H2020-SC5-2018-2: PLASTICS TO BE CLEANED BY SORTING AND SEPARATION OF PLASTICS AND SUBSEQUENT RECYCLING OF POLYMERS, BROMINE FLAME RETARDANTS AND ANTIMONY TRIOXIDE

D1.1: LIMITATIONS, BARRIERS, STANDARDS FOR USING RECYCLED POLYMERS

Project details			
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ABBREVIATIONS

Table 1. list of abbreviations

Acronym	Definition	Acronym	Definition
ASTM	American society for testing and materials	EoW	End of waste
ABS	Acrylonitrile butadiene styrene	GA	Grant agreement
ATO	Antimony trioxide	HIPS	High impact polystyrene
BFR	Brominated flame retardant	PFR	Phosphoric flame retardant
CMR	Carcinogenic, Mutagenic, toxic for Reproduction	POP	Persistent organic pollutant
E&E	Electrical and Electronic	SVHC	Substance of very high concern
Echa	European Chemicals Agency	REACH	Registration evaluation authorisation and Restriction of chemicals
EFSA	European food safety authority	RoHS	Restriction of hazardous substances.
EU	Europe	WEEE	Waste electrical and electronic equipment
Sb	Antimony	Cd	Cadmium
Ba	Barium	Cr	Chromium
Br	Bromine	Pb	Lead

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EXECUTIVE SUMMARY

PLAST2bCLEANED will develop a circular loop for polystyrene plastics used in Electrical and Electronic Equipment. The waste plastics of this segment contain phased out hazardous compounds like flame-retardants, stabilizers and plasticizers. Sorting of the plastics with/without these hazardous compounds will enable mechanical recycling of the non-hazardous fractions. PLAST2bCLEANED will add a new physical recycling step to remove all hazardous substances of the sorted plastics (ABS and HIPS) and retrieve the bromine flame retardants and antimony trioxide for recycling. This will result in a clean, new ABS or HIPS, ready for use.

However, recycled materials must fulfil some requirements for their further use in industrial applications. This deliverable summarises the legal limitations and the thresholds for the sorting, the processing and the final recovery of products that need to be considered within PLAST2bCLEANED project development, as well as the main technical requirements for the reuse of the recycled plastics, ABS and HIPS, in new E&E application.

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1. INTRODUCTION

PLAST2bCLEANED (GA no. 821087) aims to develop a recycling process for WEEE plastics in a technically feasible, environmentally sound and economically viable manner. To fulfil this aim, PLAST2bCLEANED addresses the recycling of the most common WEEE plastics, acrylonitrile butadiene styrene (ABS) and high impact polystyrene (HIPS), that contain up to 20 wt.% brominated flame retardants (BFR) and up to 5wt% of the synergist antimony trioxide (ATO). PLAST2bCLEANED will close three loops: (1) polymer, (2) bromine, and (3) ATO.

PLAST2bCLEANED will develop a circular loop for polystyrene plastics used in Electrical and Electronic equipment. The waste plastics of this segment do contain phased out hazardous compounds like flame-retardants, stabilizers and plasticizers. Sorting of the plastics with/without these hazardous compounds will enable mechanical recycling of the non-hazardous fractions. PLAST2bCLEANED will add a new recycling step to remove all hazardous substances of the sorted plastics (ABS and HIPS) and retrieve the bromine and antimony fraction for recycling. This will result in a clean, new ABS or HIPS, ready for use. However, recycled materials must fulfil some requirements for their further use in industrial applications.

This deliverable D1.1 summarises all requirements that need to be considered within PLAST2bCLEANED project development:

- Legal limitations and thresholds for both sorting and processing the recovered plastics in final products.
- An overview of the status of WEEE-additives restrictions in the REACH, POP and RoHS regulations is presented.
- Purity requirements and limitations of feeding sorted WEEE materials in the polymer recovery and reprocessing processes to be developed in the project.
- The "end user" requirements for the reuse of recycled plastics, clean ABS, and HIPS granules, in new E&E applications.

Europe's aspiration for a Green Deal, and, as such, for promotion of plastics recycling, would benefit from a transparent and updated overview of all these legislations and directives for plastics recyclers. This exercise taught that there is no single information location. We hope this overview will contribute to the start of such an information database or site.

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2. P2BC GOALS

The overall aim of PLAST2bCLEANED is to develop a human and environmentally safe recycling process using a superheated dissolution process to remove undesirable contaminants from plastics used in electronic products in order to generate purified secondary plastics for new advanced applications in a technically feasible and economically viable manner. Three loops will be closed: plastics, Bromine and Antimony.

The purified plastics will be used for manufacturing new E&E parts, a washing machine doorframe and an inner liner of a household refrigerator's cabinet, while extracted bromine and antimony will be reused.

3. LEGISLATION

The screening of applicable legislation is limited to ABS and HIPS WEEE residues. Within this scope, other plastics or origins (like end of life vehicles or packaging) are excluded.

The different directives and legislations are constantly updated while reviewing new substances or reducing limits for reuse or unintentional traces. This overview states the situation of February 2020.

3.1 RELEVANT LEGISLATION OVERVIEW: SPECIFIC E&E REGULATIONS

Waste of electrical and electronic equipment (WEEE) such as computers, TV-monitors, fridges, and cell phones is one of the fastest growing waste streams in the EU[1].

The Global E-waste Monitor 2017[2], a joint effort of the ITU (United Nations specialized agency for information and communication technologies), the United Nations University (UNU) and the International Solid Waste Association (ISWA), provides the most comprehensive overview of global e-waste statistics. The global quantity of e-waste generation in 2016 was around 44.7 million metric tonnes (Mt), or 6.1 kg per inhabitant. It is estimated that in 2017, the world's e-waste generation will exceed 46 Mt. The amount of e-waste is expected to grow to 52.2 Mt in 2021, with an annual growth rate of 3 to 4%.

[1] E-waste: An overview on generation, collection, legislation and recycling practices, Amit Kumara,∗, Maria Holuszkoa, Denise Crocce Romano Espinosa in 'Resources, Conservation and Recycling' 122 (2017) 32–42

[2] https://www.itu.int/en/ITU-D/Climate-Change/Pages/Global-E-waste-Monitor-2017.aspx#FullReport

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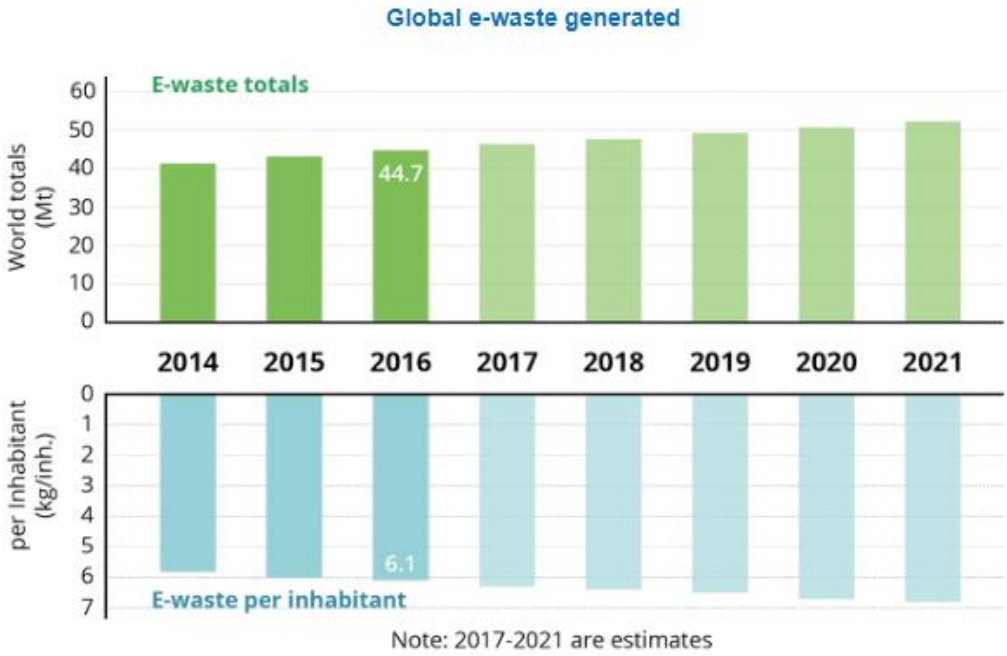

Figure 1: Global e-waste generated according to 'Global E-waste monitor 2017'

To address the need for proper collection, and treatment and clear identification of the hazards in this waste stream, two pieces of legislation are in place in Europe:

- the Directive on waste electrical and electronic equipment (**WEEE Directive**) and
- the Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (**RoHS Directive**).

WEEE DIRECTIVE (Directive 2002/96/EC and 2012/19/EU[3]) provided, in most member states, a system of collection schemes in which consumers return their discarded appliances free of charge. These schemes aim to increase the recycling of WEEE and/or re-use.

This legal framework uses the principle of Extended Producer Responsibility, which requires producers to organise and/or finance the collection, treatment, and recycling of their products at end-of-life.

The Directive requires that plastics containing brominated flame retardants be removed from WEEE, and subsequently properly treated.

PLAST2bCLEANED creates new processes to recycle plastic wastes compliant with these principles.

[3] European Commission (7/4/2012): Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE)Text with EEA relevance. WEEE2. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0019&from=EN

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THE ROHS DIRECTIVE (2011/65/EU[4]) restricts the use of certain hazardous substances in electrical and electronic equipment. It regulates "that EEE placed on the market does not contain the substances which are listed." Substances used in E&E are assessed, listed, reviewed and, if needed, restricted.

RoHS legislation determines the maximal concentrations for re-use in electrical and electronic equipment put on the market.

3.2 RELEVANT LEGISLATION OVERVIEW: GENERAL EU LEGISLATION

EU wants to protect consumer's health and wants to provide environmental safety by different initiatives:

- The European Commission's (EC) White Paper of 2001 on a 'future chemical strategy' proposed a system that requires chemicals manufactured in quantities of greater than 1 tonne to be 'registered', those manufactured in quantities greater than 100 tonnes to be 'evaluated', and certain substances of high concern (for example carcinogenic, mutagenic and toxic to reproduction - CMR's) to be 'authorised'. In 2006 **Reach** was born.
- Next to this long-term initiative to review all chemical substances, EU adopted the principles of the **Stockholm convention** to avoid the use of persistent organic pollutants on short term.

The recycled products have to comply with both regulations.

REACH (EC 1907/2006) aims to improve the protection of human health and of the environment through the accurate and early identification of the intrinsic properties of chemical substances. This is done by the four processes of REACH, namely the **R**egistration, **E**valuation, **A**uthorisation, and **R**estriction of chemicals. The process is in the hands of ECHA.

Anything classified as 'waste' is actually exempt from the REACH legislation – it's only if recycled materials are to be reclassified as no longer waste (= "end of waste") that the REACH provisions come into effect.

Registration and evaluation phases do not have any impact on our project.

The **authorisation process** aims to ensure that less dangerous substances or technologies progressively replace substances of very high concern (SVHCs) where technically and economically feasible alternatives are available.

The REACH Regulation requires that ECHA recommends priority substances from the "Candidate List", for inclusion in **Annex XIV** of REACH (the "Authorisation List"). For these substances, the REACH regulation proposes Annex XIV entries (i.e. transitional arrangements and, where relevant, exemptions and review periods) to the European Commission.

This list includes all substances that have been included in ECHA's draft or final recommendations for inclusion of Candidate List substances in Annex XIV of the REACH Regulation. Regular reviews of substances at the end of the evaluation phases lead to an update of the XIV list.

[4] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32011L0065&from=nl

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Substances on the candidate list can be used in mixtures and articles, but there is an obligation to provide information, such as:

- a safety data sheet- communication on safe use
- responding to consumer requests within 45 days and
- notification of ECHA if the article they produce contains an SVHC in quantities above one tonne per producer/importer per year, and if the substance is present in those articles above a concentration of 0.1% (w/w).

Restricting the use of substances mostly happens after authorization, when all authorized applications are phased out.

Annex XVII to REACH includes all the restrictions adopted in the framework of REACH and the previous legislation, Directive 76/769/EEC. Each entry shows the substance or group of substances or the mixture, and the conditions of their restriction.

The list of restrictions contains those substances (on its own, in a mixture or in an article) for which manufacture, placement on the market or use is limited or banned in the European Union.

PLAST2bCLEANED aims to filter out the restricted substances from ABS and HIPS, ensuring that the substances are below the regulatory limits.

STOCKHOLM CONVENTION on persistent organic pollutants was adopted on 22 May 2001 in Stockholm, Sweden, and entered into force on 17 May 2004. The convention takes measures to reduce and ultimately eliminate the release of POPs. It restricts several substances formerly used in E&E applications. In the mean time this agreement is transposed in EU legislation under POP Recast Regulation (EU)2019/1021.

POPs or persistent organic pollutants are organic chemical substances. They possess a **specific** combination of physical and chemical properties that causes them to remain intact for exceptionally long periods of time, once released in the environment . They become widely distributed throughout the environment and accumulate in the fatty tissue of living organisms. They are toxic to both humans and wildlife.

When a new product is put on the market, or waste is sold as raw material, substances of **Annex I**[5] have to be avoided. This annex is to be applied for all products, not only for E&E applications.

Waste with POPs content higher than the POP concentration limits in **Annex IV**[6] of the regulation must be disposed of or recovered in such a way that the POP content is destroyed or irreversibly transformed. Therefore, the remaining waste does not contain the POP substances above the regulatory limits. Disposal or recovery operations that may lead to recovery, recycling, reclamation, or re-use of the POP on their own, is prohibited.

Within this project, all POPs are expected to be recovered and transformed into new brominated substances that are not persistent or toxic pollutants after the treatment. Thus, the concentration of POPs in recycled plastics is also expected to be below restriction limits.

[5] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R1021&from=EN

[6] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R1021&from=EN

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3.3 Recycled polymers & BFR (Restriction limits)

Considering all expected additives in ABS and HIPS, different directives and regulations have been screened. The results of this screening are summarized in Table 2. We anticipated future decisions of ECHA, deciding on additional SVHC substances.

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Table 2: Overview of the substances of WEEE and restriction limits (ppm)

Substance ID			Regulation limits					Comments		
Substance name	EC number	CAS number	SVHC	XIV	XVII	RoHS	POP I/IV	Reason for entry	Comments on substance	Remark
2-ethoxyethanol	203-804-1	110-80-5	1000					Toxic for reproduction	Solvent	
2-methoxyethanol	203-713-7	109-86-4	1000					Toxic for reproduction	Solvent	
Bis(pentabromophenyl) ether (decabromodiphenyl ether)	214-604-9	1163-19-5	1000		1000	1000	*500*	PBT - vPvB	Bromine-Based Flame Retardant	*Limit related to sum of tetra, penta, hexa, hepta and decaBDE*
1-Methyl-2-pyrrolidone (NMP)	212-828-1	872-50-4	1000		3000			Toxic for reproduction	Solvent	
Hexabromocyclododecane (HBCDD)	-	-	1000	3000				PBT	Bromine-Based Flame Retardant	
gamma-hexabromocyclododecane	-	134237-52-8	1000	3000			100	PBT	Bromine-Based Flame Retardant	
beta-hexabromocyclododecane	-	134237-51-7	1000	3000			100	PBT	Bromine-Based Flame Retardant	
1,2,5,6,9,10-hexabromocyclodecane	221-695-9	3194-55-6	1000	3000			100	PBT	Bromine-Based Flame Retardant	
Hexabromocyclododecane	247-148-4	25637-99-4	1000	3000			100	PBT	Bromine-Based Flame Retardant	
alpha-hexabromocyclododecane	-	134237-50-6	1000	3000			100	PBT	Bromine-Based Flame Retardant	
Tetrabromodiphenyl ether	254-787-2	40088-47-9				1000	*500*	PBT - vPvB	Bromine-Based Flame Retardant	*Limit related to sum of tetra, penta, hexa, hepta and decaBDE*
Pentabromodiphenyl ether	251-084-2	32534-81-9				1000	*500*	PBT - vPvB	Bromine-Based Flame Retardant	*Limit related to sum of tetra, penta, hexa, hepta and decaBDE*
Hexabromodiphenyl ether	253-058-6	36483-60-0				1000	*500*	PBT - vPvB	Bromine-Based Flame Retardant	*Limit related to sum of tetra, penta, hexa, hepta and decaBDE*
Heptabromodiphenyl ether	273-031-2	68928-80-3				1000	*500*	PBT - vPvB	Bromine-Based Flame Retardant	*Limit related to sum of tetra, penta, hexa, hepta and decaBDE*
Polychlorinated Biphenyls (PCB)	-	1336-36-3					50	Carcinogenicity, mutagenicity, repro	Chlorine-Based Flame Retardant	
Hexabromobiphenyl	-	36355-01-8				1000	50	Carcinogenicity, mutagenicity, repro	Bromine-Based Flame Retardant	
Cadmium and its compounds	-	-			100	100		Carcinogenicity, suspected mutager	PVC Stabilisers and Colourants	
1,6,7,8,9,14,15,16,17,17,18,18-Dodecachloropentacyclo[12.2.1.16,9.02,13.05,10]octadeca-7,15-diene ("Dechlorane Plus"™)	-	-	1000					vPvB	FR for all purposes. When used (10 - 30%)	Proposed as POP
rel-(1R,4S,4aS,6aR,7R,10S,10aS,12aR)-1,2,3,4,7,8,9,10,13,13,14,14-dodecachloro-1,4,4a,5,6,6a,7,10,10a,11,12,12a-dodecahydro-1,4:7,10-dimethanodibenzo[a,e]cyclooctene	-	-	1000					vPvB	FR for all purposes. When used (10 - 30%)	
1,6,7,8,9,14,15,16,17,17,18,18-dodecachloropentacyclo[12.2.1.16,9.02,13.05,10]octadeca-7,15-diene	236-948-9	13560-89-9	1000					vPvB	FR for all purposes. When used (10 - 30%)	
rel-(1R,4S,4aS,6aS,7S,10R,10aR,12aR)-1,2,3,4,7,8,9,10,13,13,14,14-dodecachloro-1,4,4a,5,6,6a,7,10,10a,11,12,12a-dodecahydro-1,4:7,10-dimethanodibenzo[a,e]cyclooctene	-	-	1000					vPvB	FR for all purposes. When used (10 - 30%)	
Lead and its compounds	-	-			1000	1000		Toxic for reproduction	Currently, lead is restricted in RoHS and Jewellery. In PVC restriction will become applicable	
Tris(2-chloroethyl) phosphate	204-118-5	115-96-8	1000	3000				Carcinogenic, toxic to reproduction	Flame retardant	
Perfluorobutane sulfonic acid (PFBS), its salts and related substances	-	-	1000					Suspected PBT/vPvB	Flame retardant used in PC	
Hexavalent Chromium	-	-			1000	1000			Chromium might be present in plastics. Whether it is hexavalent or not is another question	
2,2',6,6'-tetrabromo-4,4'-isopropylidenediphenol (TBBPA)	201-236-9	79-94-7	Not yet entered			in evaluation			Bromine-BPA -Based Flame Retardant	Under evaluation for PBT, ED.
1,1'-(ethane-1,2-diyl)bis[pentabromobenzene] (DBDPE)	284-366-9	84852-53-9	Not yet entered						Bromine-Based Flame Retardant	Under evaluation for PBT, vPvB
1,1'-[ethane-1,2-diylbisoxy]bis[2,4,6-tribromobenzene] (BTBPE)	253-692-3	37853-59-1	Not yet entered						Bromine-Based Flame Retardant	Likely to meet the following criterias : carcinogenicity, mutagenicity, or reproductive toxicity
HexaBromoBenzene	201-773-9	87-82-1	Not yet entered						Bromine-Based Flame Retardant	Likely to meet the following criterias : carcinogenicity, mutagenicity, or reproductive toxicity
Cocarboxylase	205-836-1	154-87-0	Not yet entered						Flame retardant	Likely to meet the following criterias : carcinogenicity, mutagenicity, or reproductive toxicity
Tris(2-chloro-1-methylethyl) phosphate	237-158-7	13674-84-5	Not yet entered						Flame retardant	Under assessment for Endocrine Disrupting
Triphenyl phosphate	204-112-2	115-86-6	Not yet entered						Flame retardant and plasticizer	Under assessment for Endocrine Disrupting
Tris(methylphenyl) phosphate	215-548-8	1330-78-5	Not yet entered						Plasticizer	Likely to meet the following criterias : carcinogenicity, mutagenicity, or reproductive toxicity

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3.4 Food Directive

One demonstrator chosen for this project is a liner of a refrigerator. This part is subjected to a food contact evaluation. This section describes the food contact requirements for recycled plastics. The complete EFSA process will not be described in this document.

Most relevant is the **COMMISSION DIRECTIVE 2002/72/EC**[7], relating to **plastic materials and articles intended to be exposed to foodstuffs**. Directive 2002/72/EC lays down the list of monomers and starting substance authorised, to the exclusion of all others (positive list) to be used in the manufacture of plastic food contact materials or articles. Only materials and articles complying with the provisions laid down in Directive 2002/72/EC should be used as input for the recycling process. This can be achieved by sorting the plastic articles before recycling. For certain materials, such as poly-olefines, due to their physico-chemical properties, 100 % sorting efficiency may be necessary to ensure recycled plastic that complies with the requirements of Article 3 of Regulation (EC) No 1935/2004. This sorting efficiency can be achieved in product loops which are in a closed and controlled chain. For other materials, for example, PET the safety of the recycled plastic can be ensured with a lower sorting efficiency as regards to its former use in food contact which is realistically achievable from kerbside collection systems. The sorting efficiency necessary for each material should be identified on a case by case basis.

Reuse of recycled plastics is regulated by **COMMISSION REGULATION (EC) No 282/2008** [8]of 27 March 2008 on recycled plastic materials and articles, intended to come into contact with foods and amending Regulation (EC) No 2023/2006. This regulation is more explicit regarding potential reuse:

Recycled plastic used behind a plastic functional barrier as defined by Directive 2002/72/EC should not be covered by the authorisation procedure in this Regulation. The rules set out in Directive 2002/72/EC for substances used behind a plastic functional barrier are regarded as sufficient to ensure the safety also of recycled plastics used behind a functional barrier.

We choose for the use behind a functional barrier.

'Food contact'

The Framework Regulation (EC) No 1935/2004 [9]"on materials and articles intended to come into contact with food ..." lays down the requirements for this product class (Art. 3) and, at the same time, establishes the manufacturing conditions to be observed in production plants.

The central point of reference for the evaluation of pigments and fillers is Article 3(1)

> ...Materials and articles shall be manufactured in compliance with good manufacturing practice, so that, under normal or foreseeable conditions of use, they do not transfer their constituents to food in quantities, which could:
>
> a) endanger human health; or
>
> b) bring about an unacceptable change in the composition of the food; or

[7] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32002L0072&from=EN

[8] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008R0282&from=nl

[9] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32004R1935&from=EN

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c) bring about a deterioration in the organoleptic characteristics thereof.

The raw materials of primary products are thus evaluated in terms of their use in the final product. Decisive here is the release (migration) of substances in respect of sub points (a), (b) and (c) under normal and foreseeable conditions.

The final products of the PLAST2bCLEANED project will not be exposed to food in the refrigerator, since we provide a final coating of primary material. However, we anticipate the possibility that conditions for recycling would change in future. Regulations that are more explicit regarding the potentially remaining additives give us an insight of the gap to close.

The use of colorants or additives in plastics is not yet regulated by a dedicated EU Directive or Regulation. In preparation of a common regulation, the Council of Europe adopted Resolution **AP (89) 1** containing **purity requirements for colorants in plastic materials intended to come into contact with foodstuffs.**

AP (89) 1 itself has no legal force, but the limit values have been incorporated into most national provisions.

Sb : 0.05 %	Cr: 0,1 %
As : 0.01 %	Pb: 0.01 %
Ba: 0.01 %	Hg: 0.005 %
Cd: 0.01%	Se: 0.01 %

Table 3: EU Resolution AP (89) lists the maximum contents of the metals and metalloids **soluble** in 0.1M of hydrochloric acid

To complete the overview, the Directive 98/83/EC [10]- quality of water intended for human consumption ('Drinking Water Directive; DWD) has to be mentioned.

This directive asks to ensure that no substances used in the preparation or distribution of water intended for human consumption, remain in water intended for human consumption in concentrations exceeding the foreseen limits.

Max 5 µg/L antimony-content

Max. 10 µg/L Bromate content.

[10] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31998L0083&from=EN

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4. P2BC PROCESSES REQUIREMENTS

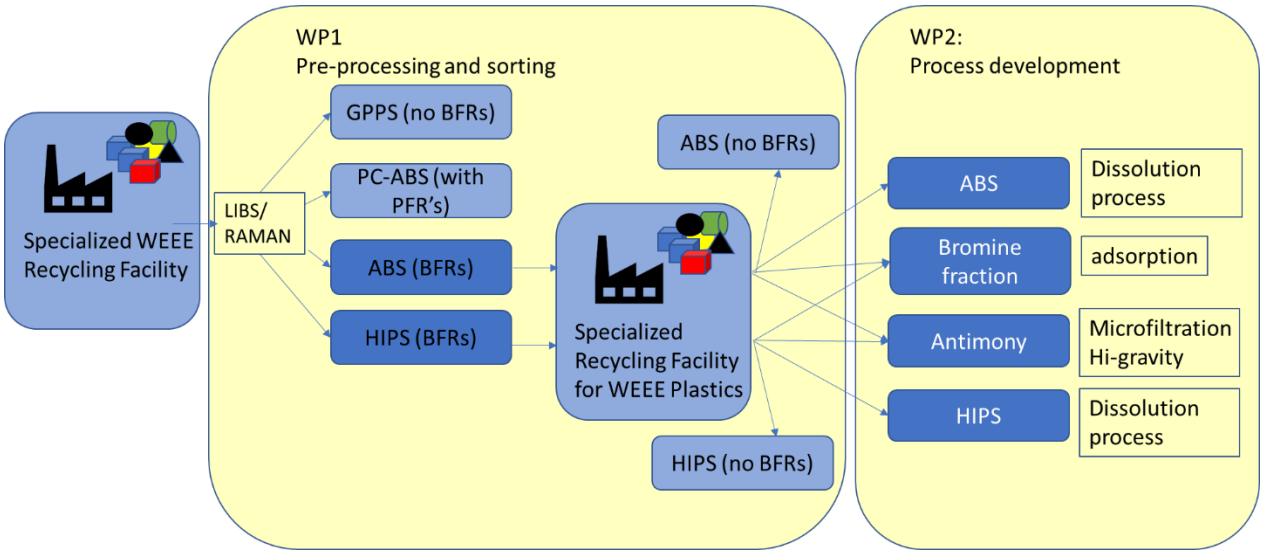

Figure 2: Overview of the PLAST2bCLEANED process.

The PLAST2bCLEANED process, given in Fig. 2, will consist of a pre-treatment of the waste material and the dissolution process with the separate removal of the bromine and the additive fraction. The additive fraction will mainly consist of the flame-retardant synergist antimony trioxide.

In this early stage of the project, an inventory of the different contaminations, mix-ups, and additives expected in the WEEE fractions, has been compiled to be aware of the problems that could generate in the purification process and their impact on that process.

The result of this review is given in Table 4.

After evaluation, we decided to include:

- extra filtration of fibrous material to prevent potential blocking.
- pre filtration of hard (sub-millimetre) particles to prevent damage to reactors/filters
- paying attention to the presence of sticky material.

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Table 4: Overview of the contaminations and ingredients of the WEEE waste.

Name	Range in the fraction (%)	Typical	Relevance	Category	Origin (starting point sorted heavy fraction at the end of sorting line Coolrec)
Dirt	0-1			Impurity	Residual from the sorting process
Non-ABS or HIPS plastics	0-5		major	Polymer impurity	Will influence the solubility efficiency.
Moisture	Depends on the fraction		relevant	Impurity	Water is critical for solubility -
Copper/aluminum	0-2	<0,1	minor	Metals	Metals from cables,
Glass fiber	cfr formul	<0,1%	minor	Filler	Filler use a reinforcement to improve the stiffness of the material
Talc	cfr formulation of the polymer		minor	Filler	Filler use a reinforcement to improve chemical resistance, stiffness and impact of the material.
Ti02	cfr formulation of the polymer		minor	Pigment	Responsible for the white colour. Highly present in fridge plastics.
Salt	0-0.5			Impurity	Residual from the density separation process;
Dust	0-1		minor	Impurity	Polymer dust or natural dust.
Synthetic or natural rubber	0-5			Polymer impurity	As an additive for improving the elasticity properties or as an impurity.
Wood	0-2	<0.1%	low	Impurity	Impurity from the diverse products
Foams	0-2	<0.1%	low	Impurity	Residual foams
Br flame retardant	cfr formulation of the polymer		major	Additive	In heavy fraction signicant mainly in ABS and HIPS
Cl flame retardant	cfr formu	<0.1%	very low	Additive	
P flame retardant	cfr formulation of the polymer		relevant	Additive	In heavy fraction significant mainly in PC/ABS and HIPS/PPO
Polychlorinated biphenyl		<0,1%	very low	Impurity	Used in capacitors and in transformers due to heat and pressure resistance
Paint			minor	Surface modification	For aesthetic
Metallic coating			minor	Surface modification	For aesthetic and mechanical puroposes
Foils	0-2	<0.1%	minor	Impurity	Residual impurity in the plastic fraction
Sn	cfr formulation of the polymer			Additive	synergist for PVC additive
Cadmium	cfr formulation of the polymer		very low	Additive	Can be used as a pigment for red (cadmium selenide) yellow color mainly old ABS
Lead	cfr formulation of the polymer		relevant	Additive	Can be used as a pigment for orange (lead chromate molybdate) and yellow (lead chromate)
Fabric	0-1		very low	Impurity	Reinforcement in composite material
Carbon black	0,20%		relevant	Pigment	
Calcium carbonate				Filler	Use to improve mechanical properties and to ease the processing (improved thermal conductivity)
Graphite	0,20%		relevant	Pigment	
Glue from stickers				Impurity	
Paper	0-3			Impurity	From labelling
Printed circuit board	0-2		very low	Impurity	Attention to be cariied on the circuit board coating (foils)
Iron oxide				Pigment	Responsible for the red colour
Chromium oxide				Pigment	Responsible for the green colour
Hexavalent chromium				Pigment	Clear red, orange, yellow and green colours (anti-corrosive treatment)
Cork	0-2		very low	Impurity	Residual impurity in the plastic fraction
Concrete and ceramics	0-2			Impurity	Residual impurity in the plastic fraction
Fungicide	0-1			Additive	
Barium sulfate	cfr formulation of the polymer			Filler	Used as a filler and as a white pigment

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5. END USERS´ REQUIREMENTS ACCORDING TO P2BC TARGETS

The recycled HIPS and ABS, purified by the PLAST2bCLEANED process, will be used in a washing machine and a refrigerator. In cooperation with Elix and Electrolux, the requirements for using these materials in those applications were gathered. Table 5 gives an overview of the main mechanical properties of standard grade polymers, which will be used as targets for the recycled polymers.

Table 5. Overview of properties

Properties	Method	HIPS Electrolux	ABS Elix
MVR (melt volume rate)	Iso 1133	At 200°C, 5kg 2.8 cm³/(10min)	at 220°C, 10 kg 5- 37 cm³/ (10 min)
Tensile modulus (1mm/min)	Iso 527-1,-2	1600 MPa	>1900 MPa ± 10%
Tensile strain at break at 50 mm/min.	Iso 527-1,-2	-	>10 %
Tensile strength at break	Iso 527-1,-2	25 MPa	-
Charpy impact strength notched	Iso179-1eA	11 kJ/m²	>5 kJ/m² at 23°C
Density	Iso 1183	1,04 g/cm³	1,04-1,10 g/cm³
Temperature of deflection	Iso 75-1,-2	-	>93° C ± 5 % under load of 1,8 MPa

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6. REGULATORY GAPS

Echa made some overviews for recyclers, such as the 'guidance on waste and recovered substances[11]'. These initiatives are appreciated, but have to be kept update.

Next to the need for overview of legislation, we would like next gaps to be closed:

European end-of-waste criteria for plastics:

End-of-waste (EoW) status is a legal status where waste legislation stops to apply, and product legislation starts to apply. A status needs to be applied for, and it should be officially documented. The Waste Framework Directive sets the frame for this status, but unfortunately, it is not defined in a specific manner.
For some waste streams, Europe has already published EoW criteria. These are a set of rules and limits that need to be complied with in order to declare the EoW status. Where there are no European rules, national rules apply. The waste national legislation can be very different from one country to another, leading to the possibility that one country does not accept the EoW status declared by another.
In order to get recycled plastics generally accepted by the public as a raw material, a well-defined European wide EoW criterion is needed. EoW criteria in Europe will lead to a broader acceptance outside the EU, since EU law is generally viewed positively in the world.

Common database of potential substances per polymer:

A centralized tool should be established to combine the different substances and their regulations. In order to ensure the compliancy of the recycled plastics to the legislation, the material must be tested. Not all substances are expected in all polymers on the market. Some substances are polymer specific. A list of substances likely to be present in a polymer fraction should be compiled, so the recycler knows what to test and to look for in the produced materials (list per styrenics, polyolefins…). This tool would help the recycler to monitor and ensure the safety of its output fraction. A good start for this is the IEC 62474 database in which all regulated substances for energy related products are mentioned.
ECHA launched a database, the SCIP, Substances of Concern In articles as such or in complex objects (Products) established under the Waste Framework Directive (WFD), where all producers must register all substances of concern per product, per part. This database could be the beginning of a classification as mentioned in this paragraph, but it is not yet known in what the direction it will develop.

Standardized method for screening REACH/ RoHS / POP substances:

According to the exhaustive number of substances restricted, some guidance regarding the testing and quantifying of those elements should be expected. Unfortunately, no methods of screening substances are yet officially released. In order to improve the safety and compliancy of the recycled plastics, a common method should be developed and used monthly by the recycler. A precise monitoring of the waste will ensure the release of compliant plastics on the market. Being transparent regarding the recycled material composition will communicate the right message regarding the safety of the recycled plastics and therefore lead to an increase of the recycling rates.

[11] https://echa.europa.eu/documents/10162/23036412/waste_recovered_en.pdf

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Standardized method to ensure representative sampling and analysis of mixed plastic wastes:

Sampling is key in order to obtain representative results. In the field of recycling, the material is heterogeneous. To increase the accuracy of the results, a proper sampling process (including size reduction in order to be able to analyse) must be performed including items of all sizes expected in the output stream and it shall be representative of the entire population. A standardized method including the following should be established:

- volume to be sampled per material size
- volume and size of material per analysis type
- method of sample size reduction keeping representativeness
- sample preparation per analysis type

A common method of analysis and sampling will make the technical characteristics of the recycled material comparable in the market and hence more accessible for the producers.

7. CONCLUSIONS

The PLAST2bCLEANED project puts targets in place, in accordance with the legislator framework.

Achieving the targets for Bromine will be the most challenging.

Table 6 summarizes the maximum Bromine content after the dissolution process in the cleaned ABS and HIPS.

Table 6. Targets PLAST2bCLEANED recycled plastics

Properties	Target
Bromine as HBCD	< 38 ppm
Bromine in total	< 380 ppm

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