HBCDD in EPS/XPS waste in the Netherlands

Inventory of size and value

Final

Ministry of Infrastructure and the Environment, The Netherlands
December 2016

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SUMMARY

In March 2016 the European Commission and the EU member states decided to regulate the production, marketing and use of the brominated flame retardant hexabromocyclododecane (HBCDD), because of its persistent and bio-accumulative properties. Wastes with an HBCDD concentration above 1000 parts per million (ppm) are to be considered as persistent organic pollutants waste (POPs waste), which means that they should be destroyed. New or recycled products that are placed on the market shall have an HBCDD concentration below 100 ppm.

In recent decades, HBCDD has been widely used in many different products, and the implementation of this new regulation affects the production, consumption and removal of such products. As an important action towards implementing the new regulation, the Dutch Ministry of Infrastructure and the Environment has decided to make an inventory of the size and value of HBCDD-containing products and waste streams. For that purpose, the Ministry has developed a project plan, which is the basis of this study.

The inventory focuses on expanded polystyrene (EPS) and extruded polystyrene (XPS) products and waste, because over 95% of the HBCDD currently used in the Netherlands is present in these two materials.

The first step was to make an inventory of the quantities and HBCDD concentrations of the various products and waste streams in the Netherlands. A simplified overview of material streams was developed that comprises:

- 6 product groups (‘packaging EPS’, ‘horticulture’, ‘ice boxes’, ‘construction EPS/XPS’, ‘civil engineering applications’ and ‘transport sector’);
- 8 waste streams (‘household packaging EPS’, ‘commercial packaging EPS’, ‘horticulture’, ‘ice boxes’, ‘EPS/XPS from construction sites’, ‘EPS/XPS from demolition sites’, ‘civil engineering applications’ and ‘transport sector’);
- 3 mechanical recycling options (‘shredding for loose fill’, ‘shredding for application in EPS products’ and ‘melting into PS granulate’);
- 2 disposal options (‘incineration with energy recovery’ and ‘landfill’).

The next step was to make an inventory of the cost aspects and future developments.

It was concluded that the new Netherlands waste management policy plan should provide for separate collection and recycling of ‘clean’ packaging EPS and prevent contamination with material containing HBCDD. Furthermore, the new policy should stimulate the development of a recycling option in which HBCDD is destroyed and polystyrene and bromine are recovered.

It appeared that little is known about the quantities of EPS and XPS waste produced by the commercial sector (which consists mainly of HBCDD-free packaging EPS) and construction and demolition waste (which consists mainly of HBCDD-containing EPS/XPS). In particular, little is known about how it is treated and what the prospects for improvement are. Therefore, further investigation of these two waste streams is needed to reveal opportunities for improvement.

A promising Dutch initiative is the ‘PolyStyrene Loop’ process, in which both polystyrene and Bromine can be recovered. This initiative should be supported by all parties involved, because it can lead to the recovery of large quantities of polystyrene in the Netherlands and neighbouring countries that would otherwise be incinerated.

1 INTRODUCTION

In 2013, hexabromocyclododecane (HBCDD), a brominated flame retardant, was added to the Stockholm Convention because of its persistent and bio-accumulative properties. Thus, both production and use of HBCDD-containing products are prohibited for all Parties to the Convention, including the Netherlands. Phasing out such products within the European Union was initially regulated through REACH ((EC) 1907/2006).

In 2016, the Dutch Ministry of Infrastructure and the Environment decided to make an inventory of the size and value of HBCDD-containing products and waste streams. For that purpose, the Ministry has developed a project plan, which is the basis of this study. (see Annex 1).

This study examines the occurrence and treatment of HBCDD-containing products and waste streams in the Netherlands, including related cost aspects.

The Ministry's inventory focuses on EPS and XPS, because these two materials account for more than 95% of the total use of HBCDD in the Netherlands. Other uses are mentioned below but mostly not quantified.

1.1 Objective

The main research objective of the inventory process is:

"To quantify the amount of EPS/XPS waste in the Netherlands and the concentration of HBCDD contained therein. Besides quantifying the amounts of waste and HBCDD, quantifying the costs associated with the various waste processing options is requested."

1.2 Methodology

The information presented in this study is derived from:

- a desk study (see literature list in Section 11);
- interviews with experts (see interview list in Annex 2);
- discussions with the steering committee;
- the researchers' knowledge and experience.

The quantities determined by this inventory process are given in Section 4. The costs of collection, recycling and disposal are presented in Section 8. These quantities and costs are the researchers' best estimates, based on all the information currently available.

1.3 Limitations to this inventory

Scope
The Stockholm Convention, which has included HBCDD since 2013, obligates the government of the Netherlands to develop and implement a national implementation plan that must lead to environmentally sound management of HBCDD in the country. An important step in developing such a plan is to make an inventory of HBCDD and materials containing this flame retardant. This inventory is the purpose of this project, and in line with the project plan (see Annex 1) the inventory is limited in scope to the size and value

of product and waste streams containing HBCDD. Other aspects of environmentally sound HBCDD management, such as assessing risks to the environment and human health, are covered by the national implementation plan but are beyond the scope of this inventory.

Focus on EPS and XPS
HBCDD is used in a wide variety of products. In the European Union, most HBCDD (>95%) is used in EPS and XPS, though HBCDD is also used in high-impact polystyrene (HIPS) and for polymer dispersion in textiles (see also Section 3).

The Netherlands Ministry of Infrastructure and the Environment has concluded that the most valuable results can be obtained by focusing the inventory on production, use and disposal of HBCDD in EPS and XPS.

HBCDD concentrations
For this inventory, only very limited data were found on measured HBCDD concentrations in products and waste streams. At this stage, calculations of HBCDD quantities are therefore based on general literature data on HBCDD concentrations. Better insight into HBCDD concentrations in the various product and waste streams should be gained by actual HBCDD measurements. (For this project's sampling and analysis programme, see Annex 4).

Terminology
In order to present a simplified overview, this study describes the products made from expanded polystyrene (EPS) or extruded polystyrene (XPS) using only a few generic terms, such as 'construction EPS/XPS', 'packaging EPS', 'horticulture', 'ice boxes' and 'civil engineering applications'. These terms represent groups of products on the market that have many different purposes, characteristics and trade names.

2 HBCDD

2.1 General characteristics

A description of the basic characteristics of hexabromocyclododecane (HBCDD) is presented in Annex 3.

2.2 Production

HBCDD has been on the world market since the late 1960s and has mainly been produced for use in EPS and XPS in buildings. The main production facilities are in China, the European Union and the United States of America. In 2011, the total production of HBCDD was estimated at around 31,000 tonnes, of which about 13,000 tonnes were produced in EU countries and the USA, and 18,000 tonnes in China [1]. In that year, the demand for HBCDD in the EU was 12,300 tonnes, which was approx. 40% of the world market demand [2]. Subsequently, annual EU demand gradually decreased to 10,800 tonnes in 2014. In 2015, there was a sharp fall to 2,800 tonnes [2].

Since HBCDD is being phased out under Stockholm Convention obligations, most of the production facilities have ceased to produce HBCDD. Currently, only a few plants are still producing HCBDD, all of them located in China. Due to the ban on its use by the Parties that ratified the Convention, the production and use of HBCDD is expected to decrease in the coming years as China also converts to alternative flame retardants.

Recently, alternatives to HBCDD have become available for EPS and XPS. Therefore, it is reasonable to assume that all EPS/XPS currently produced in Europe no longer contains HBCDD.

2.3 Use

The primary use for HBCDD in the EU has been in expanded polystyrene (EPS) and extruded polystyrene (XPS) foam insulation (more than 95%). Secondary uses include textile back coatings (approximately 2%)[1] and high-impact polystyrene (HIPS) used in electronics housings (approximately 2%) [1].

The main textile application has been in fabrics used in furniture, mattresses and curtains in public buildings such as schools, hotels, hospitals and prisons. The quantities used in this context were small, as HBCDD was only added to the main brominated flame retardant, DecaBDE, which was needed for desirable physical properties including fabric softness. The typical product lifetime is 5-15 years and eventually the fabrics are normally incinerated rather than recycled.

[1] Use of HBCDD in textiles decreased drastically when the European flame retardant industry (EFRA members) stopped supplying to this market in 2010 [interviews]. Elimination of HBCDD from textiles is ongoing. Its occurrence is diminishing year by year and is expected to be practically zero by 2030 [33].

Table 2.1 (below) gives an overview of HBCDD applications in products. For an impression of the various products that are made from EPS, see Annex 7.

Table 2.1: HBCDD use patterns (ECHA 2009 with additions) [1]

Material	Use/Function	End-products (Examples)
Expanded polystyrene (EPS)	Insulation	• Construction, insulation boards, (packaging material) • Insulation boards (against cold or warm) of transport vehicles e.g. lorries and caravans • Insulation boards in building construction e.g. houses walls, cellars and indoor ceilings and 'inverted roof' (outdoor) • Insulation boards against frost heaves of road and railway embankments • Packaging material (minor use and not intended in food packaging)
Extruded polystyrene (XPS)	Insulation	• Construction, insulation boards • Insulation boards (against cold or warm) of transport vehicles e.g. lorries and caravans • Insulation boards in building constructions e.g. houses walls, cellars and indoor ceilings and 'inverted roof' (outdoor) • Insulation boards against frost heaves of road and railway embankments
High impact polystyrene (HIPS)	Electrical and electronic parts	• Electric housings for VCR • Electrical and electronic equipment e.g. distribution boxes for electrical lines • Video cassette housings
Polymer dispersion for textiles	Textile coating agent	• Upholstery fabric • Bed mattress ticking • Flat and pile upholstered furniture (residential and commercial furniture) • Upholstery seating in transportation • Automobile interior textiles • Draperies, and wall coverings • Interior textiles e.g. roller blinds

The most important applications for HBCDD are in thermal insulation materials. Such materials are mainly expanded polystyrene (EPS) and extruded polystyrene (XPS). Stybenex, the Dutch Association of EPS producers, and ICL-IP, the world's largest bromine producer, add to Table 2.1 that where 'insulation' is mentioned this refers to 'thermal insulation' and that the following end products should be added:

- Shape moulds (EPS)
- Beads in loose fill for cavity insulation (EPS)
- Blocks and boards for civil engineering application (EPS)
- Floating/buoyancy blocks and boards (EPS)
- Special (shape moulded) parts/void filling blocks and boards, horticulture/agriculture (EPS)
- Electric, electronic and automotive acoustic system (EPS)

- Spare tyre holders (EPS)
- Boards for civil engineering applications (XPS)
- Electric, electronic and automotive junction and fuse boxes (HIPS)

In Table 2.1 packaging material is mentioned between brackets, because the occurrence of HBCDD in packaging material is uncertain. Generally, HBCDD was not used in packaging EPS, because a flame retardant is seldom required for packaging applications [3]. In the interviews, some Dutch EPS converters stated that they had never used HBCDD for packaging EPS.

Use in the Netherlands
Safety regulations differ from country to country. Compared to other European countries, HBCDD use in the Netherlands has been relatively high due to a high level of safety regulations for buildings. A major difference from many other countries is that underground applications of EPS/XPS must also contain flame retardant. Dutch insurance policies also require flame retardants in EPS/XPS for construction of storages [3].

2.4 HBCDD concentrations

HBCDD has been used as a flame retardant in EPS and XPS products for which this was required. The typical HBCDD concentration range for EPS was between 0.5% and 1.0% (5,000-10,000 ppm) [34, interviews], with an average of 0.7%. The HBCDD loading range in XPS was between 0.8% and 2.5% (8,000-25,000 ppm) [34, interviews], with an average of 1.5%. HBCDD concentrations are always based on weight not volume.

For EPS and XPS products that have been placed on the market, HBCDD concentrations can generally be found in producers' material safety data sheets. With the stated HBCDD content, the products must pass the required flammability test. Such information enabled HBCDD concentrations to be determined within a range of 10% to 20% [interviews].

For waste streams, data on HBCDD content are generally not available.

In all construction EPS and XPS in the Netherlands, HBCDD was used between 1975 and 2015. A minor exception is use in certain civil engineering applications. An unknown proportion of the EPS used in civil engineering applications did not contain flame retardant.

Probably, most EPS for packaging that was produced between 1975 and 2015 did not contain HBCDD, because a flame retardant was seldom required for such applications [3]. However, some literature sources and interviews indicate that HBCDD was used in (some) packaging material, though no specific information on occurrence and HBCDD concentrations is presented [3, 4, 5, interviews]. Specific literature data on HBCDD content in packaging EPS are scarce. Two recent articles on measurement of HBCDD in EPS/XPS samples were found:
- Research conducted in South Korea in 2013 reported HBCDD in a range of Korean packaging and construction EPS in concentrations ranging from 0.0% to 0.1% (0-1,000 ppm) [6].

- Research conducted in Germany in 2015 reported HBCDD in a range of European HBCDD-containing EPS and XPS products (type of products not specified) in concentrations ranging from 0.1% to 0.9% (1,000-9,000 ppm) in EPS and 0.6% – 1.4% (6,000-14,000 ppm) in XPS [7].

In addition, some information was found on HBCDD in materials used in the transport sector (see Section 7), mainly in road vehicles but also in trains, ships and aeroplanes.

Overall, measurement-based data on HBCDD content in materials are scarce. This is particularly true for HBCDD in packaging materials and waste streams. Therefore, a programme should be conducted to assess HBCDD content in various product and waste streams (see Annex 4).

For this inventory, assumptions of HBCDD content in EPS/XPS products produced between 1975 and 2015 are:

- Construction EPS: 7,000 ppm
- Packaging EPS (percentages based on information from interviews)
    - 7,000 ppm in 4% of total quantity of packaging[2]
    - 0 ppm in 96% of total quantity of packaging
- XPS: 15,000 ppm

All EPS/XPS products used in the Netherlands can be assumed to be HBCDD free since August 2016, three months after ICL-IP's production plant completely stopped producing HBCDD in April 2016.

2.5 HBCDD in stockpiles

Between 1989 and April 2016, HBCDD was produced in the Netherlands by ICL-IP at its production facility in Terneuzen. The installed capacity was 2,500 tonnes/year until 1995, after which the installed capacity was increased to 5,000 tonnes/year. During this production period, 50% to 90% of the installed capacity was used. The total weight of HBCDD produced in the Netherlands over approximately 25 years is estimated at 50,000-90,000 tonnes.

In recent years, EPS bead producers have replaced HBCDD as a flame retardant with alternatives, especially polymeric brominated flame retardant (PolyFR) [7].

In the EU, HBCDD was imported until the end of 2015. As HBCDD is being phased out in the EU and Dutch EPS bead producers no longer use it, it is reasonable to assume that all HBCDD stocks have now been used and that as of January 2016 no HBCDD stockpiles remained in the Netherlands.

[2] The assumption that 4% of the packaging material contains 7,000 ppm HBCDD is the researchers' best estimate based on interviews only. Since no measurement based information is available, the percentage and concentration could appear to be different in practice when measurements take place.

3 LEGAL FRAMEWORK

3.1 Stockholm Convention, REACH and POP regulations

In 2013 the brominated flame retardant hexabromocyclododecane (HBCDD) was added to the Stockholm Convention [38] because of its persistent and bio-accumulative properties. During the process of adding HBCDD to the Stockholm Convention there was an extensive discussion on how to deal with the legacy of HBCDD, which is still present in construction EPS/XPS in buildings and will be released as waste over the coming decades. The discussion did not lead to an HBCDD exemption for recycling, as was the case with POP-BDEs[3]. (See Annex A, Stockholm Convention).

In the EU, the production, marketing and use of HBCDD in EPS and XPS is regulated by REACH 1907/2006/EC and POP 850/2004/EC. In March 2016, the European Commission and the EU Member States reached agreement on including HBCDD in POP 850/2004/EC:

a. The HBCDD concentration above which EPS/XPS waste is to be considered as POPs, meaning that the POP component of such waste should be eliminated and destroyed, is 1000 ppm (low POP content in Annex IV 850/2004/EC); and
b. The maximum HBCDD concentration allowed for new or recycled products to be produced and placed on the market is 100 ppm (value in annex I 850/2004/EC).

In accordance with the REACH regulation, the use, production and application of HBCDD has been prohibited in the EU since 21 August 2015. A consortium of European EPS suppliers successfully applied for authorization and extension of this date to 21 August 2017. The main reason for this bridging application was the potential insufficient availability of an alternative flame retardant. However, since then the availability of this alternative has proven to be sufficient. In November 2016, the vast majority of the consortium that applied for the derogation withdrew their authorizations, because HBCDD is no longer needed in their production processes [8].

Subsection 3.2 discusses a specific issue in the EU legal framework that needs special attention: the regulation of hazardous waste.

3.2 EU regulatory framework for hazardous waste

'Hazardous Waste' is defined by Article 3(2) of Waste Framework Directive 2008/98/EC (WFD) as *"waste which displays one or more of the hazardous properties listed in Annex III".* The classification into hazardous and non-hazardous waste is based on the system for classifying and labelling dangerous substances and preparations, established by the CLP Regulation (Regulation (EC) No 1272/2008), which entered into force in June 2015, replacing Directive 67/548/EEC and Directive 1999/45/EC.

In December 2014, Annex III of the WFD was renewed (see EU regulation No. 1357/2014). That annex lists properties of waste which render it hazardous. Whether EPS/XPS waste containing HBCDD is considered hazardous depends on whether it exhibits one or more hazardous properties defined in that annex (referred to as 'H criteria').

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[3] POP-BDE's are substances widely used as flame retardants in other products than EPS/XPS. They are Brominated Diphenyl Ethers that are included in the EU regulations for Persistant Organic Pollutants.

According to the EU List of Waste, HBCDD-containing EPS/XPS waste is classified as a ‘mirror entry’. Such waste can either be hazardous or non-hazardous, depending on the specific case and the composition of the waste.

Table 3.1: General consequences if waste is considered hazardous [9]

The WFD stipulates a number of specific obligations for waste producers and waste holders in case waste is considered hazardous, inter alia a mixing ban (Article 18), labelling (Article 19), and specific requirements for treatment facilities (Article 25(2)). At the same time, treatment-related legal documents such as the Landfill Directive or the Industrial Emission Directive in its provisions on waste incineration facilities, make important distinction whether the waste to be treated is hazardous or not; Evidently, The requirements for treating hazardous waste are quite stricter which in turn leads to treatment costs for hazardous waste being considerably higher than for non-hazardous waste. Member States have to ensure that hazardous waste is subject to specific control (Article 17 WFD), including a tracking system.

Table 3.2 presents the classification of HBCDD in the harmonized classification of Annex VI of Regulation (EC) no. 1272/2008 (CLP Regulation).

Table 3.2: Classification of HBCDD according to the European CLP regulation

Hazard Class and Category Code	Hazard Statement Code and description	Multiplying factor
Repr. 2	H361: Suspected of damaging fertility or the unborn child	-
Lact.	H362: May cause harm to breast-fed children	-
Aquatic chronic 1	H410: Very toxic to aquatic life with long-lasting effects	10

The classification H410 is linked to the property HP 14 ‘Ecotoxic’, and the classification H361 is linked to HP 10 ‘Toxic for reproduction’ as the property which renders the waste hazardous (see Regulation (EU) No. 1357/2014).

As regards the HP 14 criteria ‘Ecotoxic’:

- Decision 2014/955/EU on the List of Waste currently does not provide detailed indications on how to perform the assessment of HP 14 in practice.
- In practice, this instruction has been interpreted in different ways in the EU member states. In some member states, eco-toxicity is assessed mainly by performing tests, whereas in others formulae or criteria based on relevant legislation on transport of dangerous goods are applied.

A recent document (May 2015) mentions that a proposal for a harmonised definition and assessment method for HP 14 was the objective of a tendered project under DG Environment [9].

For those wastes for which hazardous and non-hazardous waste codes could be assigned, as is the case for HBCDD containing EPS/XPS waste, an assessment
The Waste Framework Directive defines HBCDD containing EPS/XPS waste as a “mirror entry” (see par. 3.2). Whether this waste is hazardous or non-hazardous depends on the specific case and the composition of this waste. An assessment of the ecotoxic property HP14 of waste is required to determine if HBCDD containing EPS/XPS has to be considered as hazardous or non-hazardous waste [40]. Until now such an assessment has not taken place.

That there is a need for such an assessment is evident in Germany, where there is debate about the treatment of HBCDD-containing EPS/XPS [10, interviews]. The German Länder have classified EPS waste containing more than 1000 ppm HBCDD as hazardous waste. This EPS waste is no longer accepted, as a number of municipal waste incinerators do not have a permit to incinerate hazardous waste. Other issues hindering acceptance are the high calorific value when the waste is compacted as well as the large volumes of EPS from construction waste. Treatment prices have reached € 800 per tonne of uncompacted EPS foam waste. Because the discussion is ongoing, it is unknown what the outcome of this discussion will be.

Classification as hazardous could also hinder the exporting of this waste, for example to the Netherlands, for treatment in a demonstration plant for physico-chemical treatment (the PolyStyrene Loop initiative, targeted in 2018, see Subsection 8.3 below). Once the waste is classified as hazardous, special permits are required to export it.

3.3 Netherlands regulatory framework

National waste policy

The Netherlands national waste policy is set out in the *Landelijk Afvalbeheersplan* (LAP). Currently, the relevant regulation is *Landelijk afvalbeheerplan 2009-2021*' (LAP2) [35], though this is shortly to be replaced by *Landelijk afvalbeheerplan 2017-2029* (LAP3) [11]. The draft version of this regulation became available in September 2016. The recent changes regarding regulation of HBCDD are incorporated in LAP3.

Similarly to LAP2, the new draft LAP3 consists of two parts. One part covers the national waste policy in general (*Beleidskader*), whereas the second part describes the waste policy for each waste stream (sector plans). For each separate waste stream, a minimum standard is defined for treatment. LAP3 has 85 sector plans, and for the first time there is a special sector plan for expanded polystyrene. Table 3.3, below, presents the separate minimum standards for packaging EPS and construction EPS.

Table 3.3: Minimum standards for treatment of EPS wastes

Waste stream	Minimum standard for treatment
• EPS from packaging or • EPS from construction without HBCDD (since 2016)	Recycling into material with HBCDD-content of max. 100 ppm
• EPS from construction containing more than 1000 ppm HBCDD (before 2016)	Disposal and (energy) recovery as defined in POP regulation (850/2004/EC), art. 7.2 and Annex V, part 1.

This minimum standard represents the lowest priority order of treatment in the waste hierarchy. Three different levels of recycling are defined:

1. Recycling of the material in an application that is the same as or similar to the original material;
2. Recycling of the material in an application that is not similar;
3. Chemical recycling.

A key element of the Netherlands policy is that it aims to encourage the application of better treatment solutions. The relevant Netherlands legislation, *Besluit stortplaatsen en stortverboden afvalstoffen,* prohibits inclusion of waste EPS in landfills.

Importing and exporting EPS/XPS waste

In a table (see Annex 5), the draft version of the new Netherlands waste policy (LAP3) presents the rules for importing and exporting EPS waste. The key message is that importing of EPS waste containing more than 1000 ppm HBCDD is allowed for either incineration R1 or treatment in the PolyStyrene Loop process (see Subsection 8.3). The pre-treatment process may include compacting.

Extended producer responsibility for packaging waste

As in many other EU countries, the Netherlands has introduced extended producer responsibility for packaging waste. In 2012, a framework agreement on packaging for the period 2013-2022 (*Raamovereenkomst Verpakkingen 2012-2022*) was signed by the Ministry of Infrastructure and the Environment, packaging importers and producers, and the Dutch association of municipalities (VNG).

With the co-operation of Stybenex, the Dutch national association of EPS producers, EPS packaging waste has been included in the framework agreement since 2013. Municipalities can collect EPS packaging waste from households as a special stream and they get compensated for this collection (see subsection 5.4.2). Commercial EPS packaging waste that is collected from organisations and private companies is excluded from the framework agreement. For this packaging waste there is no compensation.

Environmental Activities Decree

The Dutch Environmental Activities Decree *(Activiteitenbesluit)* includes generally applicable rules for the separate collection of EPS from household waste recycling centres (HWRCs) and organisations. From HWRCs, EPS must be collected separately. If this is not done, the residual waste from this HWRC has to undergo separation treatment before it can be transported to the incineration plant. However, even if this separation treatment takes place and the dry recyclables like plastics and paper are taken out, the EPS fraction is not separated from the residual waste. This means that EPS waste from the HWRCs that is not collected separately needs to be incinerated in all cases.

According to the Environmental Activities Decree, the general rule for organisations is that EPS waste must be collected separately if it is more than 3 kg (=120 liters) per week, if reasonably possible. No distinction is made between packaging and construction waste.

4 OVERVIEW OF QUANTITIES AND HBCDD CONCENTRATIONS

This section presents the quantities of the various streams of EPS/XPS products and wastes. As mentioned in Subsection 1.2, above, these quantities are the researchers' best estimates based on all the information currently available.

For reasons of clarity, the researchers chose to present the overview using exact values instead of ranges for each quantity. Cleary, however, quantities can vary from year to year and depend heavily on market developments and the economic situation, especially when it comes to the EPS for construction purposes.

All the quantities in Figure 4.1, except the legacy quantities, are shown in tonnes/year. The legacy quantities (products/wastes in the yellow cells) are shown as absolute values in tonnes.

Figures 4.1 and 4.2 present overviews of the quantities of EPS/XPS in the Netherlands based on quantities of EPS and XPS products that are placed on the market. Theoretically, production figures of the feedstocks for EPS and XPS, including EPS beads, polystyrene or flame retardant, could also be used to make estimates, but these figures have proven to have little value because the importing and exporting of such feedstocks is not well registered [interviews].

In 2016, the total weight of EPS/XPS products placed on the Netherlands market was approx. 62,500 tonnes, of which approx. 50,500 tonnes was EPS and 12,000 tonnes XPS [interviews].

In the Netherlands, approx. 10,000 tonnes/year of packaging EPS (packaging, horticulture, iceboxes, etc.) is placed on the waste market, based on production plus import minus export (see Figure 4.1).

The actual collection, recycling and disposal of EPS/XPS wastes and their expected future development are presented in Tables 4.3, 4.4 and 4.5.

The notations for HBCDD concentrations that are used in Tables 4.1 to 4.5 are in accordance with the concentration limits of EC regulation 850/2004/EC:

- < 100 ppm no HBCDD or levels of HBCDD allowed (for products)
- < 1000 ppm low HBCDD level, suitable for recycling (for wastes)
- > 1000 ppm HBCDD levels, destruction or irreversible transformation in conformity with Stockholm and Basel Conventions

The origins and backgrounds of the quantities and concentrations presented in Figures 4.1, 4.2, 4.3 and 4.4 are described in Section 5 (Packaging EPS), Section 6 (Construction EPS) and Section 7 (Transport sector). The backgrounds of the quantities included in Table 4.4 (future developments) are presented in Section 8.

Table 4.1: Production, import and export of EPS/XPS (2016, in tonnes/year)

Dutch market	production < 100 ppm	+ import < 100 ppm	-export < 100 ppm	total < 100 ppm
packaging	5,000	4,500	-1,300	8,200
horticulture /ice boxes	3,300	1,050	-2,350	2,000
Total packaging	**8,300**	**5,550**	**-3,650**	**10,200**
construction	40,000	13,500	-500	53,000
civil	2,250	500	0	2,750
Total construction	**42,250**	**14,000**	**-500**	**55,750**
transport sector	0	1,400	0	1,400

Table 4.2: Legacy of EPS/XPS in buildings and storage in homes/companies (2016, in tonnes)

Legacy (cumm.)	< 1000 ppm	> 1000 ppm	total
packaging	2,050	0	2,050
horticulture /ice boxes	900	0	900
Total packaging	**2,950**	**0**	**2,950**
construction	336,000	1,702,000	2,038,000
civil	17,000	85,000	102,000
Total construction	**353,000**	**1,787,000**	**2,140,000**
transport sector	21,000	0	21,000

Landfill	< 1000	> 1000	total
EPS/XPS in landfills	34,500	6,100	40,600

Table 4.3: Collection of EPS/XPS waste (2016, in tonnes/year)

Collection	seperate collection < 1000 ppm	seperate collection > 1000 ppm	mixed waste < 1000 ppm	mixed waste > 1000 ppm	total
household packaging	500	0	3,500	0	8,200
commercial packaging	600	0	3,600	0	
horticulture /ice boxes	1,850	0	150	0	2,000
Total packaging	**2,950**	**0**	**7,250**	**0**	**10,200**
EPS construction sites	100	0	700	0	1,100
EPS demolition sites	0	0	0	300	
civil	0	50	0	0	50
Total construction	**100**	**50**	**700**	**300**	**1,150**
transport sector	1,400	0	0	0	1,400

Table 4.4: Estimated collection of EPS/XPS construction waste in 2030 and 2050 (in tonnes/year)

Estimated collection of construction EPS waste in 2030

	seperate collection < 1000 ppm	seperate collection > 1000 ppm	mixed waste < 1000 ppm	mixed waste > 1000 ppm	total
EPS construction sites	200	0	600	0	3,300
EPS demolition sites	400	100	1,500	500	
civil	0	100	0	0	100
Total construction	**600**	**200**	**2,100**	**500**	**3,400**

Estimated collection of construction EPS waste in 2050

	seperate collection < 1000 ppm	seperate collection > 1000 ppm	mixed waste < 1000 ppm	mixed waste > 1000 ppm	total
EPS construction sites	200	0	600	0	32,600
EPS demolition sites	1,700	4,700	6,600	18,800	
civil	0	400	0	0	400
Total construction	**1,900**	**5,100**	**7,200**	**18,800**	**33,000**

Figure 4.5: Recycling and disposal of EPS/XPS waste (2016, in tonnes/year)

Import	< 1000 ppm	> 1000 ppm
total EPS/XPS	2,500	0

↓

	recycling		incineration		landfill		
Disposal	< 1000 ppm	> 1000 ppm	< 1000 ppm	> 1000 ppm	< 1000 ppm	> 1000 ppm	**total**
packaging	1,100	0	7,100	0	0	0	8,200
horticulture /ice boxes	4,350	0	150	0	0	0	4,500
Total packaging	**5,450**	**0**	**7,250**	**0**	**0**	**0**	**12,700**
EPS construction sites	100	0	700	0	0	0	1,100
EPS demolition sites	0	0	0	270	0	30	
civil	0	0	0	50	0	0	50
Total construction	**100**	**0**	**700**	**320**	**0**	**30**	**1,150**
transport sector	1,400	0	0	0	0	0	1,400

5 PACKAGING EPS

5.1 Quantities and composition of packaging EPS (excluding horticulture and ice boxes)

Most EPS packaging material is used to transport and protect electronic/electrical consumer appliances and furniture, which is imported in large volumes from Asia, the USA and EU countries. The products are mostly placed on europallets and imported in 40-foot sea containers via Dutch ports. The sea containers are transported to wholesale companies, and the pallets are stored in large warehouses. Once ordered, the products are transported to retail companies and further distributed to households.

The EPS waste in the commercial sector is generated in a wide group of small and medium enterprises. These companies separately store and recover cardboard boxes, but there is no standardised collection system for other packaging materials, including EPS. Only large distributors and production companies operate a separate collection system for EPS [interviews].

In the Netherlands, approximately 10,200 tonnes/year of packaging EPS is placed on the market (see Figure 4.1).

On the quantity of packaging EPS produced in the Netherlands, several documents are available [15, 17, 18, 27, 29]. In addition, the quantity that is produced in the Netherlands is registered by Stybenex and Eumeps [interviews].

In a Stybenex assignment in the period 2004-2005 the amount of imported packaging waste was assessed for the entire Netherlands [13]. The methodology was to estimate the amount of EPS per product and to multiply the amounts by the number of products sold. The inventory revealed that, apart from ice boxes and garden trays, a quantity of 4,500 tonnes of EPS packaging was imported annually into the Netherlands, 3,900 tonnes with electrical and electronic equipment and 600 tonnes with bathroom products and furniture. More recent data were not found. These quantities can be reasonably assumed to be still valid.

The EPS that is used in packaging other than horticulture and ice boxes is mostly used as industrial packaging material. Approx. 20% of the packaging material is exported. Horticulture packaging is mainly exported to Belgium and Germany. Ice boxes are predominantly exported to the UK, Belgium, Germany and France [12]. No specific data were found on the destination of the other packaging waste.

The imported EPS waste streams consist mainly of packaging waste for commercial purposes and ice boxes. Used garden trays are also imported as waste but in much smaller quantities [interviews].

The quantity of EPS packaging waste produced by the commercial sector is largely unknown, as is the way in which it is treated. For this inventory, the quantity of this waste stream was estimated by deduction. Since there are reasonably reliable estimates of all the other EPS packaging waste streams, the amount of EPS in the commercial sector is assumed to be the remainder. It is known that some organisations in the commercial sector, mainly the larger companies, compress their EPS packaging waste before collection [interviews], but it is not known which proportion of this waste stream is treated in that way.

HBCDD concentration

Currently, HBCDD is being phased out in the Netherlands. For this reason, Figure 4.1 presents the assumption that the HBCDD content of all EPS that is produced, imported and exported is less than 0.1% (100 ppm).

Degree of contamination

Generally, packaging EPS is a clean waste stream. Most packaging EPS is not laminated or cached (e.g. with cardboard, etc.) and the waste stream is free from contamination. It should be stored in a dry and clean location to prevent contamination with dirt and algae. It has good recycling characteristics. It is most important to organise the collection structure and obtain sufficiently large waste quantities.

Special attention is required for the separation of packaging waste from construction EPS at household waste recycling centres (HWRCs). The HBCDD in construction waste may render the EPS that is collected through HWRCs unsuitable for recycling if it is not collected separately from the packaging EPS (see also Subsection 5.3).

Legacy in households and companies

The legacy of packaging in the Netherlands has been calculated by making the following assumptions:

- the average lifetime of most packaging EPS (95%) is short (6 months);
- a small proportion of the packaging EPS (5%) is kept by consumers for a longer period (5 years);
- packaging EPS with a short lifetime does not contain HBCDD;
- of all the packaging EPS in the Netherlands that is kept by consumers for a period of 5 years, 4% contains HBCDD (7,000 ppm). This is an average estimate. HBCDD content may vary strongly between different packaging applications.

Legacy in landfills

The amount of EPS that has ended up in landfills in the Netherlands can be calculated from historical data. Because of the introduction of landfill tax and the 1997 ban on including household waste and similar waste from the commercial sector in landfills, the legacy quantities over the past decades can be reasonably assumed to be practically zero.

The historic EPS in landfills consists of a mixture of packaging waste and construction waste. This legacy is estimated to be 34,500 tonnes of ‘clean’ packaging EPS and 6,100 tonnes of HBCDD containing construction EPS. This figure was calculated using the data presented in Table 5.1.

Table 5.1: Parameters for calculation of EPS legacy in landfills in the Netherlands

Period	EPS packaging waste (1), (2) (tonnes/year) [12]	EPS construction waste (2) (tonnes/year) [15], 2% cut-offs [19]	% landfill [39], interviews]	% incineration [39], interviews]
1960-1975	500	0	not appropriate	not appropriate
1976-1985	1,500	300	90%	10%
1986-1995	3,000	500	50%	50%
1996-2005	4,000	600	15%	85%
2006-2015	6,500	600	0%	100%
2016	6,500	700	0%	100%

(1) Including horticulture applications and ice boxes
(2) EPS packaging waste that is recycled is not included

5.2 Quantities and composition of horticulture EPS

Quantities
The quantities of horticulture EPS produced, imported and exported are presented in Figure 4.1. The horticulture EPS market has two applications: flowers/plants and groceries/fruit. The latter application is very small and has therefore not been investigated in detail.

In order to grow, transport, store and protect flowers and plants, a wide variety of EPS packaging materials are used in the market. The market can be subdivided into the following groups, with market size:
- Transport trays approx. 75% of total volume
- Seed and nursery trays approx. 25% of total volume
- Special trays (e.g. for cacti)

EPS waste originates from:
- repackaging at trade companies to client-specific packaging;
- repackaging after auction sales to reduce transport volume;
- retail shops;
- potted plant companies who re-pot the young plants.

EPS garden trays is a specialised market. The number of producers of garden trays in the Netherlands is small. The producers of EPS garden trays in the Netherlands have successfully set up a recycling system for the garden trays in which a large proportion of the garden trays that are produced are recycled into EPS that is used for civil engineering applications.

HBCDD concentration
According to the interviewees, HBCDD has never been used in the production of garden trays.

Degree of contamination
The used garden trays can be contaminated with stickers and adhered dirt (soil etc.).

Legacy
The main application of horticulture EPS is in garden trays. A proportion of such garden trays are disposable and are only used once. The rest are used several times. Based on information from the interviews, the legacy of garden trays has been estimated using the following assumptions:

- 50% of the garden trays are only used once and have a lifetime of 6 months;
- 50% of the garden trays are used several times and have a lifetime of 3.5 years.

Horticulture EPS does not contain HBCDD, due to the implementation of a voluntary guideline issued by all members of the Stybenex organization in 2006 [interviews].

5.3 Quantities and composition of ice boxes

Quantities
The quantities of ice-box EPS produced, imported and exported are presented in Figure 4.1. Ice boxes are mostly used in the fisheries sector. In the Netherlands annually, approx. 7.5 million EPS ice boxes are sold in several dimensions (5 – 10 – 20 kg). All fresh fish from auctions is packed in reusable plastic or EPS ice boxes. Approx. 75% are for export; 25% are for the Dutch market. Approx. 90% is transported in EPS ice boxes for exporting. The remaining 10% is transported in reusable ice boxes that are used for short distances to larger clients.

In the Netherlands there are 100-250 fish distributors, mostly concentrated near the fish auctions (Vlissingen, Scheveningen, IJmuiden, Den Helder, Urk and Lauwersoog).

Ice boxes are imported from many destinations, though mainly from North-European countries (salmon) and the Mediterranean Sea.

Table 5.2: Ice boxes in the Netherlands in 1996

Origin	Destination in % fish	Packaging in % fish	Quantity of boxes
NL auctions	25% NL market	10% in EPS boxes	270,000 items
		90% other	
	75% export	90% in EPS boxes	7,230,000 items
		10% other	
Import	100% NL market	100% EPS boxes	2,100,000 items
Total in NL			**2,370,000 items**

Source: Dutch sea fish wholesale sector, 1996

Table 5.2 shows that in 1996 approx. 2.4 million ice boxes were dispatched by wholesalers and retailers. The sector estimates approx. 80% at wholesale and 20% at retail. A large proportion of these ice boxes are exported containing Dutch fresh fish products. A smaller proportion are imported with fish products.

HBCDD concentration
No information was found on the use of HBCDD in ice boxes in the EU. According to the interviewees, ice boxes have never contained HBCDD because the flame retardant is not approved for food contact and ice boxes are always produced from virgin EPS beads.

Recent measurement by a recycler have confirmed that ice boxes that are collected for recycling do not contain HBCDD [interviews].

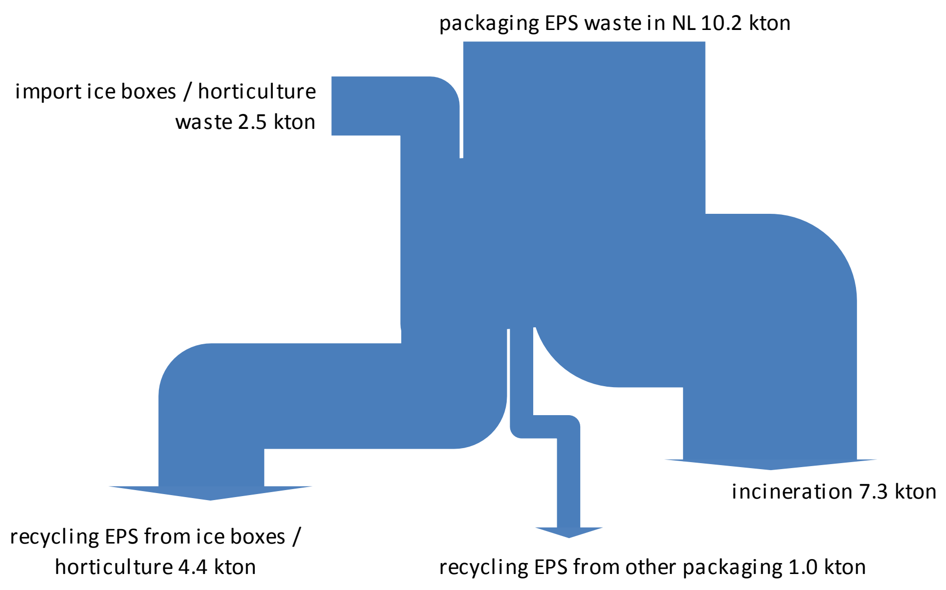
Degree of contamination
Used ice boxes are wet and may have an unpleasant odour because of the ice and fish they contained.

Legacy
Because ice boxes are used to store fresh foods, for hygienic reasons they can only be used once. They are produced immediately prior to use, because storage of empty ice boxes occupies much space. Therefore, the lifetime of an ice box is very short, only 1-2 weeks. The legacy of ice boxes in the Netherlands has been calculated by assuming an average lifetime of 10 days. It is assumed that ice boxes do not contain HBCDD.

5.4 Collection, recycling and disposal of EPS packaging waste

An overview of the collection, recycling and disposal of packaging EPS is presented in Figure 5.3.

Figure 5.3 – Mass flows of packaging EPS waste



5.4.1 General introduction

From the information that was gathered for this inventory it became clear that packaging EPS needs to be collected separately to be suitable for recycling. In general in the Netherlands, if EPS ends up in mixed waste it is no longer removed from this waste for recycling.

For the separate collection of packaging waste, several collection systems operate simultaneously. Mostly there is a specific collection system for each type of packaging waste (see the rest of this subsection).

Given the restrictions that the REACH and POP regulations impose on the use of HBCDD in products and recycling, special attention is given to the collection of EPS packaging waste from households and commercial organisations. These collection channels are susceptible to contamination with construction EPS containing HBCDD, since many people involved in this collection are unaware of the differences between packaging and construction EPS. At least one of the Dutch recyclers uses XRF to sort out EPS waste containing HBCDD. No quantitative data are available regarding the contamination of these waste streams.

For the recycling of EPS, four different mechanical processes were found [interviews]. These are:

1. Re-use of waste and cut offs from EPS production;
2. Shredding EPS into loose EPS particles that can be used as filling material in a range of products;
3. Shredding EPS into loose EPS particles and moulding them together with at least 80% virgin EPS to form construction EPS parts or EPS blocks for civil engineering applications;
4. Melting EPS into polystyrene granulate.

The first process takes place in the production plants of EPS converters. This process is not included in this inventory because it is not relevant. The latter three processes take place on the premises of recycling companies. In the Netherlands, EPS recycling is dominated by three recyclers [interviews].

Garden trays can be shredded into loose EPS particles but are not suitable for melting into polystyrene granulate because of their contamination with soil/sand. Ice boxes can be melted into polystyrene granulate but are unsuitable for reuse as loose particles because of their water content and bad smell [interviews].

Until recently EPS/XPS from construction and demolition sites was used for recycling too. With the new regulations on HBCDD these recycling activities have stopped in 2015 [interviews]. Recyclers also stopped accepting other waste streams that they suspect to contain HBCDD [interviews].

Mostly, the recyclers receive the EPS for recycling free of charge. If the material is already compacted a gate fee can be paid to the collector, depending on the amount and quality.

One of the large players in the Netherlands that operates internationally in this area is De Vries Recycling. This company explains the recycling process graphically on their website, in both Dutch and English (www.devriesrecycling.com). This and other recycling companies, for example in Germany, screen for the presence of HBCDD by sampling the input material to ensure that their process input and output meet the relevant specifications [interviews]. No information is available however on how the screening process takes place.

An overview of the quantities that are separately collected and undergo subsequent recycling is presented in Table 5.3.

Table 5.3: Collection of packaging EPS in The Netherlands (2016, in tonnes/year)

	seperate collection		mixed waste		
Collection	< 1000 ppm	> 1000 ppm	< 1000 ppm	> 1000 ppm	**total**
household packaging	500	0	3,500	0	8,200
commercial packaging	600	0	3,600	0	
horticulture /ice boxes	1,850	0	150	0	2,000
Total packaging	**2,950**	**0**	**7,250**	**0**	**10,200**

The EPS packaging waste that is not collected separately remains in the mixed waste and is transported to one of the 12 waste incineration plants in the Netherlands. All of these incineration plants incinerate with energy recovery and qualify as such (R1 status) according to the EU Waste Management Directive.

In total, the 12 Dutch waste incineration plants incinerated 6,000 kilotonnes of waste generated in the Netherland in 2014. An additional 1,500 kilotonnes of waste were imported from other countries, mainly residues from separation processes [29]. Whether these imported wastes contained EPS is unknown and was not investigated. Since the origin and characteristics of these materials are largely unknown and since their impact on waste handling in the Netherlands is limited, this waste stream is not included in the inventory.

It is assumed that packaging EPS is not included in landfills in the Netherlands. A recent Dutch overview showed that no household waste was landfilled in 2014 [29].

5.4.2 Packaging EPS from households

In the Netherlands, the separate collection of packaging EPS takes place in household waste recycling centres (HWRC's).

In 2011, Stybenex started a promotional programme with the support of the Netherlands Ministry of Infrastructure and the Environment to stimulate separate collection of EPS packaging products from households. The programme introduced a new collection system at HWRCs, using large plastic collection bags. A few locations were introduced where consumers could dispose of their EPS packaging into these bags. The transparent plastic bags allow the HWRC employee to check the content (only white mono material is allowed, not composed or cached).

The results of this separate collection of EPS from households through HWRCs are encouraging. In 2015, 75 of the 400 Dutch municipalities were using this new collection system. In 2016 the system was expected to grow to 100 municipalities [17], though progress is slow [interviews].

Nationwide growth to 250-300 municipalities will lead to an expected waste quantity of 1250 tonnes per year. For 2030, a further growth to 1,500 tonnes per year is expected.

The municipalities are compensated for collected EPS from the Dutch fund for extended producer responsibility for packaging waste. The fund is managed by the Dutch organisation Nedvang. Nedvang has contracted three EPS recyclers to arrange collection and recycling of this material. The quantities that are collected are registered in a computer application called 'Waste Tool'. The collected EPS packaging waste stream must comply with DKR Product Specification 04/2009. The compensation for such collection was € 788/tonne in 2016 and will gradually decrease to € 650/tonne or less over the period to 2022.

The packaging EPS that is collected at the HWRCs is mainly from households (95%), though a small proportion comes from the commercial sector [interviews].
For large quantities (100 m^3), the EPS is collected without transport costs. An amount of € 530/tonne remains. For smaller quantities (up to 40 m^3) the costs are € 75 per transport.

Since the EU's introduction of the REACH and POP regulations, which control the use of HBCDD in EPS and XPS and the treatment of HBCDD-containing EPS/XPS waste, special attention is needed for the collection of packaging EPS from households. Contamination of this waste stream with HBCDD-containing construction EPS/XPS could render this waste stream unsuitable for recycling, because the average HBCDD content of the recycled product would exceed 100 ppm.

The packaging EPS from households that is not recycled is found in residual household waste. In The Netherlands its concentration in household waste ranges between 0.06% and 0.1% [interviews].

5.4.3 Packaging EPS from the commercial sector

For commercial EPS packaging material a distinction must be made between smaller organisations that produce little packaging waste and larger organizations that produce larger quantities. Smaller organisations tend to dispose of their EPS packaging together with their residual waste.

For the larger distribution centres and production companies, it is profitable to keep the EPS, foils and cardboard separately and create a return system. Companies with 10-15 tonnes of EPS packaging per year sometimes buy their own screw compactor. They can compact their EPS to 150 kg/m^3 in small blocks (dimensions 15 cm x 15 cm x approx. 50 cm). There are a few specialised waste collection companies that either collect the uncompacted EPS or deploy a mobile compactor one day each month at the client's address. This results in significant saving on transport costs.

Specific information about what is done with the packaging EPS that becomes waste in the commercial sector is scarce. From interviewees we learned that approx. 600 tonnes per year of EPS packaging is separately collected from the commercial sector in the Netherlands. If a company has a fully loaded 40 m^3 container, the collections costs are equal to the revenues from the recycling company; that is, € 350-400/tonne. In that case the client does not have to pay anything for waste removal. For smaller fractions, the clients can either bring their waste themselves to collection companies (in some municipalities to the HWRC) or pay a collection fee of € 70-80 per hour.

Interviewees revealed that the larger commercial organisations have a reverse logistic system that brings the packaging waste from the local affiliates back to the main distribution point (which may be outside the Netherlands), where this waste is separated into several waste streams including EPS. From here, this EPS packaging waste may be transported to recyclers. However, no detailed information was found on these practices, and attempts to collect data from large companies and branch organisations were unsuccessful.

In 2030 it is expected that 1,600 tonnes/year of EPS packaging will be separated and recycled from companies in the Netherlands. This is because incineration tariffs are expected to increase (with higher EPS volumes, the caloric value of the waste stream increases, which may lead to higher gate fees) and recycling revenues will increase due to higher oil prices.

5.4.4 EPS from horticulture

EPS waste from horticulture consists mainly of garden trays. EPS producers have created their own recycling system for garden trays, whereby specialised recycling companies collect the used trays. Most of the garden trays in the Netherlands are collected through these recycling systems. Used garden trays are ground into particles, which can then be used as filling material or can be mixed with virgin EPS before being moulded into large EPS blocks for use in civil engineering applications.

For the recycling of used garden trays into EPS in civil engineering applications, the level of contamination with other materials must be limited to no more than a few percent. Stickers and adhered dirt are manually stripped from used garden trays.

5.4.5 Ice boxes

Fish traders in the Netherlands that deliver fresh produce to their customers in ice boxes tend to recover them for recycling. These ice boxes are transported to EPS recycling companies in the Netherlands. Some of the major players on the market compact their EPS ice boxes before delivering them to the recyclers.

Before recycling, the ice boxes are manually checked. Stickers, foils and other contaminations are removed. Then the material is compacted using a screw press into polystyrene blocks that have a density of up to 600 kg/m^3. After compacting, this material is mainly processed into general purpose polystyrene regranulate. The regranulate is sold to the plastics industry, for purposes including the production of XPS (see www.devriesrecycling.com).

6 CONSTRUCTION EPS/XPS

6.1 Quantities and composition of construction EPS/XPS for houses and industrial buildings

Quantities

Figure 4.1 gives an overview of the quantities of EPS/XPS representing the current situation in the Netherlands. Construction EPS/XPS is used for isolation (e.g. roof isolation, floor isolation, external thermal insulation composite systems (ETICS) and loose fill).

The amount of EPS that is brought onto the Netherlands domestic market is largely registered by Stybenex, the Dutch National Association of EPS producers. Literature data on the quantities has also been found [15, 18, 27, 30, 31, 32]
In the Netherlands, approx. 40% of construction EPS is applied in industrial buildings. The remaining 60% is applied in houses [19].

The amount of EPS/XPS from building demolitions has been very limited until now. This estimate is based on the assumption that the average lifetime of a building is 75 years. Previous studies, including that by Consultic from 2011 [15], indicated higher quantities of waste construction EPS/XPS from buildings (5,300 tonnes/year). Current practice in the Netherlands is that EPS/XPS is not collected separately, and no data were found on the content of EPS/XPS in the mixed demolition waste. Therefore, it must be concluded that an accurate figure for the amount of waste construction EPS/XPS from construction and demolition sites cannot be calculated. The differences in the estimated quantities probably originate from different assumptions in the lifetime of buildings.

In the Netherlands there are three producers of EPS beads: Synbra Technology BV, Synthos Breda BV en Unipol Holland BV [18, interviews]. For the production of EPS the Netherlands have a small number of large-scale EPS converters and a handful of smaller EPS converters. The total amount of EPS used in construction of buildings is approx. 40,000 tonnes/year.

All the XPS used in the Netherlands is imported. The sole producer in the Netherlands was DOW Terneuzen, though XPS production at this location ceased in March 2012. The total quantity of XPS used for building construction has been estimated to be approx. 12,000 tonnes/year [interviews].

HBCDD concentration

When the use of EPS started in the 1960s, no flame retardant was added. HBCDD was first added in or around 1975, but in the first few years not all of the EPS for construction applications contained HBCDD. For this inventory, it is assumed that all EPS for construction contained HBCDD in the normal concentration (7,000 ppm) from 1990 until August 2016 (see also Subsection 2.4), though in practice many EPS converters stopped using HBCDD well before that date [interviews]. Since construction EPS no longer contains HBCDD, EPS/XPS waste from construction sites should be free of HBCDD. However, in the coming decades most construction EPS from demolition sites will contain HBCDD (see Subsection 8.3).

Degree of contamination

EPS used in construction applications is often contaminated with other materials when it becomes waste. A study on the recycling of EPS from construction applications in the Netherlands from 1997 onward [19] reveals that until 1983 the ratio of 'EPS board' to 'EPS in composites' in construction EPS was 7:3. After 1983, composites became more common, which caused this ratio to shift to 1:3. Construction waste recyclers mention that they see no real opportunity to recycle EPS from construction or demolition waste while it is in the form of 'EPS in composites' [interviews]. In most cases, EPS that is used as loose fill in cavity walls cannot be recycled, as it is highly contaminated with dirt.

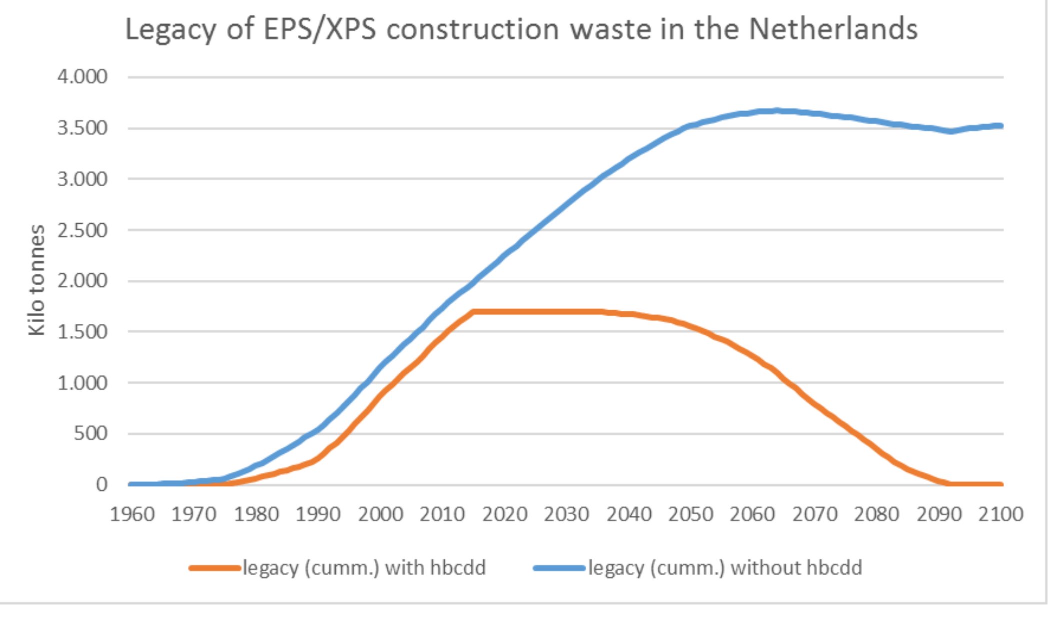
Legacy in buildings

Historical data on produced quantities of EPS have been used to estimate the legacy of construction EPS in buildings in the Netherlands, based on the following assumptions:

- The average lifetime of buildings is 75 years, with the following (simplified) deviation:
  - 25% of the buildings have a lifetime of 60 years;
  - 50% of the buildings have a lifetime of 75 years;
  - 25% of the buildings have a lifetime of 90 years;
- There is no HBCDD in construction EPS from the period 1960-1975;
- There is HBCDD in 50% of construction EPS from the period 1975-1990;
- There is HBCDD in 100% of construction EPS from the period 1990-2015;
- There has been no HBCDD in construction EPS since 2016.

The legacy of construction EPS/XPS in buildings in the Netherlands is presented in Figure 6.1. The total legacy in buildings in the Netherlands is the sum of the quantities with and without HBCDD.

Figure 6.1



A strong growth of EPS/XPS in buildings can be seen since the 1990s. Recently, the use of HBCDD has been reduced. As shown by the red line, from 2016 onward it has no longer been used. According to our calculations, the total amount of HBCDD-containing EPS will decrease to almost zero around the year 2090.

According to our calculations, in the coming 60 years (2016-2075) the following quantities will be generated as waste in the Netherlands:

- EPS/XPS with HBCDD: 1,130 kilotonnes
- EPS/XPS without HBCDD: 370 kilotonnes

Legacy in landfills
There is a legacy of construction EPS in landfills, consisting mainly of EPS from construction activities (cut-offs). This legacy was described above in the context of the legacy of packaging waste in landfills (see Subsection 5.1).

6.2 Quantities and composition of construction EPS for civil engineering applications

The quantities of produced, imported and exported EPS for civil engineering applications are presented in Figure 4.1. In the EU, EPS has been used in civil engineering applications since 1972 [16]. Civil engineering applications in the Netherlands are assumed to have started in or around the same year. No documentation was found on the historical use of EPS in civil engineering applications in the Netherlands.

Because large areas of the Netherlands have high groundwater levels and local soil conditions can be very poor, there are many opportunities for applying EPS in civil projects. The market for EPS in civil engineering applications can vary significantly from year to year, depending on whether there are projects or not. In some projects, large quantities of EPS can be required.

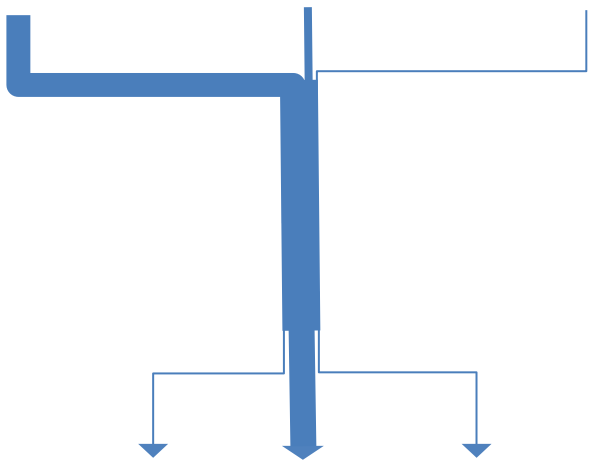
HBCDD concentration
The members companies of the Stybenex organisation decided to add HBCDD to EPS for civil engineering applications to reduce fire hazards wherever appropriate. Possibly, companies in the Netherlands or abroad have not always used HBCDD in the EPS provided for such purposes. It is not known what proportion of the EPS in civil engineering applications contains HBCDD. For this inventory, it has been assumed that all EPS in civil engineering applications contains HBCDD.

Legacy in civil projects
To calculate the legacy of EPS for civil engineering applications it is assumed that 5% of the total annual quantity of construction EPS is used as EPS for civil engineering applications.

6.3 Collection, recycling and disposal of construction EPS

An overview of the collection, recycling and disposal of packaging EPS is presented in Figure 6.2.

Figure 6.2: Mass flows of construction EPS/XPS waste (2016)



From the information that was gathered for this inventory it became clear that construction EPS, similarly to packaging EPS, must be collected separately to be suitable for recycling. In general in the Netherlands, if construction EPS ends up in mixed waste it is no longer removed from this waste for recycling.

For recycling of construction EPS it is important that the EPS is well separated from the other material, because recyclers only allow small amounts of contamination by other products (up to a few percent on weight basis). Preferably, the material should be kept separately in plastic bags.

For the description of collection, recycling and disposal of construction EPS a distinction must be made between construction EPS from construction sites and construction EPS from renovation or demolition sites.

Construction EPS from construction sites
Based on information from the interviewees it can reasonably be assumed that very little of the EPS/XPS waste that is produced at construction sites is currently separated for recycling. Either the EPS that is used is part of a composite insulation product and therefore cannot be separated easily from the other materials, or the amount of EPS waste is too small to keep it separated for collection. Where plain EPS products (EPS insulation boards, etc.) are used, collection of EPS from construction sites is possible, though the interviewees revealed that EPS converters and EPS recyclers (temporarily) avoid recycling construction EPS from construction sites because of the risk of contaminating the production process with material containing HBCDD.

In addition to the HBCDD issue, EPS/XPS that is collected from construction sites needs handling (for manual removal of contaminants) before it can be recycled. On the one hand, the handling costs for the recycling are therefore relatively high. On the other hand, the costs for EPS incineration are relatively low because of the low density of the material. These factors mean that EPS from construction sites is only collected separately for recycling to a very limited extend. In principle all EPS converters can recycle EPS from construction sites (and if clean, also from demolition sites) into new EPS products. The amount of recycled EPS in products could be up to a maximum of 15%. This form of mechanical recycling has stopped in 2015 as a consequence of the legal obligations [interviews].

Construction EPS from demolition sites

The Netherlands waste management policy plan (LAP) is based on the principle of separate collection, and the draft LAP3 elaborates this principle in *Sectorplan 28: Gemengd bouw- en sloopafval*'. Nevertheless, in reality construction EPS/XPS from demolition sites in the Netherlands is mostly collected in a mixed demolition waste stream that is transported to a recycling company that separates this waste into recyclables and residual waste. The general practice is that EPS is not considered to be a recyclable in this separation process.

Waste recyclers that were interviewed for this inventory mention that until now they have hardly found substantial quantities of EPS construction waste in demolition projects. One Dutch website was found that offers the service of separate collection of EPS construction waste (www.piepschuim-recycling.nl, launched by Van Lier Containers), but this service appears to no longer exist.

The interviewees revealed that demolition companies occasionally do their best to keep the EPS within the residual waste fraction because incinerators are reluctant to accept large quantities of EPS as ordinary residual waste due to its high caloric value.

As a result, after separation of construction and demolition waste practically all EPS/XPS construction waste ends up in the residual fraction and is incinerated (see Subsection 5.1.4).

No information was found on the collection and treatment of construction EPS for civil engineering purposes, probably because so far such projects have seldom reached the demolition phase. Since (most of the) EPS in civil engineering applications contains HBCDD, recycling of this material is not allowed. It has been assumed that this material is incinerated, though it remains uncertain whether this material is accepted at the waste incineration plant because of the required permit, its high caloric value and its volume when compacted.

It is assumed that a small proportion of the EPS in construction waste from demolition is still being included in landfills, together with other materials that are not suitable for incineration.

An overview of the annual quantities of construction EPS/XPS is presented in Table 6.1.

Table 6.1: Overview of disposal options and quantities for construction EPS waste (tonnes/year)

Disposal	recycling		incineration		landfill		total
	< 1000 ppm	> 1000 ppm	< 1000 ppm	> 1000 ppm	< 1000 ppm	> 1000 ppm	
EPS construction sites	100	0	700	0	0	0	1,100
EPS demolition sites	0	0	0	270	0	30	
civil	0	0	0	50	0	0	50
Total construction	**100**	**0**	**700**	**320**	**0**	**30**	**1,150**

7 TRANSPORT SECTOR

7.1 Quantities and composition

The main part of this sector is automotive, though it also includes train transport, shipping and aviation.

Figure 4.1 presents an overview of the quantities of materials representing the current situation in the Netherlands transport sector.

Polystyrene products containing HBCDD are used in the transport sector in composite products. The production and use of HBCDD in the transport sector is included in this inventory because it concerns a substantial quantity of material. However, the occurrence of HBCDD in the materials used in this sector is probably low. In 2014, a survey on brominated flame retardants in the plastic components of vehicles manufactured in Japan showed that HBCDD was absent from the vast majority of all the samples, and only 2 out of 515 materials/components contained HBCDD in quantities above 1000 ppm [20]. In both cases, the source was floor covering. An investigation of brominated flame retardants in New Zealand in 2010 showed that HBCDD was present in EPS car child seats and EPS floor insulation, both in concentrations of approx. 3,000 ppm [24].
The interviews revealed that HBCDD might have been used in insulation material used in campers and caravans [interviews].

Most of the plastics from waste originating in the Netherlands transport sector end up in the waste processing plant of Auto Recycling Nederland (ARN) in Tiel. This plant receives the light fraction of shredder waste from several hundred car-dismantling companies in the Netherlands. Overall, the light fraction shredder waste of 85-90% of all end-of-life vehicles in the Netherlands is treated at this plant [21].

In a factsheet, ARN states that in 2014, from the light fraction shredder waste that is treated in the processing plant, a quantity of 3,000-3,500 tonnes of light plastics is produced that consist of 40% polystyrene-based polymers (mixture of acrylonitrile butadiene styrene and polystyrene) [22]. According to information from the interviewees, the HBCDD content in the light plastics fraction is below 50 ppm after shredding.

The light plastics that contain polystyrene are sold to a recycler who processes the material to produce a compound used in the automotive industry.

An important issue in this sector is that articles that contain HBCDD are mixed with other materials by shredding, while the POP regulation of the Stockholm Convention requires separation of HBCDD-containing articles before recycling, if technically and economically feasible.

Legacy

For calculation of the legacy of polystyrene in the transport sector, the following assumptions have been made:

- All polystyrenes from the transport sector end up in the light fraction from shredders;
- 90% of the light fraction from shredders is treated in the waste recycling plant at Tiel;
- 50% of the styrenes mixture consists of polystyrenes;
- The average lifetime in the transport sector is 15 years;

- The concentration of HBCDD in the polystyrenes used in the transport sector is below 100 ppm after shredding.

It should be noted that the HBCDD-containing materials in the transport sector are polystyrenes not necessarily in the form of EPS/XPS. The dense polystyrene material is very different from EPS/XPS. This material is also found in other sectors, including electrical and electronic equipment.

8 FUTURE DEVELOPMENTS AND COST ASPECTS

8.1 Introduction

The new regulations controlling HBCDD in materials – REACH 1907/2006/EC and POP 850/2004/EC – have transformed how materials that (may) contain HBCDD are processed during their production, collection, treatment, transport, recycling and disposal. For certain proportions of these materials, new recycling and removal routes will have to be developed. In addition to determining the quantities involved, cost estimates are necessary to assess the viability of alternative solutions. This section therefore examines cost estimates and expected future developments

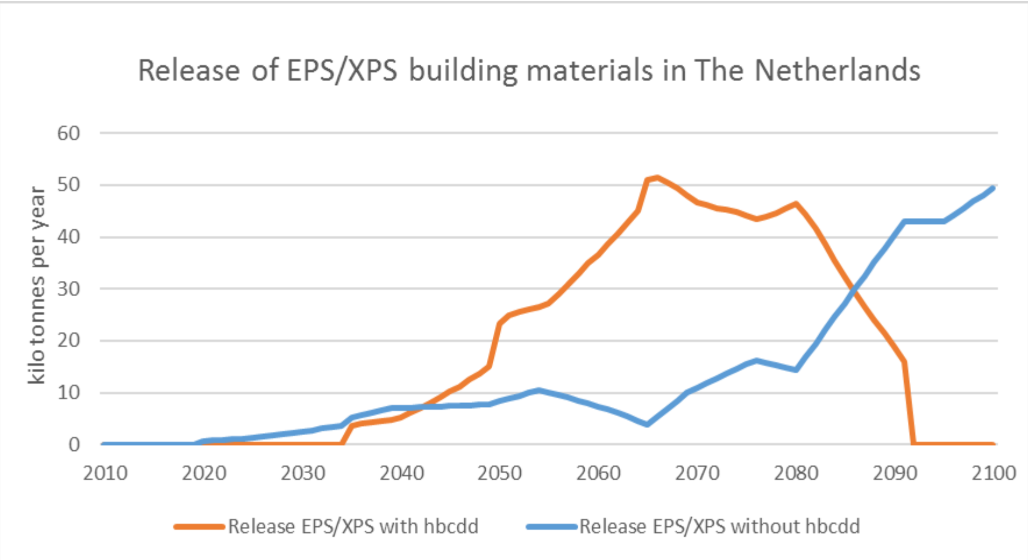
8.2 Future developments in quantities

In the Netherlands, development in the total quantity of packaging EPS is expected to undergo only slight changes in the coming years. The amount of HBCDD in packaging material is already very low and will continue to be so. EPS for packaging produced in the EU does not contain HBCDD. All non-EU producers have been informed about the EU rules on HBCDD, so it is expected that the amount of HBCDD-containing EPS for packaging will be zero in short time.

The situation for construction EPS is quite different. Over the past decade, approx. 50,000 tonnes/year of new construction EPS/XPS have been produced. The production of large quantities of construction EPS is expected to continue in the future, albeit with an alternative flame retardant.

Until now, only limited quantities of EPS waste have been released from demolition sites. With the information used to estimate the legacy (i.e. historical data of construction EPS/XPS in the Netherlands, average lifetime of a building assumed to be 75 years — see Subsection 6.1.1) future quantities of EPS/XPS construction waste to be released from demolition sites can be estimated, as presented in Figure 8.1.

Figure 8.1



According to this estimate, approx. 1,500 tonnes of EPS/XPS waste will be produced in 2025 and approx. 5,500 tonnes in 2035. A large part of this material consists of thin EPS board, because until 1978 construction EPS/XPS mainly consisted of insulation boards with a thickness of 1.5 cm [19]. From 2050 onward, approx. 20,000 tonnes will be released, and around 2065 there will be a peak of approx. 50,000 tons per year.[4] At that time, most of the released material will contain HBCDD. After 2080, the quantity of HBCDD-containing EPS will decrease sharply (red line), whereas the quantity of HBCDD-free EPS/XPS (blue line) will rise sharply.

8.3 The PolyStyrene Loop initiative

In 2015, a Netherlands-based foundation launched an initiative known as the PolyStyrene Loop [23, 25], a process schematic of which is presented in Figure 8.2. The objective is to provide an additional end-of-life option for HBCDD-containing EPS/XPS wastes by building a demonstration plant for the physico-chemical treatment of these wastes in Terneuzen.

The PolyStyrene Loop (PS Loop) process uses CreaSolv technology (physical treatment) to dissolve the EPS/XPS wastes, followed by destruction (chemical treatment) of the HBCDD in a hazardous-waste incinerator. The PS Loop process recovers both bromine and polystyrene. The applied technology has already existed for 10 years, has been tested up to pilot scale and has proven to be effective. The demonstration plant will use this technology at a planned capacity of 3,000 tonnes per year. It should start operating in 2018. According to the business case for the demonstration plant, a gate fee of € 250/tonne could be paid for the incoming waste. The following parameters determine the economics:

- variation of incoming costs for waste (from a negative incineration value of minus € 140/tonne to minus € 800/tonne in Germany);
- sales value of recycled polystyrene between € 900 and € 1,500/tonne over the next ten years;
- available annual waste quantities varying between 1000 and > 3000 tonnes;
- composition of the waste (impurities → inerts need to go to landfill or be incinerated);
- solvent consumption due to inerts needs to be optimised.

The PS Loop process also produces bromine that can be reused. However, the benefits from this product are small due to the small quantity of bromine in the feedstock and its relatively low market price.

If incinerators do not accept polystyrene foams, the PolyStyrene Loop will be the only available solution, so the economic prospects will continue to be positive. The processing fee will be € 500-700 per tonne of recycled polystyrene.

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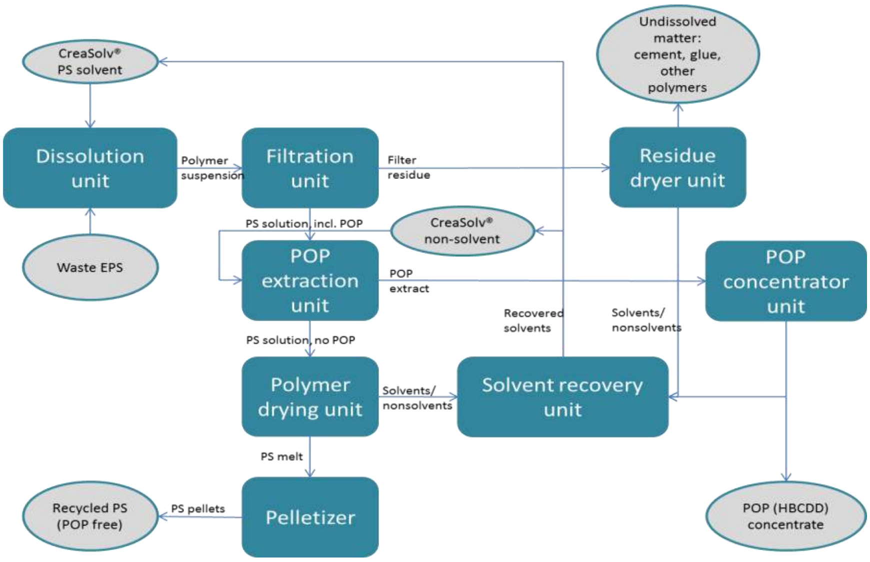
[4] To give an impression of the size of this peak quantity of 50,000 tonnes/year, it is relevant to indicate the volume: 50,000 tonnes/year equals 3.5 million m^3/y, which equals 30 truckloads of 40 m^3 per day.

Figure 8.2: The PolyStyrene Loop process



Just as for the other recycling options for EPS/XPS waste, the incoming material must be clean (contamination with other materials less than a few percent). Therefore, a demolition guideline needs to be written on how to handle polystyrene foam waste. The handling will entail further sorting, cleaning and possibly logistics up to a range of 100 km, followed by a compaction step before entering the PS Loop process with a further maximum range of 250 km. For transport over longer distances, a proposal has been written for the Basel Convention Technical Guidelines [37], whereby a dissolving process is proposed as a pre-treatment step to the existing hazardous waste treatment for HBCDD destruction. The final outcome is expected in May 2017 at the next Convention of Parties in Geneva.

This inventory shows that currently there does not seem to be sufficient EPS/XPS construction waste in the Netherlands to meet the capacity of the planned installation. This situation is likely to change in the future. The Dutch recycling sector is already encountering difficulties in sending mixed demolition waste streams containing EPS/XPS materials to incinerators because of the high caloric value of the included EPS/XPS [interviews].

In Germany, the acceptance of HBCDD-containing EPS/XPS has recently become a problem. As a result, incineration prices have occasionally reached € 7,000/tonne and long-term contracts with prices of € 800/tonne have been signed [interviews].

8.4 Cost estimates for collection, recycling and disposal

An overview of the cost estimates for collection, treatment and transport of EPS is presented in Table 8.1. The total costs for recycling and disposal of EPS/XPS waste streams are presented in Table 8.2.

The key figures that were used to estimate the costs presented in Tables 8.1 and 8.2 are presented in Annex 6.

Table 8.1: Current cost estimates for collection, treatment and transport of EPS/XPS waste streams

	collection+treatment+transport		collection costs
Type of EPS	contamination	description	€/tonne
household EPS packaging	clean	bags + cont + collection + compaction	600-800
	light	cont + mixed waste collection	60
commercial EPS packaging	clean	bags + collection + compaction	450-700
	light	cont + mixed waste collection	100
horticulture/ ice boxes	light	cont + collection + cleaning + compaction	400-550
	light	cont + mixed waste collection	100
EPS construction sites	light	cont/bags + collection + compaction	500-650
	heavy	cont + mixed waste collection + sorting	180
EPS demolition sites	light	cont + collection + sorting + compaction	550-700
	heavy	cont + mixed waste collection + sorting	180
civil	heavy	cont + seperate collection	350-480
transport sector	light fraction	compaction + transport	120

prices have a range of +/- 20% : depending on quantity per location and transport distances

Table 8.2: Cost estimates for disposal of EPS/XPS waste streams

	recycling and disposal	process costs	value of semi-finished products	total disposal (gate fee)
Type of EPS	description	€/tonne	€/tonne	€/tonne
household EPS packaging	grinding and recycling as PS granulate	300-400	-600 to -750	-300 to -350
	incineration	90		90
commercial EPS packaging	grinding and recycling as PS granulate	300-400	-600 to -750	-300 to -350
	incineration	90		90
horticulture / ice boxes	grinding and recycling	200-400	-500 to -750	-300 to -350
	incineration	90		90
EPS construction sites	grinding and recycling as EPS blocks	200-400	-500 to -600	-200 to -300
	incineration	90		90
EPS demolition sites	chemical treatment and recycling (future)	350-450	-600 to -750	-250 to -300
	incineration	90		90
civil	incineration	90		90
transport sector	grinding and recycling as fill material	200-300	-150 to -200	50 - 100

prices have a range of +/- 20% : depending on quantity per location and transport distances

The resulting total chain costs are shown in Table 8.3.

Table 8.3: Cost estimates for total chain costs of EPS/XPS waste streams

Type of EPS	collection, treatment & transport	€/tonne	recycling and disposal description	total disposal €/tonne	other revenues €/tonne	total chain costs €/tonne
household EPS packaging	coll. from recycling parcs	600-800	recycling	-300 to -350	-788	-350 to -500
	mixed waste	60	incineration	90		150
commercial EPS packaging	seperate collection	450-700	recycling	-300 to -350		150-350
	mixed waste	100	incineration	90		190
horticulture/ice boxes	seperate collection	400-550	recycling	-300 to -350		100-200
	mixed waste	180	incineration	90		190
EPS construction sites	seperate collection	500-650	recycling	-200 to -300		200-450
	mixed waste	180	incineration	90		270
EPS demolition sites	seperate collection	550-700	chem. treatm & recycling	-250 to -300		300-400
	mixed waste	180	incineration	90		270
civil	seperate collection	350-480	incineration	90		440-570
transport sector	no coll. (on site)	120	incineration	50 - 100		170-220

prices have a range of +/- 20% : depending on quantity per location and transport distances

8.5 Estimate of total costs for the Netherlands

A rough estimate of the total costs for removal of EPS/XPS wastes in the Netherlands is presented in Table 8.4. This estimate is based on the quantities from this inventory and the cost estimates presented in Tables 8.1, 8.2 and 8.3.

Table 8.4: Cost estimates for disposal of EPS/XPS waste streams (2016)

Total costs on national level in 2016		ton/year	€/tonne	euro/year
household EPS packaging	from recycling parcs	500	-440	-220,000
	mixed waste	3,500	150	525,000
commercial EPS packaging	seperate collection	600	220	132,000
	mixed waste	3,600	190	684,000
horticulture / ice boxes	seperate collection	4,350	80	348,000
	mixed waste	150	190	29,000
EPS construction sites	seperate collection	100	250	25,000
	mixed waste	700	270	189,000
EPS demolition sites	seperate collection	6	300	2,000
	mixed waste	294	270	79,000
civil	seperate collection	100	520	52,000
transport sector	no coll. (on site)	1,400	250	350,000
		15,300	**144**	**2,200,000**

Based on the quantities of the EPS/XPS waste streams determined by this inventory, the total projected costs for the Netherlands in 2030, 2050 and 2065 are presented in Table 8.5.

Table 8.5: total costs for the Netherlands in 2030, 2050 and 2065

Total costs on national level	ton/year	euro/year	compared to 2016
in 2016	15,300	2,200,000	
in 2030	17,500	3,600,000	1,400,000 extra
in 2050	47,000	11,300,000	9,100,000 extra
in 2065	71,000	17,900,000	15,700,000 extra

8.6 Future aspects of the PolyStyrene Loop initiative

Looking to the year 2030 and beyond, large quantities of demolition EPS/XPS waste will be released from buildings, as high as 20,000 tonnes/year in 2050. For the PS Loop project to be expanded from a demonstration plant of 3,000 tonnes/year, the availability of new plants of this type needs to keep pace with the increasing waste streams. It is easy to scale up a demonstration plant to a unit capable of processing 10,000 tonnes/year. Alternatively, additional units can be installed up to the desired capacity. For the further implementation of the PS Loop project, co-operation with construction/demolition waste recycling companies is essential. Smart co-operation in collection and transport can lead to a cost-minimising synergy. The required investment in a demonstration plant is approx. € 6-7 million, though scaling up to 10,000 tonnes/year installed capacity should cost approx. € 15 million.

The implementation of the PS Loop will have several positive effects:
- More high-quality EPS will be available to the recycling industry;
- Revenues for construction/demolition waste recycling companies will rise;
- The recycling industry will gain extra growth opportunities, especially if large quantities are not accepted by incineration companies due to their high volumes and caloric value;
- Destruction of HBCDD;
- Recovery of polystyrene and bromine.

The treatment of this hazardous waste will be cost-neutral up to a negative cost of € 800/tonne, depending on the composition and volumes available.

ICL-IP in Terneuzen previously installed a bromine recovery unit (BRU) that can be used for the destruction of HBCDD. It has an installed capacity that is sufficient for all PS Loop plants that are expected to be built in the EU in the coming 20 to 30 years.

For the start-up phase and further development of the process in Terneuzen, the PolyStyrene Loop project has applied for funding by the EU Life2020 programme. The decision on this application is expected in June 2017 [interviews].

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

This inventory of size (i.e. quantities) and values of EPS/XPS containing materials in the Netherlands has led to the following conclusions.

9.1.1 Legal framework

- The EU Waste Framework Directive defines HBCDD-containing EPS/XPS waste as a 'mirror entry' (see Subsection 3.2). Whether this waste is hazardous or non-hazardous depends on the specific case and the composition of this waste. An assessment of the ecotoxic property HP14 of waste is required to determine if HBCDD containing EPS/XPS has to be considered as hazardous or non-hazardous waste. Until now such an assessment has not taken place.
- The new Netherlands waste management policy plan (LAP3, draft version) requires all HBCDD-containing EPS/XPS from construction and demolition sites to be destroyed. The Dutch Environmental Activities Decree *(Activiteitenbesluit)* obligates municipalities and organisations to collect EPS waste separately but does not distinguish between packaging EPS and construction EPS. The new regulations for HBCDD in materials – REACH 1907/2006/EC and POP 850/2004/EC – require that HBCDD-containing construction EPS waste be separated from HBCDD-free packaging EPS waste. Where this separation will take place is to be decided in the context of LAP3.

9.1.2 Quantities

- An overview of the quantities of EPS/XPS products and waste streams in the Netherlands is generated (see Section 4).
- Collection of EPS packaging waste from households via household waste recycling centres (HWRCs) is developing well, stimulated by national waste policy measures including the Netherlands system of extended producer responsibility. The collection rate is expected to grow in the future, though only gradually.
- The amount of packaging waste from the commercial sector has been deduced from other quantities. However, where this packaging waste is generated and what is done with it is largely unknown. In this sector, the large quantity of packaging EPS that ends up in the mixed waste stream (3,600 tonnes/year) gives rise to the idea that a higher level of recycling can be obtained from this stream.
- The separate collection of EPS/XPS waste from demolition has barely started in the Netherlands. According to the new Netherlands waste management policy plan (LAP3, draft version), separate collection is the guiding principle. This principle is elaborated in a special plan for this sector *(Sectorplan 28: Gemengd bouw- en sloopafval)*. In the coming years, separate collection of this material is expected to grow because the total quantity of this material released from buildings is increasing and the incineration of large quantities of this material is expected to be problematic because of its high volume and high caloric value.

9.1.3 HBCDD concentrations

- Much is known about the HBCDD concentrations in products. Until recently, XPS that was placed on the market generally contained 1.5% (15,000 ppm) HBCDD, whereas construction EPS contained 0.7% (7,000 ppm) HBCDD. Packaging EPS generally did not contain HBCDD, though it is unclear whether this has always been true for 100% of this material.
- The HBCDD content of waste streams is largely unknown. Better insight into HBCDD concentrations is required to ensure that production, collection and recycling of EPS/XPS materials conforms to the new regulations for HBCDD in materials. This is particularly true for the packaging EPS coming from household waste recycling centres and the commercial sector. Without paying special attention to this material, HBCDD-containing EPS could contaminate these waste streams and render them unsuitable for recycling.

9.1.4 Degree of contamination

- For the recycling of EPS/XPS waste streams, separate collection is essential, as this material has to be very clean to be suitable for recycling (only a few percent of contamination with other materials is allowed). It is practically impossible to separate EPX/XPS from packaging or construction applications from other waste materials once it is mixed and contaminated with other types of waste and dirt.
- Thanks to past initiatives by EPS converters, very high recycling percentages have been achieved for horticulture trays and fishery ice boxes due to specific systems for separate collection.

9.1.5 Costs

- Costs per tonne for collection and recycling of EPS/XPS materials are relatively high, whereas the total quantity in tonnes is relatively small. Separate collection and recycling of these materials will increase if more value is given to the environmental benefits of removal. For these materials, quantity reduction leads to a strongly reduced transport impact.
- Currently, the total costs for the removal of EPS/XPS in the Netherlands are quite limited (just over € 2 million/year). However, these costs will gradually rise to over € 17 million (using 2016 price level) in 2065 because of the higher quantities.

9.1.6 Knowledge gaps

- The amount of EPS/XPS from building demolitions has been very limited until now (1,100 tonnes/year). This estimate is based on the assumption that the average lifetime of a building is 75 years. Previous studies, including that by Consultic (2011), indicated higher quantities of waste construction EPS/XPS from buildings (5,300 tonnes/year). Current practice in the Netherlands is that EPS/XPS is not collected separately, and no data were found on the content of EPS/XPS in the mixed demolition waste. Therefore, it must be concluded that an accurate figure for the

amount of waste construction EPS/XPS from construction and demolition sites cannot be calculated.
- Little is known about the occurrence of HBCDD in waste from the transport sector. Literature data suggest that HBCDD only occurs in certain materials from certain types of cars. With the existing system for the treatment of end-of-life vehicles in the Netherlands, it is impossible to separate HBCDD-containing material from the rest of the material before it is recycled.
- The PolyStyrene Loop initiative represents a promising recycling solution (material recovery) for waste construction EPS/XPS containing HBCDD and other similar materials. Implementation of the PolyStyrene Loop would lead to a major environmental improvement. However, it is unknown whether sufficient suitable EPX/XPS material from construction and demolition waste streams can be found to match the installed capacity and whether hurdles in the legal framework can be overcome.

9.2 Recommendations

This inventory of quantities and values of EPS/XPS-containing materials in the Netherlands leads to the following recommendations.

9.2.1 Legal framework

- As the EU Waste Framework Directive defines HBCDD-containing EPS/XPS waste as a 'mirror entry' (see Subsection 3.2), an assessment of its hazardousness is needed to determine at EU level whether this waste is hazardous or non-hazardous.
- The Netherlands Ministry of Infrastructure and the Environment should promote a coherent approach in the EU regarding the status of HBCDD-containing wastes as non-hazardous waste.
- Support from the Netherlands Ministry of Infrastructure and the Environment is needed to ensure that recycling technology such as the PolyStyrene Loop process be added as pretreatment in the General Technical Guidelines of the Stockholm and Basel Convention.
- The Netherlands Ministry of Infrastructure and Environment should facilitate the importing of HBCDD-containing EPS/XPS wastes for treatment in the best possible manner (incineration with energy recovery or physico-chemical treatment).
- Incorporation in the new Netherlands waste management policy plan (LAP3, draft version) is required to enable recycling of the new type of HBCDD-free construction EPS/XPS. Polystyrene with an HBCDD content below 100 ppm must be recycled. Incineration of this 'clean' polystyrene should be prevented.
- The Netherlands waste management policy plan (LAP3) should further obligate municipalities and the commercial sector to separately collect packaging EPS and construction EPS/XPS.
- The Netherlands waste management policy plan (LAP3) should obligate certain commercial sectors to register the collection and removal of packaging EPS and construction EPS/XPS. This would lead to a substantial increase in the quantities of separately collected packaging EPS and construction EPS/XPS, thus contributing to the circular economy.

- Guidance is needed on how to handle polystyrene foam in construction and demolition waste, especially concerning the handling of combinations of EPS with concrete, stone, wood and bitumen.

9.2.2 Quantities

- In order to stimulate the separate collection of packaging EPS in the commercial sector, it is recommended that there be investigation of how the commercial sector currently handles its waste packaging EPS and how the separate collection of this material can be improved.
- It is also recommended that there be investigation of opportunities for the separate collection of EPS/XPS waste from demolition waste, both in the Netherlands and in neighbouring countries. Such an investigation may be helpful in finding sufficient waste construction EPS/XPS to enable development of a recycling option for HBCDD-containing EPS/XPS.

9.2.3 HBCDD concentrations

- To ensure that production, collection and recycling of EPS/XPS materials conforms with the new regulations for HBCDD in materials, measurements of HBCDD concentrations in the various product and waste streams are recommended. This is especially important for imported EPS products and EPS packaging material for recycling that may include HBCDD-containing EPS/XPS.

9.2.4 Costs

- It is recommended that, in co-operation with large organisations and recyclers, there be investigation of opportunities for compacting waste EPS/XPS before transporting it to recycling or disposal. This could lead to a significant reduction in the quantity of transport that is required, leading to a major environmental benefit.

9.2.5 Knowledge gaps

- It is recommended that there be investigation of the composition, quantities and quantity development of EXP/XPS waste from demolition and other potential HBCDD-containing waste. Better insight into the characteristics of these waste streams is essential to assess the quantities of EPS/XPS waste that are suitable for the physico-chemical treatment process of the PolyStyrene Loop.
- As HBCDD concentrations in the light fraction shredder waste from end-of-life vehicles affects recycling prospects, elimination of HBCDD from end-of-life vehicles in the transport sector could be facilitated by determining which parts from which vehicles contain HBCDD.
- The PolyStyrene Loop initiative should be developed further to demonstrate that collection, sorting, cleaning and recycling of HBCDD-containing EPS/XPS is possible and can lead to a better solution for the treatment of this type of waste.

giraf results

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Annex 1 - Project plan "Inventory of the size and value HBCDD containing waste streams" (dated 12 September 2016)

The central research question is:

To quantify the amount of polystyrene (EPS) waste released in the Netherlands and the concentration HBCDD contained therein. Besides quantifying the amounts of waste and HBCDD, quantifying the costs associated with the various waste processing options is requested.

In 2013 hexabromocyclododecane (HBCDD), a brominated flame retardant, has been added to the Stockholm Convention because of its persistent and bioaccumulative properties. Thus, production and use of HBCDD containing products are prohibited for all parties to the Convention. Articles containing HBCDD already in use at the time of the entry into force of this ban are excluded, whereas an exemption can be requested for the application of HBCDD for EPS (expanded polystyrene) in buildings. The latter exemption is valid for five years from the date of implementation. This means that the ban on this application shall enter into force only in 2019 if notified.

Before HBCDD was added to the Stockholm Convention, it was already regulated through the REACH regulation, where it was incorporated in the authorization list (annex XIV). Thirteen companies have made use of the opportunity to request authorization to produce and use this substance. Therefore, Europe has notified the United Nations that it would opt-out from the Stockholm Convention ban in November 2014, before the Convention would become effective. In August 2015 Europe has notified the UN for a prolongation of the opt-out as the European Commission (EC) and its member states has not made a decision yet on whether or not to grant authorization.

The EC and the EU Member States have not yet reached agreement on the inclusion of HBCDD in the EU POP Regulation 850/2004 / EC. Discussion points here are:
a. the HBCDD concentration above which EPS waste to be considered as POPs waste that must be destroyed (low POP content in Annex IV 850/2004 / EC) and
b. the maximum HBCDD concentration allowed for new or recycled products to be produced and to be put on the market (value in annex I 850/2004 / EC)

HBCDD is added to polystyrene because of the fire-resistant properties, and for this reason is mainly used on a large scale in the construction industry, both in the housing as well as in a variety of civil engineering applications. HBCDD is (has) also (been) used in applications in textiles and electronics. HBCDD is not included on the positive list of food contact material (EC 10/2011). However, it cannot be excluded that HBCDD is found in other applications of polystyrene, such as in packaging and consumer applications such as plastic razors, clothes hangers and CD cases. Although the application in such uses seems limited, there are a few publications reporting on HBCDD in consumer products, see for example Samsonek & Puype 2013 and Rani et al 2014.

During the process of inclusion of HBCDD in the Stockholm Convention there has been extensive discussion about dealing with the amount of HBCDD, which are still in buildings and in due course will be released as waste. In Germany, for example, the amount of EPS is estimated at 5 million tonnes, containing 35,000 tons of HBCDD. This

building EPS will be released in the coming decades. However, this has not led to an exception for recycling as for POP-BDEs (See Annex A Stockholm Convention).
A proper analysis of the amounts of HBCDD in various waste streams has not taken place, nor a balanced discussion on the preferable waste options. The documents for the Stockholm Convention include general information about the waste stage. Specific information on HBCDD concentrations in waste streams and applications, however, is not clear. Nor is it clear what costs are associated with the different options for processing and incineration, recycling, landfill or export.

The research focuses on the analysis and description of the relevant articles and polystyrene waste in the waste stage. It is important to make an estimate of the size of the various waste flows and the HBCDD concentrations present therein. Furthermore, it is important to determine whether HBCDD-containing polystyrene waste streams are, or can be separated from other waste streams, whether this can be done effective and in a practical way and to describe this for the subsequent process options: recycling, incineration or landfill

The study sought to answer the following questions:
• How does the waste processing of EPS takes place (collecting, sorting, separation, incineration, landfill, recycling,..)?
• What is the size of the various polystyrene waste streams (construction waste, building waste, packaging material waste, consumer waste)?
• What are the concentrations of HBCDD in these waste streams? Data to be based both on literature and through an indicative number of samples both before and after recycling as well as import and export.
• What circumstances and conditions play a role (e.g. by incineration)?
• Is an effective separation between polystyrene with and polystyrene without HBCDD possible and does it take place in practice?
• What are the risks to humans and the environment during the various processing options?
• What are the costs of the various treatment options?

In the first instance, the situation is outlined for the NL market. Possibly an estimate can be given for several countries or even for the EU as a whole through key performance indicators.

The results of the project provide information on the Dutch reporting obligations under both the Stockholm Convention and the EU POP Regulation. Moreover, it provides information to reach an informed decision in Europe on how to deal with HBCDD containing waste streams.
The end product is an English report. This report will be used as a basis for defining the position of the Netherlands, as well as input into the EU decision making process. In addition, it can be introduced as a concrete example in the debate on finding a balance between maximizing recycling (Circular economy) and the minimization of SVHCs in the circuit (non-toxic material cycles).

Annex 2 - Steering committee and interviewed experts

The steering committee that was formed for this project is presented in Table 1.

Table 1: Steering committee

Nr.	Organisation	Name
1	Ministry of Infrastructure and the Environment	Mr C. Luttikhuizen (Chairman)
2	Ministry of Infrastructure and the Environment	Mr P. Frijns
3	RIVM	Mr M.P.M. Janssen
4	Eumeps	Mr E. Meuwissen
5	Synbra	Mr J. Noordegraaf
6	ICL	Mr L. Tange
7	Stybenex	Mr H. E. Las

A list of the experts that were interviewed for this project is presented in Table 2.

Table 2: Interviewed experts

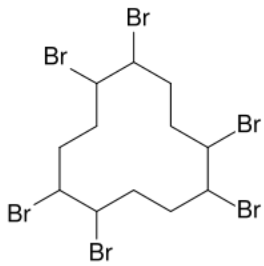
Nr.	Organisation	Name
1	Hordijk EPS	Mr W. Roodzant
2	Marvision	Mr A. Scholten
3	Icova	Mr H. Hageman, Mr G.P. Grundman
4	Eco Fill (B)	Mr K. van Roy
5	De Vries Recycling	Mr G. van Veen
6	Afvalspiegel	Mr T. Daamen
7	Suez	Mr R. de Schrevel
9	Nedvang	Mr C. Bertens
10	Vereniging Afvalbedrijven	Mr L. Urlings
11	Rijkswaterstaat	Mr B. van Huet
12	Exiba	Mr C. Block
13	BRBS	Mr M. de Vries
14	Kras Recycling	Mr B. Kras
15	Poredo	Mr B. de Wijs
16	Oosterbeek EPS	Mr H. Averesch
17	Beelen	Mr M. Schutte Mr V. van Meerlanden
18	Baetsen	Mr T. Kees
19	Van Vliet Contrans	Ms N. Donker
20	Rense Milieu Advies	Mr R. Rense

Annex 3 - Characteristics of HBCDD

The context from this annex was published in 'Guidance for the inventory, identification and substitution of Hexabromocyclododecane (HBCD)', UNEP,April 2015 [1].

Hexabromocyclododecane (HBCDD) has a cycle ring structure with Br-atoms attached (see Table 2-1). As a commercially available brominated flame retardant, HBCDD is lipophilic, with low water solubility and a high affinity to particulate matter. The molecular formula of the compound is $C_{12}H_{18}Br_6$ and its molecular weight is 641 g/mol. For commercial uses, HBCD usually has three stereoisomers, which consists of 70-95 % γ-HBCDD and 3-30 % of α- and β-HBCDD, while in theory 16 stereoisomers could be formed.
Information about HBCDD characteristics are shown in Table A3.1.

Table A3.1: Basic information of HBCDD

Chemical Properties	**Characteristics of Chemical**
Chemical name (IUPAC)	Hexabromocyclododecane
Identification numbers (CAS number, EC number)	CAS No. 25637-99-4, 1,2,5,6,9,10-hexabromocyclododecane (CAS No: 3194-55-6) and its main diastereoisomers: alpha-Hexabromocyclododecane (CAS No: 134237-50-6); beta-hexabromocyclododecane (CAS No: 134237-51-7); and gamma-hexabromocyclododecane (CAS No: 134237-52-8). EC number: 247-148-4
Molecular Formula and Structure (general) and molecular weight:	C12H18Br6 (641.7 g/mol) 
Names of the major diastereoisomers identified	alpha-hexabromocyclododecane (CAS No 134237-50-6) beta-hexabromocyclododecane (CAS No 134237-51-7) gamma-hexabromocyclododecane (CAS No 134237-52-8)
Trade name:	Cyclododecane, hexabromo; HBCD; Bromkal 73-6CD; Nikkafainon CG 1; Pyroguard F 800; Pyroguard SR 103; Pyroguard SR 103A; Pyrovatex 3887; Great Lakes CD-75P™; Great Lakes CD-75; Great Lakes CD75XF; Great Lakes CD75PC (compacted); Dead Sea Bromine Group Ground FR 1206 I-LM; Dead Sea Bromine Group Standard FR 1206 I-LM; Dead Sea Bromine Group Compacted FR 1206 I-CM.
Density	2.24 g/cm^3 to 2.38 g/cm^3
Auto flammability	Decomposes at >190 °C
Vapour pressure	6.3·10-5 Pa (21 °C)

Annex 4 – Plan for sampling and analysing HBCDD in products and waste streams

1. Introduction

This annex presents a measurement plan for assessing the HBCDD content in EPS/XPS materials.

2. Reasons for measuring

For the scope of this inventory there are two distinct reasons for wanting to measure HBCDD in EPS/XPS materials.

The first reason is to check whether the use, recycling and disposal of EPS/XPS products in the Netherlands follows the new European regulation. The two HBCDD concentrations for EPS/XPS materials in this respect come from the POP Regulation 850/2004/EC, being:
a. 1000 ppm as the HBCDD concentration above which EPS/XPS waste is to be considered as POPs waste that must be destroyed (low POP content in Annex IV 850/2004/EC) and
b. 100 ppm as the maximum HBCDD concentration allowed for new or recycled products to be produced and to be put on the market (value in annex I 850/2004/EC).

The three central questions for correct use recycling and disposal are:
1 Do all EPS products on the Dutch market have a HBCDD content below 100 ppm?
2 Do all EPS waste streams that are used for recycling have a HBCDD content below 1000 ppm?
3 Are all EPS waste streams with a HBCDD content above 1000 ppm available for incineration or the PSL project?

The second reason for wanting to measure HBCDD is to prepare an indicative overview of the occurrence of HBCDD in materials in the Netherlands, in use, recycling and disposal. For this overview the HBCDD concentration in each product and waste stream should be determined, preferably in a statistical manner. After this is done HBCDD quantities can be calculated for each product and waste stream by multiplying quantities and concentrations for each stream.

3. Analysing techniques

For the measurement of the HBCDD content in EPS/XPS materials the three main options are:

1. State of the art laboratory methods
The state-of-the-art laboratory methods use internationally standardized gas chromatography-mass spectrometry (GC-MS) or liquid chromatography –mass spectrometry (LC-MS) techniques. These techniques can be applied to all materials. A small sample of material has to be dissolved in liquid for each measurement. The techniques detect HBCDD specifically in materials from the low µg/kg range. The price per sample for this type of methods is high (in the range of € 200-250 per sample).

2. X-ray fluorescence spectroscopy

X-ray fluorescence spectroscopy (XRF) can be used to detect the element Bromine (Br) in materials. The XRF measurement can be applied on the materials itself. No samples are needed. This measurement technique is relatively cheap. Although the XRF scanner itself is expensive (approx. € 30.000), scanning is cheap because measurement is simple. XRF scanners are available as handhelds. The limit of detection of Bromine for the XRF scanner is approx. 10 mg/kg (10 ppm) which corresponds to approx. 14 mg/kg HBCDD [7].

A problem with XRF is that it detects Bromine and not HBCDD. Since new flame retardants that have replaced HBCDD are also brominated components, these new flame retardants are also measured. XRF cannot distinguish between HBCDD and other brominated flame retardants.

3. X-ray fluorescence spectroscopy including extractive method

A new analysing method (2014) was developed by Fraunhofer (HBCD-IG) for the rapid offline identification of HBCDD in EPS/XPS using X-ray fluorescence spectroscopy (XRF) on EPS/XPS samples that are dissolved in acetone (2 g material in 5 g acetone) [7]. This method can distinguish between HBCDD and other polymeric brominated flame retardants because HBCDD dissolves in acetone and other flame retardants (polymers) hardly dissolve. The lower detection limit of this technique is approx. 50 mg HBCDD per kg (= 50ppm).

Problem with this analysing method is that there is little validation or interlaboratory study available and it is not accepted as an international standard yet. Another problem is that the UNEP Guidance for POP analysis (2007) that the limit of quantification (LOQ, the lowest concentration that can be quantitatively determined with suitable precision) is 2-3 times the lower detection limit. For this method LOQ would be 100 – 150 ppm. This means that this method is not very suitable for EPX/XPS samples with concentrations close to the maximum HBCDD concentration for product (100 ppm).

The method is attractive however because the analysing method is much simpler than GC-MS or LC-MS and the price per sample will therefore be much lower. The method could also be used by recycling companies. An exact price per analysis is not available at this stage but can be estimated to be in the range of € 20-100 per sample once an XRF spetroscope is available.

Because better and cheaper analysing techniques for HBCDD are required, especially in the lower range of HBCDD concentrations, there is a programme for further development of these techniques under the supervision of a working group of the International Electrotechnical Commission (IEC) [interviews].

4. Sampling of material streams – many samples

Sampling and analyses is needed to learn more about the actual HBCDD-content of each of the material streams. Figure A4.1 shows the separate product and waste streams in which the HBCDD-content should be determined for the check on correct use and recycling or for the preparation of the HBCDD overview.

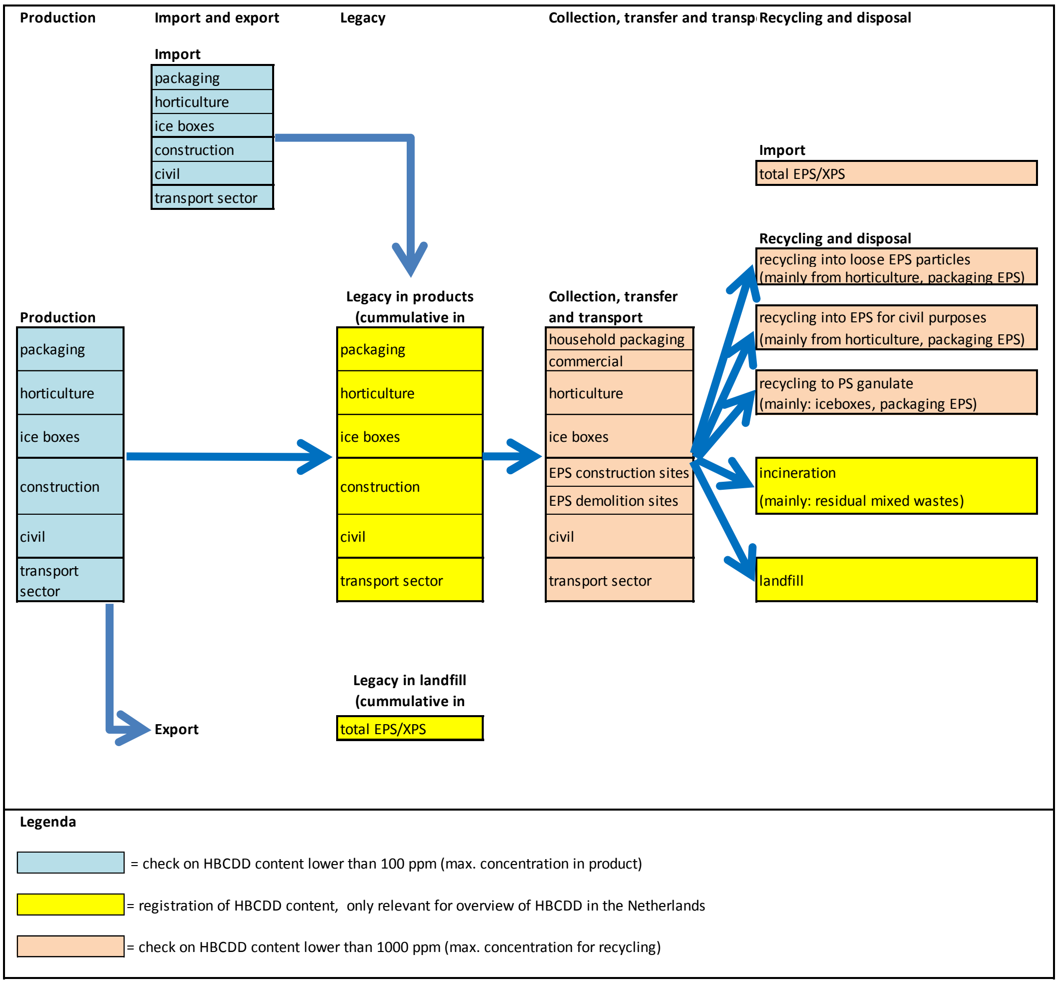
Regarding the measurement strategy the product and waste streams can be divided into the following three categories:

- *new or recycled products*
  In these materials the HBCDD content should be lower than 100 ppm (value in annex I 850/2004/EC). In Figure A4.1 these materials are indicated in blue.

- *waste streams for recycling*
  These materials are unsuitable for recycling and should be destroyed if the HBCDD content is above 1000 ppm (low POP content in Annex IV 850/2004/EC). In Figure A4.1 these materials are indicated in orange.

- *Materials in legacy and waste streams for incineration*
  For these materials there is no restriction on their HBCDD content. The HBCDD content of these materials is only relevant for the overview of HBCDD in materials in the Netherlands. In Figure A4.1 these materials are indicated in yellow.

Figure A4.1 – EPS/XPS materials and their measurement strategy



The fact that there are many material streams in which the HBCDD content should be measured implicates that many samples have to be taken and analyzed.

5. Taking samples

For the measurement of Bromine with XRF no sampling is needed. A handheld XRF device can be used to measure the bromine concentration from the material itself. A problem with polystyrene foams is that the XRF screening method is not so accurate, because of the low density of the material. A compaction step might be needed. Another problem for this screening method could be getting access to the materials from which the measurements must be taken.

Taking samples from materials for analysis of HBCDD in dissolved material is more complex when the type of material from which the sample should be taken is not homogeneous, as is the case with all waste streams. In this case many small bits of material have to be collected to make a sample that represents the entire stream.
This especially complicated in packaging waste streams where most items do not contain HBCDD but an unintended item of material contains HBCDD in the range of construction material i.e. 7000 ppm.
The general standard for taking samples for waste streams is NVN 5860: 1999 nl (Dutch version).

6. Programme for sampling and analysis in three phases

For the best results at acceptable costs a programme for sampling and analysis in three phases is proposed.

Phase 1 – Screening with XRF
In the first phase a screening on brominated flame retardants in material is performed with XRF (handheld device). The following materials should be screened:
- All types of material that are produced
- All types of material that are imported
- All types of packaging wastes (household, commercial, horticulture and ice boxes) and waste from transport sector
- Packaging waste from import
- All materials coming from EPS recycling (PS regranulate, loose recycled EPS)

In this screening phase several hundred samples must be analysed from approx. 50 different locations.

Phase 2 – Analysing HBCDD in specific products and waste streams
The results of phase 1 are used to develop the strategy for analysing HBCDD in products and waste streams in the second phase. The products and waste streams that should be analysed could be selected based upon:
- The existence of a concentration limit for the HBCDD content of the material (the blue and orange type of materials in Figure A4.1);
- The indication from the phase 1 screening that HBCDD levels might be too high.

To limit the costs for analysis in this phase it is suggested to use new analyzing method using X-ray fluorescence spectroscopy including extractive method (see under 3.). It is suggested to analyse HBCDD content using in approx. 50 samples taken from:

- Imported packaging
- Imported construction products
- Imported materials in the transport sector
- Collected waste material from the transport sector
- Recycling products (loose fill, fill for civil engineering applications and PS granulate)

As discussed under 3., the X-ray fluorescence spectroscopy including extractive method is not so accurate for materials with HBCDD contents in the lower range (around 100 ppm). Therefore it is suggested to analyse the part of the samples that were analysed using X-ray fluorescence spectroscopy including extractive method and that showed a low content of HBCDD (approx. 50% of the 50 samples) also with gas chromatography-mass spectrometry (GC-MS) or liquid chromatography –mass spectrometry (LC-MS).

Phase 3 – Completing the overview of HBCDD in the Netherlands
As an option the HBCDD content of all the types of material presented in Figure A4.1 could be measured. This is particularly interesting when an estimation is needed for the amount of HBCDD that is in the legacy in products and landfill.
To limit the costs for analysis in this phase it is suggested to use new analysing method using XRF measurement of dissolved material (see under 3.).

Annex 5 – New Netherlands national policy for importing and exporting EPS waste (in Dutch, from LAP 3, draft version)

Overbrenging vanuit Nederland:

Overbrenging vanuit NL:	*In beginsel toegestaan?*	*Toelichting, voorwaarden of uitzondering*
(voorlopige) nuttige toepassing:		
t.b.v. voorbereiding voor hergebruik	Ja	Voor EPS-verpakkingsmateriaal, indien (voorbereiding voor) hergebruik technisch mogelijk is tenzij uiteindelijk zoveel van de overgebrachte afvalstof wordt gestort of anderszins verwijderd dat de mate van recycling de overbrenging niet rechtvaardigt (zie beleidskader paragraaf B.13.5.2).
	Nee	Voor EPS-bouwmaterialen, omdat nuttige toepassing niet is toegestaan op grond van de POP-verordening.
t.b.v. recycling of, t.b.v. voorlopige nuttige toepassing gevolgd doorrecycling	Ja	Voor EPS-verpakkingsmateriaal tenzij uiteindelijk zoveel van de overgebrachte afvalstof wordt gestort of anderszins verwijderd dat de mate van recycling de overbrenging niet rechtvaardigt (zie beleidskader paragraaf B.13.5.2).
	Nee	Voor EPS-bouwmaterialen, omdat nuttige toepassing niet is toegestaan op grond van de POP-verordening.
t.b.v. andere nuttige toepassing	Nee	voor EPS-verpakkingsmateriaal, omdat recycling mogelijk is.
	Ja	Voor EPS-bouwmaterialen, uitsluitend indien het hoofdgebruik als brandstof betreft (R1).
(voorlopige) verwijdering:		
t.b.v. verbranden en t.b.v. andere vormen van (voorlopige) verwijdering[2] dan verbranden of storten	Nee	Voor EPS-verpakkingsmaterialen, omdat recycling mogelijk is.
	Ja	Voor EPS-bouwmaterialen indien de verwerking in overeenstemming is met de bepalingen uit de POP-verordening (zie de opmerking boven deze tabel)
t.b.v. storten	Nee	Op grond van nationale zelfverzorging en in veel gevallen ook omdat storten slechts zeer beperkt is toegestaan op basis van de POP-verordening.

Overbrenging naar Nederland:

Overbrenging naar NL:	*In beginsel toegestaan?*	*Toelichting, voorwaarde of uitzondering*
(voorlopige) nuttige toepassing		
t.b.v. voorbereiden voor hergebruik	Ja	Voor EPS-verpakkingen, indien (voorbereiding voor) hergebruik technisch mogelijk is en er geen wettelijke belemmeringen voor hergebruik zijn.
	Nee	Voor EPS-bouwmaterialen omdat: • op de markt brengen hiervan in strijd is met de bepalingen uit bijlage 1 van de POP-verordening; en • omdat uitsluitend overbrenging voor inzet als brandstof (R1) of voor verwijdering (D9 of D10) is toegestaan.
t.b.v. recycling	Ja	Voor EPS-verpakkingen.
	Nee	Voor EPS-bouwmaterialen omdat uitsluitend overbrenging voor inzet als brandstof (R1) of voor verwijdering (D9 of D10) is toegestaan.
t.b.v. andere nuttige toepassing	Nee	Voor EPS-verpakkingen, omdat recycling mogelijk is.
	Ja	Voor EPS-bouwmaterialen indien de verwerking in overeenstemming is met de minimumstandaard (R1).
(voorlopige) Verwijdering		
t.b.v. verbranden en t.b.v. andere vormen van (voorlopige) verwijdering dan verbranden of storten[2]	Nee	Voor EPS-verpakkingen, omdat recycling mogelijk is.
	Ja	Voor EPS-bouwmaterialen indien de verwerking in overeenstemming is met de bepalingen uit de POP-verordening (zie de opmerking boven deze tabel)
t.b.v. storten	Nee	Op grond van nationale zelfverzorging en/of op grond van nationale wettelijke bepalingen en (voor EPS-verpakkingen) omdat recycling mogelijk is.

Annex 6 – Key figures for cost calculations

This annex presents the key figures that were used to calculate costs as presented in Section 8 of this document.

Key figures for collection, treatment and transport (Table 8.1)[5]:

- Bags for separate EPS collection: € 150/t (approx. € 1 per bag with 6 – 7 kg EPS)
- Storage container (40 m3): renting a 40 m3 container costs 30 – 60 € / month. In a year approx. 3 – 5 tonnes of EPS is collected at a household waste recycling centre, so price is € 100-150/t
- Separate collection of EPS: between € 170-250/t
- Sorting (only little contamination) and compaction: 100-150 €/t
- Transport: € 30-50/t

Key figures for the cost estimates of disposal of EPS/XPS waste streams (Table 8.2):

- Shredding and extrusion to PS granulate: 200 to 400 €/t for clean waste streams and 300 to 400 € when light sorting has to be done.
- Shredding and creating EPS for civil engineering applications sector: 280 to 700 €/t
- Incineration costs: average price for residual and household waste: € 90 / t. For high caloric waste the gate fee is 150 to 200 €/t.
- Market price of loose beads for drainage /furniture market: 900 to 1000 €/t
- Market price for PS granulate is at the moment circa 600 €/t. The market price is depending on the quality of the material and price of virgin material (in general 900 to 950 €/t)
- For the transport sector the costs from the recycling factory of ARN in Tiel to the recycling industry in France are calculated. Since it is a mixed semi-final product (light fraction) we calculated with a revenue of 150 to 200 €/t.

Key figures for the cost estimates of the total chain costs of EPS/XPS waste streams (Table 8.3):

- Other revenues: for household packaging EPS there is a positive return for municipalities of approx. 788 €/t due to the VANG contribution. This has a positive effect on the further introduction of the bag collection system at household waste recycling centres.

[5] These figures are based on interviews with waste-recycling experts as well as logistical calculations incorporating volume, frequency and density of the waste fractions (separate EPS/XPS or mixed waste).

Annex 7 – Examples of EPS products

This annex presents several example photographs of EPS products.

<u>EPS packaging for commercial activities</u>

<u>EPS packaging for electrical appliances</u>

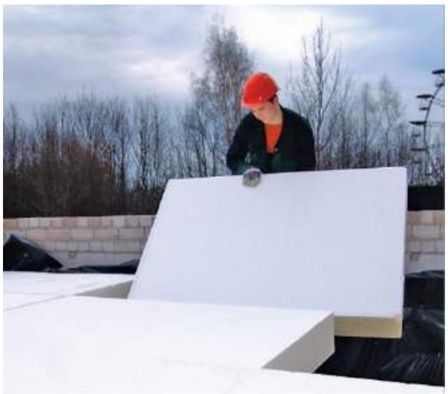
<u>EPS packaging in horticulture</u>

Examples of iceboxes

EPS and HIPS high-density products

EPS box for
protecting paintings

EPS construction materials



giraf
results

Civil engineering applications

11 COLOPHON

Client	:	Ministry of Infrastructure and the Environment, The Netherlands
Project	:	HBCDD in EPS/XPS waste in the Netherlands
File	:	P102.01
Report size	:	65 pages
Authors	:	G. Erens M.Sc., J. van Dijk M.Sc.
Date	:	22 Dec. 2016
Name/Paraph	:	

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