Guidance for the inventory of polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants

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unitar
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Abbreviations and acronyms

ABS	acrylonitrile-butadiene-styrene
ASR	automotive shredder residue
BAT/BEP	best available technologies/best environmental practices
BFR	brominated flame retardant
c-PentaBDE	commercial pentabromodiphenylether (TetraBDE and PentaBDE)
c-OctaBDE	commercial octabromodiphenyl ether (hexaBDE and heptaBDE)
COP	Conference of Parties
CRT	cathode ray tube
DecaBDE	decabromodiphenyl ether
DSI	detailed site investigation
EEE	electrical and electronic equipment
ELV	end-of-life vehicle
EMPA	Eidgenössische Materialprüfungs- und Forschungsanstalt
EPS	expanded polystyrene
ESM	environmentally sound management
EU	European Union
FEQGs	Federal Environmental Quality Guidelines (Canada)
GC/MS	gas chromatography/mass spectrometry
HBB	hexabromobiphenyl
HBCD	hexabromocyclododecane
HIPS	high impact polystyrene
HS	Harmonized Commodity Description and Coding Systems
LCD	liquid crystal display
MCV	maximum concentration value
NGOs	non-governmental organization
NIP	national implementation plan
IT	information technology
PBB	polybromobiphenyl
PBDE	polybrominated diphenyl ether
PBT	polybutylene terephthalate
PC	personal computer
POPs	persistent organic pollutants
POP-BDEs	persistent organic pollutants-polybrominated diphenyl ethers
PSI	preliminary site investigation
PUR	polyurethane
PVC	polyvinyl chloride
RoHS	Restriction of the use of certain hazardous substances in electrical and electronic equipment
SAICM	Strategic Approach to International Chemical Management
SC	Stockholm Convention
SCCP	short-chain chlorinated paraffins
TV	television
UK	United Kingdom
US	United States
WEEE	waste electrical and electronic equipment
XRF	X-ray fluorescence
XPS	extruded polystyrene

1 Introduction

In May 2009, the Conference of the Parties amended the Stockholm Convention on persistent organic pollutants (POPs) to add certain brominated flame retardants (BFRs) to Annex A:

- Hexabromobiphenyl (HBB) [1]
- Two polybrominated diphenyl ethers (collectively referred to as POP-PBDEs in this document):
    - Hexabromodiphenyl ether and heptabromodiphenyl ether
    - Tetrabromodiphenyl ether and pentabromodiphenyl ether

Like all POPs, these chemicals possess toxic properties, resist degradation, and bioaccumulate. They are transported through air, water and migratory species, across international boundaries and deposited far from their place of release, where they accumulate in terrestrial and aquatic ecosystems.

Parties to the Convention, for which the amendments have entered into force, have to meet the obligations under the Convention leading to the elimination of the listed BFRs. Due to the complexity and magnitude of usage of the POP-PBDEs, eliminating them represents a challenge for many Parties.

These chemicals have been widely used in many industrial sectors for the manufacture of a variety of products and articles, including consumer articles. For example, POP-PBDEs have been used in the electronics industry for the manufacture of plastic casings for computer equipment and in the transport industry for the manufacture of foam cushioning in automobiles.

1.1 Purpose of the guidance document

Under Article 7 of the Stockholm Convention, Parties are required to develop and endeavour to implement a plan for the implementation of their obligations under the Convention. This national implementation plan (NIP) has to be updated with information on how Parties, for which the amendments have entered in force, will address obligations arising from amendments to the Convention to list new chemicals, in accordance with decision SC-1/12 of the COP.

To develop effective strategies that can lead to the elimination of the listed BFRs, Parties need to acquire a sound understanding of their national situation concerning these chemicals. Such information can be obtained through an inventory of listed BFRs. The establishment of inventories is thus one of the main phases in the development of NIPs and is recommended as part of the elaborated process for reviewing and updating of NIPs, endorsed by the COP (decision SC-2/7).

The main purpose of this document is to provide technical guidance to Parties of the Convention on the establishment of inventories of the POP-PBDEs (and HBB) listed under the Convention in 2009. This document will be of use to national focal points for the Convention, the coordinator of the NIP review and update process, and task teams responsible for establishing the inventory. It will also be of interest to other stakeholders concerned with the elimination of POP-PBDEs and HBB.

1.2 Objectives of the inventory

The main objective of the inventory is to obtain information needed for the implementation of their obligations in the Stockholm Convention. More specifically, the objectives are to:

- Evaluate whether the current recycling of products and waste management meet the requirements of the Convention and identify areas where they do not.

[1] Since known production of HBB stopped in 1970s, the majority of products and articles that contain HBB were disposed of decades ago. As a result, the scope of the HBB inventory in many countries may be limited.

- Provide the basis for development of a strategy in the NIP (i.e. identify the economic sectors that should be prioritized and the type of actions required for those sectors).
- Report to the COP of the Convention on progress made to eliminate POP-PBDEs.
- Identify areas where financial or technical support are needed (when resources are limited, to fill the gaps in the inventory/fulfill the obligations of the Convention).

The information obtained about POP-PBDEs through the inventory includes the following:

- Past and current uses/production of POP-PBDEs at the national level
- Presence of products and articles containing POP-PBDEs on the consumer market
- Flows into a country of products and articles containing POP-PBDEs
- Presence of products and articles containing POP-PBDEs in the recycling streams
- Disposal practices for products and articles containing POP-PBDEs when they become wastes
- Any chemical stockpiles
- Potential contaminated sites

Collected information on the above will provide broader understanding of the sources of POP-PBDEs, the scope of their impact and the risks that they pose to human health and the environment in a country. The information is important for Parties to evaluate whether they comply with obligations under the Convention regarding POP-PBDEs and identify areas where they need to develop effective strategies and action plans for managing POP-PBDEs in order to meet the obligations. Information collected as part of the inventory will also provide a valuable basis for Parties to report to the COP on measures taken to implement the provisions of the Convention and the effectiveness of such measures.

The inventory process is usually iterative. In establishing the inventory of POP-PBDEs for the first time, Parties will also identify resources and technical capacity needed to further improve the accuracy of the inventory.

1.3 Structure of the guidance

The guidance is divided into seven chapters.

Chapter 1 outlines the purpose of the guidance and the major objectives for undertaking an inventory.

Chapter 2 provides necessary background information on the POP-PBDEs and HBB for undertaking the inventory.

Chapter 3 outlines the five main steps involved in conducting a general inventory of POP-PBDEs. It also provides an overview of considerations that are important for planning the inventory and defining its scope.

Chapters 4 and 5 contain specific guidance for the two main sectors of concern for the inventory of POP-PBDEs: electrical and electronic equipment (EEE) and related waste (WEEE), and the transport sectors. These are the sectors in which POP-PBDEs have been predominantly used and that are likely to be relevant for many countries.

Chapter 6 provides background information on minor applications of POP-PBDEs that may be relevant for certain countries.

Chapter 7 provides guidance on how to investigate whether the locations with previous activities related to POP-PBDEs are potentially contaminated.

The key design and content features of this guidance are:

Step by step approach: The guidance is designed to provide a clear step-by-step approach that can be followed and implemented by a wide variety of users. A five-step approach is provided for the overall inventory from the planning stage to preparation of the inventory report (also see chapter 3). More detailed and specific guidance on stakeholders, data collection etc. for key sectors can be found in chapters 4 to 7.

Questionnaires and reporting format: Additional information, such as the listing of POP-PBDEs, questionnaire, quality guidelines, are provided in annexes 1 to 6.

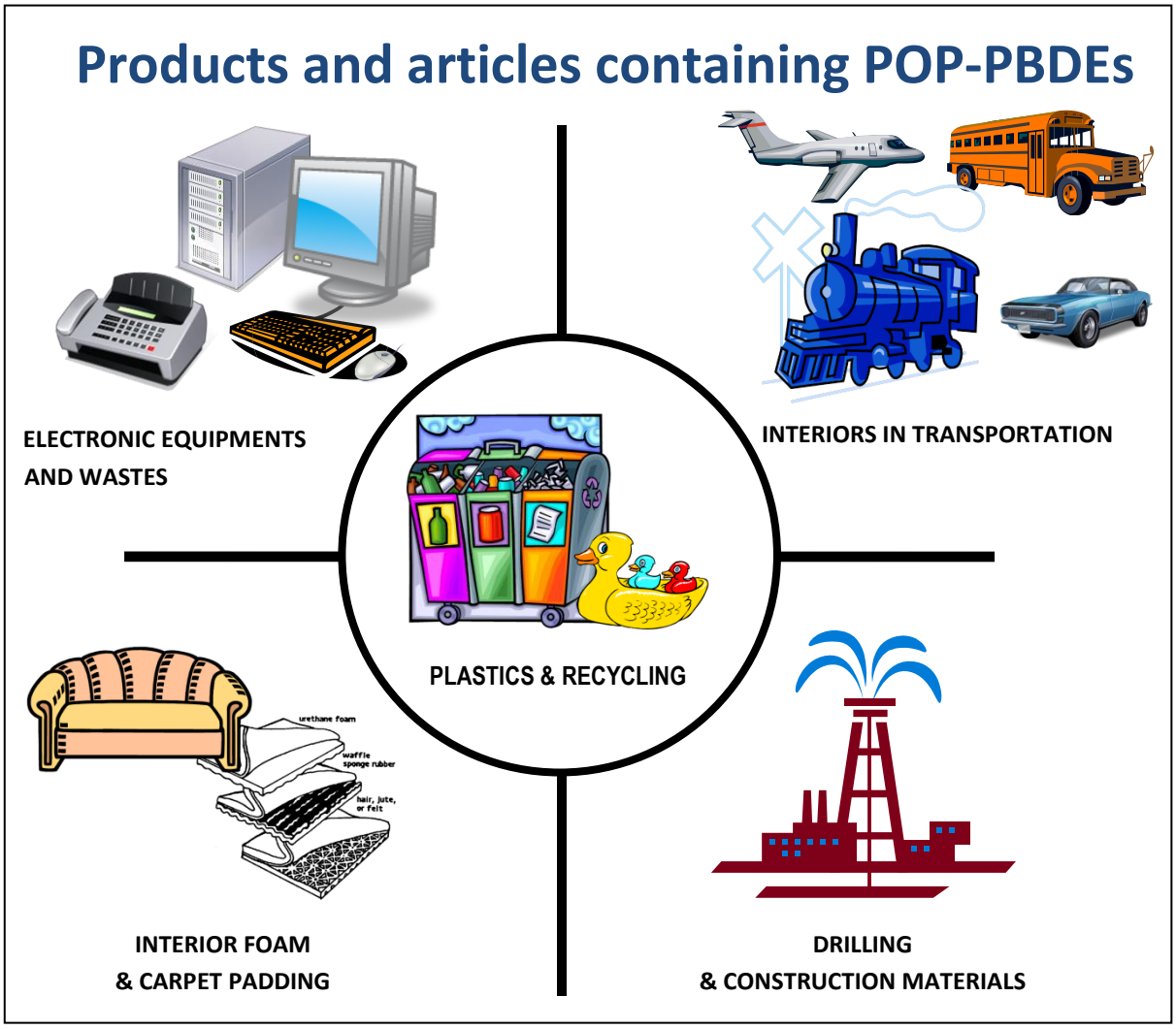

Figure 1-1: Products and articles containing POP-PBDEs

2 Background information on c-PentaBDE, c-OctaBDE and HBB

Commercial PentaBDE (c-PentaBDE), the homologues "tetrabromodiphenyl ether and pentabromodiphenyl ether"[2] as well as c-OctaBDE, "hexabromodiphenyl ether and heptabromodiphenyl ether"[3] are listed under the Stockholm Convention.

TetraBDE, pentaBDE, hexaBDE and heptaBDE are listed in Annex A of the Convention, and their production and use have to be eliminated by Parties subject to the exemptions allowed by the Convention. These listed POPs are referred to in this document as POP-PBDEs.

Hexabromobiphenyl (HBB) is listed in Annex A of the Convention. There is no specific exemption for its production or uses.

2.1 POP-PBDEs and HBB in the Convention

Polybrominated diphenyl ethers (PBDEs; figure 2-1) are a group of industrial aromatic organobromine chemicals that have been used since the 1970s as additive flame retardants in a wide range of - mainly - consumer products. PBDEs were produced with three different degrees of bromination, and marketed as c-PentaBDE, c-OctaBDE and commercial DecaBDE (c-DecaBDE) (Alaee et al., 2003; Prevedouros et al., 2004; SFT, 2009). Typical homologue distributions of c-PentaBDE and c-OctaBDE are shown in tables 2-1 and 2-2. Although c-DecaBDE[4] has not been found to contain POP-PBDEs, it can form POP-PBDEs by debromination during its life cycle, thus representing an important reservoir of POP-PBDEs (UNEP, 2010c; Ross et al., 2009).

The octaBDE, nonaBDE, and decaBDE homologues present in the mixture are not listed. These highly brominated PBDEs, however, can be degraded to POP-PBDEs by debromination (UNEP, 2010b, 2010c).

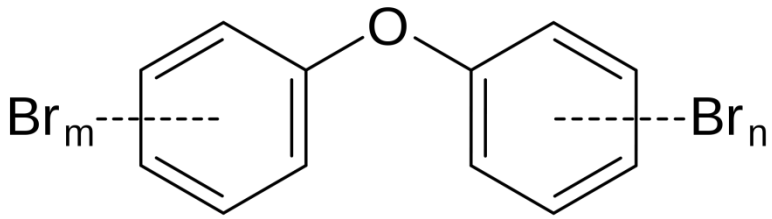

Figure 2-1: Structure of polybrominated diphenyl ethers (PBDEs)

[2] With the main congeners 2,2',4,4'- tetrabromodiphenyl ether (BDE-47 CAS No. 40088-47-9) and 2,2',4,4',5-pentabromodiphenyl ether (BDE-99 CAS No. 32534-81-9) and other tetra and pentabromodiphenyl ethers present in commercial pentabromodiphenyl ether.

[3] With the main congeners 2,2',4,4',5,5'-hexabromodiphenyl ether (BDE-153, CAS No: 68631-49-2), 2,2',4,4',5,6'-hexabromodiphenyl ether (BDE-154, CAS No: 207122-15-4), 2,2',3,3',4,5',6-heptabromodiphenyl ether (BDE-175, CAS No: 446255-22-7), 2,2',3,4,4',5',6-heptabromodiphenyl ether (BDE-183, CAS No: 207122-16-5) and other hexa- and heptabromodiphenyl ethers.

[4] DecaBDE can degrade in thermal processes, environment processes and in biota to lower brominated PBDEs including POPPBDEs (UNEP, 2010c). Other key degradation products are polybrominated dibenzofurans and, depending on conditions, polybrominated dibenzo-*p*-dioxins (Weber and Kuch, 2003; Ebert and Bahadir, 2003).

Table 2-1: Composition of c-PentaBDE*

(derived from La Guardia et al., 2006; SFT, 2009; Schlummer et al., 2011)

Categories of PBDE	Tribromodi-phenyl ethers		Tetrabromodi-phenyl ethers	Pentabromodi-phenyl ethers		Hexabromodi-phenyl ethers		Heptabromodi-phenyl ethers
Congener	BDE-17	BDE-28	BDE-47	BDE-99	BDE-100/85	BDE-153	BDE-154	BDE-183
Content	Traces	Traces	Major	Major	Minor	Minor	Traces	Traces
Distribution for calculations*	0.5%**		**33%*****	**58%*****		**8%*****		**0.5%*****

*The homologue distribution in commercial PBDE has a variation depending on producer or production lot. For inventory purposes, a distribution considered as an average distribution of PBDE homologues in products was chosen.

**TriBDE is not listed as a POP and therefore does not need to be included in the inventory.

***The percentage of the PBDE homologues that are POP-PBDEs.

Table 2-2: Composition of c-OctaBDE*

(derived from La Guardia, 2006; SFT, 2009; Schlummer 2011)

Categories of PBDE	Hexabromo-diphenyl ethers		Heptabromodipheny l ethers			Octabromodiphenyl ethers			Nonabromodi -phenyl ethers		Decabromodi - phenyl ethers
Congener	BDE-154	BDE-153	BDE-183	BDE-180	BDE-171	BDE-197	BDE-203	BDE-196	BDE-206	BDE-207	BDE-209
Content	Traces	Minor	Major	Traces	Traces	Major	Minor	Minor	Minor	Minor	Traces
Distribution for calculations *	**11%*****		**43%*****			35%**			10% **		1%**

*The homologue distribution in commercial PBDE has a variation depending on producer or production lot. For inventory purposes a distribution considered as an average distribution of PBDE homologues in products was chosen.
**OctaBDE, nonaBDE and decaBDE are not listed as POPs and therefore do not need to be included in the inventory.
***The percentage of the PBDE homologues that are POP-PBDEs.

Hexabromobiphenyl (HBB) is listed in Annex A. The major congeners of commercial HBB (FireMaster FF-1) were largely 2,2',4,4',5,5'-hexabromobiphenyl (PBB 153), accounting for 50-60% of the total mass, followed by 2,2',3,4,4',5,5'-heptabromobiphenyl (PBB 180; 10-15%), and 2,2',3,4,4',5'-hexabromobiphenyl (PBB 138; 5-10%) (Pijnenburg et al., 1995).

2.2 Production of commercial PBDE mixtures and HBB

C-PentaBDE was produced in Israel, Japan, the United States and the European Union (EU), and possibly China (UNEP, 2006a, 2010b). Production in the EU ceased in 1997. It is assumed that since

the late 1990s POP-PBDEs were mainly produced in the United States and production ended in 2004.[5]

C-OctaBDE was produced in the Netherlands, France, the United States, Japan, United Kingdom and Israel. Production stopped in the EU, United States and the Pacific Rim in 2004, and there is no information indicating that it is being produced in developing countries (Annex 3; BSEF 2007).

The compilation of PBDE production data prepared for the POPs Reviewing Committee (POPRC) of the Stockholm Convention estimated the total production of all PBDEs from 1970 to 2005 as between 1.3 million and 1.5 million tonnes (UNEP, 2010a). The total amounts of c-PentaBDE and c-OctaBDE used in the world were estimated at around 100,000 tonnes each. The production of c-DecaBDE,[6] which is not listed, was estimated at over 1.1 million tonnes until 2005 (see table 2-3). While the production of POPs c-PentaBDE and c-OctaBDE ended in 2004, the production of DecaBDE continues.

Table 2-3: Estimated total production of PBDE commercial mixtures, 1970-2005

Commercial mixture	Tonnes
c-PentaBDE	91,000 to 105,000
c-OctaBDE	102,700 to 118,500
c-DecaBDE	1,100,000 to 1,250,000

Source: UNEP, 2010a; derived from Schenker et al., 2008 and Li et al., 2010

Approximately 5,400 tonnes of HBB were produced in the US from 1970 to 1976. Available information suggests that production and use of HBB ceased in most, if not all, countries in the 1970s. It is possible, however, that HBB is still being produced in developing countries or in countries with economies in transition.

2.3 Former uses of POP-PBDEs

The main manufacturing sectors that have used POP-PBDEs are as follows:

- Organobromine industry;
- Electrical and electronics industry;
- Transport industry;
- Furniture industry;
- Textiles and carpet industry;
- Construction industry;
- Recycling industry;

2.3.1 Former uses of c-PentaBDE

It is considered that between 90% and 95% of the use of c-PentaBDE was for the treatment of polyurethane (PUR) foam. These foams were mainly used in automotive and upholstery applications. Minor uses included textiles, printed circuit boards, insulation foam, cable sheets, conveyer belts, lacquers and possibly drilling oils (UNEP, 2007). The total amount of c-PentaBDE used for these minor uses is estimated to account for 5% or less of the total usage (SFT, 2009; UNEP, 2010b). Alcock et al. (2003) estimated that 85,000 tonnes of c-PentaBDE were used overall

[5] Some uncertainty exists about the c-PentaBDE production in China and when this production ended (UNEP ,2010a, 2010b).

[6] DecaBDE is degraded over time to the lower brominated PBDEs including POP-PBDEs (UNEP, 2010b, 2010c).

in the United States and the remaining 15,000 tonnes in Europe. There may have been production and use in Asia but reliable data are not available.

An approximate distribution of global c-PentaBDE use of 36% in transport, 60% in furniture and a 4% residual in other articles is considered to be reasonable and is generally consistent with the analytical data for different waste streams (UNEP, 2010b). Table 2-4 summarizes the former uses of c-PentaBDE in various materials and applications.

Table 2-4: Former uses of c-PentaPBDE in polymers/resins, the applications and articles

Materials/polymers/resins	Applications	Articles
Polyurethane (PUR)	Cushioning materials, packaging, padding, construction	Furniture, transportation, sound insulation, packaging, padding panels, rigid PUR foam construction
Textiles	Coatings	Back coatings and impregnation for carpets, automotive seating, furniture in homes and official buildings, aircraft, underground
Epoxy resins	Circuit boards, protective coatings	Computers, ship interiors, electronic parts
Rubber	Transportation	Conveyor belts, foamed pipes for insulation
Polyvinylchloride (PVC)	Cable sheets	Wires, cables, floor mats, industrial sheets
Unsaturated (Thermoset) polyesters (UPE)	Circuit boards, coatings	Electrical equipment, coatings for chemical processing plants mouldings, military and marine applications: construction panels
Paints/lacquers	Coatings	Marine and industry lacquers for protection of containers
Hydraulic oils	Drilling oils, hydraulic fluids	Off shore, coal mining

Source: UNEP 2009

The average content of c-PentaBDE in PUR foam is reported to be around 3-5% (wt %) for upholstery, cushions, mattresses, and carpet padding (ENVIRON, 2003; UNEP, 2010a; see table 2-5) used in particular in countries with flammability standards for these applications (e.g. United States, United Kingdom). PUR foam in the transport sector might have been used in lower concentrations for applications like seats or arms/head rests at 0.5-1 wt % (Ludeka, 2011). Considering the approximately 100,000 tonnes of c-PentaBDE and a use of 4% in PUR foam, the historic production of c-PentaBDE treated foam can be conservatively estimated to be approximately 2.5 million tonnes. This number might have been significantly higher considering that a major application (PUR foam in transport in the United States) used c-PentaBDE at a lower level. Furthermore, recycling of contaminated PUR foam mixed together with non-impacted PUR foam led to increased total quantities of POP-PBDEs-contaminated PUR foam materials.

Table 2-5: Usage of pentaPBDE in PUR foam

PUR foam density/use area	PentaBDE in Polymer (wt %)
[a]19 kg/m^3	5.45
[a]24 kg/m^3	4.30
[a]29 kg/m^3	2.77
[b]PUR foam in (US) transport (seating, head/arm rest)	0.5-1
[b]olded carpet padding	2-5
[b]lamination to headliner fabric	Up to 15

Source: [a]Cambell, 2010; [b]Ludeka, 2011

2.3.2 Former uses of c-OctaBDE

The main former use of c-OctaBDE was in acrylonitrile-butadiene-styrene (ABS) polymers, accounting for about 95% of c-OctaBDE supplied in the EU. The treated ABS was mainly used for housings/casings of electrical and electronic equipment (EEE), particularly for cathode ray tube (CRT) housings and office equipment such as copying machines and business printers.[7] Other minor uses were high impact polystyrene (HIPS), polybutylene terephthalate (PBT), and polyamide polymers. Although the majority of these polymers were used in electronics, there was also some use in the transport sector.

Other minor uses found in literature include nylon, low density polyethylene, polycarbonate, phenolformaldehyde resins, unsaturated polyesters, adhesives and coatings (UNEP, 2010a, 2010b). Table 2-6 summarizes the former uses of c-OctaBDE in various materials and applications.

Typical concentrations in the major applications were between 12 wt % and 18 wt %, with approximately 100,000 tonnes of c-OctaBDE at an application rate of 15 wt %. The primary treated polymers can be estimated at approximately 800,000 tonnes. Considering the recycling of c-OctaBDE in new plastic products (secondary contamination), the total quantity of impacted plastics is likely to be considerably higher than this.

Table 2-6: Former uses of c-OctaBDE in polymers/materials, the applications and products (ESWI 2011)

Polymers/materials	Application	Articles
Acrylnitrile-Butadiene-Styrene (ABS)	Polymer casings/parts in electric and electronic appliances	Computer- and TV casings (CRTs); office equipment; (other electronic equipment)
High Impact Polystyrene (HIPS)	Polymer casings/parts in electric and electronic appliances	Computer- and TV casings (CRTs); office equipment
	Cold-resistant layer	Refrigerator
Polybutylen-Terephtalate (PBT)	Polymer casings	Electronic appliances
	Transport sector	Connectors in vehicles
	Household	Iron
Polyamide-Polymers	Textiles	Furniture
	Construction	Pipes and plastic foil

[7] In some regions such as Europe and Japan, CRT monitor housing and copying machines are already normally treated separately.

2.4 Former uses of HBB

HBB was used as a flame retardant in three main commercial products (Neufeld et al., 1977; IPCS, 1994; ATSDR, 2004):

- ABS thermoplastics (plastic for constructing business machine housings and in industrial (e.g. motor housing) and electrical (e. g. radio and TV parts) sectors);
- PUR foam for automotive upholstery;
- Coatings and lacquers;

Due to the small production and limited use, it is likely that most HBB-containing materials were disposed of decades ago. Hence, the chemical is of minor relevance for the inventory process in many countries.[8] Levels in food (e.g. in European countries that used HBB to some extent in the past) were mostly below detection levels (EFSA, 2010). HBB and HBB-containing articles are not further mentioned in this guidance document because the use area of HBB, and thus the inventory approach, is identical to that of POP-PBDEs.

2.5 POP-PBDEs in material/recycling flows and at end-of-life

Even though POP-PBDEs are considered to be no longer produced, the main challenge for their elimination is the identification of existing stockpiles and articles containing POP-PBDEs and their disposal at end-of-life.

Large volumes of these materials are in the global recycling flow and will continue to be used in consumer articles (UNEP, 2010a, 2010b; Shaw et al., 2010). The existing reuse and recycling of materials and wastes containing POP-PBDEs were the trigger for the COP4 specific exemption that allows recycle and reuse under certain conditions. This is addressed in the *Guidance on Best Available Techniques and Best Available Practices for the Recycling and Disposal of Articles Containing Polybrominated Diphenyl Ethers (PBDEs) Under the Stockholm Convention on Persistent Organic Pollutants (PBDE BAT/BEP Guidance*; Secretariat of the Stockholm Convention, 2012).

2.5.1 C-PentaBDE in reuse, recycling and waste flows

The main uses of c-PentaBDE were in PUR foam used in the transport sector (e.g. cars, buses, trains etc.) and furniture (e.g. couches, seats, cushions etc.), with limited use in mattresses and some other uses. Therefore, the reuse and recycling of these major material flows need to be addressed in the inventory. Other applications with former minor uses (e.g. insulation in construction, treated rubber, textiles, polyvinylchloride (PVC), epoxy resins in printed circuit/wiring board, etc.; see table 2-4) might only be assessed if they appear relevant in a country. The major use and recycling flows of materials containing c-PentaBDE are shown in figure 2-2.

[8] A good indicator for the relevance of HBB in a country is the level in human milk, which is monitored in the frame of the Global Monitoring Project by the World Health Organization (WHO) and UNEP.

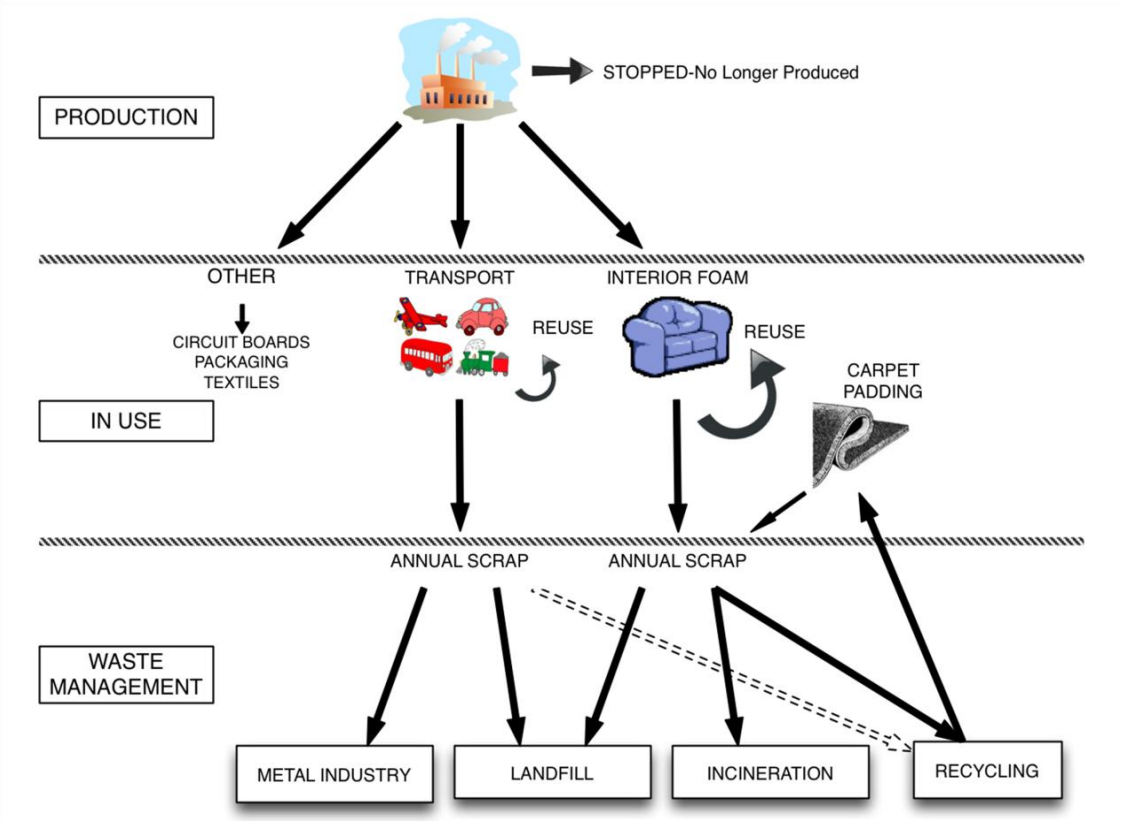

Figure 2-2: Schematic diagram of the life cycle of c-PentaBDE (Adapted from Alcock et al., 2003; UNEP, 2010a, 2010b)

Transport

The lifespan for cars in industrial countries is 10 to 12 years, while buses and trains might have a longer life expectancy. A considerable share of cars and other transport has been and is still being exported from industrial countries to developing countries and countries with economies in transition where the vehicles are often used for a long time before they finally break down (spare parts are also used further) (UNEP, 2010a, 2010b). Therefore, today a large share of the transport fleet from 1970 to 2004[9] (cars, buses and possibly trains) containing c-PentaBDE is still in operation today, likely in developing countries, and will need to be identified in respect to reuse and recycling when these vehicles reach end-of-life. It is therefore reasonable to assume that the transport sector (cars, trucks, buses, trains, ship, and planes) is the largest stockpile for c-PentaBDE in developing countries. The inventory of POP-PBDEs in the transport sector is addressed in chapter 5.

Furniture and mattresses

The use of c-PentaBDE (and other flame retardants) in furniture or mattresses depends on the flammability standards of a country (Shaw et al., 2010). Due to flammability standards for furniture in the United States and United Kingdom, in particular, furniture in North America and the United Kingdom is often flame retarded. Therefore, old furniture and mattresses (in particular from

[9] It is important to note, however, that dust samples from automobiles made in or after 2004 showed measurable levels of BDE-47 and BDE-99 with highest levels from cars manufactured in the United States (Lagalante et al., 2009). This might be a consequence of the use of rebond from recycled PUR foam containing c-PentaBDE in new cars. It may also be partly due to the debromination of c-DecaBDE (Lagalante et al., 2011). Other flame retardants are now used in the transport sector including e.g. HBCD in textile back-coating. HBDD is proposed for listing as a POP at COP6 in 2013.

institutions like prisons, military facilities, hospitals or hotels) in these regions/countries may contain c-PentaBDE (and other flame retardants).

The lifespan of furniture in industrial countries is estimated at about 10 years. Therefore it is estimated that a considerable share of furniture containing c-PentaBDE in these regions has been deposited or incinerated (ESWI, 2011) with a minor share recycled e.g. in carpet rebond (see below). The extent of furniture exported from North America and the United Kingdom for reuse and recycling to other regions has not been assessed and needs to be considered as a possible source for c-PentaBDE input for other countries.

C-PentaBDE was also used in rigid PUR foam in construction, but this is considered a minor use. Further recycling activities of rigid PUR foam are not known. Inventory considerations for POP-PBDEs in furniture and mattresses are discussed in chapter 6.

Textiles and rubber

C-PentaBDE has been used[10] in limited quantities for the treatment of textiles for uses including back-coating, for curtains and for functional textiles (UNEP, 2009). Although the extent of recycling of POP-PBDEs-containing textiles is unclear, it can reasonably be assumed to be small for composite materials such as those used in transport. There may be some limited recycling of other c-PentaBDE-containing textiles but it is likely that only relatively small quantities of POP-PBDEs-containing textiles are in use as the application of c-PentaBDE stopped about a decade ago. The POPRC decision to recommend hexabromocyclododecane (HBCD), for which the textile sector is a major application, to the Conference of Parties for listing as a POP might imply that the management of textiles treated with BFRs with POPs-like properties could become more relevant in the near future. C-PentaBDE has also been used in rubber for conveyor belts and other minor uses (see chapter 6).

Printed circuit/wiring boards

The use of c-PentaBDE in printed circuit/wiring boards (PWBs) has been phased out.[11] PWBs are a component of WEEE that end up in certain developing countries, where the metals are recovered using primitive methods in the informal sector, or by simple smelters. This can be the source of certain levels of POP-PBDEs and PBDD/PBDF (see e.g. Yu et al., 2008). The inventory of PWBs in the country needs to be carried out in relation to the POP-PBDEs inventory.

Recycling of PUR foam to new articles

PUR foams in furniture, transport, end-of-life vehicles and mattresses are partly recycled into new articles by processes such as carpet rebond and regrinding. The resulting new articles need to be captured by the inventory.

Carpet rebond

Large-scale recycling of PUR foam into carpet padding/rebond is currently practised in the United States and Canada (Ludeka, 2011; see chapter 6 of the *PBDE BAT/BEP Guidance*). The extent of this recycling activity in other regions is unknown but appears to be limited (DiGangi et al., 2011). Relevant exposure of PUR recyclers and carpet installers to POP-PBDEs has been demonstrated in a first study in the United States (Stapleton et al., 2008), and there are obvious risks of further exposure of consumers.

[10] DecaBDE and HBCD are still used in the impregnation of textiles.

[11] The main flame retardant use in PWB is tetrabromobishenol A and its derivatives.

Other uses

While the majority of PUR foam scraps is processed into carpet rebond (in the US market), scrap can also be shredded and used as packaging and stuffing for pillows, pet bedding, insulation and staffed toys. Foam scraps might also be used for some furniture cushioning, sound insulation, gymnastic mats, or school bus seats (UNEP, 2010b; USEPA, 1996; Zia et al., 2007).

Re-grinding

Eaves (2004) noted that this innovative process allowed manufacturers to non-cryogenically grind foam scraps into ultrafine powders that displaced approximately 20% of the virgin material in the manufacture of new foams.

2.5.2 C-OctaBDEs in reuse, recycling and waste flows

Europe and Japan stopped the use of c-OctaBDE in the 1990s. The production of c-OctaBDE in the United States stopped in 2004. The largest c-OctaBDE content is found in polymers (in particular ABS and HIPS) that are used in EEE and WEEE. The use of c-OctaBDE in polymers in the transport sector was limited. Figure 2-3 shows the life cycle of c-OctaBDE.

EEE in use, second-hand EEE and WEEE electronic waste:

Electronics produced before 2005 may be flame retarded with c-OctaBDE. The main appliances are televisions and computer CRT monitors. Large quantities of old EEE and WEEE were - and in some cases still are - exported from industrial countries/regions (e.g. United States, Europe and Japan) to developing countries for reuse or recycling. Primitive recycling technologies for WEEE have resulted in large contaminated areas in developing countries and exposure of recyclers and the general population (Wong et al., 2007; UNEP, 2010a, 2010b).

Plastics from WEEE recycling and production of articles from recycled plastic

The mechanical recycling of plastic for further use is strongly favoured from a waste hierarchy and life cycle assessment perspective. When plastics are contaminated with POPs and other hazardous materials, however, particular care has to be given to how the waste hierarchy is followed. The recycling of WEEE results in a fraction of flame-retarded plastic, possibly containing POP-PBDEs. Some plastic from WEEE is sent to developing countries such as China and India where it is recycled into new articles. Recent studies have shown that plastics containing POP-PBDEs and other BFRs have been recycled in the production of articles for which no flame retardancy is required including children's toys, household goods and video tapes (Hirai & Sakai, 2007; Chen et al., 2009; Chen et al., 2010). This shows that the flow of plastics containing POP-PBDEs and other flame retardants for recycling are not well controlled and that plastics containing POP-PBDEs are being mixed with non-flame retarded polymers for the production of items with sensitive end uses. Therefore, in some cases, the use of recycled plastic may be significantly more hazardous than the original use (recycling from a printer housing into a toy that may be chewed by a child, for example).

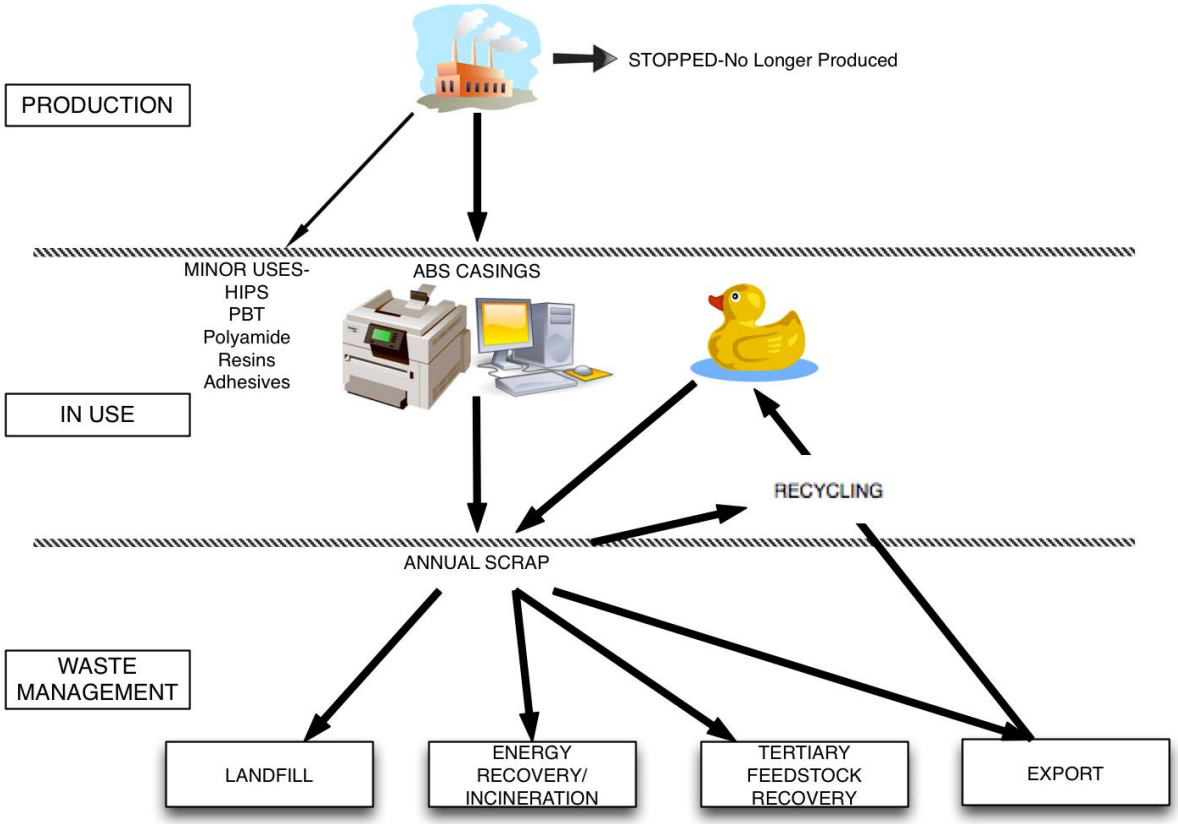

Figure 2-*3*: Schematic diagram of the life cycle of c-OctaPBDE and potential for emissions (adapted from Alcock et al., 2003)

2.6 Potential contaminated sites

All sites where POP-PBDEs have been used, for any of the activities outlined in figures 2-2 and 2-3, could be potentially contaminated with POP-PBDEs. Landfills are the ultimate destination of many POP-PBDEs-containing materials due to their widespread application in a multitude of consumer and industrial goods. POP-PBDEs can be leached from refuse by landfill leachate.

Users of this guidance document can utilize the information provided in chapters 3 to 6, while also examining general and hazardous solid waste practice in their countries, to carry out the contaminated site inventory. Landfills and dumpsites that are scattered all over the major cities may be potentially contaminated with POP-PBDEs. The inventory will identify all the sectors involved, manufacturing locations and locations of storage, wastes being disposed, biosolids application, methods of waste disposal or treatment, and waste disposal locations.

POP-PBDEs are precursors of brominated dibenzofurans (PBDF) and dibenzo-p-dioxins (PBDD). They are largely formed during primitive recycling of e-waste and incineration of POP-PBDEs-containing materials (UNEP, 2010b). The locations of these activities should also be identified. In addition, biosolids from wastewater treatment plants are known to contain POP-PBDEs, which were disposed in landfills and applied in agricultural lands.

3 How to conduct a POP-PBDEs inventory

This chapter outlines five broad steps for planning and carrying out a national POP-PBDEs inventory. The national focal point of the Stockholm Convention or national project coordinator could be responsible for initiating the inventory process. The existing Steering Committee on POPs that was formed for the original NIP development could be re-established for updating the NIP and involved in the planning of the inventory.

Figure 3-1 provides an overview of the inventory process.

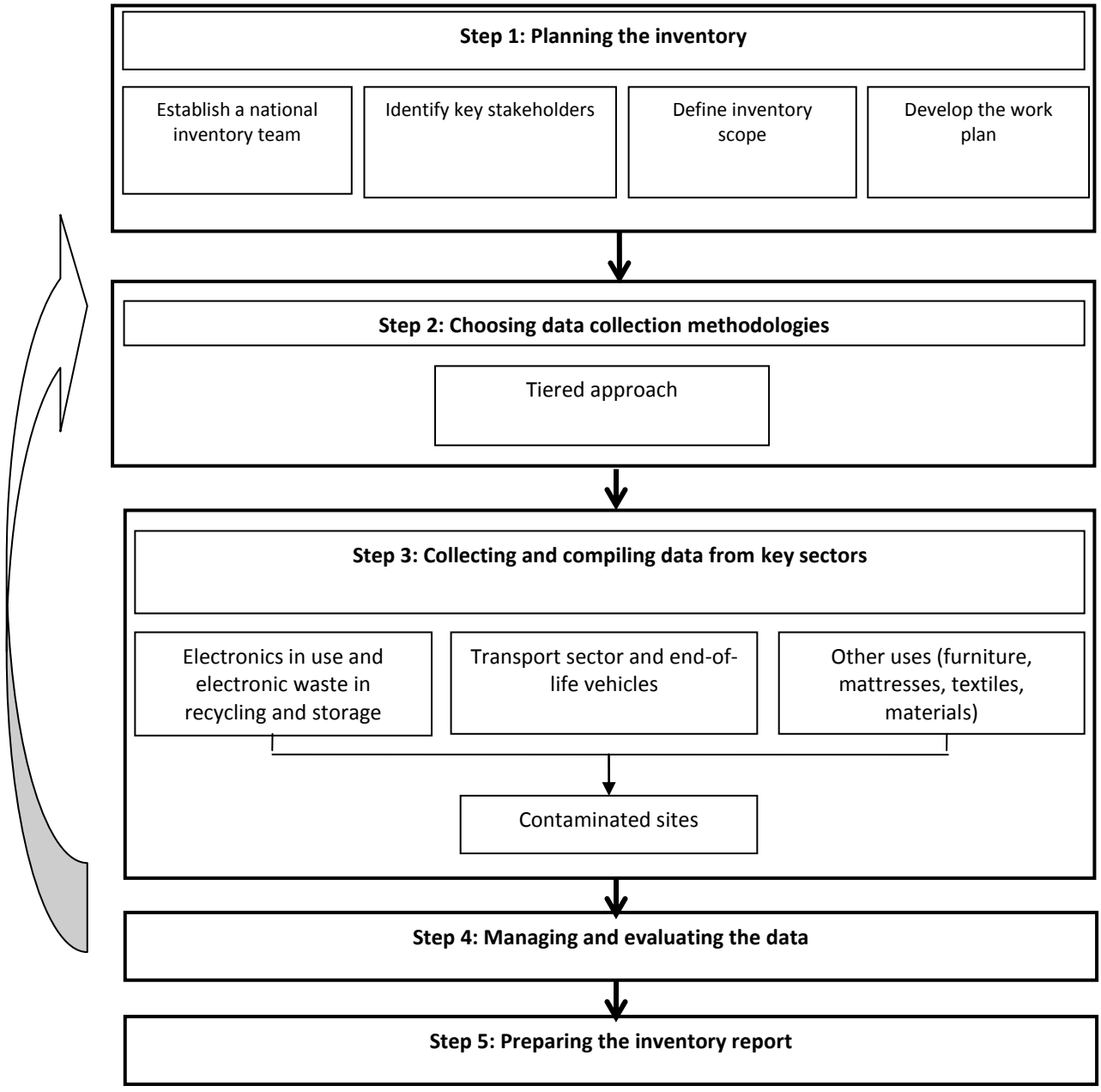

Figure 3-1*:* Overview of the national POP-PBDEs inventory development process.

The inventory process is not intended to be conducted in an entirely linear fashion. The inventory team may need to repeat activities in earlier steps depending how the inventory proceeds and which sectors are involved. For example, although the identification of stakeholders is shown in step 1 (figure 3-1), there may also be a need to identify further stakeholders at different points during data collection in step 3).The arrow going from step 4 (Managing and evaluating the data)

back to step 2 (Choosing data collection methodologies) in figure 3-1 indicates that steps 2 to 4 can be repeated until the data quality and coverage of the inventory reach a satisfactory level. The inventory team will decide on the complexity of the methodology appropriate for their particular situations, taking into account their financial and technical capacities. For many countries, it could be evident at the beginning of the process that the higher tier approaches requiring complex analyses (see section 3.2) would be out of reach. Others could decide after evaluating the results of the initial inventory to undertake more in-depth data collection (move to a higher tier) in the future, and even include such activities as an action plan in their NIP.

3.1 Step 1: Planning the inventory

The first issue to consider in developing a national inventory is to define the scope of the inventory and target the national relevant sectors for POP-PBDEs. The development of a national inventory of products and articles requires cooperation with the relevant authority in charge of manufacturers of consumer products, suppliers, retailers and the customs service, as well as other relevant authorities and organizations. It is important to clearly define the responsibility for developing the inventory. Parties that have no regulations on POP-PBDEs and have to do a full inventory are advised to establish a multi-stakeholder national inventory team.

3.1.1 Establish a national inventory team

The national focal point of the Stockholm Convention could establish and/or lead a multi-stakeholder national inventory team to acquire the necessary competences and access to relevant inventory information. This team would comprise government ministries with a mandate for chemicals and waste management, the national customs service, the private sector, non-governmental organizations (NGOs), and academics and researchers from universities and research institutes working on old and new POPs, waste management and possibly material flows. among others. National POP or waste management consultants and material flow experts, knowledgeable in these issues, could also be hired to facilitate the work of the team.

The national focal point and/or the consultants would brief and educate the team on the Stockholm Convention's mandates, obligations and the new POPs.

3.1.2 Identify key stakeholders

The first meeting of the national inventory team provides the opportunity to determine the available information in various stakeholder organizations and to brainstorm on how to best proceed with the inventory exercise. As the process of identifying articles containing POP-PBDEs is complex, it is important to identify further stakeholders (using the background information provided in chapter 2).

The inventory development requires cooperation between relevant government authorities and official agencies, producers, importers and distributors, manufacturers, fabricators, community-based organizations and NGOs, organized labour and trade unions, industrial enterprises, other private-sector organizations, the waste management and recycling sector, and users and owners of articles possibly containing POP-PBDEs. Many countries are also engaged in ongoing activities related to the management of EEE/WEEE. Members of these working groups could be invited to join the inventory team, as well as working groups on the management of vehicles and end-of-life vehicles. Depending on the outcome of the scope setting exercise (see section 3.1.3), representatives from the key sectors could be included in the inventory team, while others could simply be asked to provide data/information.

The manufacture of articles containing POP-PBDEs may be inconsiderable due to discontinued POP-PBDE production and mainly related to recycling activities only. Previous activities may have included several manufacturers, suppliers and downstream users; and the supply chain could be further extended to importing and exporting across borders. Some countries may have to identify and describe, for example, professional users of POP-PBDEs-containing articles and materials, the national supply chain and the downstream users of articles containing POP-PBDEs. Table 3-1 outlines the sectors and stakeholders involved in the use of POP-PBDEs-containing materials.

Table 3-1: Sectors and stakeholders involved in the use of POP-PBDEs

Use	**Stakeholders**
Electrical and electronic equipment (EEE) and waste electrical and electronic equipment (WEEE)	• Ministry of environment and ministry of industry; • Ministry responsible for waste management ; • NIP coordinator and steering committee; • Basel Convention focal point (and stakeholders in Basel activities on e-waste) ; • Importers and exporters of electronics ; • Retailers of electronics and second-hand electronics; • Recyclers of WEEE; • Recyclers and users of polymers from WEEE; • NGOs working on WEEE; NGOs working on POPs ; • Other relevant stakeholders in the country.
Transportation and end-of-life vehicles	• Ministry of transport or other ministry responsible for transport sector; • Ministry responsible for waste management; • Association of importers and exporters of cars and other vehicles; • Retailers of vehicles (in particular, second-hand vehicles); • Association and/or main stakeholders of scrap recycling; • Association and/or main stakeholders of polymer recycling; • University groups working on material flows or transport issues; • NGOs working on transport; NGOs working on POPs; • Other relevant stakeholders in the country .
Other uses: Furniture Textiles Mattresses Construction materials	• Ministry of environment and ministry of industry; • Ministry responsible for waste management ; • NIP coordinator and steering committee; • Importers and exporters of furniture, textiles, mattresses, and construction materials; • Retailers of furniture, mattresses and textiles and related second-hand articles; • Recyclers of polyurethane or other sectors (e.g. textiles, polymers in building materials, rubber)Montreal Protocol focal point; • Other relevant stakeholder in the country.
Contaminated sites	• Consumers; • Producers; • Importers and distributors; • Manufacturers; • Fabricators; • Engineering offices specializing in contaminated sites; • University or research institute working on contaminated sites; • Community-based organizations (CBOs) and NGOs; • Organized labour and trade unions; • Government organizations.

Making preliminary contact

Making contact with stakeholders at the beginning of the inventory exercise can give them a better understanding of its background, scope and objectives and provide them with an opportunity to communicate their views and questions. This initial feedback can help make the inventory more effective by targeting the relevant areas of national use.

General tools that can be used to identify and contact stakeholders include:

- Telephone interviews;
- Postal communication;
- Email/Web-based information sourcing;
- Face-to-face interviews;
- Phone books;
- National registers.

Consulting with a small number of relevant stakeholders

During the inventory planning stage, it may be more efficient to contact and consult only a small number of relevant stakeholders such as larger manufacturers, national industrial associations and the customs service. Gap analyses conducted in the evaluation of the initial assessment or the preliminary inventory could result in the need to contact some of these stakeholders again to get more information or identify other stakeholders to be contacted to help fill in the information and data gaps.

Holding stakeholder group meetings

There may be a range of stakeholder groups involved depending on the areas of use: electronics, transport, furniture, textiles, mattresses and construction materials, and waste categories and management.

3.1.3 Define the scope of the inventory

Defining the scope of the inventory involves identifying the relevant national sectors to be investigated further. This can be achieved by consulting key stakeholders (see table 3-1) and paying special attention to the use categories and life cycle stages discussed in chapter 2. Since the major uses of POP-PBDEs (sections 2.3 and 2.5) are electrical and electronic equipment and uses in the transport sector, these two are likely to be the main focuses of the inventory.

Main information includes:

- Types and quantities of articles containing POP-PBDEs;
- Types of articles containing POP-PBDEs that are recycled, the possible extent of recycling, and the types of articles produced from recycling;
- Types and quantities of POP-PBDEs (chemical) stockpiles and wastes from former production and use in industries (countries that produced POP-PBDEs or used POP-PBDEs in industries);
- Locations where activities have occurred that could be potentially contaminated with POP-PBDEs.

The following criteria are important in defining the scope of the inventory:

- Obligations for POP-PBDEs under the Stockholm Convention (see chapter 1);
- Objectives of a POP-PBDEs inventory (see chapter1);

- Existing resources and capacity;
- National priorities;

The degree and depth of the inventory can be defined by consulting the sections below on data methodology (section 3.2) and data collection (section 3.3), and considering the resources needed for an inventory in relevant national sectors using a tiered approach. Minor uses should be considered in the inventory only if manufacturers in this category are established in the country or existing information indicates that those uses could be relevant.

3.1.4 Develop the work plan

The core inventory team is expected to develop a work plan for the inventory, which can be discussed with the stakeholders. Elements of the plan include:

- Inventory strategy on what needs to be done to identify the sectors;
- Methodologies to be used (see section 3.2);
- Activities needed and assignments;
- Resources allocation including responsibility and budget;
- Timeline and milestones.

The inventory team may need to augment and revise the work plan as the inventory proceeds.

3.2 Step 2: Choosing data collection methodologies

The next step is to choose appropriate methodologies for data collection, using a tiered approach.

3.2.1 Tiered approach

The tiered approach to collecting data in a POP-PBDEs inventory is illustrated in figure 3-2. The suggested methodologies for data collection in the three tiers are described in section 3.2.2. This approach provides flexibility to a wide range of Parties with varying priorities and capacities. The suggested methodologies for data collection in the three tiers are described in section 3.2.2. Each tier represents a level of methodological complexity. Moving from lower to higher tiers implies a Party is opting for approaches that are progressively more demanding in terms of complexity and data requirements, and therefore more resources may be needed. Lower tier methods usually rely on readily available statistics in combination with estimates for key parameters (provided in this guidance). Higher tiers methods involve more resource-intensive data collection activities and country-specific measurements but should also yield more accurate results.

Parties should endeavour to use methods that provide the highest level of certainty while making efficient use of available resources and taking into account available technical capacity. The initial assessment (tier I) provides the inventory team with a general idea of where the problems may lie and, more importantly, which sectors require further investigation. The tier I outputs may be rather qualitative (section 3.2.2) or require (subsequent) verification. The preliminary inventory (tier II) focuses on specific sectors. The in-depth inventory (tier III) uses analytical measurement methods to obtain precise data on these sectors.

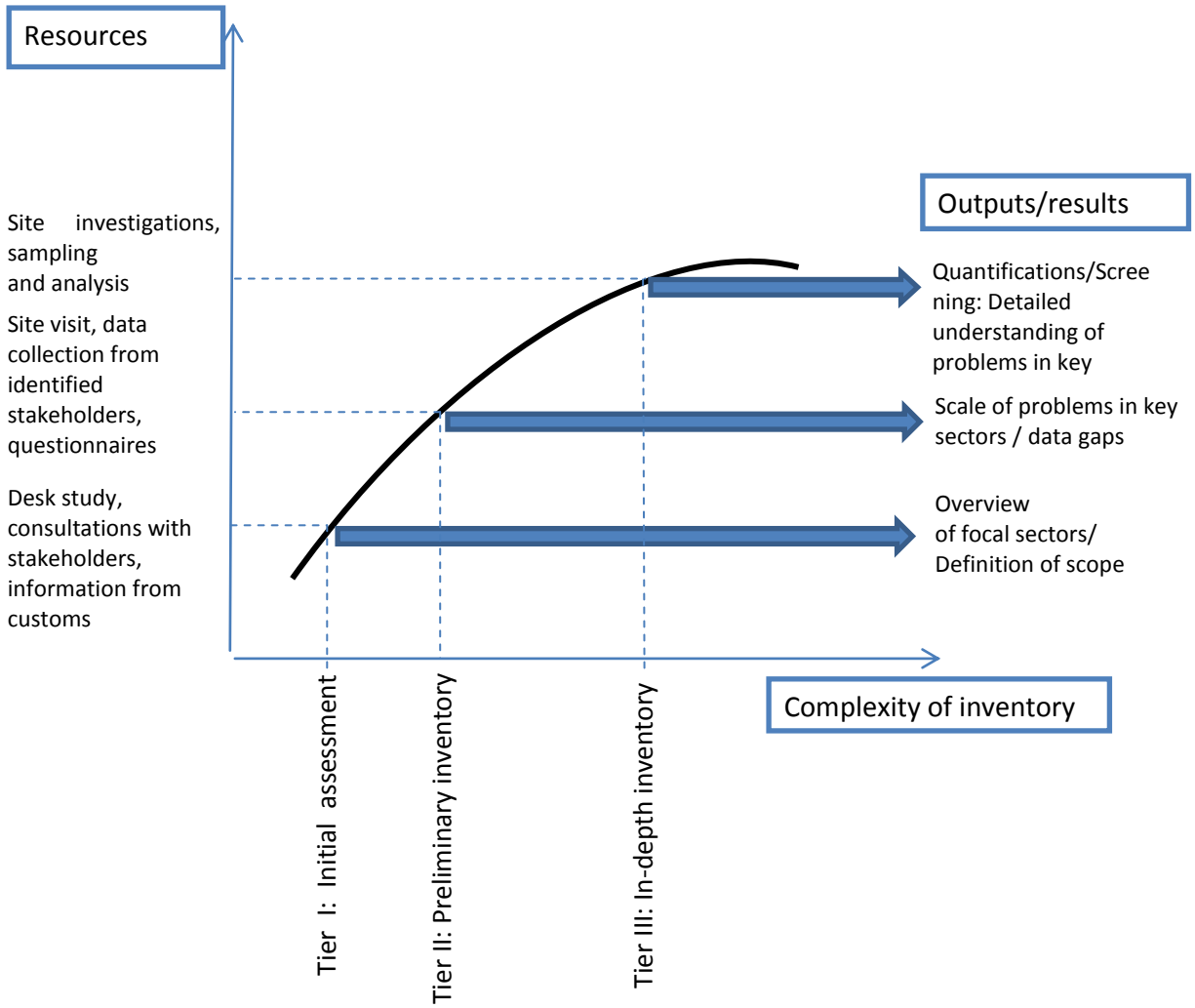

Figure 3-2: The tiered approach to the inventory of POP-PBDEs

Tier I: Initial assessment

The initial assessment generally relies on desk studies, interviews etc., i.e. methods that do not require expensive on-site visits or elaborate data collection activities (the team may decide to conduct the interviews on-site). First, the team gets an overview of the former use of c-PentaBDE and c-OctaBDE in articles and waste/recycling flows:

- Production of POP-PBDEs (section 2.2.);
- Use of POP-PBDEs (section 2.3);
- POP-PBDEs in waste and recycling flow (section 2.5);
- Life cycle of c-PentaBDE and potential for emissions (figure 2-2);

- Life cycle of c-OctaBDE and the potential for emissions (figure 2-3).

Next, the team collects information about existing past and present national data on the import and use of POP-PBDEs and articles containing POP-PBDEs from major stakeholders including:

- Ministry of Industry and Ministry of Transport;
- Customs service, the National Bureau of Statistics and the National Central Bank;
- Published literature in scientific journals;
- Technical reports or notes, commissioned research reports and development assistance study reports;
- Desk study and online research;
- Responses to the inquiries and interviews.

The team may have to revisit step 1 to include other relevant stakeholders (or increase number of stakeholders in one category), redefine the scope and refine the work plan before moving on to the next tier.

Tier II: Preliminary inventory

The preliminary inventory generally focuses on specific sectors, as shown in figure 3-2. It involves surveys and site visits to better estimate national data that were identified as missing in the initial assessment/tier I.

Possible applications (tables 2-4 and 2-6) and target locations can be identified, followed by site visits including

- Former production of POP-PBDEs;
- E-waste collection centres and recyclers;
- Possible site visits of e-waste management facilities;
- Possible site visits of end-of-life vehicles treatment facilities;
- Possible site visits of storage and disposal locations materials containing POP-PBDEs.

Tier III: In-depth inventory

The in-depth inventory—may be undertaken if the preliminary inventory concludes that POP-PBDEs could pose high human health and environmental risks in the country and more accurate data are needed to prioritize risk reduction measures and estimate their costs. Data collection in this tier relies on the use of analytical methods that may include screening using X-ray fluorescence (XRF) and measurements using gas chromatography and electron capture detector (ECD) or mass spectrometry (GC-MS) (Sindiku et al 2011, 2012). It may also involve detailed inspections of sites mentioned in tier II.

3.2.2 Indicative, qualitative and quantitative methodologies

A number of different methodologies can be used for gathering information about POP-PBDEs. The methodologies can be divided into three groups:

- **Indicative method:** provides initial information for further planning of the inventory depending on the amount of resources (i.e. human and financial situation). This method is quick and does not require significant human and financial resources. Activities include desk study of existing information, workshops, and interviews. This method is normally used in the initial assessment.

- **Qualitative method**: uses questionnaires to obtain more specific data. Data management is based on estimations from known levels of quantities of POP-PBDEs used and total production volumes in production processes, and manufacture of products and articles. Workshops and interviews with stronger obligations (legal tools) may also be helpful in obtaining data from the industry. This method is normally used in the initial assessment and preliminary inventory.
- **Quantitative method**: provides accurate and specific numerical information, but needs to be carried out by experts in the relevant fields of POP-PBDEs and the sectors of investigation. This is an advanced stage of the inventory that includes site inspection, sampling and analysis. The investigations are extensive and labour intensive and chemical analysis is costly. This method is normally used in the in-depth inventory.

Four approaches that can be used for data collection are discussed briefly in the next sections.

Desk study of existing information

The desk study involves gathering information about existing past and current national data on former production and use of POP-PBDEs (if any), and articles containing POP-PBDEs. This information can be obtained from the customs service, national bureau of statistics, and national central bank; published literature in scientific journals, technical reports or notes, commissioned research reports, development assistance study reports and Internet searches. The information should be collated, evaluated and verified if possible, and a gap analysis of the data could be undertaken as well.

National sensitization workshop on Stockholm Convention and new POPs including POP-PBDEs

This national workshop involves major stakeholders from all sectors and groups in which products and articles containing POP-PBDEs have been used or are still being used. The national importance of the inventory exercise would be emphasized to participants while also demanding their full cooperation and unhindered release of available data in their custody in the national interest.

Breakout sessions and group meetings can be organized during the workshop to ensure that all sectors in which POP-PBDEs have been used are adequately covered as well as to get consensus on how best to collect and compile data.

Questionnaire surveys

Questionnaire surveys are valuable instruments for primary data collection in inventory programs. Based on preliminary contact and consultation meetings with stakeholders, a questionnaire with explanatory notes can be developed and sent to the relevant stakeholders. Examples of questionnaire formats that can be used for different sectors are given in annexes 2-5.

Questionnaires can be administered through various outreach mechanisms, including postal distribution; supply chain distribution; distribution via trade unions, NGOs, local governments and community leaders; and hand delivery in one-on-one interviews, electronic means, etc. The use of questionnaires together with stakeholder meetings has been successful in previous inventories of POP-PBDEs.

Site inspection, sampling and analysis

Samples of products and articles can be gathered during in site inspections of relevant storage facilities, recycling locations, and waste disposal/storage facilities.

3.3 Step 3: Collecting and compiling data from key sectors

The inventory team needs to investigate if the following exist in the country:

- Production of POP-PBDEs. Most countries do not produce POP-PBDEs. And only some countries produce chemical agents and preparations used in the manufacture of textiles, foam, synthetic carpets and electronic and electrical articles and devices.
- Industries formerly using POP-PBDEs;
- Products and articles containing POP-PBDEs in households;
- POP-PBDEs in waste and how they are managed;
- Articles containing POP-PBDEs that are recycled, the possible extent of recycling, and the types of articles produced from recycling, including the life cycle of c-PentaBDE and its potential for emissions and the life cycle of c-OctaBDE and its potential for emissions;
- Stockpiles and wastes from former production and use in industries (countries that produced POP-PBDEs or used POP-PBDEs in industries);
- Sites/locations where activities have occurred that could be potentially contaminated with POP-PBDEs.

The following types of numerical data need to be collected and compiled in the inventory:

- Quantities of POP-PBDEs in waste and stockpiles;
- Quantities of POP-PBDEs present in articles and products.

Data collection approaches will vary from country to country based on the data gathered in steps 1 and 2; they may be by estimations, using statistical data or possibly measurements. Estimations of POP-PBDEs quantities in the country for major POP-PBDEs former use sectors are provided in chapters 4 and 5. Measurements could be performed by analytical screening on representative samples (see *Guidance on Screening and Analysis of POPs in Articles and Products*).

The focal sectors to be investigated in the national inventory fall under four key areas:

- Electric and electronic equipment (chapter 4);
- Transport sector (chapter 5);
- Other uses (chapter 6);
- Identification of potential contaminated sites and hot spots (chapter 7).

In addition, data collected for the first three key areas will form the basis for the preliminary inventory of the contaminated sites, waste and stockpiles.

3.4 Step 4: Managing and evaluating the data

3.4.1 Data management

Since Parties have different designs and levels of legal framework, political organization and economic support for environmental management, different methodologies will be applied in the data gathering process as described in section 3.3. The management of collected data should be done as consistently and as transparently as possible. During the data processing, all the

assumptions and conversion coefficients adopted as a result of expert judgement, where needed, should be noted/recorderd and mentioned when the results are presented.

Before the inventory starts, all the data formats including questionnaire survey formats should be determined to anchor the consistency of the data collection as much as possible. If some data conversions and estimations are done by stakeholders, the inventory team must provide training on how to estimate the amount of POP-PBDEs and how to fill out the questionnaire. This will reduce the possibility of errors during the data management activities.

Estimations will be needed to provide the total quantities in a country. Estimations are a valuable tool for providing the data needed when resources are limited. Since direct measurements of POP-PBDEs in products and articles are resource intensive, a preliminary inventory could be fully based on estimations in many cases (see section 3.2).

3.4.2 Mechanism for evaluation of the inventory

Some challenges may still exist at the end of the inventory including a lack of information. An evaluation of the process, strategy used and information collected can take place along with a decision on what further actions are needed to make the inventory more complete.

The evaluation includes identification of the following:

- Gaps and limitations;
- Need for validation of the information compiled in the inventory;
- Further actions needed to make the inventory more complete;
- Further actions needed to meet the requirements of the Stockholm Convention.

important elements in this evaluation step are to identify any gaps and limitations, and the measures needed to make the inventory more complete. Other ways to involve the stakeholders and other data collection strategies (see steps 2-4) could then be considered. A gap analysis in the evaluation of the initial assessment or preliminary inventory could result in the need to contact some of the stakeholders again to get more information or identify other stakeholders to be contacted to help fill the gaps.

For inventory sectors with limited information, information campaigns and stakeholder meetings or workshops may be a necessary measure. In some cases, government regulations may be required to ensure that stakeholders report their holdings, cooperate with the national authorities and engage in the national inventory. To draft a regulation and make it come into force can sometimes require a long time (an year at a minimum in some places).

Gaps, limitations and necessary actions to complete the inventory will also be valuable information for the NIP, especially for developing countries with need of financial support for their inventory. It is important for developing countries to identify whether and what technical and financial support will be necessary to complete the inventory. Even if the inventory is very incomplete, the NIP is expected to provide information on gaps and the limitations of a country's resources and capacities — information that is useful to identify technical and financial needs.

It is also important to identify whether the current situation meets the requirements of the Convention, including the actions needed to fulfil the obligations in the NIP, i.e. elimination of POP-PBDEs without specific exemption. Information on BAT/BEP measures are provided in the *PBDE BAT/BEP Guidance*.

The inventory will also require revision at a later stage when the action plan is updated. This can also be done using the strategies described in this guidance.

3.5 Step 5: Preparing the inventory report

The final step for the inventory team is to prepare the POP-PBDEs inventory report. This report will include the inventories of all key sectors investigated by the country (chapters 4, 5, 6, and 7), compiled in a single document. Although its aim is to support the development of the NIP, the report can be also used for other purposes such as feeding into Article 15 reportin, developing post NIP projects, and developing effective strategies and action plans for managing listed BFRs in to meet the obligations under the Convention.

The essential elements of the report are:

- Objectives and scope;
- Description of data methodologies used and how data were gathered;
- Final results of the inventory for each sector considered a priority for the country (using a format to be provided in this guidance, as such or adapted from that format);
- Results of the gap analysis and limitations identified for completion of the inventory;
- Further actions (e.g. stakeholder involvement, data collection strategies) to be taken to complete the inventory and recommendations.

Other information (e.g. stakeholder list) could be included in the report depending on the national requirements.

4 Inventory of POP-PBDEs in electrical and electronic equipment (EEE) and related waste (WEEE)

Electrical and electronic equipment is one of the fastest growing material flows of goods as well as a large waste and recycling flow. It is the largest material flow containing c-OctaBDE (see chapter 2). An inventory of EEE and WEEE is an important step for addressing the challenge of managing c-OctaBDE-containing materials.

Inventories of EEE/WEEE have been developed to support the implementation of sustainable WEEE management systems under the Basel Convention. Among others, Thailand, Ghana, Nigeria and Tanzania have generated good examples of EEE/WEEE inventories (see annex 3; BCRC-SEA, 2007; PACE, 2010; Magashi and Schluep, 2011, Ogungbuyi and al 2011).

In most countries that have not conducted an EEE/WEEE inventory, the inventory of EEE/WEEE fractions containing POP-PBDEs could be seen as a first step for developing an inventory for EEE/WEEE. The amount of POP-PBDEs, mainly c-OctaBDE (hexaBDE and heptaBDE), in this sector could be calculated and reported following the steps below. The results could provide policy makers with a basis for decision-making and planning the EEE/WEEE management. This aspect needs to be taken into consideration when developing an inventory of POP-PBDEs (see case study on inventory of PPBDEs in EEE and WEEE; and *PBDE BAT/BEP Guidance*).

4.1 Step 1: Planning the inventory and identifying stakeholders

This first step focuses on defining the scope of the inventory and developing a work plan (see section 3.1.). The major amount of c-OctaBDE is found in the polymer fraction of casings from CRT computer and TV monitors (mainly in ABS) produced before 2005 (see section 2.3.2 and 2.2). Therefore, these are the key target EEE/WEEE fractions to be addressed by the POP-PBDEs inventory. Modern flat screens are unlikely to contain POP-PBDEs[12] (since production of c-OctaBDE stopped in 2004).

The inventory of POP-PBDEs in EEE/WEEE is therefore expected to address the following:

- Second-hand EEE imported in the inventory year and the previous years during which possibly POP-PBDEs-containing EEE/WEEE were/are imported as a base for estimating stocks;
- EEE stocks (in use and/or stored in the possession of consumers);[13]
- EEE entering the waste stream i.e. WEEE;
- WEEE plastics for recycling (from domestic WEEE and imported WEEE polymer fraction).

[12] Polymers from recycling of WEEE can contain a minor amount of POP-PBDE due to dilution then present at levels below the 0.1% RoHS threshold.

[13] Consumers here include households, and public- and private-sector institutions and organizations.

Appropriate members of the inventory task team need to be selected to conduct the inventory of this sector. Specific stakeholders for the inventory of EEE and WEEE are listed in table 3-1. The core inventory team could be extended as appropriate.

Informal sectors are often involved and play a significant role in collection and recycling in developing countries.[14]

4.2 Step 2: Choosing data collection methodologies

4.2.1 Tier I: Initial assessment

The aim of the initial assessment is to find out if any inventory data on EEE and WEEE are already available in the country. The inventory team could contact the Basel Convention focal point to discuss the status of the EEE/WEEE inventory (available data as well as current and planned activities). The ministries of environment and ministry in charge of industry and telecommunication could also be contacted and asked for available information. If WEEE inventory data are available (on CRTs and the information technology and consumer electronics sectors), the POP-PBDEs inventory can be calculated using the methodology described in sections 4.3 to 4.5.

Countries that have not yet established an EEE/WEEE inventory could initiate the inventory by estimating the minimum POP-PBDEs amount in CRT in the country. This requires estimating the country's penetration rate (number of appliances per capita) in analogy to countries with similar economic development and consumer behaviour (see table 4-4), and then extrapolating from the per capita data to the target country. Table 4-5 shows the per capita data reported in the past.

Once the per capita data have been estimated, the POP-PBDEs content in CRT casings (TVs and computer monitors) can be calculated taking into consideration the following additional data:

- Population of the respective country;
- Weight of the CRTs: **25 kg per device** (estimated average weight of a CRT monitor, either TV or PC monitor; see also table 4-5);
- Polymer content of CRT casings: **30%** (estimated average, see table 4-9);
- A range of c-OctaBDE content, **0.87-2.54 kg/tonne,** for these polymers used in CRT casings (estimated average; see also table 4-11).

A range of c-OctaBDE in CRT devices can be calculated as follows:

$M_{PBDE(i)}$ = [Number of CRTs/capita$_{Region}$] x population x 25 kg x 0.3 x [0.00087 to 0.00254]

Where:

- $M_{PBDE(i)}$ is the amount of POP-PBDEs (i) in [kg]

  (in Polymer (k) of electrical and electronic equipment (EEE) (j))

The POP-PBDEs (heptaBDE and hexaBDE) in the c-OctaBDE can be calculated according to the homologue content shown in table 4-12 (of c-OctaBDE, the heptaBDE homologue is estimated as 43% and the hexaBDE as 11%).

[14] For example, in Nigeria there are associations representing the informal sector; such associations could be one of the stakeholders with great implications for the potential socio-economic impact of the POP-PBDE-containing materials

Table 4-1: Total and per capita amounts of CRT (TVs and personal computer (PC) monitors) in different regions and countries. The average weight of a CRT device used in this table is 25 kg.

Country/Region	Total weight (10^3 tonnes)	Total number (million units)	Population (million)	CRT weight/person (kg/capita)	No. of CRTs /person (units/capita)	Source
Asian average (including Australasia)	16'226	649	3'906	4.1	0.17	Gregory, 2009
North American average	14'623	585	529	27.6	1.11	Gregory ,2009
LAC[15] average	5'189	207	572	9.1	0.36	Gregory, 2009
Benin	17.4	0.7	8.7	2.0	0.08	Basel Convention, 2011
Côte d'Ivoire	78.0	3.1	20.8	3.75	0.15	
Ghana, 2010	112	4.48	24.2	4.6	0.19	Green Advocacy & Empa, 2011
Nigeria, 2010	670	26.8	154.7	4.33	0.17	BCCC-Nigeria et al., 2011
Colombia, 2008/2009	343	13.7	46	7.46	0.3	León, 2010
Switzerland, 2008	54	2.2	7.7	7.05	0.28	BfS, 2011

4.2.2 Tier II: Preliminary inventory of POP-PBDEs in CRT casings

Since the CRT casings (TVs and computer monitors) are expected to contain more than 50% of the total POP-PBDEs present in EEE, data calculated in the initial assessment could provide an estimate of the major portion of POP-PBDEs in the EEE/WEEE sector in the country.

By further improving the accuracy of the number of CRTs per capita, the estimated c-OctaBDE data could be sufficient for a preliminary POP-PBDEs inventory. The results could give a first indication of management needs in a country where CRT are the predominant source of POP-PBDEs.

After a Party has carried out a preliminary inventory, step 3 onwards (except the questionnaire) could be followed to summarize the results using table 4-12.

4.2.3 Tier III: In-depth inventory of POP-PBDEs-containing EEE/WEEE

The in-depth inventory can consist of the field survey using the questionnaires on EEE in use or stored at the consumer level (stocks), as explained in section 4.3.1.2. The information collected from such survey will improve preliminary inventory data reported in table 4-12. The level of commitment and resources for this in-depth inventory will be equivalent to that needed for the e-waste assessment for the Basel Convention, if a wider range of EEE/WEEE categories are included in the inventory.

[15] LAC: Latin America and the Caribbean.

The POP-PBDEs content can be estimated using field measurement equipment such as sliding sparks and XRF handheld equipment (see *POP-PBDEs BAT/BEP Guidance*) This could help identify CRTs and other EEE/WEEE plastics contain bromine/POP-PBDEs (Sindiku et al. 2011). Please note that the field screening equipment can only detect the total bromine content, and a confirmation may be required by using instrumental analysis for positive tested samples (Sindiku et al. 2012) *Guidance on Screening and Analysis of POPs in Articles and Products*. The use of a material flow analysis of the EEE/WEEE sector and the related substance flow of POP-PBDEs has been found useful (see case study on inventory of PBDEs in EEE and WEE and could be considered in the development of an in-depth inventory.

4.3 Step 3: Collecting and compiling data from sectors

The aim is to establish the total amount of BDEs in EEE. The amount of total POP-PBDEs in EEE can be calculated as:

$M_{PBDE(i)} = M_{EEE(j)} \mathbf{x} f_{Polymer(k)} \mathbf{x} C_{PBDE(i);Polymer(k)}$

Where:

- $M_{PBDE(i)}$ is the amount of POP-PBDEs (*i*) in [kg]
  (in Polymer (*k*) of electrical and electronic equipment (EEE) (*j*))
- $M_{EEE(j)}$ is the amount of EEE (*j*) in [in tonnes]
  (imported, stockpiled or entering the waste stream)
- $f_{Polymer}$ is the total polymer fraction in [weight-%]
- $C_{PBDE(i);Polymer}$ is the content of the POP-PBDEs (*i*) in the total polymer fraction in [kg/tonne]

Based on the formula above, the information needed is the amount of EEE/WEEE in the country, share of the relevant polymers in different EEE/WEEE categories and POP-PBDEs content of those polymers. This section explains how to determine the following:

- The inventory of stocks and flows of EEE and WEEE in the country (section 4.3.1);
- The estimation of the polymer fraction in relevant EEE and WEEE containing POP-PBDEs (section 4.3.2);
- The estimation of the POP-PBDEs content in the WEEE polymer fraction (section 4.3.3).

Information on WEEE polymers recycled and exported and the amount of WEEE polymers imported is also needed for the in-depth inventory.
An overview of the material flow of EEE, WEEE and related plastic fractions is shown in figure 4-1.
The establishment of a material flow of EEE/WEEE and the related substance flow of POP-PBDEs has been found useful and could be considered in the development of an in-depth inventory.

Figure 4-1: Material flow of the EEE/WEEE and related plastics and the life cycle stages where POP-PBDEs are inventories

4.3.1 Inventory of stocks and flows of EEE/WEEE

For the development of a final comprehensive EEE/WEEE inventory, the key EEE/WEEE categories need to be considered (see table 4-2). As the EU already has categories of EEE/WEEE and information has been accumulated based on them, the EU's categories are applied in this section: category 1 "large household appliances", category 2 "small household appliances", category 3 "IT and telecommunications equipment" and category 4 "consumer equipment".[16]

Studies have shown that c-OctaBDE occurs in relevant concentrations mainly in ABS casings of CRT televisions and computer monitors. For the purposes of an inventory of POP-PBDEs in EEE/WEEE, the priority is categories 3 and 4 with a special focus on CRT monitors and televisions. The inventory of stocks and flows of EEE/WEEE needs to address three stages in the life cycle of EEE (as shown in the following text:

- Imports of new and second-hand EEE;
- EEE stocks (EEE in use or stored);
- EEE entering the waste stream.

Table 4-2: Expected presence of POP-PBDEs in WEEE categories

#	WEEE Category[1)]	Presence of POP-PBDEs
1	Large household appliances	Expected not present or at average concentrations clearly (i.e. more than an order of magnitude) below 0.1 wt%[2)]
2	Small household appliances	Expected not present or at average concentrations clearly (i.e. more than an order of magnitude) below 0.1 wt%[2)]
3	IT and telecommunications equipment	Average concentrations in computer CRT monitors above 0.1 wt% and in other products below or around 0.1 wt%[2)]
4	Consumer equipment	Average concentrations in TV CRTs possibly above 0.1wt% and average concentrations below or around 0.1wt%[2)]

[1)] According to the EU Directive 2002/96/EC of the European Parliament and of the council on waste electrical and electronic equipment (WEEE).

[2)] RoHS MCV = 0.1% (by weight) = Maximum Concentration Value according to the EU Directive 2002/95/EC of the European Parliament and of the Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS Directive). Several other countries have adopted the RoHS cut-off values for EEE including China and India. Currently no low POPs limits have been defined by the Basel Convention.

4.3.1.1 Imports of new and second-hand EEE

Imports of EEE can be assessed by analyzing trade statistics from international databases, national statistics and trade records compiled by customs and port authorities. The most widespread available international database is the UN Comtrade Database (http://comtrade.un.org/db). The database uses different classification codes to organize commodities, of which the most common is the Harmonized Commodity Description and Coding Systems (HS). This HS system has different categories from those used in the EU WEEE Directive. The most important HS codes relevant for the inventory of POP-PBDEs in EEE are given in table 4-3.

[16] 97% of the total plastic amount in EEE is used in the WEEE categories 1 – 4 (APME, 2001).

Table 4-3: UN Comtrade Database HS codes relevant for the POP-PBDEs inventory for EEE

WEEE Category	HS Code	Description
3	8471	Automatic data processing machines and units thereof; magnetic or optical readers, machines for transcribing data onto data media in coded form and machines for processing such data, not elsewhere specified or included.
3	8443	Printing machinery used for printing by means of plates, cylinders and other printing components of heading 84.42; other printers, copying machines and facsimile machines, whether or not combined; parts and accessories thereof.
3	8470	Calculating machines and pocket-size data recording, reproducing and displaying machines with calculating functions; accounting machines, postage-franking machines, ticket-issuing machines and similar machines, incorporating a calculating device; cash reg.
3	8517	Telephone sets, including telephones for cellular networks or for other wireless networks; other apparatus for the transmission or reception of voice, images or other data, including apparatus for communication in a wired or wireless network
4	8527	Reception apparatus for radio-broadcasting, whether or not combined, in the same housing, with sound recording or reproducing apparatus or a clock.
3/4	8528	Monitors and projectors, not incorporating television reception apparatus; reception apparatus for television, whether or not incorporating radio-broadcast receivers or sound or video recording or reproducing apparatus.
4	8540	Thermionic, cold cathode or photo-cathode valves and tubes (for example, vacuum or vapour or gas filled valves and tubes, mercury arc rectifying valves and tubes, cathode-ray tubes, television camera tubes).
4	8519	Sound recording or reproducing apparatus.
4	8521	Video recording or reproducing apparatus, whether or not incorporating a video tuner.
4	8525	Transmission apparatus for radio-broadcasting or television, whether or not incorporating reception apparatus or sound recording or reproducing apparatus; television cameras, digital cameras and video camera recorders.

Trade statistics usually do not contain information about the share of second-hand articles in imports. This information is crucial, however, as POP-PBDEs are only expected to be contained in second-hand imports (production of c-OctaBDE stopped in 2004) and second-hand imports can comprise up to 70% of total imports in certain developing countries (Green Advocacy and EMPA, 2011). Table 4-4 summarizes some import data, including information about the share of second-hand EEE for some African countries. This data might be used by countries without second-hand EEE import data to estimate the share of second-hand imports in analogy to countries with similar economic development and consumer behaviour (e.g. neighbouring countries).

If such analogies cannot be drawn, a comprehensive assessment needs to be done by conducting interviews with importers and port authorities. Questionnaires (found in annexes 2-5) address the following key indicators:

- Type of imported products;
- Amount of imported products (e.g. in units, in tonnes, in full containers, etc.);
- The share of new vs. second-hand imports (e.g. in weight %);
- The share of CRT monitors and CRT-TVs.

Table 4-4: Import data, including information about the share of second-hand EEE for some African countries

Country	Year	Population	Imports		Sources
		Millions	units/year	thereof second-hand EEE ($f_{EEE(j);second\text{-}hand}$)	
Ghana	2008	23.8	750,000	70%	Green Advocacy & Empa, 2011
Nigeria	2009	154.7	2,200,000	35-70%	BCCC-Nigeria et al., 2011
Morocco	2009	32	900,000	<11%	Laissaoui & Rochat, 2008; GIZ, 2010
South Africa	2007	47.6	1,900,000	8%	Finlay & Liechti, 2008
Tanzania	2009	42.5	120,000	13%	Magashi & Schluep, 2011
Uganda	2007	28.8	29,000	14%	Wasswa & Schluep, 2008

4.3.1.2 EEE in use or stored at the consumer level (stocks)

Stocks of EEE in use or stored at the consumer level can be divided into three main groups:

- Private consumers (households);
- Institutional consumers (public institutions, government, parastatals, health and educational sector);
- Corporate consumers (hotels, large businesses (industries), small business enterprises).

Since POP-PBDEs in EEE are mostly found in older appliances, and especially in CRT monitors and TVs, it is expected that the largest share of the problematic fractions can be found in the households of private consumers who tend to keep appliances longer and are also the largest buyers of second-hand EEE. Institutional consumers also often tend to keep a stock of older appliances, especially CRT monitors, either in use or in storage. Corporate consumers are less likely to hold a significant share of problematic appliances containing POP-PBDEs as they tend to exchange their ICT infrastructure rather rapidly with new appliances.

Private consumers (households)

For a first estimation, EEE stockpiled at the private consumer level can be approximated by using penetration data (measured by e.g. installed appliances per person) for specific appliances from other countries (see table 4-5), which best represent the consumer patterns in the target country. To calculate the total amount of appliances in a country on a weight base, these numbers need to be multiplied by the average weight of the appliance (see table 4-6) and the population of the country.

For an in depth inventory, interviews with households need to be conducted (see annex 3 for generic questionnaire that can be used). Household surveys will produce data in the format of "per household". National statistics on the number and average size of households will be necessary to extrapolate data to the entire country, keeping in mind differences in rural and urban consumer behaviours and income classes. Therefore, household surveys could be carried out in both rural and urban areas, and among different income classes. The questionnaire will address at least the following key indicators:

- The type and amount of installed EEE in the household, with a special focus on the number of CRT monitors and CRT-TVs;

- Average life span of each individual appliance (distinguishing between how long an appliance is in use and how long it is stored before being given away/ entering the waste stream, respectively);
- Size of the household (number of persons);
- Demographic location of the household (rural or urban);
- Income class of the household (classified according to the official national income classification, in order to be compatible with national statistics).

Depending on the type of information that can be retrieved, extrapolations can be made from the amount of each type of article to the amount of all other articles in entire WEEE categories, and vice versa, using the sample data as summarized in tables 4-7 and 4-8.

Table 4-5: Penetration rates of specific EEE in various countries (appliances/person)

	Cat.[1)]	**Ghana**[2)]	**Nigeria**[3)]
Fridge	1	0.26	0.16
Air conditioner	1	0.09	0.12
Iron	2	0.19	0.14
Kettle	2	0.12	0.11
Personal computer	3	0.08	0.13
Mobile phone	3	0.72	0.60
TV	4	0.20	0.25
Radio/HiFi system	4	0.28	0.36

[1)] Categories according to the EU WEEE Directive 2002/96/EC large household appliances (cat. 1), small household appliances (cat. 2), IT and telecommunications equipment (cat. 3), consumer equipment (cat. 4).

[2)] Green Advocacy and EMPA, 2011.

[3)] BCCC- Nigeria et al., 2011.

Table 4-6: Weight estimation of specific articles in categories 3 and 4 (adapted from Green Advocay and EMPA, 2011)

Articles	**Weight (kg)**	**Source**
Category 3: Information and communication technologies		
CRT monitor	14.1	Laffely, 2007; Zumbuehl, 2006
LCD monitor	4.7	SWICO Recycling Guarantee, 2006; ecoinvent v2010
Desktop computer (incl. mouse and keyboard)	9.9	Eugster et al., 2007
Laptop computer	3.5	SWICO Recycling Guarantee, 2006;ecoinvent v2010
Mobile phone	0.1	Estimate
Telephone	1	Huisman et al., 2008
Printer	6.5	Laffely, 2007
Photocopier	52	Furniture re-use network, 2009
Category 4: Consumer electronics		
Television (CRT)	31.6	Zumbuehl, 2006
Television (LCD)	15	Estimate
Radio	2	Huisman et al., 2008
Hi-fi system	10	Huisman et al., 2008

Table 4-7: Share of specific WEEE categories 3 and 4 articles from the entire category stockpiled in households in Nigeria (Ogungbuyi et al. 2011)

Category	Articles	Nigeria (%)
3	CRT monitor	7.5
	LCD monitor	4.5
	Desktop PC	13.3
	Laptop	10.1
	Printer	7.0
	Mobile phone	5.5
	Rest	52
	Total	100
4	CRT-TV	42.5
	Flat panel TV	14.8
	Radio	3.2
	HiFi	8.9
	Rest	30.7
	Total	100

Table 4-8: Weight based share of WEEE categories 1-4 in households from various countries (EMPA, 2011)

Country	WEEE-Cat. 1 (%)	WEEE-Cat. 2 (%)	WEEE-Cat. 3 (%)	WEEE-Cat. 4 (%)
EU27 average [1)]	63	10	13	14
Switzerland [2)]	66	10	24	
Nigeria[3)]	52	12	11	25

[1)] Huisman et al., 2008.
[2)] Müller & Widmer, 2010.
[3)]Ogungbuyi et al., 2011.

Institutional and corporate consumers

For a first estimation**,** EEE stockpiled at institutional and corporate consumers can be approximated by using exemplary data from other countries, where data are available, on the weight distribution of EEE in stockpiles between private consumers and institutional/corporate consumers. Based on this data, EEE stockpiled at institutional and corporate consumers can be calculated. Figure 4-2 shows an example of this distribution from Nigeria by WEEE category and consumer type. This distribution, however, very much depends on the development status of a country and the size of the services and industrial sector. Therefore, in many cases, such a simple approximation might not be possible. Alternatively, institutional and corporate consumers could be neglected in the first estimation and a more comprehensive assessment would need to be carried out.

For a in depth inventory, interviews with institutional and corporate consumers need to be conducted (see annex 4 for a generic questionnaire). The questionnaire needs to take into account different economic sectors that might feature different consumer behaviours, e.g. the banking sector might consume more ICT appliances than the producing industry. The chosen economic activities in the questionnaire could be in accordance with national statistics about employee distribution levels between the different economic activities (i.e. sectors). This will make it possible to extrapolate from the survey results to the national level. The questionnaire will address at least the following key indicators:

- The type and amount of installed EEE in the organization, with a special focus on the number of CRT monitors (and CRT-TVs);
- Average life span of each individual appliance (distinguishing between how long an appliance is in use and how long it is stored before being given away/entering the waste stream, respectively);
- Size of the organization (number of employees);
- Type of organization and main activity (institutional or corporate, economic sector).

An understanding on questionnaire use, resulting data and inventory development can be developed by studying the existing WEEE inventory reports.

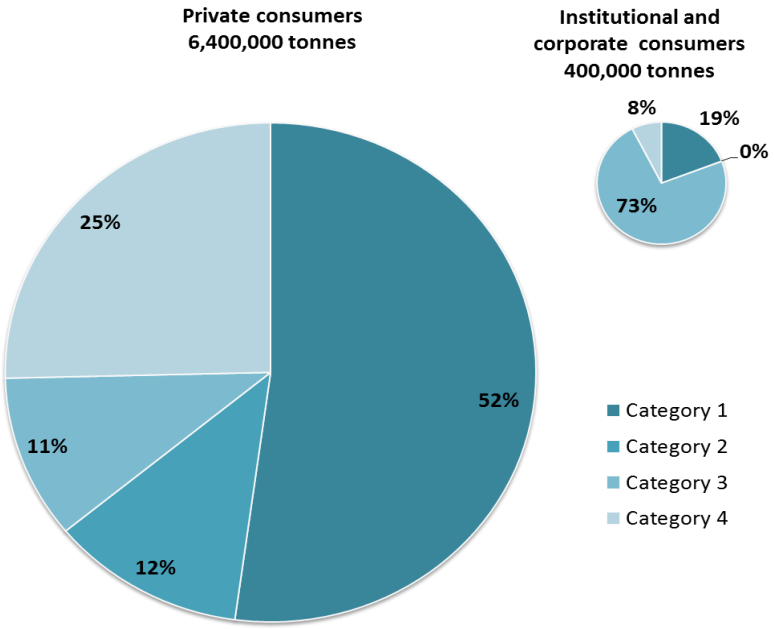

Figure 4-2: Weight distribution of EEE stockpiled by WEEE category for private and institutional/corporate consumers in Nigeria (EMPA, 2011)

4.3.1.3 EEE entering the waste stream

There are various approaches to calculating EEE articles entering the waste stream or WEEE flows, respectively (Streicher-Porte, 2006). The two key inputs for this calculation are (i) the amount of EEE stockpiled (see 4.3.1.2) by consumers and (ii) the average life span (combined time of being used and stored by consumers). These numbers need to be assessed through the consumer questionnaires as explained in the previous section. EEE entering the waste stream or WEEE generated can then be calculated using the "consumption and use" method (Bureau B&G, 1993):

WEEE generated per year = $M_{EEE(j)}^{stockpiled} / ls_{EEE(j)}$

Where

- $M_{EEE(j)}^{stockpiled}$ is the amount of EEE (*j*) stockpiled at the consumer [in metric tons]
- $ls_{EEE(j)}$ is the average life span of the specific appliance (*j*) [in years] (combined time of being used and stored at the consumer)

If further details about the final disposal and treatment process of WEEE are essential, it may be necessary to conduct field studies and hold interviews with key stakeholders of the waste sector. A questionnaire for recyclers can be found in annex 5.

4.3.2 Total polymer fraction in relevant EEE/WEEE

As discussed earlier in this chapter, relevant EEE/WEEE related to POP-PBDEs only includes (single) product types and WEEE categories having an average concentration of POP-PBDEs around or above the RoHS' MCV (see table 4-10). The corresponding data for the total polymer fraction are compiled in table 4-9.

Table 4-9: Total polymer fractions in the relevant EEE/WEEE in Europe. Printed wiring boards and cables are not included (Waeger et al., 2008)

Category/Article		Total polymer fraction $f_{Polymer}$ [in % by weight]		
		Minimum	Maximum	**Mean**
3	ICT equipment without monitors	26%	58%	**42%**
4	Consumer equipment without monitors	21%	26%	**24%**
3	CRT monitors	13%	38%	**30%**
4	CRT-TVs	15%	38%	**30%**

4.3.3 POP-PBDEs content in the polymer fraction

To complete the inventory of the POP-PBDEs in EEE, data about their concentration in the total polymer fraction of the relevant EEE are needed ($C_{PBDE(i);Polymer(k)}$).

According to a study that analyzed the concentrations of RoHS substances in mixed plastics from WEEE in Europe, the average concentration of c-OctaBDE exceeds the RoHS' MCV in certain product types in WEEE categories 3 and 4 (Waeger et al., 2010). In all cases, the polymer containing those concentrations was ABS.

Table 4-10 provides the concentration of c-OctaBDE in the total polymer fraction used in the relevant EEE. It should be noted that the provided data were derived from mixed polymer fractions from different WEEE recycling plants in Europe in 2010 (Waeger et al., 2010). The sampling procedure is described in detail in the study.[17]

Table 4-10: c-OctaBDE content in total (mixed) polymers fractions of different WEEE in Europe (concentration ranges in European WEEE Forum countries as described in Waeger et al., 2010)

Category/Article		c-OctaBDE content in total polymer fractions in [kg/ metric tonne] * ($C_{OctaBDE;Polymer}$)		
		Minimum	Maximum	**Mean**
3	ICT equipment w/o monitors	0.05	0.4	**0.225**

[17] http://ewasteguide.info/files/Waeger_2010_Empa-WEEEForum.pdf

3	CRT monitors	0.14	10.6	**2.54**
4	Consumer equipment w/o monitors (1 composite sample)	-	-	**0.15**
4	TV CRT monitors	0.05	3.54	**0.87**

* RoHS limit for c-OctaBDE is 0.1% or 1 kg/metric ton; CRT casings treated with c-OctaBDE contain approximately 15% c-OctaBDE including about 10% POP-PBDEs (hexaBDE and heptaBDE).

4.3.4 How to use collected data for the estimation of the POP-PBDEs inventory

This section outlines how to use collected data in calculations to get the estimation for inventory of POP-PBDEs in WEEE and related plastic in a country (see figure 4-1). Due to the differing natures (flow or stock) of the three stages (imported EEE, 4.3.4.1; stockpiled EEE, 4.3.4.2; EEE entering the waste stream, 4.3.4.3) in the life cycle of EEE/WEEE under consideration, the calculation approach is described for each stage.

Table 4-11 presents the most important numbers for the estimation. A crucial number is the c-OctaBDE content in the total polymer fraction varying with age and type of the EEE. As these data were used from mixed polymers in WEEE from Europe in 2010, it can be assumed that the given c-OctaBDE contents reflect a (European) mix of EEE manufactured before and after the ban of c-OctaBDE.

Table 4-11: Total polymer fractions and c-OctaBDE concentrations in relevant EEE categories (data from Europe; Waeger et al., 2010)

Relevant EEE	**Total polymer fraction (mean)**	**c-OctaBDE content (mean) in plastics**
	$f_{Polymer}$ [in % by weight]	$C_{OctaBDE;Polymer}$ in [kg/ metric ton]*]
WEEE category 3 (without CRTs)	42%	0.225
CRT computer monitors	30%	2.54
WEEE category 4 (without CRTs)	24%	0.15
CRT-TVs	30%	0.87

* RoHS limit for c-OctaBDE is 1 kg/metric ton or 0.1 wt %.

4.3.4.1 POP-PBDEs in imported EEE

Since POP-PBDEs production has stopped, new EEE imported are of minor concern for this inventory.[18] Hence the estimation can be limited to second-hand imports. The amount of POP-PBDEs is calculated as follows (see also figure 4-3):

$$M_{c\text{-}OctaBDE;imported\ EEE(j)} = M_{EEE(j);imported} \times f_{EEE(j);second\text{-}hand} \times f_{Polymer} \times C_{c\text{-}OctaBDE;Polymer}$$

Where:

- $M_{c\text{-}OctaBDE;imported\ EEE(j)}$ is the amount of c-OctaBDE in imported second-hand EEE(j) in [kg]

[18] Some c-OctaBDE (normally below 1%) is discovered in some EEE plastic due to recycling of polymers from WEEE (Bantelmann et al., 2010).

- $M_{EEE(j);imported}$ is the amount of imported (new + second-hand) EEE(*j*) in one year in [in metric tons] see section 4.3.1.1.
- $f_{EEE(j);second\text{-}hand}$ is the share of second-hand EEE(j) among the imports in [weight-%] see section 4.3.1.1 and table 4-4.
- $f_{Polymer}$ is the total polymer fraction in EEE(j) in [weight-%] see section 4.3.2 and table 4-9
- $C_{OctaBDE;Polymer}$ is the content of the c-OctaBDE in the total polymer fraction of EEE(j) in [kg/ metric tons] see section 4.3.3 and table 4-11

Consequently the POP-PBDEs (c-OctaBDE) contents of all relevant EEE(j) can be added up, in order to present an aggregated number for the sum of POP-PBDEs (c-OctaBDE) in all imported EEE.

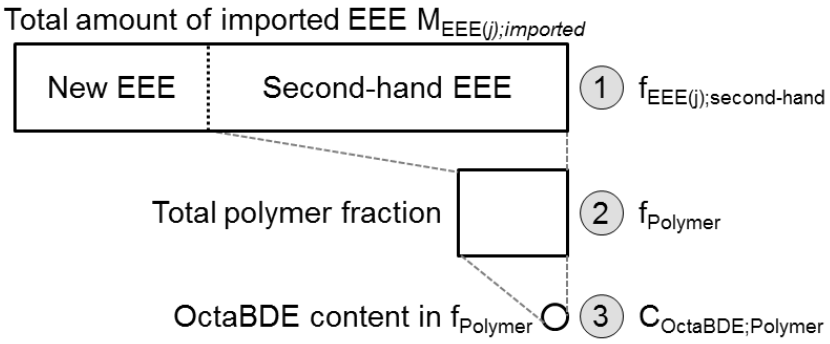

Figure 4-3: Scheme to estimate the amount of c-OctaBDE in imported EEE

4.3.4.2 POP-PBDEs in stocks of EEE

In contrast to the imported EEE, it is not feasible to split the stockpiled EEE into shares of old (second-hand) EEE and new EEE. Thus, the amount of POP-PBDEs is estimated considering the whole bulk of stockpiled EEE (see also figure 4-4):

$$M_{c\text{-}OctaBDE;EEE(j)} = M_{EEE(j);stockpiled} \times f_{Polymer} \times C_{c\text{-}OctaBDE;Polymer}$$

Where:

- $M_{c\text{-}OcctaBDE;stockpiled\ EEE(j)}$ is the amount of c-OctaBDE in stockpiled EEE(j) in [kg]
- $M_{EEE(j);stockpiled}$ is the amount of stockpiled EEE(*j*) in [in metric tons] see section 4.3.1.2
- $f_{Polymer}$ is the total polymer fraction in EEE(j) in [weight-%] see section 4.3.2 and table 4-9
- $C_{OctaBDE;Polymer}$ is the content of the c-OctaBDE in the total polymer fraction of EEE(j) in [kg/metric ton] see section 4.3.3 and table 4-11

Consequently the POP-PBDEs (c-OctaBDE) contents of all relevant EEE(j) can be added up, in order to present an aggregated number for the sum of POP-PBDEs (c-OctaBDE) in all stockpiled EEE.

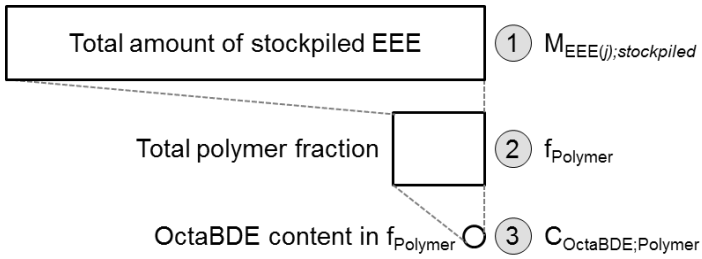

Figure 4-4: Scheme to estimate the amount of c-OctaBDE in stockpiled EEE

4.3.4.3 POP-PBDEs in EEE entering the waste stream

The amount of POP-PBDEs in WEEE is estimated as follows (see also figure 4-5):

$$M_{c\text{-}OctaBDE;WEEE(j)} = M_{WEEE(j)} \times f_{Polymer} \times C_{c\text{-}OctaBDE;Polymer}$$

Where:

- $M_{c\text{-}OctaBDE;WEEE(j)}$ is the amount of c-OctaBDE in WEEE(j) in [kg]
- $M_{WEEE(j)}$ is the amount of generated WEEE(*j*) in one year in [in tonnes] see section 4.3.1.3
- rest: see above

Consequently the POP-PBDEs (c-OctaBDE) contents of all relevant EEE (j) can be added up, in order to present an aggregated number for the sum of POP-PBDEs (c-OctaBDE) in EEE entering the waste stream. If WEEE is exported, this fraction can be calculated separately (see figure 4-1).

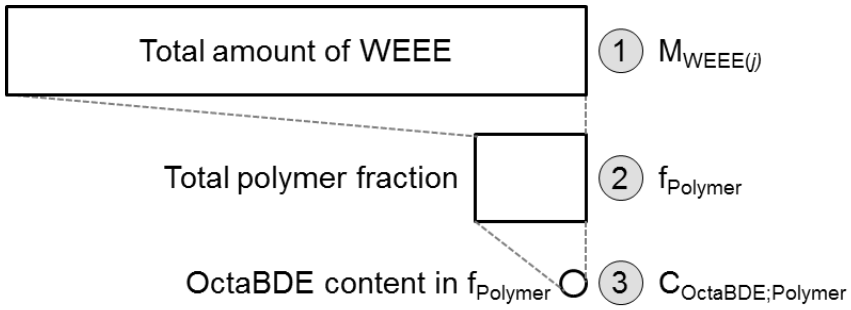

Figure 4-5: Scheme to estimate the amount of c-OctaBDE in EEE entering the waste stream (WEEE)

4.3.4.4 POP-PBDEs in secondary polymers from recycling from WEEE and imports

Information on further management and treatment of polymers generated from WEEE needs to be identified as such polymer fractions could be also further used and may influence the successful implementation of the Stockholm Convention (see figure 4-1). Therefore both material streams need to be considered.

Polymers generated from WEEE recycling are either:

- Thermally treated or disposed of in the country;

- Recycled to articles within the country (see also chapter 4 of *PBDE BAT/BEP Guidance*);
- Exported to other countries for recycling.

The material flows of plastic from domestic WEEE recycling and of imported WEEE plastic for recycling need to be monitored for their final end-of-life management or recycling. Information can be gathered from the facilities recycling WEEE and, if import of WEEE or used polymers are relevant, from customs. Also facilities processing WEEE/used plastic for recycling or for thermal treatment need to be contacted and assessed, and information on amounts noted.

If recycling activities of WEEE polymers take place in the country, the amount of the WEEE polymers used could be collected either from the recycling plant, the facilities providing the WEEE polymers or customs. Details of sampling and analysis of these polymers are described in the *Guidance for Strengthening the Regulatory Framework/Voluntary Agreements Regulating the Monitoring of Products/Articles that Contain or May Contain New POPs* (*Strengthening POPs Regulatory Framework Guidance*, Secretariat of the Stockholm Convention, 2012). The inventory can be done by estimating the amount of total polymers from WEEE used in recycling and the respective concentration of POP-PBDEs in these polymers (similar to the approach described above or by using own measurements).

Articles made from POP-PBDEs-containing materials could be labelled. It also needs to be assured that POP-PBDEs-containing materials are not recycled into articles with sensitive uses (see chapter 5 of *PBDE BAT/BEP Guidance*). Finally, these products need to be treated at end-of-life in an environmentally sound manner (see *PBDE BAT/BEP Guidance*; Stockholm Convention, Annex A, Parts IV and V).

4.3.5 Recalculation from c-OctaBDE content to POP-PBDEs

For the final inventory and article 15 reporting, the listed hexaBDE and heptaBDE (from c-OctaBDE) need to be calculated from the c-OctaBDE total amount. Average c-OctaBDE consists of the 43% of heptaBDE homologue and 11% the hexaBDE homologue (see table 4-12). Calculated numbers are the values that are to be submitted.

Table 4-12: HexaBDE and heptaBDE present in EEE, WEEE and in polymers in recycling

Homologues	Distribution homologues c-OctaBDE	POP-PBDEs in import for inventory year 20XX*	POP-PBDEs in stocks for inventory year 20XX*	POP-PBDEs entering the waste stream 20XX*	POP-PBDEs in recycled polymers for inventory year 20XX*
Inventoried c-OctaBDE		Σc-OctaBDE (4.3.4.1)	Σc-OctaBDE (4.3.4.2)	Σc-OctaBDE (4.3.4.3)	Σc-OctaBDE (4.3.4.4)
HexaBDE	**11%**				
HeptaBDE	**43%**				
OctaBDE**	35%				

* 20XX should be replaced by the year of the inventory.

** If polymers from WEEE are exported, these should also be inventoried.

**Not listed as POP-PBDEs in the Convention and therefore excluded from reporting.

Note: C-PentaBDE has been used to an unknown and most probably minor extent in PWBs with no measured data available. Therefore this is currently not quantitatively considered in the POP-PBDEs inventory. The quantity of PWBs in the Party's territory might be estimated and noted until contamination levels have been established.

4.4 Step 4: Managing and evaluating data

When a country improves the inventory of the EEE/WEEE over time, the data quality will become better and more reliable. It is assumed that countries establish and update inventories of EEE/WEEE for waste management and material recovery purposes and that this will result over time in more robust inventories.

In this step the data need to be assessed for completeness and plausibility, possibly including the comparison with data from other countries in the region. Data gaps may (partly) be filled by extrapolation of available statistical data.

The gathered general inventory data for EEE and WEEE could be managed in an appropriate database and sent to the governmental agency responsible for statistics. Since the data are highly valuable for the (waste) management of EEE and WEEE, they could be made available to departments responsible for waste and resource management in the country (Ministry of Environment or other responsible ministries) and to the competent authority of the Basel Convention. The data could possibly be fed into and further managed within a database of the governmental body responsible for waste and resource management.

4.5 Step 5: Preparing the inventory report

The compiled data for this sector are included with the methodology used and the detailed calculations in the POP-PBDEs inventory report. This inventory can appear as a chapter in the overall report. Any country-specific adjustments and estimates could be noted and described.

5 Inventory of POP-PBDEs in the transport sector

The transport sector (cars, buses, trucks, trains, planes, and ships) is one of the large material flows of goods and ultimately becomes a large waste and recycling flow. The end-of-life management of the transport sector is a highly relevant material flow for the recovery of materials and for managing pollutants (see *PBDE BAT/BEP Guidance*; Vermeulen et al., 2011).

A large proportion of c-PentaBDE use has been within the transport sector; the major use was for treatment of flexible PUR foams (automotive seating, head rests, car ceilings, acoustic management systems, etc.) and a minor use was in back-coating of textiles used on car seats. C-OctaBDE has also been used to some extent in plastics vehicle parts (steering wheels, dashboards, door panels, etc.).

Cars and other vehicles (trucks and buses) are the major portion of the transport sector containing the largest volume of POP-PBDEs. The focus and methodology for the inventory are therefore centred on these vehicles. Ships and aeroplanes are not included in the described calculation methodology so as to simplify the details. If a country has a relevant aeroplane and/or ship fleet, these sectors may be calculated and inventoried by an analogous approach.

Since POP-PBDEs were produced and used in the period from approximately 1975 to 2004 (see chapter 2), only vehicles produced during this period need to be inventoried for POP-PBDEs.[19]

If the Party has already established an inventory for the transport sector, the POP-PBDEs inventory can build on these data (see below). Such detailed inventories of the transport sector, however, do not often exist in developing countries. In these cases the development of the POP-PBDE inventory could lead to developing an inventory of the transport sector in support of the waste/resource management of this material flow. A step-by-step approach is suggested for the development of the POP-PBDEs inventory in a country (refer to figure 3-1). See the case study on inventory of PBDEs in EEE and WEEE.

5.1 Step 1: Planning the inventory

This first step focuses on defining the scope of the inventory and developing a work plan.

The inventory of POP-PBDEs in the transport sector is expected to address the following:

- Vehicles (second-hand) imported (for the inventory year and for the years with relevant vehicle imports as a base for estimating stocks);
- Vehicles in use;
- End-of-life vehicles in the inventory year and those having already reached end-of-life;
- Polymers from end-of-life vehicles.

Since POP-PBDEs were produced and used in the period from approximately 1975 to 2004 (see chapter 2), only vehicles produced during this period need to be inventoried for POP-PBDEs.

Appropriate members of the inventory task team with relevant qualifications and related experience need to be selected to conduct the inventory of this sector. Specific stakeholders for the inventory of the transport sector are listed in table 3-1. It is important that the inventory task team members include key stakeholders to conduct the inventory. It has been found effective in pilot studies to include a research group working on waste management and material flows in the inventory team. Additional stakeholders for data collection and as information sources could be contacted during the information gathering and evaluation steps.

In developing countries informal sectors are often involved and play a significant role in collection and recycling. It is important to involve such sectors to capture the activity in the inventory of end-of-life vehicles.

5.2 Step 2: Choosing data collection methodologies

A detailed methodology for establishing an inventory in the transport sector is described in this chapter. The approach can be evaluated and tailored to the national situation (see e.g. case study on Nigeria). Training on conducting the inventory is usually given, often as a workshop. Feedback from the stakeholders could be considered in articulating inventory methodologies.

5.2.1 Tier I: Initial assessment

The aim of the initial assessment is to find out if inventory data on the transport sector have already been compiled in the country. Readily available data on the transport sector may be

[19] HBB was used in PUR foam in the transport sector from 1970 to 1976 mainly in the United States and can be considered in the inventory.

gathered from national statistics, international statistics[20] and statistics of industrial associations related to the transport sector (importers of vehicles, end-of-life treatment) and ministries with relevant information. Such data may be sufficient for a preliminary inventory.

Statistics or import data from other countries in the region can be used for approximate estimates for the inventory where there are few national data available.

Data to be gathered for the initial assessment include:

- Number of registered vehicles (cars, buses and trucks) in use and on sale in the country, including:
  - Year of manufacture (for estimating the share of vehicles manufactured between 1975 to 2004);
  - Approximate percentage distribution of the regions from which the vehicles were imported;

  If this information is not available, it has to be estimated by extrapolation of available statistical data and by expert judgement.

- Numbers of imported (and exported) vehicles and vehicles produced in the country including available data from:
  - International statistics on the trade of vehicles;
  - National import (and export) statistics, and import statistics from customs and port authorities;
  - Information from importers (and exporter) or retailers.

  It is helpful to utilize all the available import data (e.g. 1975 to 2010) to calculate the total import of POP-PBDEs over the years and to show any trends (see case study of Nigeria).

- Numbers of vehicles having reached their end-of-life stage in the past (since 1980) until the inventory year (considering the proportion produced between 1975 and 2004):

  This information could be derived from deregistration of vehicles, statistics compiled on end-of-life vehicles or by the average (estimated) lifespan.

- Available information on current and past waste management practices of end-of-life vehicles in the country:

  This information needs to be compiled in particular for the polymer fraction. Information might be available from ministries working on transport or waste management (ministries of environment, transport, industry, etc.), city governments/competent authorities and/or related industrial sectors and research institutions.

- Recycling practices of the polymer materials from the end-of-life treatment of cars/vehicles:

  This information should include the plastics (dashboard, bumpers etc.) and PUR foams (seats and head/arm rest etc.).

Compilation and evaluation of the available data and further information needs

After compilation of the data any missing information needed to fill out the data compilation tables (see tables 5-1 to 5-6) can be identified in order that the gaps can be filled (step 4) and the compiled data can then be updated to an preliminary inventory.

[20] For example, UN Comtrade: http://unstats.un.org/unsd/comtrade/

5.2.2 Tier II: Preliminary inventory

All useful data compiled in Tier I should be utilized as base for Tier II (preliminary inventory). A strategy could be developed to address any data gaps. i.e.:

- Which task team member might be able to provide missing data;
- If other stakeholders are needed to fill gaps;
- Which data gaps could reasonably be filled by extrapolation of the available data;
- If a specific consultancy contract might be needed for a part of the missing information and the terms of reference for such a task.

This information gathering step might also include:

- Communication with regional/city authorities on their statistics on transport and end-of-life management;
- Interviews with vehicle importers and retailers;
- Interviews/questionnaires with scrap recyclers (cars and other vehicles);
- Interviews with recyclers of polymers.

Any data still missing need to be filled/estimated using expert judgement based on the data collected. Where larger uncertainties exist in the chosen factors (e.g. share of vehicles from 1975 to 2004 for a certain inventory sector; regional distribution of imports), the possible range of values could be noted in the inventory.

Tables 5-1 to 5-6 can be filled out by following step 3 and onwards.

5.2.3 Tier III: In-depth inventory

An in-depth inventory can be carried out by further improving the data reported in tables 5-1 to 5-6 for the preliminary inventory. This might be achieved by closing data gaps and improving statistical data.

It can be assessed if engaging field measurement equipment such as sliding sparks and XRF handheld equipment could support such a refining. This helps evaluate if any plastics or PUR foam used in vehicles from a certain region contain POP-PBDEs. Please note that the field screening equipment can only detect the total bromine content, and a confirmation may be required by using instrumental analysis for positive tested samples (see *Guidance on Screening and Analysis of POPs in Articles and Products*). Statistically significant measurement data can be reflected to get more accurate data for tables 5-1 to 5-6. Technical experts need to supervise any sampling and measurement activities. Such screening studies might be coordinated on a regional basis to minimize cost and maximize output.

The establishment of a material flow analysis of the transport sector and the related substance flow of POP-PBDEs has been found to be useful and could be considered in the development of an in-depth inventory.

5.3 Step 3: Compiling data from sectors

As it is predominantly unknown which vehicle manufacturers used POP-PBDEs as well as the period of such use. Monitoring data for POP-PBDEs in vehicles are also not available publicly[21] and only few data on POP-PBDEs in shredder residues are available. Therefore the following factors are needed to estimate the presence of POP-PBDEs in this sector:

- For which years POP-PBDEs have been used in the transport sector (5.2.1)
- Factors for calculating the total amount of POP-PBDEs include:
  - Amount of POP-PBDEs in individual vehicles (5.3.1);
  - Number of POP-PBDEs impacted vehicles (5.3.1);
  - Regional differences of use of POP-PBDEs in vehicles and factors to account for the regional differences (5.3.2).

5.3.1 Amount of POP-PBDEs in impacted cars, trucks and buses

C-PentaBDE in the major PUR foam fraction in transport (seats, head and arm rests) has been applied to 0.5 to 1% by weight (Ludeka, 2011). For headliners, up to 15% of c-PentaBDE has been used (Ludeka, 2011).[22] Considering an average use of 1% c-PentaBDE by weight in PUR foam in transport, the following estimates can be made:

- **Cars:** POP-PBDEs treated cars with approximately 16 kg (14 to 18 kg; Ludeka, 2011) of PUR foam contain approximately 160 g c-PentaBDE.[23] This estimate is a bit low compared to another estimate for c-PentaBDE in treated cars of 250 g/car (ESWI, 2011);
- **Trucks**: The amount of PUR foam is estimated to be similar as for a passenger car and therefore 160 g c-PentaBDE per impacted truck;
- **Buses**: An average PUR foam use is estimated at approximately 100 kg.[24] With a similar average application rate of c-PentaBDE, an impacted "average" bus is estimated to contain 1 kg c-PentaBDE. For countries that mainly have mini-buses (often the case in developing countries), the content of PUR foam for mini-buses can be used (see the case study in the Transport Sector).

[21] Some data on levels in dust in cars have been published.

[22] Depending on whether raw foam materials or composite seating, headliners or floor coverings are tested, compliance with MVSS 302 requires varying amounts of flame retardant content.

[23] C-PentaBDE was also used in back-coating in textiles in transport. Since the 160 g c-PentaBDE is rather an upper conservative estimate, no additional POP-PBDEs are considered for this minor use for simplification purposes. That textiles from cars might be treated with c-PentaBDE can, however, be considered in the waste management of textiles from the transport sector (see chapters 5 and 6 of *PBDE BAT/BEP Guidance*). Also some cars might only have some PUR foam or only textiles treated and therefore contain less than 160 g POP-PBDEs.

[24] For mini-buses 32 kg of PUR-foam is considered, small buses (approx. 20 seats) 60 kg of PUR foam, and larger buses (approx. 80 seats) 240 kg PUR foam. An average of 100 kg PUR foam for the category "bus" was chosen for reasons of simplification. Countries can adjust this factor to their reality (see case study of Nigeria).

5.3.2 Total use of POP-PBDEs in transport, regional use patterns and related impacted factors

Total numbers of impacted cars[25]

Only a portion of the cars produced between 1975 and 2005 worldwide have been treated with c-PentaBDE. It is estimated that about 37% of the approximately 100,000 tonnes c-PentaBDE production (approximately 37,000 tonnes) has been used in the transport sector (UNEP, 2010a, 2010b). Considering the estimated 160 g of c-PentaBDE/car, approximately 230 million cars containing in total 3.7 million tonnes c-PentaBDE treated PUR foam could have been impacted.

Regional use pattern and regional factors

The use of c-PentaBDE depended on the national/regional legislation and production/use patterns. Approximately 90% of c-PentaBDE has been used in the United States/North America (UNEP, 2010a, 2010b). Therefore, approximately 200 million cars and other vehicles produced there from 1975 to 2004 could have been contaminated with c-PentaBDE. This does not cover all vehicles produced[26] during the period in question due to the use of other flame retardants (e.g. phosphorous flame retardants and later also the brominated alternative Firemaster 550/600). In addition, a significant share of vehicles was imported. Therefore, a factor of 0.5 (50% of vehicles impacted) is selected for adjustment for vehicles in/from this region.[27]

A factor of 0.05 is suggested as a regional adjustment factor for Europe (5% of cars produced in the region between 1975 and 2004 are estimated to be impacted by POP-PBDEs). This factor is derived from measurements of European automotive shredder residues having contained an average of approximately 7 g c-PentaBDE per car in around 2000, corresponding to 4.4% impacted cars when considering 160 g c-PentaBDE for an impacted car (Morf et al., 2003, using data from Danish EPA, 1999).

In vehicles produced in Asia the overall use of c-PentaBDE treated cars might be even lower since Japan discontinued its use of c-PentaBDE in the early 1990s. But since there are some uncertainties about c-PentaBDE production and use in China, a factor of 0.05 (5% of cars produced between 1975 and 2004 in the Asian region are estimated to be impacted by c-PentaBDE) is also selected for vehicles in/from this region.

For vehicles produced in Latin America and the Caribbean region and in the African regions no data on POP-PBDEs content in transport are available. Due to the main use of POP-PBDEs in North America also the low impact factor of 0.05 is suggested as regional factor until data are available.

It should be kept in mind that for Europe, Asian and other regions, this estimate is an upper limit for POP-PBDEs in vehicles as the use of POP-PBDEs was discontinued long before 2004.[28]

The suggested approach and, particularly, the impact factors might be refined by bromine screenings[29] in combination with POP-PBDEs measurement for the transport fleet within a region.

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[25] The calculation is developed with cars since they are by far the largest part of the transport fleet. C-PentaBDE was also used in other vehicles (buses or trucks), but total use was considerably lower.

[26] Approximately 260 million vehicles were produced in the United States from 1975 to 2004. (http://de.wikipedia.org/wiki/Wirtschaftszahlen_zum_Automobil#Nach_L.C3.A4ndern)

[27] Approximately 50% of vehicles from this region produced between 1975 to 2004 are considered c-PentaBDE treated.

[28] Since c-PentaBDE and c-OctaBDE were produced until 2004, they might also have been used in Europe and Asian countries. This also justifies that vehicles are considered possibly impacted by POP-PBDE in these regions. After data from screening of POP-PBDEs in vehicles are generated, the factors could be adjusted in the future.

To minimize monitoring costs and efforts, any monitoring could be coordinated by Stockholm Convention regional centres, for example.

Please note: Cars/vehicles from all regions produced after 2004[30] or produced before 1970 can be considered largely POP-PBDEs and HBB free with the exemption of recycled polymers used.

5.3.3 General formula to calculate POP-PBDEs in vehicles

The following formula is used to calculate the POP-PBDEs content of vehicles for the different categories (cars, trucks or buses) in different life cycle stages (see section 5.3.4; figure 5-1):

$$\text{Quantity of POP-PBDEs}_{\text{Vehicle category}} = \text{Number of vehicles}_{\text{category}} \times \text{POP-PBDEs}_{\text{category}} \times F_{\text{regional}}$$

Where:

- *Number of vehicles*$_{category}$ is the number of vehicles (manufactured in 1975-2004) present in a category (car, bus or truck) calculated for the different life cycle stages (see 5.3.4 for a brief explanation of the reason to calculate these for the key life cycle stages).
- *POP-PBDEs*$_{category}$ is the quantity of POP-PBDEs in an individual car, truck or bus treated with POP-PBDEs.
- $F_{regional}$ The regional factor for vehicles are described in section 5.3.2.

5.3.4 Individual stages of the vehicle life cycle for data compilation

For the data compilation of POP-PBDEs in the transport sector it is useful to assess and inventory the vehicles in the following life cycle stages (see figure 5-1):

- The import (export)[31] of vehicles (manufactured until the end of 2004) (section 5.3.6). These data provide information on how much POP-PBDEs are entering (leaving) the country via this route in the inventory year and are the starting point for managing this material flow. (Please note that the imported vehicles are also included in the inventory of "currently in use and sale" and that these two categories are not meant to be added);
- The vehicles currently in use or on sale (vehicles produced until the end of 2004) (section 5.3.5). This is the main stock of POP-PBDEs to be managed in the future from this sector;
- The end-of-life and end-of-use vehicles taken out of operation in the inventory year (removed from the vehicle registration) and requiring waste management or are sold on the market or exported (section 5.3.7). The data on end-of-life vehicles should be collected separately for planning appropriate waste management;
- The amount of POP-PBDEs-containing materials disposed of in the past from the transport sector. Note that this contributes/is related to the contaminated site assessment (section 5.3.8).

And if (part of) the polymers from end-of-life vehicles are recycled in the country:

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[29] The detection of bromine in PUR foam in vehicles produced before 2005 is a strong indication for c-PentaBDE since it was the major brominated flame retardant used for PUR foam applications.

[30] Some uncertainty exists about the former production of c-PentaBDE in China (UNEP, 2010a, 2010b).

[31] Most countries (in particular developing countries) are importing and not exporting vehicles to a significant extent. Therefore only import is considered here. For countries exporting vehicles to a significant extent, the same table can be used to calculate the export of vehicles.

- The amount of POP-PBDEs-containing polymers recycled from the end-of-life vehicles for the inventory year (section 5.3.10). These data are relevant in deciding on the appropriateness of those recycling activities and, depending on the POP-PBDEs content,[32] if these activities should be registered as specific exemptions for recycling of POP-PBDEs-containing materials.

After generation of these national data on vehicles in the life cycle stages, the quantity of POP-PBDEs in the individual stages can be estimated by the calculations detailed in tables 5-1 to 5-6 and based on the calculation formula described above.

The assessment of POP-PBDEs can be refined by analytical measurements in vehicles (preferably end-of-life) and automotive shredder residues.

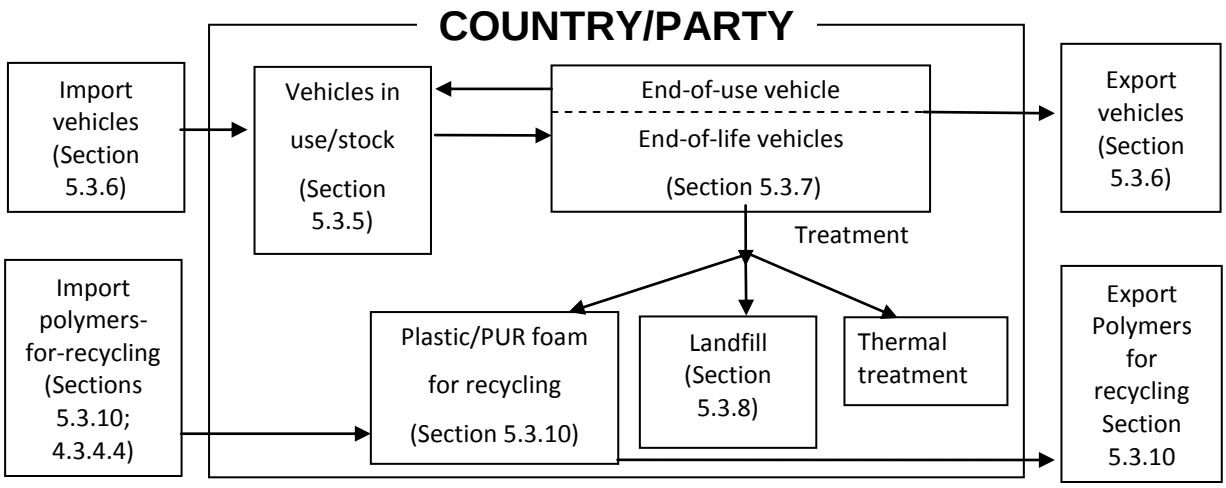

Figure 5-1: Material flow of the transport sector and the life cycle stage for POP-PBDEs inventories

(Note: countries with production need to consider manufactured vehicles)

5.3.5 Calculation of POP-PBDEs of vehicles in current use/sale

Vehicles in use represent a major stock of POP-PBDEs and are important for the future planning of waste management of the transport sector. The inventory of POP-PBDEs is directly relevant to the implementation of the Stockholm Convention. These vehicles are normally registered and the data might include the year of manufacture. If this information is not available, an estimate needs to be made of the percentage of cars, trucks and buses that have been produced before 2005 and are still in use.

If national data are not available or very fragmented, international statistics could be used for a preliminary inventory. Data reported as penetration rates (normally vehicles per 1,000 persons)[33] can be combined with expert judgement to generate a simplified age distribution estimate and the regions from which they were imported and might be used for a preliminary inventory and can be refined in an in-depth inventory. Any assumptions made, together with uncertainties, should be noted in the inventory.

[32] For the conclusion on the appropriateness of recycling, actual measurement data could be generated.

[33] For the average amount of vehicles in a country per 1,000 inhabitants see for example http://www.nationmaster.com/graph/tra_mot_veh-transportation-motor-vehicles

The calculation of POP-PBDEs in vehicles in current use can be compiled according to table 5-1.

Table 5-1: Amount of POP-PBDEs in PUR foam of vehicles in current use in the inventory year

Number of cars/trucks (manufactured in US before 2005)	Amount of c-PentaBDE per car/truck	Total amount POP-PBDEs in cars in use manufactured in US
5-1a)	160 g per car	**No. of cars and trucks x 0.16 kg x 0.5*= _____kg**
Number of cars/trucks in use (manufactured in other regions before 2005)	Amount of c-PentaBDE per car	Total amount POP-PBDEs in cars in use (manufactured in regions other than US)
5-1b)	160 g per car	**No. of cars and trucks x 0.16 kg x 0.05*= _____kg**
Number of buses in use (manufactured in US before 2005)	Amount of c-PentaBDE per bus	Total amount PBDE in buses in use (manufactured in US)
5-1c)	1000 g per bus	**No. of buses x 1 kg x 0.5*= _____kg**
Number of buses in use (manufactured in other regions before 2005)	Amount of c-PentaBDE per bus	Total amount POP-PBDEs in cars in use (manufactured in regions other than US)
5-1d)	1000 g per bus	**No. of buses x 1 kg x 0.05*= _____kg**
Total c-PentaBDE 5-1)	-	**Sum of c-PentaBDE: _____kg**

*Factor estimating the share of impacted vehicles in the region of production (1975-2004)

5.3.6 Calculation of POP-PBDEs in imported/exported vehicles

The import of used cars, buses, trucks and other transport can be a major and ongoing source of POP-PBDEs, particularly for low and middle-income countries, and needs to be quantified.

For the calculation of the amount of POP-PBDEs imported via the transport sector, the number of vehicles (produced between 1975 and 2004) imported for the specific inventory year need to be compiled. It is helpful to utilize all available import data (e.g. 1975 to 2010) to calculate the total import of PBDE over the years and to show any trends. The number of imported vehicles could be derived from import statistics, international trade statistics, and data from customs and port authorities or from associations dealing with sales of cars and other vehicles.

If the year of manufacture is not available in the import statistics, the number of second-hand cars produced before 2005 in the imports should be estimated. The average value of the imported cars could be derived from custom statistics and used to estimate such share. Calculation of POP-PBDEs in the import of vehicles can be calculated according to table 5-2.

With the same approach also the export of vehicles can be assessed in an own analogous calculation. If a country exports end-of-use vehicles, the inventory could treat the exports in the opposite way to imports and deduct the exported POP-PBDEs from the total. The amount of exported POP-BDEs via export of vehicles (and exported polymers see 5.3.10) should also be noted in the inventory.

Table 5-2: Amount of POP-PBDEs in PUR foam of imported vehicles in the inventory year

Number of imported cars/trucks (manufactured in US before 2005)	Amount of c-PentaBDE per car/truck	Total amount POP-PBDEs in cars imported from US in 20XX
5-2a)	160 g per car/truck	**No. of cars and trucks x 0.16 kg x 0.5*= _____kg POP-PBDEs**
Number of imported cars/trucks (manufactured in other regions before 2005)	Amount of c-PentaBDE per car/truck	Total amount POP-PBDEs in cars imported in 20XX from regions other than US
5-2b)	160 g per car/truck	**No. of cars and trucks x 016 kg x 0.05*= _____kg POP-BDEs**
Number of imported buses (manufactured in US before 2005)	Amount of c-PentaBDE per bus	Total amount POP-PBDEs in imported buses in use (manufactured in US before 2005)
5-2c)	1000 g per bus	**No. of buses x 1 kg x 0.5*= _____kg POP-BDEs**
Number of buses (manufactured before 2005 in regions other then US)	Amount of c-PentaBDE per bus	Total amount POP-PBDEs in imported buses in use (manufactured before 2005 in regions other than US)
5-2d)	1000 g per bus	**No. of buses x 1 kg x 0.05*= _____kg POP-PBDEs**
Total c-PentaBDE 5-2)	-	**Sum of c-Penta-BDE: _____kg**

*Factor estimating the share of impacted vehicles in the region of production (only from 1975-2004)

5.3.7 Calculation of POP-PBDEs in ELVs for the respective inventory year

The inventory of ELVs in a specific year is an important consideration for waste management and the related recycling sectors.

Data on the number of vehicles being scrapped might be derived from national statistics or the number of vehicles whose registration was cancelled. If such data are not available, the number of end-of-life vehicles might be estimated by the number of total vehicles in use and their estimated life expectancy.

The export of end-of-use/end-of-life vehicles and related exported POP-PBDEs are considered in section 5.3.6. Exported POP-PBDEs in polymers from ELVs are considered in section 5.3.10. The calculations of POP-PBDEs from end-of-life vehicles can be compiled in table 5-3.

Table 5-3: Amount of POP-PBDEs in PUR foam of end-of-life vehicles in the inventory year

Number of ELV cars/trucks (manufactured in US before 2005)	Amount of c-PentaBDE per ELV car/truck	Total amount POP-PBDEs in ELV cars/trucks in 20XX (manufactured in US before 2005)
5-3a)	160 g per car/truck	**No. of cars and trucks x 0.16 kg x 0.5*= _____kg POP-PBDEs**
Number of ELV cars/trucks (manufactured in other	Amount of c-PentaBDE per car/truck	Total amount POP-PBDEs in ELV cars/trucks in 20XX (manufactured outside the US before 2005)

regions before 2005)		
5-3b)	160 g per car/truck	**No. of cars and trucks x 0.16 kg x 0.05*= _____kg POP-PBDEs**
Number of ELV buses (manufactured in US before 2005)	Amount of c-PentaBDE per bus	Total amount POP-BDEs in ELV buses in 20XX (manufactured outside the US before 2005)
5-3c)	1000 g per bus	**No. of buses x 1 kg x 0.5*= _____kg POP-BDEs**
Number of ELV buses (produced from other regions before 2005)	Amount of c-PentaBDE per bus	Total amount POP-PBDEs in ELV buses in 20XX (produced in other regions than US before 2005)
5-3d)	1000 g per bus	**No. of buses x 1 kg x 0.05*= _____kg POP-PBDEs**
Total c-pentBDE 5-3)	-	**Sum of c-Penta-BDE: _____kg**

*Factor estimating the: share of impacted vehicles in the region of production (only from 1975-2004)

5.3.8 Calculation of POP-PBDEs in historically disposed wastes from vehicles

In most countries the wastes from ELV containing the POP-PBDEs fraction (the Automotive Shredder Residues (ASR) or the seats and other polymer parts) have been and are mainly disposed to landfills or dump sites. An inventory for POP-PBDEs (and other pollutants present in these end-of-life vehicle fractions) could address these POP-PBDEs deposits since they can be considered secondary pollutant sources or, depending on the extent of deposit, might be considered as contaminated sites (see e.g. Takeda, 2007; Weber et al., 2011).

For the calculation, the total amount of POP-PBDEs-containing materials from end-of-life vehicles disposed to landfills/dumps from 1980 until the current inventory year 20XX should be inventoried.

POP-PBDEs in landfill/dumps from end-of-life vehicles are calculated according to table 5-4.

Table 5-4: Amount of POP-PBDEs in wastes from end-of-life vehicles disposed to landfills/dumps from 1980 until the inventory year

Number of cars/trucks (manufactured in US before 2005) where wastes have been disposed.	Amount of c-PentaBDE per car/truck	Total amount of POP-PBDEs in disposed wastes from cars/truck (manufactured in US before 2005) from 1980 to inventory year 20XX
5-4a)	160 g/car	**No. of cars and trucks x 0.16 kg x 0.5*= _____kg POP-PBDEs**
Number of cars/trucks (manufactured in other regions 2005) where wastes have been disposed.	Amount of c-PentaBDE per car/truck	Total amount of POP-PBDEs in disposed wastes from cars/truck (manufactured outside the US before 2005) from 1980 to inventory year 20XX
5-4b)	160 g/car	**No. of cars and trucks x 0.16 kg x 0.05*= _____kg POP-PBDEs**
Number of buses	Amount of c-PentaBDE	Total amount of POP-PBDEs in disposed wastes

(manufactured in US before 2004)	per bus	from buses (manufactured in US before 2005) from 1980 to inventory year 20XX
5-4c)	1000 g per bus	**No. of buses x 1 kg x 0.5*= _____kg** POP-PBDEs
Number of buses (manufactured in other regions before 2005)	Amount of c-PentaBDE per bus	Total amount of POP-PBDEs in disposed wastes from cars/truck (manufactured outside the US before 2005) from 1980 to inventory year 20XX
5-4d)	1000 g per bus	**No. of buses x 1 kg x 0.05*= _____kg** POP-PBDEs
Total c-PentaBDE 5-4)	-	**Sum of** c-PentaBDE**: _____kg**

*Factor estimating the share of impacted vehicles in the region of production (only from 1975-2004)

5.3.9 Calculation of listed PBDEs in the transport sector

It is not the amount of c-PentaBDE or c-OctaBDE in the material flow that is reported for the Stockholm Convention but more specifically the relevant POP-PBDEs homologues: TetraBDE, pentaBDE, hexaBDE and heptaBDE. These homologues can be calculated from the estimated amount of c-PentaBDE (or c-OctaBDE) by considering the percentages of homologues in the commercial mixtures shown in table 5-5.

For management considerations the associated polymer volumes possibly impacted by POP-PBDEs would also be noted in the inventory report.

Table 5-5: Recalculation of POP-PBDEs* present in the transport sector (data from tables 5-1 to 5-4) to the listed POP-PBDEs homologues (tetraBDE, pentaBDE, hexaBDE and heptaBDE) for the relevant life cycle stages

	Distribution homologues c-PentaBDE	POP-PBDEs in vehicles currently in use in inventory year 20XX** (in kg)	POP-PBDEs imported***[34] in vehicles in the inventory year 20XX** (in kg)	POP-PBDEs in end-of-life vehicles in the inventory year 20XX** (in kg)	POP-PBDEs disposed off in the past from the transport sector (in kg)
Inventoried POP-PBDE*		Σ PentaBDE (Table 5-1)	Σ PentaBDE (Table 5-2)	Σ PentaBDE (Table 5-3)	Σ PentaBDE (Table 5-4)
tetraBDE	33%				
pentaBDE	58%				
hexaBDE	8%				
heptaBDE	0.5%				

*c-OctaBDE possibly contained in plastic in vehicles in low levels of 50 ppm (around PCB low POPs content; Morf et al., 2003) are not considered here in the inventory but only if these plastic is recycled (see 5.3.10).

** For countries with relevant export activities of used cars this sector should also be calculated

*** In the respective inventory year; it can be useful to calculate other years with available data (e.g. from 1980 on).

[34] Please note that the imported vehicles are also included in the inventory of "currently in use/sale" and that these two categories are not summed up.

5.3.10 Estimation of POP-PBDEs from ELVs entering recycling processes[35]

The polymer fractions (both PUR foam and plastics) from ELVs are treated by disposal, recycling and/or thermal treatment. The Stockholm Convention has specific exemption for POP-PBDEs recycling, and therefore it is important to estimate the recycling amount of POP-PBDEs in the transport sector.

The recycling of PUR foam and plastic from ELVs is possibly undertaken by specialized companies (Vermeulen et al. 2011) or by the informal sector. While in the past most polymers from transport were disposed, more recycling in this sector can be expected in the future due to legislative requirements in respect to recycling quota in certain regions (Vermeulen et al. 2011) and the general need for more closed material cycles.

Such recycling operations could be assessed and quantified in the inventory process. The extent of recycling and the related information (company, method, articles) could be reported to the national focal point or the steering committee. The technologies and approaches used in the companies could be reviewed by referring to the *PBDE BAT/BEP Guidance*.

The extent of recycling of c-PentaBDE-containing PUR foam from ELVs can be calculated according to table 5-6.

For plastics from end of life vehicles currently no impact factor can be given. The only measured data is from Europe around 2000 and indicated low values around 50 ppm already at that time (Morf et al 2003)[36]. If relevant domestic recycling activities of polymers from transport sector take place, measurements of POP-PBDEs[37] in the used polymers could be conducted to evaluate if and to what extent POP-PBDEs are present. If POP-PBDEs are detected in the input material, separation could be considered (see *PBDE BAT/BEP Guidance*). If the country decides to recycle the POP-PBDEs- containing materials, the articles that are manufactured from these materials would be inventoried.

Also if import of used polymers-for-recycling is discovered this should be noted. If the imported material contains POP-PBDEs, it could be included in the inventory (see also section 4.3.4.4). If polymers from ELVs are exported this could also be noted and possibly inventoried.

Table 5-6: Amount of POP-PBDEs in PUR foam recycled from transport sector in the inventory year

PUR foam recycled from end of life vehicles _____kg (This amount could be estimated from the estimated amount of PUR foam in end-of-life vehicles in table 5-3 and the recycle share)	**PUR foam recycled from vehicles (kg) x 0.01[#] x** **((share vehicles US x 0.5) + (share vehicles other regions x 0.05))*** **= _____kg c-PentaBDE** **The breakdown of c-PentaBDE is as follows.** **tetraBDE (kg c-PentaBDE x 0.33) _____kg** **pentaBDE (kg c-PentaBDE x 0.58) _____kg** **hexaBDE (kg c-PentaBDE x 0.08) _____kg** **heptaBDE (kg c-PentaBDE x 0.05) _____kg**

[35] Please note that the recycling of POP-PBDE-containing materials requires an exemption to be registered.

[36] As a c-OctaBDE contamination factor for plastic in vehicles, a Swiss study reported approximately 5.6 g c-OctaBDE per car (in 110 kg polymers) corresponding to 50 g per tonne (Morf et al., 2003) and therefore at levels around the low POPs limit for PCBs. Therefore the c-OctaBDE from transport was not included in this inventory.

[37] As methodology for measuring average POP-PBDE in polymers the approach of Waeger et al. (2010) for measuring POP-PBDE in WEEE polymers might be applied with appropriate modifications.

The POP-PBDEs content in the plastics used for vehicles (Ludeka 2011)

*For the %-distribution of the regions the distribution from the transport inventory may be used.

5.4 Step 4: Managing and evaluating data

In the data evaluation step the data need to be assessed for completeness and plausibility, possibly including a comparison with data from other countries in the region. Data gaps may (partly) be filled by extrapolation of available statistical data. If the quality of the data is considered inadequate, further data collection can be undertaken.

When a country improves the inventory of the transport sector over time, the data quality will become better and more reliable. It is assumed that countries establish and update inventories of the transport sector for automobile taxes, urban planning, as well as waste management and material recovery purposes, and that this will result over time in robust sector inventories. Such updated inventories for the transport sector could be utilized for the update of the POP-PBDEs inventory.

The gathered general inventory data for the transport sector could be managed in an appropriate database and sent to the governmental agency responsible for statistics. Since the data are highly valuable for the (waste) management of end-of-life vehicles, they should be made available to departments responsible for waste and resource management in the country (ministry of environment or other responsible ministries) and possibly to the competent authority of the Basel Convention. The data could possibly be fed into and further managed within a database of the governmental body responsible for waste and resource management.

5.5 Step 5: Preparing the inventory report

The final data for this sector need to be accompanied by the methodology used and the detailed calculations as an audit trail in a separate chapter of the POP-PBDEs inventory report. All country-specific adjustments and estimates should be noted and described.

6 Inventory of POP-PBDEs in other uses

Other uses of POP-PBDEs (e.g. furniture, mattresses, rebond materials, textiles, construction materials, rubber, and drilling operations) are thought to be of minor relevance for most countries due to:

- The relative low overall usage in most of these applications apart from furniture, for which PUR containing c-PentaBDEs was used in large quantities in the United States (UNEP, 2010a, 2010b);
- The lack of flammability standards for specific use areas in most countries at the time of POP-PBDEs usage (only a few countries had specific flammability standards e.g. for furniture in the United States and United Kingdom).;
- The limited export of such flame-retarded second-hand articles[38] from countries with flammability standards and related stocks (e.g. export of used furniture containing PUR foam produced before 2005 from the United States or United Kingdom).

[38] Some uncertainty exists about c-PentaBDE production in China and when this production ended (UNEP, 2010a, 2010b).

The original application of POP-PBDEs and the articles in these categories (PUR foam in furniture, mattresses, and rigid foam in construction) mainly took place in the United States, to some extent in Europe, and possibly in China (UNEP, 2010a, 2010b; Ludeka, 2011). Export of these articles to developing countries from the United States and United Kingdom is considered limited. For other countries and regions, c-PentaBDE in these applications are considered low and might not be of relevance for a POP-PBDEs inventory (UNEP, 2010a, 2010b).

6.1 Inventory approach for POP-PBDEs in other uses

An inventory of c-PentaBDE for these minor uses or regional uses is unlikely to be very helpful in countries that do not have specific flammability standards and that are not importers of second-hand articles containing PUR foam from countries with such flammability standards (mainly the United States and United Kingdom). It is most likely that an inventory without minimum monitoring efforts would not lead to meaningful data.

Nevertheless, if the task team (see table 3-1) decides to carry out an inventory, perhaps due to some existing information/field data indicating the historical presence of c-PentaBDE-containing articles in these other uses in the territory of the Party or region, a simplified inventory approach could be used. The first task could be to seek data on the percentage of POP-PBDEs-containing articles/materials in the region for the minor uses. Such data might have been established/compiled by Stockholm/Basel Convention regional centres. Otherwise, a study screening and determining the impact could be performed. A first step could consist of bromine screening of these articles (see *Guidance on Regulatory Framework for Monitoring New POPs in Articles* and *Guidance of Analysis of New POPs in Articles*).

Once contamination factors for individual uses have been established, similar steps to those described for EEE/WEEE (chapter 4) and the transport sector (chapter 5) could be adopted.

The most challenging part of such an inventory would be the estimation of the share of POP-PBDEs-containing articles in the respective use sector. The most practical approach could be to screen samples in the potential use sectors for bromine content. The technology is described in the *PBDE BAT/BEP Guidance* and the monitoring approach in the *Guidance on Screening and Analysis of POPs in Articles and Products.* If relevant bromine levels in selected use sectors are detected, positive tested samples can be further assessed for their POP-PBDEs content. A regional approach involving Stockholm/Basel Convention regional centres could be considered in particular for developing countries with limited resources and analytical capacity.

In addition, questionnaires could be sent to importers and distributors as well as producers to establish the quantities of articles imported, distributed, and produced in the past, up to a cut-off year when the production of POP-PBDEs was discontinued.

6.1.1 POP-PBDEs-containing furniture, mattresses and rebond material

The overall use of c-PentaBDE in PUR foam in furniture is estimated to represent approximately 60% of total production but actual levels are closely linked to the flammability standards in a country. Countries with no specific flammability standards for furniture/mattresses can be considered to have low levels of POP-PBDEs in furniture and mattresses unless a significant amount of these materials have been imported from countries with specific flammability standards (such as the United States and United Kingdom). The use of c-PentaBDE in mattresses was a relatively minor application (Ludeka, 2011) even in the United States; but mattresses in jails, military camps and hospitals were partly treated with c-PentaBDE (Ludeka, 2011).

A refined POP-PBDEs inventory could include screening a representative sample of furniture/mattresses for bromine using sliding spark or handheld XRF equipment (see *Guidance on*

Screening and Analysis of POPs in Articles and Products). Analysis of the positive tested samples could then determine the c-PentaBDE content (or reveal other BFRs present). These levels could then be multiplied by the estimated amount of impacted PUR foam-containing furniture and mattresses etc. in the country.

If POP-PBDEs-containing furniture/mattresses have been used in a country/region, an inventory of the amount of historically deposited POP-PBDEs-containing furniture, mattresses, rebond etc. could be prepared to assess the environmental risks that may arise from wastes in landfills (see chapter 7).

6.1.2 POP-PBDE-containing textiles

Only a limited quantity of c-PentaBDE was used in textiles (specifically workwear, curtains, back-coated textiles in vehicles and furniture) and therefore this sector is only of a minor relevance. Furthermore, since the lifetime of many textiles is under 10 years, they would already have entered end-of-life treatment. Back-coated textiles in vehicles are already considered in the transport inventory. Specific applications of potentially flame-retarded materials that might have longer lifetimes (e.g. curtains in theatre, cinemas or hotels) could be addressed by the inventory. The screening approach described above can also be applied for targeted textile uses.

Considering that Hexabromocyclododecane (HBCD) was/is used as a flame retardant in the textile sector and that the POPRC has proposed HBCD for listing as a POP at COP6 of the Stockholm Convention in 2013, the textile sector is expected to become more important for POPs inventories in the future. Therefore, the screening of bromine and assessment of positive-tested samples for the specific BFR used, including HBCD, could be useful for establishing both POP-PBDE and likely future POP contamination levels.

6.1.3 POP-PBDE-containing construction materials

Another use of c-PentaBDE was in rigid PUR foam for construction use. The use depends on the fire safety regulations of the country and insulation needs. In Europe where large quantities of polymer insulation materials and foam fillers were/are used, c-PentaBDE in construction was reported as a relevant use (Morf et al., 2003). Since no recycling activities are reported for rigid PUR foam, it is considered of lower relevance (ESWI, 2011). For the end-of-life treatment of insulation foams, the described screening methodology could be applied.

For a preliminary inventory, construction companies could also be interviewed on their use of rigid PUR foam in 1980 to 2004 and related uses of POP-PBDEs.

6.1.4 POP-PBDEs in rubber

Since only a minor use of c-PentaBDE for rubber goods (conveyer belts, coating and floor panels) is reported, this source is also considered of low relevance. For countries with larger industries using rubber conveyer belts, an assessment possibly including bromine screening could be considered. A regional approach coordinated by the Stockholm/Basel Convention regional centres might be useful to reduce the burden on individual countries.

6.1.5 Former POP-PBDEs use in drilling operation

C-PentaBDE may have been used as hydraulic fluid (as a component of a mixture) in petroleum drilling and mining; if so, the use was discontinued 10 to 20 years ago (UNEP, 2006b).

Since this use was an open application, there would be no stocks or impact on recycling flows. This use is thus addressed and covered by the discussion of contaminated sites (see chapter 7). An inventory of the former use in this application could provide information on the potential extent of contamination in areas where it has been used for oil drilling.

7 POP-PBDEs-contaminated sites

7.1 Scope and background information

Creating and maintaining a public inventory of POP-PBDE-contaminated sites is the first important step for a regulatory agency in formulating a contaminated site management strategy. A contaminated site database is vital as a country develops, its population grows, land is redeveloped and land uses changes.

This chapter aims to aid developing countries with the identification of POP-contaminated sites for the inventory. In doing so, the inventory team is recommended to follow the step-by-step approach in UNIDO's *Persistent Organic Pollutants: Contaminated Site Investigation and Management Toolkit* (*Contaminated Site Toolkit*), which covers systematically identifying POP-contaminated lands, assessing risk, setting priorities and applying appropriate remediation technologies. The inventory needs to report information collected during the site investigation from Module 2, preliminary site investigation, stage 1 and/or stage 2, of the Toolkit. This information includes the site profile, past and present activities, spill releases, and site owners.

Landfills are the ultimate destination of many POP-PBDE-containing materials due to their widespread application in a multitude of consumer and industrial goods (see chapter 8 of *PBDE BAT/BEP Guidance*; Weber et al., 2011). POP-PBDEs can be leached from these materials by landfill leachate or released via landfill fires.

To carry out the contaminated site inventory, the team is expected to utilize the information provided in chapters 3 to 6 and the outcomes of these inventories, while also examining general and hazardous solid waste management/practice in the country. The step-by-step guidance is given below.

7.2 Inventory approach for potential POP-PBDE-contaminated sites

7.2.1 Step 1: Planning the inventory

Information from the identified relevant sectors could be used to identify potential POP-PBDE-contaminated sites and then set priorities for remediation.

A contaminated site management policy requires established “maximum permissible levels” and “levels of concern” (values that trigger action) in corresponding media. Such permissible levels are, however, hardly available as of 2012 for POP-PBDEs at the national level let alone at the international level. Only Norway has the normative values used to identify contaminated sites for POP-PBDEs. The values for soil are 0.08 mg/kg for pentaBDE (BDE-99) and hexaBDE (BDE-154), and 0.002 mg/kg for decaBDE (Aquateam, 2007; NGU, 2007). Another example is Environment Canada's *Federal Environmental Quality Guidance (FEQGs) for PBDEs* for risk management practice. FEQGs developed directly from toxicity data relating to PBDEs included water quality guidance to protect aquatic life, the mammalian diet guidance, and bird egg guidance (Environment Canada, 2010).

With time and mature scientific understanding, more “safe” levels may be established for POP-PBDEs in air, water, soil, and food. For the purposes of this inventory, however, the following may be useful information.

Identify further stakeholders

Identification of stakeholders could consider all those listed in table 2-1, in addition to personnel from local government such as municipal wastewater treatment plants, those responsible for disposal of biosolids, farmers, landfill owners, and the general public.

Environmental contamination from these processes and deposits can affect air, water/sediments and land. Therefore, the investigation is necessary to identify all the sectors involved, manufacturing, recycling and storage locations, wastes being disposed, biosolids application, methods of waste disposal or treatment, and waste disposal locations and the related release (former) sectors. Potential POP-PBDE-contaminated sites are listed in table 7-1. The step-by-step approach in the *Contaminated Site Toolkit* should then be followed to systematically identify the POP-PBDE-contaminated sites, keep records, develop a registration system, and then perform risk assessment/prioritization on the POP-PBDE-contaminated sites.

Table 7-1: Potential POP-PBDE-contaminated sites

Sector	Activities	Facility locations
POP-PBDEs production	Production	Organobromine industry
	Destruction of production waste	Sites where production waste has been destroyed
	Deposition of production wastes	Landfills related to production
	Former water discharge	River sediment and banks related to releases from production site
Application of POP-PBDEs	Production sites of POP-PBDE-containing polymers	Production site and deposited wastes
	Textile industry and other industries formerly using POP-PBDEs	Production site and landfill with deposited wastes, river sediment and banks related to releases
	Oil drilling	Contaminated soil and groundwater, off-shore contamination
End-of-life treatment	Recycling area of EEE	Recycling areas and landfills with deposited wastes and ashes
	Metal industries treating POP-PBDE-containing materials	Production site and deposited wastes/ashes
	Deposition of POP-PBDE-containing waste	Landfill and surrounding from leachate from POP-PBDE-containing wastes
	Incineration of waste	Deposits of ash from incineration
	Discharge of POP-PBDEs via wastewater	Sewage sludge
	Application sites of sewage sludge containing POP-PBDEs	Agriculture land

7.2.2 Steps 2 and 3: Methods for collecting and compiling data to identify potential POP-PBDEs sites

A site is generally considered contaminated by POP-PBDEs when the concentration of one or more contaminants exceeds the regulatory criteria (see section 7.2.1, see annex 6) or poses a risk to humans and/or the environment. Site investigation, comprising preliminary site investigation (PSI) and detailed site investigation (DSI), provides valuable information on a site, including:

- The nature and location of contaminants with respect to the soil and groundwater table;
- Potential pathways for contaminant migration;
- The location of nearby sensitive receptors;
- Potential for direct human exposure to the contaminants;
- Potential of food and feed contamination.

Carrying out the PSI stages 1 and 2 for those locations of potential POP-PBDE contamination listed in table 7-1 is suggested for the purposes of the inventory.

The objective of PSI stage 1 is to gather sufficient information to estimate the likelihood of POP contamination that may be present at a site. Sampling relevant environmental media and investigations of subsurface conditions are not required at this stage.

PSI stage 1 includes the following activities:

- **Historical review:** review of a site's historical use and records to determine current and past activities or uses, accidents and spills, and practices and management relating to potential contamination at the site and at adjacent sites.;
- **Site visits:** one or more walk-through site visits to verify the information gathered during the literature review for indicators or presence of contamination;
- **Interviews:** interviews with current or former owners, occupants, neighbours, managers, employees, and government officials who can, with reasonable attempts, be contacted about information on activities that may have caused contamination.

It should be noted, however, that while the information that is required in PSI stage 1 readily flows in developed countries, it is not always available or accessible in most developing countries. It is hoped that over time there will be a systemic and attitudinal change in the populace of developing countries. For now, site investigators will have to make do with the best information that they can collect.

PSI stage 2 should be conducted only if stage 1 indicates there is a likelihood of POP contamination at the site or if there is insufficient information to conclude that there is no potential for POP contamination. The objective of stage 2 is to confirm the presence or absence of the suspected contaminants identified in stage 1 and to obtain more information about them. To achieve this objective, site investigators must carry out the following activities:

- Development of a conceptual site model;
- Development of a sampling plan.;
- Sampling of relevant environmental media laboratory or field instrumental analysis of sampled and selected environmental media for substances that may cause or threaten to cause contamination.

7.2.3 Step 4: Managing/evaluating data

Based on the data collected, a conceptual site model (CSM) can be then developed to establish the relationship between the contaminants, exposure pathways and receptors (see figure 7-1). The CSM, which should be developed at the very beginning of PSI stage 2, identifies the zones of the site with different contamination characteristics (i.e., whether contaminants in the soil are likely to

be at the surface or at deeper levels, distributed over an entire area or in localized "hot spots"). Exposure pathways and receptors should be identified, where appropriate, for both current and future uses of the site. The CSM is based on a review of all available data gathered during stage 1, and should be continuously modified as more information becomes available during stage 2 and the detailed site investigation.

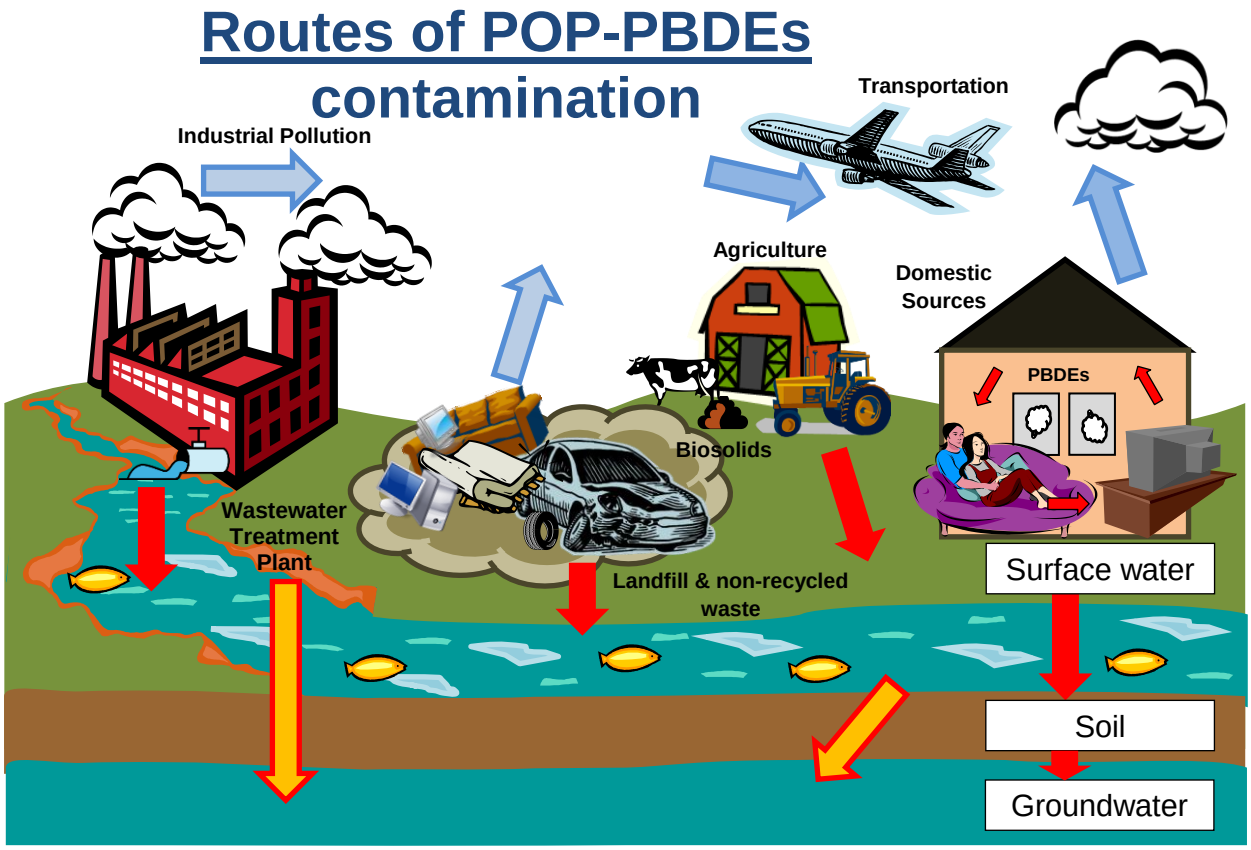

Figure 7-1: Routes of contamination migration

Key elements of a conceptual site model:

- Site history and setting;
- Potential contaminants of concern – contaminant properties and behaviour;
- Potential areas of environmental concern (Source Zones);
- Geology and stratigraphy;
- Regional and local;
- Overburden – sedimentary, glaciology, depositional processes;
- Bedrock – fracture networks, representative elementary volume;
- Hydrogeology;
- Aquifers and aquitards;
- Groundwater levels and elevations;
- Hydraulic gradients and velocities;
- Boundaries;
- Plumes and pathways;
- Groundwater and vapour;
- Transport and attenuation processes;
- Heterogeneity, anisotropy and scale;
- Receptors and risk.

Clearly, the accuracy of the information gathered and analyzed during the investigation is vitally important because it forms the basis for the risk assessment phase, for making decisions on the need for, and type of, remedial action and, eventually, for the design and implementation of necessary actions.

During a site investigation, every item of information collected must be recorded properly in words, along with photographs of the site and the surrounding area, with a radius of about 50-100 m (depending on the size of the site). Reporting is essential for each stage of the investigation as site-specific information is invaluable to decision makers in their efforts to protect the environment.

It is suggested that national levels should be established for contaminated sites. Data collection and compilation, data management, and evaluation should refer to the *Contaminated Site Toolkit*.

7.2.4 Step 5: Reporting of potential POP-PBDE-contaminated sites.

Reporting is essential for each stage of the investigation as site-specific information is invaluable to decision-makers in their efforts to protect the environment.

The PSI stage 1 report should identify potential contamination:

- Potential source of contamination;
- Potential contaminants of concern;
- Areas of potential environmental concern (potential lateral extent, vertical extent, media).

The PSI stage 2 report should identify contamination and potential contamination including:

- Source of contamination;
- Contaminants of concern (i.e. types of POPs);
- Areas of environmental concern (potential lateral extent, vertical extent, media);
- Recommendations for action.

For further information on reporting, refer to the *Contaminated Site Toolkit*.

The inventory of contaminated sites could include:

- Types and quantities of POP-BDE-containing materials disposed;
- The names and addresses of those entities responsible for disposal of POP-PBDE-containing materials;
- Details of the treatment of waste before disposal;
- Records of site contamination.;
- Details of the clean-up process (if any) once a site has been registered as being contaminated;
- Information on the monitoring of contaminated sites;
- Records of ongoing monitoring and research.

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Annexes

Annex 1. List of E-waste inventories from developing countries

In several developing countries EEE/WEEE inventories acoording to the "EMPA" methodology have been conducted (see table below). The related reports are also available in the internet online (selected under http://ewasteguide.info/ewaste/case-studies)

Country	Year	Focus[1)]	Programme	References
Benin	2010/11	Categories 1-4	Basel Convention	Aina et al. 2011
Burkina Faso	2010/11	Categories 1-4	PACE	PACE 2011
Côte d'Ivoire	2010/11	Categories 1-4	Basel Convention	Messou et al. 2011
Ghana	2010/11	Categories 1-4	Basel Convention	Amoyaw-Osei et al. 2011
Nigeria	2010/11	Categories 1-4	Basel Convention	Ogungbuyi et al. 2011
Tanzania	2010	Category 3 & 4	UNIDO	Magashi et al. 2011
Uganda	2008	Category 3 & 4	UNIDO	Wasswa and Schluep 2008
South Africa	2008	Categories 1-4	Swiss e-waste programme	Finlay and Liechti 2008
Morocco	2008	Category 3 & 4	Hewlett Packard	Laissaoui and Rochat 2009
Chile	2007	Category 3	Swiss e-waste programme	Steubing 2007;, Steubing et al. 2010
Colombia	2008	Category 3 & 4	Swiss e-waste programme	Ott 2008
Brazil	2009	Categories 1-4	Swiss e-waste programme	Rocha 2009
Kenya	2008	Category 3 & 4	Hewlett Packard	Waema and Mureithi 2008

[1)] Category 1: Large household appliances, Category 2: small household appliances, Category 3: IT and telecommunications equipment, Category 4: consumer equipment

Annex 2. Questionaire for EEE importers

Date:	Location:	Interviewer:

Interview introduction
I am …….. (name interviewer) coming from ….
We are collecting data on e-waste generation and management in order to ….
Can we ask you some questions about e-waste? / Thank you for participating in our survey

General information about company	
☐ **Import and/or** ☐ **Production of electrical and electronic equipment (EEE)**	
Name of company	
Address / City	
Number of employees	
Year of foundation	
Name and function of contact person	
Telephone	
E-mail	
Main activity	
To which economic se	☐ **Collection** ☐ **Dismantling/Recycling** ☐ **Refurbishment** ☐ **other:**
Is your institution ISO 14001 certified? *(ISO 14001 is an international certification for an environmental management system)*	☐ **YES** ☐ **NO**

Introducing question
(Introduction & introductory question, answers will not be evaluated. First question should ideally be answered with yes in order to set up a positive atmosphere for the interview to be held.) **Do you know what e-waste or waste of electrical and electronic equipment (EEE)/ waste of electrical and electronic equipment (WEEE) is?** *(describe to interviewed person what EEE)/WEEE is, if necessary….)*

1. Questions about awareness and behaviour			
	Question	*Answer*	*Enhance the replies with comments, suggestions, details, etc.*
1.1	**Are you aware about the environmental hazards caused by discarded EEE**	☐ **YES** ☐ **NO**	
1.2	**Are you aware that some EEE parts may be profitably recycled?**	☐ **YES** ☐ **NO**	
1.3	**Are you aware that some hazardous fractions in EEE need a special treatment in order to be safely disposed of?**	☐ **YES** ☐ **NO**	

2. Imported / produced electric and electronic equipment (EEE)

2.1 EEE-products

a) **Which EEE-products does your company import / produce?**

b) **How many units per year of each product does your company sell?**

c) **Which percentage of your imported products are second hand products? (please tick)**

d) **What is the (estimated) national market share in % of your company for each product?**

e) **According to your experience, what's the average life span of each product?**
*(**from the purchase** by the consumer **to the disposal** by the consumer)*

a) *Product*	*b)* *units/year*	*c)* *% second hand*	*d)* *market share %*	*e)* *ø life span (years)*
*If PCs or TVs are imported/ produced, **ask for the LCD-CRT ratio** of the monitors!*				

2.2 Distribution of products / customers	
Product	**Who are the (main) customers for each product?**
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐ Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐ Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐ Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐ Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐ Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐ Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐ Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐ Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐ Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐ Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐ Direct sale to corporate users ☐others:

3. General questions			
	Question	*Answer*	*Enhance the replies with comments, suggestions, details, etc.*
3.1	**Is the principle "Extended Producer Responsibility" (EPR) known in your company?**	☐ **YES** ☐ **NO**	**if yes: could you describe it shortly?**
3.2	**Is your company working on a formal basis or is it an informal company?** ☐ **formal** ☐ **informal**		
3.3	**Is your company member of any association or body of importers and/or producers of electrical and electronic equipment (EEE)?**	☐ **YES** ☐ **NO**	**if yes: name of body/association?**
3.4	**Is your company member of any association or body which is in charge of a proper e-waste management (collection and recycling)?**	☐ **YES** ☐ **NO**	**if yes: name of body/association?**
3.5	**Please describe your company's strategy to collect and recycle the e-waste generated by its customers?**		
3.6	**From your point of view, what are the main obstacles for a proper e-waste treatment?**		
3.7	**What should be done to facilitate e-waste management (to your company)?**		
3.8	**Would you be willing to pay for a service/organisation which collects and treats the e-waste generated by your customers?** ☐**YES** ☐**NO**		

	If yes: at what conditions? *(e.g. pickup service, guarantuee of proper disposal, reliability, etc.)*

3.9	**General remarks**

Annex 3. Questionaire for households (EEE)

Date:	Location:	Interviewer:

Interview introduction
I am …….. (name of interviewer) coming from ….
We are collecting data on e-waste generation and management in order to ….
Can we ask you some questions about e-waste? / Thank you for participating in our survey

Interviewed person	
Name (female/male)	
Suburb	
City & State	☐ **rural area** ☐ **urban area**
Telephone	
E-mail	

0. Introducing question
(Introduction & introductory question, answers will not be evaluated. First question should ideally be answered with yes in order to set up a positive atmosphere for the interview to be held.)
Do you know what electrical and electronic equipment (EEE) or waste of electrical and electronic equipment (WEEE) is?
(describe to interviewed person what e-waste is, if necessary….)

1. Questions about awareness and behaviour		
1.1	**Are you aware that some hazardous fractions in e-waste need a special treatment in order to be safely disposed of?**	☐ **YES** ☐ **NO**
1.2	**Do waste collectors come and pick up waste at your door?** **Do they pick up e-waste too?**	☐ **YES,everything** ☐ **YES, but no e-waste** ☐ **NO**

1.3	**a) Is the current e-waste collection convenient to you?** **b) What could be improved?**	a) ☐ **YES** ☐ **NO**	b)

2. Number (#) of electrical and electronic equipment in the household

How many appliances of each electric and electronic product do you have in your household (in use and stored)?

Large household appliances (category 1)	
Product	*#*
Fridges*	
Air conditioners*	
Washing machines*	
Freezers	
Clothes dryers	
Electric heaters	
Dish washers	
Grillers	
Electric/Gas stoves	
(Steam-)Ovens	
Electric hot plate	

Small household appliances (category 2)	
Product	*#*
Irons*	
Kettles*	
Blenders*	
Microwaves*	
Hair dryers	
Mixers	
Fans	
Vacuum cleaners	
Carpet sweepers	
Toasters	

Popcorn makers	
Rice cooker	
Water dispenser	
Cables	
Extension boxes (?)	
Soldering iron	
Electric lawn-mowers	
(Alarm) Clocks	

IT and telecommunications equipment (category 3)	
Product	*#*
PCs* (central unit)	
CRT monitors*	
LCD monitors*	
Laptops*	
Mobile phones*	
Phones	
Printers	
Copy machines	
Scanners	
Fax machines	
Modems	

Consumer equipment (category 4)	
Product	*#*
TVs (CRT)*	
TVs (flat panel)*	
Radios*	
Stereos*	
DVD players	
VCR players (video-cassette recorder)	
MP3-players	
Cameras	
Game consoles	

Other _____ **_____**	
Product	*#*

3. Tracer products

3.1Life span of the tracer product

a) From the <u>moment you buy</u> the product <u>until the moment you dispose it or give it away</u>: How many years do you have the product in your household, approximately?

b) For how many years do you use the product?

c) After its usage, for how many years do you store the product in your household?

note: adding up answer b) and c) should equal answer a) → *b) + c) = a)*

Cat.	*Product*	*a)*	*b)*	*c)*
		[in years]		
1	Fridge			
1	Air conditioner			
1	Washing machines			
1				
1				
2	Iron			
2	Kettle			
2	Blender			
2	Microwave			
2				
2				
3	PC (central unit)			
3	CRT monitor			
3	LCD monitor			
3	Laptop			
3	Mobile phone			
3				
3				

Cat.	*Product*	*a)*	*b)*	*c)*
		[in years]		
4	TV (CRT)			
4	TV (flat panel)			
4	Radio			
4	Stereo			
4				

4				
5	Light bulb			
5	Fluorescent tube			
	….			

Annex 4. Questionaire for corporate and institutional consumers

Date:	Location:	Interviewer:

Interview introduction
I am …….. (name interviewer) coming from ….
We are collecting data on e-waste generation and management in order to ….
Can we ask you some questions about e-waste? / Thank you for participating in our survey

General information about organization	
Name of organization	
Type of organization	☐ **public authority** ☐ **educational organization** ☐ **private company** ☐ **NGO** ☐ **other:** ……
Address / City	
Number of employees	
Name and function of contact person	
Telephone	
E-mail	
Main activity	
For <u>private companies</u>: **Economic activity of the company**	☐ **MiningManufacture of industrial products** ☐ **Bank/Insurance** ☐**Sales** ☐**Telecommunication** ☐ **Tourism** ☐**Other services** ☐ **other:**
Is your organizationISO 14001 certified? *(ISO 14001 is an international environmental certification)*	☐ **YES** ☐**NO**

Introducing question
(Introduction & introductory question, answers will not be evaluated. First question should ideally be answered with yes in order to set up a positive atmosphere for the interview to be held.) **Do you know what electrical and electronic equipment (EEE) or waste of electrical and electronic equipment (WEEE) is?** *(describe to interviewed person what e-waste is, if necessary….)*

1. Questions about awareness and behaviour			
	Question	*Answer*	*Enhance the replies with comments, suggestions, details, etc.*
1.1	**Are you aware about the environmental hazards caused by discarded electronic equipment?**	☐ YES ☐ NO	
1.2	**Are you aware that some electronic parts may be profitably recycled?**	☐ YES ☐ NO	
1.3	**Are you aware that some hazardous fractions in e-waste need a special treatment in order to be safely disposed of?**	☐ YES ☐ NO	
1.4	**Does your organization have a policy or strategy for the management of e-waste?**	☐ YES ☐ NO	
1.5	**Does your organization keep inventories of the electric and electronic equipment discards / stores?**	☐ YES ☐ NO	

2. Number (#) of electrical and electronic equipment in the organization

a) **How many appliances of each product do you <u>totally</u> have in your organization (in use and stored)?**

b) **How many of them are <u>not in use</u> (stored)?**

IT and telecommunications equipment (category 3)		
Product	*a) total*	*b) not in use*
PCs* (central unit)		
CRT monitors*		
LCD monitors*		
Laptops*		
Mobile phones*		
Landline phones*		
Printers*		
Copy machines*		
Scanners		
Fax machines		
Modems		

Large household appliances (category 1)		
Product	*a) total*	*b) not in use*
Fridges*		
Air conditioners*		

Small household appliances (category 2)		
Product	*a) total*	*b) not in use*
Kettles		
Microwaves		
Fans		
Water dispenser		

Consumer equipment (category 4)		
Product	*a) total*	*b) not in use*
TVs (CRT)*		
TVs (flat panel)*		
Radios*		
Video projector		
DVD players		
Cameras		

Lighting equipment (category 5)		
Product	*a) total*	*b) not in use*
Light bulbs		
Fluorescent tubes		
Long life light bulbs (energy saving)		
Rechargeable lamps		

Other _____ _____		
Product	*a) total*	*b) not in use*

3. Tracer products

3.1 Life span of the tracer product

a) From the <u>moment the product is bought until the moment it is disposedof or given away</u>:
How many years* does your organisation *have the product, approximately?

b) For how many years is the product in use?

c) After its usage, for how many years is the product usually stored in your organisation?

note: adding up answer b) and c) should equal answer a) → b) + c) = a)

Cat.	*Product*	*a)*	*b)*	*c)*
		[in years]		
3	PC (central unit)			
3	CRT monitor			
3	LCD monitor			
3	Laptop			
3	Mobile phone			
3	Phone			
3	Printer			
3	Copy machine			
3				
Cat.	*Product*	*a)*	*b)*	*c)*
		[in years]		
1	Fridge			
1	Air conditioner			
4	TV (CRT)			
4	TV (flat panel)			
4	Radio			

3.2 Detailed information about tracer products				
Category	*Product*	**Where does your organization buy its products?** *(e.g. supermarket, second hand market, friends, etc.)*	**How many new appliances does your organization buy per year?**	**How many years does yourorganization storea product before its disposal?**
	In general			
3	PC (central unit)			
3	CRT monitor			
3	LCD monitor			
3	Laptop			
3	Mobile phone			
3	Phone			
3	Printer			
3	Copy machine			
1	Fridge			
1	Air conditioner			
4	TV (CRT)			
4	TV (flat panel)			
4	Radio			

3.3Disposal of tracer product (please tick)										
What does your company do with the electrical and electronic equipment which is not of use anymore?										
Category	*Product*	Sell to a second hand dealer	Give or sell to a scrap dealer	Dispose with general waste	Hand over to an e-waste collection	Sell via tender offer	Sell/hand over to employees	Sell to individuals	Donate	Other
	In general									
3	PC (central									

	unit)									
3	CRT monitor									
3	LCD monitor									
3	Laptop									
3	Mobile phone									
3	Phone									
3	Printer									
3	Copy machine									
1	Fridge									
1	Air conditioner									
4	TV (CRT)									
4	TV (flat panel)									
4	Radio									

4. General questions			
	Question	*Answer*	*Enhance the replies with comments, suggestions, details, etc.*
4.1	**Are you aware of what happens to the equipment you have discarded?**	☐ **YES** ☐ **NO**	
4.2	**From your point of view, what are the main obstacles for a proper e-waste treatment?** *(e.g costs, lack of infrastructure and/or policy within your company, lack of legislation, absence of recycling solutions, absence of collection system, etc.)*		
4.3	**What should be done to facilitate e-waste management (to your organization)?**		
4.4	**Would you be willing to pay for your equipment to be collected and treated?**	☐ **YES** ☐ **NO**	**If yes: at what conditions?** *(e.g. pickup service, guarantuee of proper disposal, etc.)*
4.5	**Is your organisation working on a formal basis or is it an informal organisation?** ☐ **formal** ☐ **informal**		
4.6	**General remarks**		

Interview closure
Thank you for participating in this survey • *The interviewer could also provide information about <u>when & where</u> the results of the survey will be available (if this is the case)*

Annex 5. Questionaire for WEEE recyclers

Date:	Location:	Interviewer:

Interview introduction
I am …….. (name interviewer) coming from ….
We are collecting data on e-waste generation and management in order to ….
Can we ask you some questions about e-waste? / Thank you for participating in our survey

General information about company	
Name of company	
Address / City	
Number of employees	
Year of foundation	
Name and function of contact person	
Telephone	
E-mail	
Main activity	
Which e-waste activities does the company carry out?	☐ **Collection** ☐ **Dismantling/Recycling** ☐ **Refurbishment** ☐ **other:**
Is your companyISO 14001 certified? *(ISO 14001 is an international certification for an environmental management system)*	☐ **YES** ☐ **NO**

Introducing question
(Introduction & introductory question, answers will not be evaluated. First question should ideally be answered with yes in order to set up a positive atmosphere for the interview to be held.)
Do you know what e-waste or waste of electrical and electronic equipment is?
(describe to interviewed person what e-waste is, if necessary….)

1. Questions about awareness and behaviour			
	Question	*Answer*	*Enhance the replies with comments, suggestions, details, etc.*

1.1	**Are you aware about the environmental hazards caused by discarded electrical and electronic equipment?**	☐ **YES** ☐ **NO**	

1.2	**Are you aware that some hazardous fractions in e-waste need a special treatment in order to be safely disposed of?**	☐ **YES** ☐ **NO**	**if yes: which ones?**

2. Collection of (waste) electrical and electronic equipment			
	Question	*Answer*	
2.1	**By which strategies and channel does your company collect e-waste?** *Which stakeholders are involved? Responsibilities? etc.*		
2.2	**In terms of amounts, which one is the most important strategy/channel?**		

2.3	**Do you cooperate with other companies/authorities for collection purposes?**	☐ **YES** ☐ **NO**	**if yes: which ones? can you provide any details?**

2.4	**Which company transports the materials during collection?**	

2.5	**What are the main obstacles for a proper e-waste collection?**	

3. Recycling / treatment of waste electric and electronic equipment (WEEE)
3.1WEEE products that are treated
Which electrical and electronic products does your company (collect and) treat? How many units or kg per month of each product does your company actually treat? (throughput) How many units or kg per month of each product could your company treat? (treatment capacity) Does your company pay or charge the treatment of the respective product? Or does it accept the product for free? If yes: how much does your company pay per unit or kg of each product? (price, on average)

a) Product	*b) actual throughput (indicate unit)*	*c) capacity (indicate unit)*	*d) pay / charge*	*e) price (indicate unit)*
*Note: don't forget to **write down the units** of the indicated numbers!*				
General (all products)			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ fee	

			☐ pay☐charge ☐ fee	
			☐pay ☐charge ☐ free	
			☐pay ☐charge ☐ free	
			☐ pay☐charge ☐ free	
			☐ pay ☐charge ☐ free	
			☐pay ☐charge ☐ free	
			☐pay ☐charge ☐ free	

3.2 Material fractions arising from WEEE

a) Which material fractionsarise from your company's recycling activities?

What does your company do with each material fraction? (treatment/destination)

Passing on the respective fraction to a further treatment, disposal, refining, etc.: is this associated with an income or with costs for your company, or does this happen for free? (please tick)

In case of income / costs: could you indicate an average price you get / pay

a) *Material fraction*	***b)*** *Treatment / destination (e.g. indicate company, market, type of treatment etc.)*	***c)*** *income/costs*	***d)*** *price (indicate unit)*
*Note: don't forget to **write down the units** of the indicated numbers!*			
		☐ income ☐ costs ☐free	
		☐ income ☐ costs ☐free	
		☐ income ☐ costs ☐free	
		☐ income ☐ costs ☐free	
		☐ income ☐ costs ☐free	
		☐ income ☐ costs ☐free	
		☐ income ☐ costs ☐free	
		☐ income ☐ costs ☐free	
		☐ income ☐ costs ☐free	
		☐ income ☐ costs ☐free	

General questions about recycling/treatment of e-waste		
3.3	**Which processes does your company carry out?** ☐ **Sorting of products** ☐ **Manual dismantling** ☐ **Shredding** ☐ **Separation of (shredded) fractions** ☐ **Cable stripping/granulation** ☐ **Burning (e.g. cables, cases)** ☐ **Leaching (e.g. printed wiring boards)** ☐ **other:**	
3.4	**How many workers are engaged in the recycling operation?**	
3.5	**What environmental measures does your company undertake to prevent the release of hazardous substances?**	
3.6	**Which measures undertakes the company to prevent health damages to the workers?**	

4. Refurbishment of (waste) electric and electronic equipment			
4.1(W)EEE products that are refurbished			
b) Which electrical and electronic products are refurbished in your company? c) How many units are refurbished per month? (throughput) d) What is the average purchase price you pay for a product your refurbish? e) What is the average sales price you get for your refurbished product?			
a) *Product*	***b)*** *actual throughput (indicate unit)*	***c)*** *purchase price (indicate unit)*	***d)*** *sales price (indicate unit)*
	*Note: don't forget to **write down the units** of the indicated numbers!*		
General (all products)			

General questions about refurbishment		
	Question	*Answer*
4.2	**Where does the company get the appliances that are apt for refurbishment?**	

4.3	**By which channels does your company sell the refurbished products?**	
4.4	**What is done with parts or products which cannot be used for refurbishment?**	

4.5	**How many workers are engaged in the refurbishment operation?**	

5. General questions			
	Question	*Answer*	*Enhance the replies with comments, suggestions, details, etc.*
5.1	**Apart from e-waste, which other materials is your company working with?**	*e.g. scrap metals, paper, plastic, etc.*	
5.2	**Is your company working on a formal basis or is it an informal company?** ☐**formal** ☐**informal**		
5.3	**Is your company member of any association or body of recyclers?**	☐ **YES** ☐ **NO**	**if yes: name of body/association?**
5.4	**Does your company cooperate with other companies or authorities in order to collect and recycle e-waste?**	☐ **YES** ☐ **NO**	**if yes: name? can you provide details?**
5.5	**From your point of view, what are the main obstacles for a proper e-waste <u>treatment</u>?**		
5.6	**What should be done to facilitate e-waste treatment (to your company)?**		
5.7	**Are you satisfied with the current financing of e-waste management?** ☐**YES** ☐**O**		
	If no: what should be improved? *(e.g. fee, regulation, corporate responsibility (EPR), etc.)*		

5.8	**General remarks:**

Interview closure
• Thank you for participating in this survey • The interviewer could also provide information about when and where the results of the survey will be available (if this is the case)

Annex 6. Federal Environmental Quality Guidelines for Polybrominated Diphenyl Ether

Federal Environmental Quality Guidelines for Polybrominated Diphenyl Ethers (Source: Environment Canada 2010)						
Homologue/ Formulation*	Congener	Water (ng/L)	Fish Tissue (ng/g ww)	Sediment** (ng/g dw)	Wildlife Diet† (ng/g ww food)	Bird Eggs(ng/g ww)
TrBDE	total	46	120	44	–	–
TeBDE	total	24	88	39	44	–
PeBDE	total	0.2	1	0.4	13 (bird)	29
	BDE-99	4	1	0.4	3	–
	BDE-100	0.2	1	0.4	–	–
HxBDE	total	120	420	440	4	–
HeBDE	total	17‡	–	–	64	–
OcBDE	total	17‡‖	–	6700‖	63‖	–
NoBDE	total	–	–	–	78	–
DeBDE	total	–	–	19‖§	9	–

*FEQG for TrBDE, TeBDE, HxBDE , HeBDE, NoBDE and DeBDE are based on data for BDE-28, BDE-47, BDE-153, BDE-183, BDE-206, and BDE-209 respectively unless otherwise noted

**Values normalized to 1% organic carbon

†Applies to mammalian wildlife unless otherwise noted

‡Values based on a mixture of HeBDE and OcBDE

‖Values adopted from Screening Assessment Report (Environment Canada, 2006). Sediment values from the SAR
appear different here because they have been normalized to 1% organic carbon

§Based on a mixture of DeBDE with some NoBDE