

GUIDE

for the collection and pre-treatment
of EPS rigid foam waste
from demolition
construction sites



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Abbreviation

S

GPPS	General Purpose Polystyrene
BRU	Bromine recovery annex
EPS	Expanded Rigid polystyrene foam
FR	Flame retardant additive
HBCD	Hexabromocyclododecane
HUB	Collection point
HWRCs	Household waste recycling centres
PPM	parts per million (parts per million)
PS	Polystyrene
PS Loop	PolyStyreneLoop
RFA	X-ray fluorescence

Introduction

PS Loop at a glance



Who is behind PS Loop?

PolyStyreneLoop (now PS Loop) was an initiative/project of the expanded polystyrene rigid foam value chain. More than 70 members and supporters from more than 15 European countries had joined together in a cooperative during the lifetime of the EU-funded PolyStyreneLoop project. The plant was opened in Terneuzen on 1 April 2021.

In the summer of 2022, the GEC Group, consisting of the German EPS manufacturing companies Karl Bachl Kunststoffverarbeitung GmbH & Co. KG, Brohlburg Dämmstoff und Recyclingwerke GmbH & Co. KG and Rygol Dämmstoffe Werner Rygol GmbH & Co. KG, took over PolyStyreneLoop B. V., which is now managed as PS Loop B.V..



What does PS Loop do?

PS Loop offers a recycling solution for HBCD-contaminated expanded polystyrene foam (EPS) waste from building demolition work. There are quality requirements for the insulation waste.



How does PS Loop achieve this?

In a physical recycling process, polystyrene and bromine are recovered and HBCD is safely destroyed at the same time. Within the legal framework conditions, the cycle for polystyrene is closed.

Why are the PolyStyreneLoop cooperation partners involved?



Since the 1960s, HBCD has been used as a flame retardant additive in EPS. Since 2016, mechanical recycling of this waste is no longer permitted. The industry is taking responsibility and actively working on a solution to conserve resources.

Where is the location of the PS Loop facility?



The PS Loop plant is located in Terneuzen, in the southwest of the Netherlands, close to the Belgian border. In the immediate vicinity is Europe's only bromine recovery plant (ICL-IP).

Introduction

HBCD in EPS

- Since the 1960s, the flame retardant additive HBCD has been used in EPS.
- For decades, HBCD was considered the best flame retardant solution to meet national fire safety regulations. Today, HBCD is considered a pollutant and may no longer be used.
- In EPS insulation materials, it was replaced ahead of schedule in Germany in 2015 by a new, harmless flame retardant additive.
- EPS waste containing HBCD may no longer be sent for mechanical recycling. For a long time, thermal recycling was considered the only feasible recycling method in Germany and Austria.
- With the innovative recycling process that PS Loop uses, a process for recycling EPS waste containing HBCD was carried out on an industrial scale. This technology has already been recognised as the best available
Recycling technology for processing HBCD waste included in the Basel Convention of the UN Environment Programme (UNEP).
- The PS Loop plant is designed for waste volumes of 3,000 tonnes of EPS waste per year. The plant, which has been adopted by the GEC Group as a pilot project, will demonstrate the technical, economic and environmental feasibility of the new recycling process and is expected to lead to the introduction of the process in more and more plants in many countries in Europe and the world.
- PS Loop thus creates a closed loop economy for EPS foams containing HBCD.

Introduction

National laws - Germany: POP Waste Ordinance, KrWG, GewAbfV, NachwV

Verification

Polluters, responsible parties, collection, transport and recycling/disposal companies are obliged to provide evidence to each other and to the authorities. Proof must be provided before the start of reprocessing in the form of a declaration by all those involved in the process chain for the planned reprocessing. A declaration of acceptance by the recycling/disposal company is also required.

/disposal company as well as confirmation of the permissibility of the planned reprocessing by the competent authority. During reprocessing, an account must be kept of the whereabouts of the POP waste (POP Waste Transition Ordinance § 4).

(POP-Abfall-ÜberwV: Ordinance on the Supervision of Non-hazardous waste containing persistent organic pollutants).

If the amount of waste generated by the polluter is less than 20 t per year by waste category and location, the polluter can provide proof of the permissibility of reprocessing with the corresponding documentation from the collection company (NachwV § 9.1.4).

(NachwV: The German Ordinance on Waste Recovery and Disposal Records is an implementing regulation of the Closed Substance Cycle Waste Management Act on the documentation of waste management, which is subject to monitoring by the police authorities).

Registration requirements

Producers, responsible persons, collectors, transporters, traders and intermediaries of POP waste must keep a register containing the following information: Quantity, type, origin, destination, frequency of collection, type of transport and reprocessing. The register must be kept for at least three years from the date of registration and must be presented to the competent authority on request (POP Waste Ordinance § 5).

Electronic record keeping

Even though EPS containing HBCD is not hazardous waste according to German legislation, the documentation requirements for hazardous waste set out in the Ordinance on Waste Recovery and Disposal Records (NachwV) do apply.

Prior to disposal, a certificate of disposal with declarations by the producer, the disposer and the competent authority on the permissibility of the planned reprocessing must be obtained (NachwV - Part 2, Section 1).

A consignment note is proof that disposal has been carried out. Waste transporters must carry a copy of the consignment note during transport (NachwV - Part 2, Section 2).

Producers, responsible parties, collectors, transporters, traders, retailers and disposers of waste must keep a register of all necessary disposal operations. This register must be kept for three years (NachwV - Part 3).

Recycling plant PS Loop

Location

The PS Loop demonstration facility is located in Terneuzen, in the southwest of the Netherlands, next to the ICL IP site.

The reason for this is the proximity to the ICL-IP's bromine recovery unit (BRU).

System performance

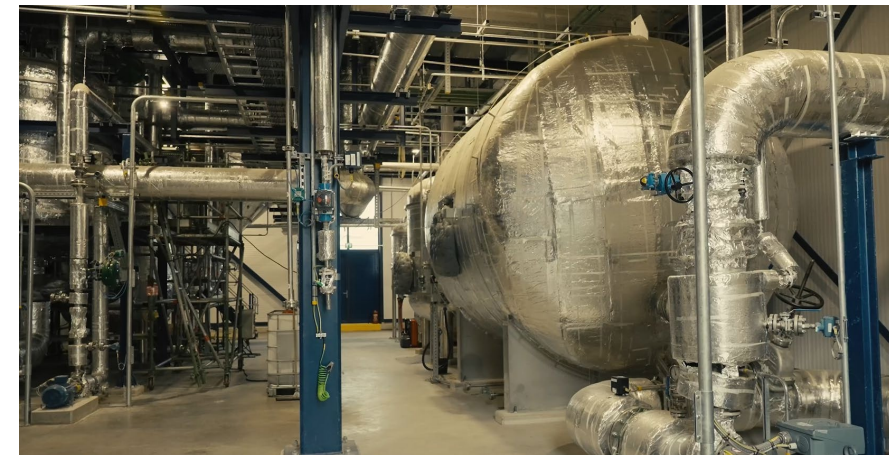
The PS Loop pilot plant is designed for a production capacity of 3,000 tonnes per year of purified PS. In the first year, the plant will start with a production of 900 tonnes, in the second year 1,350 tonnes are planned, and in the 3rd year the full output of 3,000 tonnes will be reached, which will then be continued in the following years.

In Germany, the cooperation partner FZ-Recycling is happy to provide supportive Services for the preparation of EPS waste at the accumulation sites (construction sites) and helps with the transfer to Terneuzen.

There, the plant can run daily in three shifts of eight hours each, five days a week. Weekend work is not planned, but feasible. This could increase production to about 8,000 tonnes per year, with limited higher variable costs.

Storage capacity

The storage capacity for compacted EPS at the PS Loop site is designed for 360 tonnes, enough for 36 days of operation at full capacity.

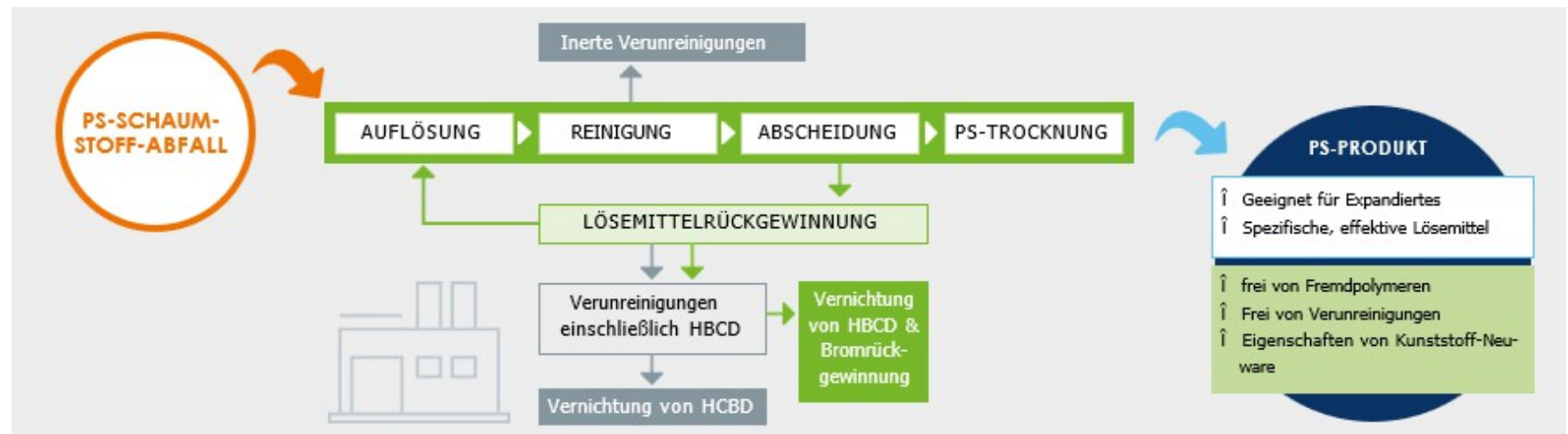


Material recycling with PS Loop

Technology

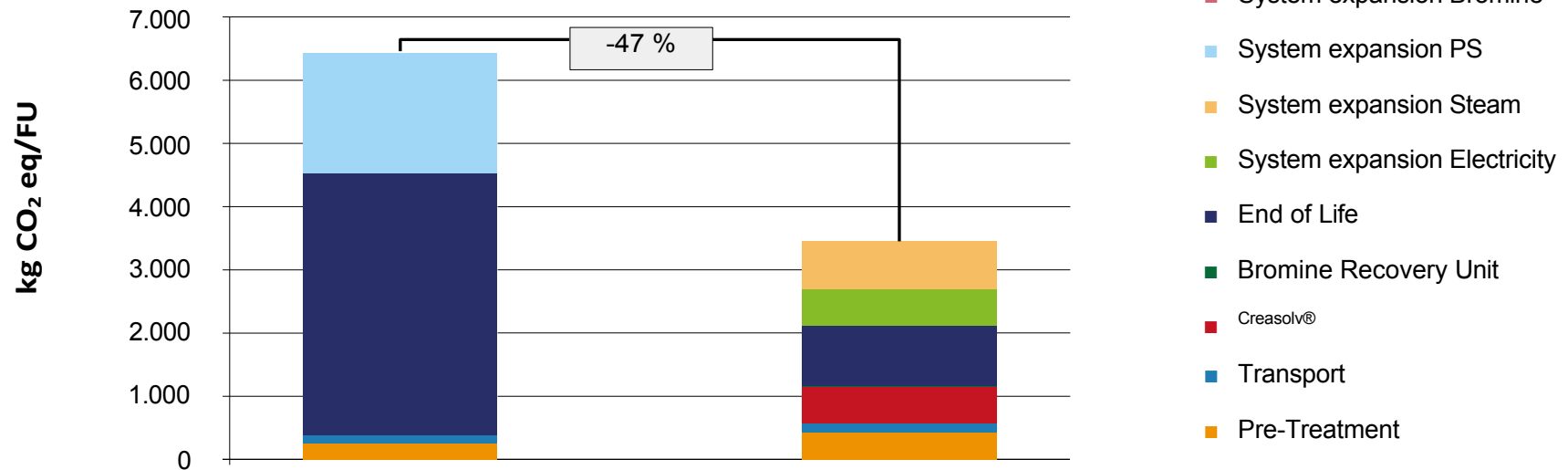
Mechanical recycling with PS Loop of EPS insulation waste containing HBCD is carried out with the CreaSolv® technology. This technology was developed by CreaCycle GmbH in cooperation with the Fraunhofer IVV. It is a physical process based on selective extraction. CreaSolv® is a registered trademark of CreaCycle GmbH.

- **Dissolution** - The core of the PS-Loop process is the dissolution process. Com- pacted EPS waste is crushed and then dissolved. Dissolving is a physical process, as the substances only change their aggregate state from solid to liquid in the process, which can also be reversed. The individual substances themselves, such as the polystyrene, are not destroyed.
- **Purification** - Insoluble impurities are separated and a clear solution is obtained. The impurities are disposed of or can be recycled if they contain valuable substances.
- **Deposition, precipitation** - By changing the dissolving properties due to the Process liquid (addition of additive) the polystyrene precipitates, the HBCD remains in the solution. After recovery of the solvent by distillation, HBCD sludge remains, which is transported to the neighbouring bromine recovery unit (BRU) of ICL-IP.
- **PS drying** - The precipitated polystyrene gel is dried.
- **PS product** - Through extrusion (continuous pressing out of shaping opening), PS pellets are created which serve as recycled raw material for the production of new PS products.
- In the case of higher HBCD concentrations in the PS waste, several runs can be carried out.



Ecological advantages of PS Loop

- The life cycle assessment analysis carried out by the German Technical Inspection Agency (TÜV) Rheinland LGA Products GmbH certifies a significant improvement in the CO₂ footprint of the PS-Loop process. Namely, a reduction of 47 % compared to new production.
- The effect presented as "climate change" is quantified in kg CO₂ equivalents per functional unit [kg CO₂ eq/FU].
- The study shows that the new options for PS production and end-of-life remanufacturing (incineration, energy recovery or recycling) are the main factors in the overall ecological balance.
- The main factor for the good balance of the PS-Loop process is the low energy consumption in the CreaSolv® process.
- The environmental impact of pre-treatment and transport is somewhat greater with the PS-loop process. The reason for this is the higher energy consumption for separation and compaction as well as further transport routes.



Collection logistics

From demolition to recycling

The material to be processed in the PS Loop plant comes from demolition sites and has to be collected, pre-treated and transported before it can finally enter the plant where polystyrene and bromine are recovered.

Demolition	Collection	Pretreatment	Transport	Recycling
<p>The majority of EPS waste containing HBCD is generated during demolition. This do one's work Demolition companies.</p> <p>In order for the EPS waste to be processed in the PS Loop plant, it must be kept as separate as possible from other waste such as concrete, construction waste, wood, glass, etc.. Plants such as those from FZ-Recycling are used for this purpose.</p>	<p>Waste collection companies collect the waste from the demolition site. The EPS must meet the palletisation and packaging requirements for the load. The EPS must be sampled per demolition site. This means that an exact allocation of the pallets to the building application per building must be made possible. The samples are currently made possible at PS Loop.</p>	<p>Contaminants must be removed. This refers in particular to bituminous adhesions and asbestos. Also mortars and plasters that from composite thermal insulation systems, among other things, may account for no more than a total share of 7 %.</p> <p>Photo documentation when submitting the cargo declaration must be used to ensure that this has been correctly pre-treated.</p>	<p>When registering material for the PS loop facility in Terneuzen, please note that a notification for cross-border traffic must be obtained</p>	<p>The dissolution of the synthetic materials is a physical process, as the materials only change their aggregate state from solid to liquid. This can also be reversed.</p> <p>For this reason, the process used by PS Loop is correctly classified as "materials recycling".</p>

Collection logistics

The role of future collection points (hub)

- PS Loop is not involved in demolition work or the collection or pre-treatment of the EPS waste to be processed, nor in its transport. These tasks are in the hands of the respective specialist companies on site.
- A network of so-called "HUBs" in the Netherlands and Germany is planned for the future.
- The main task of a hub will be to ensure the pre-treatment of the material in accordance with PS Loop's waste acceptance requirements.
- Currently, there are partners who assist in ensuring the waste acceptance requirements and also provide the technology to support compaction/dewatering and sampling.
- In Germany, the company FZ-Recycling GmbH & Co. KG, Im Schülert 13, 56745 Niederzissen, www.fz-recycling.com, can be contacted for this purpose.



Waste market - Origin of EPS construction waste

From demolition to recycling

Waste from demolition work

- The focus of PSLoop is on EPS waste containing HBCD. There are other recycling options for EPS insulation waste without HBCD.
- The majority of EPS waste containing HBCD will come from demolition work. The pure HBCD waste volume in Germany is expected to increase to more than 37,000 tonnes p.a. over the next 50 years.
- As buildings are demolished at the end of their useful life, an increasing amount of waste will have to be processed in the future. This is because more and more buildings with insulation will gradually reach the end of their useful life. Even if one usually assumes a building lifetime of up to 100 years.
- To comply with the permitted HBCD limits for all end-of-life products, recyclers who mechanically recycle must sort out any EPS packaging waste that may contain HBCD.
- The amount of EPS waste containing HBCD from demolition work will increase over the next decades as older buildings are gradually deconstructed or modernised.
- An X-ray fluorescence analysis (laboratory) can determine whether the material is bromine-free and thus free of flame retardants.
- If it is not flame retardant-free, a subsequent extraction method can determine which brominated flame retardant is contained.
- If HBCD is confirmed, the waste can then be compacted and transported to PSLoop for processing.

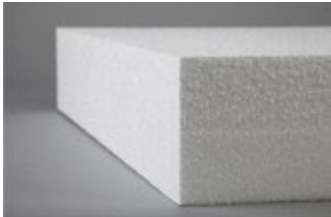


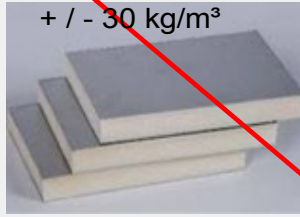
Collection of EPS at municipal recycling centres

- Citizens can bring different types of waste to municipal recycling centres. This waste is collected separately there. Particularly large recycling centres can collect up to 20 different types of waste. There are municipal recycling centres in most European cities and municipalities.
- EPS packaging materials usually did not contain HBCD. A small part of the imported packaging material contains flame retardant additives in the form of polymer FR. No evidence was found that the flame retardant additives FR-720 and SR-130 are used in packaging material. In principle, packaging waste should not be mixed with construction waste. This is detrimental to recycling in the PS Loop plant.

Scenario A	EPS Construction waste in tonnes	HBCD-free EPS construction waste in tonnes	EPS construction waste containing HBCD in tons
2022	51.000	19.433	31.567
2025	56.065	21.372	34.693
2030	64.322	27.259	37.063
2035	72.791	36.145	36.646
2040	82.417	45.772	36.645
2045	92.929	57.600	35.329
2050	104.502	69.778	34.724

Insulation differentiation

Only EPS, expanded polystyrene rigid foam, is recycled by PS Loop, no other rigid foam insulation materials!

	EPS, expanded polystyrene rigid foam	XPS, extruded polystyrene rigid foam	PUR, polyurethane rigid foam	PIR, polyisocyanurate
Use Appearance	Construction and packaging	predominantly	Construction	Construction
Breaking by hand	Smooth and rigid, individual EPS beads visible to the eye	smooth and rigid construction	smooth and rigid	smooth and rigid
Cell structure	quite possible		Possible, but difficult, porous structure	Possible, but difficult, porous structure
Polymer type	closed thermoplastic	Very heavy, homogeneous/smooth structure	closed	closed
Colours	white, grey, white with grey-em granules	closed thermoplastic	thermosettin	thermosettin
Density	12-30 kg/m ³	yellow, white, pink, blue, green, violet	g yellow/brown	g yellow/white
	30-60 kg/m ³ 		+ / - 30 kg/m ³ 	+ / - 30 kg/m³ 

Insulation material differentiation - EPS waste for PS Loop

- PolyStyreneLoop processes EPS waste containing HBCD.
- EPS does not contain (H)CFCs.

How can EPS be recognised?

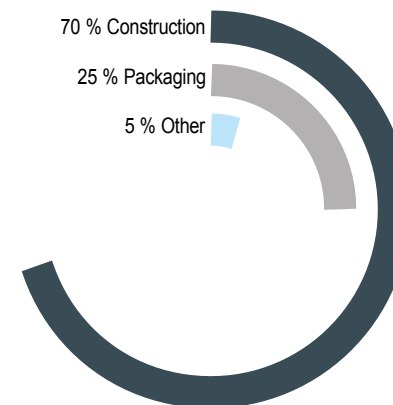
- EPS is a solid insulation material with a cellular structure made from welded, expanded polystyrene. EPS has a closed-cell structure filled with air (98 % air).
- EPS insulation boards are hard insulation products with a rectangular shape. The board edges can be equipped with stepped rebate or tongue and groove. EPS as a loose filler is produced in the form of air-filled beads in the factory.
- EPS insulation boards are white or grey or white-grey speckled.



Where is EPS used?

- EPS is used in the three areas:
 - Construction, especially as thermal insulation material for buildings
 - Packaging for industry and food
 - Other (automotive, medical, marine, sports and leisure, etc.)
- Approx. 70 % of EPS is used in the construction and insulation sector. The useful life of this construction EPS is about 50 years, which is considerably longer than the useful life of EPS packaging.
- A European survey showed that in 2017, packaging waste accounted for the largest share of EPS waste in Europe (74%). This is because the lifespan of insulation material in particular is significantly longer than that of packaging. Only 26 % of the waste came from construction. The recycling potential lies in the large quantities from refurbishment projects.

EPS production

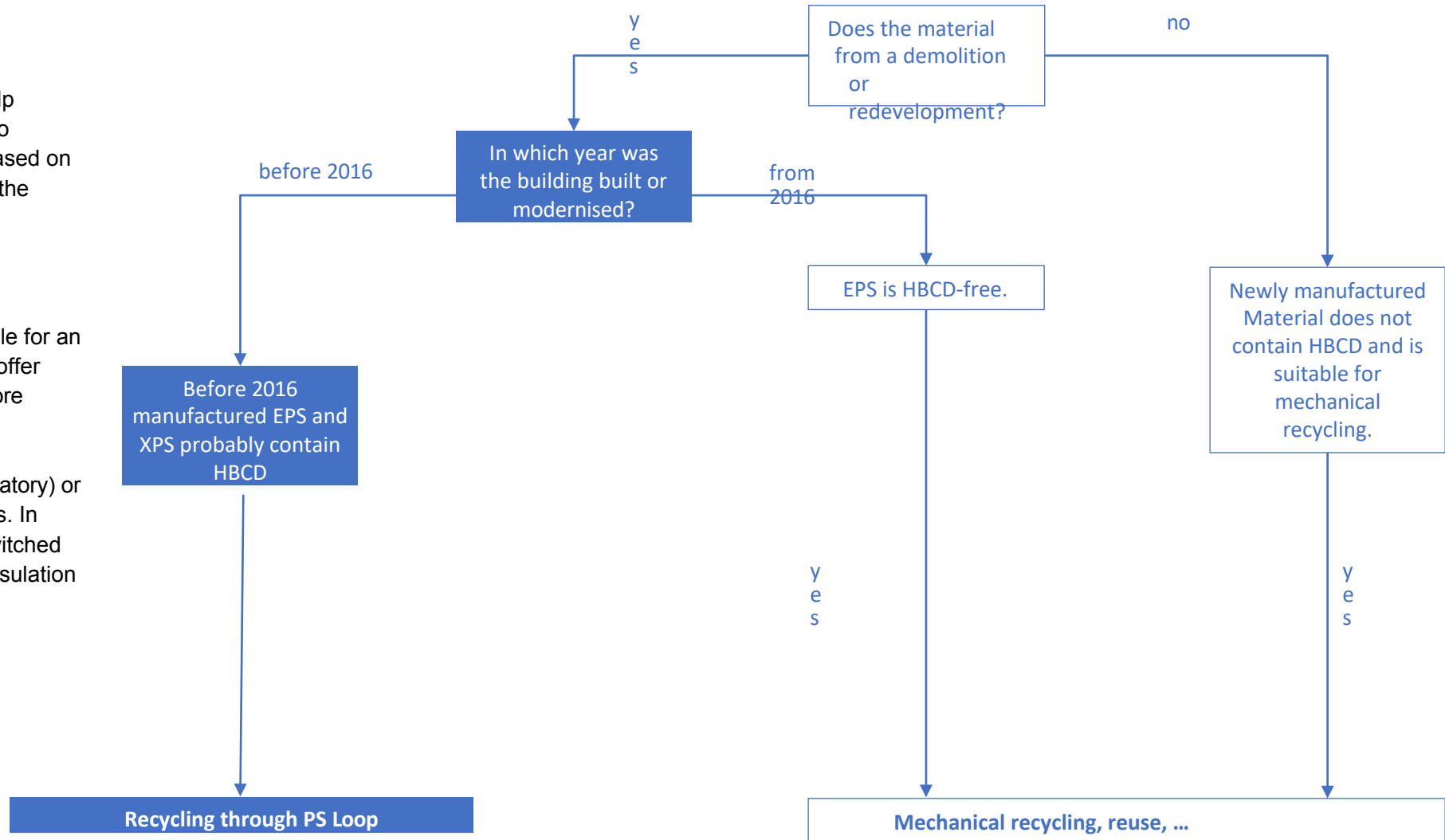


Insulation differentiation

EPS waste with HBCD?

The decision aid opposite can help determine whether EPS is likely to contain HBCD. The decision is based on the origin of the waste. Similarly, the decision is based on the date of construction of the building being demolished or refurbished.

The decision-making aid is suitable for an initial classification, but does not offer one hundred percent certainty. More precise Results provide the X-ray fluorescence analysis (laboratory) or a more elaborate GC-MS analysis. In Germany, EPS manufacturers switched to HBCD-free raw materials for insulation products in 2015.



Contamination, pre-treatment processes

Types of pollution are for example:

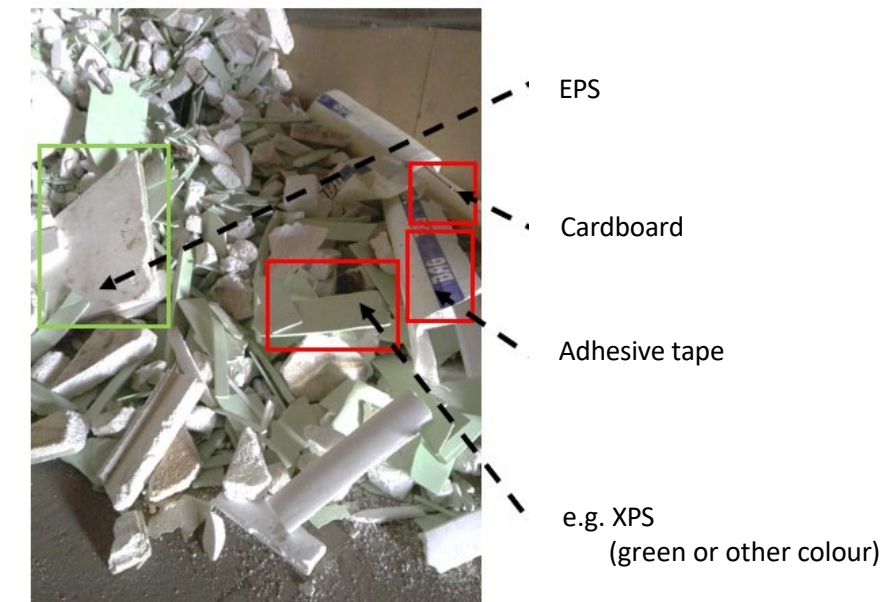
- Adhesions of sand, clay, concrete, glue, stickers, adhesive tape, water, asbestos, asphalt, nails and other insulating materials.
- Chemical contamination by iron oxides, minerals, phosphates
- Odour pollution: odours from animal husbandry or fish storage

Adhesives must be removed as far as possible. Sand, concrete, adhesives and stickers cause solvent losses, generate waste and can damage the PS Loop demonstration unit. Asphalt is also a persistent organic pollutant. Asbestos is classified as hazardous. Therefore, both pollutants must be completely removed.

Chemical soiling and odour impairments do not harm the PS- Loop process. These influence the quality of the final PS Loop product.
not.

The PS Loop process is affected by water. Water reduces the performance of the solvent. To prevent water from entering the process, the EPS waste is dried before feeding. Access specifications require that the water content of the fed briquettes is less than 3% by weight. EPS waste from cold stores may contain larger amounts of water because water condenses in the EPS cells.

EPS must be separated from other insulation materials etc.



Contamination, pre-treatment processes

Compact and pack

Compacting EPS waste

- Before EPS is pressed, contaminants such as concrete, other plastics such as glue, nails, wood, etc. must be removed.
- EPS waste may contain water, e.g. if the material is used by so-called "waterlogged" roof insulation. In this case, it must be pre-treated so that water is squeezed out during compacting.
- EPS is compacted in screw compressors. Such systems are available with capacities between 10 and 250 kg/h.
- There, EPS waste is compacted by a factor of 5 to 64, i.e. from 12-30 kg/m³ to 100-450 kg/m³.
- Such a plant normally consists of a crusher, if necessary a silo and the screw compressor. The EPS insulation boards are crushed in the crusher so that they can be fed into the screw compressor. For larger capacities, a silo is located between the crusher and the screw compressor so that the crusher does not have to be continuously fed.
- During compacting, the temperature in the screw compressor can rise unintentionally and with it the temperature of the EPS. If the temperature of the material rises above 90 °C, EPS begins to melt. This can cause the molecules of the polystyrene to break up and thus affect the quality of the PS-Loop product.
- The undisturbed passage of material in the screw compressor must therefore be monitored.



Transport packaging and storage

- Compacted EPS bars are to be stacked on pallets.
- Compacted EPS bars on pallets are wrapped tightly in PE shrink film. This prevents loose material from getting into the environment. At the same time, this facilitates transport.
- Pallets with compacted bars can be stacked on top of each other for optimal transport.



Transport

Transport within Germany

- Shipping documents are required for the domestic transport of the compacted material. The papers must be carried during transport.
- Information on the consignor and consignee, as well as on the waste, such as weight and the European waste code, must be noted on the shipping documents.
- Receipt of the material shall be acknowledged.



Cross-border transport

- The **EU Waste Shipment Regulation (WWR)** sets out procedures and controls for the shipment of waste. The waste transport company has to notify the transboundary waste shipment every year.
- EPS waste containing HBCD is not on the so-called "Green List" of the EU Waste Regulation. **Notification** is required for transport.
- The competent authorities of the sending and receiving countries must approve the reprocessing and notification.
- For cross-border transports, **notification and transport documents** are required and must be carried during transport.
- The documentation contains information on the sender and receiver as well as all details on the waste including the waste codes.
- Receipt of the material shall be acknowledged within three working days.
- Acceptance of the material must be confirmed within six months of receipt. This is the transfer of ownership from the hub to PS Loop.
- Proper reprocessing of the material shall be confirmed within twelve months of receipt.
- It is important to check the national legislation of each sending country to ensure that all requirements for cross-border transport are met.

Quality assurance for EPS construction waste - access quality for PS Loop

Acceptance conditions for EPS for recycling by PS Loop

1. Which material is suitable for the PS Loop process?

Insulation made of expanded polystyrene (EPS) from building sites, which contains HBCD (hexabromocyclododecanes).

The material was approved for installation in Germany until 2016. To check the material, a sample must be sent to PSLoop and checked there for its suitability.

The delivered material must be identical to the sampled material match. Provided large deviations exist, the material shall be rejected. Any additional costs incurred will be invoiced to the supplier.

These specifications are based on current knowledge and are general in nature. In the case of specific deliveries, a detailed discussion must take place between PS Loop and the supplier company in order to identify the cause and effect of certain delivery conditions and to reach an understanding and procedure after the rejection of material. Changes to the delivery specifications cannot be ruled out.

Material description	Insulation material made of expanded polystyrene (EPS) in the form of blocks of the boards, which contain HBCD. Mixtures with other EPS insulation materials are considered as unacceptable contamination (e.g. XPS).
Flame retardant	Less than 1.5 % Hexabromocyclodecane (HBCD) No contamination with other flame retardants allowed, e.g. polymer FR).
Form	Compacted material blocks with a compression ratio of 50:1
Material weight	Maximum weight of the material blocks: 25-50 kg
Material density	100-400 kg/m ³ - Loosely pressed material brings with it higher impurities - Material that is pressed too hard can melt during pressing.
Water	Maximum less than 3 % volume fraction.
Asbestos	0.0 % - the material must not be contaminated with asbestos under any circumstances.
Bituminous impurities	0.0 % - the material must not have any bitumen build-up.
Other impurities	The maximum percentage of impurities must not exceed 5 %. This measurement applies per block. Impurities refer to PUR, glass wool, rock wool, cement, mortar, nails, iron, adhesives. Residual sections of EPS insulation materials with the flame retardant Polymer-FR are not considered "other impurities". The 0 % rule applies here.
Delivery	The compacted blocks shall be loaded on pallets and tightly wrapped with transparent polyethylene film. The material is loaded, transported and stored in the open air and must be protected from water ingress. The film is therefore to be wrapped on the top of the load first, furthermore: - 3-fold winding against wind attack - 2-fold wrapping as last wrapping on top of the pallet (rain protection) - One product declaration per pallet (no mixed material)
Size pallets	1.2 x 1.2 metres - reusable Europe pallets

Quality assurance for EPS construction waste - access quality for PS Loop

Acceptance conditions for EPS for recycling by PS Loop

2. Documentation

All delivery documents also count for deliveries abroad. The documents from the notification, the delivery note (CMR) and the weighing note must be kept ready as a copy for the delivery. If a weighing slip is not available, weighing can be carried out at a weighing facility locally in Terneuzen. The weighing costs shall be borne by the supplier.

3. Registration on delivery

The delivery must be notified, a period of 2 days applies for this. (at least 36 hours). Acceptance can take place during business hours from Monday to Friday from 8 to 4. Use the following contact details for notification.

QA/Laboratory	Chris Child	ckind@PSLoop.eu
Back Office	Richard Geevers	invoice@PSLoop.eu
Operations Team		operations@PSLoop.eu

- 1. mention of subject: "Delivery - name of supplier - date - tour number 001".
- Please include a photo of the delivery with the notification.

4. Key number

Key no.	Designation	Common names
17 06 04	Insulation material, but not those listed under No. 17 06 01 and No. 17 06 03 named	ESP insulation, polystyrene, installed before 2016

5. Waste classification

European Union	Not classified as hazardous waste, notification in the case of transboundary Traffic necessary
Netherlands	Not classified as hazardous waste
Basel Convention	Technical guidelines for the environmentally sound management of waste which have HBCD.

6. Logistics

Transport	Truck with trailer, no height limit. Logistics company free choice or www.wielemaker.nl
Permits	Notification required for cross-border transport per shipment. Obtaining the permit takes 4 - 6 weeks (EU Waste Shipment Regulation 1013/2006).

Netherlands



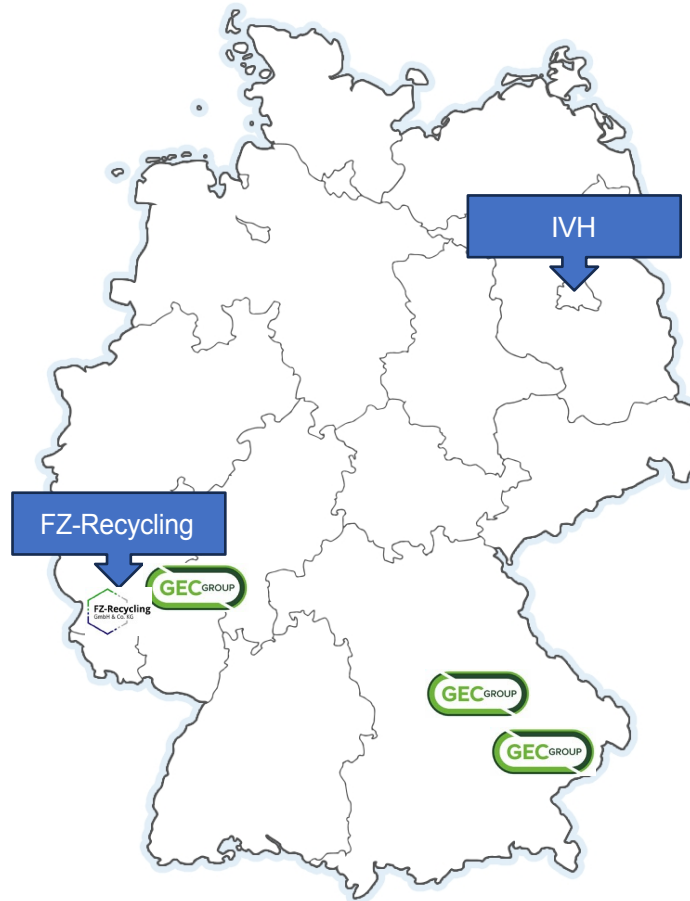
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Belgium www.plasticseurope.org/en

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Polystyrene GPH

Austrian association of EPS industry
Brückenstraße 3, 2522 Oberwaltersdorf, Austria
www.gph.at

Styfabel

Belgian association of EPS industry
Henri Regastraat 14, 3000 Leuven, Belgium
www.styfabel.be

Stybenex

Dutch association of EPS industry
Hatertseweg 598 6535 ZX Nijmegen, Netherlands
www.stybenex.nl

AFIPEB

French association of EPS industry
3 Rue Alfred Roll 75017 Paris,
France www.afipeb.org

ANAPE P2

Spanish association of EPS industry
Castellana, 203 - 12 Izquierda 28046 Madrid, Spain
www.anape.es

EXIBA

European association of XPS industry
Rue Belliard 40, box 16 1040 Brussels,
Belgium www.exiba.org

FPX German association of XPS industry

Friedrichstraße 95, 10117 Berlin, Germany
www.xps-spezialdaemmstoff.de/

BRBS

Dutch association for recycling and demolishing industry
Van Heemstraweg West 2B, 5301 PC Zaltbommel,
Netherlands
www.brbs.nl/

VERAS

Dutch association for demolition industry
Rijksstraatweg 69, 4194 SK Meteren, Netherlands
www.sloopaannemers.nl/

BVSE

German association special waste management
Fränkische Straße 2, 53229 Bonn, Germany
www.bvse.de/fachverband-sonderabfall.html

ZVDH

German association of roofers
Fritz-Reuter-Str. 1, 50968 Cologne,
Germany www.dachdecker.org