Effects on ELV waste management as a consequence of the decisions from the Stockholm Convention on decaBDE

- Report -

This study is commissioned and funded by ACEA,
the European Automobile Manufacturers Association.

Darmstadt, 18.9.2018

Authors

Dr.-Ing. Georg Mehlhart
Oeko-Institut e.V.

Alexandra Möck
Oeko-Institut e.V.

Prof. Dr. Daniel Goldmann
TU Clausthal

Freiburg Head Office
P.O. Box 17 71
79017 Freiburg, Germany
Street address
Merzhauser Strasse 173
79100 Freiburg, Germany
Tel. +49 761 45295-0

Berlin Office
Schicklerstrasse 5-7
10179 Berlin, Germany
Tel. +49 30 405085-0

Darmstadt Office
Rheinstrasse 95
64295 Darmstadt
Tel. +49 6151 8191-0

info@oeko.de
www.oeko.de

Table of Contents

List of Tables

List of Figures

Abstract

decabromodiphenyl ether (decaBDE) is a flame retardant. Total production of c-decaBDE in the period 1970-2005 was between 1.1-1.25 million tonnes. Data on use of c-decaBDE indicate that prior to 2008, 80–90% of c-decaBDE was used in EEE products, with textile applications accounting for most of the remaining 10–20%. In the past decaBDE has been used in certain parts of vehicles.

Since 2017, decaBDE has been listed in the Stockholm Convention on Persistent Organic Pollutants (POP). The (draft) amendment of the EU POP Regulation, implementing the revised Stockholm Convention on an EU level, is announced for release for the 3rd quarter of 2018. This amendment will include provisions for appropriate management of waste components containing decaBDE (thus including end-of-life vehicles (ELVs)). This study assesses different options for ELV management for components containing decaBDE.

Manual dismantling of vehicle parts from ELVs suspected to contain decaBDE turns out not to be meaningful, as it would not be well-targeted and would include many unnecessary separation steps without any change in emissions or reintroduction risks. Such high (and in most parts unnecessary) effort for deep manual dismantling would jeopardise the profits of legally-operated authorised treatment facilities (ATFs) and expose the sector to the risk of an increasing number of illegal operators, thus having the opposite effect than originally intended.

Manual dismantling is also not recommended since feasible alternatives do exist: post-shredder technologies (PST) can separate output fractions with high PBDE content and fractions with low PBDE content. Fractions with higher content are either used as a reducing agent for blast furnaces (equivalent to feed stock recycling) or sent to waste incineration plants. Both options are considered possible treatment operations for destroying decaBDE.

A precondition for the treatment of decaBDE-containing ELVs is the strict enforcement of best management practices for the operation of shredders, including the management of the input flow with the aim to avoid deflagrations and fire. This precondition not only applies due to the listing of decaBDE in the POP regulation or for the treatment of ELVs but also in order to avoid emissions of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) and polychlorinated biphenyl (PCB) during deflagration and fire caused by halogenated substances e.g. from WEEE in input materials. In principle, this is a standard topic addressed when handling organic waste streams containing halogenated substances.

Shredder residues from ELVs where POP-containing parts are not manually separated during dismantling and without treatment of shredder residues with advanced PST might not in future be allowed for disposal in landfills.

The recycling targets of the ELV Directive are achievable if PST are applied.

This study is commissioned and funded by the European Automobile Manufacturers’ Association (ACEA) with the aim to assess the effects of listing decaBDE in the European POP Regulation.

1. Executive summary

This study aims to assess the effects of the listing in 2017 of decabromodiphenyl ether (decaBDE) in Annex A to the Stockholm Convention on Persistent Organic Pollutants (POP) on the management of end-of-life vehicles (ELVs).

In the past, decaBDE has been commonly used in vehicle parts manufactured out of hard Acrylnitril-Butadien-Styrol-Copolymere (ABS) and High Impact Polystyrene (HIPS) plastics, electronic parts and their casings, as well as in some vehicle textiles, especially seats and artificial leather for seat covers and interior lining (MinEnv. Finland, 2016). Typically, 10%-15% of decaBDE by weight has been added to plastics (MinEnv. Finland, 2016). Some textiles contain a maximum of 12% of the substance (Bipro, 2015b). According to information provided by ACEA, decaBDE was previously also found in higher concentrations in shrinking tubes, e.g. for wiring harnesses and connectors and in adhesives tapes.

The use of flame retardants classified as POPs in vehicles varies based on the manufacturer, the model and year manufactured. Detailed information on the substances used in different vehicle models is not available (MinEnv. Finland 2016).

The last aspect is confirmed by this study. Information on decaBDE is not available for today's ELVs as it was declared in the International Material Data System (IMDS) starting in 2005 only[1]. Currently, IMDS contains information on decaBDE concentration in parts and components but it does not display in which make/ model/ specific vehicle this part is used.

Even if such information were available, the parts suspected of containing high concentrations of decaBDE might have changed or have been replaced during a typical lifespan of 15-20 years. Without such vehicle-specific information, the general dismantling of parts/ components suspected to contain decaBDE would not be well targeted. Furthermore, most of the effort spent would have been wasted, as most of the separated components would be free of decaBDE.

For instance, dismantling wiring harnesses would at least double the effort of authorised treatment facilities (ATFs, as defined by the ELV Directive) compared to depollution. And as only shrinking tubes or connectors might be affected (and not copper and other plastics), the share of decaBDE in the wiring harness is very low, and more detailed micro dismantling would be needed to target components with high decaBDE content. The cost for separation and disposal of the separated material remains with the ATF. At the same time, such effort would not significantly affect treatment, as the manually dismantled wiring harness would be comminuted and processed in a manner quite similar to shredder residues.

Such a dismantling approach, suspected to be wasted time in most cases, would completely jeopardise the economic benefit for the ATF and make illegal dismantling more attractive. In addition, it is to be questioned whether ATF staff is prepared/ willing to follow such a burdensome approach, which is at the same time known to be poorly targeted and exposes the ATF to economic risks. Strict enforcement by public authorities at 12 000 ATFs across the EU is, given such conditions, not likely.

Instead, decaBDE-containing parts might be separated and directed into specific fractions by post shredding technologies (PST) that would both allow a feedstock recycling or energy recovery out of these fractions and guarantee the efficient and safe destruction of decaBDE.

---

[1] This is a general problem for products with a 15-20 year use-phase where new regulations for materials apply.

However, the step before PST is shredding, and shredder plants for the treatment of end-of-life vehicles are mentioned in Annex C, Part III, of the Stockholm Convention on POPs as one of the potential source categories for the unintentional formation and release of Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) and polychlorinated biphenyl (PCB (see abstract). The main reasons for this unintended release are deflagrations and fire. As demonstrated by the draft BREF document for waste treatment (BREF WT 2017), the performance of automotive shredders is quite diverse. While several shredders succeed in avoiding any deflagration for several subsequent years, others regularly report more than 10 deflagrations per year. One single deflagration might exceed the entire annual emission allowance under normal operating conditions.

It is known that deflagrations are less a question of the treatment technique established at the site than a question of the management and control of the input stream. Techniques like pre-shredders might reduce the risk of deflagrations as well.

We recommend enforcing the application of best management practices by penalising those shredder facilities which do not properly manage input streams and have no measures in force to avoid deflagrations. If, for instance, more than an acceptable number of deflagrations occurs in a certain period (for example 1 in 12 months), the permit to treat ELVs and WEEE might be (temporarily) withdrawn until a new management plan (addressing measures to avoid deflagrations and fire including measures to manage the input stream) is accepted by the relevant authorities.

If best management practices of shredders is enforced in a manner as described before, the combination of shredder/ PST is considered as a functional alternative to manual dismantling.

Recent analyses of different output flows of the PST plant of ARN Recycling in the Netherlands indicate quite different levels of bromine (Br) content in different output streams (Table 1). decaBDE has a Br content of about 83%. XRF-detection of Br can be done on site. For 25 samples[2] of PST output, Strååt, M.; Nilsson, C. (2018) compared the results for Br content detected with XRF with results of concentrations of brominated flame retardants detected with GC-MS. The report concludes that it is very difficult to draw any meaningful relationship between the Br-concentration measured in shredder residues using XRF and the concentration of restricted brominated flame retardants measured using GC-MS. This conclusion is in principle supported by the analysis of ARN (see Table 2). “The only thing that can be said with certainty is that the concentration of restricted flame retardants measured is lower than 25% of the Br-concentration measured using XRF” Strååt, M.; Nilsson, C. (2018).

Considering these limitations, Br might be used as a proxy for onsite monitoring to indicate the levels of brominated flame retardants (including those not banned). If for instance the Br content is below 1 000 mg/kg, it is very unlikely that the decaBDE content is more than 1 000 mg/kg. The advantage of Br measured with XRF is that it could be used onsite, which is much cheaper than sample preparation and analysis for decaBDE in a certified laboratory.

---

[2] Thereof, 20 samples from WEEE input, 3 samples for ELV input and 2 samples for mixed ELV / WEEE

Table 1 Results for XRF detection of bromine content for different output streams at the PST site of ARN

	No. of samples	Min	Max	Median	Average	Values < 1000 mg / kg Br	Values < 500 mg / kg Br
		mg/kg Br					
Br in shredder sand	72	30	515	197	211	100%	99%
Br in shredder fluff	58	154	3 594	527	729	83%	47%
Br in shredder granulate < 1.1 g/cm^3	48	18	2 494	86	202	96%	96%
Br in shredder granulate $\geq$ 1.1 $\leq$ 1.3 g/cm^3	335	41	6 386	2 220	2 277	4%	<1%
Br in shredder granulate > 1.3 g/cm^3	40	94	5 864	2 600	2 749	5%	5%

Source: ARN, analysis in the period 2015 - 2017

Table 2 Bromine, decaBDE and PBDE for PST fractions of ARN

Date (dd.mm.yyyy)	Bromine (HUK)1) mg/kg	Bromine (ARN)2) mg/kg	decaBDE3) mg/kg	Sum PBDE3) mg/kg
	Granulate < 1.1 g/cm^3			
13.12.2017	341	27	<50	<200
27.12.2017	336	426	<50	<200
10.01.2018	<100	30	11	<100
24.01.2018	136	277	<10	<100
07.02.2018	<100	566	12	<100
	Fluff			
13.12.2017	536	434	<50	<200
27.12.2017	340	448	<50	<200
10.01.2018	316	979	24	<100
24.01.2018	117	272	27	<100
07.02.2018	313	475	48	<100

1) DIN EN 14582

2) with XRF after sample comminution

1) and 2) not exactly the same sample but from the same batch only!

3) Measured according to DIN EN ISO 22032

Source: ARN

Table 3 **Bromine, decaBDE and PBDE for PST fractions in France, UK and Austria**

Sample ID	Country	Plastic type	Waste stream, product/ waste category	Info on treatment in facility	Br (XRF) mg/kg	BDE- 209 (GC-MS) mg/kg	ΣPBDE (GC-MS) mg/kg
20	France	PS/ABS	ELV	Density separation	470	140	140
35	UK	PP			274	<5	<5
38	UK	ABS			286	5,1	5,1
40	Austria	PP	ELV + WEEE (small domestic appliances)	Density + electrostatic separation	613	85	85
41	Austria	PS			970	94	94

Source: Strååt, M.; Nilsson, C. (2018)

Considering the results displayed in the tables above the following conclusions can be drawn:

- The Br content in shredder sand is low and decaBDE or PBDE concentrations above 1000 mg/kg are not likely.
- The Br content of the fluff fraction is on average a bit higher, with a few outliers (Table 1). If such outliers are detected and separated with advanced separation technologies, or if the fluff fraction is used as energy carrier or reducing agent in power plants, cement kilns or blast furnaces, the complete and safe destruction of decaBDE can be secured.

  According to the results of ARN for 5 samples, decaBDE in fluff is always well below 100 mg/kg (Table 2).
- The Br content in shredder granulate < 1.1 g/cm^3 is on average low. In only one out of 48 samples the Br content exceeds 500 mg/ kg and even for the outlier decaBDE or PBDE concentrations above 1000 mg/kg are not likely. According to the results of ARN for 5 samples decaBDE in Granulate < 1.1 g/cm^3 is always well below 100 mg/ kg (Table 2).
- For the shredder granulate with a density of ≥ 1.1 ≤ 1.3 g/cm^3 the detected Br content is somewhat higher. This material is best anyhow as reducing agent in blast furnaces which is a treatment operation for destroying decaBDE and considered as feed stock recycling. Advanced sorting technologies might enable separation of POP-containing particles and serve as an option for material recycling of the depleted fraction in the future.
- Shredder granulate with a density of > 1.3 g/cm^3 has high concentrations of PVC and is therefore not suitable for use as a reducing agent in blast furnaces or cement kilns. For this reason this fraction is either directed to chemical recycling processes like the Vinyloop process or to advanced waste incineration plants.

Several shredders across Europe do not send their shredder output to onsite or off-site PST plants. As displayed in Table 16 at least 260,000 tonnes of shredder light fraction (SLF) from ELVs treated in Europe are disposed of without further treatment. It is suspected that some of this material is sent to landfills. As displayed in Table 22 such mixed fractions might exceed concentration of 1000 mg/kg decaBDE.

Even if such fractions disposed of in landfills might be under the concentration limit referred to in Article 7(4)(a) of the POP Regulation (“lower concentration limit”), such disposal may not be allowed in the future.

The recycling targets of the ELV Directive are achievable if PST is applied.

2. Context / Introduction

2.1. Stockholm Convention

The Stockholm Convention on Persistent Organic Pollutants is an international environmental treaty, signed in 2001 and effective from May 2004, that aims to eliminate or restrict the production and use of persistent organic pollutants (POPs). As of May 2018, there are 182 parties to the Convention, (181 states and the European Union). Notable non-ratifying states include the United States, Israel, Malaysia, and Italy.

POPs are toxic chemical substances that degrade slowly, bioaccumulate in the food chain and travel far from the sources of the pollution. They can cause significant health and environmental hazards.

The Stockholm Convention was adopted into EU legislation through Regulation (EC) No 850/2004[3] (hereinafter the “EU POP Regulation”).

Since entering into force, the Stockholm Convention has been amended several times. Decision SC8/10 of the COP 8 to the Stockholm Convention[4] added c-decaBDE[5] to Part I of Annex A of the Stockholm Convention, with detailed exemptions and provisions for transitional periods.

After a new POP substance has been added to the Stockholm Convention, the countries that are party to the convention must incorporate it into their national legislation within one year of the secretariat of the Stockholm Convention recording the decision of the Conference of the Parties in the United Nations Treaty Collection. In the EU Member States, the changes to the Stockholm Convention are implemented by adding the new compounds to the EU POP Regulation.

2.2. Basel Convention

Article 6 paragraph 2 (c) of the Stockholm Convention establishes that the Conference of the Parties shall cooperate closely with the appropriate bodies of the Basel Convention to, inter alia: work to establish the concentration levels of the POPs listed in Annexes A, B and C in order to define the low POP content.

The Basel Convention has developed technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with POPs. Parties to the Stockholm Convention are invited to take these guidelines into account when implementing their obligations under Article 6 of the Convention.

---

[3] Regulation (EC) No 850/2004 of the European Parliament and the Council of 29 April 2004 on persistent organic pollutants (OJ L 158, 30.4.2004, p. 7)

[4] Conference of the Parties to the Stockholm Convention on Persistent Organic Pollutants, Eighth meeting, Geneva 24 April - 5 May 2017.

[5] Commercial mixture of DecaBDE

2.3. EU POP Regulation

As a member of the Stockholm as well as the Basel Conventions, the EU has implemented 25 POPs and concentration limits in the EU POP Regulation.

Since entering into force, the Regulation has been amended several times, with the latest amendment in 2016. As legislation changes, end-of-life products that previously had no obligations associated to POP legislation must be treated according to the stipulations of the EU POP Regulation. Thus, the recycling of end-of-life products containing POP are effected by the EU POP Regulation.

In 2017 the EU POP Regulation included a total of 25 persistent organic compounds or groups of compounds.

Waste containing POP above the lower concentration limits must be treated using the methods stipulated by the Regulation. The POPs contained in the waste must be destroyed or irreversibly transformed so that they do not exhibit the characteristics of persistent organic pollutants. The permitted treatment methods for waste streams from ELVs contaminated with decaBDE include R1, D9, D10[6] and R4[7] (Annex V EU-POP-Regulation). In exceptional cases, the waste can be placed in a landfill for hazardous waste or deep inside safe bedrock or a salt mine. If the upper concentration limit is exceeded, additional restrictions apply.

With regard to waste management, the EU POP regulation stipulates in Annex V:

> *Pre-treatment operation[8] prior to destruction or irreversible transformation pursuant to this Part of this Annex may be performed, provided that a substance listed in Annex IV that is isolated from the waste during the pre-treatment is subsequently disposed of[9] in accordance with this Part of this Annex. Where only part of a product or waste, such as waste equipment, contains or is contaminated with persistent organic pollutants, it shall be separated and then disposed of in accordance with the requirements of this Regulation. In addition, repackaging and temporary storage operations may be performed prior to such pre-treatment or prior to destruction or irreversible transformation pursuant to this part of this Annex.*

The import and export of waste is also affected. Waste shipments between EU Member States and outside the EU are regulated by the Regulation (EC) No 1013/2006 of the European Parliament and of the Council (Waste Shipment Regulation). Waste containing POPs above the lower limit cannot be treated as green list waste (MinEnv. Finland (2016)).

---

[6] R1: Incineration with energy recovery. D9: Physico-chemical treatment. D10: incineration without energy recovery.

[7] R4: Recycling/reclamation of metals and metal compounds, under the following conditions: The operations are restricted to residues from iron- and steel-making processes such as dusts or sludges from gas treatment or mill scale or zinc-containing filter dusts from steelworks, dusts from gas cleaning systems of copper smelters and similar wastes and lead-containing leaching residues of the non-ferrous metal production. Waste containing PCBs is excluded. The operations are restricted to processes for the recovery of iron and iron alloys (blast furnace, shaft furnace and hearth furnace) and non-ferrous metals (Waelz rotary kiln process, bath melting processes using vertical or horizontal furnaces), provided the facilities meet as minimum requirements the emission limit values for PCDDs and PCDFs laid down in Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste (1), whether or not the processes are subject to that Directive, and without prejudice to the other provisions of Directive 2000/76/EC where it applies and to the provisions of Directive 96/61/EC.

[8] Comment of the authors of the study: Shredding is considered as a pre-treatment operation. Shredding is not a final treatment operation but a separation with subsequent final treatment (recovery or disposal) operations.

[9] Comment of the authors of the study: "disposed of" in this context does not refer exclusively to disposal operations indicated with D-Codes. Recovery operations like R1 or R4 might be allowed as well if destruction or irreversible transformation is ensured.

The use of commercial decaBDE is currently stipulated by the EU REACH Regulation.[10] Since the EU POP Regulation stipulates the use of POPs as well, decaBDE will, after being added to EU POP Regulation, be deleted from EU REACH Regulation.

For the PBDE, introduced earlier to the EU POP regulation, the concentration limits are established as displayed in Table 4.

Table 4 Provisions set out in Article 7 of the EU POP regulation for selected PBDE

Substance	Concentration limit referred to in Article 7(4)(a) (“lower concentration limit”)	Max. concentration limits of substances listed in Annex IV (“upper concentration limit”)
Tetrabromodiphenyl ether, $C_{12}H_6Br_4O$	Sum of the concentrations of tetra-, penta-, hexa- and heptabromodiphenyl ether: 1 000 mg/kg	Sum of the concentrations of tetra-, penta-, hexa- and heptabromodiphenyl ether: 10 000 mg/kg
Pentabromodiphenyl ether, $C_{12}H_5Br_5O$		
Hexabromodiphenyl ether, $C_{12}H_4Br_6O$		
Heptabromodiphenyl ether, $C_{12}H_3Br_7O$		

For decaBDE the concentration limits are not introduced yet. However the process to amend the EU POP Regulation started and the EC intends to complete the amendment in 2018.

2.4. Scope of the study

Initiated and funded by ACEA, this study addresses brominated flame retardants listed by the Stockholm Convention, focussing on the newly listed decaBDE and the effects on recycling of end-of-life vehicles (ELVs).

Considering the above-mentioned context, this study addresses the following questions:

a) Is it feasible to detect and separate PBDE / decaBDE-containing parts / components during ELV treatment?

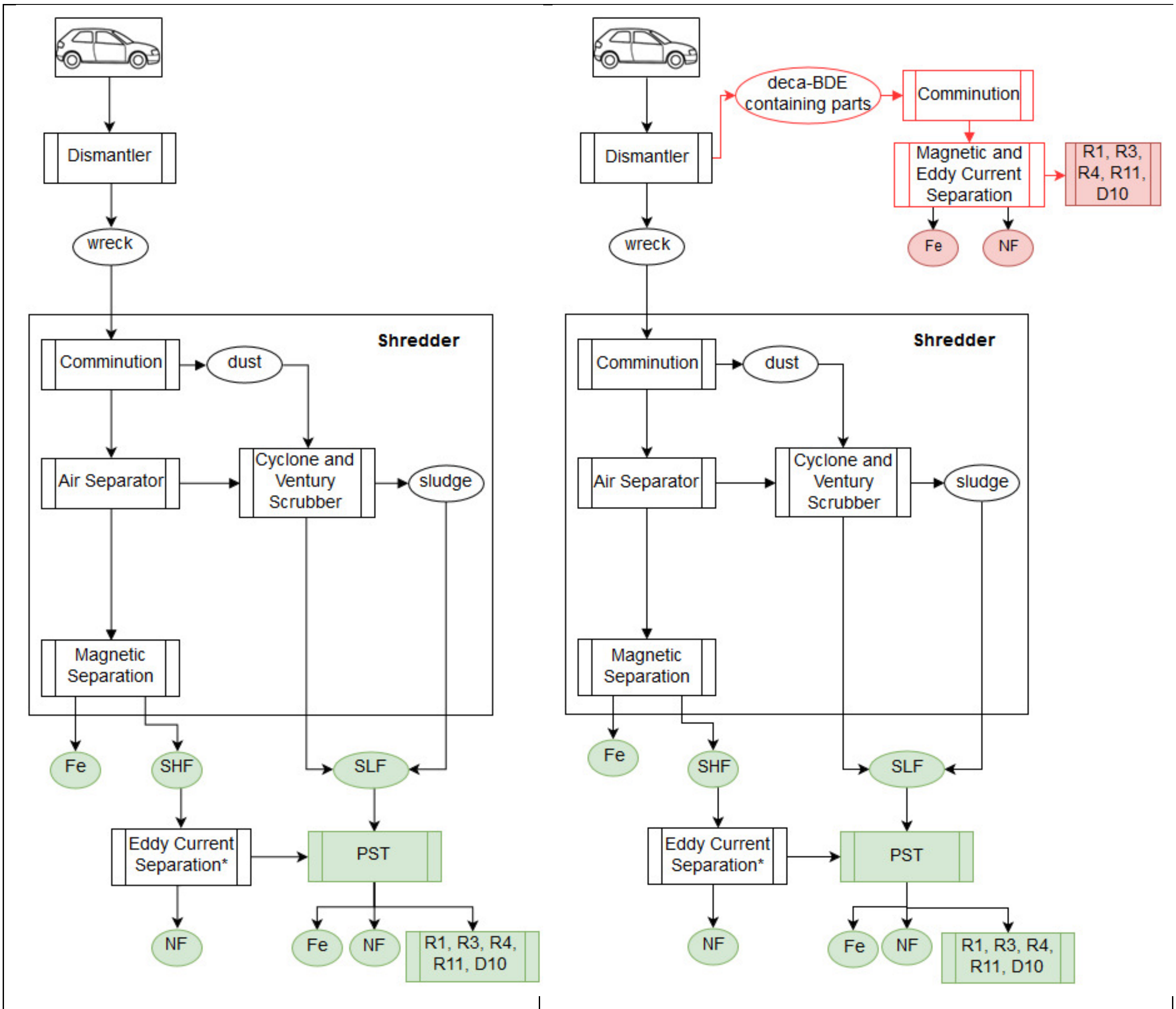
b) Is it feasible to pre-treat ELVs in shredders and to separate PBDE / decaBDE-containing parts / materials after shredding with post shredder technology (PST)?

c) If PST is not applied, is it necessary to treat the entire Automotive Shredder Residues (ASR) fraction as potentially PBDE / decaBDE containing waste above the lower POP concentration limit? And if so, what effects on the recycling and recovery rates of ELVs such approach would have?

Figure 1 displays the two different options in principle. The scheme to the left displays the situation today. PBDE is not separated during dismantling and, as demonstrated in Section 4.2, follows the route to PST. The scheme to the right displays the option where dismantlers separate decaBDE-containing components and send them to treatment plants (R1 or D10). Instead of sending them to R1/D10 the residues from the decaBDE-containing parts might be sent for PST treatment with the aim to separate recyclables.

---

[10] Regulation (EC) No 1907/2006 of the European Parliament and the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency (OJ L 396, 30.12.2006, p. 1)



Fe: Ferrous metals	**NF: Non-ferrous metals**	**PST: Post shredder technologies**
SLF: Shredder light fraction	SHF: Shredder heavy fraction	R1, R3, R4, R11: recycling operations according to Waste Framework Directive, Annex 2
D10: Disposal operation according to Waste Framework Directive, Annex 1: Incineration on land		

Figure 1 Left: typical ELV treatment today, PBDE directed to PST
Right: PBDE separated during dismantling (theoretical)

3. Identification and separation of PBDE / decaBDE containing components during depollution and dismantling of ELVs

As just mentioned, the **key question** for this chapter is to assess if it is feasible to detect and separate PBDE / decaBDE-containing parts / components during ELV treatment.

For this purpose the subsequent chapters

- assess the available information in different sectoral databases (Section 3.1),
- provide a literature review on PBDE in parts and components (Section 3.2) and
- assess the conditions at dismantling sites / ATFs (Section 3.4).

Section 3.5 provide first conclusion with regard to the key question before.

3.1. Information from databases, OEMs and associations

3.1.1. Global Automotive Declarable Substance List (GADSL)

In recent years many individual declarable substance lists were developed by vehicle manufacturers to exchange information regarding the material and substance composition of automotive parts and to avoid usage of critical substances in their products. These multiple lists have shown that the declaration process could be further improved. This was a key reason for developing a single, globally harmonized list with clear criteria and a transparent process to manage future versions of the Global Automotive Declarable Substance List (GADSL).

The GADSL is the result of the efforts of a global team of vehicle manufacturers, automotive parts suppliers (tier suppliers) and the chemical/plastics industries. The GADSL covers exclusively substances that are expected to be present in a material or part that remains in a vehicle at the point of sale. It lists all substances that fulfil the criteria above and that are either already regulated or in the regulatory pipeline in any region of the world.

As displayed in Annex 6 PBDE and decaBDE were first added to the GADSL in January 2005. In consequence the automotive supply chain is required to report on these substances in the International Material Data System (IMDS) for new products, materials and components (see next chapter).

3.1.2. International Material Data System (IMDS)

IMDS, established in 2000, is designed to act as an easily accessible online system to help vehicle manufacturers and their supply chain to record and track substance and material compositions of their components. The system aims not only to achieve legal compliance but also is an integral part of the industries quality processes. System users today include:

- Around forty name-brand manufacturers, representing more than 90 different brands of vehicles
- More than 120,000 automotive suppliers of materials and components.

Since its implementation into the automotive processes, IMDS, in conjunction with the GADSL, has become the state of the art information system for material declarations along the supply chain in the automotive industry.

It is important to note that IMDS is not a “full material disclosure” system (for manifold legal, technical and especially business-related reasons) but the suppliers are obliged to report 90% of the substances used in the material / component only. Materials listed in the GADSL however must be reported in IMDS, regardless their share (respectively down to the reporting threshold listed in the GADSL). Following this rule it can be concluded that all of the critical substances are reported along the supply chain.

However this reporting obligation in general applies only from the date when the substance was listed for the first time in the GADSL. IMDS declarations before that date remain valid and a changed IMDS reporting is submitted only when a declaration is due (e.g. new supply contract, new vehicle type, new part development, etc.). IMDS started to collect data in the year 2000, decaBDE has been listed in the GADSL since 2005.

The contractor applied for official access to IMDS and assessed data available with standard requests. For this purpose we searched in the section “Where-Used Analysis” for “Basic Substances” in the MDS / Module for “decaBDE” for “accepted” and “published” Material Data Sheets (MDS). The response displays different categories as “materials”, “semi components” (=parts) and “components” (= Original Equipment Manufacturer (OEM) parts) depending on the category of the production chain. However the descriptions are quite diverse and in many cases cryptic abbreviations and product nomenclatures are displayed. On top different languages for the name of the materials/ components are applied without standard translations. There is no hierarchical definition system in force to steer the description of the parts and to conduct statistical analysis. In result it was not possible to determine where the identified parts are used in vehicles. In addition the share of decaBDE in the identified MDS is quite diverse in the range of less than 0.1% up to 20% (for some materials). No tool is available to the standard user to conduct statistical analysis on the share of decaBDE (or other contaminations) for the identified materials and parts. It is not possible to determine whether the material / part was ever used or if simply a supplier offered the part but it was never used by the OEMs. As IMDS does not provide a link to the bill of materials for vehicles it is not detectable from IMDS which part / component is used in which vehicle. Only the OEM himself is able to retrieve this information for his own parts in his in-house system, as the information transmission is B2B and may be sensitive regarding intellectual property.

As mentioned by the steering group members for this project the bill of materials are effectively different for each vehicle, and providing a link between IMDS and vehicles would cause a tremendous data volume difficult to handle with today’s tools. It would also affect OEMs’ confidential proprietary rights..

At the request of the contractor ACEA launched for the purpose of this study a specific request for advanced access to IMDS to identify materials, parts at the lowest Tier level and OEM parts affected by decaBDE and PBDE. Table 5 displays the total number of materials and parts listed in IMDS and affected by decaBDE and Table 6 provides information on materials affected. Comparing table 5 with table 6 makes clear that in IMDS many material variants exist which can be allocated to around 10 different basis polymers types.

Table 5 Total number of materials and parts listed in IMDS and affected by decaBDE

	Listed in IMDS	Affected by > 0.1% decaBDE	Affected by > 0.0% decaBDE
Materials	38 000 000	5 454	5 494
Parts (lowest Tier)	27 000 000	87 422	149 937
OEM parts*	330 000 000	268 563	269 131

* Multiple counts at OEMs because of trim level and variants of a car type.

Table 6 Materials listed in IMDS and affected by decaBDE

Affected by > 0.1% decaBDE
PE, PET, Adhesive, PP, Coating, PU, EPDM, PA, PBT, Epoxy, PAH, PVC, ABS,

3.1.3. Information provided by OEMs and automotive suppliers

An assessment in 2013 of Volkswagen identified components in current vehicles (2013) containing decaBDE as displayed in Table 7.

Table 7 Components potentially affected by decaBDE in current vehicles (2013) (source Volkswagen)

Component name	Material
Shrink tubing of electrical cables (connecting cables, wiring harnesses) in all parts of the vehicle (e.g. rear window, exterior mirror mount, antenna connection, airbag module, etc.)	Different thermoplastics
Covers (seats (all parts incl. headrest), parcel shelf, door trim, roof trim, A-/B-/C-/D-pillar trim)	Artificial leather
Fuel lines and similar (shrink-on sections)	Thermoplastics
wiring harnesses made of TPS-SEBS	TPS-SEBS[11]
Upholstery pads (chafing protection)	PA 6.6-Textil
Bumpers (occasionally)	adhesive

According to a sector-wide investigation (ACEA 2015), decaBDE has been found in typical materials, e.g. in PE, PP, adhesives, microfiber polyester, TPS-SEBS, nylon and typical applications, seat covers, cooling fans and hoses, electrical switches and housings, heat shrink tubing's, fuel systems, tunnel isolations and sealing.

---

[11] TPS: Thermoplastic elastomers (TPE) based on styrene block copolymers; SEBS: Styrene-ethylene-butylene-styrene

According to the same presentation (ACEA 2015), the automotive industry has been phasing out decaBDE over the past years, globally. As displayed in Figure 2, very few applications still contained decaBDE in 2015. Since 2006, the number of components containing decaBDE has been reduced by >90%.

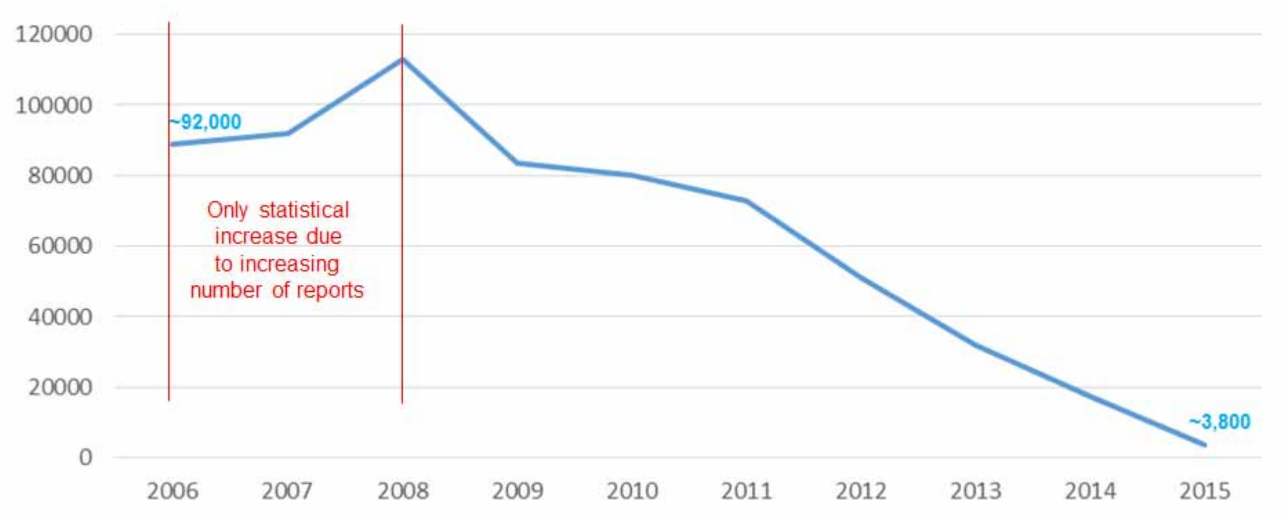


Figure 2 **Amount of annual transmitted data sheets containing decaBDE (ACEA 2015)**

In May 2018 the automotive suppliers associations Automotive Industry Action Group (AIAG) and European Association of Automotive Suppliers (CLEPA) provided at the request of the ACEA information on decaBDE-containing materials and parts as displayed in Table 8 below.

Table 8 **AIAG and CLEPA: replies to a survey on decaBDE in materials and parts for vehicles**

In which materials decaBDE has been used by your company?
AIAG: Adhesives, plastics (PET, PE), resins, epoxies, flame retardant, acrylics, shrink tubes and thermoplastic elastomers (TPS-SEBS); was used in TPE …now replaced with BDE-free
CLEPA (supplier 3): Mainly in PUR/PET and rubber, small amount of PE
CLEPA (supplier 4): Thermoplastic materials of heat shrink tubes

In which parts has it been used (we expect mostly shrink tubes and probably also other convoluted tubing applications)?
AIAG: For the most part, the decaBDE is / was in heat shrink tube, tape, wires and cable; tubing and/or coatings of tubing.
CLEPA (supplier 1): We had decaBDE in some of the PE shrink/corrugated tubes used to protect cables. We also had a flame

retardant coating that contained decaBDE (approx. 20% concentration in coating material) and was applied on Tyvek adhesive tapes in the US.

CLEPA (supplier 3):

in trim, headrest structure and shrink tubes. Trim always is the textile component, headrest structure describes the inner parts of the headrest, but normally without trim: Most of the findings are in the back liner of the textiles. It seems that it is contained in the adhesive used to glue textile and back liner together.

CLEPA (supplier 4):

heat shrink tubes: decaBDE has been used in shrink tubes of electrical connectors of heating fields and antennas of Automotive Glazing parts - mostly toughened backlights.

Until when was decaBDE used? Where there any regional differences?

AIAG:
No common answer, here are the responses from companies:

- The bulk of components were converted to decaBDE-free by 2015.
  - Do not see a regional difference – even Chinese suppliers appear to have eliminated it.
  - May 2017- no information about regional differences. EU removed first…most in last 10 years

CLEPA (supplier 1):
We replaced materials when OEMs started to mark the substance as restricted/prohibited in their specifications. So, when decaBDE was included in Annex XVII, most of our products were already free of decaBDE. (concentrations from 0.2 to 10-12% in PE material)

CLEPA (supplier 2):

We detected presence of decaBDE in our products in the past, but in the most cases this substance has been already replaced. Last time it was detected in parts in South Korea and Brasil, in tubes.

CLEPA (supplier 3):

Replacements were done during 2014-2016 timeframe. Right now all wire harnesses are decaBDE-free, but trim and headrest structures still have decaBDE present in some cases: regional difference: main use detected in Asia/Pacific region

CLEPA (supplier 4):

Replacement in 2013 and before – all regions

In which concentrations has decaBDE been used?

AIAG:

No common answer, here are the responses from companies:

- Mostly in the 10-21% range, but there were a few heat shrink tubes, conduit and cables as low as 3.5%
- 20-40% in TPE
- 33.33%, 15.5%, 11.5%, 20%, 16%. Concentration in the material.

CLEPA (supplier 3):
Material level: around 7% (textile). 5% (rubber); 15% shrink tube; part level: around 0.005% for all affected parts

CLEPA (supplier 4):
15-21%

Can you provide an average length or mass of a wiring harness in a car and related to that figures of shrinking tubes (length, mass)

AIAG:

No common answer, here are the responses from companies:

- The values below are based on a few different harness pns used for each type of decaBDE-containing component; since the sample size is so small, those harness weights could vary greatly – it is just based on the data I had easily available and could complete quickly):
  - Heat shrink tube = 4.1g versus average harness weight of 8441g
  - Cable assembly = 47g versus average harness weight of 6193g
  - Tape = 14.9g versus average harness weight of 9292g
- IMDS do not provide length but mass in wires are available:

Component Name	Weight
Cable	1.34 g
Wire FFC	0.617 g
Wire FFC, 18 Cond	4.85 g
Sensor cable	0.56 g
Ribbon cable steering	4.49 g
Heat Shrink Tube	0.50 g
Thermoshrink Tube	1.2 g

CLEPA (supplier 3):

Wire harness around 600g , shrink tube around 0.2g

CLEPA (supplier 4):

Typical mass of an electrical connector assembly: 3-6g/typical mass of decaBDE per connector: 0,04-0,1g

3.1.4. International Dismantling Information System (IDIS)

IDIS is the information system for pre-treatment and dismantling information for end-of-life vehicles (ELV). The data in IDIS is compiled by the vehicle manufacturer and is not reviewed or controlled by any other institution. Access to IDIS is provided free of charge to commercial enterprises in the ELV business.

IDIS contains safe handling information with a focus on airbag deployment instructions, handling and treatment of high voltage batteries as well as gas vehicles. Additionally, it provides user-friendly navigation to an extensive database with practical information on pre-treatment, dismantling of potentially recyclable parts and other elements mentioned in ELV regulations (e.g. mercury, lead, cadmium and chromium VI).

All vehicle data is organised in different areas. According to the IDIS systematic these areas are the following:

- Batteries
- Catalysts
- Pyrotechnics
- Controlled Parts to be removed
- Fuels
- Tyres
- Air Conditioner
- Other Pre-Treatment
- Draining
- Dismantling

It is important to know that this information is available by vehicle type[12], details of models or equipment variants are not addressed.

With regard to finding information on reusing parts, manufacturers offer access to their repair and maintenance information (RMI) websites. Access to RMI may incur a fee.

3.1.5. Conclusion on information / data available for dismantling

a) PBDE and decaBDE were first added to the Global Automotive Declarable Substance List GADSL in January 2005. Before that date the suppliers were required to report on PBDE / decaBDE in IMDS only if the substance was included in the OEM individual restricted substance lists or if the share exceeded the volume specified in the IMDS specifications. IMDS is a voluntary B2B agreed system and not legally mandatory.

b) By 2005 the automotive supply chain was required to report PBDE / decaBDE in IMDS for new products (materials and parts). Following the IMDS rules it must not happen that after the date of the GADSL-listing suppliers continue to deliver materials / components for a certain time without an updated declaration.

c) Based on a review of declared materials / components in IMDS, decaBDE is found in various materials and plastics and subsequently in parts scattered over the vehicles.

d) The number of components containing decaBDE has decreased since 2007 and by July 2018 decaBDE will be phased out in all new developments and current production vehicles worldwide (ACEA 2015).

e) IMDS does not refer to a specific vehicle or specific VIN nor to a specific type, as it does not contain the information on the parts used in a specific vehicle / specific type (bill of materials).

f) Even if it would be possible to link IMDS information on parts to individual VINs it is not certain that after-sales manipulation did not change (add or take out) contaminated parts.

g) IDIS does not provide information to the dismantlers on PBDE / decaBDE. The design of IDIS refers to vehicle type and does not provide information on model or VIN level.

h) In result no database / source is available which provides detailed information to the dismantlers on parts with decaBDE for vehicles of the relevant age.

i) At ACEA's request, AIAG and CLEPA supported this study with details on the use of decaBDE. A key aspect is that even if parts / components such as seats or (wiring) harness are removed, the concentrations of DecaBDE for the removed part / component are low.

---

[12] in the meaning of type approval

3.2. Literature review on PBDE/ decaBDE content of parts/ components

Currently, six brominated flame retardants have been classified as POPs: tetra-, penta-, hexa- and hepta-bromodiphenyl ethers (BDE), hexabromobiphenyl (HBB) and hexabromocyclododecane (HBCDD). decaBDE, was included in the Stockholm Convention in 2017.

decabromodiphenyl ether (decaBDE) is a flame retardant. Total world production of c-decaBDE in the period 1970-2005 was between 1.1-1.25 million tonnes (Bipro, 2017). Data on use of c-decaBDE indicate that prior to 2008, 80–90% of c-decaBDE was used in EEE products, with textile applications accounting for most of the remaining 10–20% (Bipro 2017). As outlined in OSPAR (2009), main uses of decaBDE had been textiles (upholstery fabrics, polypropylene drapery and carpets), furniture and electronics. According to findings from OSPAR (2009) and Swedish Chemicals Inspectorate (KemI) (2004) about 80% of the use of decaBDE in 2001 in the EU can be attributed to electronic articles. KemI (2004) allocates the remaining 20% of uses in EU to textiles. Overall, OSPAR (2009) states that there are insufficient data to assess the magnitude of the various flows of PBDE and PBB and the resulting releases. Since 2008 the EU RoHS Directive has been restricting c-decaBDE use in certain EEE products. As a result, the use profile has changed so that transportation and textiles now represent a much larger percentage of c-decaBDE use in products (Bipro 2017).

MinEnv. Finland (2016) gives an overview of the usage of different brominated POPs listed in the Stockholm Convention. Annex 1 to this report presents products and materials that may contain PBDEs in more detail. However, attention should be paid to the fact that the use of flame retardants classified as POPs in vehicles varies based on the manufacturer, model and year of manufacture. Detailed information on the substances used in different vehicle models is not available (MinEnv. Finland 2016).

MinEnv. Finland (2016) gives percentages for the use of some POPs as flame retardants:

decaBDE has been commonly used in vehicle parts manufactured out of hard ABS and HIPS plastics, electronic parts and their casings, as well as vehicle textiles, especially seats and artificial leather for seat covers and interior lining. Typically, 10-15% of decaBDE by weight has been added to plastics. Textiles contain a maximum of 12% of it (Bipro, 2015b). On February 2017 Regulation (EU) 2017/227 was published to include decaBDE restriction in Annex XVII to Regulation (EC) No 1907/2006 (REACH Regulation). decaBDE shall be subject to a limit of 0.1% (by weight) for its use in the production of or placing on the market in another substance as a constituent, a mixture, or an article or any part thereof after 2 March 2019 (Regulation (EU) 2017/227).

Commercial pentaBDE has been used especially in vehicle seats from polyurethane (PUR). Typically, approximately 4% has been added to the PUR. It has also been used to a certain degree in circuit boards.

Commercial octaBDE has been used in hard plastic, such as casings, especially in ABS and to a lesser extent in HIPS. Typically, 10–18% of octaBDE by weight has been added to ABS plastic and 12–15% of the total weight to HIPS plastic.

HBCDD has been used in vehicle upholstery materials in e.g. seats, casings and interior materials and especially body parts manufactured out of HIPS plastic. Approximately 1–7% of HBCDD by weight has been added to HIPS and approximately 2–4% by weight to textiles (MinEnv. Finland 2016).

PBDEs were examined in BMRA (2013) for some types of seat foam and seat fabric. Samples of seat foam materials within the shredder residue fraction were randomly collected from the fragmentiser installations. The results of the analysis of the two samples indicated that the presence of PBDE was below the limit of detection (1 mg/kg). Further investigation was also undertaken by sampling the PUF (seat foam) and fabric from four ELVs: BMW (26 years), Vauxhall (18 years), Ford (16 years) and Peugeot (11 years). The results of this analysis indicated that PBDE was below the limit of detection for both foam and fabric in all samples (BMRA 2013).

Table 9, Table 10 and Table 11 display results of the analysis on decaBDE.

Table 9 decaBDE (BDE209) in vehicles (IVM, IVAM 2013)

Part/material	country	no. of samples	detection frequency	concentration mg/kg	min mg/kg	max mg/kg
seat cover, Pontiac transport 1997	NL	1	1	22 500		
seat cover, Mazda 1998	NL	1	1	22 700		
car seats, 1974-2002	NL	11	2	→	nd	131 (#)
seat cover, Chrysler Saratoga 1991	NL	1	1	256		
PUF, Pontiac 1997	NL	1	1	522		
PUF, Mazda 1998	NL	1	0	nd		
PUF, US cars (*)	NL	5	5	→	0.11	17
Interior, Pontiac 1997	NL	1	1	18		
Interior, Mazda 1998	NL	1	1	52		
different components (**)	NL	11	0	nd		

(*) US cars = Chrysler (1993), Buick (1992), Ford (1993), Chevrolet (1999), Pontiac transport (1995)
(**) e.g. Headlining, light cover, carpet, bumper, air hose, insulating material
nd = not detected
(#) “value from a car assembled in 1998”

Table 10 decaBDE in vehicles (MEPEX 2012 cited in e.g. Bipro 2017)

Part/material	country	no. of samples	detection frequency	concentration mg/kg
seat cover	NOR	1	1	27 000
interior material (door, headlining, cover)	NOR	1	1	17 000
Printed circuit boards sample 1	NOR	1	1	200
Printed circuit boards sample 2	NOR	1	0	nd
Printed circuit boards sample 3	NOR	1	0	nd
Printed circuit boards sample 4	NOR	1	1	33
Soundproofing material sample 1	NOR	1	0	nd
Soundproofing material sample 2	NOR	1	1	7 000
airbag material	NOR	1	0	nd
luggage compartment material	NOR	1	0	nd
Radiator, outer material	NOR	1	0	nd

Table 11 decaBDE in vehicles (Bipro 2015)

Part/material	country	no. of samples	detection frequency	concentration mg/kg	Original source
PUF (old cars)	SE	17	14	nd (min) 2.1 (max)	Niinipuu 2013
interior	NL	2	0	nd	Ballesteros-Gomez et al. 2013
interior	CN	5	3	8	Chen-S-J et al. 2010

As displayed in Table 9 decaBDE (BDE209) was examined by IVM, IVAM (2013) for different parts and vehicles assembled in different years. decaBDE in different components (interior (excl. seats) and bumper) was found to be under 3.6 mg/kg. Only the values of the interior of the Mazda 1997 (52 mg/kg) and Pontiac Transporter 1998 (18 mg/kg) were higher. In comparison, concentrations found in seat foam and seat covers were higher than in interior and other components (<4.4 to 256 mg/kg). The values found in seat cover of the Mazda 1997 and Pontiac 1998 were extraordinarily high (22 700 and 22 500 mg/kg).

Table 10 of this report shows values for decaBDE in different components found in MEPEX 2012. The values are cited, inter alia, in Bipro 2017. The original study (MEPEX 2012) was not available so there is no further information about the vehicles under examination. High values were found in seat cover, interior and soundproofing material (27 000, 17 000 and 7 000 mg/kg). For seats and interior material only one sample was examined, for soundproofing material two samples. In the second sample of soundproofing material decaBDE was not detectable.

Three other sources give values for decaBDE in PUF and interior respectively. Values were between “not detectable” and 8 mg/kg (Table 11).

The highest values are found in seat covers, with 22 500 mg/kg for the Pontiac 1997 and 22 700 mg/kg for the Mazda 1998. The third high value (27 000 mg/kg) is for an unknown car brand and reported by MEPEX (2012) for Norway. The material of the seat cover and whether it was artificial leather or not is not known to the authors of this study for ACEA.

The high outliers in ‘interior’ and ‘soundproofing material’ are also reported by MEPEX (2012). Because of the lack of access to MEPEX (2012) the authors cannot provide more details / reasoning on these high values.

Despite these four samples with high values, all values in the reviewed literature are between 0 and 522 mg/kg. The highest detection frequency is found for ‘PUF’.

3.3. Components and parts containing PBDE/ decaBDE

Considering the analyses discussed in Sections 3.1 and 3.2, a number of parts are suspected to contain decaBDE with relevant concentrations. This applies for seat covers, interior, shrinking tubes and soundproofing material. Suspected means that decaBDE and / or PBDE was detected in high concentrations in a small number of samples, but not all samples of seat (covers), interior, shrinking tubes and soundproofing parts contained PBDE in relevant concentrations or PBDE was even below the detection threshold. The available information from literature on parts with high contents of decaBDE / PBDE does by far not suffice to design and roll out a European-wide separation program.

Considering diverse databases (Section 3.1) the only potentially relevant one is IMDS (Sub-section 3.1.2). Considering IMDS, a number of OEM parts are suspected to contain decaBDE like (wiring) harnesses, artificial leather, wire, electrics, coatings and seals. However some key information is, for the time being, not detectable from IMDS:

- The share of the mentioned OEM parts contaminated compared to the total of this kind of component
- IMDS does not provide a direct link to individual VINs.
- Even if a link to an individual vehicle would be possible, changes after sale may occur.

3.4. Conditions at sites carrying out depollution and dismantling

3.4.1. ELV Directive

Depollution and dismantling is regulated in the EU by the ELV Directive[13]. Article 6 establishes the general requirements for treatment and Article 6(3) gives more details on depollution:

> *3. Member States shall take the necessary measures to ensure that any establishment or undertaking carrying out treatment operations fulfils at least the following obligations in accordance with Annex I:*
>
> *(a) end-of life vehicles shall be stripped before further treatment or other equivalent arrangements are made in order to reduce any adverse impact on the environment. Components or materials labelled or otherwise made identifiable in accordance with Article 4(2) shall be stripped before further treatment;*
>
> *(b) hazardous materials and components shall be removed and segregated in a selective way so as not to contaminate subsequent shredder waste from end-of life vehicles;*
>
> *(c) stripping operations and storage shall be carried out in such a way as to ensure the suitability of vehicle components for reuse and recovery, and in particular for recycling.*
>
> *Treatment operations for depollution of end-of life vehicles as referred to in Annex I(3) shall be carried out as soon as possible.*

(Annex I(3) to the ELV Directive) gives the following details:

> *3. Treatment operations for depollution of end-of-life vehicles:*
>
> - *removal of batteries and liquefied gas tanks,*
> - *removal or neutralisation of potential explosive components, (e.g. air bags),*
> - *removal and separate collection and storage of fuel, motor oil, transmission oil, gearbox oil, hydraulic oil, cooling liquids, antifreeze, brake fluids, air-conditioning system fluids and any other fluid contained in the end-of-life vehicle, unless they are necessary for the re-use of the parts concerned,*
> - *removal, as far as feasible, of all components identified as containing mercury.*

In addition, Article 6(5) stipulates that

> *Member States shall encourage establishments or undertakings, which carry out treatment operations to introduce, certified environmental management systems.*

Member States might implement more strict requirements in their national legislation[14].

3.4.2. Number of ATFs in EU Member States

Annex 2 shows an overview for the numbers of authorised and registered treatment facilities (ATF) in EU Member States as well as the number of ATFs with certified environmental management

---

[13] Directive 2000/53/EC of the European Parliament and the Council of 18 September 2000 on end-of life vehicles (OJ L 269, 21.10.2000, p. 34)

[14] Based on the Treaty establishing the European Community, Article 175(1)

systems. Around 12 893 ATFs are reportedly operating in the EU of which 1130 – 1150 apply certified environmental management systems (ARGUS, 2016). With the Czech Republic, Germany, Latvia, Slovakia and UK, some of the largest Member States did not contribute to the reporting on the number of certified ATFs. Thus the number for ATFs with certified environmental management systems is incomplete.

3.4.3. Characteristics of ELV directed to dismantlers

3.4.3.1. Average age of ELVs

From the national reports accompanying the reports to the EC on the number of ELVs treated the age characteristics are known for several MS.

Figure 3 displays the age distribution for Portugal in 2015 and Figure 4 displays the assumptions on the dismantlers for France.

France reported an average age of ELVs processed in 2015 of 17.5 years (ADEME 2017), Portugal of 20 years (Portuguese Environment Agency 2017) and in Poland an average age of deregistered vehicles for dismantling of 19.5 years (Polish Ministry of the Environment 2017). Germany reported for 2014 an average age of approximately 14 to 15 years and for 2015 of approximately 17 to 18 years (German Federal Ministry for the Environment 2017).

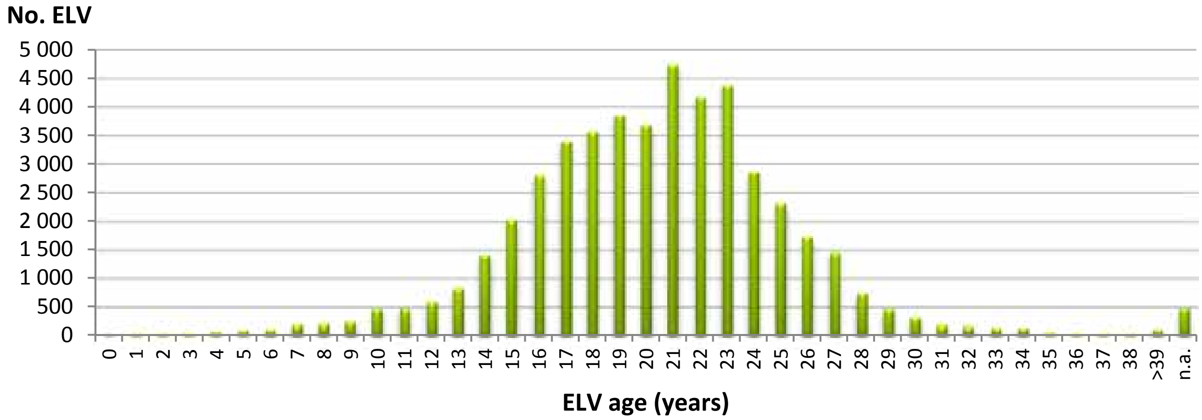


Figure 3 Age breakdown of ELVs delivered to dismantlers in Portugal in 2015, data based on 58% of certificates of destruction issued; Portuguese Environment Agency 2017

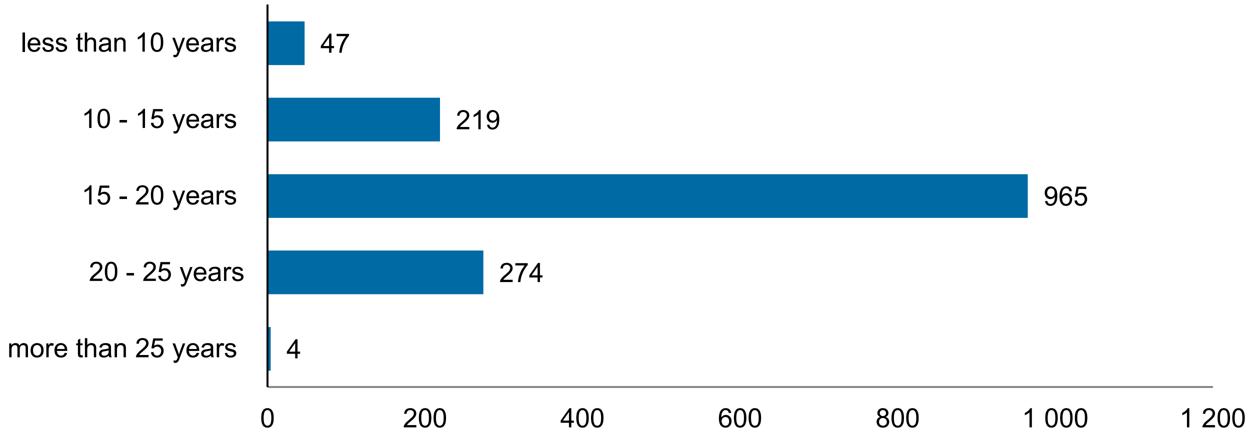


Figure 4 **Dispersion of average ages declared by authorised dismantlers (in number of dismantlers per average age category) for France in 2015, ADEME 2017**

3.4.3.2. Composition of ELVs, exemplary data for France

For 2015, the composition of ELVs in France is shown in Table 12, expressed in percentage and in mass (kg) per ELV, based on an average ELV mass of 1 051.24 kg in 2015. In practice around 5% (52 654 units) of ELV were set on fire and non-metal materials burned before delivered to dismantlers. Ademe applied a correction accordingly displayed in the 3rd column. The average corrected mass of an ELV is of 1 040.58 kg for 2015 (ADEME 2017).

Based on the average ELV composition displayed in Table 12, ADEME estimates the tonnages of materials that the entire ELV sector received in 2015 as displayed in Table 13.

Table 12 Average composition of an ELV in 2015 in France (ADEME, 2017)

Material	Proportion of each material (%)	Mass of each material in kg/ELV	Corrected mass of each material in kg/ELV
Ferrous metals	70.0%	735.87	735.87
Polypropylene (PP) - other parts	4.4%	46.25	43.86
Non-ferrous metals (excluding wiring harnesses)	4.0%	42.05	42.05
Tyres	3.4%	35.74	35.74
Glass	3.0%	31.54	29.90
ABS, PVC, PC, PMMA, PS, etc.	2.2%	23.13	21.93
Polyurethane foam	2.0%	21.02	19.94
Textiles, other	1.7%	17.35	16.45
Lead starter battery	1.4%	14.72	14.72
Other rubber compounds	1.1%	11.56	10.96
Polypropylene (PP) - bumpers	1.1%	11.56	10.96
Wiring harnesses	1.0%	10.51	9.97
Polyamides (PA)	1.0%	10.51	9.97
Paint	0.8%	8.41	7.97
Polyethylene (PE) - fuel tanks	0.8%	8.41	7.97
Spent oil and filters	0.7%	6.94	6.94
Catalytic converters	0.5%	5.26	5.26
Polyethylene (PE) - other parts	0.5%	5.26	4.98
Cooling or brake fluids	0.4%	4.63	4.63
Air-conditioning fluids	0.1%	0.53	0.53
Total	100.0%	1051.24	1040.58

Table 13 Estimated quantities of materials of ELVs processed in 2015 in France (ADEME, 2017)

Material	Estimated materials received by dismantlers in tonnes	Estimated corrected materials received in tonnes
Ferrous metals	747 881	747 881
Polypropylene (PP) - other parts	47 010	44 576
Non-ferrous metals (excluding wiring harnesses)	42 736	42 736
Tyres	36 326	36 326
Glass	32 052	30 388
ABS, PVC, PC, PMMA, PS, etc.	23 505	22 288
Polyurethane foam	21 368	20 266
Textiles, other	17 629	16 719
Lead starter battery	14 958	14 958
Other rubber compounds	11 752	11 139
Polypropylene (PP) - bumpers	11 752	11 139
Wiring harnesses	10 684	10 133
Polyamides (PA)	10 684	10 133
Paint	8 547	8 100
Polyethylene (PE) - fuel tanks	8 547	8 100
Spent oil and filters	7 051	7 051
Catalytic converters	5 342	5 342
Polyethylene (PE) - other parts	5 342	5 061
Cooling or brake fluids	4 701	4 701
Air-conditioning fluids	534	534
Total	1 068 401	1 057 570

3.4.4. Current situation

In the context of the ELV Directive several countries report voluntarily on the volume of dismantled large plastic parts as displayed in Table 14. Most of the volume dismantled is directed to recycling and less volume is directed to reuse. Compared to the shredder light fraction displayed in addition in Table 14, the share of dismantled large plastic parts by country differs between less than 1% and more than 40% of the sum of shredder light fraction plus dismantled large parts from dismantling.

Table 14 Large plastic parts dismantled from ELVs compared to shredder light fraction, in tonnes (Eurostat)

	Disposal	Energy recovery	Recycling	Reuse	Disposal	Energy recovery	Recycling	Dismantled
	Large plastic parts from dismantling				Shredder light fraction			%
BE	0	0	218	1	1 469	3 323	5 259	2.1%
CZ (2104)			612		14 327	0	0	4.1%
DE	26	0	1 285	45	15 265	30 141	45 892	1.5%
EE	47	69	87	45	891	0	0	21.8%
EL	0	0	197	106	0	2 730	3 025	5.0%
ES	0	0	904	0	34 542	50 288	12 572	0.9%
FR		35	4 727		33 688	42 645	34 363	4.1%
HR			249		60	1 002	5 447	3.7%
CY			55		474	0	0	10.4%
LV	3	0	28	24	0	0	245	18.3%
HU	10	0	61	47	148	0	0	44.4%
AT	2		382	0	1 159	2 876	849	7.3%
PT	0	0	475	40	3 179	6 379	0	5.1%
SI (2014)	194	7	62	10	218	236	115	32.4%
SK	17	34	442	32	171	0	821	34.6%
IS	15	0	0	28	0	0	341	11.2%

Note: the shredder light fraction displayed might contain the volume treated nationally only for ELV generated in that country. SLF exported for final treatment is reported to Eurostat in a separate table as an aggregate with other materials and cannot be distinguished from these other materials.

In order to assess the organisational, logistical and, above all, economic feasibility or challenge of an extended dismantling of vehicles, selected[15] dismantlers in Germany were interviewed on the current situation in spring 2018. According to these interviews dismantlers accept ELVs free-of-charge and remove oil, brake fluid, etc. (draining). Dismantlers have different business models. Basically, the models differ between a material-oriented and a part-oriented model. In the material-oriented model, the dismantlers drain the cars and sell the wreck to shredders. The profit margin depends on the (swaying) scrap price.

In the part-oriented model, the dismantlers remove individual parts after draining to sell them as spare parts. The wreck is then also sold to shredder companies. Often small dismantlers also repair used cars and trade with used vehicles. The economic relevance of the different activities depends on several regional and general conditions.

During the same interviews the dismantlers provided input on new dismantling obligations.

In general, the extra effort of dismantling depends on the components to be dismantled. For instance: If the wire harness has to be removed, an intensive dismantling of the vehicle must occur in order to get to the component, while seats, etc. are directly accessible.

---

[15] The dismantlers interviewed here are bigger companies with 10-50 employees while a lot of dismantlers in Germany are smaller (< 10 employees).

In the context the dismantlers mentioned that, depending on the general approach they would need

- information about which component they should remove, provided by manufacturers or legislators in a form giving companies easy access (for example, via software accessible via smartphone (possibly embedding in IDIS)).
- more employees, since more intensive dismantling takes a lot longer,
- training / qualification of employees
- measuring device (XRF)
- more space where the components can be stored separately plus more space for the dismantling process (more space per car is needed when the car has to be further dismantled)

Regarding the area, most dismantlers noted that there is already not enough space. In the case of extended disassembly not only more storage space must be created, but also more disassembly places to ensure a sufficiently high throughput of vehicles. Creating more space is difficult. The company site would have to be expanded with a lot of effort. If there was not enough space for a direct expansion on the former company site, the new area would have to be set up further away. This would require further logistics and great effort to convert operations.

If the dismantling volume is high, additional employees would also have to be hired. In addition to the expense of the actual disassembly the expense for the logistics would thus also increase.

Additional expenditures will not only be incurred due to the additional workforce, space and logistics but also for the disposal of the dismantled parts.

Further questions to be solved are:

- Who organizes the logistics of the disposal of the contaminated removed parts? The dismantlers said they had no capacity to organize the logistics (transports from dismantler to disposal site).
- In what form (list on paper, software) do the dismantlers get the necessary information? Especially if the dismantling of components depends on specific characterizations of the vehicle (type, year of construction etc.) the dismantlers suggest getting the information electronically (software).

Overall, it should be borne in mind that the dismantling companies surveyed were larger businesses. For smaller dismantling companies, there could be even greater problems in the implementation of the extended dismantling (for example, lack of equipment or even worse economic conditions).

Tec4U Ingenieurgesellschaft mbH (2002) carried out a survey of ATFs in Germany. 115 (around 10% of all ATFs) contributed with meaningful responses. As a rule the operating area is 7-15m² per vehicle put through. With increasing vehicle throughput, the space requirement per vehicle throughput decreases significantly. Draining times are divided into two groups: One group of ATFs reaches the drainage in less than 60 minutes, the other in 80 to 140 minutes. Most ATFs of the group, with drainage times of less than 60 minutes, have throughputs of more than 500 vehicles per year. Most ATFs of the other group, with drainage times of 80 to 140 minutes have throughputs of less than 500 vehicles per year. This is in line with expectations, since increasingly professional and automated work can be assumed with increasing throughput. The majority of companies believe that dashboards, bumpers, plastic tanks and windows can be removed in less than 20 minutes each.

More recently Terra SA - Deloitte - BioIS (2015) carried out a study for Ademe on the economic evaluation of the ELV treatment chain in France. The economic analysis of the ELV activity of ATFs alone is complex, as the majority of companies do not have cost accounting specific to this ELV activity, which often coexists with other activities: purchase/sale of damaged vehicles and second-hand vehicles, sale of new spare parts, trade in scrap metal. The first stage consisted of defining a representative sample of 25 ELV centres and 7 approved shredders in metropolitan areas. The subsequent analysis of the responses to the survey and interviews revealed a weighted average loss of 23.90 €/ ELV. However the sample conceals a significant disparity in the overall results, which range from -225.20 €/ELV to +109.80 €/ELV for the sample analysed.

The result of the ATFs activity is particularly positive for ATFs whose share of ELV turnover is greater than 75% of the company's total turnover, the result being negative on average for companies whose ELV turnover represents less than 75% of the company's total turnover.

All in all the findings from the interviews and the studies demonstrate that such additional obligations to remove parts will have (depending on the specific component) huge effects on the current dismantling with the risk of jeopardising the economic viability of the dismantling in legally-operating ATFs.

From the experience in the sector it is known that worsening the economic conditions in the official activities increases the risk of illegal activities in the sector. Avoiding such illegal activities requires huge efforts by public authorities to ensure appropriate enforcement of future regulations.

3.4.5. Options for management of additional dismantling

Figure 5 below displays theoretical options for separating PBDE-containing parts from ELVs during dismantling. The details of these options and relevant shortcomings with regard to decaBDE are discussed below.

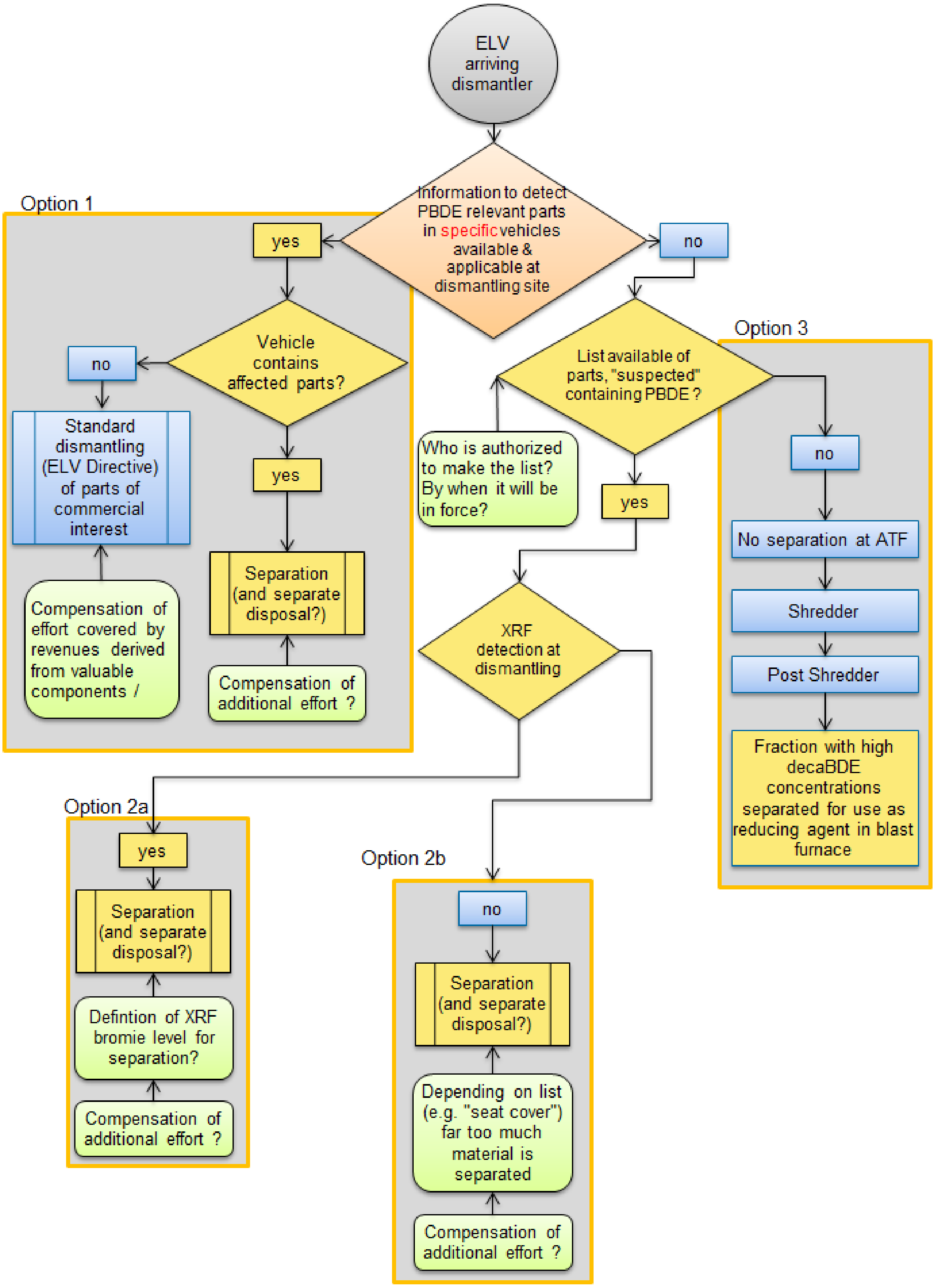


Figure 5 **Options for separation during dismantling and depollution**

3.4.5.1. Option 1: Information to detect PBDE is available for each single car.

Information that is required for the dismantling sector to effectively separate POPs from ELVs would be a detailed description/ location of each POP-containing component in relation to the individual vehicle specification.

A “normal” vehicle type is usually available in thousands of different configurations. Thus there is great diversity within vehicle types.

An exact description of material compositions for each individual vehicle would be technically challenging and it is questionable whether it would be useful to the dismantlers, as such information might not be processed on the dismantling site.

The systems available in the sector (IMDS/ IDIS) therefore are not developed to provide detailed and exact information about substances used in individual vehicles.

In result this option 1 is theoretical only, because no database / source is available to provide detailed information to the dismantlers on parts with decaBDE.

However, even **if** the information were available, the following shortcoming would apply:

If, for instance, the wire harness has to be removed, the vehicle has to be dismantled very intensively. During the production process of a vehicle, the wiring harness is one of the first components to be assembled into a vehicle. Insulation, carpets, seats, instrumental panel, consoles, covers and finishers are installed after the wiring harness. During the dismantling process it is thus one of the last parts to be removed from the vehicle. Furthermore, the wiring harness of a vehicle is highly branched (see Figure 6); therefore, the dismantling of the wiring harness approaches totally dismantling the vehicle – a very complex and highly time-consuming process.

Table 15 shows the dismantling duration for an example of an up-to-date compact car of an ACEA member who frequently performs dismantling studies, including detailed documentation of parts and dismantling times.

To remove the wiring harness from the vehicle, many predecessor parts must first be removed. All mentioned dismantling times are net times, which means that the measurement of time starts when the worker is already equipped with the required tool and is placed in front of the dismantled part.

The required gross time includes the dismantling of many different parts, which requires frequent changes of tools, removal of parts, paths time of the worker, etc. Therefore, the gross time for removing the complete wiring harness ends up being two to three times higher than the measured net time of 1h22. A complete manual[16] dismantling of a wiring harness requires about 2h45 to 4h00. Comparable results have been confirmed by a third party service provider who carries out dismantling studies for several OEMs. For further details please refer to Annex 7.

2h45 up to 4h00 is compared with the effort for drainage of 1h00 to 2h20[17] (see sub-section 3.4.4 above), quite a long time, and it would call into question the potential gain for the dismantler.

---

[16] A more robust dismantling, for instance pulling from the main part would not be meaningful as the main contamination is suspected in the shrinking material / connectors, which would remain in the vehicle when non-manual dismantling is applied.

[17] Depending on the throughput of ELVs.

And, as only the shrinking tube or the connectors might be affected (and not copper and other plastics), the share of decaBDE in the wiring harness is very low. More detailed manual micro-dismantling would be needed to target the component with the high decaBDE content.

However, such manual micro-dismantling is out of any scope. Instead, the manually dismantled wiring harness would be comminuted and processed in quite a similar manner as shredder residues. This also raises the question of the usefulness of manual disassembly.

The harnesses may not be the only components that need to be removed (see Chapter 3.1 and 3.2).

The cost for separation and disposal of the separated material remains with the ATF.

In addition, it is to be questioned whether current technician education is sufficient to carry out intensive dismantling and accurate separation.

Figure 6 **Location of wiring harness (red), © Volkswagen**

Table 15 Net dismantling time for wiring harness per module, for gross dismantling time net time was multiplied by factor 2- 3

Wiring Harness	**Net-Dismantling Time [h:min:sec]**	**Gross-Dismantling Time [h:min:sec]** (Factor 2-3 net time)	**Weight Wiring Harness [g]**
Engine Compartment	8:10	16:20 - 24:30	4 890
Instrumental panel	24:30	49:00 – 1:13:30	2 862
Interior	19:30	39:00 – 58:30	8 293
Doors	20:50	41:40 – 1:02:30	1 945
Rear end/ rear door	4:10	8:20 – 12:30	1 480
Underbody	5:30	11:00 – 16:30	2 255
SUM	1:22:40	2:45:20 – 4:08:00	21 725

Source: Kai Siegwart (Opel Manager Take-Back Network), unpublished

3.4.5.2. Option 2: List for dismantling in force

Option 2 is based on the assumption that, as the identification of components to be dismantled from individual vehicles is not feasible as the link to the VIN is not given, a list of components suspected to contain decaBDE is used. The first question is: Who shall decide on such a list, based on what mandate and what information? In principle it could be added to Annex I of the ELV Directive in clause (3) on treatment operations for depollution of end-of-life vehicles. However such an amendment will take time and it is all but sure that an assessment of such an amendment would recommend such a list compared to the separation of decaBDE during PST.

Thus Option 2 is theoretical, as it is based on the assumption that, by whatever means, a list is available to the dismantler on components suspected to contain decaBDE / PBDE and that this list is properly applied by the dismantler and its employees.

Even if the list would be available it risks being insufficiently specific:

- If for instance “artificial leather” is targeted, many non-contaminated seats and interiors might be dismantled. To avoid such useless separation the dismantler might check the suspected artificial leather seats and interior with a handheld XRF detector for bromine content.[18]
- If for instance wiring harness is targeted, huge effort is spent to separate such wiring harness (see Option 1 above). The shrinking tube might be the only part of the wiring harness suspected to contain decaBDE. And if the XRF detector indicated the absence / low level of bromine all the effort for the manual separation of wiring harness will have been wasted.

Such elaborated procedures are more than unlikely to be applied by the dismantlers as it is not in their interest to detect seats / interior with high bromine content, as it would cause relevant space

---

[18] XRF can only measure bromine content (but not the specific DecaBDE content). During the measurement all bromine is detected. In order to ensure that the corresponding part is removed if the limit value is exceeded, this limit value would have to be defined as the bromine limit value. More experience in comparing XRF results and laboratory analysis is needed to define an appropriate level of bromine for the detection of contaminated parts. With regards to regulations a threshold concentration would be needed for separation application.

for storage of the separated materials and relevant disposal cost. Effective surveillance is not likely either.

3.4.5.3. Option 3: No dismantling, as no information for individual vehicles is available and no list is in force

If no information for individual vehicles is available (Option 1) and no list of parts suspected to contain decaBDE is in force (Option 2), the dismantlers have no means to target components for separation (Option 3). In result no dismantling of parts with decaBDE will be performed by ATFs. The depolluted wreck will be sent to the shredder as before. As long as PST is applied, disposal on landfill of PST fractions is prohibited and high caloric fractions are instead used as reducing agents (see Chapter 5), this is considered as a feasible option. For more details on this option please refer to the subsequent chapters.

3.5. Conclusions

The key question for this chapter was to assess the feasibility of detecting and separating PBDE / decaBDE -containing parts / components during ELV dismantling.

- The average age of ELVs is between 17 and 20 years. A relevant number of ELVs is even more than 25 years old.
- From 2005 onward suppliers of OEMs were to report PBDE and decaBDE to IMDS, however there is no direct link to individual VIN to detect PBDE and decaBDE -containing parts in individual ELVs. During life spans components and parts might be added / exchanged. No means are in place to detect whether such components and parts added to an individual vehicle contain decaBDE or other PBDE.
- In result it is not possible to provide a data set to dismantlers to identify for each VIN which parts need to be dismantled.
- Analyses of parts suspected to contain higher levels of PBDE and decaBDE revealed quite diverse results. For seat covers made of artificial leather, interior, shrinking tubes and soundproofing material decaBDE was detected in higher concentrations in a small number of samples. Not all samples of seat covers, interior, shrinking tube and soundproofing parts contain decaBDE in relevant concentrations or decaBDE might even be below the detection threshold. The available information from literature on parts with high contents of decaBDE refers to a very small number of analyses only does not nearly suffice to design and roll out a European-wide separation program.
- A dismantling requirement based on the above-described information would be not well targeted. Much of the effort would be spent for separation of non-contaminated parts. As time goes on this worthless spent effort will increase as fewer parts are contaminated, in particular for vehicles produced from 2012 onwards.
- Any extension / intensification of dismantling requires more space and personnel. Separated parts would be directed to the treatment facilities. The costs for logistics (reporting, storage and shipment) and disposal of the dismantled parts are combined with the costs of space and personnel. This would not be affordable under the given economic conditions for dismantlers (especially for smaller businesses) and dismantlers may tend to avoid such costs.
- In fact it would jeopardise the current model of the economic viability of depollution and dismantling at ATFs and thus increase the risk of illegal operations. To avoid such detriment, the entire funding system for the 12 893 ATFs across EU (dismantling around 6 Million ELVs in Europe per year) needs to be changed and public authorities must ensure much stricter enforcement at ATFs (and competing illegal sector) than today.
- For shredder operators it is difficult (if not impossible) to assess whether the parts possibly containing PBDE and decaBDE are separated by the ATFs. In consequence government agencies must supervise the separation and safe disposal of these components at 12 893 ATFs across the EU.
- Last but not least it is more than likely that the dismantled parts will be shipped to the same (kind of) disposal or recycling facilities (used as reducing agents) as the shredder residues resulting from these parts. And thus all the effort and distortion of the sector again is questioned.

4. Treatment of ELVs in shredders and PST installations

The general reference for this section is the final draft of the Best Available Techniques (BAT) Reference Document for Waste Treatment as published in October 2017, subsequently referred to as "BREF WT (2017)"

4.1. Shredder

The main process steps in a shredder are:

1. delivery, reception and acceptance;
2. pre-sorting and pre-treatment;
3. Pre-sorting is an important way to guard against deflagrations or items causing harm to the shredder plant. It can be done manually or mechanically (e.g. with a grab/magnet).
4. shredder technology including pre-shredder technology (see Sub-section 4.1.2)
5. post-shredder processes (see also Section 4.2);
6. end-of-pipe abatement techniques.

The majority of such shredders are located in the open air, not enclosed within buildings.

The typical operations of shredders are displayed in the Figure 7. In 2014 a total of 352 "automotive shredders" were operating in the EU and Norway. Most of them were located in Italy (62), France (50), UK (47), Germany (43) and Spain (31). The remaining 33% of this kind of shredders are distributed among 20 countries. A detailed list of all ELV processing shredders in 2014 can be found in Annex 3.

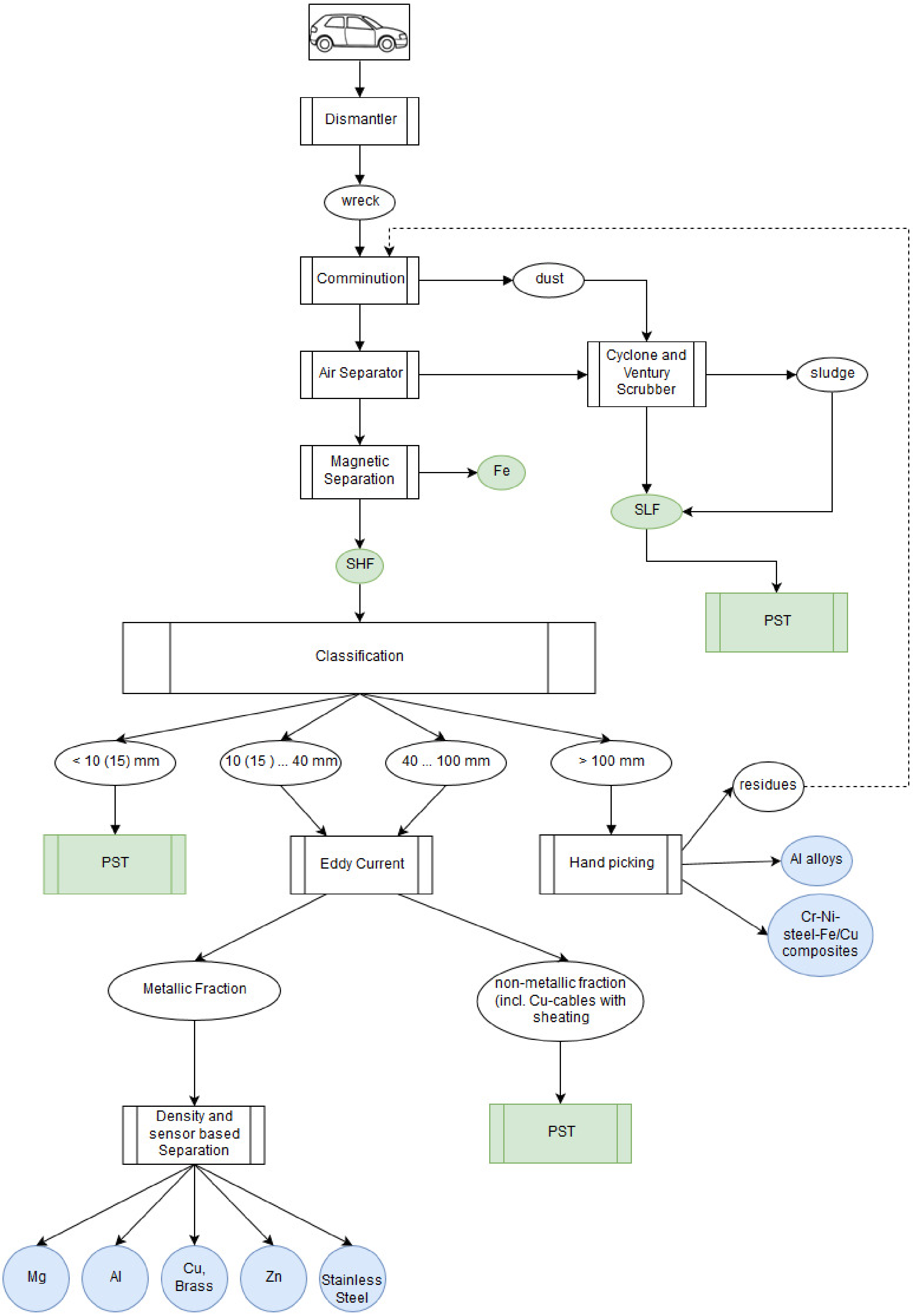


Figure 7 Typical process of ELV treating shredders, details might differ with regard to dust treatment or sieve cut

4.1.1. Total shredder output from ELVs

According to the ELV Directive the EU Member States have to report the volumes of ferrous metals, non-ferrous metals, shredder light fraction and other materials from shredding end-of-life vehicles. For different reasons these data might not reflect the situation accurately:

- Many countries do not refer to effective shredder output but rather calculate the shredder output with models. The argument for applying such models is that shredders treat a mix of ELVs, construction scrap and WEEE scrap and it is therefore difficult for the operator to distinguish and report on shredder output from ELVs.
- At the same time the number of ELVs treated is apparently underestimated in Europe as demonstrated by Mehlhart (2017). This would result in additional shredder output from ELVs of 20% to 40% in total.
- According to the stipulations of the ELV Directive regarding the exported ELVs, depolluted hulks are not reported in detail and therefore might also cause additional amounts of shredder output from ELVs.
- Some countries report implausible shares of shredder output (possibly also caused by the stipulations on reporting on export).

In result the volumes displayed in Table 16 represent the minimum volume of shredder output with a volume of at least 740 000 tonnes of SLF, more likely an output of around 1 million tonnes or more of SLF per year from ELVs.

Table 16 Materials form shredding of ELVs in Europe, 2015 in tonnes (Eurostat)

	Disposal	Energy recovery	Recycling	Total
Ferrous scrap (steel) from shredding	572	2	3 040 847	3 041 421
Non-ferrous metal from shredding (aluminium, copper, zinc, lead, etc.)	1 705	3 889	207 683	213 277
Other materials arising from shredding (ELoW: 191005+191006)	62 663	51 107	49 351	163 121
Shredder Light Fraction (SLF) (ELoW: 191003+191004)	260 916	249 589	226 654	737 159
Total shredding (incl. Sweden, detailed data above excl. Sweden)	335 002	331 831	3 670 672	4 337 505

Export (unknown if / what shredder output is included)	23 974	24 562	20 5647	254 183

Note: Including data for NO and IS; NL, RO, SI: Data for 2014; No shredder in LU, MT, LI; No data on shredder output from ELV treatment for BG; No breakdown for different output for Sweden (included in total shredding only),

4.1.2. Shredder and pre-shredder technology

There are different **shredder technologies** in use for vehicles:

- Dry operated (or conventional) shredders

  These plants are the largest and most common type of shredding plants in the EU.

Cars (in the form of depolluted end-of-life vehicles) usually form only a minority percentage of the material being processed by such plants.

- Wet shredders

  Wet shredders operate with pre-wetted shredder material or water injection into the comminution unit. Scrap vehicles and light to medium-heavy scrap metal and industrial scrap are shredded in wet shredders.

A pre-shredder or ripper (shears or pre-shredders) can reduce the risk of deflagrations, for example when car wrecks that may contain fuel traces or gas tanks are treated. It is a slow-running machine installed up-stream from the main shredder. While a pre-shredder can prevent deflagration, it may also possibly be a source of emissions. For reasons of space, the pre-shredder may not be available for all larger shredders whose requisite throughput would need several such units. New developments may create a chance to integrate a separation step between pre-shredder and the shredder plant.

Figure 8 **Example of a pre-shredder; Source: BREF WT 2017**

4.1.3. Emission level

Air emissions from a shredder plant are likely to be in the form of dust, including particles of (heavy) metals, VOCs, water vapour. The sources of potential diffuse emissions are manifold: from the large drop height of scrap handling, through openings in the shredder building, from an insufficient suction unit or insufficient road cleaning, etc. Figure 9 shows potential sources of air emissions at a shredding plant. (BREF WT 2017)

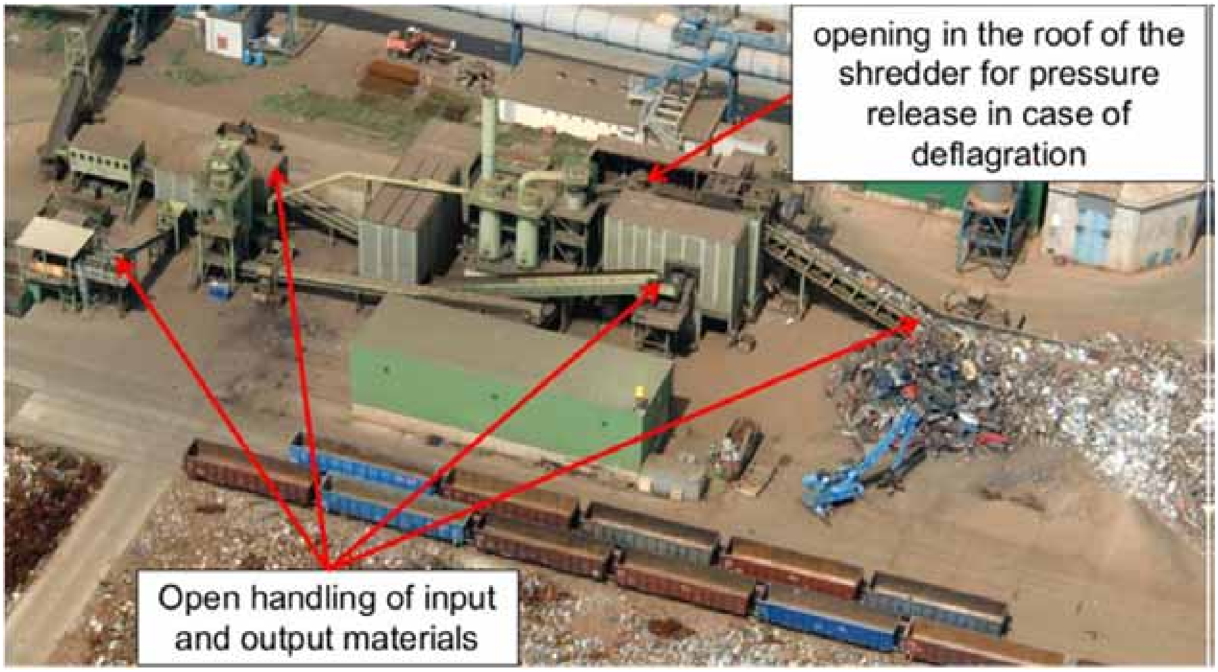


Figure 9 Potential sources of air emission at a shredder plant (BREF WT 2017)

Additionally, under other than normal operating conditions (e.g. deflagration), smoke, dust and potentially dioxins can be released. Deflagrations can be caused by residual fuel left in end-of-life vehicles. Figure 10 shows the emission from a shredding plant during a deflagration. (BREF WT 2017)

Figure 10 Emission from a shredding plant during a deflagration (BREF WT, 2017)

At the high throughput rates of the shredders, even with a strict visual control of the input, it is difficult to prevent some materials capable of producing a deflagration from entering. The number of deflagrations varies from one shredder site to another. An efficiently managed shredder is able to reduce the number of deflagrations to one per year. (BREF WT, 2017)

Table 17 shows the number of deflagrations per year in 24 shredders in the EU. The amount of shredders presented in the BREF WT (2017) is only 7% of the total shredders in Europe. Only 40%

of the countries that have shredders in operation are shown in the BREF WT (2017), whereby the countries with the most shredders are represented (Italy, France, UK, Germany, Spain, Belgium and Poland have together 75% of the European shredders). However, the distribution of shares is not entirely representative: only 2% of European shredders are in Austria, but 21% of the investigated shredders in the BREF WT (2017) are from Austria, whereas French shredders are underrepresented (two in BREF WT (2017) out of 50 in total). Overall, 42% of the shredders in BREF WT (2017) had at least 4 deflagrations in 2012; 60% of them had 10 or more deflagrations. In 2012, in Germany as well as in Austria, there were deflagrations almost every five days.

The shredders in BREF WT (2017) are not explicitly selected according to certain criteria but the participation was voluntary. Plus the number of the presented shredders is not very high. So there is no certainty about the situation of shredders in Europe. It may be that the worse shredder did not participate and that the deflagration rate is higher than the numbers in Table 17 indicate. At the same time some of the best equipped and run shredder plants are on the list, representing a technological level that can be reached under economic conditions.

Table 17 **Mechanical treatment in shredders of metal waste – Number of deflagrations per year, 2010-2012 (BREF WT 2017)**

Plant code	Location/ country	Number of deflagrations		
		2010	2011	2012
25	AT	14	14	4
26	AT	8	16	4
27	AT	NI	70	47
28	AT	NI	NI	9
29	AT	0	0	0
54	BE	0	0	0
95	DK	NI	21	53
100	DK	0	0	0
136	FR	0	0	0
137	FR	0	0	0
285	DE	11	12	10
286	DE	10	14	13
288	DE	0	0	0
289	DE	0	0	0
290	DE	0	0	0
291	DE	0	1	0
293	DE	NI	42	43
294	DE	22	6	4
364-365	IT	0	0	0
432	PL	NI	0	0
464	ES	0	0	0
516 (1)	UK	60	30	220 (2)

Plant code	**Location/ country**	**Number of deflagrations**		
		2010	2011	2012
517 (1)	UK	50	NI	NI
571	PT	NI	NI	0

(1) Calculated on the basis of the reported number of deflagrations/tonnes of waste, and the reported waste input quantities.

(2) A specific receiving inspection process has been implemented in this plant, allowing the ratio to be decreased to 2.5 deflagrations/ 10 000 tonnes of waste treated in 2014.

NB: NI = No information.

To avoid or reduce emissions to air (through dust), shredders have to be equipped with dust collection systems compatible with deflagrations, comprising cyclones and Venturi scrubbers. Because of the deflagration risk, in some areas of the EU there is no dust collection in the shredding step; some operators prefer to use water injection for emission control (damp shredding) in the shredding step and conventional emission control only in the second step. (BREF WT 2017)

Shredder plants for the treatment of end-of-life vehicles are mentioned in Annex C, Part III, of the Stockholm Convention on POPs as one of the potential source categories for the unintentional formation and release of PCDD/Fs and PCB. (BREF WT 2017)

Regarding dioxins, company tests have shown that temperatures in the shredding chamber generally do not exceed 70°C (although it can be higher locally). Consequently, except under other than normal operating conditions such as deflagration, which have to be further reduced as much as possible, the material composition of the products entering the plant is the same as that found at the different outlets of the plant. (BREF WT 2017)

PCB emissions may occur because end-of-life goods in which PCB has been widely utilised in the past are processed in shredder plants. Commercial PCB products always contained a small quantity of dl-PCB and less PCDD/Fs, and the emissions measured can be explained by re-emission of former used PCB.

End-of-life goods that may generate PCB emissions when processed include:

- PCB-containing capacitors and transformers;
- PCB-containing dip paints for copper windings in electric motors;
- PCB-containing parting compounds in electronic waste, e.g. coated papers, pulps and plastics; and
- metal waste with PCB-containing coatings, e.g. tables, chairs, window frames, steel beams, support materials for sawtooth roofs.

The shredding process, including the handling of scrap and residues, may generate a relevant amount of dust containing pollutants such as heavy metals, which are very susceptible to dispersion into the environment (channelled and diffuse emissions). Table 18 gives the levels of PCDD/F and PCB emissions reported through the data collection. (BEF WT 2017)

Table 18 PCDD/F and PCB emissions from mechanical treatment in shredders of metal waste – Periodic measurements (BREF WT 2017)

Plant code	Location/ country	Pollutant/ parameter	Conc. Min. (ng/Nm^3)	Conc. Average (ng/Nm^3)	Conc. Max. (ng/Nm^3)	Main techniques to prevent/reduce emissions	Number of deflagrations over the 3-year reference period	Number of periodic measurements over the 3-year reference period
054_1	BE	PCB	0.009	0.009	0.009	Activated carbon adsorption, Cyclonic separation, Water spraying (dust), Venturi scrubber system	0	1
054_2	BE	PCB	0	0	0	Cyclonic separation, Water spraying (dust), Venturi scrubber system	0	1
055_a*	BE	PCDD/Fs	0.0048	0.0062	0.0075	Cyclonic separation, Water spraying (dust), Wet scrubbing	NI	NI
55_b*	BE	PCDD/Fs PCB	0.013 0.05	0.015 0.05	0.018 0.05	Cyclonic separation, Water spraying (dust), Wet scrubbing	NI	NI
095	DK	PCDD/Fs	0.008	0.013	0.015	Venturi scrubber system	74	3
285_1	DE	PCDD/Fs dl-PCB	0.03 0.15	0.03 0.15	0.03 0.15	Cyclonic separation, Wet scrubbing	33	1
285_2	DE	dl-PCB	0.0030	0.0030	0.0030	NI	33	1
288_1	DE	PCDD/Fs PCB	0.0002 2.4	0.0002 2.5	0.0002 2.9	Venturi scrubber system, Cyclonic separation	0	1 3
288_2	DE	PCDD/Fs PCB	0.003 8.5	0.003 12	0.003 14	Cyclonic separation, Wet scrubbing, Venturi scrubber system	0	1 3
364_1	IT	PCB	0.02	0.5	0.9	Bag/fabric filter system, Venturi scrubber system, Activated carbon adsorption	0	4
364_2	IT	PCB	0.3	0.3	0.5	Bag/fabric filter system	0	3

NB: dl-PCB and PCDD/F concentration values are expressed as ng I-TEQ/Nm^3. NI = No information.
* Mechanical treatment in shredders of metal waste but not represented in deflagration table

Table 19 shows measured PCDD/F and dioxin-like PCB emissions at three Flemish shredding plants. These shredders have at least a cyclone filter system for dedusting the waste gases. The waste gas flow rates are typically about 75 000 Nm^3/h. All PCDD/F concentrations, except one, were below 0.1 ng TEQ/Nm^3. Concentrations of dioxin-like PCB varied significantly between the different shredders and measurement days. Differences in waste gas cleaning and the type and PCB content of the material being shredded during the measurements are the reasons for this. During the measurements, no particular correlation could be found between dust emissions and PCDD/F or PCB emissions. A Flemish study concluded that diffuse emission sources may have a major impact on the environmental contamination, especially for dioxin-like PCB, and therefore have to be taken into consideration for the environmental impact of the mechanical treatment in shredders of metal waste.

Table 19 PCDD/F and dioxin-like PCB emissions at three Flemish shredder plants (BREF WT 2017)

Emission measurement	PCDD/F (ng TEQ/Nm^3)	Dioxin-like PCB (sum of 12) (ng TEQ/Nm^3)
Shredder 1	0.0098 0.012 0.0048	0.048 0.41 0.073
Shredder 2	0.077 0.043 0.022	0.74 1.06 0.30
Shredder 3	0.0088 0.37 0.025	0.171 0.34 0.73

4.2. Post Shredder Technologies (PST)

Post-shredder technology (PST) is the further reprocessing of shredder residues. Some but not all shredders have integrated PST or separate PST on site; other shredders send residues of the shredding process to offsite PST plants. Typical operations of PST are displayed in Figure 11 below. PST is considered as a necessary operation to fulfil the recycling quotas defined by the ELV Directive.

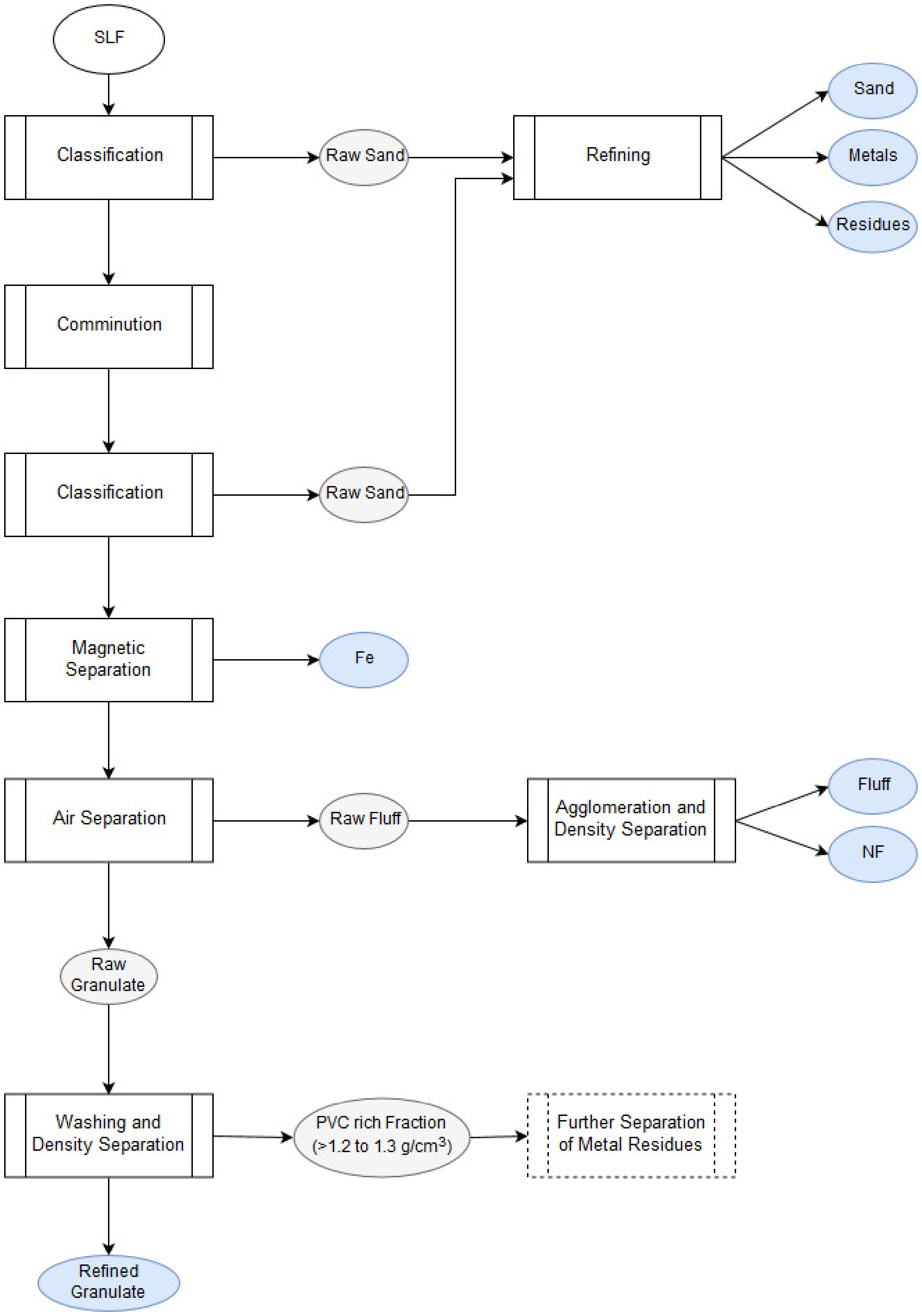


Figure 11 Typical PST operations, details might differ for specific plants

The most common PST are:

- Classification (size separation);
- Metals separation: Magnetic separation of ferrous metals, Eddy current separation of non-ferrous metals, All-metal separators (for negative sorting of e.g. plastics);
- Density separation: Air classification, Ballistic separation, Sink-float devices, Air tables; and
- Sensor-based sorting for separation of different metals and alloys.

Further technologies might be applied as well:

- Sensor-based sorting: NIR-Spectroscopy

  The detector consists of a near infrared spectroscopy (NIR-S) sensor which scans the material and transmits the characteristic spectra of the different materials to a data processor. The data processor transmits a signal if the detection of a material is positive and the air jet blows it out (BREF WT, 2017).

- NIR-S (near-infrared spectroscopy)
  - can be used to identify the type of plastic and separate the plastic most likely to contain POPs (PUR, ABS and HIPS plastics) from the plastics that contain bromine
  - is suitable as a continuously operating measurement method on a separation line
  - is not well suited to identifying black plastic yet[19] but new developments under way

4.2.1. Post Shredder Technologies (PST) - Example: VW-SiCon process

Highly developed Post Shredder Technologies are applied, to separate all major components of shredder residues, aiming for higher recycling rates and reducing the amount of material to be discarded. The VW-SiCon process has been installed in several European countries in original or adapted version.

The VW-SiCon process was developed by Volkswagen AG and SiCon GmbH and is still extended to produce additional fractions and qualities for further applications together with other technology partners. Material fractions from the shredder residues (granulate, fluff, sand, a.o.) were separated and purified and successfully introduced into various industrial processes as substitute of primary raw materials. Most of the material streams are used in a path that is counted as feedstock recycling. Some specific hard plastic fractions as well as fibers and mineral components might be removed additionally for a material recycling path.

Figure 12 shows the shredder residues as well as the refined material flows and their usage. These refined material flows are in detail (Goldmann 2007 plus further developments):

- Shredder granulate used as a reducing agent in a blast furnace to substitute heavy oil or coal dust.
- PVC-rich plastic fraction that after a further enrichment process can be used in the Vinyloop process to produce PVC recyclate.
- Shredder fluff used in sewage sludge dewatering as a drainage aid to substitute coal dust or as reducing agent in blast furnaces.

---

[19] As mentioned in Chapter 4.2.3 new equipment (e.g. UniSort BlackEye) succeeded to overcome the shortcoming mentioned in BREF WT, 2017.

- Fibres used as additives in cement kilns and potentially in production of waterfront facing sheeting.
- Shredder sand, composed of mineral components (sand, ceramics, a.o.), glass, rust, residual NF-metals and paint residues. After a further processing step, output fractions could be used as feed for specific building materials, ferrous and non-ferrous metallurgy and for backfilling applications.
- Additional ferrous and non-ferrous metals recovered from the shredder residues for metallurgical processes

With regard to the sales channels for Volkswagen-SiCon products, it must be emphasized that the market capacities of these channels are in any case larger than possible delivery potentials for the corresponding fractions. Krinke et al. (2005) and Goldmann (2007) demonstrated with LCA that the application of PST and feedstock recycling of the derived fractions is often more favourable than dismantling and subsequent material recycling.

Figure 12 shows the three original main output fractions of the VW SiCon-process.

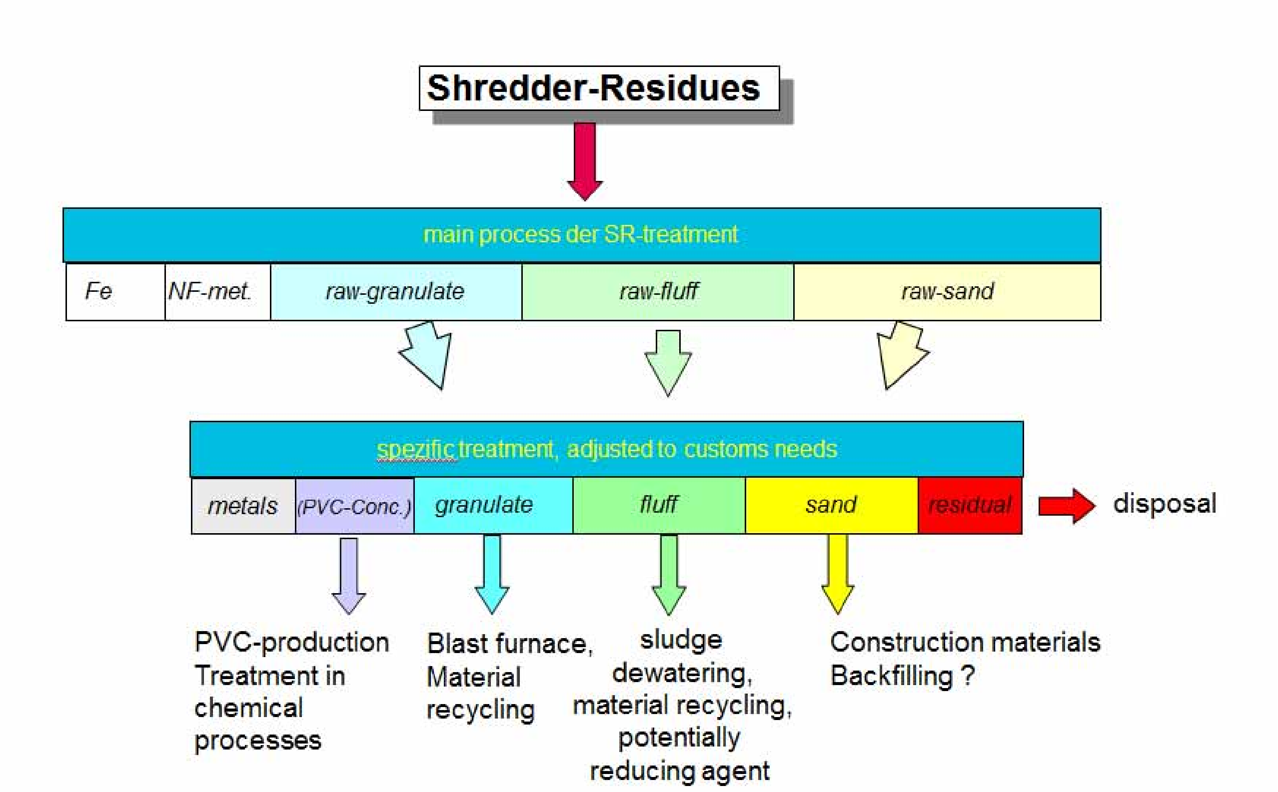


Figure 12 Shredder residues and refined material flows from VW SiCon-process and their usage

		
Granulate	**Fluff**	**Sand**
Rigid plastics (incl. PVC), rubber	foam materials, textile, wood, cardboard, paper	glass, ceramics, minerals, rust, NF metals

Figure 13 Main output fractions of VW-SiCon process

The products of the first processing stage in the VW-SiCon-process (raw granulate, raw fluff and raw sand) are processed in a second stage to produce adapted input to specified consumer plants.

4.2.1.1. Treatment of raw granulate as a reducing agent for a blast furnace

A specifically purified granulate fraction is a highly appreciated reducing agent for blast furnaces, with a market value occasionally above 70 €/t. Grainsize distribution, C-H-N ratio, Ca+Mg/Si ratio, and sufficient low concentrations of Cl, S, Pb, Zn and Cu are a prerequisite for this value.

These specifications can be reached by washing adherent Pb- und Zn-containing dust from the surfaces of the granules, followed by a density separation step at 1.2 – 1.3 g/cm³ (separation of PVC, rubber (tyres), copper wires). Figure 14 shows the distribution of different polymers in different density ranges. The vast majority of particles are found in the fraction < 1.3 g/cm³ and reveal an average composition of commodity thermoplastic polymers. Halogenated hard plastic components in general are made of PVC or bromine-containing thermoset polymers, both with an average density higher than 1.3 g/cm³. The amount of hard plastic components with flame retardants containing decaBDE in the light fraction are expected to be very low, mainly due to density raising additional components in these materials. For specific results from an ARN processing campaign see chapter 4.2.2.

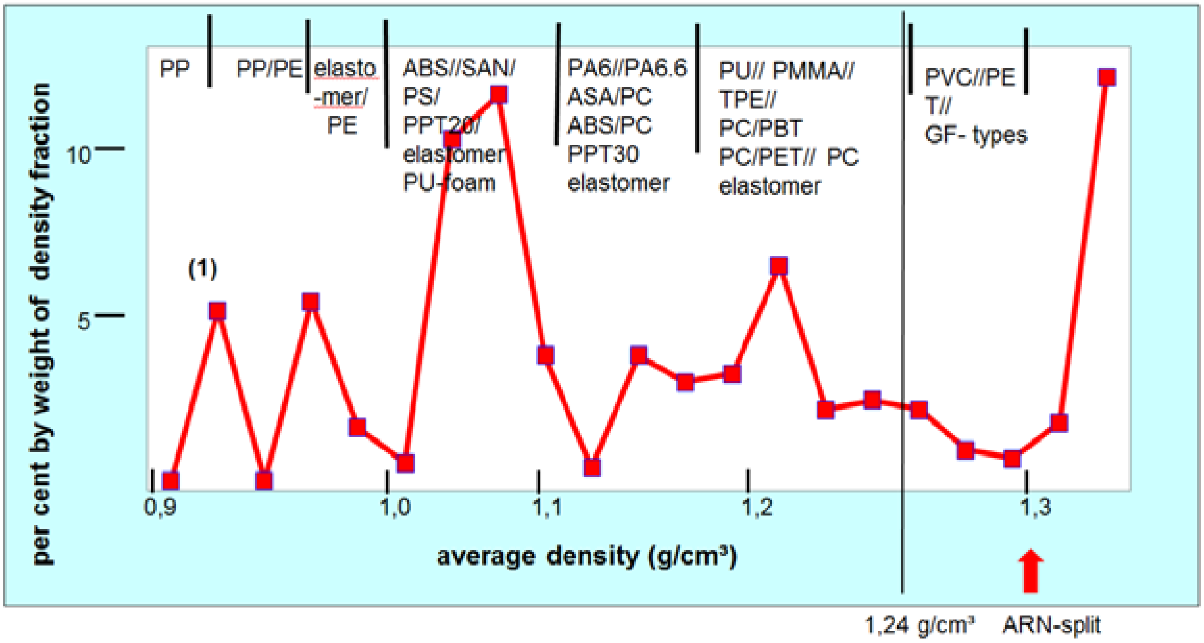


Figure 14 Distribution of different polymers in different density ranges

4.2.1.2. Treatment of raw fluff for dewatering sewage sludge or as a reducing agent for a blast furnace

A specifically refined fluff fraction can be used effectively as an additive for dewatering sewage sludge or as a reducing agent for a blast furnace. In both cases, adhesive dusts and residual copper wires have to be removed from the fibre and foam particles of the fluff. A combination of impact milling, screen, air table and sifter treatment allows a strong depletion of these components. In a final step, the particle shape and size of the refined fluff is adapted by an agglomeration process. The wire fraction can be used directly in copper metallurgy; the dust is directed to a waste incineration plant. Both fractions make up a small part of the overall mass of the raw fluff. POP/ decaBDE-containing fibres cannot be removed from the rest of the mass using this approach. Though they will not be very common, they may affect the POP-content and lead to erratic peaks. Especially when using this fraction as a reducing agent in a blast furnace (feedstock recycling), there is no risk for any exposure of POP to the environment. For specific results from an ARN processing campaign see chapter 4.2.2.

4.2.1.3. Treatment of raw sand for use as feed in the production of building materials and metallurgical applications

To use the sand fraction either as feed for the production of building materials or even for backfilling in underground mines, the organic content of raw sand has to be reduced drastically, reducing at the same time possible contents of POP. Refined mineral fractions from raw sand as well as additionally derived metal fractions do not have any relevant POP content. The residual light organic fraction from the sand refining process is directed to waste incineration or, in the case of relevant amounts circulated, to the fluff refining process.

4.2.2. Analytics on output fractions from the ARN PST plant

Applying a state-of-the-art PST technology, different output fractions as concern decaBDE can also be analysed. In a first approach the bromine content can be measured[20]. The Dutch vehicle recycling company ARN, running an extended version of a Volkswagen-SiCon plant, in 2014 to 2017 measured the bromine content in different PST fractions, as shown below.

Bromine content (detected with XRF) in shredder sand (Figure 15) is low (as expected) and non-compliance unlikely. As a result, recycling is not questioned.

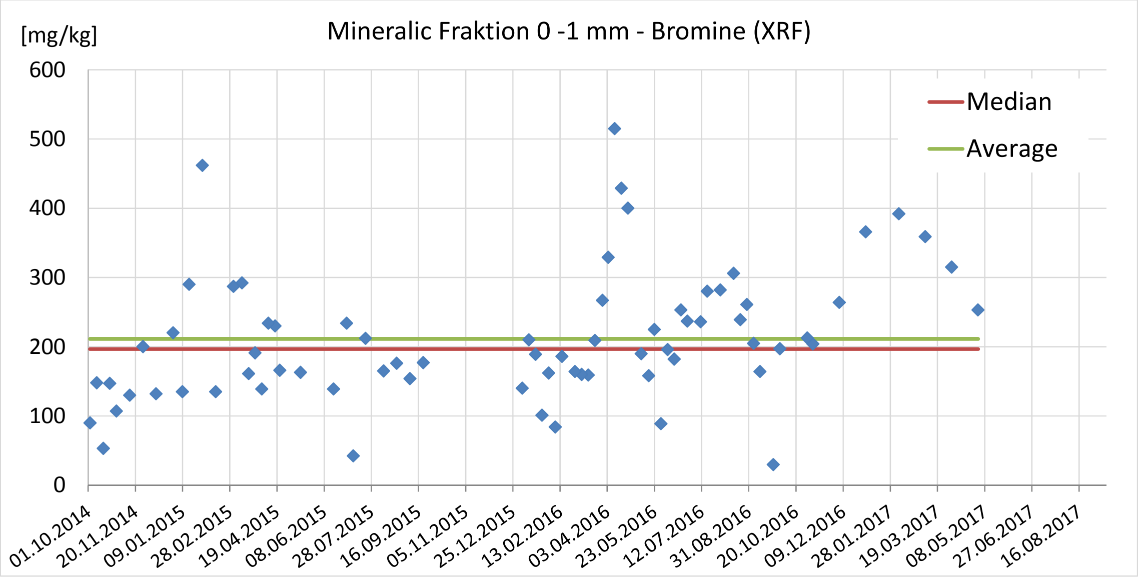


Figure 15 Br-content (XRF) in shredder sand (mineralic fraction 0-1 mm)

Bromine content (detected with XRF) in shredder fluff (Figure 16) is on average still low but with high fluctuations. Specific risks (e.g. artificial leather) have been mentioned in chapter 4.2.1 as concern this fraction. As a result, material recycling may be critical. However, use as a reducing agent in metallurgical processes (to be considered as feedstock recycling) would not cause any problems with respect to POP emissions.

---

[20] Commercial formulations of DecaBDE have a bromine content of about 83% (US EPS 2017). However, bromine from other sources might be detected.

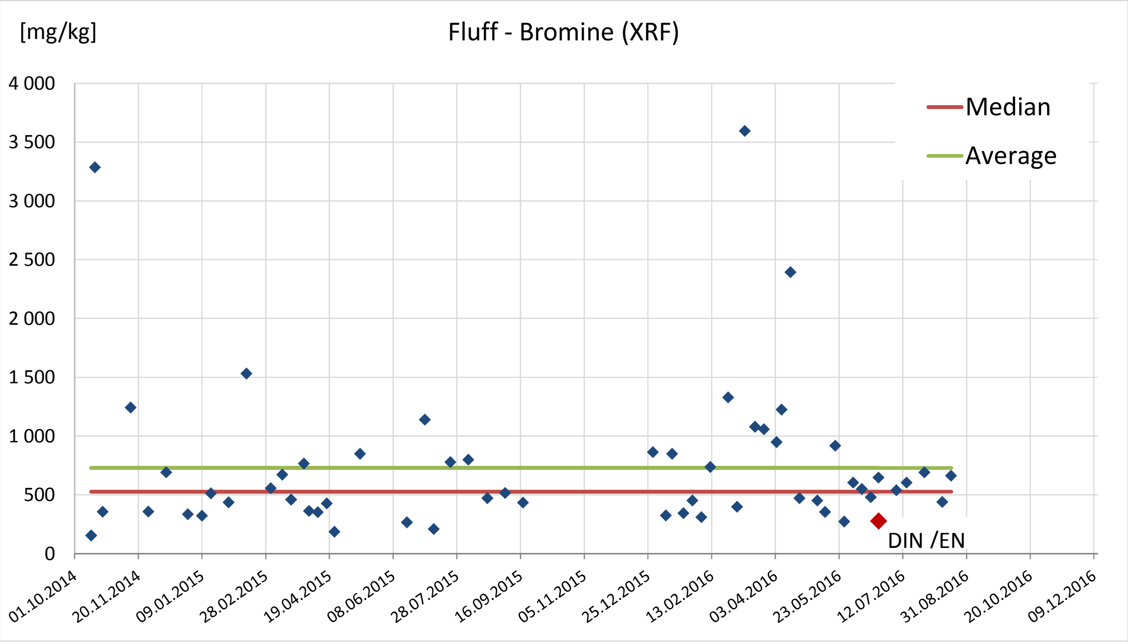


Figure 16 Br-content (XRF) in shredder fluff

Bromine content (detected with XRF) in shredder granulate < 1.1 g/cm^3 (Figure 17) is on average low (202 mg/kg) and with very few outliers (2 samples out of 48). Separation technology to separate bromine-containing parts is in principle available, thus material recycling might be an option.

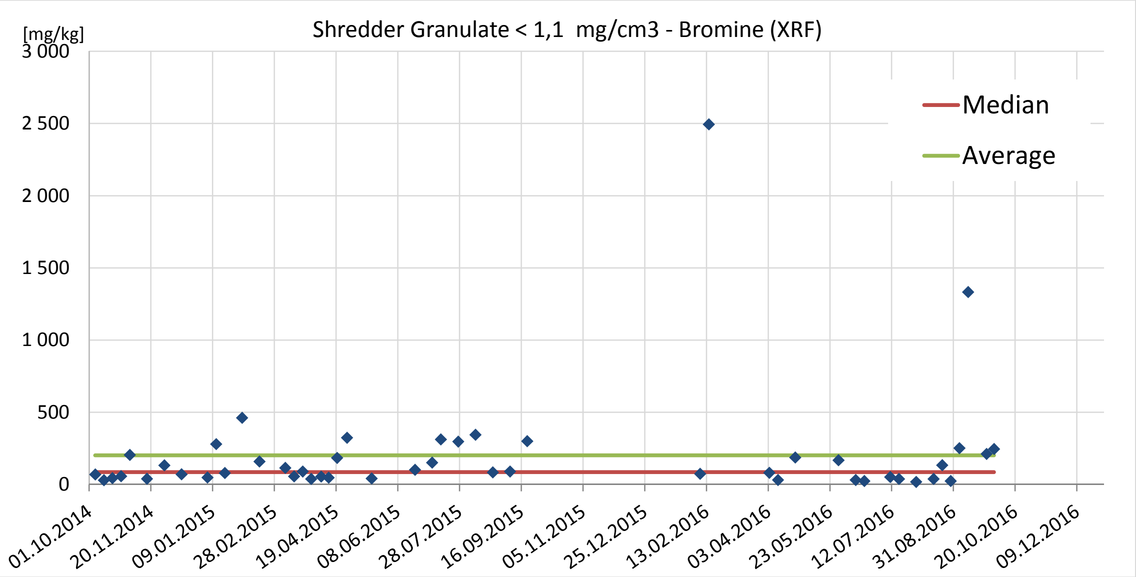


Figure 17 Br-content (XRF) in shredder granulate < 1.1 g/cm^3

Bromine content in shredder granulate (detected with XRF) of $\geq$ 1.1 g/cm^3 and $\leq$ 1.3 g/cm^3 (Figure 18) is comparatively high. As a consequence, the use as a secondary raw material for new products (material recycling) is not favourable. Moreover, the mixture of different sorts of plastics in this fraction would not allow material recycling without material specific separation. However, it can be used as a reducing agent in a blast furnace (feedstock recycling), in contrary to the fraction sized > 1.3 g/cm^3.

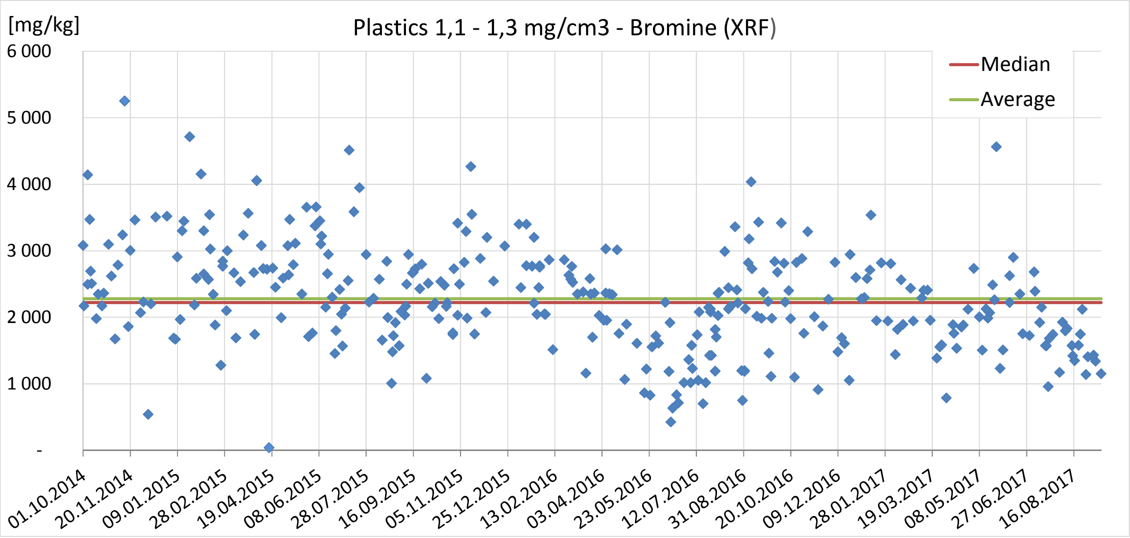


Figure 18 Br-content (XRF) in shredder granulate, sized ≥ 1.1 g/cm^3 and ≤ 1.3 g/cm^3

Bromine content (detected with XRF) in shredder granulate sized > 1.3 g/cm^3 (Figure 19) is, as expected, on average fairly high and it is known to contain halogenated mixed plastics (e.g. PVCs). Due to its high chlorine content, which would result in corrosion in the furnace, this fraction is normally not accepted for the use as a reducing agent in metallurgical processes. It either can be sent to waste incineration (energy recovery or thermal disposal) or (after further treatment) could be introduced into chemical recycling processes like Vinyloop®.

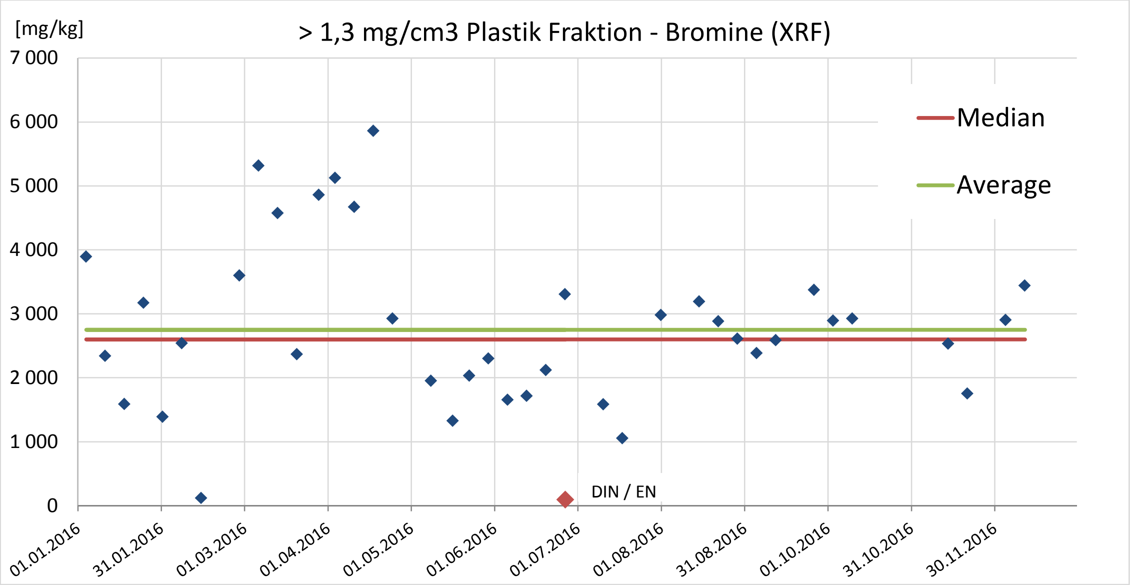


Figure 19 Br-content (XRF) in shredder granulate > 1.3 g/cm^3

Table 20 summarises analyses of the different fractions discussed above.

Table 20 **Number of samples (n), minimum, maximum, median and average, share of values under 1000 or 500 mg/kg**

mg/kg	n	Min	Max	Median	Average	values < 1000	values < 500
Br in Shredder Sand	72	30	515	197	211	100%	99%
Br in Shredder Fluff	58	154	3 594	527	729	83%	47%
Br in Shredder Granulate < 1.1 g/cm^3	48	18	2 494	86	202	96%	96%
Br in Shredder Granulate $\geq$ 1.1 $\leq$ 1.3 g/cm^3	335	41	6386	2220	2277	4%	<1%
Br in Shredder Granulate > 1.3 g/cm^3	40	94	5 864	2 600	2 749	5%	5%

Source: ARN

Table 21 shows the bromine, decaBDE and PBDE content for samples collected every two weeks in 2017/2018 over a period of two months and measured in a laboratory (HUK) according to DIN EN ISO 22032 and with an XRF-device (ARN). ARN retained a portion of the samples that were sent to the HUK laboratory and tested on their own with XRF. Before the XRF measurements, the samples were comminuted and homogenized. Since not exactly the same samples of ARN and HUK were measured, the two methods cannot be compared directly. However, both analyses show similar results: for fluff and plastics sized < 1.1 mg/cm^{3,} the bromine content is below 1 000 mg/kg. Except for three values, all bromine values are even below 500 mg/kg.

Table 21 **Bromine, decaBDE and PBDE for PST fractions of ARN**

Date	Bromine (HUK)1) mg/kg	Bromine (ARN)2) mg/kg	decaBDE3) mg/kg	Sum PBDE3) mg/kg
	Granulate < 1.1 g/cm^3			
13.12.2017	341	27	<50	<200
27.12.2017	336	426	<50	<200
10.01.2018	<100	30	11	<100
24.01.2018	136	277	<10	<100
07.02.2018	<100	566	12	<100
	Fluff			
13.12.2017	536	434	<50	<200
27.12.2017	340	448	<50	<200
10.01.2018	316	979	24	<100
24.01.2018	117	272	27	<100
07.02.2018	313	475	48	<100

1) DIN EN 14582; 2) with XRF after sample comminution

1) and 2) not exactly the same sample but from the same batch

3) DIN EN ISO 22032

Source: ARN

4.2.3. Detection technologies for hard plastic

Looking especially to the path of material recycling for some hard plastic components, detection of POP/ decaBDE -content might be relevant to separate contaminated particles.

In general, two options for separating contaminated plastic after shredding are available. The first is to remove all parts of a specific type of plastic (e.g. PP) that is often contaminated. Therefore, detection of different types of plastics is needed (e.g. NIRS or HSI). The second is to remove all plastic particles, showing concentrations of bromine above a certain level. Such element detection could be carried out with a XRF-device. For both cases: if contaminated plastics are to be effectively and efficiently separated from each other after shredding, appropriate technologies must be used. These must meet the following requirements:

7. Applicable to every kind of plastic, especially black plastics since the majority of plastic parts in vehicles are black; and
8. Clean sorting of contaminated parts with a reasonably high throughput.

One technology that can sort plastics (including black plastics) by type of polymer is UniSort BlackEye from STEINERT[21] (Figure 20). The UniSort BlackEye uses hyper spectral imaging (HSI) technology, with which also black plastic can be sorted by polymer type and with a particle size of 10-30 mm.

Figure 20 **UniSort BlackEye for sorting black plastic**

A technology to sort plastics by elemental detection is REDWAVE XRF[22] to identify materials based on the chemical composition (Figure 21). REDWAVE XRF offers:

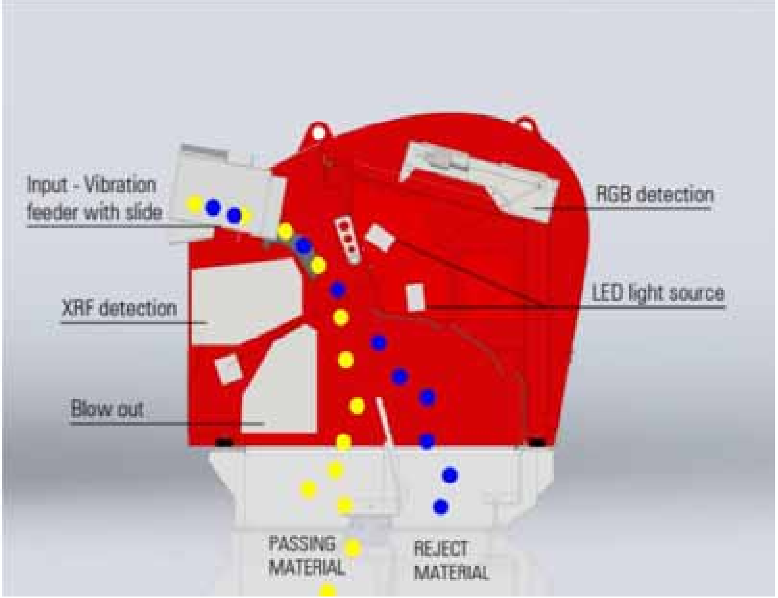
- Best available XRF detection
- Qualitative (element) and quantitative (% of element) analysis
- Wide grain size distribution (6-45 and 45-180 mm)
- High capacity- up to 15 t/h

---

[21] http://www.steinertglobal.com/de/de/produkte/unisort/unisort-blackeye/

[22] http://www.redwave.com/produkte/redwave-xrf/

- High efficiency and purity
- Low maintenance costs



x

Figure 21 REDWAVE XRF- Chute/Slide system

4.3. BAT for waste treatment (final draft October 2017)[23]

4.3.1. Scope

The BAT conclusions concern the following activities specified in Annex I to Directive 2010/75/EU[24], namely:

(a) Disposal of non-hazardous waste with a capacity exceeding 50 tonnes per day involving one or more of the following activities, and excluding activities covered by Council Directive 91/271/EEC of 21 May 1991 concerning urban wastewater treatment:

[…]

(v) treatment in shredders of metal waste, including waste electrical and electronic equipment and end-of-life vehicles and their components.

(b) Recovery, or a mix of recovery and disposal, of non-hazardous waste with a capacity exceeding 75 tonnes per day involving one or more of the following activities, and excluding activities covered by Directive 91/271/EEC:

[…]

(iv) treatment in shredders of metal waste, including waste electrical and electronic equipment and end-of-life vehicles and their components.

The objectives and measures of BAT for shredders are:

a) Reduction of explosions, deflagrations and scrap yard fires

b) Reduction of hotspots in milling chamber

c) Reduction of dust and gaseous emissions

4.3.2. BAT conclusions for waste treatment in general

Generally for all waste treatments, BAT is to implement and adhere to an environmental management system (EMS).

Currently, only 9% of ATFs in the EU have, according to the national reports, implemented an EMS (see chapter 3.4.2 of this report). The share of shredders having implemented an EMS is not known.

Other BATs regarding waste treatment in general are:

- In order to improve the **overall environmental performance** of the plant, BAT is to use all of the techniques given below:
  a) Set up and implement waste characterisation and pre-acceptance procedures

---

[23] Joint Research Centre Directorate Growth and Innovation Unit Circular Economy and Industrial Leadership European IPPC Bureau: Best Available Techniques (BAT) Reference Document for Waste Treatment. Final Draft. October 2017

[24] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control), OJ L 334 17.12.2010 page 17

  b) Set up and implement waste acceptance procedures
  c) Set up and implement a waste tracking system and inventory
  d) Set up and implement an output quality management system
  e) Ensure waste segregation
  f) Ensure waste compatibility prior to mixing or blending of waste
  g) Sort incoming solid waste

- In order to facilitate the reduction of **emissions to water and air**, BAT is to establish and to maintain an inventory of waste water and waste gas streams, as part of the environmental management system, that incorporates all of the following features:
  a) information about the characteristics of the waste to be treated and the waste treatment processes
  b) information about the characteristics of the waste water streams
  c) information about the characteristics of the waste gas streams
- In order to reduce the environmental risk associated with the **storage of waste**, BAT is to use all of the techniques given below:
  a) Optimised storage location
  b) Adequate storage capacity
  c) Safe storage operation
  d) Separate area for storage and handling of packaged hazardous waste
- In order to reduce the environmental risk associated with the **handling and transfer of waste**, BAT is to set up and implement for handling and transfer procedures

Additionally there are BATs for monitoring including substances/ parameters, standards and minimum monitoring frequency. BAT to prevent or minimise air emissions (dust, organic compounds and odour), noise and vibrations, emissions to water and emissions from accidents and incidents is also given.

4.3.3. General BAT conclusions for the mechanical treatment of waste and for the mechanical treatment in shredders of metal waste

In addition to the general BAT conclusions, there are general BAT conclusions for the mechanical treatment of waste and air emissions.

In order to reduce air emissions as dust and of particulate-bound metals, PCDD/F and dioxin-like PCBs, BAT is to apply BAT 14d[25] and to use one or a combination of the following techniques: cyclone, fabric filter, wet scrubbing, water injection into the shredder. BAT-associated emission

---

[25] Containment, collection and treatment of diffuse emissions. This includes techniques such as:

- Storing, treating and handling waste and material that may generate diffuse emissions in enclosed buildings and/or enclosed equipment (e.g. conveyor belts);
- Maintaining the enclosed equipment or buildings under an adequate pressure;
- collecting and directing the emissions to an appropriate abatement system (see Section 6.6.1) via an air extraction system and/or air suction systems close to the emission sources. The use of enclosed equipment or buildings may be restricted by safety considerations such as the risk of explosion or oxygen depletion.

The use of enclosed equipment or buildings may also be constrained by the volume of waste.

level (BAT-AEL) for channelled dust emissions to air from the mechanical treatment of waste is 2-5 mg/Nm^3 (10 mg/Nm^3 when a fabric filter is not applicable).

Further, there are BAT conclusions for the mechanical treatment in shredders of metal waste that are described in the following.

In order to improve the overall environmental performance, and to prevent emissions due to accidents and incidents, BAT is to use BAT 14g (cleaning of waste treatment and storage areas) and all of the techniques given below:

a) implementation of a detailed inspection procedure for baled waste before shredding

b) removal of dangerous items from the waste input stream and their safe disposal (e.g. gascylinders, non-depolluted ELVs, non-depolluted WEEE, items contaminated with PCBs or mercury, radioactive items)

c) treatment of containers only when accompanied by a declaration of cleanliness

In order to prevent deflagrations and to reduce emissions when deflagrations occur, BAT is to use a deflagration management plan and either pressure relief dampers and/or pre-shredding. The first two techniques are generally applicable, while pre-shredding is generally applicable for new plants, depending on the input material or for major plant upgrades where a significant number of deflagrations have been substantiated.

4.3.4. Emerging techniques

Article 3(14) of Directive 2010/75/EU defines an ‘emerging technique’ as a 'novel technique for an industrial activity that, if commercially developed, could provide either a higher general level of protection of the environment or at least the same level of protection of the environment and higher cost savings than existing best available techniques.

The emerging techniques listed for shredders are: online XRF analysis and techniques to avoid and reduce VOCs that are not important in the context of this study.

4.4. Literature review on PBDE/ decaBDE in shredder residues

Table 22 shows values for decaBDE measured in different fractions from shredder residues. It includes mean values as well as minimums and maximums. ELV shredder residue as well as mixed SR (ELV + WEEE) and WEEE SR were examined in literature.

IVM, IVAM (2013) provides a POP-BDE dataset for the relevant plastic waste streams in the Netherlands. POP-BDEs were found in very few single automotive parts, while in the shredder material of cars and WEEE, decaBDE was frequently found (92-100% of the samples). Only 1 of 24 samples investigated did not contain decaBDE. decaBDE values found in ASR are lower than in mixed SR (from WEEE, ELV and other sources), including SR from WEEE.

In COWI (2013), decaBDE content in fluff from shredder residues from cars, mixed feedstock, WEEE and complex metal scrap in Norway were examined. The large differences between highest and lowest values show the challenges of taking representative samples from a heterogeneous material such as fluff. However, the results indicate that the decaBDE content in fluff from cars (average 11 to 40 mg/kg) compared to those from WEEE (average 5 and 6 mg/kg) could be slightly higher.

MOE survey (2011) reports results for ASR from 70 ELVs produced earlier than 1996 and from 70 ELV produced after 2000 for Japan. The data indicate decreasing levels of decaBDE in ASR over time with higher levels in ASR from cars produced before the year 1996 compared to levels from cars produced after the year 2000.

Additional data on ASR from Japan from ELV produced in 1999 (2 samples) and 2011/12 (1 sample) confirm the decreasing trend (JAMA 2015). ASR from ELV produced in 1999 and in 2011/12 had decaBDE levels of 335 mg/kg and 120 mg/kg respectively.

WRc addendum (2012) provides data on ranges of PBDEs found in UK waste electrical and electronic equipment and end of life vehicles. There is one outlier within the ASR of 3 915 mg/kg. This value is a maximum from a “mixed medium density shredder fraction”[26] measured in UK. In total, these decaBDE levels in ASR reported from the UK are relatively high compared to other sources.

In ELVES (2015) two representative samples for ASR (solely stemming from the automotive sector) (“ASR” and “ASR fines”) from Irish ELVs in 2014 were examined. The limit of detection for decaBDE was 50 µg/kg. decaBDE was detected within “ASR” and “ASR fines” at a concentration of 3.5 mg/kg and 2.55 mg/kg respectively.

Sinkkonen et al. (2004) measured the content of PBDEs in electronic plastic waste and in ASR from Finland. A low decaBDE value was measured in the ASR light fraction (0.01 mg/kg).

BMRA (2013) reports the levels of PBDEs in samples of seat foam materials within the shredder residue fraction. The results of analysis for the two samples of seat foam materials indicated that the presence of PBDE was below the limit of detection.

In Mayer (2015) samples of ASR from 400 ELVs in the UK were examined. The age of the ELV was on average 15 years, with a range of 8 to 35 years. decaBDE was detected within ASR at a concentration of 3.1 mg/kg.

In Defra (2016) representative samples from three different ASR fractions were examined: mixed fines, Mixed Automotive Plastics (MAP10) and Solid Recovered Fuel (SRF30). From existing mate-

---

[26] The split between medium and heavy density plastic is not specified and it is not for sure that it can be compared with the split applied in the Netherlands.

rial mass balances it is estimated that 40% in the MAP10 and 80% of materials in the SRF30 stream have originated from ELVs. Large domestic appliances (expected to contribute approximately 13% of plastic in MAP10) are likely to contain flame retardants and therefore may contribute to overall POPs content in MAP10. In SRF30, 20% do not originate from ELVs and may contain HBCD. Sampling was conducted between November 2015 and January 2016. A total number of 30 samples were collected: 15 samples of MAP10 and 15 of SRF30. MAP10 consists of hard plastic, rubber and elastomers (85%), fluff and wood (10%), metals (5%). SRF30 consists of textiles and foam (40-50%), elastomers and plastic (30-35%), wood (10%), inerts (5%), metals (<1%). The decaBDE content in mixed fines is between 14 and 78 mg/kg, in MAP10 between 30 and 270 mg/kg and in SRF30 between 33 and 110 mg/kg. (Defra 2016)

In a presentation from ARN (2015) it is stated that in the medium density plastic fraction (1.1 to 1.3) decaBDE levels of 800 mg/kg are measured in mixed shredder residues.

More recent results in Strååt, M.; Nilsson, C. (2018) analysed different fractions from Shredders / PST (see Table 24). All analysed plastic types are of a density of < 1.1 mg/cm^3 and all have decaBDE content of less than 200 mg/kg.

In summary, from literature it is not always possible to detect which fraction of shredder / PST output was analysed. Many analyses refer to a mix of shredder residues from WEEE and ELVs. decaBDE values found in ASR are on average lower than in mixed SR (from WEEE, ELV and other sources) and SR from WEEE. Several of the analyses refer to specific PST output, either indicating a specific density or a specific type of plastic.

In mixed and ELV SRs, the values are below 1 000 mg/kg, with the exemption of analyses from the UK for two PST fraction with medium and high density.

In foam/ fluff and plastic with higher densities (>1.1), higher values tend to be found than in other fractions.

Table 22 Literature overview of decaBDE in different SR fractions from ELV and mixed shredders

<table>
<tr><th>Source</th><th>Country</th><th>Samples from</th><th>decaBDE mg/kg</th><th>Comment</th><th>Conclusions</th></tr>
<tr><td>IVM,IVAM 2013</td><td>NL</td><td>ASR</td><td>0.2 – 70</td><td>depending on the fraction:<table><tr><th>ASR fraction</th><th>mg/kg</th></tr><tr><td>fibre fraction</td><td>70</td></tr><tr><td>d< 1.1 (hard plastic)</td><td>0.2</td></tr><tr><td>1.1<d<1.3 (black soft)</td><td>5.5</td></tr><tr><td>1.1<d<1.3 (black hard)</td><td>2</td></tr><tr><td>1.1<d<1.3 (coloured)</td><td>1</td></tr><tr><td>1.1<d<1.3 (white/grey)</td><td>3.3</td></tr></table></td><td>These findings in IVM, IVAM 2013 indicate higher levels of decaBDE in WEEE SR compared to ASR
(a description of the values for mixed SR and WEEE can be found further below in the table)</td></tr>
<tr><td>COWI 2013</td><td>NOR</td><td>ASR fluff</td><td>11 - 40</td><td></td><td>It is challenging to take representative samples from a heterogeneous material such as fluff.
decaBDE content from cars could be slightly higher compared to the other fluff types</td></tr>
<tr><td>MOE survey 2011</td><td>JP</td><td>ASR from cars before 1996
ASR from cars after 2000</td><td>190 to 590 (av. 406)
37 to 180 (av. 123)</td><td></td><td>The results demonstrate a decreasing trend over time for decaBDE in ASR (at least in Japan).</td></tr>
<tr><td>JAMA 2015</td><td>JP</td><td>ASR from cars produced 1999
ASR from cars produced 2011/12</td><td>335
120</td><td></td><td>These data confirm the decreasing trend (in Japan).</td></tr>
<tr><td>WRc addendum 2012</td><td>UK</td><td>ASR</td><td>11.5 - 3 915</td><td>depending on the fraction:<table><tr><th>fraction</th><th>mg/kg</th></tr><tr><td>light (textiles and foams)</td><td>130 - 151 (av. 138)</td></tr><tr><td>mixed light plastic</td><td>11.5 - 229 (av. 118)</td></tr><tr><td>mixed medium density plastic</td><td>644 - 3 915 (av. 2 163)</td></tr><tr><td>mixed high density plastic</td><td>1 357 (one sample only)</td></tr></table></td><td>These decaBDE levels in ASR reported from the UK are relatively high compared to other sources.
The high value (3 915 mg/kg) is from mixed medium density plastic. For the interpretation of this values please refer to footnote 26 before.</td></tr>
<tr><td>ELVES 2015</td><td>Ireland</td><td>ASR
ASR fines</td><td>3.5
2.5</td><td>201 ELVs (av. 15a, 10-26a)</td><td>this recent and very well documented shredder trial indicates very low levels of decaBDE in current samples of ASR.</td></tr>
<tr><td>Sinkkonen et al. 2004</td><td>FN</td><td>ASR light fraction</td><td>0.01</td><td></td><td></td></tr>
</table>

Source	Country	Samples from	decaBDE mg/kg	Comment	Conclusions
BMRA 2013	UK	ASR	n.d.		The results of analysis for the two samples of seat foam materials within the shredder residue fraction indicated that the presence of PBDE was below the limit of detection
Mayer 2016	UK	ASR	3.1	400 ELVs (av. 15a, 8-35 a)	
Defra 2016	UK	ASR (“not all from auto”) mixed fines MAP10 SRF30	14 -78 30 – 270 33 - 110	A detailed presentation of the results of the different groups is given at the end of this table.	The results for the fraction with plastic (MAP10) are slightly lower than for the fraction with textiles (SRF30). All results are significantly below 1 000 mg/kg.
IVM,IVAM 2014	NL	mixed SR	6 - 819	depending on the fraction: **fraction** **mg/kg** fiber fraction 155 d 0-1 27 d<1.1 6 1.1<d<1.3 810	
Petreas et al. 2009	US	mixed SR	average 43.5	The ASR was collected from the seven auto shredder facilities in California (note: mixed input from automobiles and major appliances (refrigerators, ovens, etc.)) in 2004/5.	
ARN 2015	NL	mixed SR	800	medium density plastic fraction d=1.1-1.3	
IVM,IVAM 2015	NL	WEEE SR	6.4 - 3 300	one WEEE company (3 samples) **fraction** **mg/kg** mixed plastic d<1 12 mixed plastic 1<d<1.2 6.4 mixed plastic d>1.2 40 one WEEE company (9 samples) 550 - 3 300 mg/kg	
COWI 2014	NOR	WEEE fluff	5 - 12		
WRc 2012	UK	WEEE SR	0.162 -138 000		
Ma et al. 2009	CN	WEEE SR	3.26 (0.98 - 6.39)		

Source	Country	Samples from	decaBDE mg/kg	Comment	Conclusions
Missing reference et al. 2007	DE	WEEE SR	0 - 3 100		
EMPA 2010		WEEE	500 -3000		

Table 23 decaBDE results from Defra 2016 (in the order of fraction and size of the values)

	mg/kg
mixed fines (1)	14
	20
	78
mixed fines ECS(2) waste	36
mixed fines lights	48
MAP 10	30
	91
	270
MAP 10 ECS waste	39
	42
	220
	230
MAP 10 lights	32
	54
	130
	230
	260
SRF	37
	52
	87
SRF ECS waste	48
	58
	61
	100
	110
SRF lights	33
	54
	62
	68
	90

(1) mixed fines are dusts and small particulates that are captured in the final stages of the shredder process. They are made up of a combination of plastics, foams, small fragments of metals and small light debris that get caught in the final traps at the end of the cycle

(2) ECS = Eddy Current Separation

Table 24 Bromine, decaBDE and PBDE for PST fractions in France, UK and Austria

Sample ID.	**Country**	**Plastic type**	**Waste stream, product/ waste category**	**Info on treatment in facility**	**Br (XRF) mg/kg**	**BDE- 209 (GC-MS) mg/kg**	**ΣPBDE (GC-MS) mg/kg**
20	France	PS/ABS	ELV	Density	470	140	140
35	UK	PP			274	<5	<5
38	UK	ABS			286	5,1	5,1
40	Austria	PP	ELV + WEEE (small domestic appliances)	Density + electrostatic	613	85	85
41	Austria	PS			970	94	94

Source: Strååt, M.; Nilsson, C. (2018)

4.5. Information from interviews with stakeholders in the sector

Several interviews with stakeholders in the sector of shredder and PST operators and plant engineering companies have been carried out. From these interviews, the following results can be derived:

- Modern shredder technologies and an adequate operation can effectively avoid explosions and thus critical emissions from the shredder plant itself. If run in an adequate way, temperature within the comminution chamber of the shredder will not exceed 70°C. After regular input control and subsequently without deflagration and overheating, emissions of shredder plants with modern filter systems should be uncritical. The BREF WT 2017 document lists shredder plants having large impact in the EU, like the plant of Galloo Metal in Menen, Belgium.
- Older, non-retrofitted shredders usually show higher emissions. Since emissions of VOC and dust have to be reduced anyhow, retrofits are to be expected at several plants.
- In Germany, the situation is generally worse compared to Belgium. For example, the Max Aicher operation (unfortunately not included in BREF WT, 2017) is relatively advanced in technology standard. Other shredder companies like TSR are planning updates. A general trend towards smaller, more specialized shredders and integrated downstream systems with new dust removal systems can be observed. At the moment it is difficult though to predict the further development in shredder standards due to political interventions on the world steel market (US sanctions, global steel production overcapacities). As well revision of the German TA Luft for shredders (although postponed but certainly not repealed) could also impact various German input streams and customers.
- Massive scrap is increasingly treated by scrap shear, not shredders, especially if the scrap is exported to steel plants working under lower environmental standards and producing lower lever steel qualities. Hence, big shredders (high throughput) are often not economically sensible in many parts of Europe.
- The statements on the pre-shredder technology in BREF WT, 2017 are interesting. However, the fairly simple technologies described may be possibly replaced by new developments, which include selective handpicking or sensor-based sorting of waste between pre-shredder and shredders.
- Based on the VW SiCon process, the plant of ARN (NL) can be considered a reference plant. In contrast to the original VW SiCon approach, the ARN plant partly integrated Galloo technology.
- The Bernegger plant in Austria is also essentially based on the VW SiCon-Method. This plant has increased its production and also takes in shredder residues from other shredder plants. Material flows from Germany (e.g. from TSR) are also shipped to Bernegger.
- Further developments at SiCon will open the way to refine shredder fluff in a continuous agglomeration process instead of the earlier batch process, with the effect that the production of reducing agents for metallurgical processes can be run economically more efficiently.
- In addition to the VW-SiCon process, further elaborated systems and technologies have been implemented, e.g. at Gallo in Belgium or SRW in Germany. Detailed information about their planned steps could not be gathered for this study. Simple Systems of PST, consisting at least of metal separation and screening steps, are found in further plants.

4.6. Conclusions

The key question this chapter seeks to address is whether or not it is feasible to handle PBDE/ decaBDE containing parts and components during ELV shredding and PST treatment in such a way that no critical emissions will occur during the process steps. The second question to be answered is if PBDE/ decaBDE containing parts and components can be directed into fractions that can be used in feedstock recycling or energy recovery processes, guaranteeing safe destruction of the critical components and thus ensuring treatment of derived fractions according to the requirements of the POP regulation (destruction potential and prohibition of emission as waste incineration plants or better).

This following first set of conclusions addresses whether shredders are appropriately prepared to treat ELV (and WEEE), considering that ELVs contain parts with PBDE:

a) Shredder plants for the treatment of ELVs are mentioned in Annex C, Part III, of the Stockholm Convention on POPs as one of the potential source categories for the unintentional formation and release of PCDD/Fs and PCB.

b) SLF from ELV is estimated to be at least 1 million tonnes per year in EU and Norway.

c) WEEE is considered as the other relevant source for emissions from shredders and a source for contamination of SR with PBDE.

d) The European Union aims to establish, in the context of the Industrial Emissions Directive (IED, 2010/75/EU), new BATs for the treatment of waste to replace the BAT established for the waste sector in 2006 which did not address shredders explicitly.

e) The Final draft for the Best Available Techniques (BAT) Reference Document for Waste Treatment published by October 2017 (BREF WT, 2017) is envisaged for adoption.

f) The BREF WT (2017) demonstrates that several shredders currently have high numbers of deflagrations and emissions beyond the level proposed in the BREF WT (2017).

g) The BREF WT (2017) proposes a set of management conditions and technologies to be applied to reduce the emissions.

h) According to Article 14(3) of the IED, BAT conclusions shall be the reference for setting the permit conditions to installations covered by the Directive.

i) To what extent existing permits will be affected by the revised BAT depends on national implementation.

j) In the context of treatment of ELVs and WEEE in shredders and considering the PBDE content in such materials, it is crucial to be in line with most recent BAT. However, during other than normal operating conditions (e.g. deflagration), a very relevant amount of dust containing PBDE might be released. Therefore, it might be relevant to establish a maximum number of deflagrations in a given time. If, for instance, more than 1 deflagration occurs in 12 months, the permit to treat ELVs and WEEE might be withdrawn until a new management plan demonstrating effort to avoid such deflagrations is prepared and accepted by the authorities.

The second and last set of conclusions for treatment of ELVs in shredders and PST installations addresses the concentrations in different output fractions.

k) Shredding in combination with PST can produce different fractions of bromine and the expected decaBDE/ PBDE content:

l) Shredder sand is apparently well below 1 000 mg/kg bromine with an average of 211 mg/kg.

m) Fluff contains on average 729 mg/kg bromine but for a relevant number of samples the bromine content exceeds 1000 mg/kg. This fraction can be used in feedstock recycling processes. If low Br-concentration can be guaranteed (analysed) it also may be subject to material recycling.

n) Bromine content of the light granulate fraction < 1.1 g/cm^3 is on average 202 mg/kg bromine; very few samples exceed 1000 mg/kg. Therefore, it may be used in material recycling processes. All analyses indicate concentrations of decaBDE well below 100 mg/kg.

o) The granulate fractions with medium density ($\geq$1.1 and $\leq$1.3 g/cm^3) and high density (>1.3 g/cm^3) reveal higher concentrations of bromine (on average 2277 and 2749 mg/kg bromine respectively). A few analyses indicate that these PST outputs might exceed the decaBDE concentrations of 1 000 mf/kg and thus are not applicable in material recycling processes. The fraction with medium density ($\geq$1.1 and $\leq$1.3 g/cm^3) could be[27] used in blast furnaces for feedstock recycling.

p) The granulate fractions revealing a high density (>1.3 g/cm^3) contain normally high concentrations of PVC and are not accepted by blast furnace for feedstock recycling; they may be processed further on in chemical treatment processes to recover PVC or go to a waste incineration plant.

q) The detected differences for the bromine content in different fractions explain some outliers in the literature, since such outliers refer to PST output fractions suspected to contain high concentrations.

r) Detection technologies like XRF supporting sorting or hyper spectral imaging (HSI) are considered emerging techniques and offer promising opportunities to achieve high quality sorting results. Since the techniques are used for other purposes in the sector as well, R&D will continue and possibly generate windfall benefits for sorting hard plastic fractions from PST.

s) For the use of ASR fractions in feedstock recycling and energy recovery processes, please refer to Chapter 5.

---

[27] ARN-fraction goes to Salzgitter Stah

5. Recovery/ recycling operation for PST fractions

5.1. Current situation

Shredder residues may not be discarded in landfills prior to processing steps in general. Simple versions of PST include metal separation and screening, producing a mineral-enriched fine grained material that is brought to landfills in some EU Member States while the coarse grained fraction is introduced into waste incineration plants. Metal concentrates are forwarded to metallurgical plants.

State-of-the-art technologies of PST, as described in chapter 4, split ASR into fractions of higher quality to be used in more efficient recovery processes. Only in very few cases are fractions for potential material recycling won as described above. The largest part is fed to feedstock recycling or energy recovery processes.

5.2. Feedstock recycling and energy recovery in thermal processes

For feedstock recycling processes the use of hard plastic granulates and agglomerates from fluff or packing material is established in blast furnaces. Several steel companies in the EU have built feed systems for their blast furnaces, especially Voestalpine Stahl in Linz/Austria (capacity of 220 000 t/a for plastic input only in one blast furnace), Salzgitter AG/Salzgitter, Stahlwerke Bremen und Eisenhüttenstadt (both Arcelor Mittal) in Germany, US Steel Kosice in Slovakia and a steel plant in Wales. The overall input capacity of these plants with respect to plastic by far exceeds the potential feed that could be generated out of suitable waste streams like shredder granulate from shredder residues. Steel plants pay occasionally more than 70 €/t for this kind of feed. Due to this sufficient capacity no relevant further channels have been developed.

Suitable fractions for the blast furnace input are introduced into the furnace at the tuyère level close to the bottom of the system. Within a few milliseconds, the material is gasified to carbon monoxide, hydrogen and nitrogen under strongly reducing conditions at approximately 2 300°C and around 4.5 bar. No organic molecule is left over and potential contents of halogens, like chlorine and bromine, pass through the coke bed to the top of the blast furnace together with the reaction gases carbon dioxide and water from the central reduction process of the wuestit phase with carbon monoxide and hydrogen to iron. On this path, the halogens react with residual hydrogen to form HCl or HBr. New formation of any organic molecules under these conditions is extremely unlikely. This technological path could be counted under the technology group “h” listed in Table 25.

In fact, blast furnaces especially may represent the top most secure technology out of this technology group for destroying and prohibiting recombination of any halogenated hydrocarbons, with perhaps the exception of some PFOs that cannot be destroyed even at extremely high temperatures. From time to time in discussions, the blast furnace process is confused with converter processes or electro arc furnace processes. Both of these latter processes are generally not suitable for introducing hydrocarbons, no matter with or without halogens.

Experience with thermal destruction of halogenated hydrocarbons, especially also with POPs, are given in the secondary copper metallurgy (Aurubis) that deals partly with much higher concentrations of these substances in their input, though not from ASR but from WEEE streams. These experiences can be used to show how save this kind of process is. This also is documented in Table 25 under category ‘h’.

The use of shredder residue fractions (either organic or potentially even the mineral part) in cement kilns also guarantees complete destruction of halogenated hydrocarbons when introduced to direct firing in the kiln (see Table 25, category 'c'). The use of organic compounds in cement production is, however, counted as energy recovery, not feedstock recycling.

Another option for energy recovery could be by using agglomerated fluff fractions in dust firing of coal-fired power plants. This process should also be safe with respect to POP destruction, although due to the general development of this type of power plant, this path may not be relevant in the future, especially since the blast furnace route would economically be more interesting.

Waste incineration plants running their processes at state-of-the-art (listed in Table 25 as ASWI Advanced Solid Waste Incineration) are generally seen as suitable technologies for destroying POPs, though Table 25 does not give specific indications to that. If a dismantling process had to be carried out for POP-containing components, these components should be brought to an ASWI process (counted as energy recovery process). With respect to temperature profile and treatment, time blast furnaces and cement kilns exhibit even more radical conditions for destroying POPs.

Table 25 Overview of technologies for the destruction and irreversible transformation of POPs in wastes

Technology	**POPs**					
	Pesticide POPs	**PCB**	**PCDDs/ PCDFs**	**PFOS**	**POP- BDEs***	**HBCD**
(a) Alkali metal reduction	Yes, for certain pesticides: chlordane, HCH	Yes	ND	ND	ND	ND
• Advanced solid waste incineration (ASWI)	ND	ND	ND	ND	ND	Yes
• Base catalysed decomposition (BCD)	Yes, for certain pesticides: chlordane, HCH DDT	Yes	Yes	ND	ND	ND
(b) Catalytic hydrodechlorinat ion (CHD)	ND	Yes	Yes	NA	NA	ND
(c) Cement kiln co- incineration	Yes for all pesticides	Yes	Yes	ND	Yes	Yes
(d) Gas phase chemical reduction (GPCR)	Yes, for certain pesticides: DDT, HCB	Yes	Yes	ND	ND	ND
(e) Hazardous waste incineration	Yes for all pesticides	Yes	Yes	Yes	Yes	Yes
• Plasma arc	Yes, for most pesticides including chlordane, chlordecone, DDT, endosulfan, heptaclor	Yes	ND	ND	ND	ND
(f) Plasma melting decomposition method (PMD)	ND	Yes	ND	ND	ND	ND
(g) Supercritical water oxidation (SCWO) and subcritical water oxidation	Yes, for certain pesticides: chlordane and DDT	Yes	Yes for PCDDs	ND	ND	ND
(h) Thermal and metallurgical production of metals	ND	ND	Yes	ND	Yes	ND

NB: ND = Not determined.
NA = Not applicable.
Source: BREF WT 2017 referring to: UNEP - Basel Convention, General technical guidelines on the environmentally sound management of wastes, of wastes consisting of, containing or contaminated with persistent organic pollutants (2015).

* Please note that at the time of the publication of this table decaBDE is not included in the POP-BDE.

5.3. Material recycling options

As mentioned above, smaller amounts of shredder residue fractions might be able to be processed in material recycling processes (see Chapter 4.2.2). Especially hard plastic in the density range of < 1.1 g/cm³ would be addressed. Such plastic includes plastic types PP, PE and ABS. To reduce the risk of protracting POPs into the waste stream, chemical recycling processes are available for thermoplastic materials, in addition to the above-mentioned technologies, using sensor-based sorting. At least one industrial plant is running (in the Netherlands) that uses the Creasolv process. After dissolution of the polymer matrix, components such as flame retardants and fillers may be separated. The thermoplastic polymer can afterwards be reprocessed.

Especially for PVC-rich fractions from the hard plastic stream in the density range of > 1.3 g/cm³, PVC can be recovered in a chemical process, where PVC is dissolved, the solid remnants are filtered out and PVC is then again reprocessed. This Vinyloop-technology, developed by Solvay is set up in a large industrial plant in Ferrara, Italy. At the moment, there is not sufficient feed for opening additional plants in the EU. Due to the lack of sufficient amounts of the mentioned fraction, PVC recycling out of shredder residues is not carried out yet.

Though still in the early research stages, technological options are emerging for recycling thermosets, which contain flame retardants, to implement separation in a combination of solvolysis and pyrolysis.

5.4. Use of derived fractions: Conclusions

The following conclusions can be drawn for the use of fractions derived from PST processes:

- In principle, thermal processes in high temperature ranges and their corresponding emission control systems (metallurgical processes, cement plants, coal combustion plants, solid waste incinerators) are suitable for processing such material flows.
- The draft BREF document for waste treatment lists potential destructions of various pollutants, including thermal processes.
- In principle, a selective release of certain ingredients or complete chemical recycling, such as the Creasolv process for thermoplastics, are suitable for destroying and/ or removing POPs.
- The economic and ecological advantage for recycling plastics from ELVs has not yet been assessed in detail. For high-quality plastics from other applications, recycling might be viable. For PVC, the Vinyloop process has been implemented.
- In the field of thermosets, technological options are emerging (but still in the early stage of research) to implement separation using a combination of solvolysis and pyrolysis (economic and ecological evaluations pending).

5.5. Use of derived fractions: reuse of bromine

Modern process chains make it possible to recover waste with higher bromine content and separate bromine for reuse. Below is an extract from a joint press release by Aurubis and Grillo:

> *Perfect implementation of the circular economy*
>
> *The project "Closing the loop - Common Recycling of Aurubis and Grillo-Werke" was awarded second prize in the VCI's national Responsible Care Prize competition …*
>
> *The Kayser Recycling System (KRS) at the Aurubis Recycling Center in Lünen is used to produce converter copper from secondary raw materials. The resulting zinc-containing filter dust ("KRS oxide") is used by Grillo-Werke as raw material for the production of zinc sulphate …*
>
> *An example of an innovative solution is the construction of a new plant at Grillo to extract bromide from the KRS oxide (as a component of flame retardants in recycled electronic scrap), including the return of bromine to the associated recycling system.*

A need for bromine in further processes has been determined, for example by Saltigo (a Lanxess subsidy).

6. Discussion of effects on the ELV Directive (recycling/ recovery rates)

The listing of decaBDE in the POP Regulation would not have an effect on the **recovery rate**, as the separated materials containing decaBDE can be treated in waste incinerators with energy recovery or in cement kilns as an energy carrier, or can be used as a reducing agent (feedstock recycling). Thus, the recovery rate would not be affected.

The effects on the recycling rate are displayed in Table 26.

In result and main effect from listing decaBDE in the POP regulation might be for shredder residues (without PST), which might be not allowed for landfilling anymore. However, this would not hamper the recycling rate required by the ELV Directive.

Table 26 Effects on recycling rate from ELV treatment

	Effects by listing of decaBDE in the POP Regulation	Average share of ELV	Comment
Parts, dismantled for reuse	No effect	n.a. depending on dismantling concept of ATF	Exemptions for spare parts in Stockholm Convention
(large) plastic parts dismantled for recycling	Limited effect	n.a. depending on dismantling concept of ATF	In principle, large parts dismantled for recycling should be checked (e.g. with handheld XRF) for bromine content. However, considering the parts suspected to contain decaBDE, the risk of contamination of exterior parts (like bumpers, hubcaps, etc.) is low.
Metal route: steel, copper,	No effect	65% to 70%	R4 as specified in the POP regulation
Metal route: aluminium	No effect	5% to 10%	R4 as specified in the POP regulation
Metal route: lead	No effect		R4 as specified in the POP regulation
Before PST	Possibly strong effect: Not longer for disposal in landfills	approx. 20%	A potential ban for landfilling will not affect the recycling target.
- *SLF*			
- *Non metallic fraction after eddy current separation*			
- *Finest fraction after classification*			
Fractions after PST			
- *Shredder-sand / shredder fines*	Depending on the lower level: no effect	approx. 6% (SIMI 2016)	
- *Fluff*	No effect		The preferred route might be feedstock recycling (reducing agent). With advanced PST, material recycling might be feasible.
- *Light density (Plastic) fraction (< 1.1 mg/cm3)*	No effect		Either for material recycling (if threshold in the EU POP regulation will be at 1000 mg/kg) or feedstock recycling
- *Medium density (Plastic) fraction (> 1.1 < 1.3 mg/cm3)*	No effect		The preferred route is feedstock recycling (reducing agent)
- *Heavy density (Plastic) fraction (> 1.3 mg/cm3)*	No effect		Feed stock recycling is not an option; advanced technology for recycling available but not yet established; energy recovery possible.
- *Metals*	No effect		R4 as specified in the POP regulation

7. Discussion of the effects on different regions across the EU

7.1. Effects on disposal of SLF from ASR

As displayed in Table 16, more than 260 000 tonnes SLF from ELVs are disposed of in the EU. Data do not indicate if this refers to incineration without energy recovery or simply landfilling. However, in several Member States, it is still allowed to dispose of SLF in landfills, as availability of waste incineration is limited/ not existent[28] or PST, ensuring qualities appropriate for use of plastics in cement kilns or furnaces is not established (yet). If disposal of SLF in landfills and other shredder residues is not allowed when decaBDE is listed in the POP Regulation, this would have immediate effects on the management of ELVs in MS that currently landfill SLF. The shredders in these MS need to establish new disposal routes with longer distances and higher costs. Depending on the transitional period allowed for adoption, this might cause disruptive effects on the shredder sector. It would not apply for shredder residues from vehicles only but from WEEE.

Therefore, we recommend to conduct a survey/ issue a question to the EC:

- Which MS prohibit the disposal of SLF in landfills?
- What is the amount of SLF landfilled (last available data)?
- What effect would a ban on SLF landfilling have on shredder plants in the respective Member State?

7.2. Effects of shredders not complying with (draft) BAT

As outlined in chapter 4, several shredders currently have high numbers of deflagrations and unintended emissions beyond the BAT level proposed. These shredders (and the related management and operation procedures) need to be adapted during an appropriate transitional period. Criteria to withdraw operation approvals for shredder/operators when the operation/management is not appropriate might be necessary.

Therefore we recommend conducting a survey and/or issuing questions from the EC:

- Which shredders in the MS treat ELVs?
- Which of them fall into the category addressed by the (draft) BREF WT?
- Which of them are compliant with the (draft) BAT?
- What transitional period for adoption is considered appropriate to establish strict compliance requirements, including requirements for management of input material?

7.3. Effects on dismantlers

The option that parts (potentially) containing decaBDE might be obligatorily dismantled before shredding would certainly change the economic situation of the more then 12 000 dismantlers, putting them at risk that their business (most of them SMEs) is no longer economically viable.

By far most of the dismantled parts would not be effected by decaBDE, as information on relevant parts to be dismantled is lacking and thus “suspected” parts would be indicated for dismantling. As a consequence, the effort to dismantle parts (potentially) containing decaBDE would not be effi-

---

[28] See Wilts et.al (2014), assessing the waste incineration capacities across Europe.

cient at all. In the end, the dismantled parts would end up in the same processing and recovery routes as materials run through a PST process.

8. Discussion of the effects for other global regions

The situation in other OECD countries like the USA or Japan is in principle similar to the situation in the EU. The limited data availability on effected parts is the same, as the databases assessed in chapter 3.1 are the same. Information on the performance of shredders (deflagrations) or the economic conditions for dismantlers in other OECD countries are not available.

In other regions of the world it is known that SLF are either spilled or often used for burning under dangerous circumstances with the risk of creating hazardous emissions.

Annex 1 PBDE in vehicles

Table A 1 Products and materials that may contain PBDEs and other substances containing bromine (MinEnv. Finland 2016 quoting ESWI 2011, Häkkinen 2012 and Myllymaa et al. 2015)

substance	usage
tetra-, penta-, hexa- and hepta-BDE	Flame retardant, e.g.: • Plastic electrical and electronic equipment casings • Circuit boards • Insulation in refrigerating equipment • Hard plastic vehicle parts, such as bumpers and dashboards • Vehicle seat and furniture padding manufactured out of polyurethane foam, mattresses • Building sound insulation boards • Imitation wood materials in buildings • Products manufactured out of recycled plastics (unintentional contamination)
HBB (Hexabromo-benzene)	Flame retardant: • Heat resistant materials • Electronic products • Coatings in the automotive industry • Polyurethane foam • Lacquers
HBCDD (Hexabromo-cyclododecane)	Flame retardant: • Polystyrene foam in building insulation (EPS and XPS) • Plastic electrical and electronic equipment casings • Video cassette casings • Stereo and video player casings • Junction and extension boxes • Furnishing fabrics • Vehicle seats, interiors and bodies

Annex 2 ATFs in EU member states

Table A 2 Number of ATFs in EU Member States (ARGUS, 2016)

	Total No. of ATFs			Total No. of ATFs with certified environmental management systems			
EU MS	**No. of ATFs**	**Reference period**	**ELVs per ATF**	**No. of ATFs**	**Share of total (%)**	**Reference period**	**Comments on certification**
BE	123	2013	1 094	5	4.1%	2011-2014	ISO 14001
BG	580	2011-2014	106	2	0.3%	2011-2014	ISO 14001
CZ	569	2015	214	:	:	:	
DK	218	2008-2010	461	218	100.0%	2010	
DE	1 366	2014	366	:	:	:	
EE	64	2011-2014	230	1	1.6%	2011-2014	ISO 14001
IE	173	2012-2013	534	9	5.2%	2008-2011	
EL	115	2011	827	26	22.6%	2011-2014	
ES	1 007	2008-2011	834	58	5.8%	2008-2011	ISO 14001
FR	1 759	2011-2014	634	153	8.7%	2011-2014	ISO 14001
HR	14	2011-2014	2 295	2	14.3%	2011-2014	ISO 14001
IT	1 699	2012	516	98	5.8%	2012	2012: EMAS: 6 companies; ISO 14001: 92 companies
CY	16	2011-2014	826	0	0.0%	2011-2014	
LV	158	2008-2010	67	:	:	:	
LT	385	2013	69	1	0.3%	2011-2014	
LU	2	2011-2014	1 145	1	50.0%	2011-2014	
HU*	171	2011-2014	87	(17)	9.9%	2011-2014	Estimate
MT	5	2011-2014	240	0	0.0%	2011-2014	
NL	448	2011	519	273	60.9%	2011	KZD standard (Quality Care Dismantling).
AT	177	2011-2014	418	64	36.2%	2011-2014	EMAS
PL	871	2013	462	10	1.1%	2013	
PT	188	2013	490	17	9.0%	2013	ISO 14001: 16 companies; EMAS: 1 company
RO	468	2014	:	95	20.3%	2014	ISO 14001
SI	18	2011-2014	340	0	0.0%	2011-2014	
SK	41	2011-2014	899	:	:	:	
FI*	113	2011-2014	879	0	0.0%	2011-2014	
SE	341	2014	556	80 - 100	23 - 29%	2011-2014	
UK	1 804	2013	637	:	:	:	
total	**12 893**			**1 130 to 1 150**			

HU* No. of ATFs include 50 (2010) and 12 (2011-2014) ELV collection points respectively
FI* For the previous reporting period (2008-2011), FI reported 33 certified establishments

Annex 3 Number of auto shredders in EU Member States


EUROPEAN AUTO SHREDDERS

For an interactive map of the 352 auto shredding locations, visit www.RecyclingToday.com/rtge0914-European-auto-shredders-map.aspx.

Shredders in the EU-28 and Norway. Sources: Base list of shredding companies and locations for 2014 was provided by the Bureau of International Recycling in cooperation with the European Shredder Group of the European Ferrous Recycling & Recovery Federation, with additional information provided by ARGE-Shredder GmbH (Austria), FEDEREC (Fédération des Entreprises du Recyclage, France), BDSV (Germany), Metaal Recycling Federatie of Netherlands, RecycleMetals.org (U.K.), and direct reporting by companies.

Figure A 1 Map of the distribution of EU auto shredders (McKenna 2014)

AUSTRIA
Amstetten
Metal Recycling Mü-Gu GmbH
Edt bei Lambach
Gratz Brothers GmbH
Götzis
Loacker Recycling GmbH
Hall in Tirol
Ragg GmbH
Knittelfeld
Fritz Kuttin GmbH
Laxenberg
Scholz GmbH

BELGIUM
Aubange
Recylux S.A.
Brussels
Georges-Derichebourg
Chatelet
Cometsambre S.A.
Engis/Liège
Belgian Scrap Terminal
Geel
Van Dalen Belgium
Genk
Stassen Recycling N.V.
Stelmet
Ghent
Refra N.V.
Kallo/Antwerp
Belgian Scrap Terminal
Marchienne au Pont
Georges-Derichebourg
Keyser & Fils S.A.
Menen
Galloo N.V.
Mol
Van Hees Metalen
Mons
Cometsambre S.A.
Willebroek
Belgian Scrap Terminal
Zutendaal
Recylux S.A.

BULGARIA
Devnya
Nadin
Transins Industry S.A.
Pernik
Stomana Industry S.A.
Plovdiv
Nadin
Sofia
Nadin
Ecometal Engineering Ltd. (2)
Rovotel
Stara Zagora
Phoenix Inverce

CZECH REPUBLIC
Kladno
Kovosrot Kladno a.s.
Tlumacov
Metalscrot Tlumacov

DENMARK
Grenaa
Stena Metall Group
Hadsund
H. J. Hansen
Odense C
H. J. Hansen
Østerbro (Copenhagen)
Stena Metall Group
Roskilde
Stena Metall Group

ESTONIA
Tallinn
Kuusakoski

FINLAND
Eurajoki
Eurajoen Romu Oy
Heinola
Kuusakoski
Kajaani
Kajaanin Romu Oy
Kuopio
Kuusakoski
Lapua
Kuusakoski
Pori
Stena Metall Group
Vantaa
Kuusakoski

FRANCE
Amneville
Eska-Derichebourg
Aniche
Galloo-Carmi
Athis Mons
Revival-Derichebourg
Blaringhem
Baudelet
Boulazac
Sirmet
Brest
Guyot Environnement
Carros
Purfer-Derichebourg
Champagne
S.A.S.U. Passenaud Recyclage
Chenove
Ets Metallurgiques E. Godard
Clairoix
Brion
Colomiers
AFM Recyclage
Condette
Strap-Derichebourg
Coulombiers
AFM Recyclage
Dainville
Delouvel Recyclage
Elliant pres de Rosporden
Le Floch
Esmans
Marchetto
Fosse
Revival-Derichebourg
Franois
Eska-Derichebourg
Gennevilliers
Revival-Derichebourg
Golbey
Eska-Derichebourg
Gond Pontouvre
Sirmet ancien Bernon
Halluin
Galloo France
Illzach
Marx Spaenlin-Derichebourg
Isigny-Le Buat
SIREC
Issoire
Praxy Centre
La Chapelle St. Luc
Bartin Recycling
Le Pian Medoc
Decons Récupération
Ledenon
Purfer-Derichebourg
Limay
Alpa
Guy Dauphin Environnement
Marignane
Purfer-Derichebourg
Marquette
Galloo-Cible
Marseille
Profer
Montereau Fault Yonne
Revival-Derichebourg
Monteux
Rossi Recyclage
Montoir-DeBretagne
Guy Dauphin Environnement
Nantes
AFM Recyclage
Nersac (pres Angouleme)
Sabatier
Rocquancouart
Guy Dauphin Environnement
St. Apollinaire
Acyclea-Praxy
St. Etienne
Jean Meli
St. Marcel
Purfer-Derichebourg
St. Pierre de Chandieu
Purfer-Derichebourg
St. Pierre des Corps
Ets J. Menut
St. Saulve
Strap-Derichebourg
Salaise sur Sanne
Guy Dauphin Environnement
Strasbourg
Eska-Derichebourg
Guy Dauphin Environnement
Vierzon
RIC Environnement
Villenave
AFM Recyclage

GERMANY
Baar-Ebenhausen
Thyssen Dück GmbH
Bochum
BRW Bochumer Recycling Wertstoffhandel GmbH
Brandenburg
TSR
Bremen
Interseroh Jade Stahl
Löbl Rohstoffbetriebe GmbH & Co. KG
Dortmund
TSR
Duisburg
TSR
Eberswalde
The Steil Group (2)
Eppingen
Alba R-Plus
Eschweiler
The Steil Group
Espenhain
Scholz Recycling
Essen
Richter GmbH
Essingen
Scholz Recycling
Flensburg
Nord-Schrott
Hamburg
TSR
Herbteringen
SWH Shredderwerk Herbteringen GmbH
Hildesheim
Willi Hennies Recycling GmbH
Homburg
SRP-Saarländische Rohprodukte GmbH
Krefeld
IMR Innovative Metal Recycling
Lahntal
Marburger Rohstoffverwertung Johannes Völker
Leer
Interseroh Evert Heeren
Lubeck
ISR-Lübecker Schrotthandel GmbH
Ludwigshafen
Günther Schmelzer GmbH
Mannheim
TSR
Merkers
RVT Rohstoffverwertung GmbH & Co. KG
Munich
Thyssen Dück Rohstoffhandel
Nuremberg
Derichebourg Umwelt
Max Aicher Recycling
Osnabrück
Münz & Söhne
Regensburg
RVR Rohstoffverwertung Regensburg GmbH
Reuth
Derichebourg Umwelt
Riesa
Feralpi Stahl
Rostock
Interseroh
Saalfeld
Scholz Recycling-SRT Schrott
Salzgitter
DEUMU
Straubing
H. Carnuth KG
Trier
The Steil Group (2)
Wetzlar
Rohstoff-Verwertung GmbH
Wilhelmshaven
Interseroh Jade Stahl
Wörth an der Isar
Iwan Koslow GmbH & Co. KG
Würzburg
Preuer

GREECE
Thessaloniki
Konstantinidis Bros.
Sidenor S. A.
Volos
Steelworks of Volos S.A.

HUNGARY
Budapest
Ereco Zrt.
Mü-Gu Kft.
Fehérvárcsurgó
Alcufer Kft.
Jobbágyi
Klein Metals Kft.
Miskolc
Shredder Center Kft.

IRELAND
Cork
Hammond Lane Metal Co. Ltd.
Dublin
Hammond Lane Metal Co. Ltd.
Limerick
Clearcircle/Onesı Group

ITALY
Ancona
G.B.F Metalli S.r.l.
Arese
Rotamfer S.P.A.
Arzano
Cartofer S.r.l.
Bagnatica
Nicoli Ecosider S.r.l.
Bari
Centro Riciclo Sud
Bollate
Metalmilv S.r.l.
Nuova Beretta S.r.l.
Borgo San Lorenzo
Geo Ambiente Waste
Brescia
RMB S.P.A.
Cagliari
West Recycling S.r.l.
Caivano
Del Fran S.r.l.
Calcara di Crespellano
Italmetalli S.r.l.
Camin
Acciaierie Venete S.P.A.
Carrè
Nuova Europ Metalli
Castelnuovo del Garda
Rotamfer S.P.A.
Catania
Alfa Acciai
Auto Demolizioni Express S.r.l.
Imprimet S.r.l.
Cervaro
Ragmetal S.r.l.
Cesena
Pagliarani Natale
Chiarano
Gruppo Dir Metal

Chieti Scalo
Life S.r.l.
Ciserano
Vitali Rottami
Cisterna di Latina
Centro Rottami S.r.l.
F.LLI Lupoli Rottami Ferro
Corsico
Corsico Rottami S.r.l.
Costigliole d'Asti
Magifer S.r.l.
Darfo Boario Terme
Pezzotti S.r.l.
Dolo
Ecosider S.r.l.
Dolzago
Carprometal S.r.l.
Empoli
Mazzoni Ferro S.r.l.
Francavilla Fontana
Fasanelli Arcangelo
Gavardo
Effedue S.r.l.
Gazzuolo
Metalricicla S.r.l. di Baruffi Otello & Co.
L'Aquila
Autobazar Adamo
Laterza
Sa.Tra.Met S.r.l.
Leini
ZaniMetal S.r.l.
Levate
Steel Metal Industries S.r.l.
Lonato
Feralpi Siderurgica S.P.A.
Mantova
Pyreco S.r.l.
Melfi
Transider S.r.l.
Mozzecane
Ferramenta Villafranca Siderurgica S.P.A.
Orvieto
Trentavizi S.P.A.
Ostellato
Ecofrantumi S.P.A.
Palma Campania
Ragmetal S.r.l.
Pontedera
Ecoacciai S.P.A.
Rezzato
Eurocomet Siderurgica S.r.l.
San Cesareo di Lecce
Ecomet S.r.l.
San Giacomo di Veglia
Cartonfer S.N.C
San Giorgio di Nogaro
Becker Italia SRL
Santa Palomba
Ecofer S.r.l. Italferro-Fiori Group
Sarezzo
Assisi Raffineria Metalli S.P.A.
Somet S.P.A
Settimo
CRS SRL Dericheboung
Siena
Pianigiani Rottami S.r.l.
Surano
Romano Roberto
Tamara
Zoffoli Metalli S.r.l.
Terlizzi
Ferramenta Pugliese S.N.C.
Terni
Ecorecuperi S.r.l.
Travagliato
CA Demolizioni S.N.C.
Verbania
Borgotti Teresa S.r.l.
Villafranca Padovana
Zampieron Rottami S.r.l.

LATVIA
Riga
Tolmets

LITHUANIA
Klaipeda
Kuusakoski

MALTA
Fgura
The Hompesch Steel Co. Ltd.

NETHERLANDS
Amsterdam
HKS Scrap Metals
Born
Euregio Recycling
Den Bosch
Gerrits AVI
Moerdijk
Van Dalen Metals Recycling & Trading
Nieuwerkerk aan den IJssel
Van Dalen Metals Recycling & Trading
Nijmegen
Van Dalen Metals Recycling & Trading
's-Gravendeel
HKS Scrap Metals
Zwartsluis
HKS Scrap Metals

NORWAY
Aalesund
Vartdal Gjenvinning
Bergen
Norscrap West-Hellik Teigen AS
Drammen
Hellik Teigen AS
Egersund
Hermod Teigen
Fredrikstad
Norsk Gjenvinning
Norsk Metallfragmentering
Gjovik
Oppland Metall
Hokksund
Hellik Teigen AS
Skien
Stena Metall Group
Trondhiem
Norsk Gjenvinning

POLAND
Bodzechow
CELSA/Zlomhut
Gdansk
CELSA/Drapol
Herby
CMC Scrapena
Katowice
CMC Zawiercie
Lowicz
Skowronski
Lublin
Jawa
Olawa
Centrozlom Wroclaw S.A.
Pruszków
Olszanski
Stalowa Wola
Wtórsteel
Swarzedz
Stena Metall Group
Tarczyn
Zlom-Pol
Tarnowskie Góry
Olmet
Warsaw
CELSA/Zlomhut

PORTUGAL
Carregado
Batistas Reciclagem de Sucatas S.A.
Carvalhos
Constantino Oliveira & Filhos S.A.
Seixal
ECOMETAIS
Setubal
Recielectric
Viseu
Interecycling

ROMANIA
Bucarest
Unspecified (2)
Cluj-Napoca
Rematinvest S.R.L.
Drobeta-Turnu Severin
Unspecified
Galatzi
Unspecified
Timisoara
Rematinvest S.R.L.

SLOVAKIA
Banska Bystrica
KOVOD a.s. Banska Bystrica
Kendice
KOVOD a.s. Banska Bystrica
Kosice
KBZ Ltd.
Kovoinvest SRO
Martin
Ekoquelet SRO
KOVOD a.s. Banska Bystrica

SPAIN
Alava
Decons Aguirain
Grupo Lyrsa
Alhama De Murcia
Hermanos Ingles S.A.
Barcelona
Ferimet S.L.
Fragnor S.L.
Francisco Alberich S.A.
Viuda de Lauro Clariana S.L.
Berrioplano
Metales de Navarra S.A.
Cadiz
Iron & Metals Blasco S.L.
Gerona
Ecogironina de Deposits S.L.
Jerez de los Caballeros
Alfonso Gallardo Group
La Coruña
Francisco Mata S.A.
Las Palmas de Gran Canaria
Recuperadora Canaria
Legutiano
Reydesa Recycling
Madrid
Grupo Lyrsa (3)
Triturados Ferricos S.L.
O Porriño
Alumisel S.A.U.
Orcoyen
Chatarras Iruña S.A.
Rubí
Roduher S.L.
San Andrés De Los Tacones
Daniel Gonzalez Riestra S.L.
Sevilla
Grupo Lyrsa (2)
Valencia
JAP-2 Recuperaciones S.L.
Metalimpex Iberica
Vic
Jaime Duran S.A.
Vizcaya
Fragnor S. L.
Zaragoza
Industrias Lopez Soriano
Iron & Metals Diez
Viuda de Lauro Clariana S.L.

SWEDEN
Angered
AB Skrotfrag
Gävle
Kuusakoski Sverige AB
Hallstahammar
Stena Metall Group
Halmstad
Stena Metall Group
Huddinge
Stena Metall Group
Malmö
Kuusakoski Sverige AB
Stena Metall Group
Oskarshamn
Skrotfragg AB (under construction)
Skellefteo
Kuusakoski
Vasteras
Ragn-Sells Metall AB

UNITED KINGDOM
Avonmouth
Sims Metal Management
Barnsley
Aluminium Recycling Ltd.
Bedford
Ampthill Metals
Belfast
Clearway Belfast (2)
Billinghurst
Charles Muddle
Birmingham
EMR
Hawkeswood Metal Recycling
Sims Metal Management
Blaydon
EMR
Bourne
B W Riddle (2)
Dagenham
Van Dalen Metals Recycling & Trading
East Tilbury
EMR
Glasgow
J R Adam & Son Limited
Hailsham
H Ripley
Hartlepool
EMR
Hitchin
Metal & Waste (Hitchin) Ltd.
Hull
Lord and Midgley
Ilkeston
Ward Recycling
Inverkeithing
R M Supplies
Ipswich
Sackers Recycling
Leeds
EMR
Liverpool
EMR
S. Norton & Co Ltd.
London
Bishopsgate Metals
EMR (2)
Manchester
S. Norton & Co Ltd.
Morecambe
Morecambe Metals
Newark
Briggs Metals
Newhaven
EMR
Newport (Wales)
Sims Metal Management
Norwich
SITA Atlas Works
Nottingham
Sims Metal Management
Portsmouth
EMR
Renfrew (Scotland)
Christie & Son
Ridham Dock
EMR
Rotherham
C F Booth
Scunthorpe
City Scrap
Sheffield
ELG Haniel
Van Dalen Metals Recycling & Trading
Smethwick
Dunn Bros.
Stockton on Tees
T.J. Thompson & Son
Towcester
Grimscote Metals
Wimborne
Sims Metal Management
Yateley
Sims Metal Management

Figure A 2 List of European auto shredders (McKenna, 2014)

Annex 4 Entries for PBDE in GLASP Reference List

Table A 3 Entries for PBDE in GLASP Reference List

GLAPS No.	**275**	**154**
Substance Name	**Polybrominated diphenyl ethers, all members**	**Decabromodiphenyl ether (Benzene, 1,1'-oxybis[2,3,4,5,6-pentabromo-)**
Synonym	PBDEs	deca, decaBDE, decabromodiphenyl oxide
CAS-No.	n.a.	1163-19-5
Other Identifier (if no CAS available)		
Applicable GLAPS Classification (R, P, N, U)	PRU	RU
GADSL Reference (Y/N)	N	Y
Detail First added	31-Jul-17	31-Jul-17
Detail Last revised		
International	U	U
Africa	U	U
Asia/Pacific	U	U
Europe	PRU	RU
European Union/EEA	R/P	R
Russia	U	U
Turkey	U	U
Europe - Other	U	U
Middle East	U	U
North America	U	U
South & Central America	U	U

Source: GLASP, accessed 9-Feb-2018

Table A 4 Entries for PBDE in GLASP for regional details

Dossier No.	**321**	**322**
Substance Name	**Polybrominated diphenyl ethers, all members**	**Decabromodiphenyl ether (Benzene, 1,1'-oxybis[2,3,4,5,6-pentabromo-)**
Synonym	PBDEs	deca, decaBDE, Decabromodiphenyl oxide
CAS-No.	n.a.	1163-19-5
Other Identifier (if no CAS available)		
GLAPS No.	275	154
Region	Europe	Europe
Region / Country	EU/EEA	EU/EEA
Specific GLAPS Classification (R, P, N, U)	R/P	R
Reason Code	LR	LR
Source (Regulation: Sub-Regulation, or other source)	POP: Annex I, Part A Stockholm: Annex A	Stockholm: Proposal
Affected Use	All uses as substances or in mixtures	All uses as substances or in mixtures
Action required	Eliminate the production, placing on the market and use.	Need to be declared
Effective Date	immediate	immediate
Regional Reporting threshold	0.1% for recycled substances; otherwise 0.001%	Intentionally added

Source: GLASP, accessed 9-Feb-2018

Annex 5 Analytical Aspects- Standards for the determination of PBDEs and decaBDE

In general, an analysis of bromine will provide preliminary information if a waste stream may fall under POP waste. If the bromine content is sufficiently low, the POP content may not exceed a critical level. If the bromine level is high, a laboratory determination should be carried out. Table A 5 shows the different possible standards for determining BDEs and decaBDE, respectively. The two standards that are applicable for measuring decaBDE differ in their detectable concentrations. A brief description of the three standards is shown below.

Table A 5 Standards for the determination of BDEs or decaBDE

Norm	Determination of decaBDE	detectable concentration for decaBDE
Characterization of waste - Determination of brominated flame retardants (BFR) in solid waste; German version EN 16377:2013	yes	applicable to samples containing 100 to 10 000 µg/kg decaBDE
Water quality - Determination of selected polybrominated diphenyl ethers in sediment and sewage sludge - Method using extraction and gas chromatography/mass spectrometry (ISO 22032:2006); German version EN ISO 22032:2009	yes	the method can be used for samples containing 0.3 to 100 µg/kg of BDE-209
Electrotechnical products - Determination of levels of six regulated substances (lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, polybrominated diphenyl ethers) (IEC 62321:2008); German version EN 62321:2009	No	decaBDE is explicitly excluded

Brief description of the three standards

Characterization of waste - Determination of brominated flame retardants (BFR) in solid waste; German version EN 16377:2013

This European Standard establishes a method for determining selected polybrominated flame retardants (BFR) which are chemically-speaking polybrominated diphenyl ethers (BDE) in wastes using gas chromatography/mass spectrometry (GC/MS) after electron impact ionisation (EI) (GC-EI-MS).

Brominated diphenyl ether (BDE) is extracted from the dried sample with an organic solvent. In the case of waste matrices with a high plastic content, low temperature comminution is required to obtain particle sizes that allow complete extraction of the analytes. Suitable extraction methods are Soxhlet extraction, ultrasonic extraction or solvent extraction under pressure. The extracts obtained are narrowed and purified by column chromatography and gel permeation chromatography (GPC). After the process of confinement and purification, the brominated diphenyl ethers are separated by capillary gas chromatography and detected by mass spectrometry in single ion detection mode using electron impact ionization (EI). Quantitative determination is carried out in accordance with the procedure using an internal standard.

When using GC-EI-MS, the method is applicable to samples containing 100 µg/kg to 5 000 µg/kg congeners of tetra- to octabromodiphenyl ether or 100 µg/kg to 10 000 µg/kg decabromodiphenyl ether. It is also possible to analyse other brominated flame retardants using the method described in this European Standard, provided that the applicability of the method has been demonstrated.

Water quality - Determination of selected polybrominated diphenyl ethers in sediment and sewage sludge - Method using extraction and gas chromatography/mass spectrometry (ISO 22032:2006); German version EN ISO 22032:2009

This standard establishes a procedure for the determination of selected polybrominated diphenyl ethers (PBDE) in sediments and sludges by means of gas chromatography and mass spectrometry detection (GC-MS) after electron impact ionisation (EI) or negative chemical ionisation (NCI). If the GC-EI/MS is used, the method can be used for samples containing 0.05 µg/kg to 25 µg/kg of tetra- to octabromine congeners or 0.3 µg/kg to 100 µg/kg of decabromodiphenyl ether (BDE-209). Other polybrominated diphenyl ethers can also be analysed according to this standard, but the applicability should always be tested.

Electrotechnical products - Determination of levels of six regulated substances (lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, polybrominated diphenyl ethers) (IEC 62321:2008); German version EN 62321:2009

The standard establishes test methods for determining the quantities of lead (Pb), mercury (Hg), cadmium (Cd), hexavalent chromium (Cr (VI)) and their compounds, as well as of two types of bromine-containing flame retardants: polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE) (except for decabrominated diphenyl ethers, decaBDE).

In the past, one of the greatest challenges has been developing methods to accurately quantify decaBDE. decaBDE is very difficult to analyse. Therefore, the analytical procedure must be specifically targeted, multi-stepped and carefully controlled to minimise contamination from external sources as well as losses from within the sample itself. For example, BDE-209 is not stable and 'disappears' at higher temperatures during gas chromatographic separation and is also sensitive to degradation by UV light. Contaminations though the laboratory are possible since many laboratories are contaminated with BDE-209. (Alcock et al. 2009)

Annex 6 Entries for PBDE in GADSL

Table A 6 Entries for PBDE in GADSL

GADSL #	Substance	CAS No,	Classification	Reason Code	Source (Legal requirements, regulations)	Effective date (Legal requirements, regulations)	Generic examples	First added	Last revised
151	Polybrominated diphenyl ethers (PBDE), all members		D/P	FI/LR	Reg. (EC) No 552/2009 Reg. (EC) No 1907/2006 (REACH) Japan Chemical Substances Control Law [Class I] GB/T 30512 (ELV China) Canada (SOR/2008-218)		Flame retardant	10-Jan-2005	1-Feb-2017
	decabromodiphenyl ether ('deca'; decabromodiphenyl oxide) (Benzene, 1,1'-oxybis[2,3,4,5,6-pentabromo-)	1163-19-5	D/P	FI/LR	Dec 2013 voluntary phase out US EPA. P by July 2015 in D.C. Reg. (EC) No 1907/2006 (REACH Candidate List)	1-Jan-14		10-Jan-2005	1-Feb-2012
	Dibromodiphenyl ether	2050-47-7	P	LR				1-Feb-2017	
	Monobromodiphenyl ether	101-55-3	P	LR				1-Feb-2017	
	Nonabromodiphenyl ether	63936-56-1	P	LR				1-Feb-2017	
	Octabromodiphenyl ether ('Octa') (Benzene, 1,1'-oxybis-, octabromo deriv.)	32536-52-0	P	LR			Flame retardants in polymers, textiles etc.	10-Jan-2005	
	Pentabromodiphenyl ether ('Penta') (Benzene, 1,1'-oxybis-, pentabromo deriv.)	32534-81-9	P	LR	Japan Chemical Substances Control Law [Class I]			10-Jan-2005	
	Hexabromodiphenyl ether	36483-60-0	P	LR	Japan Chemical Substances Control Law [Class I]			1-Feb-2010	1-Feb-2011
	Heptabromodiphenyl ether	68928-80-3	P	LR	Japan Chemical Substances Control Law [Class I]			1-Feb-2010	1-Feb-2011
	Tetrabromodiphenyl ether	40088-47-9	P	LR	Japan Chemical Substances Control Law [Class I]			1-Feb-2010	1-Feb-2011
	Tribromodiphenyl ether	49690-94-0	P	LR				1-Feb-2017	

Note: Reporting threshold for the displayed substances: 0.1% w/w in a material
Source: GADSL, accessed 9-Feb-2018

Annex 7 Details dismantling test

			Net-Dismantling Time [h:min:sec]	**Weight Wiring Harness [g]**
Engine Compartment	**Engine Compartment**			
	Predecessor	Engine Cover	00:00:20	
		Heat protection shield	00:01:00	
		Cover, positive pole	00:00:10	
		Cover, relay box	00:00:10	
		Wiring harness, Engine Compartment	00:03:00	1.395
		Wiring harness, Engine Compartment 2	00:02:30	2.350
		Wiring harness, Battery	00:01:00	1.145
		TOTAL	**0:08:10**	**4.890**
		SUM Engine Compartment	**0:08:10**	**4.890**

			Net-Dismantling Time [h:min:sec]	**Weight Wiring Harness [g]**
Instrument Panel	**Instrument panel**			
	Predecessor	Molding instrumental panel	00:00:30	
		Air nozzle	00:00:30	
		Storage box, driver side	00:00:05	
		Headlamp switch	00:00:10	
		Air-condition, regulation switch	00:00:20	
		Air-condition, control unit	00:00:15	
		Display, infotainment	00:00:40	
		Cover, Steering column, upper	00:00:20	
		Instrument display	00:00:40	
		Glove box	00:00:50	
		Speaker, instrument panel, center	00:01:20	
		Steering wheel incl. Airbag	00:02:40	
		Storage box, center console	00:00:10	
		Sicherungskasten, Mittelkonsole	00:00:40	
		Instrument panel, cover, bottom	00:00:40	
		Instrument panel, cover side	00:00:20	
		Instrument panel	00:04:00	
		Wiring harness, instrument panel	00:03:30	2.795
		TOTAL	**0:17:40**	**2.795**
	Heater housing			
	Predecessor	Instrument panel	00:00:00	
		Crossbeam	00:05:00	
		Heater housing	00:01:30	
		Wiring harness, heater housing	00:00:20	67
		TOTAL	**00:06:50**	**67**
		SUM Instrument panel	**0:24:30**	**2.862**

			Net-Dismantling Time [h:min:sec]	Weight Wiring Harness [g]
Interior	**Interior**			
	Predecessor	B-pillar trim, lower	00:00:40	
		Sill finisher, inner	00:00:20	
		Rear seat	00:01:00	
		Seat, driver side	00:02:00	
		Seat, passenger side	00:02:00	
		Center console incl. predecessor	00:03:10	
		Carpet incl. isolation, interior	00:02:00	
		Wiring harness, interior	00:03:30	8.105
		TOTAL Wiring harness, interior	**0:14:40**	**8.105**
	Headliner			
	Predecessor	Sun shield incl. attachment	00:01:30	
		Handle, headliner	00:02:00	
		Lighting, headliner, front	00:00:20	
		Lighting, headliner, rear	00:00:20	
		Headliner	00:00:20	
		Wiring harness, headliner	00:00:20	188
		TOTAL wiring harness, headliner	**0:04:50**	**188**
		SUM Interior	**0:19:30**	**8.293**

			Net-Dismantling Time [h:min:sec]	Weight Wiring Harness [g]
Doors	**Door front**			
	Predecessor	Cover, door trim	00:00:20	
		Cover, door panel	00:00:10	
		Cover, door handle, lock cylinder	00:00:40	
		Door handle, outside	00:00:40	
		Door trim, front	00:02:40	
		Vapor barrier, door front	00:00:30	
		Lock cylinder, door inside, front	00:01:00	
		Door lock, door front	00:01:20	
		Wiring harness, door front	00:01:40	1.170
		TOTAL Wiring harness, door front	**0:09:00**	**1.170**
	Door rear			
	Predecessor	Cover, door trim	00:00:20	
		Cover, door panel	00:00:10	
		Cover, door handle, lock cylinder	00:00:40	
		Door handle, inside	00:00:40	
		Door trim, rear	00:02:40	
		Vapor barrier, door rear	00:00:30	
		Lock cylinder, door inside, rear	00:01:00	
		Door lock, door rear	00:01:20	
		Wiring harness, door rear	00:01:20	650
		TOTAL wiring harness, door rear	**0:08:40**	**650**
	Rearview mirror			
	Predecessor	Rearview mirror, complete	00:01:20	
		Mirror glass	00:00:20	
		Mirror unit, actuator	00:01:20	
		Cable set, rear view mirror	00:00:10	125
		TOTAL wiring harness, rear view mirror	**0:03:10**	**125**
		SUM Doors	**0:20:50**	**1.945**

			Net-Dismantling Time [h:min:sec]	**Weight Wiring Harness [g]**
Tailgate/ Rear	**Tailgate**			
	Pred.	Tailgate, cover	00:00:20	
		Wiring harness, tailgate	00:00:30	485
		TOTAL wiring harness, tailgate	**0:00:50**	**485**
	Starter battery			
	Predecessor	Trunk floor, carpet	00:00:10	
		Starter battery, mount	00:00:20	
		Starter battery	00:00:50	
		Starter battery, box	00:01:30	
		Wiring harness, starter battery, rear	00:00:30	995
		TOTAL Wiring harness, Starter battery	**0:03:20**	**995**
		SUM Tailgate/ Rear	**0:04:10**	**1.480**

			Net-Dismantling Time [h:min:sec]	Weight Wiring Harness [g]
Underbody	**Fuel tank**			
	Predecessor	Fuel tank, support strap	00:00:30	
		Heat shield, fuel tank	00:01:20	
		Fuel tank	00:01:30	
		Wiring harness, fuel tank	00:00:20	275
		TOTAL wiring harness, fuel tank	**00:03:40**	**275**
	Underbody			
	Pred.	Heat shield, rear	00:01:00	
		Wiring harness, battery, underbody	00:00:50	1.980
		TOTAL wiring harness, battery, underbody	**0:01:50**	**1.980**
		SUM Underbody	**0:05:30**	**2.255**

References

ACEA 2015 Presentation during the POP-RC11, 20th October 2015, Rome: Challenges for the automotive industry and possible solutions: POPs containing Spare parts under the Stockholm Convention

ADEME 2017 Annual Report End-of life vehicles 2015, France 2017

Alcock et al. 2009 Alcock R.E., McGillivray B.H., Busby J.S.: The measurement and management of decaBDE- Why the continued certainty of uncertainty? In: Martorell S., Guedes Soares C., Barnett J. (eds.): Safety, Reliability and Risk Analysis: Theory, Methods and Applications (S. 993 ff.), Taylor & Francis Group, London, 2009.

ARGUS 2016 Summary report on the implementation of the ELV Directive for the periods 2008-2011 and 2011-2014, ARGUS – Statistics and Information Systems in Environment and Public Health GmbH, Berlin, 07 November 2016

Portuguese Environment Agency (2017): QUALITY REPORT: Description of the data submitted according to Commission Decision 2005/293/EC on the monitoring of the reuse/recovery and reuse/recycling targets on ELV, September 2017

Ballesteros-Gomez et al. (2013): Ballesteros-Gómez A., de Boer J., Leonards P.E.G. (2013): Novel analytical methods for flame retardants and plasticizers based on gas chromatography, comprehensive two-dimensional gas chromatography, and direct probe coupled to atmospheric pressure chemical ionization-high resolution time-of-flight-mass spectrometry. Analytical Chemistry, 85

Basel Convention UNEP-Basel Convention on the control of transboundary movements of hazardous wastes and their disposal.

Bipro 2017 Bipro (2017): Consultancy service on collecting, summarising and analysing information on c-decaBDE in waste. Analysis of the information received by the Basel Convention related to c-decaBDE as called for in decision BC-12/3. Reference number: 2016/4072. Final Report. For: Norwegian Environment Agency.

Bipro 2015 Bipro (2015): Literature Study – decaBDE in waste streams. Reference number: 2015/10094. Final Report. For: Norwegian Environment Agency.

Bipro 2015b Bipro (2015): Identification of potentially POP-containing Wastes and Recyclates – Derivation of Limit Values. Project No. (FKZ) 3712 33 342. For: Federal Environment Agency (Germany).

BMRA 2013 British Metals Recycling Association (2013): BREF Style Report. Metal Fragmentising Operations. Industrial Emissions Directive. Project Reference 71983

BREF WT 2017	Best Available Techniques (BAT) Reference Document for Waste Treatment, Final Draft, October 2017, JRC Science for Policy Report.
Chen-S-J et al. 2010	Chen S.J., Ma Y.J., Wang J., Tian M., Luo X.J., Chen D., Mai B.X. (2010): Measurement and human exposure assessment of brominated flame retardants in household products from South China. Journal of Hazardous Materials, 176.
ELV Directive	Directive 2000/53/EC of the European Parliament and the Council of 18 September 2000 on end-of life vehicles (OJ L 269, 21.10.2000, p. 34)
ESWI 2011	ESWI (2011): Study on waste-related issues of newly listed POPs and candidate POPs. Final report, Consortium ESWI (Expert Team to Support Waste Implementation). Umweltbundesamt, Bipro & Enviroplan, 25 March 2001 (updated 13 April 2011).
EU POP-Regulation	Regulation (EC) No 850/2004 of the European Parliament and the Council of 29 April 2004 on persistent organic pollutants and amending Directive 79/117/EEC (OJ L 158, 30.4.2004, p. 7)
German Federal Ministry for the Environment 2017:	Annual report on end-of-life vehicle re-use/recycling/recovery rates in Germany for 2015
Goldmann 2007	Goldmann, D. „Erzeugung verwertbarer Stoffströme mit dem Volkswagen-SiCon-Verfahren“ in: Thomé-Kozmiensky et al. (ed.): „Produktverantwortung“, pp. 389-395 TK Verlag Karl Thomé-Kozmiensky, Neuruppin, 2007
Häkkinen 2012	Häkkinen E. (2012): Pysyviä orgaanisia yhdisteitä (POP) sisältävät jätteet ja niiden käsittelyä koskevat velvoitteet – Tukholman yleissopimuksen velvoitteiden kansallisen täytäntöönpanosuunnitelman 2012 taustaraportti. Finnish Environment Institute (SYKE), Centre for Sustainable Consumption and Production. 21 December 2012.
IVM, IVAM 2013	Institute for Environmental Studies (IVM) & IVAM, University of Amsterdam (2013): POP-BDE waste streams in the Netherlands: analysis and inventory. Report R13-16
Krinke et al. 2005	Krinke S., Boßdorf-Zimmer B., Goldmann D.: Ökobilanz Altfahrzeug-Recycling. Vergleich des VW-SiCon Verfahrens und der Demontage von Kunststoff-Bauteilen mit nachfolgender werkstofflicher Verwertung. Im Auftrag von: Volkswagen AG. Wolfsburg, 2005.
McKenna 2014	McKenna, L. (2014): Stacked field: The European Unions’s auto shredding capacity has grown significantly in recent decades, with more than 300 plants now in operation. Recycling today global edition September / October 2014
McKenna 2014b	Mc Kenna: European Auto Shredder List and Map- An interactive map of auto shredding plants in the 28 member states of the European Union plus Norway.

http://www.recyclingtoday.com/article/rtge0914-european-auto-shredders-map/ (07.03.2018)

Mehlhart 2017 Mehlhart, G.; Kosińska, I.; Baron, Y.; Hermann, A.: Support to Commission's Compliance Promotion Initiative to assess the Implementation of Directive 2000/53/EU on end-of life vehicles (the ELV Directive) with emphasis on the end-of-life vehicles with unknown whereabouts; Study commissioned by EC, DG Environment, December 2017, ISBN 978-92-79-81311-5

MEPEX 2012 Mepex Consult AS: Assessment of the need for new requirements for the environmentally sound treatment of end-of-life vehicles. 2012.

MinEnv. Finland 2016 Ministry of the Environment Finland (2016): Requirements for the management of waste containing persistent organic pollutants. Rules concerning waste in the POP Regulation and their application to waste electrical and electronic equipment and end-of-life vehicles. Unofficial translation, the original guideline has been published in Finnish.

Myllymaa et al. 2015 Myllymaa T. (ed.), Moliis K., Häkkinen E., Seppälä T. (2015): Occurrence, identification and separation of Persistent Organic Pollutants (POP) from plastic waste. Reports of the Ministry of the Environment 25/2015. Ministry of the Environment. Helsinki, 2015.

Niinipuu 2013 A comparative evaluation of brominated compounds in end-of-life vehicles. Polybrominated diphenyl ethers and polybrominated dibenzo-pdioxins and dibenzofurans in car seats. Master's thesis at the Department of Chemistry, Umeå University, Sweden

OSPAR (2009) OSPAR Background document on certain brominated flame retardants update 2009 Bo Nyström, Sweden; https://www.ospar.org/documents?d=7202

Polish Ministry of the Environment 2017: Report from Poland on the rates of reuse/recovery and reuse/recycling of end-of-life vehicles achieved in the period from 1 January 2015 to 31 December 2015, 2017

Regulation (EU) 2017/227 Commission Regulation (EU) 2017/227 of 9 February 2017 amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards bis(pentabromophenyl)ether.

Regulation (EC) No 1907/2006: Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC.

Swedish Chemicals Inspectorate (KemI) (2004): Dekabromdifenyleter (dekaBDE) - underlag till ett nationellt förbud, Rapport från ett regeringsuppdrag, Stockholm, November 2004 https://www.kemi.se/global/rapporter/2004/rapport-5-04.pdf

Stockholm Convention United Nations Environment Programme (UNEP): STOCKHOLM CONVENTION ON PERSISTENT ORGANIC POLLUTANTS (POPs).

tec4U Ingenieurgesellschaft mbH 2002: Beschreibung des Standes der Technik bei der Vorbehandlung, insbesondere der Trockenlegung von Altautos gemäß AltautoV, gefördert durch den Umweltforschungsplan des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit (FKZ) 200 33 323 (2002) Im Auftrag des Umweltbundesamtes

Terra SA - Deloitte - BioIS 2015: Evaluation Economique de la filiere de traitment des véhicules hors d’usage (VHU), Ademe 2015

US EPA 2017 Office of Chemical Safety andPollution Prevention: Preliminary Information on Manufacturing, Processing, Distribution, Use, and Disposal: decabromodiphenyl Ether, August 2017

VDEh 2014 Wirtschaftsvereinigung Stahl Stahlinstitut VDEh: Fakten zur Stahlindustrie in Deutschland. Düsseldorf, 2014. http://www.stahl-online.de/wp-content/uploads/2013/12/Fakten_Stahlindustrie_2014-04_6.pdf (07.03.2018)

Wilts et.al. 2014 Wilts H and von Gries N: Municipal Solid Waste Management Capacities in Europe – Desktop Study. European Topic Centre on Sustainable Consumption and Production (ETC/SCP), Copenhagen, Denmark, ETC/SCP working paper 8/2014.

WRc 2012 Peacock J., Turrell J., Lewin K., Glennie E. (2012): Analysis of Poly-Brominated Biphenyl Ethers (PBDEs) in Selected UK Waste Streams: PBDEs in waste electrical and electronic equipment (WEEE) and end of life vehicles (ELV). Final report for Defra, Report No.: UC8720.05

WRc addendum 2012 Peacock J., Turrell J., Lewin K., Glennie E. (2012): Analysis of Poly-Brominated Diphenyl Ethers (PBDEs) in UK Waste Streams: PBDEs in end of life vehicles (ELV) - Addendum to WRc Report

Abbreviations

ABS	Acrylnitril-butadien-styrol-copolymere
ACEA	European Automobile Manufacturers Association
ASR	Automotive shredder residue
ATF	Authorised treatment facility: a term introduced by the ELV Directive for treatment facilities appropriately equipped and maintaining the requirements to depollute and dismantle ELVs
BAT	Best available technology
BREF	Best available technique reference document
c-decaBDE	commercial decabromdiphenylether
COP	Conference of the parties
D10	Incineration on land: Disposal operation according to Waste Framework Directive, Annex 1:
EC	European Commission
ELV	End-of-life vehicle, as defined by the ELV Directive
EU POP Regulation	Regulation (EC) No 850/2004 on persistent organic pollutants (OJ L 158, 30.4.2004, p. 7)
EPDM	Ethylene propylene diene monomer
EVA	Ethylene-vinyl acetate
Fe	Ferrous metals
GADSL	Global Automotive Declarable Substance List
GLAPS	Global List of Automotive Process Substances
HIPS	High Impact Polystyrene
IDIS	International Dismantling Information System
IED	Industrial Emissions Directive (IED, 2010/75/EU)
IMDS	International Material Data System
ELoW	European List of Waste code
NF	Non-ferrous metals
OEM	Original Equipment Manufacturer
PA	Polyamide
PBB	Polybrominated biphenyls
PBT	Polybutylene terephthalate

PBDE	Polybrominated diphenyl ethers
PBDD/Fs	Polybrominated dibenzo-p-dioxins and dibenzofurans
PE	Polyethylene
PET	Polyethylene terephthalate
POP	Persistent organic pollutant
PP	Polypropylene
PST	Post shredder technologies
PUF	Polyurethane foam
PVC	Polyvinylchloride
R1, R3, R4, R11	Recycling operations according to Waste Framework Directive, Annex 2
SC	Stockholm Convention
SR	Shredder residues
SHF	Shredder heavy fraction
SLF	Shredder light fraction
VIN	Vehicle Identification Number