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Provincie Zeeland

PolyStyreneLoop

Guideline on the Collection and Pre-treatment of polystyrene foams for PolyStyreneLoop

About Giraf Results

Giraf Results provides consultancy and project management services in solid waste management and has a strong background in circular economy projects and polystyrene foam recycling. The development of the Guideline on the Collection and Pre-treatment of polystyrene foams for PolyStyreneLoop is part of the activities for LIFE grant 16 ENV/NL/000271.

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List of abbreviations

BRU	Bromine Recovery Unit
EPS	Expanded polystyrene
FR	Flame retardant
HBCD	Hexabromocyclododecane
HWRCs	Household waste recycling centres
PIR	Polyisocyanurate Foam
PPM	parts per million
PS	Polystyrene
PSLoop	PolyStyreneLoop
PUR	Polyurethane Foam
XPS	Extruded Polystyrene
XRF	X-ray fluorescence

INTRODUCTION

Relevance	**Demolition** **Collection** **Pre-treatment** **Transport**
Content	**PolyStyreneLoop at a glance** • Short answers to the most important questions
	The context explained • Background information on HBCD and (H)CFCs
	Logistical network for collection • From demolition to recycling • The HUBs

Introduction

PolyStyreneLoop at a glance

PolyStyreneLoop in a nutshell

Who is PolyStyreneLoop?

- PolyStyreneLoop (PSLoop) is an initiative by the polystyrene foam value chain.
- We count over 70 members and supporters from over 15 European countries organized in a cooperative.

What does PolyStyreneLoop do?

- PolyStyreneLoop offers a recycling solution for expanded and extruded polystyrene (EPS and XPS) waste coming from demolition.

Why does PolyStyreneLoop do it?

- Since the 1960s HBCD has been used as flame retardant in EPS and XPS. Since 2016 the mechanical recycling of this waste stream is no longer permitted. Today, as an industry we work together to take our responsibility and find a solution within the regulatory framework that preserves resources.

How does PolyStyreneLoop do it?

- Through a physico-chemcical recycling process polystyrene and bromine are recovered and HBCD is safely destroyed.

Where is PolyStyreneLoop located?

- The PolyStyreneLoop plant is located in Terneuzen in the south-west of the Netherlands close to the border with Belgium.

When is PolyStyreneLoop operational?

- The plant will be operational in Q4 2020/Q1 2021. We are now starting with the construction of the plant and setting up the logistical network for the collection and pre-treatment of the PS foam waste.

The context explained

The story of HBCD in EPS and XPS

- Since the 1960s, the flame retardant HBCD has been used in EPS and XPS.
- For many years, it was the best solution to ensure safety in case of fire and to meet national fire regulations. However, HBCD is now considered a pollutant. It can therefore no longer be used and has since been replaced by another flame retardant.
- Millions of tons of PS foam waste can no longer be regularly recycled and for a time incineration or in some rare cases landfilling were the only treatments available. A best practice agreement for the handling of this waste is essential. With the innovative recycling process used by PolyStyreneLoop, an industry-scale recycling process for PS foams containing HBCD will be developed. This technology has already been included in the UNEP Basel Convention as a best available recycling technology to handle HBCD waste.
- The PolyStyreneLoop demonstration plant - with the capability to handle 3,000 tons of PS waste per year - is aimed to start up in Q4 2020/Q1 2021. The project will demonstrate the technical, economical and environmental viability of this new recycling process, and will lead on to further roll out the process at more plants in many countries throughout Europe and the rest of the world.
- The PolyStyreneLoop initiative is launched to create a circular solution for PS foams that contain HBCD.

The story of (H)CFCs in XPS

- HBCD is not the only component that has to be removed from XPS before the polystyrene can be recycled. In many cases XPS products that are produced before 2002 contain (H)CFCs short for (hydrogenated) chlorofluorocarbons, that were used in the production of XPS as blowing agent.
- (H)CFCs are ozone depleting substances that were brought under the international treaty of the Montreal Protocol in 1989 [1]. (H)CFC's may not be recycled and according to EU regulation a destruction technology for XPS that contain (H)CFC must remove and destruct with an efficiency of at least 95% [2].
- XPS foam that is produced after 2001 no longer contain (H)CFCs. After 2001 other ozone friendly blowing agents are used.
- PolyStyreneLoop is working on a technology that will release and capture (H)CFCs before they are further treated.

Introduction

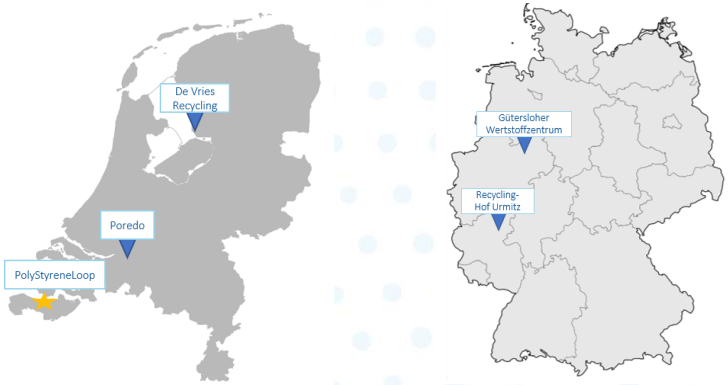
Logistical HUB network

Organizational set-up

The role of the HUB

- PSLoop does not demolish, collect, pre-treat or transport the PS foam waste to be treated. This is done by professionals in the field. PSLoop has set-up a network of so-called “HUBs” in the Nethelands and Germany which will continue to grow in the future.

HUB locations in the Netherlands (left) and Germany (right)

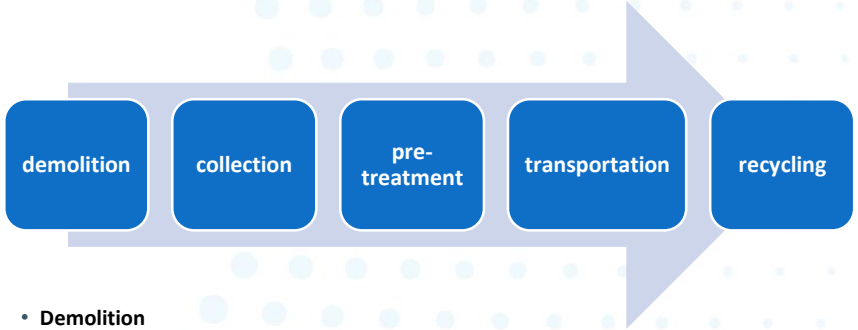


Certification and contracting

- HUBs can be working in one or more steps prior to recycling at the PSLoop plant. What defines a HUB however is that it ensures that the material is pre-treated in such a way that it meets the input specifications of PSLoop. For the quality of the EPS waste that the HUBs have to supply to PSLoop an acceptance sheet is developed (see Appendix 4).
- HUBs are members of the PSLoop cooperative and have direct supply agreements with PSLoop. This supply agreement defines the general conditions for cooperation.
- PSLoop has set up a certification system for the HUBs supplying sorted and compacted EPS waste to the PSLoop demonstration plant. This certification is a measure to safeguard the required quality of the incoming material.
- As a first step PSLoop is focusing on the sourcing of EPS waste containing HBCD.

Collection logistics

- Material recycled by PolyStyreneLoop comes from demolition sites and has to undergo a process of collection, pre-treatment and transportation before it is finally treated in the plant where polystyrene and bromine are recovered.



- **Demolition**
  - The major part of the HBCD-containing PS foam waste is generated at sites where old buildings are demolished. This work is done by demolition companies. In order to keep the waste suitable for treatment in the PSLoop demonstration plant, the PS foam waste has to be kept separate as much as possible from other waste like concrete, rubble, wood, glass etc..
- **Collection**
  - From the demolition sites waste collection companies collect the waste and bring it to the pre-treatment facility.
- **Pre-treatment**
  - Impurities are further removed and material is compacted and prepared for transport. This is done by recyclers already working in the EPS industry or demolishers with possibility to also pre-treat the material. Pre-treatment is a core task of a HUB as here they ensure that the material complies to the input specifications of PSLoop.
- **Transportation**
  - PS foam waste is transported to the PSLoop plant in Terneuzen. This can be done via own or external carriers.

IDENTIFICATION

Relevance	**Demolition** **Pre-treatment**
Content	**Expanded Polystyrene (EPS)** • How to identify it and where it is used
	Extruded Polystyrene (XPS) • How to identify it and where it is used
	Overview of the most common insulation materials and their charateristics
	Decision-tree • Questions that can help guide towards identifying HBCD or (H)CFCs
	Pre-screening with XRF

Identification

EPS and XPS

Introduction

- PolyStyreneLoop will treat both EPS and XPS waste containing HBCD. Due to the additional challenge of (H)CFCs in XPS we are working on a pre-treatment technology that will release and capture the (H)CFCs. The focus of this Guideline is therefore more on EPS than XPS.

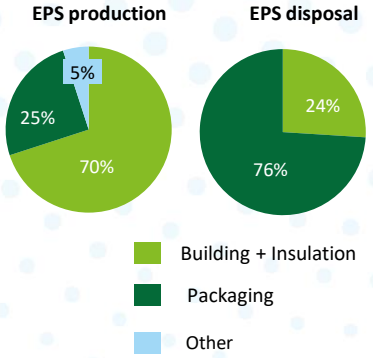
Expanded polystyrene (EPS)

How can I recognize EPS?

- Expanded polystyrene (EPS) is a rigid foam distinguishable by its color and texture.
- Most of the time EPS is white and sometimes grey or a mix of the two. New material will sometimes contain black beads from graphite or carbon black.
- The texture of EPS allows a visual separation of different beads. When breaking a piece of EPS, the material can be crumbled back into the beads.
- EPS is made from polystyrene, a thermoplastic polymer that melts at higher temperatures and can be moulded into different shapes.

In which applications can I find EPS?

- EPS can be used in the following three applications:
  - Building + Insulation
  - Packaging (Industrial + Food)
  - Others (Automobile, Medical, Marine, Sports & Leisure, etc.)
- Although 70% of the EPS that is put on the market is for Building + Insulation purposes, the situation is different for EPS material in the end-of-life phase because the lifetime of EPS in construction is much longer than in packaging.
- A European study showed that in 2017 the largest part of EPS waste in Europe (74%) consisted of packaging waste. Only 26% originated from building and construction. In this study "Other EPS" was not monitored [1].



Extruded polystyrene (XPS)

How can I recognize XPS ?

- Extruded polystyrene (XPS) is a foam that is made out of polystyrene, just like EPS. XPS is produced using extrusion technology. The result is a smooth and rigid foam, that exists in different colours. The colour can be linked to the company that produced the XPS board.

The various colours of XPS

In which applications can I find XPS?

- XPS is primarily used in the construction sector for building and insulation purposes. The most common applications for XPS include perimeter insulation, thermal bridge insulation, cavity wall insulation, flat roof insulation and sandwich panels

How do I know whether the XPS contains (H)CFCs?

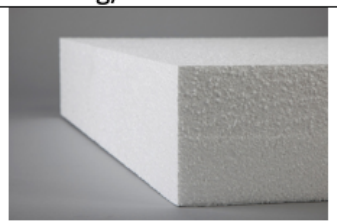
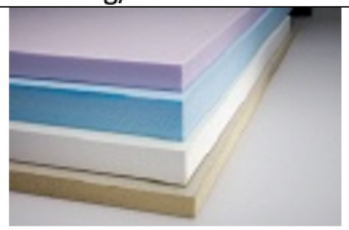
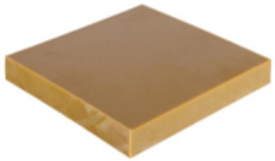
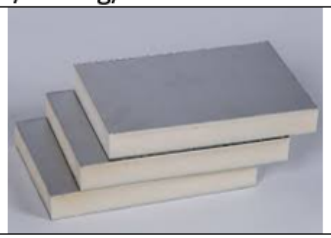
- In practice it appears to be difficult to distinguish XPS containing (H)CFCs from XPS that was produced with new blowing agents. Whether an XPS plate contains (H)CFCs can however be derived from the production type code. This code is shown on the surface of the plates, on old plates the code can sometimes be unreadable.
- Pre-screening with an XRF-scanner can detect whether XPS contains chlorine or not. (H)CFCs are chlorine connections. More about pre-screening analysis can be found on slide 11.

Identification

Types of insulation material

What different types of insulation materials are there?

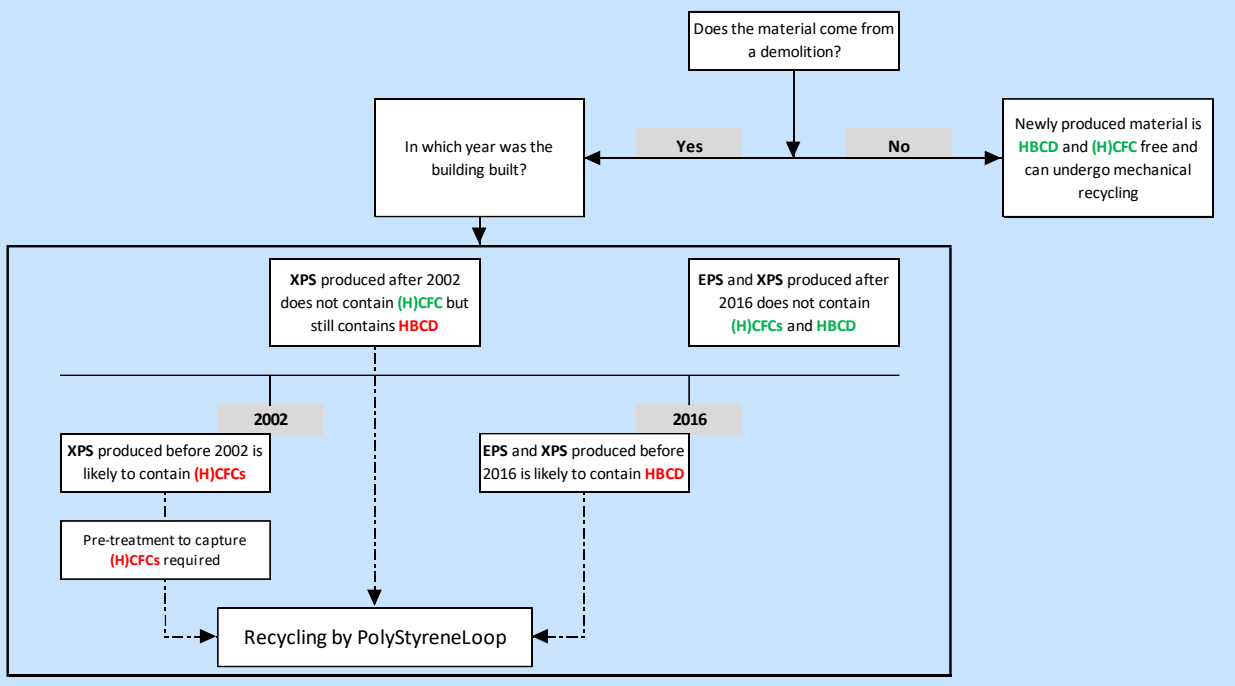
- Next to EPS and XPS there are a number of other insulation materials on the market. In order to properly distinguish them, the overview below will help.

	EPS Expanded polystyrene	XPS Extruded polystyrene	PUR Polyurethane	PIR Polyisocyanurate
Application	Construction and Packaging	Mostly construction	Construction	Construction
Appearance	Smooth and rigid, individual EPS beads visible to the eye	Smooth and rigid	Smooth and rigid	Smooth and rigid
Manual breaking	Manual breaking possible between the EPS beads	Manual breaking very difficult, homogenous/smooth structure	Manual breaking possible but difficult, porous structure	Manual breaking possible but difficult, porous structure
Cell structure	Closed	closed	closed	closed
Polymer type	Thermoplastic	Thermoplastic	Thermoset	Thermoset
Colours	White, grey, white with grey beads	yellow, white, pink, blue, green, purple	yellow/brown	yellow/white
Density	15-20 kg/m³	30-60 kg/m³	+/- 30 kg/m³	+/- 30 kg/m³
Picture				

Identification
HBCD and (H)CFCs

Decision tree

- The decision tree can help with identifying whether EPS and XPS that are likely to contain HBCD and whether XPS also contains (H)CFCs.
- The decision is based on the origin of the waste and the construction date of the building that is being demolished.
- The decision tree is a good first step to categorize but cannot give 100% certainty.
- Further screening with an XRF (see below) or more elaborate GC-MS analysis can give an accurate result.



Pre-screening with X-ray fluorescence (XRF) analysis

- HBCD is a brominated flamer-retardant (FR). XRF only detects the the elemental bromine (Br) and does NOT distinguish between HBCD and other types of brominated FRs.
- In Europe, packaging EPS waste mostly does not contain FRs. If the pre-screening, shows a positive result, the packaging is likely to come from Asia. As HBCD is still allowed to be used in some Asian countries and HBCD can be cheaper than the other brominated FRs, the chance that the packaging contains HBCD is higher.
- In order to not take any risks, it is recommended to keep suspected streams on the side, pre-treat them if necessary, compact them and transport them for further treatment to PSLoop.
- (H)CFCs are chlorine based. The XRF can therefore also detect chlorine and provide a pre-screening result on the presence of (H)CFCs.

THE MARKET

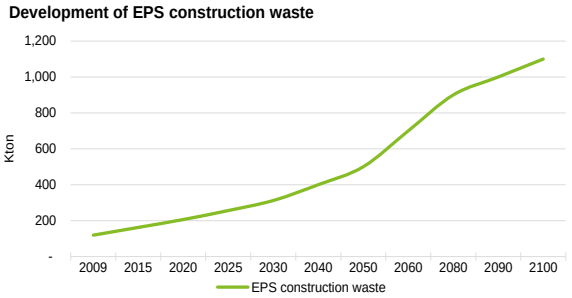
Relevance	**Demolition** **Pre-treatment**
Content	**Growing supply of PS foam waste from demolition**
	EPS Packaging Waste coming from Household Waste Recycling Centres

The Market

Supply of PS foam waste

Growing supply of PS foam waste from demolition projects

- PSLoop focuses on PS foam waste with HBCD. For PS foam without HBCD there are other and often more lucrative recycling options.
- The largest HBCD containing PS foam waste stream is produced by demolition activities. It is expected that this waste stream will grow to over 800 kilotons in Europe within the next 50 years.
- As buildings are demolished at the end of their service life, commonly between 30-100 years, an increasing amount of waste has to be processed as more insulated buildings reach the end of their service life.
- The adjacent figure shows the projected development of PS foam construction waste in Europe.



Household waste recycling centres

- Household waste recycling centres (HWRCs) are locations where citizens can dispose of their different waste streams. HWRCs allow for the separate collection of many different types of waste streams. The most extensive HWRCs may collect up to 20 different waste fractions. HWRCs exists in most municipalities throughout Europe.
- In the Netherlands, EPS is one of the fractions that is collected separately on a great number of HWRCs. The focus here lies on the collection of packaging waste only.

Collection of EPS from household waste recycling centres

- Packaging materials currently placed on the market do not contain HBCD. A small part of the imported and produced packaging material contains a brominated flame retardant in the form of PolyFR. No indication was found that the flame retardants FR-720 and SR-130 are used in packaging material [1].
- A study conducted in 2018 showed that also construction EPS is sometimes collected on HWRCs. Furthermore, a small part of packaging EPS might still contain HBCD [1]. The reason for this is that part of the older packaging EPS material comes from Asia, where HBCD is sometimes used in packaging EPS.
- To ensure that all recycled products are compliant to the concentration limits for HBCD, mechanical recyclers need to sort-out all EPS packaging waste suspected to contain HBCD. Attention needs to be paid to the increasing volume of EPS construction waste containing HBCD that will come free in the decades to come to ensure this does not contaminate mechanical recycling but is appropriately treated.
- An XRF-scanner can help with pre-screening. The suspected stream can then be compacted and transported to PSLoop for further treatment.

DEMOLITION

Relevance	**Demolition** **Collection** **Pre-treatment**
Content	**Overview of EPS applications** • Insight into the impurities to expect, the advised collection method on the demolition site and pre-treatment technologies to remove impurities

Demolition

Overview of applications, impurities, collection mode and pre-treatment technologies

Explanation of Terminology

- **Possible impurities:** looks into how different applications are used (in ground or in combination with other materials) and what type of impurities this may lead to. These impurities need to be removed as much as possible
- **Collection**: how the application is collected on the demolition site
  - **Mixed**: the application will likely be collected together with other materials
  - **Separate**: impurities are separated resulting in a rather clean EPS stream
  - **Selective**: the application is a composite and on-site the different layers may be removed
  - **Composite**: the composite application is collected as system
  - **Vacuum**: EPS is collected through vacuum
- **Pre-treatment**: Different pre-treatment steps that can be undertaken to receive a clean EPS stream. This will most likely take place on the site of the HUB
  - **Density-based:** separating the EPS from other impurities based on their varying densities. Wind-sifting or sink-flow technologies are an option.
  - **Removal**: manual or mechanical removal of layers of other material
  - **Brushing**: brushing off with a broom to remove sand or dirt
  - **Crushing**: crushing the material to smaller pieces. This is done for applications that are collected as mixed or composite systems, followed by density-based sorting to obtain a clean EPS stream

Foundation formwork

Foundation formwork

Possible impurities: dirt/sand, cement, steel, wood, PS-film, water
Collection: mixed demolition waste
Pre-treatment: density-based sorting
Germany: mostly from XPS
Netherlands: EPS and XPS

Beams and blocks

Beam floor

Possible impurities: dirt/sand, cement, water
Collection: separate - cement separated from EPS through "triling" on site, 80% EPS collected in containers
Pre-treatment: density-based sorting

Floor plates

Possible impurities: dirt/sand, cement
Collection: separate or as mixed demolition waste
Pre-treatment: depending on installation removal of layers and brushing or crushing and density-based sorting

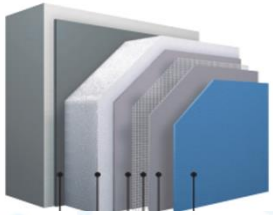
Ground- and waterworks

Filling elements

Possible impurities: dirt/sand, water
Collection: separate
Pre-treatment: brushing

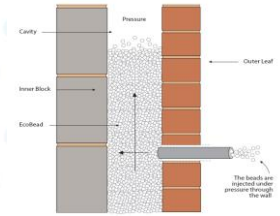
Walls and facades

External Thermal Insulation Composite Systems (ETICS)



Possible impurities: adhesives, coating with reinforcing mesh, plaster, nails
Collection: selective or as composite
Pre-treatment: crushing followed by density-based sorting. FH Münster and RWTH Aachen are currently researching best collection and pre-treatment technologies.

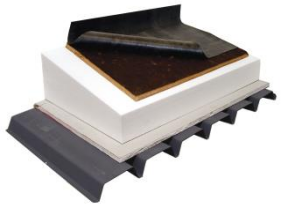
Cavity wall insulation with EPS beads



Possible impurities: sand/dirt, vermin
Collection: vacuum through cavity
Pre-treatment: density-based sorting

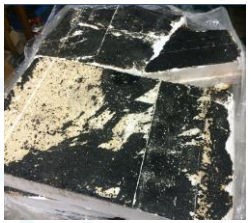
Roofs

Sloping roof



Possible impurities: aluminium, bitumen, polymer membrane (e.g. PVC)
Collection: selective or as composite
Pre-treatment: depending on installation and level of impurities. For composites: crushing followed by density-based sorting

Flat roof



Possible impurities: aluminium, bitumen, polymer membrane (e.g. PVC)
Collection: selective or as composite
Pre-treatment: depending on installation and level of impurities. For EPS with bitumen: EPS Powerbrush has developed a technology for pre-treating EPS boards from flatroofs with bituminous sheeting.

PRE-TREATMENT

Relevance	**Pre-treatment** **Transportation**
Content	**Required input quality** • Input description, Eural codes accepted, EPS Acceptance Sheet
	Contamination • Physical contamination to remove • Chemical and odorous contamination to be aware of • The impact of water
	Compaction • The necessity to compact, the technology available
	Transportation • Conditioning the compacted material for transport

Pre-treatment

Required input quality

Input description

PS foam waste

- The input for the PSLoop demonstration plant is PS foam waste. Because the PSLoop demonstration plant is developed for the treatment of PS foam containing HBCD the input will predominantly consists of PS foam waste from the demolition of buildings.
- PS foam is often polluted with other materials like glue, bitumen, cement residue etc.. It must therefore be pre-treated.
- After pre-treatment PS foam then needs to be compacted and prepared for transportation to reduce transportation costs and emissions.
- As PSLoop is currently predominantly contracting EPS waste containing HBCD the subsequent information focuses on EPS.

Eural codes

- PSLoop has the permit to treat material with the following Eural codes:

Eural Code	Eural Code Name	Remarks
17 06 04	Construction and Demolition Waste	EPS insulation material
15 01 02	Industrial Waste	Only EPS packaging suspect of containing HBCD
20 01 39	Plastics	
02 01 04	Waste Plastics (except packaging)	

Input specifications

- To be a suitable input for the PSLoop demonstration plant PS foam waste must meet certain specifications. The material must be pre-treated and compacted. Impurities are only allowed until certain thresholds.
- Below the input specifications for EPS waste that can also be found in Appendix 4.

Material description	EPS pre-sorted and compacted
Material shape	Various briquette shapes accepted Condition: compacted and packed according to specifications
Material weight	Briquette weight of 15-50 kg Condition: packed according to specifications
Material density	100-450 kg/m³ **Too high compaction will cause the material to melt, this has to be avoided!**
HBCD content max	< 1.5 wt.%
Water	as low as possible, preferably under 3wt% measured per briquette
Asbestos	0.0% wt. - material may absolutely not be contaminated with asbestos
Bituminous impurities	as low as possible, preferably almost 0 wt.%
Other impurities PUR, glass wool, rock wool, cement, nails and iron, glue	The total of all impurities ≤7 wt.% measured per briquette
Delivered	• Compacted briquettes stacked on pallets and tightly wrapped in PE shrink film • Compacted briquettes in big bags
Packaging specifications	• A wide range of pallets is accepted. • Maximum height 2.6 meter

Pre-treatment

Removing contamination

Contamination

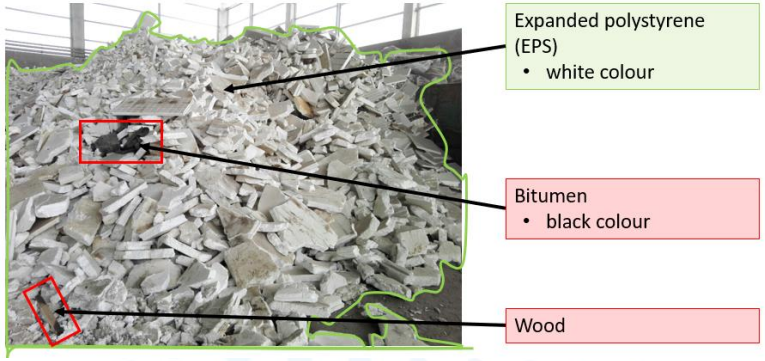
- Contamination can consist of:
  - physical contamination: sand/clay, concrete, glue, stickers, tape, water, asbestos, asphalt, nails, other insulation materials
  - chemical contamination: iron oxides, minerals, phosphates
  - odor contamination: odors from animal breeding or fish storage
- Physical contamination must be removed as much as possible. Solid impurities like sand, concrete, glue and stickers cause solvent loss, generate waste and might harm the PSLoop demonstration plant. Asphalt is also a persistent organic pollutant and asbestos classified as hazardous, both therefore need to absolutely be removed. EPS and XPS also need to be separated from one another.
- Chemical and odor contamination are unlikely to harm the PSLoop process, the expectation is that these contaminations do not influence the quality of the PS end product.
- The PSLoop process is negatively influenced by water. Water reduces the capacity of the CreaSolv® solvent to dissolve EPS. To avoid water from entering the process the PS foam waste that enters the process undergoes a drying step. The input specifications state that the water content of supplied briquettes needs to be below 3 wt%. Especially EPS foam from cold stores can contain large amounts of water as a result of water condensation inside the EPS cells.

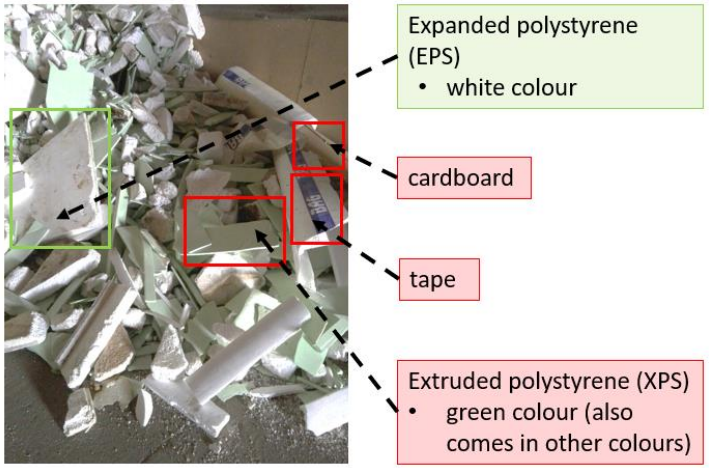
Removal of (H)CFCs in XPS

- While common contaminations such as cardboard, wood and tape also need to be removed from XPS, XPS also needs to undergo a pre-treatment which releases and captures the (H)CFCs.
- Under the Montreal Protocol >95% of the (H)CFCs need to be captured.
- The best way to release (H)CFCs is currently under investigation. A combination of grinding, shredding and compaction for release with capture via a deep cool unit are possible solutions.

Common contaminations

- Material such as bitumen, wood, cardboard and tape are among the contaminations often found with EPS waste.
- While PSLoop is able to treat XPS it needs to be separated from EPS and undergo a separate treatment which releases and captures (H)CFCs.





Pre-treatment
Compaction

Compaction of EPS

- Before the EPS enters the compactor it must be freed of contaminations like concrete, other plastics like stickers, nails, wood etc.
- EPS waste can contain water, especially when it comes from cold stores or a wet underground environment. If EPS contains too much water, compression of EPS is not successful.
- Compaction of EPS is done by screw compression. Such systems are available with capacities ranging from 10 – 250 kg/hr.
- By screw compression EPS waste is compacted 5 to 64 times from 15-20 kg/m³ to 100-450 kg/m³.
- A typical screw compression installation consists of a crusher, a silo and a screw compressor. The crusher is needed to reduce the size of the EPS foam to such extent that it can enter the screw compressor. With the larger capacities a silo is placed between crusher and screw compressor to reduce the necessity to feed the crusher continuously.

Screw compression technolgy for EPS compaction

- The temperature inside the screw compactor is a critical issue in EPS compaction. The temperature of the EPS rises when it is compacted. If the temperature of the material raises above 90°C EPS starts to melt, influencing the melt flow index. This leads to the break-off of the molecular length of polystyrene and is harmful for the quality of the polystyrene product. Furthermore, it might lead to clogging in the screw mechanism.

Pallets and wrapping

- Compacted EPS blocks can either be transported and stored in bigbags to be put on pallets or directly stacked on pallets. Compacted EPS blocks on pallets need to be tightly wrapped in PE shrink film. The wrapping will prevent any loose material to spread in the environment and facilitates transport. Pallets with compacted blocks can be stocked on top of each other for optimal transportation.

Compacted material wrapped in shrink film on pallet and loaded onto truck

TRANSPORT

Relevance	**Transportation**
Content	**National transportation from within the Netherlands** • Documentation needed
	Cross-border transportation • European Waste Shipment Regulation (EWSR) • Notification procedure • Documentation needed

Transportation

National and cross border

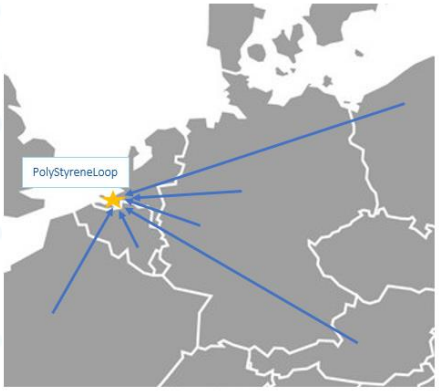
Transportation

National transportation

- For material coming from within the Netherlands shipping documents are required. The documents need to be taken along during transportation.
- On the shipping document the details of the sending and the receiving party as well as details on the waste such as weight and Euralcode need to be mentioned.
- Arrival of material needs to be confirmed.

Cross border transportation

- The EU Waste Shipment Regulation (EWSR) establishes procedures and control regimes for the shipment of waste [1]. Annually a notification procedure for waste transported over the boarder needs to be submitted by the company transporting the waste.
- PS foam waste with HBCD is not on the green list and XPS containing (H)CFCs is classified as hazardous waste which means that a notification is required.
- The competent authorities of the sending and recipient countries need to approve the treatment and the notification procedure.
- For transportation across the border notification (annex IA) and transportation (annex IB) documents are required and need to be taken along during transport.
- The documentation includes information on the sending and the receiving parties as well as all the details of the waste including waste and Eural code.
- Arrival of material needs to be confirmed within 3 working days.
- Acceptance of material needs to be confirmed within 6 months upon arrival. This will result in the change of ownership from HUB to PSLoop.
- Proper treatment of material needs to be confirmed within 12 months of arrival.
- Important to check the national legislation of each sending country to ensure that all the requirements for cross-border transportation are met.



RECYCLING

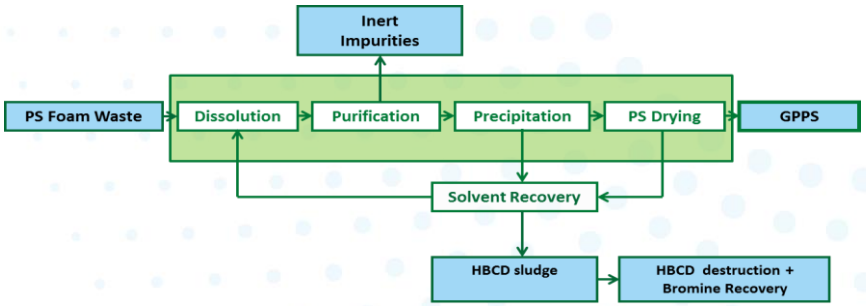
Relevance	**General Information**
Content	**Technology** • CreaSolv® Process description • XPS in the process • Demonstration plant proof and quality control
	Demonstration plant • Location • Construction • Production capacity • Storage

Recycling
Technology

Dissolution technology

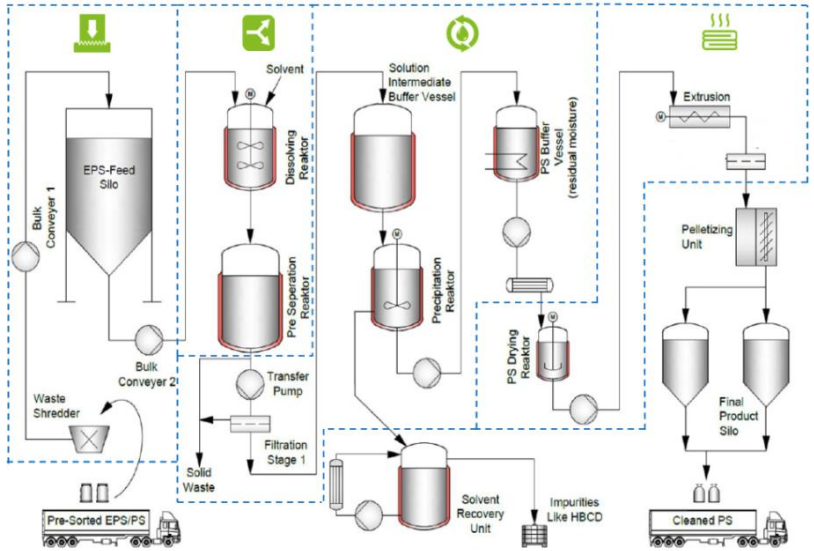
Process description

- The CreaSolv® Technology is key to the PSLoop project and a development of CreaCycle GmbH in cooperation with Fraunhofer IVV. It is a physico-chemical process based on selective extraction. CreaSolv® is a registered trademark of CreaCycle GmbH.
- The core of the PSLoop process is dissolution. Compacted PS foam waste is shredded into small particles and subsequently dissolved into a solution.
- The CreaSolv® Technology ensures that the PS is selectively separated from impurities and enables the mechanical separation of undissolved materials.
- Sourcing of the proprietary CreaSolv® formulation is secured with a supply agreement between PSLoop and CreaCycle GmbH. During the process almost all of the solvent will be recovered for reuse in the recycling process.



- After dissolution of EPS foam waste the introduction of an additive causes the polystyrene to precipitate, forming a gel that can be separated, dried and pelletized to produce PS.
- While polystyrene precipitates, HBCD remains in the solution. When the process solvent is recovered by distillation, HBCD sludge remains. This sludge is transported to the adjacent Bromine Recovery Unit (BRU) of ICL-IP for bromine recovery.
- Because the precipitated polystyrene gel still contains some HBCD, certain washing steps are needed to remove HBCD from the gel. The higher the HBCD concentration in the input material, the more washing is needed.

Graphic impression PSLoop process



XPS in the process

- (H)CFCs that were not released and captured during pre-treatment need to be released and captured during the process. The technology to capture the (H)CFCs is not yet included in this overview. A removal rate of >95% of (H)CFCs needs to be achieved.

Demonstration plant proof and quality control

- The PSLoop demonstration plant will proof the technology on industrial scale.
- Different input streams of PS foam, containing different levels of contaminants could lead to fluctuations in plant performance and PS quality. Quality control of the input streams is necessary for a feasible output. Subsequently, processing levels need to be adjusted to specific inputs.

Recycling
Demonstration plant

Location

- The PSLoop demonstration plant will be situated in Terneuzen, in the Southwest part of the Netherlands, next to the site of ICL-IP.
- Main reason for this location is that the plant will be close to the Bromine Recovery Unit (BRU) of ICL-IP.

Construction

- Engineering and construction management is performed by EPC Engineering & Technologies GmbH, part of EPC Group who have extensive experience in the design and realisation of industrial plants and infrastructural projects.
- Sub-contractors are selected by EPC for the construction of the proprietary equipment and by PSLoop for the civil works and facility including the installation of the recycling installations.

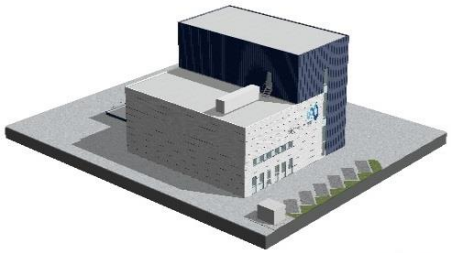
Production capacity

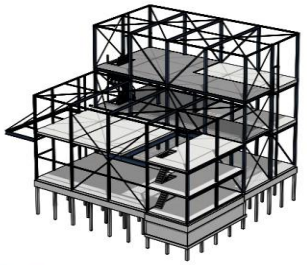
- The PSLoop demonstration plant has a production capacity of 3,000 tons cleaned PS. The facility will gradually increase its production output from 900 tons in year 1, to 1,350 tons in year 2 and finally reach full capacity with 3,000 tons in year 3. Afterwards the facility will maintain its production at full capacity
- For a constant stream of waste the sourcing of the material will be done within a 200-400 km radius around the plant, contributing to cost-efficiency and reduction in emissions.
- The plant produces in 3 shifts of 8 hours per day, 5 days per week. Weekend shifts are not planned but are feasible. This could increase the output to approximately 4,000 tons per year at limited extra variable costs.

Storage

- The capacity for storage of compacted EPS on the site of PSLoop is designed for 360 tons, enough for a production period of 36 days full capacity.

Impressions of production site





OUTPUT

Relevance	**General Information**
Content	**Output streams** • HBCD sludge with subsequent bromine recovery • Polystyrene
	Characteristics of PS • Comparison virgin GPPS with PS-recyclate from EPS

Output

Recovered polystyrene and bromine

Product description

Output

- The two main outputs of the PSLoop plant are clean polystyrene and a sludge containing HCBD.
- HBCD sludge goes to the adjacent Bromine Recovery Unit (BRU) of ICL-IP, where the HBCD is destructed, recovering the bromine that is present in the material. The bromine can be used for the production of other bromine containing materials (e.g. new flame retardants).
- The PS that is produced is ready for the use as raw material for PS foam. Cleaned polystyrene in this context is defined as PS containing less than 100 ppm HBCD.
- As a recycled product, cleaned PS can reduce the demand for virgin fossils, contributing to the circular economy and competitive prices for PS relatively to the supply of PS from virgin fossils.
- To produce 1MT of cleaned PS 1.1 MT pre-sorted PS foam waste is required as input.

Key output

Polystyrene (PS)

Bromine

- Although there is no practical experience until now, PSLoop expects to produce a residual waste stream of about 10%. This material is sent to a waste incineration plant.

Characteristics of PS

- Research on pilot scale showed that the characteristics of the EPS recyclate that is produced with the PSLoop process are similar to the characteristics of virgin PS. The main difference is that EPS recyclate is often dark where virgin PS is clear. The dark colour in EPS recyclate comes from the carbon black or graphite that is present in part of the waste EPS. Because of this colour EPS recyclate can only be used to produce coloured EPS.
- Recycled PS that is produced by PSLoop is preferably sold to PSLoop members only.

Parameter	virgin-GPPS	EPS-recyclate PSLoop
weightloss 24 h at 70°C	n.a.	540 ppm
GPC		
* Mn	100,000	101,191
*Mw	200,000	196,519
* Pd (121)	2	1,95
XRF		
* Zn	<1	44 ppm
* Br	<1	5 ppm
Karl Fisher	<0.05%	0.047 % moisture
MFI	5 g/10 min.	7.6 g/10 min.
GC Styrene monomer	100 ppm	23 ppm
Color/shape	clear pellets	black
Appearence		

THE HUBs

Relevance	**Demolition** **Collection** **Pre-treatment** **Transport**
Content	**Location and Contact Details of the HUBs** • The Netherlands • Germany

The HUBs

Netherlands

HUB	Contact details	
De Vries Recycling	Contact person	Gerrit van Veen
	Address	Zwolsche Diep 7 i, 8321 MJ Urk, Netherlands
	Phone	+31 (0)527 69 0466 / +31 (0)6 5496 5986
	Mail	info@devriesrecycling.com
	Website	https://www.devriesrecycling.com/
Poredo	Contact person	Bart de Wijs
	Address	De Slof 26, 5107 RJ Dongen, Netherlands
	Phone	+31 (0)162 31 45 31
	Mail	postbus@poredo.nl
	Website	https://www.piepschuim.nl/

The HUBs

Germany

HUB	Contact details	
Gütersloher Wertstoffzentrum	Contact person	Frank Kramer
	Address	Osnabrücker Landstraße 255, 33335 Gütersloh, Germany
	Phone	+49 (0)5241 21046 0
	Mail	info@wertstoffzentrum.de
	Website	www.unternehmensgruppe-hagedorn.de
Recycling-Hof Urmitz	Contact person	Uta Böhm
	Address	Rudolf-Diesel-Straße 25, 56220 Urmitz, Germany
	Phone	+49 (0)2630 9626-0 (via AWR GmbH)
	Mail	info@rhu-gmbh.de
	Website	www.rhu-gmbh.de

CONTACTS

Relevance	**General Information**
Content	**Relevant Contact Details**

Contacts

Page 1 of 2

Name	Contact details	Extra information
PolyStyreneLoop	Frankrijkweg 10 4538 BJ Terneuzen, Netherlands www.polystyreneloop.eu	Recycling of PS-foam with HBCD
Plastics Europe	Rue Belliard 40, box 16 1040 Brussels, Belgium www.plasticseurope.org/en	European association for plastic manufacturers
NRK	Loire 150 2491 AK The Hague, Netherlands www.nrk.nl/	Dutch association of rubber- and plastic industry
EUMEPS	Blvd. Auguste Reyers 80 1030 Brussels, Belgium https://eumeps.org/	European association of EPS industry
Styropor GPH	Brückenstraße 3 2522 Oberwaltersdorf, Austria www.gph.at/	Austrian association of EPS industry
Styfabel	Henri Regastraat 14, 3000 Leuven, Belgium www.styfabel.be/	Belgian association of EPS industry
Stybenex	Hatertseweg 598 6535 ZX Nijmegen, Netherlands https://stybenex.nl/	Dutch association of EPS industry
IVH	Friedrichstraße 95 / PB 152 10117 Berlin, Germany www.ivh.de/Start_I28.whtml	German association of EPS industry
AFIPEB	3 Rue Alfred Roll 75017 Paris, France www.afipeb.org/	French association of EPS industry
ANAPE	Pº Castellana, 203 - 1º Izquierda 28046 Madrid, Spain www.anape.es/	Spanish association of EPS industry

Contacts

Page 2 of 2

Name	Contact details	Extra information
EXIBA	Rue Belliard 40, box 16 1040 Brussels, Belgium www.exiba.org/home	European association of XPS industry
FPX	Friedrichstraße 95 10117 Berlin, Germany xps-spezialdaemmstoff.de/	German association of XPS industry
BRBS	Van Heemstraweg West 2B 5301 PC Zaltbommel, Netherlands www.brbs.nl/	Dutch association for recycling and demolishing industry
VERAS	Rijksstraatweg 69 4194 SK Meteren, Netherlands www.sloopaannemers.nl/	Dutch association for demolition industry
BVSE	Fränkische Straße 2 53229 Bonn, Germany www.bvse.de/fachverband-sonderabfall.html	German association special waste management
ZVDH	Fritz-Reuter-Str. 1 50968 Köln, Germany https://dachdecker.org/startseite/	German association of roofers

Appendix 1

The PolyStyreneLoop initiative

Relevance	**General Information**
Content	**Characteristics of PolyStyreneLoop**
	Organisational structure
	The cooperative
	Financial support
	Environmental benefits

The PolyStyreneLoop initiative

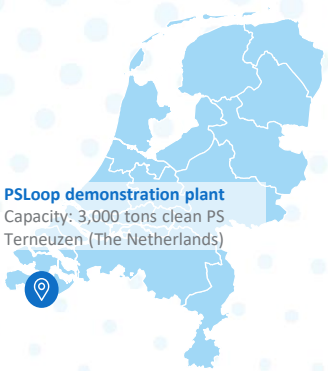
Characteristics

Rationale for PolyStyreneLoop

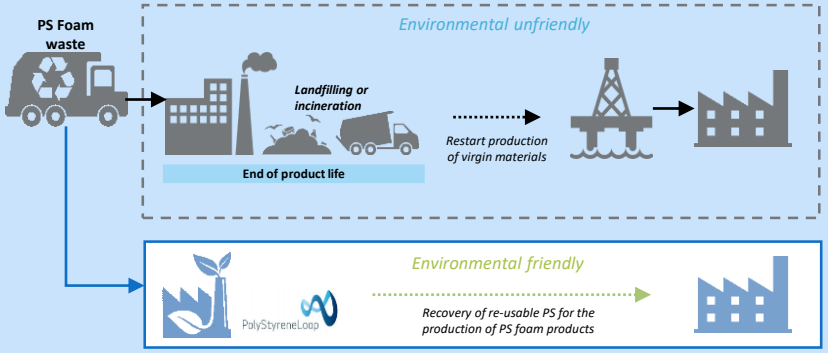
- PS foam (EPS and XPS) is used for a broad range of products and applications, predominantly as insulation in the construction sector and as packaging material.
- Until 2015, a large portion of the PS foam used for isolation included the flame-retardant HBCD. In the European REACH legislation agreed in 2015 [1] this so-called Persistent Organic Pollutant (POP) is no longer allowed to be placed on the market and recycling is no longer possible by the currently available techniques.
- In 2017 the total PS foam waste from demolitions in Europe is 140,000 tons per year [2] and will increase strongly in the next decades.
- Incineration or landfilling of PS foam waste leads to several environmental consequences, in addition to the increased use of virgin fossil feedstock (incl. benzene, ethane) required for the production of new PS foam.
- In order to process the increasing amount of PS foam waste (which includes HBCD) and ensure the sustainable supply of sufficient PS, a new recycling technique is required. The PSLoop demonstration plant will be the first facility to use the patented CreaSolv® Technique (CreaSolv® is a registered trademark of CreaCycle GmbH) to recycle PS foam which meets EU regulations on an industrial scale.

Location

- The PSLoop demonstration plant is located next to the ICL-IP site and its existing BRU facility in Terneuzen, in the Southwest part of the Netherlands.
- The plot is appr. 5,400 m² in size with space to store raw materials and the final product.
- PSLoop management will oversee and manage the operations in the PSLoop demonstration plant. The extracted HBCD will be directly fed into the production process of the BRU of ICL-IP.
- Engineering and construction management is performed by EPC Engineering & Technologies GmbH. EPC Group has extensive experience in the design and realisation of industrial plants and infrastructural projects.

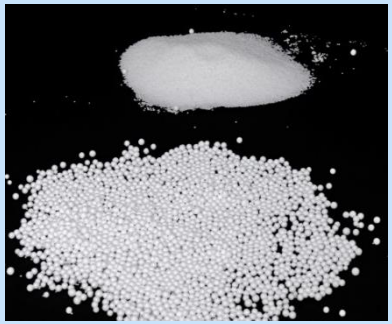


A better use of PS foams



Product

- Pre-sorted PS foam waste from demolition sites will be used as input for the demonstration plant. Waste should contain less than 7 wt. % impurities, such as glue and concrete and less than 3 wt. % water. The material will need to be compressed for the transportation to the plant.
- The end product of the plant is clean PS which will be preferentially sold to manufactures in the value chain.
- A residual product from the process is the separated pollutant HBCD. This product will be processed by the adjacent ICL-IP Bromine Recovery Unit (BRU). The bromine is recovered and used as raw material for new brominated products, such as flame-retardant.



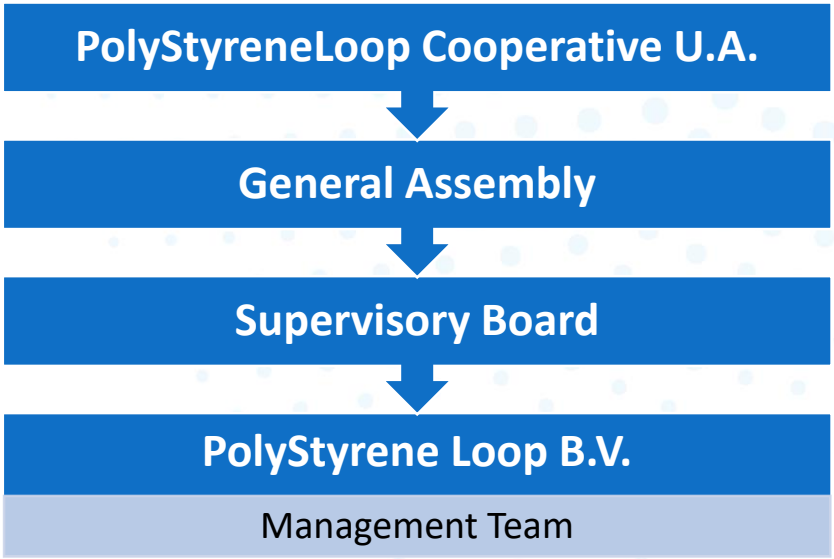
Top **– Polystyrene granulates (PS)**
Bottom **– Expanded Polystyrene (EPS)**

The PolyStyreneLoop initiative

Organisational structure

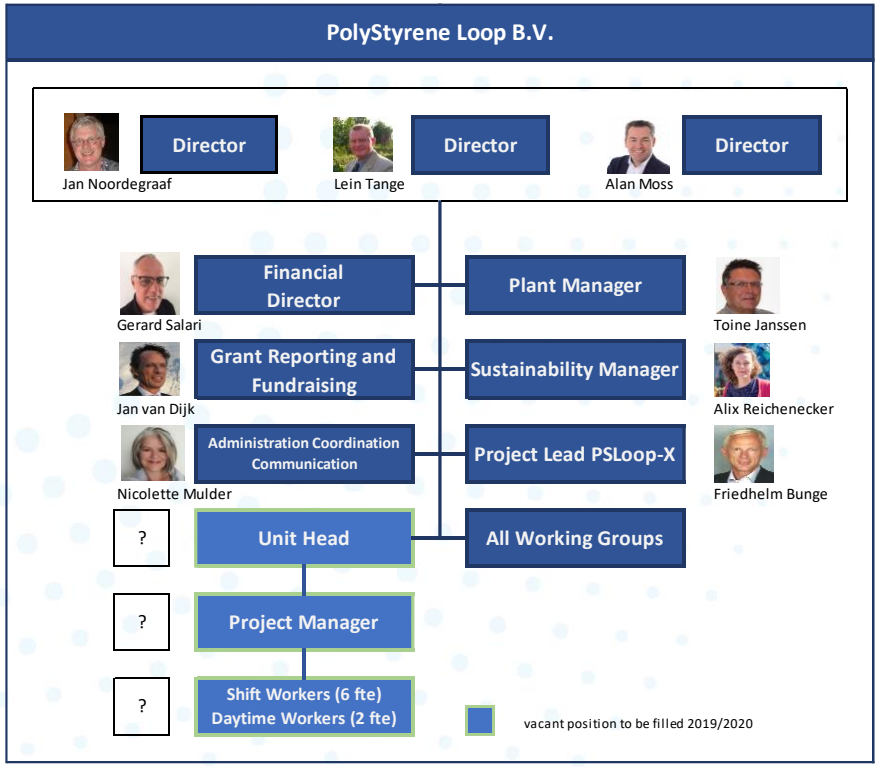
Organisational structure

- The PolyStyreneLoop organization is a cooperative with members and supporters from the entire polystyrene foam value chain.
- Both members and supporters contributed financially to the cooperative, but members have voting rights and while supporters do not have voting rights.
- The head of the organization is the PolyStyreneLoop Cooperative U.A. with all members and supporters.
- Next is the General Assembly in which members are assembled. The weight of the influence of a member depends on the type of group they belong to and their financial contribution. None of the members has more than 10% of the voting rights.
- The Supervisory Board is a selected group of members and supporters providing guidance.
- Finally, the actual business behind the cooperative is PolyStyrene Loop B.V. with its Management Team.



Organigram of PolyStyrene Loop B.V.

- The PolyStyrene Loop B.V. is made up of a small dedicated team. Members and supporters offer their respective expertise in a working groups around a number of topics such as Collection and Pre-treatment, Engineering and Communications.



The PolyStyreneLoop initiative

The cooperative

Members and supporters

PS Foam producers / converters

- PS Foam producers and converters are aware of the environmental and economic benefits of recycling PS foam construction waste.
- Participation by leading parties increases awareness throughout the plastics industry.

Associations

- Associations active in the plastics industry set objectives and standards for the industry and at the same time lobby for new participants to join.

Raw material suppliers

- Raw material suppliers produce the raw material for PS foam.
- For EPS this raw material is the EPS beads used by EPS converters to produce EPS foam. For XPS this is the XPS material itself, used by producers of insulation systems.

Foam collectors / recyclers

- Foam recyclers collect and pre-treat PS foam waste by sorting, grinding and compacting. PS foam without HBCD is sold as feedstock for new PS products. PS foam with HBCD is transported to the PSLoop demonstration plant as feedstock.
- PSLoop makes agreements with certified foam recyclers that function as HUBs for PSLoop to ensure good quality of input material for the demonstration plant.

Flame Retardant Producers

- The demonstration plant is situated on premises next to flame retardant producer ICL-IP. PSLoop has a Service Level Agreement over the use of some of the ICL-IP facilities, among others for the recovery of bromine in the Bromine Recovery Unit (BRU) of ICL-IP.

Other

- Know-how providers have specific knowledge over part of the technology that is used by the PS foam sector.
- System applicators process PS foam in a variety of products, such as External Thermal Insulation Composite Systems (ETICS), thermal coatings and other insulation systems.
- Machinery suppliers produce equipment that is specific for the PS foam sector.

The PolyStyreneLoop initiative

The cooperative at a glance – members, supporters, partners and allies*

Overview of the cooperative and geographical coverage

*status August 2019

The PolyStyreneLoop initiative

Financial support

Financial support

- The PolyStyreneLoop initiative is financially supported by the EU LIFE program for EPS recycling and by the Province of Zeeland and the Dutch Ministry of Ministry of Agriculture, Nature and Food Quality for XPS recycling.

LIFE program

LIFE16 ENV/NL/000271
period 2017 to 2021

- The EU LIFE program supports environmental, nature conservation and climate action projects with subsidies. Applicants in this program demonstrate an innovative technology that can be replicated, transferred and mainstreamed.
- With the PSLoop demonstration plant, recycling PS foam waste not only contributes to the sustainable use of plastics, also the high energy consuming production process from petroleum to virgin polymer is reduced. This prevents CO_2 emissions and the usage of other materials like ethane, elements that have significant impact on environment.
- With the commissioning of recycling plants for PS foam, only part of the energy used for processing virgin materials is needed.
- In 2017 EPS producer Synbra (current name BEWiSynbra) in a consortium with ICL-IP (flame retardant producer), Fraunhofer IVV (research institute) and PolyStyreneLoop (member cooperative), received a grant from the EU LIFE program for the PolyStyreneLoop initiative
- The PSLoop initiative qualified to the norms of the LIFE program and has been granted a subsidy of € 2.7 mio for the period 2017-2021 with a possible extension of 1 – 2 years.
- The grant is registered under Grant no. LIFE 16 ENV/NL000271
- In 2018 the EU qualified the PSLoop initiative as an ambitious innovative and replicable project with a significant scale and impact that helps to reduce the environmental problems of construction and demolition waste, one of the Commission's priority areas for waste.

Innovative PS foam recycling

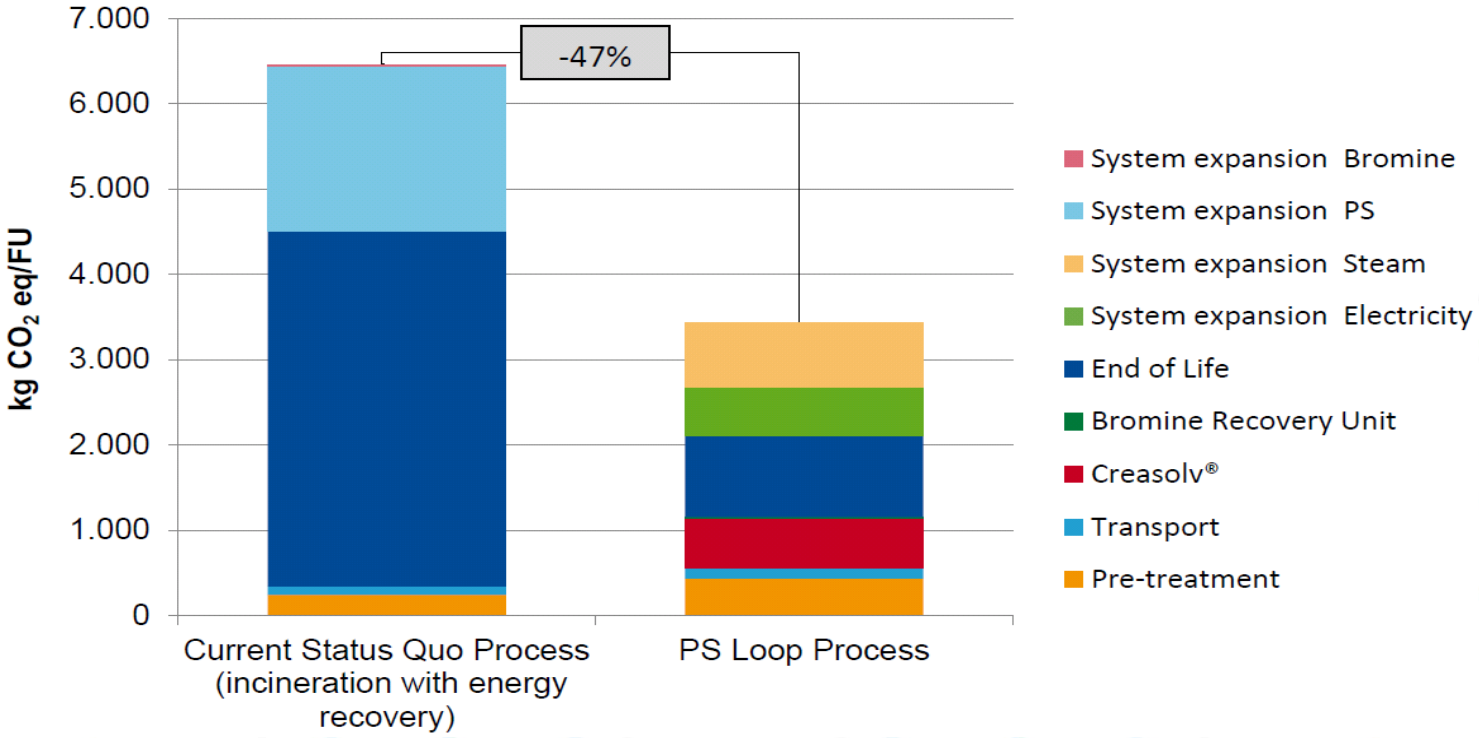
- With a subsidy of € 1 mio from the province of Zeeland (programme “Zeeland in stroomversnelling”) the PSLoop organization runs a separate development project to make the PSLoop plant also suitable for the treatment of XPS waste from demolition. The name of this project is “Innovative PS foam recycling”.
- Eventually approx. 10% of the capacity of the PSLoop plant will be used for the treatment of XPS waste.
- The main challenges of the “Innovative PS foam recycling” project are:
  1. removal of the (H)CFCs from the XPS foam
  2. capture of the (H)CFCs for subsequent destruction in a specialized destruction facility outside the Netherlands
- A series of practical tests will be done to find the best solution. This solution will be engineered and built into an installation that can pre-treat the XPS in such a way that the (H)CFCs are effectively removed and the remaining material can be used as feedstock for the PSLoop demonstration plant.

The PolyStyreneLoop initiative

Environmental benefits

Environmental aspects

- The Life Cycle Assessment study performed by TÜV Rheinland LGA Products GmbH (Germany) showed a key improvement in carbon footprint for the PSLoop process, amounting to 47% lower carbon footprint compared to incineration [1].
- The effect is expressed as "Climate change" in kg CO_2eq./FU:



- The study shows that system expansion (production of PS) and end of life treatment (incineration or recycling) are the main drivers on the overall environmental impacts.
- Main contributor of the PSLoop Process is the required energy demand for the CreaSolv® Process.
- Impacts for pre-treatment and transportation steps are slightly higher for the PSLoop Process. The reason for this is the higher energy demand for separation and compaction and longer transport distances.

Appendix 2
Legislation

Relevance	**General Information**
Content	**Regulatory aspects** • Classification, Production and Use, Treatment, Legal waste framework, Transboundary movement and shipment of waste
	Regulatory aspects at a glance • Timeline of regulations around HBCD • Overview of HBCD concentrations
	National regulations • Dutch regulations • German regulations

Legislation
Regulatory aspects

Regulatory aspects

Classification

- 2008 – HBCD is included on the list of Substances of Very High Concern (SVHC) [1].
- 2008 – The EU Classification, Labelling and Packaging regulation (CLP) classifies HBCD with hazard statement codes (H361 and H362). H361 indicates a concern for effects on fertility and H362 harm to breast-fed children [2].
- 2013 – HBCD is listed in Annex A as POP of the UN Stockholm Convention (2001). The production and use of HBCD needs to be eliminated [3].
- 2014 – The EU regulation sets the concentration limit for waste constituents for the hazardousness classification. H362 does not play any role in the assessment of hazardousness. H361 falls under Hazard Property Code 10 (HP10). The concentration limit for H361 is 3%. This means that EPS and XPS wastes with a HBCD concentration below 3% (30,000 ppm) are classified as non-hazardous waste (provided that the material does not contain high concentrations of other constituents falling under one of the Hazard Property Codes of the CLP regulation) [4].
- 2016 – The EU POP Regulation that focuses on the control of production, placing on the market and use of POPs [5] is amended by two Regulations on the concentration limits for HBCD in products and waste [6], [7].

Production and Use

- The production and use of HBCD is to be eliminated. The latest application date by which any applications for use had to be submitted to the European Chemicals Agency (ECHA) was 21. February 2014. The sunset date after which HBCD could not be used or imported into the EU without authorisation from ECHA was 21. August 2015.

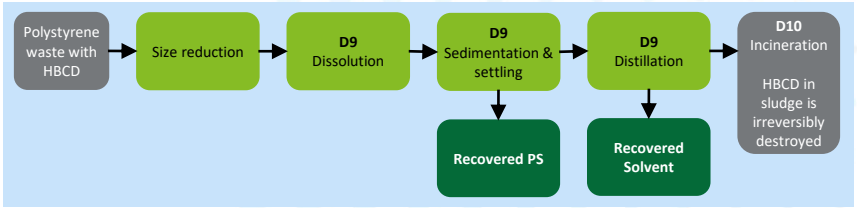
Treatment

- The amendments to the EU POP Regulation set the concentration limit for HBCD in products and waste.

HBCD concentration	Concentration limit for HBCD in products and waste	Legislation
≤100 ppm	Products placed on the market (unintentional trace contamination).	EC 2016/293 [7] To be reviewed 22. March 2019
<1,000 ppm	Recovery or disposal	EC 2016/460 [8] To be reviewed 20. April 2019
≥1,000 ppm	Physical-chemical treatment (i.e. PSLoop) or incineration	Basel Convention [9]

Legal waste framework for physical-chemical treatment - PSLoop

- In the Technical Guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with POPs of the UN Basel Convention, treatment steps describing the CreaSolv® Process, including size reduction, have been added as a way to treat PS-foam waste with HBCD. The CreaSolv® Process will be embedded in the treatment process of the PSLoop plant [8].



- The low POP concentration as of which PS-foam with HBCD needs to be incinerated or can undergo the PSLoop treatment is still under review. The concentration will either be set at <100 ppm HBCD or <1,000 ppm HBCD.

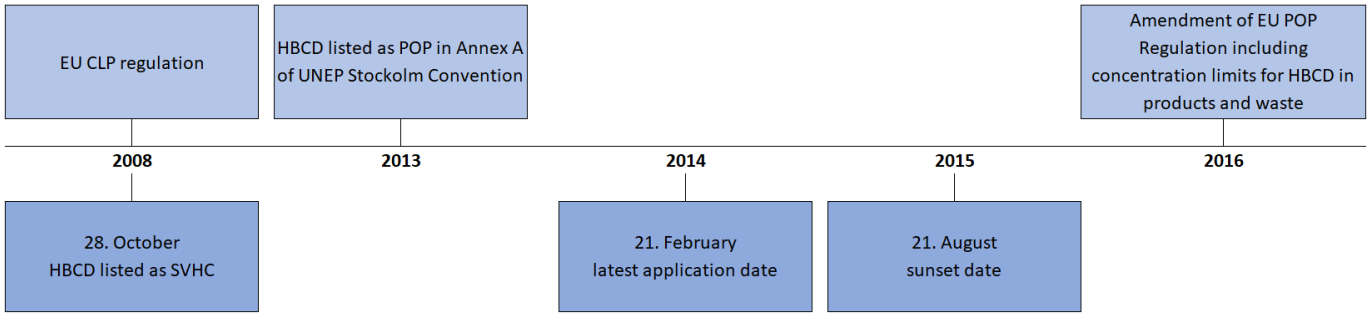
Transboundary movement and shipment of waste

- 2006 – The EU waste shipment regulation (EWSR) establishes procedures and control regimes for the shipment of waste. Annually a notification procedure for waste transported over the border needs to be submitted by the company transporting the waste. Transport requires notification (annex IA) and transportation (annex IB) documents [9].

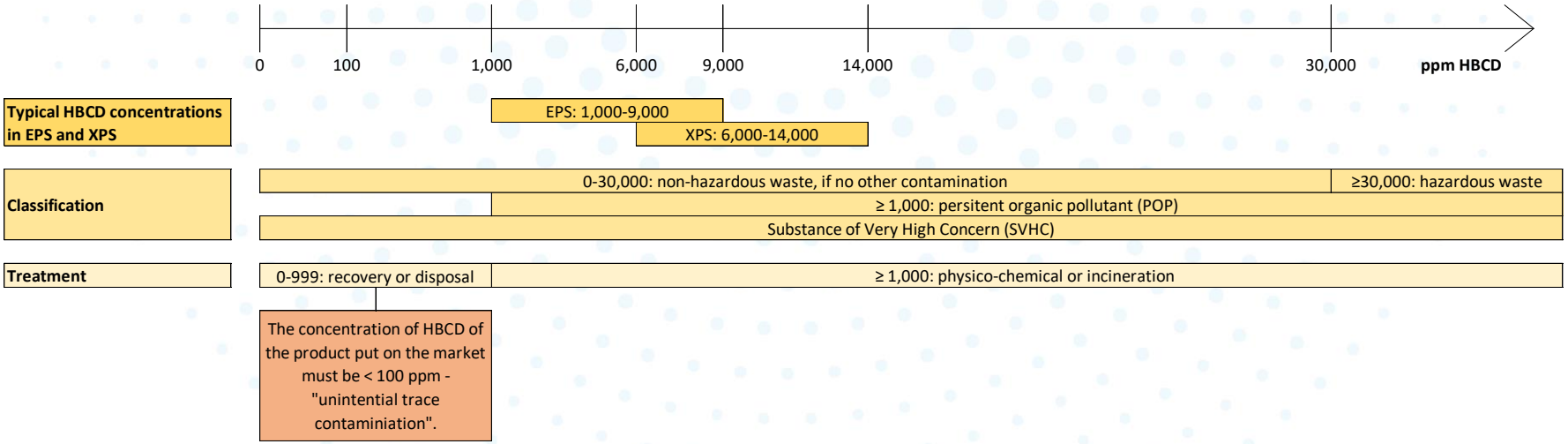
Legislation

Regulatory aspects at a glance

Timeline of regulations around HBCD



HBCD concentrations



Legislation
National regulations

PolyStyreneLoop

National regulations

Dutch regulation: LAP3, Sectorplan 85

- Classification: POP (≥, 1,000 ppm HBCD), non-hazardous, SVHC = zeer zorgwekkende stof (ZZS)
- Landelijk Afvalbeheer Plan 3 (LAP3) [1]:
  - Dutch National Waste Management Plan 2017-2029
- Sectorplan 85 – EPS [2]:
  - Exclusively for EPS not XPS.
  - Minimum treatment standard for packaging and construction EPS.
  - Construction EPS
    - No HBCD: treatment with higher quality of recovery than destruction or irreversible transformation if kept separate from other material.
    - < 1,000 ppm HBCD: recycling allowed. Subject to restrictions of POP regulation.
    - ≥ 1,000 ppm HBCD: physico-chemical treatment (D9) or incineration (D10). Subject to restrictions of POP regulation.

German regulation: POP-Abfall-ÜberwV, KrWG, GewAbfV, NachwV

HBCD concentration	Classification as POP or not	POP-Abfall-ÜberwV applicable?
<1,000 ppm	Not POP	No
≥1,000 ppm	POP	Yes

- **General**
  - As in Germany waste falls under the jurisdiction of the federal state it is important to check the decrees of the environmental ministries of the individual federal states (Bundesländer).
- **Separate collection**
  - The decisive factor is how the waste is generated. As such, waste that is generated separately is to be collected separately. However, waste that arises as a composite (i.e. ETICS) does not have to be separated on site. Waste that is generated as mixed waste and that has concentrations <1,000 ppm HBCD are not subject to the POP-Abfall-ÜberwV. As construction PS-foam with HBCD always has concentrations ≥1,000 ppm HBCD producers and owners have to collect and transport waste separately depending on the treatment it has to undergo (POP-Abfall-ÜberwV § 3.1.) [3].
  - The obligation for separate collection shall cease if this is considered technically not possible (i.e. not enough space for containers) or economically unreasonable (if costs for separate collection are disproportionate to mixed collection with subsequent pre-treatment) (GewAbfV § 8.2.) [4].
  - The technical and economical feasibility are to be regarded as guiding principles.
- **Treatment**
  - Environmental protection, social consequences and technical feasibility considerations to be made when choosing the treatment. A treatment is considered technical feasible even if pre-treatment is required. Economic viability is attained if the treatment costs are not disproportionate to the costs of disposal. If the treatment chosen requires separate collection and transport, the mixing of this waste or the dilution of POP-waste with other waste is inadmissible unless the mixing method is state of the art (KrWG § 7) [5].
  - A proper treatment follows applicable law and does not cause adverse effects on health and environment.
- **Burden of proof**
  - Producers, owners, collectors, carriers and recyclers/disposers have the burden of proof towards each other and towards the competent authority. Proof is kept before the start of the treatment in the form of a declaration by all parties in the treatment chain for the intended treatment, an acceptance declaration of the recycler/disposer and the confirmation of the permissibility of the intended treatment by the competent authority. The whereabouts of the POP-waste need to be accounted during treatment process (POP-Abfall-ÜberwV § 4) [3].
  - If the amount of waste generated by producer does not exceed 20 t/year per waste category and per site the producer can provide burden of proof for the permissibility of the treatment through the appropriate documentation of the collector (NachwV § 9.1.4) [6].
- **Registration requirement**
  - Producers, owners, collectors, carriers, traders and brokers of POP-waste have to keep a register with the following information: amount, type, origin, destination, frequency of collection, mode of transport and the treatment. The registry needs to be kept for a minimum of three years from date of registration and presented to the competent authority upon their request (POP-Abfall-ÜberwV § 5) [3].
- **Electronic documentation**
  - Although PS-foam with HBCD is not a hazardous waste under German law it has to follow the documentation obligations for hazardous waste as stipulated in the Nachweisverordnung (NachwV).
  - A disposal certificate with the declaration by the producer, disposer and the competent authority needs to be obtained on the permissibility of the intended treatment, prior to disposal (NachwV – part 2, section 1) [6].
  - An accompanying certificate is proof of the carried out disposal. Carriers of the waste need to make sure to hold a copy of the accompanying certificate during transport (NachwV – part 2, section 2) [6].
  - Producers, collectors, carriers, dealers, brokers and waste disposers need to keep a registry on all the disposal operations that need to be operated. The registry needs to be kept for three years (NachwV – part 3) [6].

Appendix 3
HBCD

Relevance	**General Information**
Content	**Different types of flameretardants**
	Hexabromocyclododecane (HBCD)
	Analytics • X-ray fluorescence (XRF) • Quick-test • Chromatography

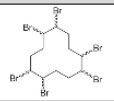
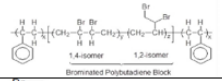
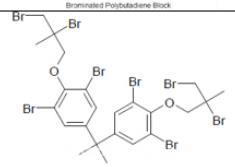
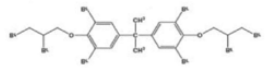
HBCD

Flame retardants (FR) and analytics

Flameretardants (FR) and Analytics

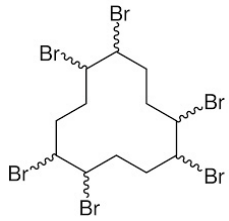
Flameretardants in PS foam

- Types of brominated FR used in PS-foam:

Full name	Also know as	Chemical structure	Application
Hexabromocyclododecane	HBCD		In EPS and XPS
FR-122P	Poly-FR		In EPS and XPS
SR-130, B843			Mostly in EPS
FR-720			Mostly in XPS

- HBCD can be found in old EPS and XPS, whereas material produced after 2016 will contain one of the other flame retardants among which poly-FR is the most common.

Hexabromcyclododecane (HBCD)



- Chemical characteristics: cycloaliphatic compound with 6 bromine molecules, no aromatic compound.
- Mode of operation: decay of molecule at 190 ˚C, formation of HBr and H_2O, obstruction of oxidation and cooling effect, extinguishing of the flame after removal of the ignition source.
- For more detailed information on HBCD consult the safety data sheet [1].
- **Important:** HBCD in PS foam is fixed in the plastic matrix and those dealing with PS foam with HBCD do not have to be concerned about exposure.

HBCD concentrations in EPS and XPS

- The typical concentration range for the application of HBCD as a flame retardant in EPS was between 1,000-9,000 ppm. For XPS it was between 6,000-14,000 ppm [2]. HBCD concentrations are always based on weight not volume.

Analytics

- **X-ray fluorescence (XRF) analysis**
  - Only detects the the elemental bromine (Br) and does NOT distinguish between the different brominated FRs.
  - If bromine is detected it is almost certainly HBCD if source of material is from demolition or renovation of a building built before 2015. As of 2015, mostly poly-FR is used.
- **Quick-test (“Fraunhofer-Method”)**
  - Used to distinguish HBCD from Poly-FR. XRF-analysis to determine brominated FR present: dissolve EPS (2 g) in acetone (5 g) for 2 minutes, XRF-analysis on supernatant. If the analysis shows a high bromine concentration it is likely HBCD, if no or very low bromine concentration likely to be poly-FR as poly-FR does not dissolve in acetone.
  - Lower detection limit around 50 ppm.
- **Chromatography and detection of HBCD**
  - HBCD can only be detected specifically in a specialized laboratory with a combination of chromatography and detection.
  - Chromatography separates a mixture of substances like EPS into its components. This technique is used to isolate HBCD from the other components. Both gas chromatography (GC) and liquid chromatography (LC) are used.
  - For the detection of HBCD and measurement of its concentration both Mass Spectrofotometry (MS) and Flame Ionization Detection (FID) are used.
  - Laboratory testing of HBCD is costly (€ 200-300/sample), time consuming (lead time several days) and complex (solving and precipitating HBCD from the plastic is difficult).
  - Further standardization is required. A DIN standardization process is under review since 2014 [3]
  - Currently none of the analyses have been accepted as international standard.

Appendix 4

EPS Acceptance Sheet

Relevance	**Demolition** **Collection** **Pre-treatment** **Transportation**
Content	**Who can supply material**
	Material and packaging specifications
	Logistics
	Euralcodes
	Legislation

EPS Acceptance Sheet

version 23 April 2019

Acceptance Information Sheet of EPS for recycling by PolyStyreneLoop

1. Who can accept and supply material for treatment by PolyStyreneLoop?

PolyStyreneLoop works together with certified HUBs. Only certified HUBs can take in material for pre-treatment and supply material to PolyStyreneLoop.

2. What kind of material is accepted by PolyStyreneLoop?

Expanded Polystyrene (EPS) from the renovating and demolition sector containing HBCD (Hexabromocyclododecane).

3. What material and packaging specifications does the material have to fulfil?

Material description	EPS pre-sorted and compacted
Material shape	Various briquette shapes accepted Condition: compacted and packed according to specifications
Material weight	Briquette weight of 15-50 kg Condition: packed according to specifications
Material density	100-450 kg/m³ **Too high compaction will cause the material to melt, this has to be avoided!**
HBCD content max	< 1.5 wt.%
Water	as low as possible, preferably under 3wt% measured per briquette
Asbestos	0.0% wt. - material may absolutely not be contaminated with asbestos
Bituminous impurities	as low as possible, preferably almost 0 wt.%
Other impurities PUR, glass wool, rock wool, cement, nails and iron, glue	The total of all impurities ≤7 wt.% measured per briquette
Delivered	• Compacted briquettes stacked on pallets and tightly wrapped in PE shrink film • Compacted briquettes in big bags
Packaging specifications	• A wide range of pallets is accepted • Maximum height 2.6 meter

These specifications are a guideline for the HUBs, based on the best available knowledge of PolyStyreneLoop to date. As not each situation can be accounted for, detailed discussions between PolyStyreneLoop and the HUB need to take place to come to an agreement on the material to be supplied. Input specifications may change over time.

4. Logistics

Transportation	Applicable means of transport for pallet packed material.
Permits	It is the responsibility of the supplier to have all necessary trans-border documents and permits in place and executed.

5. Eural codes

Eural code	Eural code name	Commonly used name
17 06 04	Insulation Materials	EPS construction and demolition waste
15 01 02	Plastic Packaging	EPS packaging waste Note: Only EPS Packaging containing HBCD or suspected to contain HBCD.
20 01 39	Plastics	
02 01 04	Waste plastics (except packaging)	

6. Legislation – Classification of EPS containing HBCD

European Union	< 3% (30.000 ppm) HBCD, not classified as hazardous waste when containing no other impurities than HBCD
The Netherlands	Not classified as hazardous waste
Germany	Not hazardous waste but needs to be registered as if hazardous waste • Elektronische Nachweispflicht
Switzerland	Not classified as hazardous waste
Other European countries	tbf

7. Legislation – Cross-border transportation

The company transporting the waste to PolyStyreneLoop must submit a notification procedure with the competent authority of the government of origin of the waste. Each transporter of waste is required to submit this notification procedure. Getting the permit to ship waste takes between 4 to 6 weeks and the permit can already be requested. The permit needs to be renewed every year. Transport of waste across the border does require proper documentation according to European Waste Shipment Regulation no. 1013/2006.

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Relevance	**General Information**
Content	**Overview of references per chapter**

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PolyStyreneLoop at a glance – slide 6

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EPS and XPS – slide 9

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The Market – slide 12

Supply of PS foam waste – slide 12

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Transport – slide 20

National and cross-border transportation – slide 21

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Appendix 1: The PolyStyreneLoop initiative – slide 33

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