthermore, they can limit the mixing of difficult to separate and incompatible materials or increasing the concentration and, hence, the economic viability of sorting out more plastics. Thus, clustering strategies have the potential to significantly improve the quality and quantity of output materials of material recycling facilities, thereby improving the WEEE plastics recycling rate.
Task 3.2 aimed to **improve the quality of recycled plastics through clustering strategies**. Such a strategy is a policy for treating products or their components jointly or avoiding to do so in a material recovery facility. To do so, three subtasks were defined: (1) experiments and meta-studies were carried out to quantify the WEEE plastics (WEEEp) flow and composition during collection and sorting in the EU. (2) Models were then developed that mimic the input/output relation of WEEEp recycling facilities as accurately as possible providing a representation of the ease with which non-compatible plastics could be separated. (3) Finally, the gathered data and optimization routines were used in a statistical cluster analysis to find promising product clusters that should undergo joint treatment from an economic and sustainability perspective.
Important pieces of information for which the research has based itself on limited sources include the following: information on the magnitude of different WEEEp streams and the polymeric and additive composition of the different WEEEp in different EU regions and the methods used for mechanical separation by WEEEp recyclers within the EU and their frequency of adoption and obtained sorting efficiencies. Practical conclusions obtained include the following:

1. **Product categories were identified as promising criteria to define clusters, as they contain distinct sources of particular polymers**. These are indicated in Figure 1. It is noteworthy that in practice, the small household/consumer equipment category is often deemed too complex to target during plastics recycling. However, a relatively small number of products compose over 50% of this stream. Some product categories have a very high plastic mass percentage and homogeneous polymeric composition. Vacuum cleaners form an example of such a category. Identifying such small household products at collection sites or in a manual sorting step prior to shredding of further sorting can significantly improve recycling rates in a straight-forward manner;
2. **For the most common large household products, disassembly prior to plastic recycling steps is worth the effort**. For example, clustering of refrigerator drawers is a viable strategy for improved HIPS recovery. Likewise, the clustering of washing machine drums (separately from the remaining washing machines) helped to increase polypropylene recycling rates;
3. **Promising clustering strategies were derived**. One such strategy is depicted in Figure X (in which colours indicate distinct clusters in the rightmost column). The aforementioned component-wise clustering approaches are suggested to increase purity. In a case study[1], clustering approaches were shown to be economically viable and increase recycling rates;
4. **A systematic manner to monitor and document WEEE plastic flows in Europe should be introduced**. By documenting the occurrence of particular products and materials therein, recyclers are aided in adequately treating input streams. A systematically maintained database of WEEE streams can also help identify and communicate difficulties recyclers encounter. This stimulates synergies throughout the value chain, for instance between recyclers and original equipment manufacturers.

[1] See J.R. Duflou, A. Boudewijn , D. Cattrysse , F. Wagner, A. Accili, G. Dimitrova, J.R. Peeters, (2020). Product clustering as a strategy for enhanced plastics recycling from WEEE. *CIRP Annals - Manufacturing Technology*, 69, pp. 29-32.

PolyCE findings 	*Smart clustering strategies (based on material types and properties) implemented at municipal collection point, at the retailers' level and, ultimately, at WEEE pre-treatment level, can facilitate the processes of material separation in WEEE pre-treatment facilities and it is potentially beneficial in terms of PCR plastic quality improvement.*
Policy instruments 	*WEEE Directive and existing European Standards such as **TC111X 50625-x series** on "Collection, logistics & Treatment requirements for WEEE"*
Policy recommendations	
R5	*The categories according to which the reporting for collection needs to be done, as described in the **WEEE-Directive**, should be better aligned to improve clustering strategies, for example:* - *Refrigerators and freezers and combi-devices;* - *Other cooling and freezing;* - *Washing machines;* - *Other large household devices;* - *Vacuum cleaners;* - *Printers;* - *Coffee machines;* - *Other small household appliances and consumer equipment.*
R6	*Advice should be included in existing **European Standards** regarding WEEE pre-treatment that suggests that operators or collection points should separate washing machines from the Large Household Appliance WEEE flow and that they should treat washing machines separately from other products.*

5.4 Quality testing for recycled plastics

Methods for the analysis of the quality of plastic flakes along the entire value chain is not well documented in literature. Especially the stage between pre-processors and recyclers is often subject to trade. Quality assessment of mixed plastic flakes at the stage between pre-processors and recyclers increases the transparency of the value chain. In addition, the material composition combined with size and colour distribution of the plastic flakes allows recyclers to estimate the yield of their process. This can serve as a basis for yield-oriented pricing models and cross-actor optimization which is considered to encompass substantial potential for improving the recycling efficiency of the entire value chain. (Wagner 2020)
In the investigations of PolyCE in Deliverable 4.4, a testing procedure for mixed plastic flakes by Fourier Transform InfraRed (FTIR) spectroscopy, X-Ray Fluorescence (XRF) spectroscopy and Manual Composition Analysis (MCA) assisted by Computer Vision (CV) has been performed.

For the case study of clustering of fridges and fridge drawers, the testing of mixed plastic flakes showed inefficiencies of previous shredding of the fridges, which would result in significant losses of material by the implemented sieving steps in the recycling process. The dismantling of fridge drawers aimed to produce high quality, possibly food contact recycled plastics. However, the financial benefit of food contact polystyrene makes this case study very challenging to be put in practice if no Original Equipment Manufacturer (OEM) is willing to pay a higher price. In addition, from a legislative perspective, the production of food contact recycled plastics would require the application of a suitable recycling system and the approval by EFSA. Consequently, the project will not file a dossier and aim for an approval of food contact recycled polystyrene but investigate the benefit of the case study purely by quality testing and compliance testing. (Wagner 2020)

The case study of washing machines and the second cluster of washing machine drum housings that were dismantled during the pre-processing, showed that the effort of dismantling is very high, resulting in a high cost that is not expected to justify this cluster from an economic perspective. The processing of washing machines alone is seen as promising to reach a suitable quality to recover recycled PP with fillers that allow the production of washing machine drum housings from the recycled plastics. Further tests will be conducted on granulate level and in application testing with industry. (Wagner 2020)

The case study of small household appliances (SHA) was about separate processing of printers, vacuum cleaners and coffee machines from other SHA. The case of printers revealed PC/ABS to be a promising plastic to be recycled from this cluster. The cluster of coffee machines showed a relatively low content of PP and high content of PC/ABS. The vacuum cleaners showed a high content of PP. The obtained quality will be tested in granulate level for the recycled plastics to verify an improved processing based on the input clustering of SHA. (Wagner 2020)

PolyCE findings 	*The introduction/implementation of systematic quality testing procedure can decrease the uncertainty and lack of information regarding the presence of chemicals of concern in recycled plastics.*
Policy instruments 	*Existing European Standards such as:* ▪ ***CEN/TR 15353:2007*** *Plastics - Recycled plastics - Guidelines for the development of standards for recycled plastics* ▪ ***EN 15343:2007*** *Plastics - Recycled Plastics - Plastics recycling traceability and assessment of conformity and recycled content (confirmed 2017)* ▪ ***EN 15347:2007*** *Plastics - Recycled Plastics - Characterisation of plastics wastes (confirmed 2017)* ▪ ***CEN/TS 16010:2013*** *Plastics - Recycled plastics - Sampling procedures for testing plastics waste and recyclates (in revision CEN/TC 249 N2473)*
Policy recommendations	
R6	*A method for the quality assessment of mixed plastic flakes is proposed between pre-processors and recyclers. Minimum requirement for mixed plastic flakes should be tested: material composition (to evaluate impurities content), size distribution (to evaluate the amount of materials that cannot be sorted) and colour distribution should be analysed. Additional metadata on the pre-treatment processes should be provided, compiling a sort of material identity card as the one proposed.*
R7	*The development of a quality management system is a key factor to increase data transparency, to structure and harmonize the communication in the plastics recycling supply chain and to support the trade and sales of PCR plastics. To ensure a proper implementation at EU level, the quality management system should be introduced in existing European standards.*

5.5 Phase gate approach for improvement of supply chain communication

The phase-gate process is an approach to improve supply chain communication, setting concrete and quantifiable gate requirements in between each process step along the value chain of PCR plastics. This value chain can be characterized into the following 7 phases:

- Collection: Collection of End-of-Life products
- Pre-Processing: Main focus is decontamination
- Metal Sorting: Removal of metals from mixed plastics
- Plastic Sorting: From mixed plastics to single streams
- Primary Compounding: First compounding step (e.g. melt filtration, additives)
- Secondary Compounding: Special compounding (e.g. glass fibers) or blending with virgin
- Product Manufacturing: Production of a plastic component

The requirements for the final product are being passed upstream and quality expectations need to be translated into material specifications and substance thresholds. These requirements are mostly inspired and based on those originating from virgin plastics. Between each step an assessment has to be conducted and information is passed on to the subsequent process step in the downstream direction of the material flow, as each individual step plays a key role for the success of producing a recycled plastic suitable to the needs of an equipment manufacturer. In practice, this information is passed on through sample batches to produce a product portfolio tailored for a specific material, the targeted use and phase in the supply chain. Figure 4 depicts an easily interpretable graphic for a better understanding of the phase-gate approach.

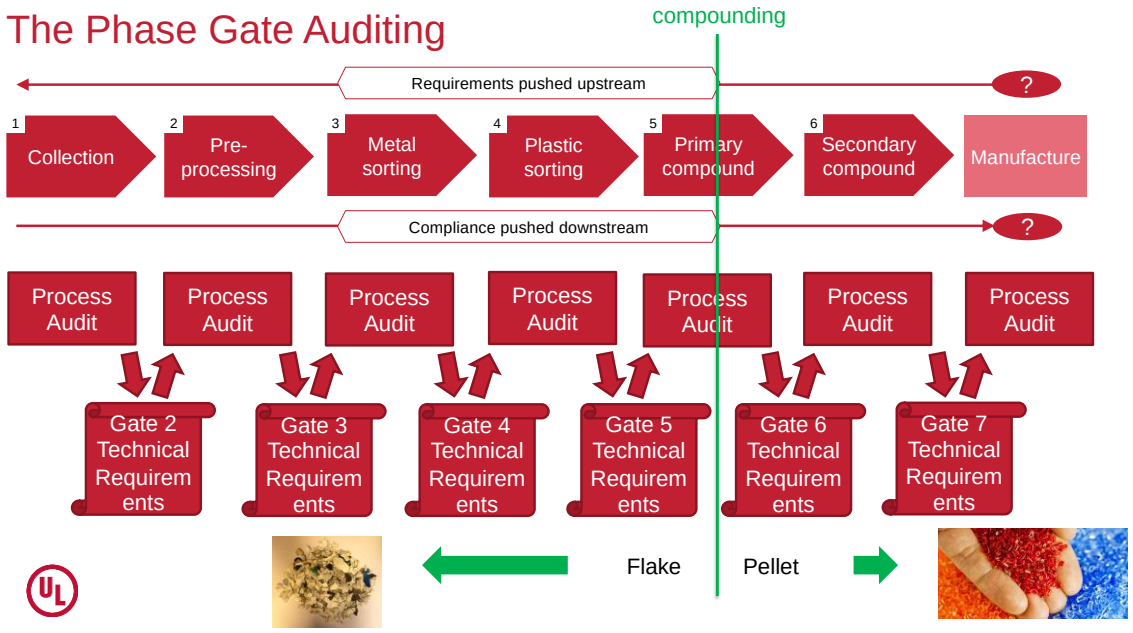

Figure 4: Plastic supply chain phases

Site auditing is separated into multiple parts including setting performance requirements for incoming and exiting material, process quality control, establishing and maintaining a chain of custody and consistent documentation of the processed materials. An agreement on performance requirements for incoming material is imperative to produce the desired outgoing material. Establishing a chain of custody (COC) is necessary as the source material will largely affect the final product. Here several COC models based on ISO 22095 were analysed and only those providing information on source content have been chosen, namely “Identity Preserved”, “Segregated” and “Controlled Blending” models. For processing of material and

quality control existing standards by CEN/TR 15353:2007 were further supplemented by process control charts and specifications for process to assure the manufacture of consistent material characteristics. Last but not least, minimum requirements for documenting material specifications and testing need to be established for communication to the next phase in progress.
As a result of these findings, gate reports in a table form have been set up for flakes and granulate, as they have to be treated separately. Detailed information about the gate reports can be find in Deliverable 4.3. Information on targets for incoming material have to be sent upstream to the previous process step within the supply chain, and values resulting from analysis have to be filled out by the supplier at the corresponding gate.

PolyCE findings 	*The concept of phase-gate is an attempt to increase the quality and value in the plastics value chain by passing OEM requirements up the supply chain to the generators of recycled content. Gate requirements are specific to the application and OEM. In the early phases of the supply chain there may be common requirements, RoHS compliance or white colour for instance. Later stages will become more specific to the application, melt flow and impact strength as examples. Auditing of the site for the ability to produce consistent product is not a new idea. What phase-gate proposes is a way to combine consistent and published requirements for product performance with a framework for auditing that can be applied at any phase in the supply chain.*
Policy instruments 	*Existing European Standards such as:* ▪ ***CEN/TR 15353:2007*** *Plastics - Recycled plastics - Guidelines for the development of standards for recycled plastics* ▪ ***EN 15343:2007*** *Plastics - Recycled Plastics - Plastics recycling traceability and assessment of conformity and recycled content (confirmed 2017)* ▪ ***EN 15347:2007*** *Plastics - Recycled Plastics - Characterisation of plastics wastes (confirmed 2017)* ▪ ***CEN/TS 16010:2013*** *Plastics - Recycled plastics - Sampling procedures for testing plastics waste and recyclates (in revision CEN/TC 249 N2473)*
Policy recommendations	
R8	*Inject the phase gate approach in existing industry standards and integrate a phase gate approach as criteria into call for tenders towards waste operators and recyclers by take back schemes.*

5.6 Substances of concern and their thresholds in recycled plastics

Most of the WEEE plastics are high value tech plastics and technology exists in the EU to produce REACH and RoHS compliant PCR plastics and ensure safe plastic recycling. A small proportion of these WEEE plastics is compounded with flame retardant substances. Only a limited number of these Flame Retardants are restricted as Persistent Organic Pollutants (POPs). Plastics containing brominated flame retardants can be separated to be discarded, thus removing and eliminating these POP BFRs. WEEE plastics recycling plants generally do not have permits to take in hazardous wastes and a classification as hazardous of WEEE plastics in some regions in Europe is hampering the recycling of WEEE plastics.[1]

By far the majority of the WEEE plastics does not contain Brominated Flame Retardants (BFRs) and of the approximately 5–10 % that do contain BFRs, only approximately 30 % consists of POP BFRs (see figure 5). Deca-BDE and the group of the PBDE's have been used intensively in electronics in the past and the EU recycling industry has to deal with this legacy of PBDE's.
The "target plastics" without substances of concern can be recycled into Post-Consumer Recycled plastics with characteristics that allow these secondary raw materials to be re-used in new electronic appliances or other durable products. In line with the above definition the compliant recycling industry monitors the identifiable stream of plastics containing restricted substances such as the POP BFRs to prove environmentally safe treatment.

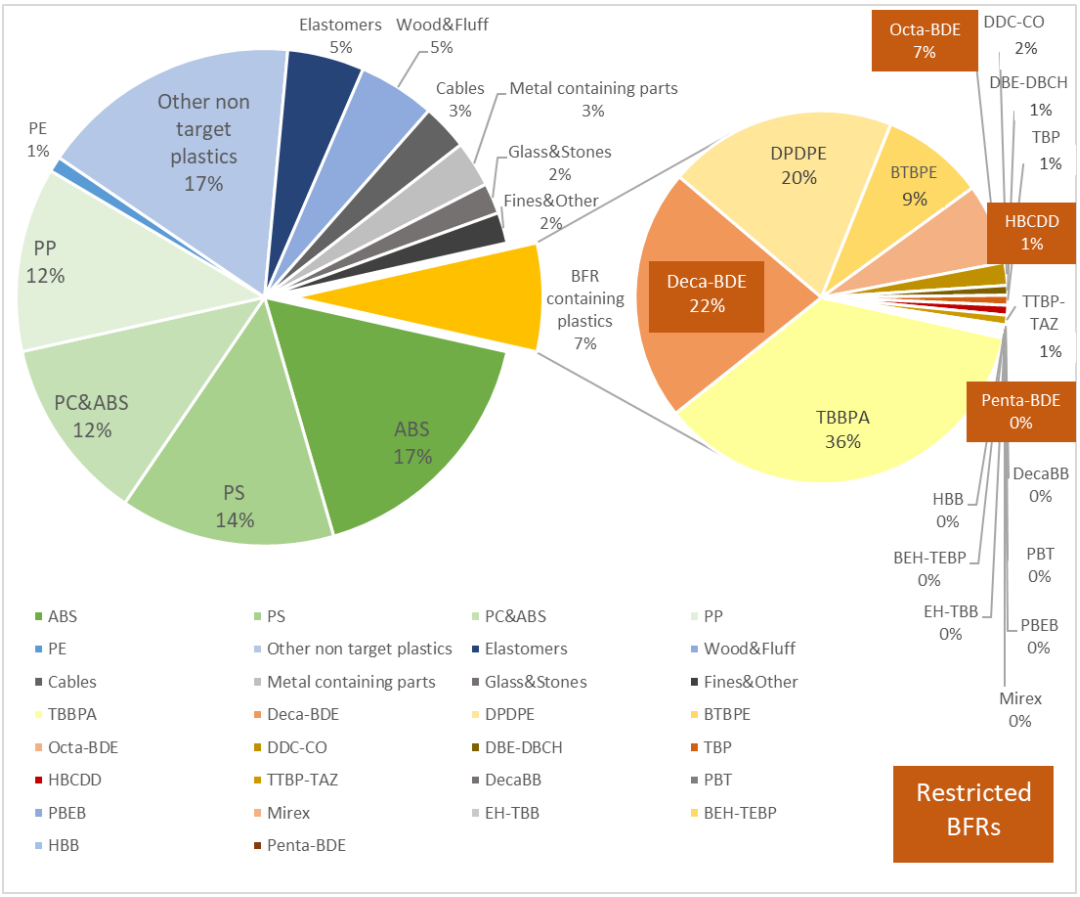

Figure 5: Different types of plastics in WEEE and containing types of brominated flame retardants

[1] https://polyce-eu.medium.com/roadblocks-for-the-circular-economy-of-weee-plastics-a-call-for-informed-classification-practices-9fc8d2da90dd

Using post-consumer recycled plastics in electrical and electronical appliances requires the compliance with several regulations: in addition to the RoHS Directive other chemical substance regulations such as REACH- and POPs Regulation must be complied with. A mentioned challenge to the recycling plastic value chain is the content of legacy hazardous substances; if not properly managed, contaminated recycling fractions from WEEE do not reach quality requirements and are unusable on specific applications due to environmental and health risks.

PolyCE findings 	*The technical method how to measure the content of Brominated Flame Retardants is based upon the analysis standard IEC EN 62321–3–1. This standard is validated for 1000 ppm of Bromine as element and there is no other viable test method available to date. As long as this test method is not available for any validated lower values, the WEEE plastics recycling community has called for keeping the maximum low POP content at 1000 ppm and the Unintentional Trace Contaminant threshold at 500 ppm for Deca-BDE or for the group of PBDEs in articles (recycled plastics)*
Policy instruments 	*POP-Directive*
Policy recommendations	
R8	*Keeping thresholds for any restricted substance that are practically verifiable.*
R9	*The complex EU legal framework on hazardous substances must be harmonized to promote a uniform Circular Economy Strategy in the current global market; the WEEE recycling industry often faces difficulties to comply with all requirements, such as the removal of brominated flame retardant or the notifications necessary for shipment of mixed WEEE plastics, that can be different in different countries.*

5.7 Recycled plastics for food-grade applications

In the frame of the PolyCE project some trials were performed related to food-grade applications. One demonstrator case carried out by Whirlpool contained WEEE sourced PS from cooling and refrigeration. They wanted to use the material for Fridge liners (big thermoforming parts). Extrusion, thermoforming, assembly, and property trials were performed. From a technical point of view the material was a great success. From the extrusion, thermoforming and assembly trials it could be concluded that the material performs as virgin. Even environmental stress cracking and mechanical properties were up to spec. A slight mismatch was seen on colour, but this could be resolved with today's possibilities. However, since there is no recycling process approved by EFSA, recycled plastics from WEEE cannot be used in food-contact applications.

Recyclates from plastic pose some challenges such as full traceability, potential misuse during the lifetime and the separation of FCM and non-FCM waste. These challenges require full value-chains solutions as they must tackle complex technical and logistical questions. At the same time, they must be able to provide the necessary guarantee on chemical safety and effectively increased recycling rates. For these reasons, the use of recycled plastics as FCM – except for bottle PET – hast not been successfully established. (Tandt et al. 2021)

PolyCE findings 	*Performed trials of recycled plastics origin from FCM material used in food grade applications were great success from a technical point of view. The material meets all technical requirements.*
Policy instruments 	*Waste Framework Directive*
Policy recommendations	
R10	*EU-wide harmonization of FCM approval, which is now still at the national level, pending entry into force of authorisations.*
R11	*Increased cooperation and communication between EFSA and the industry regarding necessary testing procedures and step-by-step transparent guidelines for waste processors and recyclers alike to conclusively achieve FCM-compliance for plastics recycling.*

5.8 Life cycle assessment (LCA) of PCR plastics

The presented results of the LCAs conducted in Task 8.4 and submitted in Deliverable 8.2 demonstrate that the environmental impact of plastic in a circular supply chain is reduced by 27 to 38 % compared to single use of plastic depending on the plastic type (see figure 6). In addition, the results of the LCA show that the potential environmental impact of a plastic component produced by injection moulding with recycled feedstock is reduced by 24 % compared to single use plastic.

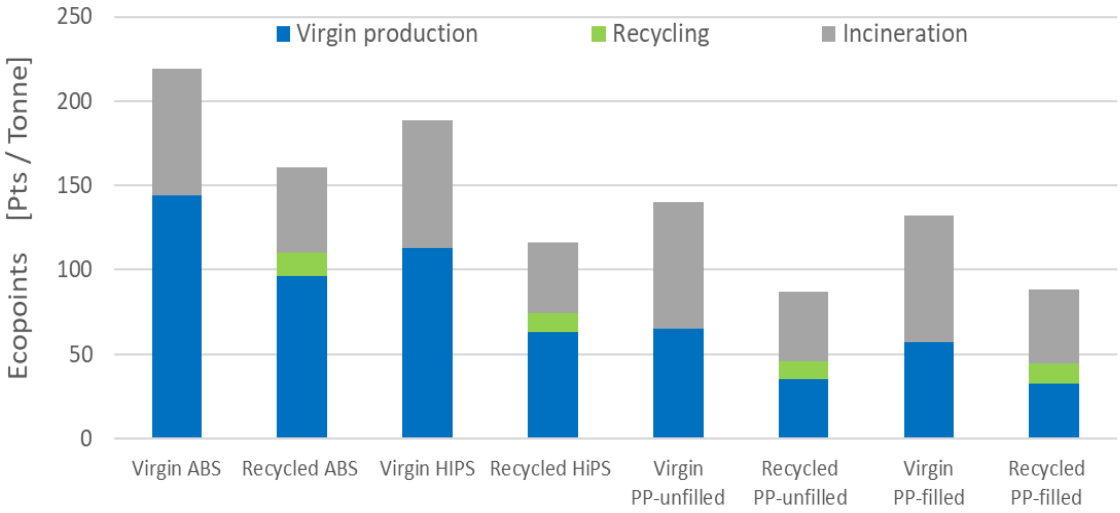

Figure 6: Comparing the environmental impact of single use virgin plastic and secondary use recycled plastic

Increasing the number of product clusters has a positive influence on the environmental burden associated with waste treatment of plastic in waste Large Household Appliances (LHA). The treatment of processing the waste in two product clusters (C&F and LHA*) lowers the environmental burden by almost 20 % compared to one single cluster (LHA). Removing products with a different plastic composition from both clusters, such as kitchen appliances and air conditioners, lowers the environmental burden by an additional 3 %. The sensitivity analysis revealed that this enhanced clustering scenario is highly sensitive to both the optic sorting efficiency during recycling and the input material composition.

Furthermore, different allocation procedures for the first and second use of plastic materials is compared to the current approach. In this study, from a circular economy perspective that envisions quality preservation, the burden is evenly distributed between the first and second use. However, commonly used allocation procedures redistribute the environmental burden based on the relative difference between virgin production and final waste treatment. Considering shared processes and evenly distributing the burden is a more appropriate approach as long as the material quality is preserved. If the quality of the material deteriorates during recycling, a material quality correction factor that reflects the potential limitations for the next use is more appropriate to adequately distribute the burden over the different lifecycles.

PolyCE findings 	*The LCA findings demonstrate the potential environmental benefits of using recycled plastics compared to single use plastics and of implementing clusters during LHA plastic recycling. Nonetheless, some limitations have to be considered in conjunction with these findings, namely the limitation of recycling systems to reduce the overall burden associated with products and the relevance of different allocation procedures when integrating recycling into an LCA.*
Policy instruments 	*Ecolabel and GPP, Product passport, Green taxonomy, Green Claims*
Policy recommendations	
R12	*Reducing the carbon footprint of products containing recycled plastics* - *For EEE products Ecolabel and GPP, set whole life cycle GWP maximum threshold (that will potentially reward the uptake of recycled contents)* - *Use PEF methodology to accelerate the setting of carbon footprinting information for products placed on the market (rather than 'reinventing the wheel' and delaying application)* - *Ensure Green claim on climate change can credit recycled plastic use with associated third party certification* - *Ensure product passport encompasses carbon footprinting (which de facto will credit the savings linked to recycled plastic use)*
R13	*Recognising the use of recycled plastic as sustainable sourcing (extended perspective versus carbon footprinting and virgin resources use reduction)* - *Reflect impact of sustainable sourcing in PEF beyond climate and material use (already the case)* - *If 'sustainable sourcing' criteria are set or a possible allegation in product policy (Ecolabel, GPP, product passport, green claims), recognise the use of recycled plastics as sustainable sourcing* - *If 'sustainable sourcing' criteria are set in criteria to qualify sustainable activity under the Green taxonomy (e.g the turn over dedicated to sustainable procurement), ensure it is recognised the use of recycled plastics as sustainable sourcing*

5.9 Export of WEEE and shipments of mixed WEEE plastic flakes

According to the latest statistics, the European plastic demand is almost 50 Mt (2016) of which 6.2 % (~3.1 Mt) is in Electrical and Electronics Equipment (EEE) sector (Plastics Europe 2018). While the plastic recycling rate has increased in recent years, considering that only about 35% of WEEE in Europe is collected through official schemes, there is a large amount of WEEE and the related plastic that is treated with not necessarily optimised-circular solutions (informal channels). (Accili et al. 2019; Baldé et al. 2017)
The challenge to foster the post-consumer recycled market is related to the significant part of WEEE stream generated in Europe that is still treated in sub-optimal manner within Europe or outside of it. According to Huisman et. al. annually 1.5 million tons leave EU. 200,000 tons are documented as export of used electrical and electronic equipment (UEEE), since it is legal to export functioning UEEE. The remaining 1.3 million tons are also predominantly UEEE (without a documented export) but are frequently mixed with WEEE before being exported. Based on literature resources it is estimated that 30 % of the remaining 1.3 million tons are WEEE (400,000 tons) (Huisman et al. 2015). A relevant environmental challenge related to the illegal – or even legal - WEEE flows concerns the mismanagement of plastics, notably those that are managed and disposed outside legal systems. Furthermore, the illegal management can undermine the recycled market. (Wagner 2018)

When it comes to the notifications implemented for mixed plastics from WEEE, experiences of plastic recyclers showed some issues with this regulation. This notification took a lot of time and cost to gets mixed plastic wastes shipped which differ from country to country. The following table shows the number of notification and the time average for import and export of our consortium partner MGG Polymers located in Austria:

	Number of notifications		***Throughput time average***		
Company	***Import***	***Export***	***Import***	***Export***	***Total Volume***
MGG Group	*56*	*12*	*90 days*	*135 days*	*165 kMT*

The number of notifications that are related to plastics are 35 of the 56 import notifications. The highest financial guarantee is close to 150 k€ and the highest costs for admin is close to 20 k€ for one single notification. One of the key problems with notifications is that the sourcing is unplannable as the throughput times of notifications can largely differ, for instance, they have one notification (for plastics) that took them 5 years to get.

The PolyCE partner MGG Polymers has the following experiences with notifications:

1. With one notification request the amount of paperwork to document the transporters alone was a file of 40 Mbyte
2. MGG Polymers have had several notification requests where the competent authorities asked for the costs of the treatment process, the revenues from sales and the costs of disposing their not recycled material. This does not give any insight on the environmentally sound treatment of the process.
3. Although they have an obligation to report all disposals and where they send this electronically to the ministry of environment in Austria (with annual on-site controls of the mass balances), they get requests by competent authorities in other countries to list all addresses of the locations where they are sending their disposal materials to. Competent authorities should only deal with the aspects of their areas of competence – i.e. the country in which they are based, why would you otherwise have competent authorities in each country?
4. In many cases MGG Polymers are now confronted with the need to apply notifications electronically locally and that these notification documents are sent by post to many other countries – which is double admin work.
5. The calculation of financial guarantees differs per country and sometimes even per region (Germany in particular) and the handling is not transparent.

6. The same counts for the admin costs.
7. In one notification MGG Polymers even had to reply to questions what and how the treatment was happening downstream from the receiver of the wastes, again in a different country.
8. Of the 5 notification requests for plastics that MGG Polymers did since January 1st, only two made were granted within the 3 months until April. These material flows were green listed before January 1st, as these suppliers already separated the BFR containing plastics. All material with the risk of containing BFRs more than 2000 ppm of Br, already had to be notified according to the Austrian interpretation of the Waste Shipment Regulation. In many countries also plastics with BFRs could travel as green listed waste before and you can imagine what a problem that means for these companies not having any experience at all with notifications.

The WEEE plastics recycling industry is much interested to get a concept accepted that they call Fast-Track Notifications, for which they ask much simpler rules and procedures, much less costly administration, and much quicker treatment, if the recyclable materials go to so called pre-consented treatment facilities. This is a status that is granted by the competent authorities for Waste Shipments to treatment facilities that have proven and have been checked to be compliant with all waste legislations.

PolyCE findings 	*Considering that the European collection rate is about 38%, there is a large amount of WEEE plastic that is not managed by documented operators. The remaining 62 % of WEEE is exported, recycled under non-compliant conditions in Europe, scavenged for valuable parts or simply thrown in waste bins by citizens.* *Due to the plastics delegated act implemented on 1st January 2021 all mixed WEEE plastic need notifications. This notification request for shipments across EU borders takes on average 3 months which lead to the issue that plastic waste shipments have become unplannable for plastic recyclers. In case of delivering to companies producing EEE products, the PCR plastics need to have a plannable production by plastic recyclers, what is prevented by these notifications.*
Policy instruments 	*Basel Convention and waste shipment regulation*
Policy recommendations	
R14	*With regard to the export of WEEE, the following adjustments should be made to the waste shipment regulation:* - *Ban or restrict the export of used EEE/WEEE to pre-consented facilities outside EU* - *Set conditions to export of used EEE, notably the association of EPR fees to ensure proper end of life management*
R15	*The EU needs Fast-Track Notifications with much simpler and harmonized business processes and waste classifications and without financial guarantees required for transporting non-hazardous wastes for recycling and without huge administrative costs for notifications.*

6 References

IEEE 1680.1-2018, 2018: 1680.1 Personal Computers - Environmental Assessment of Personal Computer Products Working Group.

IEEE 1680.2-2017, 2017: 1680.2 Imaging Equipment - Environmental Assessment of Imaging Equipment.

IEEE 1680.3-2017, 2017: 1680.3 Televisions - 1680.3 Environmental Assessment of Televisions.

Accili, A.; Campadello, L.; Vincenti, N.; Amade, A.; Arienti, G.; Sala, M. (2019): Quantification of material flows along the entire chain. PolyCE Deliverable 3.1. ECODOM.

Baldé, C. P.; Forti, V.; Gray, V.; Kuehr, R.; Stegmann, P. (2017): The global e-waste monitor 2017. Quantities, flows, and resources. Geneva: International Telecommunication Union.

Banti, Maria (2020): EU agenda on Circular Economy and Circular Electronics Initiative. European Commission. Online verfügbar unter https://www.bsef.com/wp-content/uploads/2020/11/Maria-Banti_CE-and-Circular-Electronics-Initiative_BSEF-002.pdf.

Berwald, A.; Dimitrova, G.; Nguyen, T. M.; Feenstra, T.; Onnekink, J.; Peters, H. et al. (2020): Guidelines on life cycle thinking integration and use of PCR plastics in new electronic products. PolyCE Deliverable 8.1. Fraunhofer IZM.

Boudewijn, A.T.P.; Peeters, J. R.; Duflou, J. R.; Cattrysse, D. (2019): Product clustering for improved collection, sorting and reprocessing and optimized recycling economics, high purity PCR plastics streams and uptake. PolyCE Deliverable 3.2. KU Leuven.

CEN/CENELEC (2021a): Standardization requests (Mandates). European Mandates. CEN/CENELEC. Online verfügbar unter https://www.cenelec.eu/aboutcenelec/whatwestandfor/supportlegislation/europeanmandates.html, zuletzt aktualisiert am 18.04.2021.

CEN/CENELEC (2021b): The Importance of Standards. CEN/CENELEC. Online verfügbar unter https://www.cencenelec.eu/research/tools/ImportanceENs/Pages/default.aspx#:~:text=Standards%20provide%20people%20and%20organizations,facilitating%20business%20interaction.

Council of the European Union (2019): Outcome of the Triple Conference of the Parties to the Basel (COP 14), Rotterdam (COP 9) and Stockholm (COP 9) Conventions (Geneva, 29 April - 10 May 2019). Online verfügbar unter https://data.consilium.europa.eu/doc/document/ST-10477-2019-INIT/en/pdf.

Dimitrova, Gergana (2017): Report on proposed Ecodesign Policy Concept and recommendation to strengthen Design for Recycling and the usage of post-consumer recycled plastics in new products. Deliverable D9.3 (intermediate version from November 29, 2017) of research project CloseWEEE, funded from the European Union's Horizon 2020 research and innovation programme under grant agreement No 641747. Hg. v. Fraunhofer IZM.

EFSA (2008): Guidelines on submission of a dossier for safety evaluation by the EFSA of a recycling process to produce recycled plastics intended to be used for manufacture of materials and articles in contact with food - Opinion of the Scientific Panel on food additives, flavourings, processing aids and materials in contact with food (AFC). EFS2 6, 7, 135. European Food Safety Authority (EFSA).

European Commission (2004): Regulation (EC) No 1935/2004 of the European Parliament and of the Council of 27 October 2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC. European Commission. Brussels, Belgium.

European Commission: Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). REACH.

European Commission (2006): Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). REACH-Regulation. Brussels, Belgium.

European Commission (2008a): Commission Regulation No 282/2008 of 27 March 2008 on recycled plastic materials and articles intended to come into contact with foods and amending Regulation (EC) No 2023/2006. European Commission. Brussels, Belgium.

European Commission (2008b): Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives. (Waste Framework Directive). European Commission.

European Commission (2011a): Commission Regulation (EU) No 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food. European Commission. Brussels, Belgium.

European Commission (2011b): Directive 2011/65/EC of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment. 2011/65/EC. RoHS-Directive. Brussels, Belgium.

European Commission (2012): Directive 2012/19/EU of the European Parliament and of the council. Online verfügbar unter https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0019&from=DE.

European Commission (2013): Voluntary Industry Agreement to improve the energy consumption of Complex Set Top Boxes within the EU. Version 3.1; 19 June 2013. European Commission.

European Commission (2014): Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement and repealing Directive 2004/18/EC. European Commission. Brussels, Belgium.

European Commission (2015): Industry Voluntary Agreement to improve the Environmental Performance of Imaging Equipment placed on the European Market. Version 5.2; April 2015. European Commission.

European Commission (2016a): Buying Green Handbook. 3rd Edition. European Commission. Brussels, Belgium.

European Commission (2016b): Commission Decision (EU) 2016/1371 of 10 August 2016 establishing the ecological criteria for the award of the EU Ecolabel for personal, notebook and tablet computers (notified under document C(2016) 5010). European Commission. Brussels, Belgium.

European Commission (2017): General Information about GPP. FAQ. European Commission. Online verfügbar unter https://ec.europa.eu/environment/gpp/faq_en.htm#framework2, zuletzt aktualisiert am 18.04.2021.

European Commission (2018): A European Strategy for Plastics in a Circular Economy. European Commission. Brussels, Belgium.

European Commission (2019a): Assessment report of the voluntary pledges under Annex III of the European Strategy for Plastics in a Circular Economy. Brussels, Belgium. Online verfügbar unter https://ec.europa.eu/docsroom/documents/34267.

European Commission (2019b): Ecolabel. European Commission. Online verfügbar unter http://ec.europa.eu/environment/ecolabel/, zuletzt geprüft am 23.07.2019.

European Commission (2019c): Regulation (EU) 2019/1021 of the European Parliament and of the Council of 20 June 2019 on persistent organic pollutants. POP-Directive.

European Commission (2019d): The European Green Deal. Brussels, Belgium.

European Commission (2019e): Voluntary Agreements under the Ecodesign legislation. European Commission. Online verfügbar unter https://ec.europa.eu/energy/en/voluntary-agreements-under-eco-design-legislation, zuletzt geprüft am 26.07.2019.

European Commission (2020): A new Circular Economy Action Plan For a cleaner and more competitive Europe. Brussels, Belgium.

European Commission (2021a): Implementation of the WEEE Directive. European standards. European Commission. Online verfügbar unter https://ec.europa.eu/environment/topics/waste-and-recycling/waste-electrical-and-electronic-equipment-weee/implementation-weee_en#ecl-inpage-649, zuletzt aktualisiert am 18.04.2021.

European Commission (2021b): List of signatories Circular Plastic Alliance. Online verfügbar unter https://ec.europa.eu/docsroom/documents/44551.

European Parliament (2006): Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). REACH-Directive.

GEN (2004): Introduction to ecolabelling. Information Paper. Global Ecolabelling Network (GEN).

Haarman, A.; Magalini, F.; Courtois, J. (2020): Study on the Impacts of Brominated Flame Retardants on the Recycling of WEEE plastics in Europe. SOFIES.

Huisman, Jaco; Botezatu, Ioana; Herreras, Lucia; Liddane, Mary; Hintsa, Juha; Di Cortemiglia, Vittoria Luda et al. (2015): Countering WEEE Illegal Trade (CWIT) Summary Report, Market Assessment, Legal Analysis, Crime Analysis and Recommendations Roadmap.

Jepsen, D.; Reihlen, A.; Sander, K.; Wirth, O. (2011): REACH und Kunststoffrecycling. Handreichung für eine sachgerechte Umsetzung der Reachanforderungen für Betreiber von Recyclinganlagen. Umweltbundesamt.

Kemna, R.; Azais, N.; van Elburg, M.; van der Voort, M.; Li, W. (2011): Methodology for Ecodesign of Energy-related Products (Part 1). MEErP. COWI Belgium spr, Van Holsteijn en Kemna B.V. (VHK.

Mugdal, S.; Tinetti, B.; Faninger, T.; Schischke, K. (2013a): Material-efficiency Ecodesign Report and Module to the Methodology for the Ecodesign of Energy-related Products (MEErP). Bio Intelligence Service.

Mugdal, S.; Tinetti, B.; Prado Trigo, A. de; Faninger, T.; Schischke, K.; Proske, M. et al. (2013b): Material-efficiency Ecodesign Report and Module to the Methodology for the Ecodesign of Energy-related Products (MEErP). Part 1: Material Efficiency for Ecodesign. European Commission - Enterprise and Industry; Fraunhofer IZM; Bio Intelligence Service.

Nordic Ecolabel (2019): The official ecolabel of the Nordic Countries. Nordic Ecolabel (Nordic Swan). Online verfügbar unter http://www.nordic-ecolabel.org/the-nordic-swan-ecolabel/, zuletzt geprüft am 30.07.2019.

DE-UZ 205-2017, 2017: Office Equipment with Printing Function (Printers and Multifunction Devices). Online verfügbar unter https://produktinfo.blauer-engel.de/uploads/criteriafile/en/DE-UZ%20205-201701-en%20Criteria-2020-06-02.pdf.

Plastics Europe (2018): Plastics - the Facts 2017. An analysis of European plastics production, demand and waste data. Plastics Europe.

DE-UZ 30a-2019, 2019: Products made from Recycled Plastics.

DE-UZ 160-2018, 2018: Routers. Online verfügbar unter https://produktinfo.blauer-engel.de/uploads/criteriafile/en/DE-UZ%20160-201801-en%20Criteria-2020-01-30.pdf.

Slijkhuis, C. (2021): E-Waste plastics recycling and its challenges. Presentation on the PolyCE workshop on circular electronic product developement. MGG Polymers.

Tandt, Ellen de; Demuytere, Cody; van Asbroeck, Elke; Moerman, Hiram; Mys, Nicolas; Vyncke, Gianni et al. (2021): A recycler's perspective on the implications of REACH and food contact material (FCM) regulations for the mechanical recycling of FCM plastics. In: *Waste management (New York, N.Y.)* 119, S. 315–329. DOI: 10.1016/j.wasman.2020.10.012.

TCO certified (2019): Join us in driving progress toward more sustainable IT products. TCO certified. Online verfügbar unter https://tcocertified.de/tco-certified/, zuletzt geprüft am 30.07.2019.

UNEP (2020): Basel Convention & Basel Protocol on Liability and Compensation. Text and Annexes (Revised in 2019). UNEP.

Villanueva, Alejandro; Eder, Peter (2014): End-of-waste criteria for waste plastic for conversion. JRC Technical Reports. Joint Research Centre (JRC).

Wagner, E. (2018): Map of market situation, derived barriers, drivers and information needs. PolyCE Deliverable 6.1.

Wagner, F. (2020): Batches of separated PCR that can be used for the tests planned in WP5. PolyCE Deliverable 4.4. KU Leuven.

DE-UZ 200-2016, 2016: Writing Utensils and Stamps.

Zygierewicz, A. (2017): The Ecodesign Directive (2009/125/EC). European Implementation Assessment. European Parliamentary Research Service (EPRS).