Limitations, Barriers, Standards and Regulatory Gaps for Using Recycled Polymers in new EEE

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CloseWEEE

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Summary

This document defines the European and local, legal and non-legal limitations, barriers and standards associated with using recycled polymers in new WEEE. It has been produced by considering available literature and (will consider) results of surveys which are conducted as part of WP10 activities. The main conclusions to be drawn from the study are as follows:

- Materials to be reused in new products need to contain less than 0.1% of 6 restricted materials listed in RoHS except cadmium (less than 0,01 %).
- The Ecodesign directive doesn't appear to affect use or re-use of different materials in target products – the directive has a greater impact on design affecting energy consumption The ecodesign directly is currently under review. Recourse efficiency requirements are discussed, but not finalised yet. Topics under discussion are: demonstration of disassembly, information requirements about the use of brominated flame retardants. For recycled plastics that could have an impact if it needs to be proven that no Br-contamination is present. It should be discussed and investigated to what extend we could technically guarantee a maximum limit of Br- contamination.
- Recovered materials need to comply with REACH – This is a requirement for the use of re-use of materials in new products
- HIPS and not PS appears to be more widely used in electronics products
- Correct use or disposal of BFR requires evaluation.
- Some labels restrict the use of BR containing plastics. The ecoflower label (**2009/300/EC)** restricts the use of FR agents with listed Risk Phrases in plastic parts. Same is valid for the *Blaue engel* label.
- Some plastic manufactures have commercial plastic grades that are 'ecoflower compliant'. Unfortunately, also the ecoflower label is under revision.

Next to legislation, each manufacturer of electronics has its own policy towards the use recycled plastics. TPVision has an obligation towards Philips ('brand licence agreement') to set targets for sustainability and for the use of recycled plastics. These targets are not yet communicated. They are communicated for other Philips products.

On the site of Philips target for SDA are reported:
http://www.philips.com/about/sustainability/ourenvironmentalapproach/greeninnovation/closingthematerialsloop.page See also the annual report which can be downloaded from this link:
http://www.philips.com/about/sustainability/integratedannualreport/index.page

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1 Executive Summary

1.1 Description of the deliverable content and purpose

The main goal of the CloseWEEE project is to increase the range and yield of recovered materials from WEEE streams – materials which can then be re-used for practical applications. An important aspect of this, is the separation and recovery of different Brominated Flame Retardant (BFR) and non-BFR plastics. This document has been prepared to enable the partners involved in the separation and recovery technologies development to better understand some of the requirements for re-use of the produced materials from both legal and non-legal perspectives. Additionally, the document will help support exploitation activities.

In the first section of the document an overview of the separated and recovered materials is given. The following materials are considered:

- BFR-ABS (Brominated Flame Retardant + Acrylonitrile Butadiene Styrene)
- BFR-PS (Brominated Flame Retardant + Polystyrene)
- PC-ABS (Polycarbonate + Acrylonitrile Butadiene Styrene)
- PPE-PS (Polyphenylene Ether + Polystyrene)

With BFR compounds being largely eliminated from use in new products, the following materials are assessed for re-use in new products:

- PC-ABS
- PPE-PS

In the second section of the document an overview of the different applications of the different polymers is given. For this section, direct sampling of recycled materials, although potentially useful, is not envisaged to give an accurate representation of the products going on to the market today – thus the aim is to look at products being manufactured today (or very recently) - and will be recycled in the future. Plastics from the following consumer electronic appliances are assessed more closely:

- Flat Panel Displays (FDP): Televisions
- Small Domestic Appliances (SDA): Mobile phones
- Information and Communications Technologies (ICT): Laptops

In the following sections of the document legislation and standardisation governing the use of the recycled plastics in the aforementioned products is discussed.

The main conclusions to be drawn from the study are as follows:

- Materials to be reused in new products need to contain less than 0.1% of 6 restricted materials listed in RoHS except cadmium (less than 0,01 %).
- The Ecodesign directive doesn't appear to affect use or re-use of different materials in target products – the directive has a greater impact on design affecting energy consumption. See my earlier remark. Directive under review.
- Recovered materials need to comply with REACH – This is a requirement for the re-use of materials in new products
- HIPS and not PS appears to be more widely used in electronics products
- Correct use or disposal of BFR requires evaluation.

1.2 Reference material

This document contains data from the following CLOSEWEEE documents:

- CloseWEEE Description of Work (1)
- CloseWEEE Grant Agreement (2)

1.3 Abbreviation list

ABS	Acrylonitrile Butadiene Styrene
ASTM	American Society for Testing and Materials
BFR	Brominated Flame Retardants
BFR-ABS	Brominated Flame Retardant Acrylonitrile Butadiene Styrene –
BFR-PS	Brominated Flame Retardant Polystyrene
BS	British Standard
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardisation
CFR	Chlorinated Flame Retardant
CLP	Classification, Labelling and Packaging
DeBDE	Decabromodiphenyl ether
DoW	Description of Work
EEE	Electrical and Electronic Equipment
EIP	European Innovation Partnership
ESO	European Standardisation Organisation
EN	European Standard
ETSI	European Telecommunications Standards Institute
EU	European Union
FPD	Flat Panel Displays
FR	Flame Retardant
GPPS	General Purpose PolyStyrene
HBCD	Hexabromocyclododecane
HF	Halogen Free
HFFR	Halogen Free + Flame Retardant
HIPS	High Impact Polystyrene
ICT	Information and Communications Technologies
IET	International Electrotechnical Commission
ISO	International Organisation for Standardisation
OcBDE	Octabromodiphenyl ether

OEM	Original Equipment Manufacturer
ODM	Original Design Manufacturer
PBB	Polybrominated Biphenyls
PBDE	Polybrominated Diphenyl ether
PC-ABS	Polycarbonate + Acrylonitrile Butadiene Styrene
PPE	Polyphenylene Ether
PeBDE	Pentabromodiphenyl ether
PMMA	PolyMethyl Metacrylate
POM	Polyoxymethylene
PPE-PS	Polyphenylene Ether + Polystyrene
PPO™	Polyphenylene Oxide (see PPE)
PFR	Phosphorous Flame Retardants
PS	Polystyrene
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RoHS	Restriction of Hazardous Substances
SAN	Styrene AcryloNitryle
SDA	Small Domestic Appliances
SDS	Safety Data Sheet
TBBPA	Tetrabromobisphenol-A
UL	Underwriters Laboratories
US	United States of America
WEEE	Waste Electrical and Electronic Equipment

2 Limitations/Barriers - Materials Market - Production

The evaluated materials have been assessed because of their common function and use in electronic products such as TVs, laptops and mobile phones.

2.1 PC-ABS

PC-ABS blends are some of the most widely used thermoplastics. PC and ABS are blended because the resulting blend has desirable properties from both materials. Normally, ABS will lend itself better to application where properties like processability, stability in flame retardant processing and chemical stress resistance are important. PC is better for heat distortion resistance and impact resistance. A blended product takes properties from both PC and ABS whilst also having UV light colour stability, low temperature impact and good ductility.

The ratio of PC and ABS in PC-ABS blends varies according to the requirements of the application. For example, in the late 1970s the company Dow Chemical developed a blend with a 30-40 wt% PC, 2-25 wt % ABS and 45-55 % rubber-modified SMA. A decade later, Sumitomo developed PC-ABS blends with 50 % part of each one with a small amount of an acid or an anhydride. In the same decade were developed by BASF a blend with 90 %wt ABS with a high deflection temperature (HTD), good mechanical, tensile and impact properties (3). But in commercial PC/ABS content normally does not exceeds 25 %wt ABS with loadings up to 0,5 wt in additive (4). Commercially, many different blends are available. SABIC, one of the market leaders, offers numerous blends with different properties according to the requirements of the applications (5). The produced blends have applications in the automotive industry in addition to their use in a variety of electronics applications including (6);

- Portable handhold devices
- Laptop enclosures
- Keyboards, monitors, and printer enclosures
- TV backcovers
- Keypads
- Adapters and chargers
- TV frames
- Mobile phone bodies

The market for PC-ABS production is dominated by big manufacturers. They often tend to take up registered trademark status on their products which are then sold through numerous resellers. Manufacturers (and their products) include:

Table 1 PC-ABS Manufacturers

Manufacturers	**Product**
Stratasys,	-
Sabic	Cycoloy®
Perrite (A. Schulman)	Ronfalin C
Trinseo	Pulse®
Bayer	Bayblend®
Ravago Plastics	Mablex ®
RTP	-
Styron	Emerge™

Manufacturers	Product
Romira	Romiloy ®

Other potential manufacturers include: Teijin, Bayer, Styron, Mitsubishi, LG Chem, BASF, Chimei, RTP, Daicel, Network, Spartech, Kumhosunny, Kingfa, Pret, Juner, Fu-day, FLX, Qide, Dellon, Wotlon, Guangda, Selon and Lihan.

The market for consumption (electronic devices only) is more fractured and includes phone, camera, and computer equipment manufacturers. Refer to applications section for more information.

2.2 PPE-PS

PPE-PS blends have a range of attractive properties. They combine the benefits of PPE resin including affordable high heat resistance, good electrical properties, excellent hydrolytic stability and the ability to use non-halogen FR packages, with excellent dimensional stability, good processibility and low specific gravity including impact strength, good dimensional stability, excellent aesthetics and heat resistance (7).

Because of their properties they are used in a wide range of applications including structural parts, electronics, household and automotive items. The main applications in electronic products are as TV back covers, and in lower quantities, other TV components, such as deflection yokes, fly back transformers and bobbins.

Table 2 - PPE-PS Manufacturers

Manufacturer	Product Range	Main Applications
Sabic	Noryl™	Telecommunications, enclosures/circuits breakers, uninterrupted power supply batteries, chassis and indoor enclosures, fiber optic connectors, connectors, automotive, instruments panels.
PRL resins	PPX resin	Not available in manufacturer webpage
Romira	Luranyl®	Functional electrical parts such as switches, transformers housing, deflector-coil formers for TV sets.
Asahi Kasei Chemicals Coporation	Xyron™	CD-room chassis, printer carriages, flyback transformers, AC adapters cases, connectors jacks, LED cases

It should be noted that some PPE-PS blends may be highly suitable for reprocessing/re-use. Sabic claims that Noryl™ resin may have a high retention of properties when processed multiple times,

under recommended processing conditions, and without contamination. This not only applies to its mechanical and thermal properties, but also to its flammability.

2.3 BFR plastics

In the past, BFRs have often been used in electronic products to slow down the spread of fire. Two plastic compounds which incorporate BFRs are target fractions for removal in the CloseWEEE project (BFR-ABS and BFR-PS). However, although the separation of some BFRs (PBDE, PBB) is required by RoHS, there are many indications that all BFRs are being phased out from new products on the market and re-use of these compounds in new electronic products is quite infeasible.

A list with the main BFR used in EEE is shown below:

- Tetrabromobisphenol-A (TBBPA) 4,4-(1-methylethylidene)bis-(2,6-di-bromophenol). It is the largest selling brominated flame retardant, it is produced by the bromination of bisphenol-A. Commercial TBBPA is available in two grades, an epoxy resin grade and a higher quality polycarbonate grade. TBBPA is a reactive flame retardant; both hydroxyl groups can be reacted with epichlorohydrin under basic conditions to form the diglycidyl ether, which is widely used in epoxy resin formulations. TBBPA is also used in polycarbonate and ether polyester resins requiring low color and good clarity. (8)
- Pentabromodiphenyl ether (PeBDE). Because of the chemical and toxic properties of its main components, isomers of tetrabromodiphenyl ether (TetraBDE) and pentabromodiphenyl ether (PentaBDE), and their wide spread occurrence in the environment and in humans PeBDE causes concern in many regions in the world. Commercial pentabromodiphenyl ether (C-PentaBDE) refers to mixtures of bromodiphenyl ether congeners in which the main components are 2,2', 4,4'- tetrabromodiphenyl ether (BDE-47 CAS No. 40088-47-9) and 2,2',4,4',5- pentabromodiphenyl ether (BDE-99 CAS No. 32534-81-9), which have the highest concentration by weight with respect to the other components of the mixture. In Europe is banned since 2004. (9)
- Octabromodiphenyl ether (OcBDE) is the common name used for the commercial polybrominated diphenyl ether product that contains approximately 79% by weight of organically bound bromine. The term Polybrominated Diphenyl Ether (PBDE's) refers to a group of halogenated compounds formed by substituting hydrogen with bromine on a diphenyl ether molecule. This compound in banned in Europe and until production was stopped, this substance was mainly used as flame retardant in ABS type plastics, which were used in consumer and commercial electronics and office equipment. Commercial OctaBDE only contained 30-35% (by weight) molecules with exactly 8 bromine atoms. The majority of the diphenylethers molecules contain 6-9 bromine atoms, with small (<0.1%) amounts of molecules with 5 bromine atoms. (10)
- Decabromodiphenyl ether (DeBDE) belongs to polybromodiphenyl ether group. Only deca-BDE is currently commercially available since the marketing and use of penta- and octa-BDE was banned throughout the EU in 2004 due to the potential to bioaccumulate in the environment. Flame retardants such as deca-BDE are added to materials to increase their resistance to burning. Deca-BDE is used in electrical equipment, including casings for televisions, computers, audio/visual equipment and mobile phones. (11)
- Hexabromocyclododecane (HBCD) is a brominated flame retardant produced in Europe, US and Asia. The only HBCD production site in Europe is in the Netherlands. It consists of a mixture of stereoisomers of 1,2,5,6,9,10-hexabromocyclododecane ranging from oils to an isomer with a 205 – 208 ◦C melting point. Commercially available HBCD contains a mixture of solid isomers and has a melting point range of 170 – 180 ◦C (185 – 195 ◦C). The main use for HBCD is as an additive-type flame retardant for extruded and expanded polystyrene foam. Other applications include crystal and high-impact polystyrene, SAN resins, adhesives, and coatings. (8) (12)

A 2010 report by ChemSec detailed the current use and intentions of many different electrical and electronic goods manufactures with regards to the use of PVC and BFRs in their products. They noted that, even in 2010, the electronics industry had already started to replace BFR substances in their products. The following table summarises the use (2010) and intended use (2014) of BFRs in products from different organisations (ref. Chemsec)

Table 3 - Use and intended use of BFRs in laptops

Company	Product	Model	2010	Planned for 2014
Panasonic	Notebook/laptops	All	No data	BFR free
Toshiba	Notebook/laptops	All	Almost BFR free	BFR free
Apple	Mac Book Pro	All	BFR free	BFR free
HCI Infosystems	Notebook/laptop	ME Series 40	BFR free	BFR free
HP	Notebook/laptop	All (except below)	Almost BFR free	BFR free
HP	Notebook/laptop	ProBook 5310m	BFR free	BFR free
Acer	Notebook/laptop	All reported	Almost BFR free	Almost BFR free
Dell	Notebook/laptop	All	Almost BFR free	BFR free
Nokia	Mini-laptop	Booklet 3G	No data	BFR free
Asus	Notebook/laptop	Eee PC 900A	BFR free	BFR free
LG	Notebook/laptop	All	Almost BFR free	BFR free
Lenovo	Notebook/laptop	Notebooks	Almost BFR free	BFR free
Samsung	Notebook/laptop	Notebooks	No data	BFR free
Sony	Notebook/laptop	All reported	Almost BFR free	Almost BFR free

Table 4 - Use and intended use of BFRs in mobile phones

Company	Product	Model	2010	Planned for 2014
Panasonic	Mobile Phones	All reported	Almost BFR free	BFR free
LG	Mobile Phones	All (except below)	Almost BFR free	BFR free
LG	Mobile Phones	GD510	BFR free	BFR free
Toshiba	Mobile Phones	All reported	Almost BFR free	BFR free
Nokia	Mobile Phones	All reported	BFR free	BFR free
Sony Ericsson	Mobile Phones	All	BFR free	BFR free
Apple	Mobile Phones	All	BFR free	BFR free
Sharp	Mobile Phones	All reported	Almost BFR free	BFR free
Motorola	Mobile Phones	All (except below)	Almost BFR free	BFR free
Motorola	Mobile Phones	Motocubo A45 eco	BFR free	BFR free
Asus	Mobile Phones	P565 PDA Phone	BFR free	BFR free

Table 5 - Use and intended use of BFRs in TVs

Company	Product	Model	2010	Planned for 2014

Toshiba	LCD TV	CELL REGZA 55 x	Almost BFR free	BFR free
LG	LCD TV	All (Europe)	Almost BFR free	BFR free
Samsung	LCD TV	All	No data	No data
Sharp	LCD TV	All reported	Almost BFR free	BFR free
Phillips	Flat TV	All	Almost BFR free	BFR free

Some companies, such as Sony Ericsson and Apple, say they have already minimised the use of BFR in their products and the Swedish NGO ChemSec noted that a wide range of alternatives exist for most applications. There are three main categories of halogen-free flame retardants that could be the substitute compounds of BFR in future: inorganics, which include mainly metal hydroxides like aluminium hydroxide and magnesium hydroxide; phosphorus-based compounds such as phosphonates and phosphinates; and nitrogen-based substances, including melamine and melamine derivatives, which are often used in combination with phosphorus-based flame retardants. (13)

In summary, there is likely to be no market for re-use of BFR polymers as most companies are driving towards eradication of CFR and BFR compounds in their products. Plastics manufactures are unlikely to supply BFR compounds. Sabic, a market leader in plastics productions appears to no longer to offer BFR (or CFR) products and instead offer other non-brominated, non-chlorinated flame retardant compounds.

2.4 PS

Polystyrene is a thermoplastic polymer made from styrene monomer. It is a light-weight polymer (about 95 % air). This polymer is generally rigid and inexpensive and has very good insulation properties.

There are several different types of polystyrene: crystal PS, expandable polystyrene, general purpose polystyrene (GPPS) and high impact polystyrene (HIPS). In EEE is used HIPS, this polymer is produced adding rubber or butadiene copolymer, which increases the toughness and impact strength of the polymer and has a good processability and chemical resistance. Their main applications are in injection moulded articles used for electric and electronic equipment, household appliances and for manufacturing of thermoformed refrigerator parts, vacuum-fomed packagings for diary industry. The main use in EEE is in television backs and domestic electrical appliances, and as housings for electrical equipment (including PCs). (8)

In Table 6 are shown the main manufacturers and their commercial trademarks.

Table 6. Manufacturers of HIPS

Manufacturer	Product
Polimeri Europa (Eni)	Edistir®
Sabic	Noryl®
Saudi Polymers	Valtra®
LG Chems	HIPS 60HI grade
Dioki	Dioki® High Impact Polystyrene

Edistir® polymer used in electrical and electronic application is Edistir® SR 550 AND Edistir® R 850 E and Rt 461 F (TV). Valtra® MA5210 is used in TV and HIPS 60 HI Grade is used in TV cases, small electric appliances and electric and electronic parts.

2.5 ABS

Acrylonitrile-butadiene-styrene is an important polymer with numerous applications. ABS and HIPS represent the industrially most important thermoplastic two-phase system with an amorphous structure. This thermoplastic polymer has special properties, such as: high impact toughness, thermally stable, unlimited shaping characteristics, and limited stability to UV radiation. The main uses are: casings for office machinery, electrical industry, electronics, telecommunications, and protective insulating components. (8) Within electrical and electronic industry, the main use is in telephone handsets, keyboards, monitors, computer housings. (14)

As it is shown in Figure 1, ABS is the main fraction in recyclable plastics from WEEE.

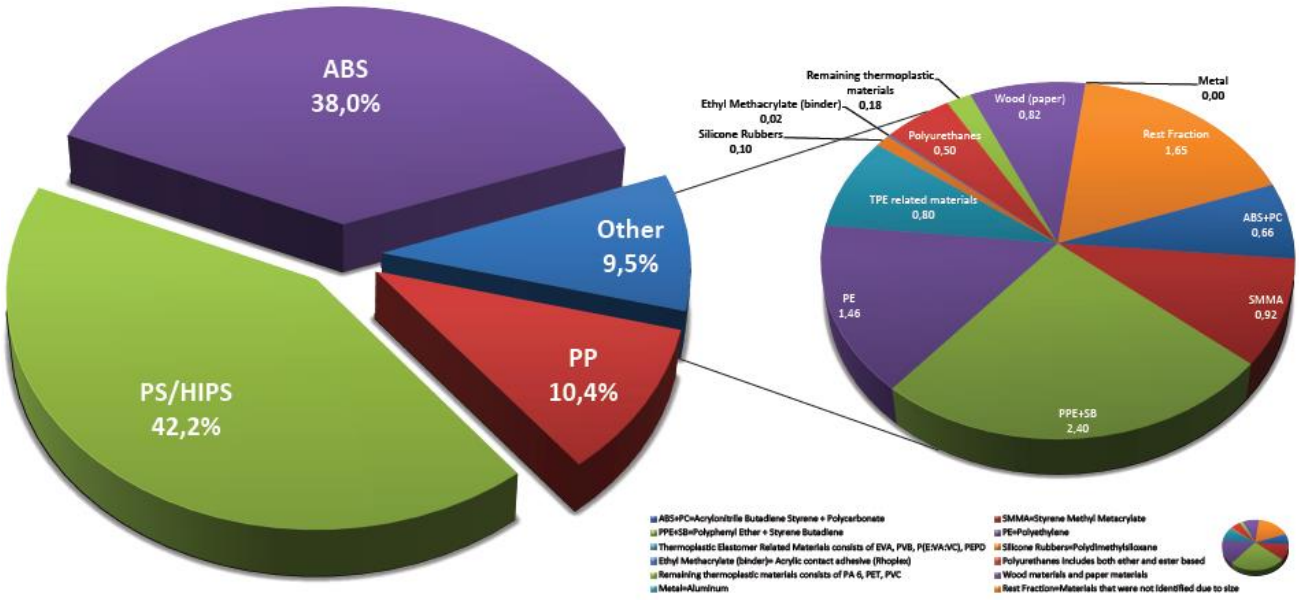

Figure 1. Composition in the recyclable plastic fraction from WEEE[1] (15)

Leading manufacturers of ABS are shown in Table 7.

Table 7. Leading manufacturers of ABS (16)

Manufacturer	Product
Bayer	
Sabic-GE plastic	Cycolac®
BASF	Terluran® GP-22, Terluran® GP-35, Teluran HI10®
Dow Chemical	Magnum™
LG Chem	Flame retardant grade ABS
Techno Polymer Co (JSR Corporation and Mitsubishi Chemical)	

ABS polymers have different grades according to the final use. Sabic has more than 20 different types of ABS resin Cyclolac®. Properties of this polymer vary according to the amount of butadiene and additives. (17)

3 Limitations/Barriers - Materials Market - Applications

Bearing in mind the target materials to be separated in the CloseWEEE project, applications have been briefly assessed to understand the demand for these materials in the different applications.

[1] Samples collected from a 600 kg batch in Sweden (2011).

3.1 Flat Panel Display Backcovers (FPD)

Flat Panel Displays are present in everywhere in daily live: mobile phones, notebooks, monitors, TVs, traffic signal and electronic signage… (18) The market of flat panel displays has grown in the last decade. In Table 8 is shown the world-wide market of FPD in the year 2000.

Table 8. FPD market in year 2000 (19)

Type of flat panel display	Number of units
Liquid crystal display (LCDs) with segmented characters	1,470,000,000
Super-twisted nematic liquid crystal displays (STN-LCDs)	45,000,000
Liquid crystal displays (AM-TFT-LCDs) with active matrix thin film transistor addressing)	48,000,000
Organic electroluminescent displays (OLEDs)	300,000
Plasma display panels (PDPs)	630,000
Fields emission displays (FEDs)	540,000
Inorganic semiconductor light-emitting diodes (LEDs)	181,000,000
Vacuum fluorescent displays (VFDs)	166,000,000
Total	1,900,000,000

A flat panel display may be several millimetres up to centimetres thick. The most important technologies used to create a FPD are LCD and OLED technologies. (OLED still very low quantities, LED is the bulk, and that will remain like this for at least a few years; the shift towards OLED is much slower than expected.)

3.1.1 Televisions

Plastics are used in the casings of flat panel display televisions– with the majority of the plastic is found on the back of the TV. A 2012 paper, written as part of the collaborative research project (which included TP Vision as a partner), PRIME (20) found that the CloseWEEE target materials made up a fraction of the plastics most commonly found in flat screen TVs in waste streams (2012). Graphical representation of the plastics found in LCD televisions in waste streams in 2012 is shown in the figures below.

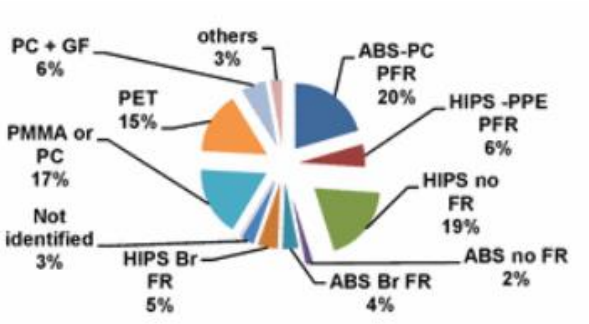

Figure 2 -Plastics of LCD TVs

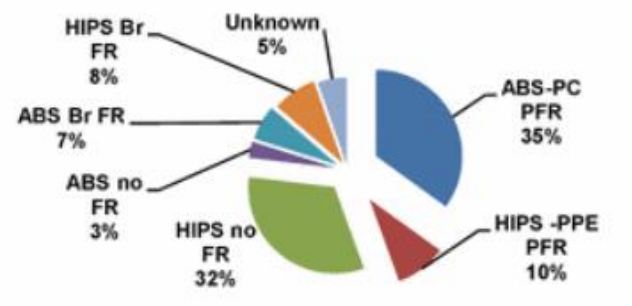

Figure 3 – Plastics of backs LCD FTVs

CloseWEEE target material ABS FR (ABS Br FR) makes up on only 4% of plastics in TVs and another CloseWEEE target material, PC-ABS (no FR) in televisions was not reported at all. In comparison, PC-ABS PFR (ABS-PC PFR) was far more common - PC/ABS in TV application is always used as a blend with phosphorous flame retardant. Other CloseWEEE target materials, PS-FR and PPE-PS, were also not reported. However, variants HIPS FR (HIPS-BR-FR), HIPS (HIPS no FR) and HIPS-PPE-FR (HIPS-PPE-PFR) made up a large fraction of the plastic materials in LCD TVs.

The same report noted that the average lifetime of TVs was 6.8 years. Average life time does not mean that the TV's are already discarded after 6.8 years. Will be used in other rooms, or stored in a basement, storage room. In this sense, a significant amount of the TVs which will be processed using CloseWEEE technologies will have actually been manufactured more recently than the report suggests. Unfortunately, data on production materials of current TVs is not easy to source without manufacturer input (what is meant exactly? - main plastic used in TV backcovers is still PC-ABS FR. Other smaller and thinner parts inside the display module may include (glass) fiber reinforced plastics (GF PC). Top TV manufactures in the world include:

- Samsung: Samsung Electronics Co., Ltd. is a South Korean multinational electronics company headquartered in Suwon, South Korea. It has been the world's largest information technology company by revenue since 2009. Samsung has been the world's largest manufacturer of LCD panels since 2002, the world's largest television manufacturer since 2006, and world's largest manufacturer of mobile phones since 2011.
- LG: LG Corporation is another South Korean multinational company which makes electronic, chemical and telecom products. This company develops electronic advances, mobile communications and appliances. This company maintains the 14 % of the market share in TV during 2015.
- TCL. It is a Chinese TV company which has increase the market share in the last year. In 2014 was the fourth TV trademark with 6.1 % market share.
- Sony. Sony Corporation is a Japanese multinational company and one of the leaders in electronic products: audio and video, pc, photo, games, mobile phones and professional products. In reference to TVs market share, in 2014 it was 6.8 % (third in top 10 TV market).
- Hisense. Hisense Ltd is a Chinese multinational dedicated to services and electronic products. Its market share is 6 %.
- Skyworth. Skyworth Group Corporation is a Chinese company established in 1988 in Hong Kong. It is a large-scale high-tech corporation mainly engaged in the development and manufacturing of consumption electronics, display devices, digital set top box, security monitors, network communication, semi-conductors, fridges and washing machines, 3C

digital, LED lighting…This company has grown has one of the leaders in color TV brands in the world. In 2014, its market share was 4.8 %.

- Toshiba. Toshiba is an electronic and electrical products company placed in Japan. Although in 2013 was number 9 (3.9 % share) in top 10 TV brands, in 2014 did not appear in this ranking.
- AOC/ TP Vision. TV Vision is a company within visual digital entertainment. It is fully committed to the renowned Philips TV brand. TP Vision engages in developing, manufacturing and marketing Philips branded TV sets in Europe, Russia, Middle East, Brazil, Argentina, Uruguay, Paraguay and selected countries in Asia-Pacific excluding China. In 2013 its market share was 3.9 %.
- Panasonic. Panasonic Corporation is a Japanese company, previously called Matsushita Electric Industrial Co., Ltd. This company was created in 1918 and currently is one of the biggest electronic products manufacturers in the world with Sony, Hitachi, Toshiba, Sharp and Canon.
- Sharp. Sharp Corporation is a Japanese company, established in 1912, which manufactures electronic products. Between its products, the most sold products are LCD TVs (Sharp Aquos brand), mobile phones, microwaves, sound systems, home cinemas, air purification systems, faxes and calculators. In 2014 was the number 9 in top 10 TV brands with 3.4 % market share.

3.2 Small Domestic Appliances (SDA)

Small domestic appliances refer to a variety of domestic appliances that are portable or semi-portable or used on platforms. They are intended to perform, enable or assist in performing a job or changing a status (21). Are considered SDA a wide range of products such as: phones, remote controls, digiboxes, electronic toys, kettles, hairdryers, mini stereos, electric toothbrushes, shavers, small kitchen appliances, irons, clocks and any other small electrical items. (22)

3.2.1 Mobile phones

The major part of the polymers used in mobile phones appears in the plastic casing. This is usually made of compounds such as PC, ABS or the blend PC-ABS, which often appear along with brominated flames retardants that are dangerous for the environment and human health. (23). Mobile phone charger is also covered by a plastic casing and contains BFR.

The main mobile phone manufacturers are: (24)

- Samsung
- LG
- Motorola
- HTC
- Apple
- Microsoft
- Sony
- Blackberry

However, there are a long list of companies that also manufacture mobile phones: Nokia, Huawei, Lenovo, Xiaomi, Alcatel, Asus, Acer, Amazon, ZTE, Google, Oppo, Meizu, Gigabyte, Pantech, Fly, Gionee, OnePlus, Toshiba, Viewsonic, Barnes&Noble, Panasonic, Nvidia, HP, Sony Ericsson, Siemens, Mitsubishi….

The basic polymers PC, ABS or blends of them may further contain glass fibres that improve mechanical stiffness. In addition, this plastic contains additives for better flow and processing, heat

and UV protectants, other stabilizers, and inorganic or organic colorants. There may also be other blends such as copolymers PC and siloxane. (25)

The typical materials found in a mobile phone and the average percentage of them are listed below: (26)

- **PC-ABS: 20 %**
- Copper: 19 %
- Silica, soda, lime (glass): 11 %
- Aluminium: 9 %
- Iron: 8 %
- Polymethyl Methacrylate (PMMA): 6 %
- Silicon dioxide (SiO2): 5 %
- Epoxy: 5 %
- PC: 4 %
- Silicon: 4 %
- Polyoxymethylene (POM): 2 %
- Polystyrene: 2 %
- Tetrabromobisphenol-A (TBBA): 2 %
- Nickel: 1 %
- Liquid Crystal Polymer (LCP): 1 %
- Gold, palladium and silver are represented as other metals as less than 1 %.

The general composition is usually 40 % metals, 40 % plastics and 20 % ceramics. (26)

3.3 Information and Communication Technologies (ICT)

Information and Communication technologies is a term that includes any communication device or application: radio, TV, mobile phones, computer and network hardware and software, satellite systems and services and applications associated with them. It has revolutionized modern living, international business, global governance, communication, entertainment, transport, education, and health care. This has been driven by unprecedented high volumes of production and usage of consumer electronic products, in particular, personal computers, mobile phones, and television sets. Access to ICT has been identified as an indicator of a country's economic and social development. (27)

3.3.1 Laptops

Most branded producer (particularly laptops) do not in fact manufacture many/any of the components for their laptops but in fact utilise a quite limited number of (mostly Taiwan based) ODMs as outlined in Table 9 (28);

Table 9 - Notebooks manufactured in 2013

Manufacturer	Reported units sold (millions)
Compal	46.0
Quanta	43.1
Wistron	24.0
Inventec	20.9
Pegatron (Spun off from Asus) (owner of ASRock)	14.0
Others (Clevo, MSI, Mitac, Arima, Hon Hai, Elitegroup)	Not defined

In turn, often the components, including cases (enclosures), for laptops are manufactured by another company again, yet it will most likely be the manufacturers which dictate the material requirements and required properties – thus they are targeted in market surveys.

Determining actual content of PC/ABS in laptops helps determine the potential market. This varies from laptop to laptop so the best-selling laptops have been analysed. CRN reported that HP were the best-selling laptop brand in the first quarter of 2014 and HPs bestselling laptop was the Elitebook 8470p (29) – however, although limited information about the laptop case available sources report the use of ABS cases and not a specifically PC-ABS blend cases in the majority of current HP products – this does not necessarily mean that PC-ABS is not used – just that it may not be specified. The following brands and machines were found to incorporate some PC/ABS in their cases:

Table 10 - Laptops with cases containing PC/ABS (30) (31)

Brand	**Model**
Lenovo (32)	Thinkpad: L440, L450, 11e, E450, E455, E550, E555
Dell	Latitude: D800 (magnesium and PC/ABS) (33)

By checking the selling price of different laptops and materials used in the casing, we can speculate that generally PC-ABS is used in mid-range laptops – high-end laptops tend to use ABS – which is slightly more expensive than the PC-ABS blend. Some manufacturers of slim-line laptops may be moving towards use of other materials which maintain functionality with lower material thickness (34).

4 Standardisation

Standards represent an agreed method of doing something – and they usually specify what information is required by the organisations which they represent. In this sense, it is important that the CloseWEEE activities adhere to the standards since this will facilitate up-take of e.g. produced materials.

There are several groups of standards which are important to consider whilst considering re-use of the materials recovered in the Close-WEEE project. They are discussed in the following pages.

4.1 Materials Safety Requirements

BS EN 62368-1 – part 1, is the British publication of the European standard IEC 62368-1. It contains the requirements for design and manufacture of safe audio/video, information and communication technology equipment. It is nearly identical to the related European standard.

As outlined in the standard, the standard is applicable to *electrical and electronic equipment within the field of audio, video, information and communication technology, and business and office machines with a rated voltage not exceeding 600V.* As such, all proposed CloseWEEE applications fall within scope of the standards.

The standard contains several clauses which are relevant to the use of plastics in new products which should potentially be considered in the developments of the CloseWEEE project. The relevant clauses and their descriptions are detailed below:

Standard Section *4.4.4 Safeguard robustness*

Standard Section *4.4.4.1 General*

Where a solid safeguard (for example, an enclosure, barrier, solid insulation, earthed metal, glass, etc.) is accessible to an ordinary person or to an instructed person, the safeguard shall comply with the relevant robustness tests as specified in 4.4.4.2 to 4.4.4.9.

Relevant sections are detailed as follows (where referenced, Clause T1, T2, T…. are detailed later in this document):

Standard Section *4.4.4.2 Steady force tests*

An enclosure or barrier that is accessible and that is used as a safeguard of: – transportable equipment; and – hand-held equipment; and – direct plug-in equipment; shall be subjected to the steady force test of Clause T.4.

For all other equipment, an enclosure or barrier that is accessible and that is used as a safeguard shall be subjected to the steady force test of Clause T.5. There are no requirements for the bottom of equipment having a mass of more than 18 kg unless the user instructions permit an orientation in which the bottom of the enclosure becomes the top or a side of the equipment.

A safeguard that is accessible and that only acts as a fire enclosure or barrier shall be subjected to the steady force test of Clause T.3.

Standard Section *4.4.4.3 Drop tests* *The following equipment shall be subjected to the drop test of Clause T.7: – hand-held equipment; – direct plug-in equipment; – transportable equipment; – movable equipment requiring lifting or handling by an ordinary person as part of its intended use, including routine relocation; NOTE An example of such equipment is a paper shredder that rests*

on a waste container, requiring its removal to empty the container. – desk-top or table-top equipment having a mass of 7 kg or less that is intended for use with any one of the following:

- *a cord-connected telephone handset, or*
- *another cord-connected hand-held accessory with an acoustic function, or*
- *a headset.*

Standard Section *4.4.4.4 Impact tests*

All equipment, other than that specified in 4.4.4.3, shall be subjected to the impact test of Clause T.6. The impact test of Clause T.6 is not applied to the following: – the bottom of an enclosure, except if the user instructions permit an orientation in which the bottom of the enclosure becomes the top or a side of the equipment; – glass; NOTE Impact tests for glass are in 4.4.4.6. – the surface of the enclosure of stationary equipment, including equipment for building-in, that is not accessible and is protected after installation.

Standard Section *4.4.4.5 Internal accessible safeguard tests* and **Standard Section *4.4.4.6 Glass impact tests*** were both deemed out of scope.

Standard Section *4.4.4.7 Thermoplastic material tests*

If a safeguard is of thermoplastic material, the safeguard shall be so constructed that any shrinkage or distortion of the material due to release of internal stresses shall not defeat its safeguard function. The thermoplastic material shall be subjected to the stress relief test of Clause T.8.

Standard Section *4.4.4.8 Air comprising a safeguard*

Where a safeguard is comprised of air (for example, a clearance), a barrier or enclosure shall prevent displacement of the air by a body part or a conductive part. The barrier shall comply with the mechanical strength test specified in Annex T, as applicable.

Referenced clauses T1-T10 re defined as follows:

T.1 General *In general, this annex describes a number of tests that are invoked by this standard. Compliance criteria are specified in the clause that invokes a particular test. No tests are applied to handles, levers, knobs, the face of CRTs or to transparent or translucent covers of indicating or measuring devices, unless parts at ES3 are* ***accessible*** *when the handle, lever, knob or cover is removed.*

T.2 Steady force test, 10 N *A steady force of 10 N ± 1 N is applied to the component or part under consideration for a short time duration of approximately 5 s.*

T.3 Steady force test, 30 N *The test is conducted by means of the straight unjointed version of the applicable test probe of Figure V.1 or Figure V.2, applied with a force of 30 N ± 3 N for a short time duration of approximately 5 s.*

T.4 Steady force test, 100 N *The test is conducted by subjecting the external enclosure to a steady force of 100 N ± 10 N over a circular plane surface 30 mm in diameter for a short time duration of approximately 5 s, applied in turn to the top, bottom, and sides.*

T.5 Steady force test, 250 N *The test is conducted by subjecting the external enclosures to a steady force of 250 N ± 10 N over a circular plane surface 30 mm in diameter for a short time period of approximately 5 s, applied in turn to the top, bottom and sides.*

T.6 Enclosure impact test *A sample consisting of the complete enclosure or a portion thereof, representing the largest unreinforced area is supported in its normal position. A solid, smooth, steel sphere of 50 mm ± 1 mm in diameter and with a mass of 500 g ± 25 g, is used to perform the following tests: – on horizontal surfaces, the sphere is to fall freely from rest through a vertical distance of 1 300 mm ± 10 mm onto the sample – on vertical surfaces, the sphere is suspended by*

a cord and swung as a pendulum in order to apply a horizontal impact, dropping through a vertical distance of 1 300 mm ± 10 mm onto the sample. For evaluating a part that acts as a fire enclosure only, the test is done as above, but the vertical distance is 410 mm ± 10 mm.

Standard Section *6.4.8 Fire enclosures and fire barriers*

Standard Section *6.4.8.1 General*

The safeguard function of the fire enclosure and the fire barrier is to impede the spread of fire through the enclosure or barrier. The fire enclosure may be the overall enclosure, or it may be within the overall enclosure. The fire enclosure need not have an exclusive function, but may provide other functions in addition to that of a fire enclosure.

Standard Section *6.4.8.2 Fire enclosure and fire barrier material properties*

Standard Section *6.4.8.2.1 Requirements for a fire barrier*

A fire barrier shall comply with the requirements of Clause S.1. These requirements do not apply provided that the material is: – made of non-combustible material (for example, metal, glass, ceramic, etc.); or – made of V-1 class material or VTM-1 class material.

Standard Section *6.4.8.2.2 Requirements for a fire enclosure*

For circuits where the available power does not exceed 4 000 W (see 6.4.1), a fire enclosure shall comply with the requirements of Clause S.1. For circuits where the available power exceeds 4 000 W, a fire enclosure shall comply with the requirements of Clause S.5. These requirements do not apply provided that the material is: – made of non-combustible material (for example, metal, glass, ceramic, etc.); or – made of • V-1 class material if the available power does not exceed 4 000 W; or • 5VA class material or 5VB class material if the available power exceeds 4 000 W. Material for components that fill an opening in a fire enclosure or that is intended to be mounted in such opening shall: – comply with the flammability requirements of the relevant IEC component standard; or – be made of V-1 class material; or – comply with Clause S.1.

Referenced tests are detailed as follows:

S.1 Flammability test for fire enclosure and fire barrier materials of equipment where the steady-state power does not exceed 4 000 W

Fire enclosure *and fire barrier materials are tested according to IEC 60695-11-5. The following additional requirements apply to the specified clauses of IEC 60695-11-5:2004.*

Clause 6 of IEC 60695-11-5:2004 – Test specimen

For fire enclosures and fire barriers, each test specimen consists of either a complete fire enclosure or fire barrier or a section of the fire enclosure or fire barrier representing the thinnest significant wall thickness and including any ventilation opening.

Clause 7 of IEC 60695-11-5:2004 – Severities

The values of duration of application of the test flame are as follows: – the test flame is applied for 10 s; – if flaming does not exceed 30 s, the test flame is immediately reapplied for 1 min at the same point; – if again flaming does not exceed 30 s, the test flame is immediately reapplied for 2 min at the same point.

Clause 8 of IEC 60695-11-5:2004 – Conditioning of test specimen

Prior to being tested, the samples are conditioned in a circulating air oven for a period of 7 days (168 h), at a temperature 10 K higher than the maximum temperature of the part measured during the test of 5.4.1.4 or 70 °C, whichever is the higher, and then cooled to room temperature. For printed boards, a preconditioning of 24 h at a temperature of 125 °C ± 2 °C in an air circulating oven and a subsequent cooling period of 4 h at room temperature in a desiccator over anhydrous calcium chloride is to be applied.

Subclause 9.2 of IEC 60695-11-5:2004 – Application of needle flame

The test flame is applied to an inside surface of the test specimen at a point judged to be likely to become ignited because of its proximity to a source of ignition. If a vertical part is involved, the flame is applied at an angle of approximately 45° from the vertical. If ventilation openings are involved, the flame is applied to an edge of an opening, otherwise to a solid surface. In all cases, the tip of the flame is to be in contact with the test specimen.
The test is repeated on the remaining two test specimens. If any part being tested is near a source of ignition at more than one point, each test specimen is tested with the flame applied to a different point that is near a source of ignition.
Clause 11 of IEC 60695-11-5:2004 – Evaluation of test results
The existing text is replaced by the following. The test specimens shall comply with all of the following: – after every application of the test flame, the test specimen shall not be consumed completely; and – after any application of the test flame, any self-sustaining flame shall extinguish within 30 s; and – no burning of the specified layer or ***wrapping tissue*** *shall occur.*

4.2 Materials Testing

In addition to the requirements specified in the safety standards, there are certain considerations which should be made with regards to the use of recycled polymers in new products (from a customer perspective). If sold on the market, there will be an expectation that these materials conform with expectations of the buyer. Thus, a brief assessment of the expectations with regards to testing of materials has been made. The table below includes the tests performed and testing procedures used by different plastic manufactures.

Table 11 – Mechanical Properties

Mechanical Property	**Test Method (US)** (35)	**Test Method (EU - Sabic)**	**Test Method - Perrite**
Tensile Stress, yield		ISO 527	
Tensile Strain, yield		ISO 527	
Tensile Stress, break		ISO 527	
Tensile Strain, break		ISO 527	
Tensile Strength (Yield)	ASTM D638		ISO 527 (assumed yield)
Tensile Strength (Ultimate)	ASTM D638		
Tensile modulus	ASTM D638		ISO 527
Tensile Elongation at Break	ASTM D638	-	ISO 527
Tensile Elongation at Yield	ASTM D638	-	
Tensile Modulus	-	ISO 527	
Flexural Strength	ASTM D790	-	ISO 178 (yield)
Flexural Modulus	ASTM D790	ISO 178	ISO 178
Flexural Strain and Break	ASTM D790	-	
Flexural Stress	-	ISO 178	
Hardness, H358/30	-	ISO 2039-1	
Hardness, Rockwell R	-	ISO 2039-2	

Table 12 - Impact Properties

Impact Property	Test Method (US)	Test Method (EU - Sabic)	Test Method - Perrite
IZOD Impact, notched	ASTM D256	ISO 180/1U	ASTM D256
IZOD Impact, un-notched	ASTM D256	ISO 180/1U	
Charpy, V-nothc		ISO 179/1eA	
Charpy, Un-nothced		ISO 179/1eU	

Table 13 - Thermal Properties

Thermal Property	Test Method (US)	Test Method (EU - Sabic)	Test Method - Perrite
Conductivity		ISO 8302	
CTE		ISO 11359-2	
Vicat Softening Temperature		ISO 306	ISO 306B
HDT/Be (heat deflection temp)		ISO 75/Be	ISO 75-2 (1.8MPa)
HDT/Ae (heat deflection temp)		ISO 75/Ae	ISO 75-2 (0.45 MPa)

5 Legislation

5.1 European

5.1.1 Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

The European Union regulation, REACH - Registration, Evaluation, Authorisation and Restriction of Chemicals, addresses the production and use of chemical substances and their potential impacts on both human health and the environment. All forms of recovery are applicable to REACH regulation – if the recovery results in one or more substances that have ceased to be waste after one or more of the recovery steps.

Although the REACH does not directly affect the use of recycled polymers it should be considered because users of the recycled polymers will have expectations that the recovery and upgrading of materials has conformed according to REACH. In addition the use of recyclates in second-life applications brings the former beyond the waste regime and therefore a subject to all REACH duties.

- Produced substances should be registered (Article 2.7.d)
- Produced materials require SDS
- CLP notification required
- Restrictions and Authorisations should be complied with

5.1.2 Restriction of the use of certain Hazardous Substances in electrical and electronic equipment – directive 2002/95/EC (RoHS)

RoHS Directive groups the products into different categories which are classified as impacted under RoHS (1, 2, 3, 4, 5, 6, 7 and 10) and exempted from compliance (8 and 9). (36) (37)

- *Category 1*. Large household appliances: refrigerators, washers, stoves, air conditioners, freezers, clothes dryers, cooking, electric stoves, electric hot plates, microwaves, electric heaters appliances, electric fans, electric radiators, air conditioner appliances….
- *Category 2.* Small household appliances: vacuum cleaners, hair dryers, coffee makers, irons, carpet sweepers, appliances used for sewing, knitting, weaving and other processing for textiles, irons, toasters, fryers, grinders, electric knives, appliances for hair-cutting, hair drying, tooth brushing, shaving, massage and other body care appliances, clock, watches….
- *Category 3*. Computing & communications equipment: computers, printers, copiers, phones, mainframes, copying equipment, electrical and electronical typewriters, pocket and desk calculators, other products and equipment for the collection, storage, processing, presentation or communication of information by electronic means, user terminals and systems, facsimile, telex, telephones, pay telephones, cordless telephones, cellular telephones, answering telephones, other products or equipment of transmitting sound, images or other information by telecommunications.
- *Category 4*. Consumer electronics: TVs, DVD players, stereos, video cameras, radio sets, Hi-Fi recorders, audio amplifiers, musical instrument and other products or equipment for the purpose of recording or reproducing sound or images, including signals or other technologies for the distribution of sound and image than by telecommunications.
- Category 5. Lighting: lamps, lighting fixtures, light bulbs, luminaires for fluorescent lamps with the exception of luminaires in households, low pressure sodium lamps…
- *Category 6*. Power tools: drills, saws, nail guns, sprayers, lathes, trimmers, blowers, tools for riveting, nailing or screwing or removing rivets, nails, screws or similar uses, tools for

welding, soldering or similar use, equipment for spraying, spreading, dispersing or other treatment of liquid or gaseous substances by other means, toolds for mowing or other gardening activities…

- *Category 7*. Toys and sports equipment: videogames, electric trains, treadmills. Computers for biking, diving, running, rowning…sports equipment with electric or electronic components, coin slot machines.
- *Category 10*. Automatic dispensers: vending machines, ATM machines., automatic dispenser for hot drinks, for hot or cold bottles or cans, for solid products, for money and all appliances which deliver automatically all kinds of products.
- *Category 8*. Medical devices and equipment. Radiotherapy equipment, cardiology equipment, dialysis, pulmonary ventilators, nuclear medicine, laboratory equipment for in-vitro diagnosis, analysers, freezers, fertilizations test and others appliances for detecting, preventing, monitoring, treating, alleviating illness, injury or disability.
- *Category 9*. Control and monitoring equipment. Smoking detectors, heating regulators, thermostats, measuring weighing or adjusting appliances for household or as laboratory equipment and other monitoring and control instruments used in industrial installations.
- National security use and military equipment
- Large stationary industrial tools
- Certain light bulbs and some batteries
- Spare parts for electronic equipment in the market before July 1, 2006.

Products such as TVs, laptops and mobile phones are within RoHs directive (Category 3).

The RoHS restricts the use of six hazardous materials in the manufacture of various types of electronic and electrical equipment. It is applicable to applications proposed for CloseWEEE recycled polymers but it refer to maximum levels for 6 restricted compounds: (36)

- Lead (Pb): < 1000 ppm. It is used in solder, lead-acid batteries, electronic components, cable sheathing and in the glass of cathode-ray tubes
- Mercury (Hg): < 100 ppm. Mercury is widely used metals in the production of electrical and electronic appliances and is concentrated in batteries, switches and thermostats, and fluorescent lamps.
- Cadmium (Cd): < 100 ppm. Cadmium is used in electronic components, car batteries, and pigments.
- Hexavalent Chromium: (Cr VI) < 1000 ppm. Chromium VI can produce toxic effects.
- Polybrominated Biphenyls (PBB): < 1000 ppm. They have been found in indoor dust and air through evaporation from plastics.
- Polybrominated Diphenyl Ethers (PBDE): < 1000 ppm. These are also flame retardants found in electronic and electrical appliances. Combustion of printed wiring boards release toxic emissions.

PBB and PBDE are BFRs and as such may be recovered through CloseWEEE technologies – but they cannot be used in new products (unless they were covered by the RoHS exemption list).

It is important to note that the maximum permitted concentrations of these materials in non-exempt products are 0.1% or 1000 ppm by weight – applicable to homogenous materials (e.g. no more than 0.1% PBB can be found in a PC-ABS blend).

5.1.3 Eco-design of energy related products

The WEEE Directive, 2012/19/EU, aims for the EU to recycle at least 85% of WEEE generated by 2016. The aim of the Directive is to ensure that around 10 million tons, or roughly 20% per capita, will be separately collected from 2019 onwards (38). Although this directive does not have a direct effect for product manufactures, some of the resulting initiatives may have an effect.

Notably, the ecodesign of Energy-related Products Directive 2009/125/EG aims to reduce the environmental impact caused during the manufacture, use and disposal of a very wide range of products. Given that the Ecodesign Directive is a framework directive only, therefore, supporting legislation is required. The directive contains general requirements and lays out a standard format and rules for specific implementing measures to be created for a specific product group or function. Laptops and mobiles do not fall within scope of specific regulation.

Televisions are governed by Regulation (EC) no 642/20009. However, the regulation is not deemed to have a significant impact on the re-use of recycled polymers since all requirements are centered around power consumption whilst televisions are in use (or on standby) and no reference was found with regards to materials of casing, etc.

5.2 National

Most legislation in Europe is EU led and Europe wide, since most countries enact laws which ensure compliance with EU directives. However, there are certain additional regulations which are often only applicable to specific countries (although certain similar legislation may be in existence in different countries. Usually, this is coherent with European legislation. An example of that are the WEEE regulations in the UK.

5.2.1 WEEE regulations - UK

The Waste Electrical and Electronic Equipment Regulations 2006 do not directly affect the use of recycled polymers in new EEE (the main purpose of this report). However, it might be worth considering that there may be an expectation from users of recovered polymers that the recovered materials adhere to these regulations. The main requirement applicable to this report is that potentially hazardous BFRs, used as additives in some plastic products, are removed before recycling.

Additionally, non-packaging plastics containing BFR are classified as hazardous waste and therefore the Hazardous Waste Regulations Directive 2005 is applicable (see European regulation).

5.2.2 Other European countries

Has not been found legislation related to the use of recycled polymers in other countries of EU. All member countries of EU are under the same European Directives and in this matter there is not a clear legislation. Relevant laws in each country are focused on the waste responsibility and battery regulations, among others. (39)

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