Analysis of Alternatives

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LIST OF ABBREVIATIONS

AoA	Analysis of Alternatives
BFR	Brominated Flame Retardant
C&L	Classification & Labelling
CAS	Chemical Abstracts Service
CEFIC	The European Chemical Industry Council

CLP	Classification, Labelling and Packaging
CSR	Chemical Safety Report
EBFRIP	European Brominated Flame Retardant Industry Panel
ECHA	European Chemicals Agency
EEA	European Economic Area
EPS	Expanded Polystyrene
eSDS	extended Safety Data Sheet
ESR	Existing Substances Regulation
ETICS	External Insulated Composite Systems
EU	European Union
EUMEP	European Manufacturers of Expanded Polystyrene
EXIBA	European Extruded Polystyrene Insulation Board Association.
FR	Flame retardant
GHG	Greenhouse Gas
HBCDD	Hexabromocyclododecane
OC	Operating Conditions
PBT	Persistent, Bioaccumulative, and Toxic
PFR	Polymeric (brominated) Flame Retardant (i.e. benzene, ethenyl-, polymer with 1,3-butadiene, brominated (CAS 1195978-93-8))
PEC	Predicted Environmental Concentration
PNEC	Predicted No Effect Concentration
POP	Persistent Organic Pollutants
RAR	Risk Assessment Report
RMM	Risk Management Measure
SEA	Socio Economic Analysis
SEAC	Socio Economic Analysis Committee
SVHC	Substance of Very High Concern
UNEP	United Nations Environment Programme
VECAP	Voluntary Emission Control Action Plan
XPS	Extruded Polystyrene

A. USE 1: FORMULATION OF FLAME RETARDED EXPANDED POLYSTYRENE (EPS) TO SOLID UNEXPANDED PELLETS USING HEXABROMOCYCLODODECANE AS THE FLAME RETARDANT ADDITIVE (FOR ONWARD USE IN BUILDING APPLICATIONS).

B. USE 2: MANUFACTURE OF FLAME RETARDED EXPANDED POLYSTYRENE (EPS) ARTICLES FOR USE IN BUILDING APPLICATIONS.

1 SUMMARY

The necessity for expanded polystyrene (EPS)[1] to be flame retarded is the result of strict regulations and standards for flame and fire proofing of building materials and building elements in the EU. Although these rules differ across the member states of the EU, the demands are sufficient to mean that the vast majority of EPS produced needs to be flame-retarded. Currently, the only material available in sufficient commercial quantities to meet full market needs for the required standards in fire safety, whilst retaining the specific required qualities of EPS for insulating building material, is by use of the Annex XIV substance hexabromocyclododecane (HBCDD)[2] as an additive flame retardant in EPS.

The conclusion of this analysis of alternatives is that there are no suitable or available alternatives for the use of HBCDD as a flame retardant in the formulation of EPS (USE 1) and the use of flame retarded EPS for the manufacture of EPS articles for insulation in buildings (USE 2).

An extensive (nine year) research programme has been carried out. This involved both the flame retardant substance manufacturers and the EPS producers, in order to identify a technically feasible alternative to HBCDD. The phased programme included the screening of possible existing alternatives as well as testing in EPS foams, and it showed that no suitable commercial alternatives existed.

The development of a brominated polymer (pFR) as an alternative has been achieved by the Dow Chemical Company and is now being manufactured under license by the manufacturers that currently supply HBCDD to the EPS formulators (i.e. Chemtura (product ‘Emerald 3000’), ICL (product ‘FR-122P’) and Albemarle (product ‘GreenCrest’).

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[1] EPS refers to *expanded* polystyrene, but is sometimes referred to as *expandable* polystyrene. As explained in this document polystyrene “pellets” made in Use 1 are *expandable* since they are later expanded to an article in Use 2. The article is *expanded* to form the blown beads that are later formed into boards etc.

[2] CSR presents two substances in section 1: a mono-constituent and a multi-constituent substance. The information presented is on the basis of information provided by the applicants on the HBCDD they are supplied with (from a number of different suppliers), for the purposes of formulation of flame retarded EPS. The two substances can be used interchangeably for the uses applied for.

The reason for this present application for Authorisation is that the EPS manufactures need time to perform the necessary actions in order to make the pFR a suitable alternative (i.e. complete a product testing programme with commercial grade pFR, ensure customer acceptability and meeting of relevant safety standards). In addition, the EPS manufacturers foresee that there will not be enough supply of the pFR to ensure continuity of the supply of their product, and it is therefore concluded that the alternative is not available to them in sufficient quantities.

The summary of substance function and the requirements for alternatives to meet these requirements is set out in Table 1.1 (reproduced in the main report at Table 2.3)

Table 1.1: Summary of essential criteria for substance function.

Essential criterion for substance function	**Justification/explanation**
1. Task performed by Annex XIV substance	HBCDD is currently the only additive flame retardant material available in sufficient commercial quantities to meet full market needs for EPS. It allows EPS articles to fulfill the requirements for fire protection in a number of EU Members states. The substance is effective at low concentrations, and does not adversely affect the key properties of EPS (in particular thermal insulating properties). In addition, it has very low/negligible migration from the EPS matrix.
2. What critical properties and quality criteria must the substance fulfill? The thermal (stability) of the flame retardant compared to the material it is protecting (i.e. EPS). Compatibility with EPS – i.e. the effect on other properties of the EPS	The compatibility of the flame retardant with EPS is essential for function. The flame retardant must thermally decompose before the EPS (in the case of HBCDD to release active bromine atoms into the gas phase as the material is decomposed in the fire (see section 2.2)). The flame retardant must be compatible with the EPS and not impact on its key properties, in particular the thermal insulation properties.
3. Function conditions Control of releases of the flame retarding agent during formulation and in the service life of the EPS articles. High effectiveness at low concentrations in the final products (ca. 0.7% w/w).	Efficiency in release control in order to prevent exposure of workers and the environment. Low effective concentrations and low migration rates in EPS are essential to ensure that the flame retardant is effective but does not negatively impact on the properties of EPS and that the substance stays within the EPS matrix.
4.Process and performance constraints	Compatibility with the process for making EPS in the European Union/EEA and its Member States.
5. Is the function associated with another process that could be altered so that the use of the substance is limited or eliminated?	There are two processes for formulating EPS: single-step and two-step. The single step process is the most energy and resource efficient (in terms of water use) way to make EPS and is universally employed in Europe. Compatibility with this system is essential to continue to make EPS in the most energy efficient way. It is necessary that the flame retardant should not interfere with the polymerisation process taking place in the reactor. In the two-step process the flame retardant is added AFTER polymerization. This gives potentially wider possibilities of possible alternatives in the two-step process because there is less potential for the flame retardant molecule to interfere with polymerization of the styrene to polystyrene. However, use of this process does not eliminate the need for a flame-retardant.
6. What customer requirements affect the use of the substance in this use?	For a number of EU member states flame retarding of EPS is the only way to meet either legal requirements or the requirements of the insurance sector.
7. Are there particular industry sector requirements or legal requirements for technical acceptability that must be met and that the function must deliver?	The requirement to meet a number of fire regulations in EU Member States for both EPS itself and building components.

Possible alternatives that have been identified are not technically feasible and/or are considered to lead to equal or greater risk compared to HBCDD. The alternative that could be technically feasible (pFR) is not available in sufficient commercial quantity and the testing of suitability for use at commercial scale is ongoing.

Table 1.2 below summarises possible substance alternatives (this is a summary version of Table 3.2 in Section 3 of this report). The identified technically feasible polymeric alternative (pFR) is listed first in the table. EPS formulators have and continue to work to fully phase-in this alternative; the actions and timing needed as well as the lack of sufficient volume available means that continued use of HBCDD is necessary to bridge the gap in time and allow enough commercially available pFR to be fully product tested and available.

Table 1.2: Summary list of possible substance alternatives for HBCDD as a flame retardant in EPS

Substance	CAS number	Commercial/ trade name	Comment
Benzene, ethenyl-, polymer with 1,3-butadiene, brominated	1195978-93-8	'Emerald 3000' 'FR-122P' 'GreenCuest' Brominated co-polymer of styrene and butadiene	Selected by the industry as the replacement for HBCDD in EPS and XPS. A programme aimed at demonstration of technical feasibility for EPS is in place and on going (see Table 1.4). This includes the performance of the necessary actions in order to make this substance a suitable alternative (i.e. complete a product testing programme with commercial grade pFR, ensure customer acceptability and meeting of relevant safety standards). Sufficient supplies are not available to ensure continuity of supply of flame retarded EPS. (see Section 4.5a)
Benzene, 1,1'-(1-methylethylidene)bis[3,5-dibromo-4-(2,3-dibromo -2-methylpropoxy)]	97416-84-7	'Pyroguard SR-130'	Indicated as a possible alternative by USEPA. Limited information on risks. Not likely to be suitable due to expected similar environmental fate and behavior to HBCDD. Limted testing in the Plastics Europe testing programme[3] and not known to be technically feasible for use in EPS in Europe. Unlikely to be available in sufficient quantities. (see Section 4.5b)
Tetrabromobisphenol-A bis (allylether)	25327-89-3	'BE 51'	Not technically feasible for use in the single step process (possible for use in the 'two-step' process has been indicated). Limited information on hazard profile. Indicated as a potential immunotoxin, not easily hydrolysed and may be resistant to environmental degradation. (see Section 4.5c)
1,2,5,6-tetrabromocyclooctane	3194-57-8	TBCO 'Saytex BC-48'	Used in the two-step process only, not feasible for the one-step process. This substance may no longer be commercially available. No information is available on production volumes in the US or in the EU. Hazardous to the aquatic environment, potentially PBT. (see Section 4.5d)

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[3] The substance is understood to be used in Japan as an alternative to HBCDD. This substance was not made available commercially to European EPS producers despite the offered of the EPS industry (via Plastics Europe) to work with the Japanese Producers Daiichi to develop the product: Plastics Europe has stated that "SR130 has been tested by EPS Alternative group .It is seen as an insurance policy in case there is any difficulty on the polymeric alternative side. EPS MC did approve the proposal to undertake the Bio accumulation test on the Daiichi material. This is the most critical step along the Reach registration of the product. Daiichi thanked us for our interest but did not want to send a sample for now." – Plastics Europe January 2012

Substance	**CAS number**	**Commercial/ trade name**	**Comment**
2,4,6- tribromophenyl allyl ether	3278-89-5	Pyroguard FR 100	Possible for use in 'two-step' process (only one–step process is used in the EU). Concerns for long range transport and bioaccumulation. (see Section 4.5e)
Tetrabromobisphenol A bis(2,3-dibromopropylether)	21850-44-2	TBBPADBPE GC SAM 55 FR 720	Some concerns for hazard profile, persistent in the environment. Possible mutagenic effects. (see Section 4.5f)
Tetrabromobisphenol A bis(2,3-dibromopropylether) & dicumyl peroxide (bis(α,α-dimethylbenzyl) peroxide)	21850-44-2 80-43-3	TBBPADBPE and dicumyl peroxide SAM 55 E (EPS)	Some concerns for hazard profile, persistent in the environment. Possible mutagenic effects. (see Section 4.5f) bis(α,α-dimethylbenzyl) peroxide) is classified as + R51/53 : Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. It is also classified as + R36/38 : Irritating to eyes and skin.
1,2-dibromo-4-(1,2-dibromoethyl)cyclohexane	3322-93-8	SAYTEX BCL 462	Potentially bioaccumulative and persistent in the environment, some indication of potential for reproductive effects on birds. (see Section 4.5g)
Clays: sepiolite (complex magnesium silicate), palygorskite/attapulgite, (magnesium aluminium phyllosilicate) or combinations thereof.	N/A	Understood to be not yet marketed (a US patent is published)	A patent for synergistic effect of a flame retardant organic molecule/clay is presented as a REACH compliant alternative to hexabromocyclododecane (HBCDD). This is presented under the INNOVEX® trade registered name. The structure or further details of the clays and whether they are intended to work in conjunction with BFRs or replace them is not clear. There have been some concerns owing to the fibre structure of sepiolite. IARC Monographs/vol68/mono68-9 concludes that: There is inadequate evidence in humans for the carcinogenicity of sepiolite. There is limited evidence in experimental animals for the carcinogenicity of long sepiolite fibres (> 5 µm). There is inadequate evidence in experimental animals for the carcinogenicity of short sepiolite fibres (< 5 µm).

This analysis of alternatives is based on the definition of the function of the substance, which is as a flame retardant in EPS. It is that function which leads the analysis to focus on other substances that may confer the necessary safety requirements without compromising the insulation properties of the EPS foam. Therefore, this analysis does not specifically need to consider other insulation materials[4]. Nevertheless, these alternatives materials are considered, since this is in line with the non-use scenario described in the SEA report. A summary of alternative materials and their suitability for replacement of flame retarded EPS is in Table 1.3 (a full version is at Table 3.5 in Section 3 of this report.)

Table 1.3: Suitability* of alternative final products to EPS

Alternative final product	Technically feasible	Economically feasible	Overall reduction in risk	Conclusion on suitability *
Non-flame retarded EPS	No	No	Yes	Not suitable
Mineral wool	Yes – for end users only	No	No – some health concerns	Not suitable
Rigid polyurethane (PUR) / Rigid Polyisocyanurate (PIR)	Yes – for end users only	No	No – some health concerns	Not suitable
Extruded polystyrene (XPS)	Yes – only with extensive change to production process	No	Same as EPS	Not suitable

*Suitability is assessed from the applicants' perspective.

The implementation of the polymeric alternative is a managed process and subject to uncertainties. This includes uncertainties on the technical feasibility, suitability and customer acceptance of the product as well as the availability of sufficient commercial volume of the polymeric alternative for the whole EPS supply chain.

Initially each EPS manufacturer would try to use the alternative (pFR) in exactly the same way as HBCDD, however there may need to be changes to the balance of other additives to ensure suspension stability, pellet size distribution and fire performance. The physical shape and size of the pFR is also important for loading into the reactor. Testing and iterations all take time and the final testing has to be done on the full scale reactors fitting in between regular production for a commercial business.

The actions to identify and develop the alternative have been successfully made; these and the further steps needed in order to fully implement the pFR are summarised in Table 1.4 (as also set out in Section 5).

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[4] The Guidance on the preparation of an application for authorisation (ECHA 2010) refers to "…*process or product that removes the need for the Annex XIV substance function altogether*." on Page 41. The focus is substance function; the function of HBCDD in EPS is a flame retardant, the function of other materials that can replace EPS is not as a flame retardant (although they may have flame retarding properties) but to provide insulation.

Table 1.4: Steps/Timing for Commercialisation of a FR Alternative

Step/action	**Timing**	**Comment**
1. Project Definition	1 day	Done
2. Identify partner(s) amongst customers for each application. Put secrecy agreements in place.	3 months	Done
3. Define a series of model structures that would have the technical advantages of HBCDD without the problematic features.	1 week	Done
4. Compare the models with commercially available chemicals and identify possible alternatives to HBCDD - in own portfolio - in literature	1 month	Done
5. Obtain or prepare samples of each potential candidate	6 months	Done
6. Evaluate in-house the possible alternatives(s) in each application - screening for technical performance - toxicity profile through software predictions - business assessment on availabilities and costs	3 months	Done
7. Present alternative(s) to customer partner(s) for their evaluation	1 month	Done
8. Prepare samples for partner(s) evaluation	2 months	Done
9. Evaluation by partner(s) in each application [a)]	6 months	Done
10. Review results - if technically and economically feasible - go to step 13 - if not technically and/or not economically feasible go to step 11	1 day	Done
11. Synthesis program for novel compounds	> 12 months	Done
12. Repeat steps 5 to 10 until a technically suitable alternative is found	n x 12 months	Done
13. Initiate toxicity testing for REACH registration - if testing OK go to step 14 - if testing is not OK, repeat steps 5 to 13 until a technically and HSE suitable alternative is found	n x 12 months	On-going (alternative substance is a polymer so not currently under REACH).
14. Assess sourcing of raw materials and manufacturing options for alternative	3 months	Done
15. Manufacturing pilot plant trials product for industrial trials	3 months	Done
16. Obtain product and process orientated research and development (PPORD) exemption from REACH registration for each country and customer where the product will be tested	3 months	On-going (alternative substance is a polymer so not currently under REACH).
17. Application pilot and industrial trials at partner(s)[b)]	6 months	To be initiated
18. Technical and organisational modifications of EPS production plants (e.g. equipment changes, tuning of process control and production parameters, training of personnel)	6 months	To be initiated
19. Build plant and start-up	12-18 months	To be initiated
20. Contingency for unexpected delays/problems/product tuning *(Chemtura experience for pFR indicates that this can be 15-18 months)*	15-18 months	To be initiated

Step/action	**Timing**	**Comment**
21. Iteration between pFR and EPS formulators and between the EPS formulators and converters – necessary to ensure product commercial viability	2 x 6 months	To be initiated
22. Commercialisation after full registration in each country (*e.g. 24 month IVH programme for Germany*) – it is not known if other members states will initiate similar programmes at member state level.	24 – 36 months	Initiated (in Germany only to date)
	Total time for initiated and on-going tasks ca.4 - 6 years	Total time for all steps ca. 7- >11 years

Table notes: a) Item 9 - timing will differ from company to company. It is possible that some partners will have to undertake several iterations of trialing to arrive at a satisfactory result whilst others will not.

b) It is known that one manufacturer of the pFR has a commercially available product; however other producers' products are in earlier stages of product development.

c) Full market implementation will depend upon the availability of an alternative to meet the market demand even if all technical, HSE, certification, etc. requirements are fulfilled. Hence the timing can be longer than that indicated.

The remainder of this document is a detailed analysis of the alternatives for the use of HBCDD in EPS for building applications. The document follows the format suggested by ECHA and is divided into the following sections:

Section 2 Analysis of Substance Function – this section identifies what the Annex XIV substance is required to do and under what conditions. It is from that analysis and evaluation of possible alternatives can be made. Key parts of this section consider how HBCDD is used to produce flame retarded EPS and how flame retardants are selected. Since the purpose of HBCDD in EPS is to meet fire safety standards, the system of fire safety standards in the EU/EEA is considered in the context of insulation materials in buildings. Finally, in section 2, a summary of essential criteria for substance function is presented in the context of the difficulties of identification of replacements for HBCDD.

Section 3 considers possible alternatives to HBCDD. This is done for both substance alternatives and other insulation materials that could be used in place of EPS. Key to this part of the analysis is R&D done by Plastics Europe that had the objective of identification of an alternative flame retardant substance for HBCDD for use in EPS and XPS.

Section 4 then considers the suitability and availability of possible alternatives. The assessment also draws on information from other studies that have considered possible substance and material alternatives to HBCDD and EPS, respectively. In this section the alternatives identified are evaluated against technical and economic feasibility, risk and availability. Since the output of the Plastics Europe research programme identified a possible alternative – the pFR, which is currently undergoing technical feasibility trials[5] that substance is central to the analysis and is taken up in the final section.

Finally, in Section 5 the overall conclusions on suitability and availability of possible alternatives for use 1 and use 2 are drawn, in particular a time based indication of the steps needed in order to make the suitable alterative (i.e. the pFR) available is presented.

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[5] It is known that one manufacturer of the pFR has a commercially available product; however other producers' products are in earlier stages of product development.

2 ANALYSIS OF SUBSTANCE FUNCTION

2.1 Assessing the function of Hexabromocyclododecane in Expanded Polystyrene

In this section the function of the substance is assessed. In order to fully understand function, the application of the substance hexabromocyclododecane (HBCDD) as a flame retardant in expanded polystyrene (EPS), the flame retarding action, the manufacturing process of EPS with HBCDD and the rules and regulations that determine fire safety requirements are described.

The function of HBCDD is an additive flame retardant for EPS. The function of HBCDD in EPS is to impart flame retarding/flame proofing qualities to the polymer matrix[6], but does not become part of the polymer itself. HBCDD slows down, controls or stops the combustion of EPS should it be in contact with flame or extreme heat, such as in a building fire.

It is necessary to use flame retarded EPS for a number of applications for building/construction due to fire safety requirements. This being the case, the function for both uses is identical and thus a common analysis of alternatives is presented here. For USE 1, the formulation of EPS pellets, the function of HBCDD is as a flame retardant in the plastic; for USE 2, the manufacture of EPS articles, it is the same, a flame retardant in the plastic, since the manufacturers of EPS articles (converters) are making blown beads from the pellets and then boards (articles) from the blown (expanded) beads.

Uses of EPS can be broadly categorised into two main groups: building applications and packaging, with most (>85%) flame-retarded (FR) EPS (i.e. containing HBCDD) being used for building applications. A list of building applications is below.

- Flat roof insulation
- Pitched roof insulation
- Floor insulation ‘slab-on-ground’ insulation
- Insulated concrete floor systems
- Interior wall insulation with gypsum board (‘doublage’)
- Exterior wall insulation or ETICS (External Insulated Composite Systems)
- Cavity wall insulation boards
- Cavity wall insulation loose fill
- Civil engineering applications
- Insulated concrete forms (ICF)
- Foundation systems and other void forming systems
- Load bearing foundation applications
- Core material for EPS used in sandwich and stressed skin panels (metal and wood fibreboard)
- Floor heating systems
- Sound insulation in floating floors (to avoid transmission of contact sound)
- Seismic applications
- EPS drainage boards

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[6] Contrast with ‘reactive’ flame retardants that become part of the polymer to which they are added, for example the substance tetrabromobisphenol-A (TBBPA) as used to flame retard electronic circuit boards.

A flame retardant may inhibit ignition, prevent combustion by altering the nature of the polymer in the vicinity of the flame, or extinguish the flame. Vapour-phase flame retardants act by interfering with free radical mechanisms, or simply reducing the availability of flammable gases and oxygen; condensed-phase flame retardants are active in the molten polymer in the vicinity of the flame, interfering with the thermal degradation processes. Intumescent systems, often used in flame retarded coatings, puff up in the presence of flame and produce charrable foams, which have low thermal conductivity (reported in Fisk *et al*., 2003).

Five specific modes of action were identified by Fisk *et al*., (2003):

- gas dilution – use of additives which decompose into non-flammable gases, thus reducing both fuel and oxygen levels in the vicinity of the flame (metal hydroxides, metal salts, and some nitrogen compounds);
- thermal quenching – flame retardants which undergo endothermic decomposition, reducing the rate of burning (metal hydroxides, metal salts, and some nitrogen compounds);
- protective coating – additives which promote charring or formation of a liquid barrier, thus shielding the flammable material from the flame (phosphorus compounds, intumescent systems based on nitrogen or phosphorus compounds);
- physical dilution of the flammable material – introduction of an inert non-flammable component (e.g. glass or minerals);
- chemical interaction – a flame retardant that decomposes into radical species, which compete effectively with the burning process (halogenated compounds).

The mechanisms by which flame retardants act are complex and can be quite specific to the nature of the material they are protecting. However, one mechanism accounting for the effectiveness of brominated flame retardants (of which HBCDD is one) is their ability to release active bromine atoms (called free radicals) into the gas phase as the material is decomposed in the fire. These bromine atoms effectively quench the chemical reactions occurring in the flame, reducing the heat generated and slowing or even preventing the burning process (from European Brominated Flame Retardant Industry Panel[7]).

The effectiveness of this category of flame retardants may be connected with the bromine Br· radical, which competes effectively with hydroxyl radical HO· and the oxygen atom ·O· for the substrate in the vapour phase, and extinguishes the flame. An alternative theory is that bromine affects the physical properties of the polymer, including its heat capacity (Fisk *et al*., 2003).

The authorisation application is specific to the use of EPS in building applications in which EPS is mainly (but not exclusively) used for its thermal insulating properties. The function of the Annex XIV substance is therefore to impart properties that slow the combustion of EPS as a safety feature/requirement for the use of EPS in buildings. HBCDD does not impart any thermal insulating properties to EPS, but allows EPS to be used for insulation where flame retarding is a requirement.

The focus of this analysis of substance function is therefore on imparting flame-retarding properties to EPS and not on thermal or other insulation properties of the EPS itself[8].

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[7] http://www.ebfrip.org

[8] It is acknowledged, however, that an analysis of alternatives could be considered incomplete if possible technical alternatives that provide the same or similar insulating properties to building applications as EPS, are not considered.

2.1.1 Production of EPS pellets (beads)

Described here is the **single-step** process for manufacture of flame retarded expanded polystyrene (FR EPS), which is the process universally employed in the EU. A 'two-step' process is used elsewhere (e.g. North America), see 2.1.3 below. There are two single-step processes, the *suspension process* and the *mass process*. The suspension process is described first in 2.1.1.1, with key differences in the mass process described in 2.1.1.2.

2.1.1.1 The suspension process

EPS is manufactured by mixing the Annex XIV substance hexabromocyclododecane, with styrene at low temperatures before charging into a closed reactor and polymerising at reaction temperature (approximately 90-120°C). Alternatively, HBCDD is not pre-mixed with styrene, but added to the reactor in the form of dry powder. The HBCDD is trapped within the polymer matrix during polymerisation. An expansion agent, pentane, is added to the reactor during polymerisation (at a temperature of approximately 130°C) and is absorbed by the polymer droplets ('beads' / 'pellets'); this provides the expansion for the pellets later in the conversion process. The HBCDD is incorporated as an integral and encapsulated component within the polymer matrix with uniform concentration throughout the bead (ECHA 2009).

A number of substances are added into a reactor in a polymerisation process in order to make expanded polystyrene (EPS) pellets, namely:

- Water
- Styrene (monomer)
- Suspension aid[9]
- Polymerisation Initiator (organic peroxides)
- Waxes
- Plasticisers[10]
- Pentane (blowing/expansion agent)
- HBCDD (as a flame retardant)
- Peroxide (synergist[11])
- Infrared absorber: carbon black, graphite (optionally used in grey EPS only). This can be added to the reactor or added during a second stage
- Colourants (optional)

After the initial polymerization is completed, the reactor is cooled down and the EPS pellets are fed to a centrifugal system (via a slurry tank/silo) in order to separate and remove water from the EPS

Nevertheless, it is important to note that the function of HBCDD (the Annex XIV substance) is only related to imparting flame resistance to EPS and therefore the analysis of the function of HBCDD is as flame retardant.

[9] Suspension aids are a dispersant added to help facilitate the dispersion and prevent the coagulation of the polymer particles swollen by the monomer in the later stage of polymerisation

[10] Plasticisers or dispersants are additives that increase the plasticity or fluidity of the pellet

[11] Synergists reduce the amount of HBCDD required while maintaining the same level of flame retardancy.

beads. Approximately 98% of water is removed at this stage which is sent to a settlement tank (see also below on the ‘mass process’).

The EPS pellets are dried (by air blowing) to remove the remaining water (ca. 2%). The EPS pellets are then sent to a silo for sieving. The EPS pellets are then filtered, coated and packed into large cardboard containers (with a plastic liner) ready for transportation to EPS converters (manufacturers of EPS articles). The concentration of HBCDD in terms of weight in EPS pellets is typically 0.7%.

2.1.1.2 The mass process

In the ‘mass process’, HBCDD is directly added to the melted polystyrene. Styrene is pumped together with a catalyst into a reactor vessel where it is polymerized (to over 90%). The ‘gel’ is subsequently de-volatilized and the pure polymer is pumped via a high pressure gear pump to downstream equipment at pressure (c.150 bar) and at elevated temperature (220^{o}C). A solid additive system meters and transfers to the side extruder the required components at the specified concentrations. Four components are added at this point, namely HBCDD, carbon black, nucleator and acid scavenger. At the exit of the extruder a gear pump forwards the melt to downstream closed equipment, at a pressure of 150 bars. A liquid metering dosing system is used to meter blowing agent (pentane) and injects it into the melt before it enters the dynamic polymer mixer. The gel, which is mixed with additives and blowing agent, is then cooled down to 170^{o}C using a static cooling exchanger. From this exchanger the gel is filtered through a gel filter and then through a diverter valve, from which it enters into a water-pressurized pelletizing system. The process water is circulated in a closed-loop system. After the dewatering system of the pelletizer, the dried pellets are transported into an EPS finishing system. The EPS finishing system consists of a sieve, surface treatment system, inventory silo and packaging line.

2.1.2 Manufacture of EPS by the two-step process

In the two-step production of EPS, styrene is dispersed in water in a reactor and polymerized (80-90°C) in the presence of initiators and suspending agents. The reaction is taken essentially to completion by raising the temperature of the reactants to finish off the polymerization. After the reactor and contents are cooled, the pellets are de-watered and dried (the waste-water is sent to a waste-water treatment facility). The dried pellets are screened into different fractions and sent to storage. Each separate polystyrene pellet fraction produced in the first step is in turn recharged to a reactor, re-suspended in water and blowing agent is added. The reactor and contents are heated to 120-130°C and held at elevated temperatures for a predetermined time, while the blowing agent is impregnated into the polystyrene beads. The reactor and contents are cooled and the final EPS product is de-watered and dried a second time. The dried pellets are screened into different sizes and the final EPS products are packed into containers for shipment to moulders[12].

It should be noted that a main difference between the single and two-step processes is that in the two-step process the blowing agent (e.g. pentane) and fire retardant (e.g. HBCDD) are added in a second step after the initial polymerization. This adds specific requirements to the fire retardant to be able to penetrate the ready-made bead. It is known that HBCDD does not penetrate polystyrene easily and is thus typically not used in the two- step process (Stockholm Convention report: Report of the Persistent Organic Pollutants Review Committee on the work of its seventh meeting page 15).

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[12] See http://www.arkema-inc.com/functional-additives/organic-peroxides/eps accessed September 2013

Comparing the one and two-step processes shows that energy and water use of the two-step process is significantly higher. This is due to the two process steps in which the pellets are put into slurry. After each step there is a drying phase and this is in contrast to the one-step process where there is only one drying phase. In addition, it is noted that only the one-step process is described in the BREF document for Polymers (EC 2007, Reference Document on Best Available Techniques in the Production of Polymers August 2007), therefore the two-step process is not one that is recognized as a relevant process in the EU.

2.1.3 Production of 'blown' (expanded) EPS beads and boards

The EPS pellets are converted to expanded beads using steam. The expanded beads can then be moulded into boards and shapes (e.g. insulation boards, specific shapes for packaging).

The five main manufacturing stages are set out below[13]:

1. Pre-expansion: The FR EPS *pellets* are expanded with the help of steam in an atmospheric or pressurised stirred vessel to form larger *beads*, each consisting of a series of non-interconnecting cells.

2. Conditioning (curing, maturing): The beads still contain small quantities of both condensed steam and pentane gas. The beads are stored in aerated silos to cool and as they cool, air gradually diffuses into the pores, lowering the pentane (blowing agent) to the optimised ratio prior to moulding.

3. Moulding: The beads are moulded to form boards, blocks or customised products, where steam and perforated aluminium moulds are used to shape/fuse each bead to its neighbours, thus forming a homogeneous product.

4. Shaping (Block cutting): The moulded FR EPS is then stored to cool down, decreasing water content and reaching dimension stability equilibrium. The moulded block is removed from the machine, and blocks are cut in boards or in specific shapes with hot wires. It is also possible to use other special techniques such as drilling or blade cutting.

5. Post-production processing: The finished product can be laminated with foils, plastics, roofing felt, fibre-board or other facings such as roof or wall cladding material (so called 'sandwich panels').

2.2 Considerations for selecting flame retardants for EPS

It is understood that certain molecules may be suitable for the two-step process that are not suitable for the one-step process (and vice versa). The reason for this is that it is necessary that the flame retardant should not interfere with the polymerisation process taking place in the reactor. In the two-step process the flame retardant is added AFTER polymerization. This gives potentially wider possibilities of possible alternatives in the two-step process because there is less potential for the flame retardant molecule to interfere with polymerization of the styrene to polystyrene.

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[13] Based on detailed provided by EUMEPS and Monotez website:
http://www.eumeps.org/manufacturing_4106.html?psid=48b0867885827f241ef221fd4693fc2d &
http://www.monotez.com/displayITM1.asp?ITMID=79

For the reasons stated in section 2.1.3, the two-step process is not used in Europe and therefore possible options for flame retardants are only those that are relevant for the single step process and it is only those that are considered here.

It should be noted that there are differences between the single step process in different reactors, let alone between single-step and two-step processes. Any technical changes, not least the introduction of a new additive such as a flame retardant, require individual tuning. The suspension process is sensitive and the demands of the single step are most critical. Technical feasibility of any possible alternatives relates to stable suspension, bead size distribution, mean bead size, loading requirements and molecular weight.

In this section, the function is explored further by explaining the considerations that need to be made when selecting a flame retardant. This gives background and understanding on why HBCDD is selected for EPS and what considerations need to be made to select an alternative to HBCDD that can be used in EPS.

There are a number of stages that can be used to simply describe the polymer flammability process:

These stages are:

a) preheating,
b) decomposition to give volatile compounds and residuals,
c) ignition of the volatiles in the presence of oxygen, and
d) combustion.

The process of combustion is a sustained exothermic cyclic process. This means that the heat-energy created by the burning releases more fuel, which in turn is burnt, thereby creating more heat and so on. This cycle continues until there is a mechanism to decrease the flammability, in this case of the polymer, involving interruption of the cyclic process at some stage.

2.2.1 The flammability process

There are a number of basic mechanistic concepts and related chemistry that are important for the understanding of flammability reduction. The selection of a flame retardant is based on a substance's flame retarding properties, but at the same time, there is the need to consider other aspects in the development of flame retardants including:

- the ease with which the substance fits with the process, and
- its effect on other properties of the material it is added to ('base material').

An ideal flame retardant polymer system should have (Pearce, 1986[14]):

- high resistance to ignition and flame propagation,
- a low rate of combustion,
- a low rate and amount of smoke generation,
- low combustibility and toxicity of combustion gases,
- no change in flammability during use,
- performance of the base material should be close to the original, and
- no difference in appearance.

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[14] Flame retardants for polymer systems Eli M. Pearce. Pure & Appl. Chem., Vol. 58, No. 6, pp. 925—930, 1986

There are also cost considerations that determine the economic viability of possible alternatives and the acceptability of the cost of reformulation.

Most flame retardant systems have incorporated chlorine or bromine, phosphorus, antimony and boron related compounds, combinations synergistic effects[15] (i.e. enhanced functionality by using materials in combination). Practically all commercial plastics are "compounded" with various additives to improve their processing and in use performance. Other than plasticizers, flame retardant is probably the largest volume additive to be used in polymeric materials.

2.2.2 Features of an ideal flame retardant

For the selection of flame retardants, it is important to consider how the flame retardant is placed into the polymer structure or final product, as well as how the modification affects a number of properties and processing parameters.

Considering the possible approaches to the desired modification for an additive for a plastic material such as EPS; in this case it is possible to incorporate the substance as an additive into the mixture that then goes to form EPS pellets and is ultimately expanded and formed into boards. Depending on the application of the flame retardant considerations include:

- durability and aesthetics,
- the development of new technology and processing efficiency, and
- control of releases during formulation.

2.2.3 Impacts on other properties

There is also the need to consider the properties that are changed in the polymer system. For example, incorporation of a comonomer[16] into a polymer system relies to a large extent on the structure i.e. ‘crystallinity’ of that polymer; its properties could have a negative effect because the crystallinity would decrease as a function of increasing comonomer concentration. For additive substances (such as with HBCDD), a consideration of how the substance will behave generally is needed, e.g. as a filler or as a plasticizer. If the flame retardant in the polymer system behaves as a plasticizer, it would be expected that reductions in melt viscosity, perhaps crystallinity and decreased tensile strength and elastic modulus[17] with some increase in elongation, could occur.

If the material that is used behaves as a filler, there needs to be consideration on how to obtain good bonding between the filler surface and the polymer, so that mechanical properties can be maximized. For example, these properties will usually show increased modulus and perhaps an increase in tenacity, but usually a decrease in elongation and impact strength. Melt viscosity will usually increase.

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[15] There are a number of compounds that act synergistically, including phosphorus and halogen compounds, antimony, (antimony compounds are not flame retardant in their own right. instead, they act as synergists with organohalogens) and other metal compounds, particularly zinc and zinc/tin compounds.

[16] A comonomer is one of the monomers that constitute a copolymer; a copolymer is a polymer derived from two (or more) monomeric species.

[17] An elastic modulus, is the mathematical description of an object or substance's tendency to be deformed elastically (i.e., non-permanently) when a force is applied to it. The elastic modulus of an object is defined as the slope of its stress–strain curve in the elastic deformation region. As such, a stiffer material will have a higher elastic modulus. http://en.wikipedia.org/wiki/Elastic_modulus

These effects on properties are considerations in designing flame retardants for specific polymer system, such as EPS. Specific effects on polymer properties, other than the flame retarding itself, are critical, such as with the thermal and other insulating properties of EPS. This is of course in addition to the important safety, health and environmental performance of the material, that is to say that EPS must achieve its function as a highly efficient insulating material whist complying with stringent rules on fire safety.

There are two general approaches that need to be considered:

- If safety and health problems diminish if a polymer additive is reacted into the polymer system
- If the polymer additive is of sufficiently high molecular weight that it does not volatize and/or readily diffuse out of the polymer system.

In both of these cases, this will decrease safety and health problems. Current approaches to design of acceptable flame retardants are based on either polymeric additives, additives of relatively high molecular weight, or additives that are reacted into the polymer system itself and also additives that inherently do not appear to be of any potential safety, health or environmental problems.

2.2.4 Thermal stability

Thermogravimetric analysis[18] data are useful for the selection of the appropriate flame retardant for a particular polymer system. This information is useful in two ways:

1) Developing a process in which the flame retardant is used; knowing its degradation profile determines whether it will be stable at the temperature of any of the processing steps. If the substance is not stable in the processing steps, then it would not be an appropriate flame retardant for that system.
2) Generally, flame retardants decrease the thermal stability of a system. It is important that the flame retardant degrades (just) before the polymer that is being flame retarded. The efficiency of matching of the degradation curves is key to effective flame retardancy. If the flame retardant additive possesses too low a thermal stability compared to that of the polymer, it will be lost before its function is needed. If the additive has greater stability, it may remain intact at the time its function is needed.

It is important to consider flammability structure relationships and in utilizing flame retardants, there are some general relationships. Many polymers can be degraded at relatively low

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[18] Thermogravimetric analysis or thermal gravimetric analysis (TGA) is a method of thermal analysis in which changes in physical and chemical properties of materials are measured as a function of increasing temperature (with constant heating rate), or as a function of time (with constant temperature and/or constant mass loss).TGA can provide information about physical phenomena, such as second-order phase transitions, including vaporization, sublimation, absorption, adsorption, and desorption. Likewise, TGA can provide information about chemical phenomena including chemisorptions, desolvation (especially dehydration), decomposition, and solid-gas reactions (e.g., oxidation or reduction).

TGA is commonly used to determine selected characteristics of materials that exhibit either mass loss or gain due to decomposition, oxidation, or loss of volatiles (such as moisture). Common applications of TGA are (1) materials characterization through analysis of characteristic decomposition patterns, (2) studies of degradation mechanisms and reaction kinetics, (3) determination of organic content in a sample, and (4) determination of inorganic (e.g. ash) content in a sample, which may be useful for corroborating predicted material structures or simply used as a chemical analysis. It is an especially useful technique for the study of polymeric materials, including thermoplastics, thermosets, elastomers, composites, plastic films, fibers, coatings and paints. http://en.wikipedia.org/wiki/Thermogravimetric_analysis temperatures, for example, at less than 200°C, to give monomer, dimer, or other low molecular weight combustible volatiles and will have low oxygen index values[19]. Thus, polymers like polyethylene, polypropylene, polyformaldehyde, polystyrene, and polymethylmethacrylate have oxygen indices of less than 21. Polymers having aromaticity in the polymer ‘backbone’ usually have improved oxygen indices. For example, the aramid, Nomex[20], has an oxygen index of 32 while nylon 66 has an oxygen index (OI) of 23. The presence of certain flame retarding elements such as halogen or phosphorus will also increase the oxygen index. Polymers which contain little or no hydrogen or contain very strong bonds or degrade to a monomer that is relatively non—flammable also have a high oxygen index, for example polytetrafluoroethylene (OI = 95)

2.2.5 Fire safety flammability standards for EPS

International building fire safety regulations relevant for the use of EPS (and extruded polystyrene (XPS)) insulation materials have been reviewed by Blomqvist *et al.* (2010); the same study is also reported extensively in a review of possible alternative materials to flame retarded EPS by the Norwegian Climate and Pollution Agency (Klif, 2011). The use of flame retarded EPS is compulsory in the majority of the EU and EFTA Member States[21] (see also Figure 2.1 below) for meeting the respective national fire safety levels (Troitzsch, 2008).

The EU regulations set out a method for testing EPS (and XPS) products in building applications. However, the specific performance requirements differ significantly in different EU Member States. In some Member States such as Sweden and Norway, only the performance of the final product (or so called building element) is tested, and the use of EPS as insulation material does not result in a formal requirement that the EPS used is flame retarded if the total building element meets the requirements. In other Member States such as Germany and Poland[22], specific material performance is required; in these states EPS used for building insulation must be flame retarded in order to meet the required fire class.

In addition to the fire safety regulations, there may also be requirements from insurance companies which stipulate the use of flame retarded grades of material. For example, in the UK the requirements from insurance companies have resulted in the majority of EPS being used in building being flame retarded.

Figure 2.1a and b below indicate the broad differences in flame retardant requirements for building insulation materials for wall and external wall applications across Europe (this is based on the EU15 and updated with information from the applicant member companies for this study).

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[19] Limiting Oxygen Index: Materials with an LOI below 21 burn readily whilst those with a value above this do not burn readily. In addition to the amount of oxygen required by the different fuels to support combustion, the temperature at which different fuels ignite also varies. From: http://www.textilesfr.co.uk/FibresFlammability.html

[20] Registered trademark for flame-resistant meta-aramid material developed in the early 1960s by DuPont

[21] European Free Trade Association – An intergovernmental organisation set up for the promotion of free trade and economic integration to the benefit of its four Member States: Iceland, Liechtenstein, Norway and Switzerland.

[22] Nordic countries typically have no FR requirements for the insulation material, as such, but the FR requirement concerns the whole (building) structure.

Figure 2.1 a: EU fire standards for building insulation material for walls

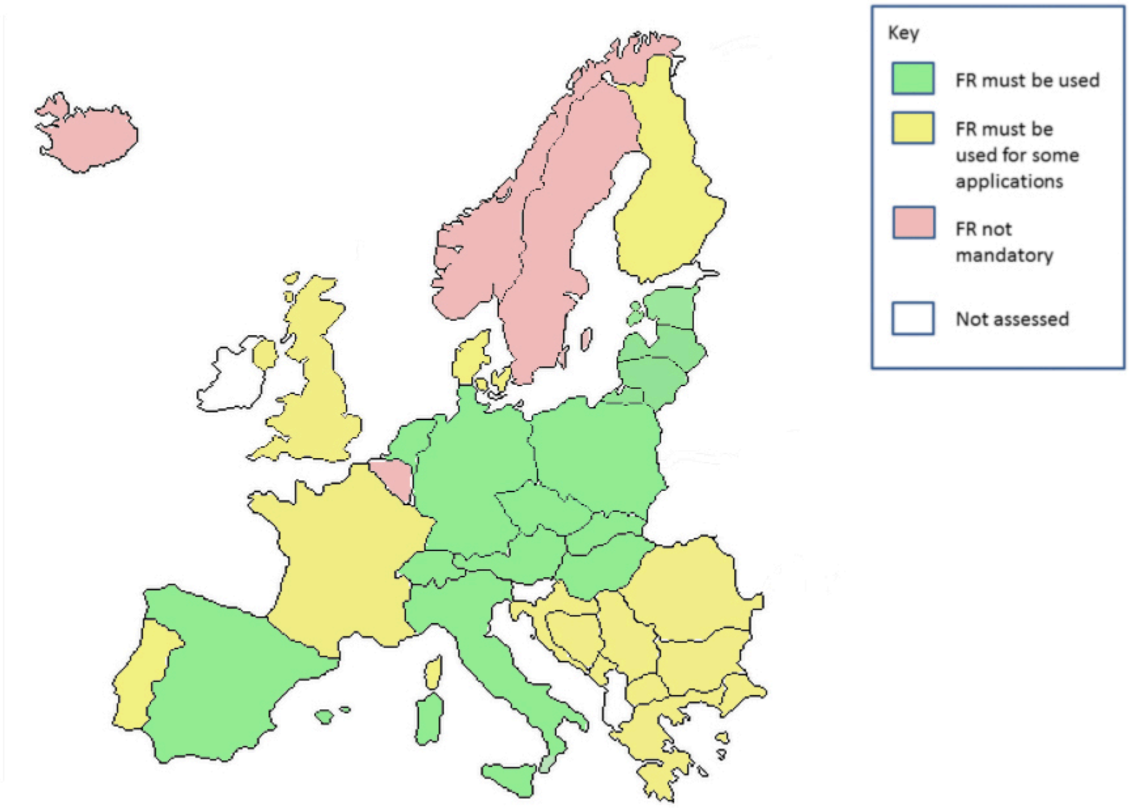
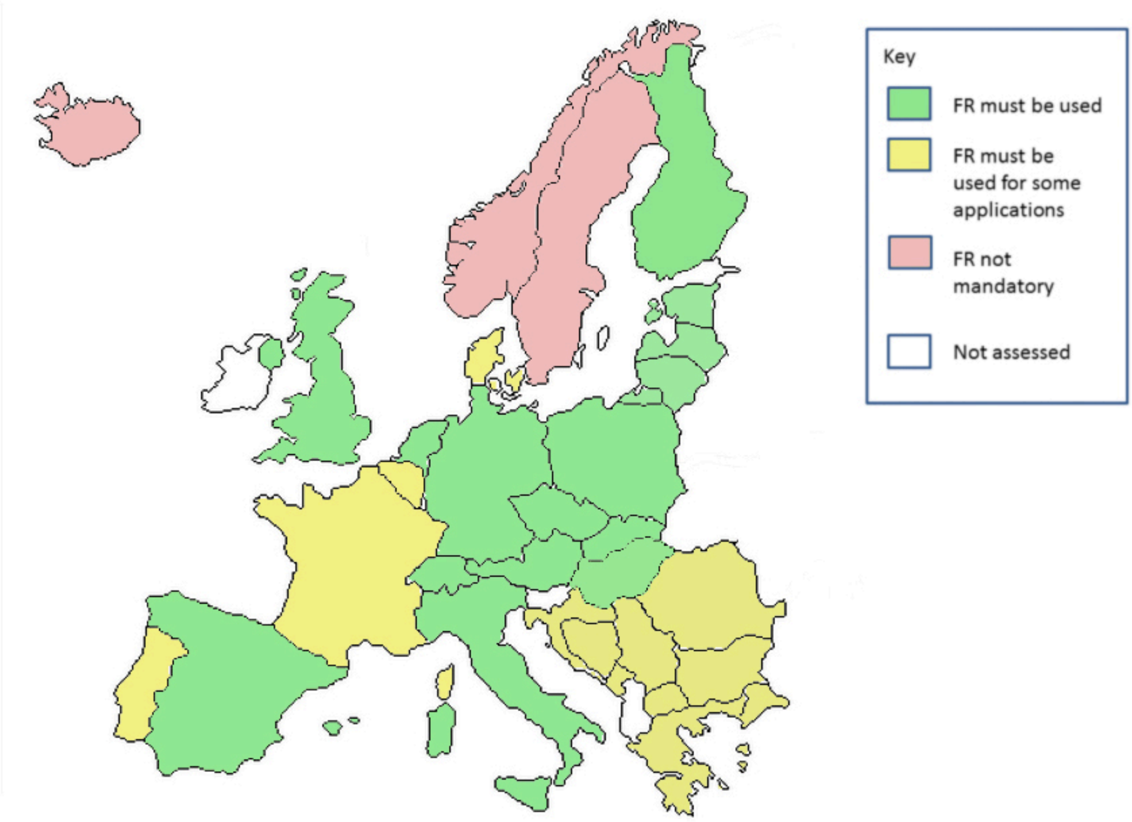


Figure 2.1 b: EU fire standards for building insulation material for External Wall (ETICS)



The information in Figures 2.1 a and b has been adapted and updated from Exiba *et al.*, 2006 and from Troitzsch (2008[23]) and also updated with direct information from EPS formulating companies on the basis of understanding of the requirements for FR EPS for specific uses in the Baltic and south east European states. This also covers some of the EU candidate and potential candidate states (such as Kosovo, Macedonia (FYROM), Bosnia Herzegovina, Serbia and Montenegro), which were missing from Exiba (2006) and Troitzsch (2008).

Building fire regulations relate both to "*Fire Resistance*" and "*Reaction-to-Fire*". Fire Resistance relates to the integrity of a building element/construction product under the influence of a fire. Fire Resistance testing assesses integrity, insulation and stability of the construction under well-defined conditions. Regulations on fire resistance are placed on construction products and building elements with a fire separating function. These types of construction products do not normally contain EPS as polystyrene would not contribute positively to the integrity or the insulation properties of the construction during a fully developed fire and is not considered relevant here.

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[23] Troitzsch (2008): "The relevance of hexabromocyclododecane for polystyrene EPS/XPS foams to meet fire safety requirements for construction products in Europe" A report for the European HBCDD Industry Working Group – formed by the European Chemical Industry Association CEFIC and the Association of Plastics Manufacturers PlasticsEurope.

The *Reaction-to-Fire* of a product deals with characteristics such as ignition, flame spread, heat release rate, smoke and gas production and the occurrence of burning droplets and parts. This is relevant to EPS in building applications.

2.2.5.1 European Fire Regulations

The Construction Products Directive (89/106/EEC), 'CPD,' is intended to promote the free trade of building products within the European Union (and some EEA states, e.g. Norway). The Directive contains six essential requirements that apply to the building itself:

- Mechanical resistance and stability.
- Safety in the case of fire.
- Hygiene, health and the environment.
- Safety in use.
- Protection against noise.
- Energy economy and heat retention.

The European fire classification and fire standardization for building products are based on the essential requirement of "safety in the case of fire." In order to determine whether a building product complies with the CPD, European classification standards are devised and referred to in Product Standards. Classification documents as developed by CEN (Comité Européen de Normalisation - the European Committee for Standardisation).

The implication of the CPD is that building products must have a fire classification based on the same standards throughout Europe. The actual application of the classification standard in each member country may be different however, because, although the European Classification Standards identify product performance, they do not stipulate what the performance should be for any given application. The level of safety that a product must have in a building application is up to the specific Member State to apply in its own building regulations. A Member State that regulates for a certain safety level will be able to identify the fire properties of a building/construction product corresponding to that level according to the European Classification Standards. Products complying with the essential requirements of the Directive are labeled with the European 'CE' mark.

The CPD has been in existence since 1989 as a Directive that is non-mandatory, this has now been replaced by Construction Products Regulation (EU) No 305/2011 (CPR), which is essentially mandatory in all EU member states and repeals the CPD.

The CPR has already entered into force and the main parts of its substantial Articles should be in place from 1 July 2013. Until then, the CPD remained in application. The already applicable parts of the CPR focus on the notification and designation processes of the Notified Bodies (NB) and the Technical Assessment Bodies (TAB).

2.2.5.2 The Euroclass System

The European Commission published the Euroclasses in the year 2000 as a basis for classification of building products. The standard for Reaction-to-Fire classification of buildings products is EN 13501-1[24]. Specific adaptations of the Euroclass system for different products have been developed

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[24] EN 13501-1:2007, Fire classification of construction products and building elements – Part 1: Classification using data from reaction to fire tests.

and are given in the relevant product standards. The specifics can deal with the methodology for testing and determination of the Euroclass for any given product, not the definition of the Euroclass itself.

Seven main classes have been included in EN 13501-1: A1, A2, B, C, D, E and F. Additional classes apply to smoke development and the occurrence of burning droplets.

In many cases the test methods used are developed within ISO, the International Standardisation Organisation and later adopted within CEN. These standards are well known and some of them have been in use in various countries throughout the world for many years. ISO/TC92/SC1 has, in liaison with the CEN, actively been involved in the development of European standards. These standards are called EN ISO to indicate that they are both global and specifically European.

The test requirements for the classes included in EN 13501-1 have been designed based on the large-scale reaction-to-fire performance of products from a number of product groups.

Class B in EN 13501-1 represents materials that do not give flashover in the reference room test, whereas Class C - Class E give flashover after a certain time in the reference room test. Classes A1 and A2 are the highest classes and are not explicitly correlated to the reference room, but represent different degrees of limited combustibility of a product. Class F signifies that Reaction-to-Fire performance has not been determined.

2.2.6 Product Standards relevant for EPS (and XPS)

2.2.6.1 European product standard for sandwich panels EN 14509

A specific European product standard exists for sandwich panels namely EN 14509 for Self-supporting double skin metal faced insulating panels - Factory made products – Specifications. It was published in December 2008. Since January 2009, sandwich panel manufacturers can choose to CE - mark their products accordingly. From October 2010, CE marking has been compulsory for all sandwich panels sold in the EU[25].

The Reaction-to-Fire classification derived from the provisions in this standard provides regulators and other users with an essential parameter concerning fire performance of sandwich panels. Exclusively based on fire safety needs and with explicit justification, regulators may, for specific intended uses, set additional requirements to ensure that the fire safety of the construction is indeed in accordance with EN 13501-1. Other classifications, such as fire resistance, may also be required to achieve the intended fire safety objectives. In exceptional cases, other instruments such as fire safety engineering may be used to assess the fire safety of the building.

For sandwich panels there are additional instructions regarding both reaction-to-fire and fire resistance tests in Annex C of EN 14509. The testing procedure of the tests required in EN 13501-1 is described in more detail in that annex. Note that the specific class required for the use of a sandwich panel in Europe is determined by the relevant regulator in each specific EU Member State.

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[25] This is in line with the CPR regulation, which became fully active in July 2013. EN14509 required earlier CE marking.

2.2.6.2 European product standard for EPS

The European Standard EN 13163 specifies the requirements for EPS products, with or without facings or coatings, which are used for the thermal insulation of buildings. The Standard specifies product characteristics and includes procedures for testing, evaluation of conformity, marking and labeling. In the case of Reaction-to-Fire performance of the products EN13163 refers to EN 13501-1 with information on required testing frequencies but with no additional testing instructions.

2.2.6.3 Euroclass testing of EPS (and XPS)

Products including EPS/XPS cannot pass the requirements of the classes A1 and A2 in EN 13501-1, even with flame retardant treatment. The inherent energy in the polymer excludes passing the criteria of non-combustibility in EN ISO 1182 and/or the criteria concerning heat of combustion in EN ISO 1716.

Therefore, the two test methods in EN 13501-1 that are relevant for EPS/XPS products are EN 13823 (SBI) and ISO EN 11925-1.

The application of the Euroclass tests for the main type of EPS/XPS product categories are summarized in Table 2.1 below (reproduced from Blomqvist *et al.*, 2010). The expected ranges of classification results for non-flame retarded (non-FR) and flame retarded (FR) EPS/XPS, respectively, are indicated in Table 2.1.

The interpretation of the indicative classification results in Table 2.1 is that Class B and C can only be obtained for EPS/XPS that has been treated with flame retardants in some way. In building elements or sandwich panels where the EPS/XPS is not exposed during the fire test, high fire performance can be obtained (corresponding to Class B and C) if the EPS/XPS insulation is sufficiently well protected from the fire. This may be the case irrespective of whether the EPS/XPS has been flame retarded.

Table 2.1: Euroclass test requirements for EPS/XPS products and estimates of classification results.

Product	Application of Euroclass tests	Non-FR product Estimate of Euroclass	FR product Estimate of Euroclass
EPS/XPS (EN13163, EN 13164)	En 13823 EN ISO 11925-2 *Resulting classification:*	< D < E *Euroclass F*	(B*)-D B-E *Euroclass (B*)-E*
Building elements including EPS/XPS	Surface: EN 13823, EN ISO 11925-2 Cut edge: EN ISO 11925-2 Covered edge: EN ISO 11925-2 *Resulting classification*	B - D B - E < E B - E *Euroclass B - F*	B - D B - E B - E B - E *Euroclass B – F*
Sandwich panels, EPS/XPS core (EN 14509)	Surface: EN 13823, EN ISO 11925-2 Cut edge: EN ISO 11925-2 Covered edge: EN ISO 11925-2 *Resulting classification*	B - D B - E < E B - E *Euroclass B - F*	B - D B - E B - E B - E *Euroclass B – E*

As sandwich panel products are often used as self-supporting building elements or mounted on a supporting frame, it is also relevant to test sandwich panel products using EN 13823 (SBI) and to link to the reference room test. This has led to the development of special large-scale tests for sandwich panels. These tests are not part of the European system but can have a role as demonstration tests in performance based fire safety engineering.

2.2.6.4 Compliance with the Construction Products Directive/Regulation and the Euroclass system

Compliance with the CPD requires that where a product standard exists, products are tested and ‘CE’ marked to allow access to the European market. This does not however, define what level of performance any given product must have to be approved for use in any specific country. In other words, the CE mark is a prerequisite for access to the European market for EPS/XPS in building applications, but the fire performance cited in the CE mark may be as low as F (no testing required). Thus, non-flame retardant products can potentially be CE marked and sold within the EU.

The specific classification requirements in each Member State determine what performance is needed in order for the product to be marketed in each Member State.

It appears that European Member States are progressing towards harmonized classification systems and testing standards, e.g. the EN 13501-1 standard for reaction-to-fire classification of surface linings in buildings. There are differences however, in applications and requirements between Member States. There can be additional requirements concerning fire performance for specific areas of applications such as insulation materials and sandwich panels in some countries. Table 2.2 (reproduced from Blomqvist *et al*., 2010) shows a summary of those applications where EPS/XPS products are affected and if there are specific regulations in the individual European countries. The table also contains information concerning whether the majority of EPS (and XPS) used in each country in building applications is flame retarded (FR) or not.

Table 2.2: Summary of the requirement areas for fire performance in European countries and information on the practice of using of FR EPS/XPS in each country available (reproduced from Blomqvist *et al*., 2010).

Country	**General requirements for materials**	**Specific requirements for insulation materials**	**Specific requirements for sandwich panels**	**Specific requirements for façades**	**Usage of FR-treated ESP/XPS**
Sweden	No	No	No	No	No
Denmark	Yes	Yes	*n.i.*	*n.i.*	No
Finland	No	Yes	No	No	*Likely*
Norway	No	No	Yes	No	*Not likely*
Iceland	Yes	*n.i.*	*n.i.*	No	*Likely*
Germany	Yes	Yes	Yes	*n.i.*	Yes
Poland	No	Yes	Yes	Yes	Yes
France	No	Yes	*n.i.*	Yes	*Likely*
Belgium	No	*n.i.*	*n.i.*	*n.i.*	Yes
Italy	No	Yes	*n.i.*	*n.i.*	Yes
Spain	No	*n.i.*		*n.i.*	Yes
UK	No	Yes	*n.i.*	*n.i.*	Yes

Table note: *n.i.* = No specific information available. A “Yes” or “No” in the Table signifies that information was confirmed, this may be based on formal (mandatory) or informal (voluntary) requirements. In cases when information was not been available an assessment based on test requirements was been made and is indicated in italics.

The European fire classification system for construction products and material does not set requirements on individual materials in building products such as EPS, but rather on the fire performance of the complete product in its intended mode of use. There are, however, a few European Member States that have national requirements that specify the fire performance on an individual material level in a building product. These countries include Germany, and to a certain extent, Iceland. The implication for the use of EPS in such products is that flame retardant products are required.

Most EU/EAA member states have specific national regulations for the fire performance of insulation materials. The EU Member States with such regulations are: Finland, Denmark, Germany, Poland, France, Italy and UK (Blomqvist *et al*., 2010).

The requirements on insulation materials can exclude the use of non –flame retarded EPS for many applications, especially for public buildings and other buildings with a high safety class, for example tall (high rise) buildings. For most applications in the Members States with fire performance of insulation materials (Finland, Denmark, Germany, Poland, France, Italy and UK), flame retarded EPS is required. Possible exceptions exist, for example applications of insulation materials in buildings with a lower safety level, such as single family dwellings. It is unlikely however that these exceptions actually exist - i.e. a small portion of the market is potentially non-flame retarded, but the whole market in these countries uses flame retarded EPS by default[26]. Nevertheless, in Denmark the national regulations for insulation materials allow non-fire retarded EPS insulation in several applications if certain conditions are fulfilled.

There are special requirements for sandwich panels[27] in Norway, Germany, Poland and Spain. The requirements in Germany, Poland and Spain exclude the use of non-flame retarded EPS. The Norwegian requirements exclude non-flame retarded EPS for some applications.

Sweden, Poland and France have special requirements for façades. As reported by Blomqvist *et al.*, (2010), it is possible to pass the Swedish test with a wall construction containing protected non-flame retarded EPS. It is reported that the majority of EPS/XPS that is used in Sweden is non-flame retarded, which is consistent with EXIBA information that the Nordic States do not use HBCDD flame retarded foams (see Figure 2.1 section 2.2.1).

In UK, there are no formal regulations that would exclude the use of non-flame retarded EPS, however, according to the UK plastic industry (The British Plastics Federation, as reported in Blomqvist *et al*., 2010) almost the entire market share for EPS in UK is flame retarded products due to requirements of the insurance sector.

For those countries where the regulations require performance of the insulation material, it would typically not be an option to replace flame retarded EPS with non-flame retarded grades, even if the construction is changed by use of thermal barrier materials. In those countries, the alternative would need to be another insulation material with the same fire properties as flame retarded EPS or better, unless the building regulations are changed.

For those countries where the use of flame retarded EPS is not governed by material performance requirements, replacing flame retarded EPS with non-flame retarded EPS is an option if the requirements for the fire performance of the building element as a whole can be met by use of fire resistant construction.

2.3 Consideration of obstacles or difficulties identified or expected in relation to finding an alternative fulfilling or replacing the equivalent function of HBCDD.

In the preceding section the function of HBCDD (the Annex XIV substance) has been discussed with specific reference to its use as a flame retardant in EPS for building uses. As can be seen from section 2.2, there are specific technical considerations for the selection of a flame retardant and its use in specific materials that it is intended to protect from fire. It is the combination of flame retardant and material that is critical; the key elements are:

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[26] Note that this is regionally dependent; it is understood to be the case for Italy, Germany and Poland, but for example some Nordic countries may use FR EPS if absolutely necessary but other countries will use FR material to meet cost, logistics, safety and insurance requirements.

[27] Sandwich panels are a building product consisting of two metal faces positioned on either side of a core of a thermally insulating material, which are firmly bonded together so that the three components act compositely when under load (wind-loading, access loads etc.). Sandwich panel systems comprise the panels, their jointing methods and the type of support provided. From: Technical Briefing: Fire Performance Of Sandwich Panel Systems - Association of British Insurers (2003)

- The thermal stability and oxygen index of the polymer (in this case EPS).
- The thermal (stability) of the flame retardant compared to the material it is protecting (i.e. EPS).
- Compatibility with EPS – i.e. the effect on other properties of the EPS (insulating properties being of key importance).
- Control of releases of the flame retarding agent during formulation and in the service life of the EPS articles.

HBCDD is considered to be unique in its compatibility with the process for making EPS in Europe and is highly effective, which allows use at low concentrations in the final products (c. 0.7% w/w). No other flame retardant is used specifically for EPS. As a result the use of a low, but effective quantity of HBCD in EPS, the desired insulation properties of EPS are maintained whilst ensuring that the EPS foam meets relevant standards for flame retardancy.

Section 3 below sets out the research and development taken by the industry to identify a technically feasible alternative, Section 5 considered the steps needed to phase in the alternative and why that cannot be done today.

In section 2.2.1, the complex regulations that govern fire protection both at National and EU level were discussed. Within the EU and EEA, whilst there is a system of standards that allows a systematic appraisal of the fire retardant qualities of a material in particular for building products, the level of standard that must be achieved in specific Member States is determined at national level. The explanation for the diversity of national standards and the justification for the application of specific standards is beyond the scope of this analysis, however it is clear that access to the European market for EPS use in building applications is determined by the need for flame retarding of the EPS that today can only be achieved by the addition of HBCDD. This is confirmed not only by the industry but by a number of studies commissioned by independent research organisations for Member State bodies as well as ECHA and the European Commission (ECHA/IOM 2008 and Klif 2011).

The guidance in the analysis of alternative template document from ECHA requests the applicant to "*Present the list of essential criteria for fulfilling the substance function that served as the basis for the assessment of the alternatives. Justify why these criteria are the most relevant for the selection of the possible alternatives by linking the criteria to the function, tasks and conditions under which the substance is used in the specific use applied for*". The function of HBCDD as a flame retardant in EPS and the use requirements for flame retarded EPS are set out above. Table 2.3 below is a summary of the *essential criteria* with a short explanation/comment to justify why that is the case; however, the detailed arguments are set out in the preceding sections. The table also takes account of the checklist for Annex XIV Substance Function suggested in the ECHA Guidance on Authorisation Applications.

Table 2.3: Summary of essential criteria for substance function.

Essential criterion for substance function	Justification/explanation
1. Task performed by Annex XIV substance	HBCDD is currently the only additive flame retardant material available in sufficient commercial quantities to meet full market needs the only additive flame retardant substance for EPS.. It allows EPS articles to fulfill the requirements for fire protection in a number of EU Members states. The substance is effective at low concentrations and does not adversely affect the key properties of EPS (in particular thermal insulating properties). In addition, it has very low/negligible migration from the EPS matrix.
2. What critical properties and quality criteria must the substance fulfill?	
The thermal (stability) of the flame retardant compared to the material it is protecting (i.e. EPS).	The compatibility of the flame retardant with EPS is essential for function. The flame retardant must thermally decompose before the EPS (in the case of HBCDD to release active bromine atoms into the gas phase as the material is decomposed in the fire (see section 2.2))
Compatibility with EPS – i.e. the effect on other properties of the EPS	The flame retardant must be compatible with the EPS and not impact on its key properties, in particular the thermal insulation properties.
3. Function conditions Control of releases of the flame retarding agent during formulation and in the service life of the EPS articles. High effectiveness at low concentrations in the final products (c. 0.7% w/w).	Efficiency in release control in order to prevent exposure of workers and the environment. Low effective concentrations and low migration rates in EPS are essential to ensure that the flame retardant is effective but does not negatively impact on the properties of EPS whilst being effective and that the substance stays within the EPS matrix.
4.Process and performance constraints	Compatibility with the process for making EPS in the European Union/EEA and its Member States.
5. Is the function associated with another process that could be altered so that the use of the substance is limited or eliminated?	There are two processes for formulating EPS: single-step and two-step. The single step process is the most energy efficient way to make EPS and is universally employed in Europe. Compatibility with this system is essential to continue to make EPS in the most energy efficient way. It is necessary that the flame retardant should not interfere with the polymerisation process taking place in the reactor. In the two-step process the flame retardant is added AFTER polymerization. This gives potentially wider possibilities of possible alternatives in the two-step process because there is less potential for the flame retardant molecule to interfere with polymerization of the styrene to polystyrene. However, use of this process does not eliminate the need for a flame-retardant.
6. What customer requirements affect the use of the substance in this use?	For a number of EU member states flame retarding of EPS is the only way to meet either legal requirements or the requirements of the insurance sector.
7. Are there particular industry sector requirements or legal requirements for technical acceptability that must be met and that the function must deliver?	The requirement to meet a number of fire regulations in EU Member States for both EPS itself and building components

3 IDENTIFICATION OF POSSIBLE ALTERNATIVES

It is considered important at this point to make the current situation with the analysis of alternatives and the reason for this current application clear. This explains the context of the analysis of alternatives that precedes and follows. In short, an alternative substance has been developed by the some of the same manufacturers that currently supply HBCDD to the EPS formulators and extruded polystyrene (XPS) manufacturers that are the downstream users of HBCDD. The proposed alternative substance is a brominated polymer: benzene, ethenyl-, polymer with 1,3-butadiene, brominated (brominated co-polymer of styrene and butadiene) CAS 1195978-93-8 (referred to as the 'polymeric alternative' or pFR (polymeric flame retardant)). That substance however may not be available to the EPS supply chain in sufficient quantities to allow continued production of the flame retarded EPS that is required by the market, beyond the sunset date for HBCDD. The pFR is believed by the applicants to be technically and economically feasible (i.e. suitable, although work is on-going on the technical feasibility for commercial use), but it is not *available* to the applicants in sufficient quantities to maintain the supply chain. The conclusion of the analysis of alternatives, that there are no alternatives, is based on non-availability of the only known technically feasible alternative that fulfils the substance function with a satisfactory sustainability profile.

Authorisation is being sought for continued use of HBCDD for a four year 'bridging' Authorisation to enable transition to this pFR alternative. The authorisation is required because there are uncertainties/concerns that the proposed polymeric alternative may not be readily available in sufficient supply after the sunset date to meet the demands of all of the applicants for all of their EPS products that require flame retarding (i.e. for use in making EPS for building applications). During this period (2015-2019) it is expected that the use of HBCDD for EPS would decline and be totally replaced by the polymeric FR alternative. The SEA and other parts of this application for authorisation take into account the uncertainties and sensitivity around that and map out the expected decline in the use of HBCDD and the increased use of the pFR as supply becomes available. However, as a worst case in the assessment of exposure and environmental impact of continued use of HBCDD it is assumed that HBCDD will be used as the flame retardant for EPS until the end of the requested authorisation period (i.e. a total switch rather than a phased transition – the latter being the more realistic situation).

Trials have been undertaken by EPS producers that indicate that a polymeric flame retardant alternative could be *technically* feasible, subject to trials and testing on the commercial grade pFR for product acceptability and performance. It is known that the pFR costs more than HBCDD, but it is assumed that this will be economically feasible, since the applicants intend to phase-in the pFR, although no full price comparison data are available.

Further understanding and research of the market needs to be done with end product users in order to establish awareness of a new product (i.e. EPS with pFR). In addition to further tests on the polymeric alternative itself, there may be requirements from the Member States to approve the use of the alternative substance as a flame retardant in EPS (i.e. to demonstrate that the selected alternative is effective at meeting the relevant fire protection standards for EPS and for building elements, as described in Section 2 of this document).

The three main producers of HBCDD hold a licence to manufacture and market (the intellectual property is owned by the Dow Chemical Company) the polymeric flame retardant alternative, which was initially designed as a replacement for HBCDD in XPS, but can also be used as effectively as a flame retardant in EPS. It has been indicated by one of the manufacturers of the alternative that they have "expanded capacity in their interim production" and many customers have requested “large-scale samples in order to qualify the product” (Chemtura, 2012). Manufacturers appear to be committed to making the polymeric alternative, but uncertainties remain as to how many production sites will be up and running by the sunset date for HBCDD and whether these will satisfy the global demand for EPS and XPS use (however the assumptions of future availability are set out in Section 4 of this document). It is understood that XPS requires a relatively greater concentration of the polymeric alternative (as a percentage of the product) than EPS and that XPS manufacturers have contracts in place for the initial supplies that will be available.

This analysis of alternatives is led by this situation, i.e. that the EPS supply chain fully expects and intends to transfer to the polymeric alternative, but that alternative is not fully available to the supply chain to allow a controlled phase-out of HBCDD and controlled phase-in of the alternative before and for some years after the sunset date. It is the lack of technical feasibility and environmental profile (as well as the uncertainties in those profiles) that limits the use of any other short-term alternatives in the interim. Nevertheless, other ‘non-suitable’ flame retardants that are possible for EPS are considered in Section 2.4. In addition, other insulating materials for similar building uses are included. Although the latter do not fulfil the *function* of the substance as described in Section 2 of this analysis, they are included for completeness and because alternative building materials are identified as options in the non-use scenario as set out in the SEA report.

Section 2.5 sets out the selection process for the polymeric alternative in as much detail as is currently permitted by the owners of that information. In section 4, the actions needed in order to make the unavailable alternative available and the uncertainties and potential delays in that programme are set out.

3.1 List of possible alternatives

In order to understand the possible alternatives and why these alternatives are not technically feasible, it is necessary to consider the chemistry of flame retardants and the chemical types of flame retardants that can be available. It is of course also necessary to consider the compatibility of substances with the polymer that it is used in. While it is clear to the manufacturers of HBCDD and to the EPS and XPS manufacturers that only HBCDD and the proposed pFR alternative are suitable for flame retarding EPS and indeed it has been reported by ECHA (see ECHA 2008) that there are no alternatives to HBCDD for EPS, there is a need to address possible concerns from third parties that other alternatives exist.

The chemistry of flame retardant substances has been categorised in a number of different ways. In general six categories can be identified:

1. Inorganic
2. Brominated organic
3. Chlorinated organic
4. Organophosphorus (mainly phosphate esters)
5. Halogenated organophosphorus (chlorinated and brominated, mainly phosphate esters)
6. Nitrogen-based

This analysis of alternatives assesses the function of HBCDD as a flame retardant in EPS as defined in section 2.1 above (and summarized in Table 2.3), i.e. providing sufficient flame retarding qualities to EPS in order to meet the various fire standards in EU Member States and be effective at concentrations low enough not to adversely affect the key properties (in particular insulating properties). This then allows an analysis of which alternatives may or may not fulfill that function. In that context, the focus is on substances that can be added to EPS to achieve the same outcome as HBCDD. Compatibility is perhaps more likely to come from substances that have a similar chemistry to the substance to be replaced, however that may not necessarily be the case. We briefly consider the main types of flame retardant substances, namely inorganic flame retardants (including metal compounds, boron compounds and phosphorus-containing compounds) and organohalogens (within that specifically brominated organics).

Most inorganic flame retardants act in the condensed phase, by various mechanisms. Most decompose endothermically, releasing water of hydration and/or carbon dioxide, which inhibit burning. Some flame heat is absorbed in such reactions, and the residue is an efficient conductor of heat away from the area, further contributing to the extinction of the flame. Many act as smoke suppressants and also promote char, and all have a dilution effect.

Metal compounds: Metal hydroxides, such as aluminium trihydroxide and magnesium hydroxide, decompose in the heat of the flame and release water of hydration. Such substances also act as smoke suppressants. These flame retardants may be used as secondary additives to flame retarded polymer systems in which other flame retardants are present (e.g. antimony trioxide, zinc borate, phosphorus-based).

Antimony oxides and sodium antimonate provide a pigment as well as flame retardancy. Antimony compounds can be used in a variety of plastics. Use in cellulosic polymers is particularly effective, due to the reaction with the hydroxyl groups present in these polymers. Antimony-silicon compounds are sometimes used although these are less effective than antimony trioxide. Antimony compounds are not flame retardant in their own right but act as synergists with organohalogens.

Antimony trioxide is usually used in conjunction with heat-labile halogenated compounds; in the heat of the flame antimony trihalide is formed, which acts in the flame phase, modifying the reactions of the polymer in the flame such that less energy is released. They cause the molten polymer in the vicinity of the flame to char rather than releasing reactive and flammable gases, creating a seal.

Some other metal compounds, particularly zinc and zinc/tin compounds act synergistically with halogenated hydrocarbons. Synergistic action means that a reduced content of additives is needed to provide the same level of protection.

Molybdenum oxide is used as a flame retardant, particularly for cellulosics. The mode of action is thought to be connected with promotion of charring. Ammonium octamolybdate is used as a flame retardant for PVC. Titanium and zirconium compounds are used as flame retardants for textiles, particularly wool.

Boron compounds: Boric acid and sodium borate are frequently used in cellulosics (especially cotton and paper) where the presence of hydroxyl groups contributes to the effectiveness of these flame retardants. In the first instance, the compounds melt in the heat of the flame and form a glasslike coating; continued exposure to the heat causes water to be released, cooling the flame. Finally an inorganic char is produced, diluting and protecting the flammable material.

Zinc borate is frequently used to flame retard PVC; hydrogen chloride released in the presence of flame reacts with the zinc borate producing nonvolatile products (which promote char), and water.

Ammonium fluoroborate and zinc borate are frequently used in conjunction with antimony trioxide. Again, flame retardancy is thought to arise through release of water and formation of inorganic char in the presence of a flame.

Phosphorus-containing compounds act by promoting dehydration of the polymer in the presence of a flame, and increasing the level of charring. Inorganic phosphates are used in cellulosic textiles. Phosphoric acid itself has been used to treat cellulosics. Ammonium polyphosphates of varying chain lengths are used in many applications, particularly in coatings, paints and intumescent applications. Other flame retardants are frequently used in conjunction with them.

Elemental phosphorus exists in several allotropic forms. The red form is used as a flame retardant in plastics, commonly polyamides.

Organohalogens: Three general classes of organohalogen flame retardant may be identified: aromatic, aliphatic and cycloaliphatic. The halogen is either chlorine or bromine - fluorinated compounds are expensive and generally not effective; iodinated compounds are effective but unstable and are therefore not used. A wide variety of organohalogens are used as additives or reactive flame retardants, and a few can be used as either depending upon the application.

Incorporation of phosphorus compounds along with halogenated flame retardants further inhibits ignition. This effect is also achieved if the phosphorus and halogen are present in the same molecule. The effect can sometimes be synergistic.

Brominated organics: These are frequently used in ‘brown’ goods such as television sets, computer hardware housings and monitors, etc. Since brominated aromatics have the highest level of thermal stability, these tend to be the most widely used. HBCDD is in this class as are tetrabromobisphenol-A (TBBPA), used as an additive and reactive flame retardant in various plastics applications, and decabromodiphenyl ether (DeBDE), used as an additive flame retardant in a range of plastics and textiles.

Fisk *et al*., (2003) identified a list of brominated compounds and identified those that are used as flame retardants (additive and/or reactive) on the UK market (see Table 3.1 below). A large variety of chemical structures have been identified, but it is notable that Industry representatives (EBFRIP, the European Brominated Flame Retardants Industry Panel) report that there are about 75 different brominated flame retardants in commercial use, implying that many of the substances listed in the table below are either historical or have never really been used as flame retardants. Some substances are considered by Industry to be 'end-cappers', i.e. used to terminate polymerisation reactions. However, they are included here since there could be problems of definition, for example compared to reactive flame retardants.

Table 3.1: A list of brominated compounds with indication of use as flame retardants on the Market (UK) – reproduced from Fisk *et al.*, (2003)

CAS no.	Name	Used as additive flame retardant	Used as reactive flame retardant
-	1,4-Bis(bromomethyl)-tetrabromobenzene	No information	No information
-	Bis(tetrabromophenoxy) ethane	No information	No information
-	Brominated epoxy – endcapped	No information	Yes
-	Brominated epoxy - partially endcapped	No information	Yes
-	Bromine compound containing LDPE masterbatch	No information	No information
-	Epoxy resin (brominated)	No information	Yes
-	Octabromotriethylphenyl indane	No information	No information
-	Pentabromophenylbenzoate	No information	No information
-	Poly(dibromostyrene) grafted poly(propylene)	No information	No information
-	Proprietary blend pentabromodiphenyl oxide	Yes	No information
-	Tetrabromo-2,3-dimethylbutane	No information	No information
-	Tetrabromobenzoate	No information	No information
-	Tribromochlorobisphenol-A	No information	No information
-	Tetrabromophthalate ester	No information	No information
-	Tribromoneopentyl phenol	No information	Yes
-	Tribromoneopentyl phenyl allyl ether	No information	Yes
-	Tribromoneopentyl phenyl maleimide	No information	Yes
-	Tribromophenol allyl ether (likely to be a misnomer for tribromophenyl allyl ether	No information	Yes
-	Trichloromethyltetrabromobenzene	No information	No information
-	Tris(tribromophenyl)cyanurate	No information	No information
-	Tetrabromobisphenol-A epoxy oligomer	No information	No information
-	2,2'-dimethyl-3-bromo-propanoic acid, isopropyl ester	No information	No information
-	Tetrabromophthalic acid, diethylhexyl ester	Yes	No information
75-95-6	Pentabromoethane	Yes	No information
79-27-6	1,1,2,2-Tetrabromoethane	No information	No information
79-28-7	Tetrabromoethylene	Yes	No information
79-94-7	Tetrabromobisphenol-A	Yes	Yes
85-22-3	Pentabromoethylbenzene	Yes	No information
87-82-1	Hexabromobenzene	No information	No information
87-83-2	Pentabromotoluene	No information	No information
87-84-3	Pentabromochlorocyclohexane	No information	No information
93-52-7	Benzene, (1,2-dibromoethyl)-	No information	No information
96-13-9	2,3-Dibromopropanol	No information	Yes
118-79-6	2,4,6-Tribromophenol	No information	Yes
124-73-2	Dibromotetrafluoroethane	No information	No information

CAS no.	Name	Used as additive flame retardant	Used as reactive flame retardant
126-72-7	Tris(2,3-dibromopropyl)phosphate	Yes	Yes
593-60-2	Vinyl bromide	No information	Yes
598-72-1	2-Bromopropanoic acid	No information	No information
608-71-9	Pentabromophenol	No information	Yes
615-58-7	2,4-Dibromophenol	No information	Yes
632-79-1	Tetrabromophthalic anhydride	No information	Yes
1163-19-5	Decabromodiphenyl ether	Yes	No information
1470-82-0	2,4,6-Tribromoaniline	No information	No information
1837-91-8	Hexabromocyclohexane	No information	No information
1960-16-3	Dibromopropyl acrylate	No information	No information
2623-87-2	4-Bromobutanoic acid	No information	No information
3066-70-4	2,3-Dibromopropylmethacrylate	No information	No information
3072-84-2	Epoxy resin, brominated	No information	No information
3194-57-8	Tetrabromocyclooctane	No information	No information
3234-02-4	2,3-Dibromo-2-butene-1,4-diol	No information	Yes
3278-89-5	Tribromophenylallyl ether	No information	Yes
3296-90-0	Dibromoneopentyl glycol	No information	Yes
3322-93-8	1,2-Dibromo-4-(1,1-dibromomethyl)cyclohexane	No information	No information
3555-11-1	1-Pentabromophenoxy-2-propene	No information	No information
4162-45-2	Tetrabromobisphenol-A-bis-(2-hydroxyethylether)	Yes	Yes
5412-25-9	Bis(2,3-dibromopropyl)phosphoric acid	No information	No information
5445-17-0	2-Bromopropanoic acid, methyl ester	No information	No information
5445-19-2	2-Bromohexanoic acid, methyl ester	No information	No information
6519-18-4	Potassium bis(2,3-dibromopropyl)phosphate	No information	No information
6710-97-2	Tetrabromobisphenol-A-bis-(2-ethylether acrylate)	No information	No information
7415-86-3	Bis-(2,3-dibromo-1-propyl)phthalate	No information	No information
20217-01-0	2,4-Dibromophenylglycidyl ether	No information	Yes
20566-35-2	Tetrabromophthalic acid diol	No information	Yes
21850-44-2	Tetrabromobisphenol-A bis(2,3-dibromopropyl) ether	Yes	No information
23488-38-2	Tetrabromoxylene	No information	No information
25327-89-3	Tetrabromobisphenol-A-bis-(allylether)	No information	Yes
25357-79-3	Tetrabromophthalic acid, sodium salt	No information	Yes
25637-99-4	Hexabromocyclododecane	Yes	No information
25713-60-4	2,4,6-Tris(2,4,6-tribromophenoxy)-1,3,5-triazine	No information	No information
26040-51-7	Phthalic acid, tetrabromo-, bis(2-ethylhexyl) ester	No information	No information
31780-26-4	Dibromostyrene	No information	Yes
32534-81-9	Pentabromodiphenyl ether	Yes	No information
32536-52-0	Octabromodiphenyl ether	Yes	No information

CAS no.	**Name**	**Used as additive flame retardant**	**Used as reactive flame retardant**
32588-76-4	Ethylene-bistetrabromophthalimide	Yes	No information
32844-27-2	Tetrabromobisphenol-A diglycidyl ether - carbonate oligomer	No information	Yes
35109-60-5	2,4,6-Tribromophenoxy-2,3-dibromopropane	No information	No information
36483-57-5	Tribromoneopentyl alcohol (different isomers)	No information	Yes
36711-31-6	Magnesium bis(2,3-dibromopropyl)phosphate	No information	No information
37853-59-1	1,2-Bis(2,4,6-tribromophenoxy)ethane	Yes	No information
37853-61-5	Tetrabromobisphenol-A-bis-(dimethylether)	No information	Yes
38521-51-6	Pentabromobenzyl bromide	No information	Yes
39635-79-5	Tetrabromobisphenol-S	No information	Yes
40088-47-9	Benzene, 1,1 –oxybis-, tetrabromo derive	No information	No information
40703-79-5	5,6-Dibromohexahydro-2-phenyl-4,7-methano-1H-isoindole-1,3(2H)-dione	No information	No information
41291-34-3	Ethylene-bis(5,6-dibromonorbornane-2,3-dicarboximide)	Yes	No information
52434-59-0	1,3,5-Tris(2,3-dibromopropoxy)-2,4,6-triazine	No information	No information
57137-10-7	Polytribromostyrene	Yes	No information
58965-66-5	Tetradecabromodiphenoxybenzene	Yes	No information
59447-55-1	Pentabromobenzyl acrylate*	Yes	No information
59447-57-3	Poly(pentabromobenzylacrylate)	Yes	No information
59789-51-4	Tribromophenyl maleimide	No information	Yes
61262-53-1	Benzene, 1,1'- 1,2-ethanediylbis(oxy) bis 2,3,4,5,6-pentabromo-	No information	No information
61368-34-1	Tribromostyrene	No information	Yes
62354-98-7	Poly(dibromostyrene)	No information	No information
64864-08-0	Sodium bis(2,3-dibromopropyl)phosphate	No information	No information
68441-46-3	1,3-Butadiene homopolymer, brominated	No information	No information
68441-62-3	Brominated polyetherpolyol	No information	Yes
68928-70-1	Tetrabromobisphenol-A diglycidyl ether oligomers	Yes	No information
69882-11-7	Poly(2,6-dibromophenylene oxide)	Yes	No information
71342-77-3	Tetrabromobisphenol-A carbonate oligomer (fully brominated; phenoxy-terminated)	No information	No information
77098-07-8	1,2-Benzenedicarboxylic acid, 3,4,5,6-tetrabromo-, mixed esters with diethylene glycol and propylene glycol	No information	Yes
84852-53-9	1,2-Bis(pentabromophenyl) ethane	Yes	No information
88497-56-7	Brominated polystyrene	Yes	No information
94334-64-2	Tetrabromobisphenol-A - carbonate oligomer	Yes	Yes
109678-33-3	Tetrabromodipentaerythritol	No information	Yes
135229-48-0	Brominated epoxy resin / tribromophenol	Yes	Yes

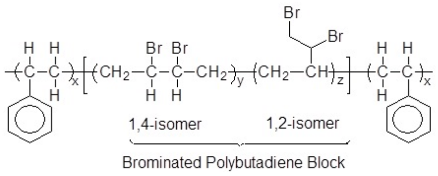
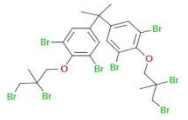
CAS no.	**Name**	**Used as additive flame retardant**	**Used as reactive flame retardant**
137370-67-3	Polypropylene/dibromostyrene copolymer	No information	No information
139638-58-7	2-Propanol, 1,1'-[(1-methylethylidene)bis[2,6-dibromo-4,1-phenylene)oxy]]bis[3-(2,4,6-tribromophenoxy)-	Yes	No information
155613-93-7	Brominated trimethylphenylindane	Yes	No information
171091-06-8	Dibromostyrene grafted	No information	No information

* May not be on the UK market.

It is only the brominated organic substances that present possibilities for technically feasible alternatives, because other flame retardant types are known to either not provide adequate fire protection at concentrations that do not adversely affect EPS properties, or are not compatible with the EPS manufacturing process or are not compatible with EPS itself. The extensive nine year research programme carried out by the Plastics Europe EPS manufacturers demonstrated that this was the case (see Section 3.2).

A list of possible alternatives, that are all brominated organic substances, is presented below. As set out in section 2.3 above, an alternative that is suitable for replacement of HBCDD in EPS has already been selected. This substance; benzene, ethenyl-, polymer with 1,3-butadiene, brominated (brominated co-polymer of styrene and butadiene) CAS 1195978-93-8, will be phased in to replace HBCDD for EPS, but will take time beyond the sunset date to do so (see Section 5 of this document for a discussion of what it will take to make this alternative fully available, including obstacles or difficulties identified or expected). The other possible alternatives listed in Table 3.2 below are substances that have been indicated to be *possible* alternatives for HBCDD in EPS, but are considered not suitable or available to replace HBCDD in EPS for building uses.

Table 3.2: Summary list of possible substance alternatives for HBCDD as a flame retardant in EPS

Substance	CAS number	Commercial/ trade name	Structure	Formula	Comment
Benzene, ethenyl-, polymer with 1,3-butadiene, brominated	1195978-93-8	‘Emerald 3000’ ‘FR-122P’ ‘GreenQuest’ Brominated co-polymer of styrene and butadiene		$(C_8H_9)_x(C_4H_6Br_2)_y(C_4H_6Br_2)_z$	Selected by the industry as the replacement for HBCDD in EPS and XPS. A programme aimed at demonstration of technical feasibility for EPS is in place and on going (see Section 5 – Table 5.1). This includes the performance of the necessary actions in order to make this substance a suitable alternative (i.e. complete a product testing programme with commercial grade pFR, ensure customer acceptability and meeting of relevant safety standards). Sufficient supplies are not available to ensure continuity of supply of flame retarded EPS. (see Section 4.5a) See 4.1
Benzene, 1,1'-(1-methylethylidene)bis[3,5-dibromo-4-(2,3-dibromo -2-methylpropoxy)]	97416-84-7	‘Pyroguard SR-130’		$C_{23}H_{24}Br_8O_2$	Indicated as a possible alternative by USEPA. Limited information on risks. Not likely to be suitable due to expected similar environmental fate and behavior to HBCDD. Limited testing in the Plastics Europe testing programme[28] and not

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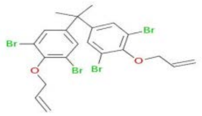
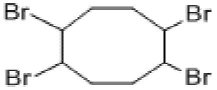
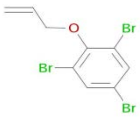
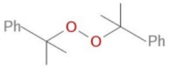
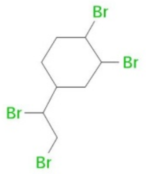
[28] The substance is understood to be used in Japan as an alternative to HBCDD. This substances was not made available commercially to European EPS producers despite the offered of the EPS industry (via Plastics Europe) to work with the Japanese Producers Daiichi to develop the product: Plastics Europe has stated that “SR130 has been tested by EPS Alternative group .It is seen as an insurance policy in case there is any difficulty on the polymeric alternative side. EPS MC did approve the proposal to undertake the Bio accumulation test on the Daiichi material. This is the most critical step along the Reach registration of the product. Daiichi thanked us for our interest but did not want to send a sample for now.” – Plastics Europe January 2012

Substance	CAS number	Commercial/ trade name	Structure	Formula	Comment
					known to be technically feasible for use in EPS in Europe. Unlikely to be available in sufficient quantities. (see Section 4.5b)
Tetrabromobisphenol-A bis (allylether)	25327-89-3	‘BE 51’		$C_{21}H_{20}Br_4O_2$	Not technically feasible for use in the single step process (possible for use in the ‘two-step’ process has been indicated). Limited information on hazard profile. Indicated as a potential immunotoxin, not easily hydrolysed and may be resistant to environmental degradation. (see Section 4.5c)
1,2,5,6-tetrabromocyclooctane	3194-57-8	TBCO ‘Saytex BC-48’		$C_8H_{12}Br_4$	Used in the two-step process only, not feasible for the one-step process. This substance may no longer be commercially available. No information is available on production volumes in the US or in the EU. Hazardous to the aquatic environment, potentially PBT. (see Section 4.1d)
2,4,6- tribromophenyl allyl ether	3278-89-5	Pyroguard FR 100		$C_9H_7Br_3O$	Possible use for ‘two-step’ process (only one–step process is used in the EU). Concerns for long range transport and bioaccumulation. (see Section 4.1 e)

Substance	**CAS number**	**Commercial/ trade name**	**Structure**	**Formula**	**Comment**
Tetrabromobisphenol A bis(2,3-dibromopropylether)	21850-44-2	TBBPADBPE GC SAM 55 FR 720		$C_{21}H_{20}Br_8O_2$	Some concerns for hazard profile, persistent in the environment. Possible mutagenic effects. (see Section 4.1f)
Tetrabromobisphenol A bis(2,3-dibromopropylether) & dicumyl peroxide (bis(α,α-dimethylbenzyl) peroxide)	21850-44-2 80-43-3	TBBPADBPE and dicumyl peroxide SAM 55 E (EPS)	 	$C_{21}H_{20}Br_8O_2$ $C_{18}H_{22}O_2$	Some concerns for hazard profile, persistent in the environment. Possible mutagenic effects. (see Section 4.1f) bis(α,α-dimethylbenzyl) peroxide) is classified as + R51/53 : Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. It is also classified as + R36/38 : Irritating to eyes and skin.
1,2-dibromo-4-(1,2-dibromoethyl)cyclohexane	3322-93-8	SAYTEX BCL 462		$C_8H_{12}Br_4$	Potentially bioaccumulative and persistent in the environment, some indication of potential for reproductive effects on birds. (see Section 4.1g)
Clays: sepiolite (complex magnesium silicate), palygorskite/attapulgite, (magnesium aluminium phyllosilicate) or combinations thereof.	N/A	Understood to be not yet marketed (a US patent is published)	N/A	$Mg_4Si_6O_{15}(OH)_2\cdot 6H_2O$ $(Mg,Al)_2Si_4O_{10}(OH)\cdot_4(H_2O)$	A patent for synergistic effect of a flame retardant organic molecule/clay is presented as a REACH compliant alternative to hexabromocyclododecane (HBCD). This is presented under the INNOVEX® trade registered name. The structure

Substance	CAS number	Commercial/ trade name	Structure	Formula	Comment
					or further details of the clays and whether they are intended to work in conjunction with BFRs or replace them is not clear. There have been some concerns owing to the fibre structure of sepiolite. IARC Monographs/vol68/mono68-9 concludes that: There is inadequate evidence in humans for the carcinogenicity of sepiolite. There is limited evidence in experimental animals for the carcinogenicity of long sepiolite fibres (> 5 µm). There is inadequate evidence in experimental animals for the carcinogenicity of short sepiolite fibres (< 5 µm).

As reported in ECHA (2008), at present, no suitable flame retardant is available to replace HBCDD in XPS or EPS as the required loadings of alternative flame retardants impair the structure and properties of the finished product to the extent that is no longer suitable for use. There are however a number of alternative forms of insulation that can be used in place of XPS or EPS. These alternative insulation systems have different characteristics to XPS and EPS and may be less appropriate for some specific use scenarios or may incorporate different environmental issues such as increased energy costs during transportation.

As indicated in Table 3.2 and in Section 3.2 below, the polymeric alternative has been selected as suitable on the basis of research and development done by the industry. The issue at hand is one of phase-in, whilst for other substances there is good evidence to show that they are not suitable (for example it is known that they not compatible with the process for manufacture of EPS and/or they have hazardous properties that would lead to environmental or health risks), for others there is less evidence. For these latter substances however, there would still be the need for extensive trials to ensure compatibility with the EPS manufacturing process and acceptability of the end product function as well as acceptance by product end users (Table 5.1 in Section 5 of this document sets out the steps and actions that need to be taken in order to put the pFR in place, with estimated timings). In addition, for the selected candidate alternative, research on supply indicates that there is uncertainty in security of sufficient volume, for other alternatives there is complete uncertainty with regard to the availability of commercial supply and thus suitability and availability of these substances is doubtful and extremely uncertain (see SEA document section 2.3). Table 3.3 below reproduces a summary table from the SEA that shows that the supply of pFR to the EPS and XPS sectors will actually be below demand by some margin up to and including 2020. Table 3.3 compares expected global supply and demand of the pFR. It shows that there is expected to be not enough supply to meet demand over the four year authorisation review period. **As noted in the SEA report there are significant uncertainties over both supply and demand figures**, and where possible optimistic (but also thought to be realistic) figures have been used. Therefore the shortage in pFR could be worse than estimated.

Table 3.3: Estimated global supply and demand of the pFR (for EPS and XPS) for 2015-2019 (tonnes)

	2015	2016	2017	2018	2019
Demand for the pFR	30,839	31,652	32,103	30,304	35,790
Supply of the pFR	23,350	29,850	31,350	31,350	31,350
Deficit/surplus	**-7,489**	**-1,802**	**-753**	**1,046**	**-4,440**

3.2 Description of efforts made to identify possible alternatives

3.2.1 Research and development

As mentioned earlier in this document, a large amount of research over a number of years has been deployed to identify and develop a viable alternative to HBCDD.

A nine year research programme was co-ordinated by the EU trade association for plastics producers, Plastics Europe. Due to legal issues, permission has not been granted for the applicants to set out full details of the research programme in this present document. Neither has permission been granted for this detail to be revealed in a separate confidential annex to this present document. What is presented here, however, does allow the extent, objectives and achievements of a coordinated research programme to be understood. It should be sufficient to show that considerable R&D has been deployed to successfully select a polymeric alternative that presents much lower overall risk than HBCDD. The text here relies heavily on a letter from Plastics Europe to the HBCDD EPS consortium entitled “Program to Identify Alternatives to HBCD as a Flame Retardant in EPS. Summary of the EPS Alternative Working Group (2003 – 2012).” – See Appendix 2.

The programme was initiated by APME - Association of Plastics Manufacturers in Europe, which subsequently became Plastics Europe[29]; EPS members embarked on a collective project in 2003 to screen potential alternatives to HBCDD. More than 40 substances as potential alternatives to HBCDD from a number of suppliers were evaluated in polymerisation, according to a standard EPS polymerisation test, and assessed for flammability performance.

The health, safety and environmental profiles of most promising substances were then evaluated, seeking as complete information as possible on the different products.

By 2010 the most promising alternative substances were found to be brominated polymer products proposed by chemicals manufacturers Chemtura, Albemarle and ICL&IP, based on a technology developed by the Dow Chemical Company. These producers progressively confirmed their commitment to the polymeric FR alternative and secured licences from Dow Chemical to commercially manufacture this substance. There was one other material which appeared to meet technical criteria which is (benzene, 1,1'-(1-methylethylidene)bis[3,5-dibromo-4-(2,3-dibromo -2-methylpropoxy)], CAS 97416-84-7, known as ‘Pyroguard SR-130’), but it was not possible to identify a manufacturer prepared to produce it for the European market and so this material has not been made commercially available[30]. The EPS Alternatives Working Group was dissolved in June 2012, having identified two potential alternatives to HBCDD, one of which was being commercialised.

The programme was subject to strict and binding agreements between Plastics Europe, its EPS Member Companies and the producers of the polymeric alternative. From a contractual perspective, this is summarised below:

1. Confidentiality agreements proposed by each of the three main European suppliers (Chemtura, Albemarle and ICL&IP).

2. Agreements between each supplier and each member participating in the ‘screening’ (i.e. testing the alternative).

3. APME requested that each agreement should allow the following:

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[29] APME EPS member companies, represent >90% production of FR EPS in Europe

[30] The substance is understood to be used in Japan as an alternative to HBCDD. This substance was not made available commercially to European EPS producers despite the offered of the EPS industry (via Plastics Europe) to work with the Japanese Producers Daiichi to develop the product: Plastics Europe has stated that “SR130 has been tested by EPS Alternative group .It is seen as an insurance policy in case there is any difficulty on the polymeric alternative side. EPS MC did approve the proposal to undertake the Bio accumulation test on the Daiichi material. This is the most critical step along the Reach registration of the product. Daiichi thanked us for our interest but did not want to send a sample from now.“ – Plastics Europe January 2012

- Exchange of information (identity of molecule / performance in standard tests) between supplier, member company and signed third parties.
- Long term confidentiality period for the information and parties above.
- Disclosure of information to signed third parties (i.e. all other members of APME EPS - not all EPS Steering Group members were members of the Alternatives working group).

The background to the process co-ordinated by APME was as follows:

- Supplier companies presented to APME the commercially available (CA) and novel compounds (N) that they were currently developing.
- APME agreed standardised tests as a first 'screen' to assess technical performance
  - Polymerisation test (can a stable suspension be prepared in presence of the HBCDD alternative). The scale of the test was member-specific.
  - B2 fire test[31]
- APME also reviewed the currently available health safety and environment (HSE) information on alternatives.

The research programme was done in three phases of activity. Phase 1 was a screening phase in which possible candidate alternative flame retardants were evaluated against key technical and safety criteria. The second phase consolidated the findings of the first phase and coordinated the further research in particular it focused on assessing the HSE performance of test Compounds that passed Phase I. A third phase was much more detailed with a thorough evaluation of candidate substances for commercial viability, however this was for the individual EPS producer-members to evaluate compounds that passed the first and second phases in commercial formulations. The third phase was not part of the Project. More detail on the research phases is presented below.

For each Alternative Candidate (AC), a first screening phase was conducted collectively by the EPS producers (that are APME members). The benefits of collective screening included quick availability of results to all EPS producers, decreased cost per member and the use of pooled expertise. An evaluation of available HSE information (e.g. safety data sheets and computer predictions of HSE performance) was also included in this phase. The main features were:

- Each AC was screened by at least two members:
- Results were discussed at meetings.
- ACs that consistently required lower loadings to pass B2 could be developed further.
- Screening information was open to all members.
- Initial screening with commercial EPS formulations.
- Results of objective tests only were shared amongst members.
- No commercial formulations were disclosed.

The objective criteria were as follows:

1. It must be possible to make EPS foam in the presence of the CA
   - Use of standardised and non-commercial procedure/recipe was agreed by EPS all producer-members

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[31] Classification of building products for the German market according to DIN 4102-1. The fire class is denoted "B2". This is a similar test method, EN ISO 11925-2. Reaction to fire tests -- Ignitability of products subjected to direct impingement of flame -- Part 2: Single-flame source test. See Section 2.2.2.3 of this report (note that 11925-1 is Reaction to fire tests -- Ignitability of building products subjected to direct impingement of flame -- Part 1: Guidance on ignitability).

- A stable polymerisation was requisite
    - Some formulation adaptation may be necessary to achieve this
    - Scale of testing equipment will varied between members (0.5 to 15 kg EPS foam production)
    - AC should allow the foam to have appropriate qualities:
        - cellular structure
        - expansion behaviour
        - moulding behaviour
        - mechanical properties

2. EPS boards with AC pass the B2 standard small scale fire test
    - EU recognised standard fire test[32] was applied to assess fire propagation and dripping.
    - Lower loading of AC was preferred:
        - less impact on foam processing
        - better cost performance
3. Potential for better performance than HBCDD in a Risk Assessment
    - Available information on HSE performance of AC from the three suppliers (ICL, Albermarle and Chemtura) was collated and assessed by the EPS producer-members
    - It was acknowledged that a number of AC may have no HSE information other than computer predictions
    - EPS producer-members considered the best way to fund future studies on candidates that perform well in phases 1 and 2
    - An additional criterion of an odour test was added to the research programme as odour was identified as a problem for production and some AC were eliminated because of the unpleasant smell for the workers.

The initial selection of the candidate alternatives were obtained in consultation with the three main European suppliers of HBCDD. According to the Plastics Europe Programme, commercially available halogen-free flame retardants as alternatives for EPS were not proposed by the suppliers or by polystyrene foam producers (EPS member producers). To ensure thoroughness, a later review was carried out in 2008-2009 by Dr. Juergen Troitzsch, Fire and Environment Protection Service, Wiesbaden, Germany for EXIBA[33]. It was confirmed that that flame retardant producers were also assessing halogen-free alternatives for polystyrene foams. However, the testing and development of these alternative systems would take several years and so these were not considered to be an option in the short-term.

Other technical alternatives

Synbra developed a system as an alternative by a post-treatment (silica-based coating) for roof application. The following article was released in the press in January 2007 (see Appendix 1). This was not considered a drop-in FR alternative for HBCDD: it requires special processing and confers different properties for EPS which are not suitable for all applications.

List of substances evaluated and suppliers

A high level review of the results of the HBCDD alternatives was summarised in 2012, this was shared with UNEP for the Persistent Organic Pollutants Review Committee[34] (see Table 2.5 –

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[32] Standard B2 test (small flame). DIN 4102

[33] European Extruded Polystyrene Insulation Board Association

[34] Related to the processes of the Stockholm Convention

Summary list of possible substance alternatives for HBCDD as a flame retardant in EPS). The initial list of possibilities from 2003 was rapidly reduced using the screening criteria adopted. It should be noted that full details of this are confidential and are only included in the comprehensive minutes of meetings since 2003 for those companies/individuals who have access. This information is not available for general release (even in the context of this authorisation application), because it is stated by Plastics Europe directly to the applicants for this application, due to the long-term secrecy agreements signed between flame retardant producers, EPS raw material producers and PlasticsEurope. This is explained in the Plastics Europe letter of August 14th and 23rd 2013 (see Appendix 2).

Outcome of the research programme.
In September 2007 the research programme concluded that there were no identified ‘drop-in’ replacements for HBCDD on the basis that none met all the criteria. Plastics Europe members concluded that it was clear that there were no candidate molecules, either commercially available or “novel” compounds which were seen as feasible alternatives to HBCDD. A similar research project was launched for XPS foams with same conclusions.

In March 2009, the list of possible alternatives had been narrowed down to five substances following the initial polymerisation, fire performance and HSE screening. A total of three substances were substances recognised by REACH (i.e. EINECS or ELINCS substances[35]) and two were novel candidates.

By 2010 the most promising alternative substances were identified as the brominated polymer products, which had been proposed by Chemtura, Albemarle and ICL. There was a progressive abandoning of non-polymeric alternatives in favour of the polymeric one as the polymer presented the best HSE profile and a low risk of PBT classification.

Plastics Europe has stated that only one other substance remained competing with those products and technically was a viable alternative. However, it became impossible to find support to pursue this substance for additional commercial manufacture for Europe.

The EPS Alternatives Working Group was dissolved in June 2012, having identified two potential alternatives to HBCDD. At that time the polymeric flame retardant using Dow Chemicals’ technology was in the process of being commercialised under licence by all three main European flame retardant producers (i.e. Chemtura, Albemarle and ICL).

Costs of the research programme
Plastics Europe set out the different steps of the research and development of an alternative substance, as well as the associated costs and time involved were outlined. It included the time estimated for registration of the new substance. The estimate was 6-10 years at a cost of € 11.5 million for the industry, without inclusion of REACH registration costs and implementation costs. A 2011 estimate for the REACH Chemical Safety Report cost for TBBPAE was in excess of €2 million and at least two years’ work.

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[35] EINECS (European Inventory of Existing Commercial chemical Substances) – i.e. ‘existing substances’ that would be registered under the REACH phase-in programme (based on tonnages use); ELINCS (European List of Notified Chemical Substances) – i.e. ‘new substances’, that are not phased in, but considered already registered under REACH, but dossiers must be updated should volume use reach the next tonnage threshold.

3.2.1.1 The identification of the polymeric flame retardant alternative.

As referred to above, the manufactures that currently supply HBCDD to the EPS downstream users, including the applicants for this authorisation application, deployed a strategy to identify alternatives to HBCDD for EPS (and XPS). Outlined below is the strategy employed by the substance manufacturer to identify and develop the specific flame retardant. In order to evaluate more environmentally sustainable flame retardants (FRs) a tiered approach was developed to obtain data and information on the environmental partitioning and PBT characteristics of candidate FRs, irrespective of chemistry. The research had the following key features:

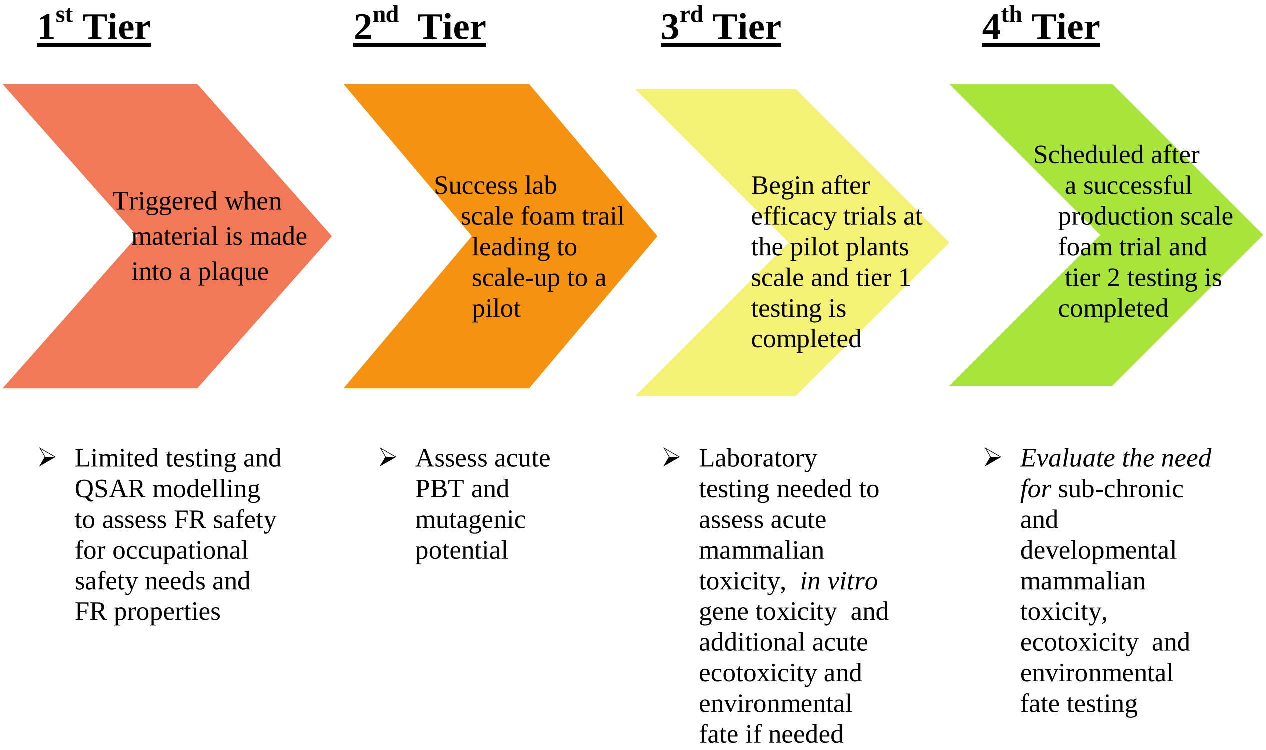
- A general approach for candidate FRs involved initial screening based on literature review for hazard assessment (for candidate or analogue) and quantitative structure–activity relationship (QSAR) models to estimate their PBT potential.

- The appropriate use of QSAR models aided in prioritising chemicals for laboratory testing and promoted the more efficient use of chemical testing resources and reduced laboratory animal use.

- Those molecules which displayed good FR characteristics (efficacy), and had a positive environmental health and safety profile were then considered for further evaluation including health and environmental testing.

The tiered approach identification of alternatives is illustrated in Figure 3.1, below:

Figure 3.1 Schematic of the alternative selection process for and EPS flame retardant (reproduced from Dow Chemicals Company)



1st Tier

Triggered when material is made into a plaque

- Limited testing and QSAR modelling to assess FR safety for occupational safety needs and FR properties

2nd Tier

Success lab scale foam trail leading to scale-up to a pilot

- Assess acute PBT and mutagenic potential

3rd Tier

Begin after efficacy trials at the pilot plants scale and tier 1 testing is completed

- Laboratory testing needed to assess acute mammalian toxicity, *in vitro* gene toxicity and additional acute ecotoxicity and environmental fate if needed

4th Tier

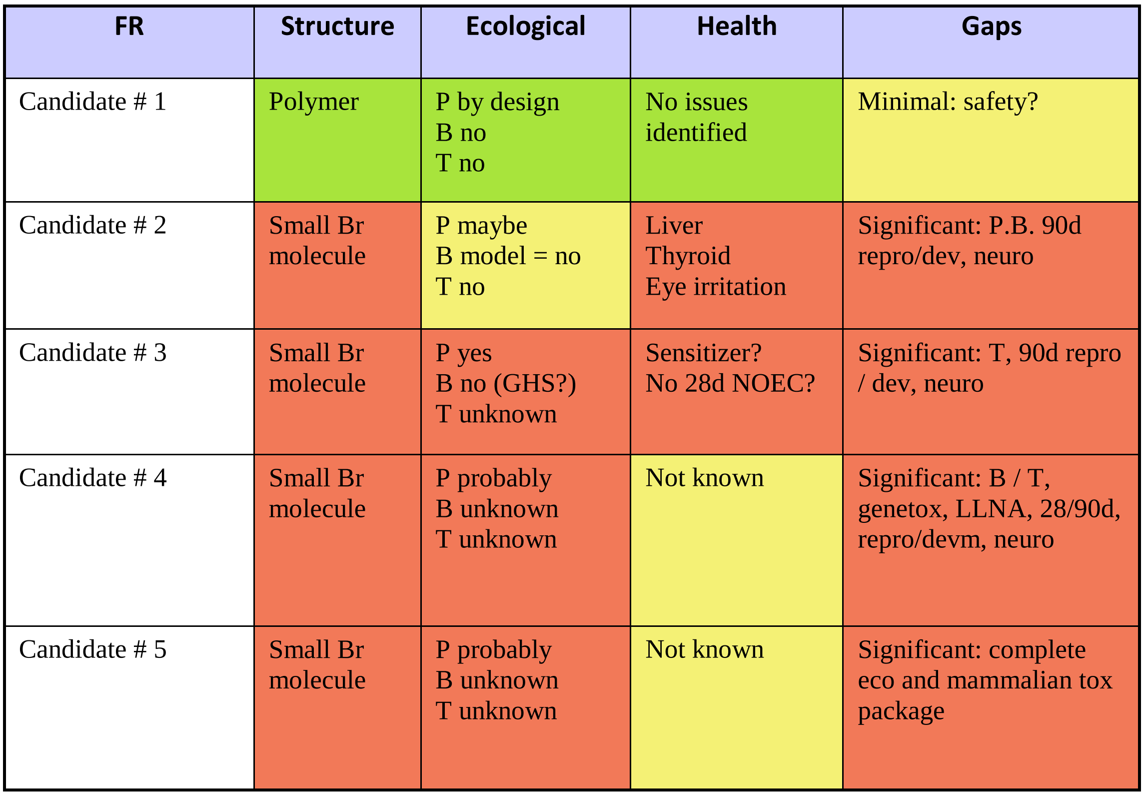
Scheduled after a successful production scale foam trial and tier 2 testing is completed

- *Evaluate the need for* sub-chronic and developmental mammalian toxicity, ecotoxicity and environmental fate testing

Candidate substances were screened for hazardous property profiles (mammalian and environmental toxicology).

An example of the comparative matrix for substance selection is illustrated in the Figure 3.2 below:

Figure 3.2 Example of a comparative matrix for the alternative selection process for and EPS flame retardant (reproduced from Dow Chemicals Company)



FR	Structure	Ecological	Health	Gaps
Candidate # 1	Polymer	P by design B no T no	No issues identified	Minimal: safety?
Candidate # 2	Small Br molecule	P maybe B model = no T no	Liver Thyroid Eye irritation	Significant: P.B. 90d repro/dev, neuro
Candidate # 3	Small Br molecule	P yes B no (GHS?) T unknown	Sensitizer? No 28d NOEC?	Significant: T, 90d repro / dev, neuro
Candidate # 4	Small Br molecule	P probably B unknown T unknown	Not known	Significant: B / T, genetox, LLNA, 28/90d, repro/devm, neuro
Candidate # 5	Small Br molecule	P probably B unknown T unknown	Not known	Significant: complete eco and mammalian tox package

It was from this process that the polymeric brominated flame retardant benzene, ethenyl-, polymer with 1,3-butadiene, brominated (brominated co-polymer of styrene and butadiene) was selected.

The profile of the pFR is indicated in Figure 3.3 below:

Figure 3.3 Hazard profile of the polymeric alternative (PolyFR) selected to replace HBCDD (reproduced from Dow Chemicals Company)

	Human Health Effects									Aquatic Toxicity		Environmental	
Chemical	**Acute Toxicity**	**Cancer**	**Mutagenicity / Genotoxicity**	**Reproductive / Developmental**	**Neurotoxicity**	**Repeated Dose**	**Sensitization**	**Irritation / Corrosivity**	**Endocrine**	**Acute**	**Chronic**	**Persistence**	**Bioaccumulation**
PolyFR	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**vL**	**NE**	**L**	**L**	**vH**	**L**

vL	very Low
L	Low
vH	very High
NE	no evidence

There is the possibility that some of the tetrabrominated substances as listed in Table 3.2 (Summary list of possible substance alternatives for HBCDD as a flame retardant in EPS), and listed again below, may be suitable, or could be used as alternatives to HBCDD, if HBCDD was not available and if insufficient pFR was available.

- benzene, 1,1'- (1-methylethylid ene)bis[3,5-dibromo-4- (2,3-dibromo-2- methylpropoxy)]; tetrabromobisphenol A bis (allylether);
- 1,2,5,6- tetrabromocyclooctane;
- 2,4,6- tribromophenyl allyl ether and
- tetrabromobisphenol A bis(2,3- dibromopropylether)

The most likely candidate (other than the pFR) is tetrabromobisphenol A bis(2,3-dibromopropylether) - (TBBPA-DBPE) that is marketed under the commercial name ‘SAM 55’. Comparisons between this substance and the pFR have been made by the suppliers of SAM 55. The suppliers of SAM 55 claim that TBBPA-DBPE has a superior technical and cost profile and that the risk profile of the pFR is superior only on the grounds that it is a polymer and not yet under the REACH regime. However as summarised above (in Table 3.2), it appears that there are some indications of hazard for TBBPA-DBPE, and also as mentioned earlier, the selection of the pFR as the replacement candidate has prompted the associated and detailed research on its viability as for replacement of HBCDD in terms of processing, quality of final product and customer acceptance of product. Suppliers of SAM 55 Green Chemicals claim that the product is suitable for XPS[36],

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[36] Presentations gives during the UNEP POPRC9 at a side event 14th October 2013

however suppliers MPi Chemi supply SAM 55 for XPS and for EPS. The EPS version SAM 55 E is as described in Table 3.2 above, the XPS version SAM 55 is with the additive dicumene (CAS 1889-67-4) rather than dicumyl peroxide (CAS 80-43-3)[37].

It should be noted that the research was a joint assessment programme with an agreed screening process. Reassessment of alternatives that only just met/failed to meet criteria was decided against; when there was a consensus on two promising alternatives. In the face of the cost of the full testing and possible REACH registration the screening process was aimed at focusing in on possible technically feasible alternatives based upon the best data available at the time. This did not mean however, that subsequently individual companies did not return to re-assess a product that looked particularly promising for their own production process. Nevertheless, the companies would only have done this if the financial incentives were strong enough (i.e. process efficiency, cost of materials, etc.) (EPS Manufacturer Pers. Comm. 2013).

The XPS and EPS manufacturers have opted for the pFR because it best fits the technical, environmental and health profiles required. However, for the EPS supply chain the issue is one of availability of the pFR, notwithstanding the additional technical testing needed to ensure full product compatibility and acceptability to customers for all uses that require flame retarding.

3.2.1.2 Alternative production process

Compatibility with EPS for some alternatives depends upon the production process that is used to make EPS. A ‘two stage’ production for EPS is understood to be used in North America. The two stage process may be more compatible with some brominated substance alternatives.

As set out in section 2.1.3 of this document, the main difference between the single and two-step processes is that in the two-step process the blowing agent (e.g. pentane) and fire retardant (e.g. HBCDD) is added in a second step after the initial polymerization. This adds specific requirements to the fire retardant to be able to penetrate the ready-made bead. It is known that HBCDD does not penetrate polystyrene easily and is thus is typically not used in the two-step process. Conversely, there are substances that can be used in the two-step process that cannot be used in the single step process. As summarised above, the research programme carried out by the EPS manufacturers considered a number of possible compounds including other non-polymeric brominated compounds. In this context, given the regulatory pressure on a number of other non-polymeric brominated compounds, it is likely that the environmental hazards profile of such compounds would not be favourable to their use as replacements for HBCDD.

3.2.1.3 Alternative final products

As set out in Section 2.3 of this document and summarised in Table 2.5 in that section, the focus of the analysis on substance function does not lead to an analysis of alternative insulation materials for building applications. The function is to flame-proof EPS and not to provide insulation, that is a property of EPS not HBCDD. However, since the non-use scenario has to consider the reaction of the market to the possible non-availability to HBCDD, then it is relevant to consider alternative building insulation materials since these may be used in place of flame retarded EPS if HBCDD is

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[37] http://www.mpi-chemie.com/product/sam-55-e.html - accessed October 2013

not available and there is not sufficient pFR. The non-use scenario is defined and set out in the SEA document as in table 3.4 below:

Table 3.4: Response of the supply chain in terms of use of non FR EPS building insulation materials

Supply chain	Possible response	Likelihood in practice (with justification)
End users in the insulation market	Use alternative FR products to EPS e.g. mineral wool, PUR/PIR, XPS with polymeric alternative	Likely – Mineral wood is the dominant material on the EU market (50-60%) so it is feasible that some end users may switch for some building applications to mineral wool where it meets technical requirements. PUR and PIR will also be feasible for some building applications but currently has a small market share.
	Use FR EPS made with the pFR alternative where available	Likely – But there will be limited supply of EPS final products made using the polymeric alternative in the short term since the converters are dependent upon a limited supply of EPS raw material with the polymeric FR alternative.

In addition, Table 3.5 below sets out the suitability different alternatives to EPS from the perspective of end use. It should be noted that this analysis is from the perspective of the applicant/s.

Table 3.5: Suitability of alternative final products to EPS

Alternative final product	**Technically feasible**	**Economically feasible**	**Overall reduction in risk**	**Conclusion on suitability ***
Non-flame retarded EPS	No – EPS beads are not flame retarded so they will not meet stringent fire safety requirements.	As EPS is not flame retarded on its own, there are limited applications for use as insulation. It is unlikely to be economically viable in the long-term to operate selling only non-flame retarded EPS.	Yes - as HBCDD is not included in EPS beads	Not suitable - Not flame retarded and not economically feasible (due to reduced demand).
Mineral wool	It is technically feasible for end users to switch EPS with mineral wool for many building use applications. However, EPS producers cannot switch production as process and products are very different. It would require very extensive process change.	No – It would require extensive process and production expenditure, requiring building new plants, which would reduce overall competitiveness in an already established mineral wool market with several producers.	Likely – the risk to the environment would be reduced as mineral wool is relatively chemically inert. There were concerns for the human health risks from inhalation exposure to mineral wool fibers but IARC has classified rockwool and slagwool as Group 3, not classifiable as to their carcinogenicity to humans. Rock wool can be recycled. Netherlands health experts reported (see note 1) that stone and glass wool consist of fibers which, on inhalation give rise to accumulation in the body, an irreversible process. Once the material has entered the lung, it can never get out and acts as a disturbing element. Chronic lung problems, including asthma and pulmonary fibrosis may be the result. The fibres of mineral wool (stone wool and glass wool) have traditionally been bonded with a resin binder, based on phenols and formaldehyde. The concentration of the binder is indicated to be in the range of 1-17% depending on the specific application. Most of the formaldehyde is removed by the manufacturing process. Stone wool may potentially release formaldehyde from the construction into indoor air. Formaldehyde	Not suitable – Not economically feasible to switch production to new type of product and production process.

Alternative final product	Technically feasible	Economically feasible	Overall reduction in risk	Conclusion on suitability *
			emission rates from uncovered stone wool falling from 72 to 50 µg/m^{2}h over a period of 28 days (reported in KLIF 2011). Formaldehyde is classified carcinogenic in the European Union (Carc. Cat. 3; R40).	
Rigid polyurethane (PUR) / Rigid Polyisocyanurate (PIR)	It is technically feasible for end users to switch from EPS to PUR/PIR for some building applications. However, EPS producers cannot switch production as process and products are very different. It would require very extensive process change.	No – It would require extensive R&D expenditure and require building a new production process which would reduce overall competitiveness in an already established PUR market with several producers.	May emit toxic fumes if burnt, otherwise low toxicity in use, but manufacture involves the use of isocyanates – potent respiratory sensitisers. Highly persistent material, long term disposal to landfill with potential for dust emissions to air and surface water, no recycling at present. For polyisocyanurate (PIR) sheets (flame retarded), halogenated phosphorous flame retardants in some types - none of the substances are considered PBT or CMR or classified as dangerous to the environment (KLIF 2011). See note 1. Dutch health experts reported possible emissions of isocyanates (MDI), a neurotoxic substance, as off gas in the cavities. MDI has a limit of 0.05 mg / m^3 (NIOSH).	Not suitable – Not economically feasible to switch production to new type of product and production process.
Extruded polystyrene (XPS)	It is technically feasible for end users to switch EPS with XPS for most building use applications. EPS producers could switch production as the technologies are similar but would require building new/changing the current production site.	XPS producers are expected to move to the polymeric alternative and are likely to secure initial supply of production. It will not make economic sense to switch from EPS production to XPS, as again this would require sufficient supply of the polymeric alternative.	Current XPS products contain more (by weight) HBCDD than EPS. New XPS will use the polymeric alternative but there is uncertainty over regarding adequate supply.	Not suitable – Current XPS uses HBCDD and there is the same issue of insufficient supply of polymeric FR alternative.

*Suitability is assessed from the applicants' perspective.

Note 1. A letter from Dutch health experts to Mr. Minister . Dr. L. F. Asscher , Ministry of Social Affairs and Employment (see Appendix 3).

It is important that this analysis of alternatives is in line with the non-use scenario; this is because what will happen in the non-use scenario represents the situation if HBCDD is not available. It is understood that for the main flame retarded EPS building applications, either extruded polystyrene (XPS), polyurethane foam (PU) or mineral wool (MW) is the most likely substitute for the reduction in flame retarded EPS on the market. This is shown in Table 3.5 below in which the dominant material on the market for that application is in a grey cell and the key EPS uses are indicated with red text (based on the EUMEPS data).

Table 3.6: Main applications of EPS within construction – EUMEPS estimate

Key building applications		**EPS**	**XPS**	**PU**	**MW**
Wall	Perimeter	✓	✓		
	ETICS	✓			✓
	Cavity	✓		✓	✓
	Internal	✓		✓	✓
	ICF	✓	✓	✓	
Roof	Flat	✓	✓	✓	
	Pitched			✓	✓
Floor		✓		✓	

Table 3.5 above indicates that are material alternatives to EPS for all building applications. The non-use scenario concludes in this context that for users of products (i.e. the construction industry) a response could be to use alternative building materials if flame retarded EPS is no longer available (either due to the banning of HBCDD or the non-availability of the polymeric alternative flame retardant).

In a recent (2011) comprehensive study, the Norwegian Climate and Pollution Agency (KLIF) reported on alternatives to the use of flame retarded EPS in buildings. The KLIF (2011) study took into account the technical feasibility of material alternatives to flame retarded EPS, possible toxic risk, as well as price and also a life cycle assessment in comparing the alternatives. KLIF (2011) did not however, attempt a cost benefit analysis. The KLIF (2011) study concluded that alternatives are available for all the building applications of flame retarded EPS that they assessed. It stated that the flame retarded EPS would most likely be replaced by different insulation materials depending on the application. That was because as no single alternative would substitute for all EPS applications, should flame retarded EPS not be available.

The KLIF (2011) study noted that the alternatives typically have better fire performance and contain less ‘problematic’ chemical substances. The price of the cheapest alternatives ranged from more or less the same price as for flame retarded EPS to approximately 30% more. They also noted that alternatives of significantly higher price exist, but these are typically used because they have some desired technical advantages and would, because of the price, probably not be the first choice substitutes for general application. For some applications, where flame resistance is not needed, non-flame retarded EPS would probably take over, to the extent that national regulations allow.

Another research project has been conducted by Plastics Europe to evaluate the performance of different insulating materials; that programme was called “A Multi-Criteria Evaluation and

Comparison of Insulation Materials in Europe". The detailed results are subject to legal agreements between the funding parties and therefore cannot be fully set out here, nevertheless a summary as presented below allows comparison of the materials and demonstrates that detailed research has been done to investigate the specific need for EPS insulating materials.

The purpose of the study was to develop a multi-criteria evaluation and comparison of different thermal insulation materials in Europe, and the result was an assessment of the contribution to sustainability, as well as a guide to the advantages and disadvantages of these materials used in buildings.

The study comprised a comparative assessment of the most important insulation materials in their building applications using Germany, Italy and Sweden as reference countries. However, no results for Sweden were available because of difficulties in obtaining reliable information on specific applications and materials used.

The study covered all typical insulation applications and the most common insulation materials used for these applications, meaning that more than 300 insulation products were analysed.it included the following applications: flat roof, pitched roof, wall (both External Thermal Insulation Composite Systems (ETICS) and ventilated façade), perimeter insulation (both below and above foundation slab). The materials studies were: Fibres; including glass wool, stone wool, wood fiber, cellulose slabs, hemp/flax and Foams; including EPS/Grey EPS, XPS, PUR/PIR, foam glass and aerogel.

The study used a life cycle analysis (LCA) methodology and made comparisons of products having the same insulation performance. It was considered methodologically essential to compare insulation materials taking the final application in the building into account. This was achieved by an assessment on the basis of the same performance (U-value[38]) for a given application, including all necessary measures to fix and protect the material. (This approach should be a prerequisite for all comparative sustainability considerations of insulation materials and is now also required by the European standardization of sustainable construction assessments meanwhile developed in CEN TC 350. Results can be different compared to a mass or volume based approach).

An important part of the findings were based on data from Environment Product Declarations (EPDs) according to ISO 14025. Although these EPDs are based on the same standard and are third party verified, it was believed that comparability might be limited because of different units taken into account and other methodological differences and that more harmonized approaches will be needed in the future. Data from Eco-Invent were used in the absence of EPD.

The most important additives with hazard classifications commonly used in thermal insulation materials were identified and simplified risk assessment undertaken, based on physical properties and eco-toxicological parameters. However, due to lack of consistent exposure data, assumptions were made on exposure probabilities.

Information on intrinsic hazards was connected with projections on exposure that were based on production volume and the wide use of a substance in many applications' possible exposure routes. It was assumed that these indicators allowed for a projection of exposure probabilities with

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[38] A U value is a measure of heat loss [transport] in a building element such as a wall, floor or roof. It can also be referred to as an 'overall heat transfer co-efficient' and measures how well parts of a building transfer heat. This means that the higher the U value the worse the thermal performance of the building envelope. A low U value usually indicates high levels of insulation. Reference: Royal Institute of British Architects (RIBA) http://www.architecture.com accessed September 2013.

sufficient exactness, while it was not claimed that these assumptions created an accurate picture of reality. (It was acknowledged however that this aspect clearly required further methodology developments to take exposure into account more accurately).

The study concluded:

- That all insulation materials, including the impact of necessary constructions and adaptations of the building, have an overall positive effect on the sustainability of a building calculated over its lifecycle.
- There is no single material that is best in all applications. Results depended significantly on the application and construction.
- The performance of natural based materials is not necessarily better than plastics or minerals.

3.2.2 Data searches

The main research on possible alternatives is as reported in Section 3 an extensive (nine year) research programme deployed involving both the substance manufacturers and the EPS producers in order to identify a technically feasible alternative to HBCDD. The phased programme that involved the initial screening of possible existing alternatives and testing in EPS foams showed that no suitable alternatives existed. The research is the property of Plastics Europe, which was consulted extensively for the preparation of this document (see Appendix 2).

The UNEP Stockholm Convention process publicly available documents were consulted to ensure that alternatives being considered under that programme were considered for this analysis.

Searches for material safety data sheets (MSDS) for flame retardants were conducted.

The SUBSPORT programme was consulted and in particular the reporting from that programme on HBCDD and alternatives - http://www.subsport.eu/.

The USEPA ‘Design for the Environment’ Programme output on HBCDD and its alternatives for use in insulation plastics was used. (http://www.epa.gov/dfe/pubs/projects/hbcd/about.htm)

Data and material from The European Manufacturers of Expanded Polystyrene – EUMEPS - http://www.eumeps.org/, was used for this study.

Data and information on the need for flame retarding EPS and XPS and the uses of foams for building insulation was from European Extruded Polystyrene Insulation Board Association – EXIBA - http://www.exiba.org/.

3.2.3 Consultations

As above, Plastics Europe was essential for the provision of information on R&D of alternatives and identification of the pFR.

Upwards in the supply chain: HBCDD and pFR manufacturers (Chemtura, ICL and Albemarle) were consulted for information on HBCDD and the expected supply of the pFR.

Downwards in the supply chain: EPS members and their customers were consulted, in particular converter companies in Europe.

Also consulted were:
The European Manufacturers of Expanded Polystyrene - EUMEPS - http://www.eumeps.org/
European Extruded Polystyrene Insulation Board Association – EXIBA - http://www.exiba.org/
UNEP process via Plastics Europe representation The European Commission – DG Environment and Enterprise – via UNEPS process

ECHA: via the pre-submission information session (PSIS) and in response to specific procedural questions regarding the application.

4 SUITABILITY AND AVAILABILITY OF POSSIBLE ALTERNATIVES

As detailed in section 3.2, an extensive research programme was done to identify and develop a viable alternative. This process identified and developed the pFR (i.e. benzene, ethenyl-, polymer with 1,3-butadiene, brominated (CAS 1195978-93-8). The research reported by Plastics Europe (see section 2.5) did not specify exactly which alternatives were tried and failed (this is known but the information is subject to legal restrictions and thus cannot be used). However the list made available by Plastics Europe and then forwarded to the UNEP (Stockholm Convention) process, is being used as the 'working list' of possible substance alternatives. These are referred to below. Note that the first alternative is the pFR benzene, ethenyl-, polymer with 1,3-butadiene, brominated (brominated co-polymer of styrene and butadiene), that is not currently available; subsequent alternatives are not suitable.

4.1 ALTERNATIVE 1

4.1 a Substance ID and properties

Chemical Name(s): benzene, ethenyl-, polymer with 1,3-butadiene, brominated (brominated co-polymer of styrene and butadiene)
Trade Name(s): Emerald 3000, FR122P, GreenCrest
CAS Number: 1195978-93-8

Information from SDS for Emerald Innovation™ 3000, Chemtura 2012

Not a hazardous substance or mixture according to Regulation (EC) No. 1272/2008.
Classification (67/548/EEC, 1999/45/EC)

Not a hazardous substance or mixture according to EC-directives 67/548/EEC or 1999/45/EC.

Acute toxicity
Acute oral toxicity: > 2,000 mg/kg, Species: rat
Acute inhalation toxicity: Remarks: Not classified due to lack of data.
Acute dermal toxicity: Remarks: Not classified due to lack of data.
Skin corrosion/irritation
Skin irritation: Species: rabbit, Result: slight irritation; Method: OECD Test Guideline 404
Serious eye damage/eye irritation, Eye irritation: Species: rabbit, Result: Mild eye irritation

Respiratory or skin sensitization
Sensitisation : Buehler Test; Species: guinea pig; Result: Does not cause skin sensitization.
Method: OECD Test Guideline 406
Mutagenicity Assessment; Remarks: In vitro tests did not show mutagenic effects
Carcinogenicity Assessment; Remarks: Not classified due to lack of data.
Reproductive toxicity Assessment; Remarks: No toxicity to reproduction
Target Organ Systemic Toxicant - Single exposure: Remarks: Not classified due to lack of data.
Target Organ Systemic Toxicant - Repeated exposure: Remarks: Not classified due to lack of data.
Aspiration hazard
Aspiration toxicity: No aspiration toxicity classification

Toxicology Assessment:
Further information: No data is available on the product itself.

Ecological information:
Toxicity to fish: Remarks: no data available
Toxicity to Daphnia and other aquatic invertebrates: EC_{50}: > 1,000 mg/l; Exposure time: 48 h
Species: *Daphnia magna* (Water flea)

Persistence and degradability:
Biodegradability: Result: Not biodegradable

Bioaccumulative potential
Bioaccumulation : Remarks: no data available

Mobility in soil:
Mobility: Remarks: no data available

Results of PBT and vPvB assessment:
This substance is not considered to be bioaccumulative or toxic (PBT), it is however known to be intentionally persistent.

Other adverse effects:
Additional ecological information: There are no data available for this product.

The SUBSPORT initiative[39] also lists the profile of the pFR, the information is summarized below:

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[39] http://www.subsport.eu/

Table 4.1 Properties of benzene, ethenyl-, polymer with 1,3-butadiene, brominated (brominated co-polymer of styrene and butadiene) - CAS 1195978-93-8 (reproduced from SUBSPORT Specific Substances Alternatives Assessment – Hexabromocyclododecane June 2013)

Chemical Properties	**Characteristics of Chemical**	**Source(s) of Information**
Physical Hazards		
Explosivity	No information available	-
Flammability	No information available	-
Oxidizing	No information available	-
Human Health Hazards		
Acute toxicity	No information available	-
Skin or eye corrosion/irritation	Slightly irritating to skin; mildly irritating to the eyes	Chemtura MSDS 2013[1]
Chronic toxicity		
Carcinogenicity	Not classified by IARC	IARC 2013[2]
Mutagenicity	No genotoxicity observed (Ames, RLCAT)	Davis 2011[3]
Endocrine disruption	No information available	-
Respiratory or skin sensitization	Non-sensitizing (Buehler GP)	Davis 2011
Neurotoxicity	Not listed by Vela et al.	Vela *et al.* 2003[4]
Immune system toxicity	No information available	-
Systemic toxicity	No information available	-
Toxic metabolites	Carbon oxides and hydrogen halides	Chemtura MSDS 2013
Environmental Hazards		
Acute/chronic aquatic toxicity	EL50>1000 mg/l, Water Accommodated Fraction (WAF) Note, source also lists LL10 = 1,000 mg/kg (WAF) “Long-term aquatic toxicity not expected”	Davis 2011
Bioaccumulation	Not determined – polymer	Davis 2011
Persistence	Persistent (by design). Note – source indicates anaerobic bio-degradation study (OECD 311) exhibited no biodegradation. Simulation test degradation (OECD 311) in progress. No biotic degradation estimated. OECD 111 test indicates no hydrolysis.	Davis 2011
Greenhouse gas formation potential	No information available	-

Ozone-depletion potential	Not found on Scorecard Montreal Protocol List of Ozone Depleting Substances; not listed on UNEP trade names of chemicals containing ozone depleting substance	Green Media Toolshed 2010 UNEP Ozone Action Branch[5]
Monitoring - has the substance been found in human or environmental samples?	No information available	-

Note – The chemical properties are those listed by Subsport and do not necessarily relate to specific hazards as identified in EU classification.

References to the SUBSPORT table:

1.) Chemtura Corporation. 2013. Material Safety Data Sheet (MSDS): Emerald Innovation 3000. Accessed at http://www.chemtura.com/msd/external/e/result/report.jsp?P_LANGU=E&P_SYS=6&P_SSN=41418&P_REP=00000000000000000360&P_RES=5201

2. International Agency for Research on Cancer (IARC). 2013. Agents Classified by the IARC Monographs, Volume 1-107. Accessed at http://monographs.iarc.fr/ENG/Classification/ClassificationsAlphaOrder.pdf

3.) Davis, John W., et al. 2011. Dow Chemical Co., 12th Workshop on Brominated and other Flame Retardants, June 5-7, 2011, Boston University, Boston, MA.

4.) Vela, M.M., Laborda, R. and Garcia, A.M. 2003. Neurotoxins: Classification Criteria and Provisional Listing. Arch Prev Riesgos Labor; 6 (1): 17 – 25.

5) Green Media Toolshed. 2011. Scorecard: Regulations: Environmental Hazard Lists: Ozone Depleting Substances List (Montreal Protocol). Accessed October 27, 2011 from http://scorecard.goodguide.com/chemical-groups/one-list.tcl?short_list_name=ods

The United States Environmental Protection Agency (USEPA) has assessed possible alternatives for HBCDD[40] including the pFR. The USEPA's assessment of the hazard profile of the pFR is set out in Table 4.2.

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[40] Flame Retardant Alternatives For Hexabromocyclododecane (HBCDD), Draft For Public Comment September 2013

Table 4.2: Properties of benzene, ethenyl-, polymer with 1,3-butadiene, brominated (brominated co-polymer of styrene and butadiene) - CAS 1195978-93-8 (reproduced from USEPA report Flame Retardant Alternatives For Hexabromocyclododecane (HBCDD), Draft For Public Comment September 2013)

Property/endpoint	Data	Reference	Data quality
PHYSICAL/CHEMICAL PROPERTIES			
Melting Point (°C)			No data located.
Boiling Point (°C)	>300 (Estimated)	Professional judgment	Cutoff value used for large, high MW solid.
Vapor Pressure (mm Hg)	$<10^{-8}$ (Estimated)	Professional judgment; EPA, 2012	Cutoff value for large, high MW polymers according to SF polymer assessment guidance.
Water Solubility (mg/L)	No dissolved organic carbon (DOC) was detected in water at pH 2, 7 and 9 at 20°C and pH 7 at 37°C after 24 hours according to test guideline OECD 120 with 0.05 and 0.5 g samples (Measured)	Dow, 2005c	OECD test guideline 120 is for solid polymers for which the Water Solubility OECD 105 test is not applicable. For OECD 120, the solution/extraction behavior of the polymer in water at a range of pH values is analyzed.
	$<10^{-3}$ (Estimated)	Professional judgment; EPA, 2012	Cutoff value for large, high MW non-ionic polymers according to SF polymer assessment guidance.
Log K_{ow}			No data located; polymers with a MW >1,000 are outside the domain of the available estimation methods.
	Approximately 2 (Measured)	Chemtura, 2011	Inadequate, the K_{OW} is not consistent with the structure of the material. Insufficient details were available to assess the quality of this value.
Flammability (Flash Point)	Nonflammable (Estimated)	Professional judgment	No experimental data located; based on its use as a flame retardant.
Explosivity	Not expected to form explosive mixtures with air (Estimated)	Professional judgment	No experimental data located; based on its use as a flame retardant.

Property/endpoint		Data	Reference	Data quality
Pyrolysis		DfE[1] assessment methodology indicates that chemicals that contain both halogens and aromatic rings have the potential to form compounds potentially hazardous compounds under high temperature conditions (Estimated)	Professional judgment	Based on analysis of the chemical structure.
pH		Not applicable	Professional judgment	Does not contain functional groups that are expected to ionize under environmental conditions.
pKa		Not applicable	Professional judgment	Does not contain functional groups that are expected to ionize under environmental conditions.
HUMAN HEALTH EFFECTS				
Toxicokinetics		There is no absorption expected for any route of exposure. This polymer is large, with a MW >1,000. It is expected to have limited bioavailability and is therefore not expected to be readily absorbed, distributed or metabolized in the body.		
Dermal Absorption *in vitro*				No data located.
Absorption, Distribution, Metabolism & Excretion	Oral, Dermal or Inhaled	No absorption expected for any route of exposure (Estimated)	Professional judgment	Estimated based on professional judgment.
Acute Mammalian Toxicity		LOW: Based on experimental LD50 values >2,000 mg/kg. This polymer is also expected to have limited bioavailability and is therefore of low potential for acute mammalian toxicity.		
Acute Lethality	Oral	rat LD50 >2,000 mg/kg	Chemtura, 2011	Limited study details and no supporting data provided.
		Oral, mouse LD50 >5,000 mg/kg	Dow, 2005a	Sufficient study details provided.
		Oral, rat LD50 >2,000 mg/kg in Up and Down Procedure.	Dow, 2007e	Sufficient study details provided.
	Dermal	Limited bioavailability expected (Estimated)	Professional judgment; EPA, 2012	Based on SF polymer assessment guidance.
	Inhalation			

Property/endpoint		Data	Reference	Data quality
Carcinogenicity		LOW: This polymer is large, with a MW >1,000. It is expected to have few to no residual monomers. Additionally, it is not expected to have crosslinking, swellability, dispersability, reactive functional groups, potential for inhalation or hindered amine groups. This chemical therefore has a low potential for carcinogenicity. No experimental data located.		
	OncoLogic Results			No data located.
	Carcinogenicity (Rat and Mouse)	Limited bioavailability expected (Estimated)	Professional judgment; EPA, 2012	Based on SF polymer assessment guidance.
	Combined Chronic Toxicity/Carcinogenicity			
Genotoxicity		LOW: This compound did not induce gene mutations in bacteria or cause chromosomal aberrations in mammalian cells in vitro. In addition, this polymer is large, with a MW >1,000. It is expected to have limited bioavailability; therefore, it has low potential for genotoxicity.		
	Gene Mutation in vitro	Negative in Ames assay in *S. typhimurium* TA98, TA100, TA1535, TA1537, and in *E. coli* WP2*uvr*A in the presence of metabolic activation	Dow, 2005b	Sufficient study details and supporting data provided.
	Gene Mutation in vivo	Limited bioavailability expected (Estimated)	Professional judgment; EPA, 2012	Based on SF polymer assessment guidance.
	Chromosomal Aberrations in vitro	Negative in rat lymphocyte chromosomal aberration test (RLCAT)	Dow, 2006	Sufficient study details and supporting data provided.
	Chromosomal Aberrations in vivo	Limited bioavailability expected (Estimated)	Professional judgment; EPA, 2012	Based on SF polymer assessment guidance.
	DNA Damage and Repair			No data located.
	Other			No data located.
Reproductive Effects		LOW: Available experimental data indicate a Low hazard designation. In addition, this polymer is large, with a MW >1,000. It is expected to have limited bioavailability; therefore, it has low potential for reproductive effects.		

Property/endpoint		**Data**	**Reference**	**Data quality**
	Reproduction/ Developmental Toxicity Screen	No reproductive effects were observed in combined repeated dose toxicity study (28-day) with reproductive/developmental toxicity screening test in Crl:CD (SD) rats orally exposed to 0, 100, 300, or 1,000 mg/kg-day via gavage. NOAEL >1,000 mg/kg-day (highest dose tested)	Dow, 2007f	Sufficient study details and supporting data provided; effects on reproductive and developmental functions including organ weights, histopathological examinations of tissues, litter size, pup survival, sex, body weight, and the presence of gross external abnormalities were evaluated; conducted according to OECD guidelines.
	Combined Repeated Dose with Reproduction/ Developmental Toxicity Screen	Limited bioavailability expected (Estimated)	Professional judgment; EPA, 2012	Based on SF polymer assessment guidance
	Reproduction and Fertility Effects			
Developmental Effects		LOW: Available experimental data also indicate a Low hazard designation. In addition, this polymer is large, with a MW >1,000. It is expected to have limited bioavailability; therefore, it has low potential for developmental effects.		
	Reproduction/ Developmental Toxicity Screen	No developmental effects were observed in combined repeated dose toxicity study (28-day) with reproductive/developmental toxicity screening test in Crl:CD (SD) rats orally exposed to 0, 100, 300, or 1,000 mg/kg-day via gavage. Developmental NOAEL >1,000 mg/kg-day (highest dose tested)	Dow, 2007f	Sufficient study details and supporting data provided; effects on reproductive and developmental functions including organ weights, histopathological examinations of tissues, litter size, pup survival, sex, body weight, and the presence of gross external abnormalities were evaluated; conducted according to OECD guidelines.

Property/endpoint		**Data**	**Reference**	**Data quality**
	Combined Repeated Dose with Reproduction/ Developmental Toxicity Screen	Limited bioavailability expected (Estimated)	Professional judgment; EPA, 2012	Based on SF polymer assessment guidance.
	Prenatal Development			
	Postnatal Development			
Neurotoxicity		LOW: This polymer is large, with a MW >1,000. It is expected to have limited bioavailability; therefore, it has low potential for neurotoxicity. There were no neurological effects reported in a 28-day repeated dose toxicity study in rats at doses as high as 1,000 mg/kg-day.		
	Neurotoxicity Screening Battery (Adult)	Limited bioavailability expected (Estimated)	Professional judgment; EPA, 2012	Based on SF polymer assessment guidance.
		There were no neurological effects observed in a combined repeated dose toxicity study (28-day) with reproductive/developmental toxicity screening test in Crl:CD (SD) rats orally exposed to 0, 100, 300, or 1,000 mg/kg-day via gavage. NOAEL >1,000 mg/kg-day (highest dose tested)	Dow, 2007f	Sufficient study details and supporting data provided; effects on neurological functions including sensory evaluation, rectal temperature, grip performance, and motor activity were evaluated; conducted according to OECD guidelines.
Repeated Dose Effects		LOW: Based on an experimental NOAEL >1,000 mg/kg-day in rats exposed via gavage for 28 days. This polymer is large, with a MW >1,000. It is expected to have limited bioavailability; however, because the number average molecular weight (MWn) is >10,000, there is the possibility of lung overloading in dust forming conditions.		

Property/endpoint	Data	Reference	Data quality
	This MWn for this polymer is >10,000; potential for irreversible lung damage as a result of lung overloading (Estimated)	Professional judgment; EPA, 2012	Based on SF polymer assessment guidance.
	No adverse effects were observed in a combined repeated dose toxicity study (28-day) with reproductive/developmental toxicity screening test in Crl:CD (SD) rats orally exposed to 0, 100, 300, or 1,000 mg/kg-day via gavage. NOAEL >1,000 mg/kg-day (highest dose tested)	Dow, 2007f	Sufficient study details and supporting data provided; conducted according to OECD guidelines.
Skin Sensitization	LOW: This polymer did not cause skin sensitization in a guideline study.		
	Does not cause skin sensitization in guinea pig by Buehler test	Dow, 2007b	Sufficient study details and supporting data provided. Conducted according to OECD Test Guideline 406
Respiratory Sensitization	No data located.		
Eye Irritation	LOW: This polymer is non-irritating to mildly irritating in rabbits eyes. Because the number average molecular weight (MWn) is >10,000, irritation may be indirect by mechanical action (i.e., scratching) due to the particles of the substance.		

Property/endpoint		**Data**	**Reference**	**Data quality**
	Eye Irritation	Mildly irritating, rabbits	Chemtura, 2011	Limited study details and no supporting data provided.
		Non-irritating (species not specified)	Dow, 2011	Limited study details and no supporting data provided.
		Irritating, rabbits Single instillation of 20 mg of the test substance caused iritis and conjunctivitis, clearing within 72 hours.	Dow, 2007c	Sufficient study details provided; study conducted according to OECD guidelines; evaluated by the Draize method; irritations may have been due to mechanical action (scratching) due to the 20 mg instillation of the test substance particles.
Dermal Irritation		LOW: This polymer is slightly irritating to the skin of rabbits.		
	Dermal Irritation	Slight irritation in rabbits according to OECD Test Guideline 404	Chemtura, 2011	Limited study details and no supporting data provided.
		Slightly irritating in rabbits; caused slight erythema that cleared within 24 hours	Dow, 2007d	Sufficient study details and supporting data provided.
Endocrine Activity		This polymer is large, with a MW >1,000. It is not expected to have endocrine activity due to its limited bioavailability and inability to be readily metabolized in the body.		
		Limited bioavailability expected (Estimated)	Professional judgment; EPA, 2012	Based on SF polymer assessment guidance.
Immunotoxicity		This polymer is large, with a MW >1,000. It is expected to have limited bioavailability; therefore, it has low potential for immunotoxicity.		
	Immune System Effects	Limited bioavailability expected (Estimated)	Professional judgment; EPA, 2012	Based on SF polymer assessment guidance.
ECOTOXICITY				

Property/endpoint	**Data**	**Reference**	**Data quality**
ECOSAR Class	Not applicable		
Acute Toxicity	LOW: Non-ionic polymers with MWs >1,000 that do not contain reactive functional groups and are comprised of minimal low MW oligomers are estimated to display no effects at saturation (NES). These polymers display NES because the amount dissolved in water is not anticipated to reach a concentration at which adverse effects may be expressed. Guidance for the assessment of aquatic toxicity hazard results in a Low hazard designation for those materials that display NES. Experimental data for *Daphnia magna* indicate NES with EC50 values > 1,000 mg/L; these reported values exceed the compound's water solubility by several orders of magnitude.		
Fish LC50	NES	Professional judgment	The large MW, limited bioavailability and low water solubility suggest that there will be NES.
Daphnid LC50	Daphnia (*Daphnia magna*) 48-hour EC50 >1,000 mg/L (Experimental)	Chemtura, 2011	Study conducted according to OECD Test Guideline 202 with limited supporting data and study details provided. The reported endpoint exceeds the water solubility by many orders of magnitude.
	Daphnia magna 48-hour EL50 > 1,000 mg/L. EL50 is the effect (immobility) loading rate resulting in 50% immobility; 24-hour EL50 > 1,000 mg/L; 48-hour no-observed-effect loading rate (NOELR) < 1,000 mg/L (Experimental)	Dow, 2007a	Sufficient study details provided. The reported value was determined using a water accommodated fraction (WAF) at a loading rate of 1,000 mg (only concentration tested); the toxicity values were determined based on the nominal loading rate used to prepare the WAF solution. As a result, the reported value exceeds this material's water solubility; immobility was reported in 10% (3/30) daphnids at the test dose (1,000 mg/L) following 24- and 48- hours of exposure, therefore the NOELR is determined to be at some concentration less than 1,000 mg/L.
	NES	Professional judgment	The large MW, limited bioavailability and low water solubility suggest that there will be NES.
Green Algae EC50	NES	Professional judgment	The large MW, limited bioavailability and low water solubility suggest that there will be NES.
Chronic Aquatic Toxicity	LOW: Non-ionic polymers with a MW >1,000 that do not contain reactive functional groups and are comprised of minimal low MW oligomers are estimated to display NES. These polymers display NES because the amount dissolved in water is not anticipated to reach a concentration at which adverse effects may be expressed. Guidance for the assessment of aquatic toxicity hazard results in a low hazard categorization for those materials that display NES.		

Property/endpoint		**Data**	**Reference**	**Data quality**
Fish ChV		NES	Professional judgment	The large MW, limited bioavailability and low water solubility suggest that there will be NES.
Daphnid ChV		NES	Professional judgment	The large MW, limited bioavailability and low water solubility suggest that there will be NES.
Green Algae ChV		NES	Professional judgment	The large MW, limited bioavailability and low water solubility suggest that there will be NES.
ENVIRONMENTAL FATE				
Transport		The negligible water solubility and estimated negligible vapor pressure indicate that this polymer is anticipated to partition predominantly to soil and sediment. The estimated Henry's Law constant of <10-8 atm-m3/mole indicates that it is not expected to volatilize from water to the atmosphere. The estimated Koc of >30,000 indicates that it is not anticipated to migrate from soil into groundwater and that it has the potential to adsorb to sediment.		
	Henry's Law Constant (atm-m3/mole)	<10-8 (Estimated)	Professional judgment; EPA, 2012	High MW polymers are expected to have low vapor pressure and are not expected to undergo volatilization according to polymer assessment guidance.
	Sediment/Soil Adsorption/Desorption Coefficient – Koc	>30,000 (Estimated)	Professional judgment; EPA, 2012	Cutoff value used for large, high MW polymers. High MW polymers are expected to adsorb strongly to soil and sediment according to SF polymer assessment guidance.
	Level III Fugacity Model			No data located
Persistence		VERY HIGH: This polymer is large, with a MW >1,000. It has negligible water solubility and is expected to have poor bioavailability to microorganisms, indicating that neither biodegradation nor hydrolysis are expected to be important removal processes in the environment. Additionally, experimental guideline studies did not detect anaerobic biodegradation of this polymer after 62 days or degradation by hydrolysis after five days at pH 1.2 to 9. Although debromination by photodegradation of polybrominated benzenes has been observed, this process is not anticipated to lead to ultimate degradation of the material; also, limited debromination is not likely to significantly alter the environmental properties of this material. As a result, a half-life for this high MW polymer of >180 days leads to a potential for Very High persistence.		
Water	Aerobic Biodegradation	Recalcitrant (Estimated)	Professional judgment; EPA, 2012	High MW synthetic polymers are expected to be non-biodegradable according to SF polymer assessment guidance.
	Volatilization Half-life for Model River	>1 year (Estimated)	Professional judgment	Based on the magnitude of the estimated Henry's Law constant.

Property/endpoint		**Data**	**Reference**	**Data quality**
	Volatilization Half-life for Model Lake	>1 year (Estimated)	Professional judgment	Based on the magnitude of the estimated Henry's Law constant.
Soil	Aerobic Biodegradation			No data located.
	Anaerobic Biodegradation	Anaerobic Biodegradation OECD 311 study exhibited no biodegradation after 62 days (Measured)	Dow, 2009a	Guideline study.
	Soil Biodegradation with Product Identification			No data located.
	Sediment/Water Biodegradation			No data located.
Air	Atmospheric Half-life			No data located.

Property/endpoint		**Data**	**Reference**	**Data quality**
Reactivity	Photolysis	Photodegradation was detected in studies using the bulk polymer and the polymer in foam; 9,600 ppm water extractable bromide was detected from 0.022 g of bulk polymer samples by IC-MS after 30 days of light exposure from a Xenon arc lamp with a UV glass filter limiting wavelengths below 290 nm at 28-39°C (Measured)	Dow, 2007h; Dow, 2009c	Bromine substituents may be susceptible to photolysis in the environment; however, this is expected to be a relatively slow process for a high MW brominated polymer and is not anticipated to result in the ultimate degradation of this substance.
	Hydrolysis	Not susceptible to hydrolysis according to OECD 111 based on average DOC values of: 1.76 ± 0.51 mg/L at pH 1.2; 0.81 ± 0.30 mg/L at pH 4; 1.25 ± 0.35 mg/L at pH 7; 1.33 ± 0.40 mg/L at pH 9 obtained from 914 ± 112 mg/L of sample at 49.9°C for 5 days (Measured)	Dow, 2007g	Guideline study.

Property/endpoint		**Data**	**Reference**	**Data quality**
	Other	This polymer is stable in PEG400 for 21 days; 2.5-250 mg/mL samples analyzed by HPLC/RI (Measured)	Dow, 2007i	This study demonstrates the stability of this compound in PEG400.
Environmental Half-Life		>180 days (Estimated)	Professional judgment	The substance is a high MW synthetic polymer and is not anticipated to be assimilated by microorganisms. Therefore, biodegradation is not expected to be an important removal process. It is also not expected to undergo removal by other degradative processes under environmental conditions.
Bioaccumulation		LOW: Due to the large size and limited bioavailability of the high MW brominated polymer, it is of low potential for bioconcentration or bioaccumulation.		
	Fish BCF	<100 (Estimated)	Professional judgment; EPA, 2012	Cut-off value for large, high MW, insoluble polymers according to SF polymer assessment guidance.
	BAF			No data located.
	Metabolism in Fish			No data located.
ENVIRONMENTAL MONITORING AND BIOMONITORING				
Environmental Monitoring		No data located.		
Ecological Biomonitoring		No data located.		
Human Biomonitoring		This chemical was not included in the NHANES biomonitoring report (CDC, 2011).		

1) USEPA's 'Design for the Environment' (DfE) Program. A DfE Alternatives Assessment identifies and compares potential alternatives that can be used as substitutes to replace chemicals that the Agency has designated for action.

References to table 4.2:

Dow 2005a. The Dow Chemical Company. Acute oral toxicity screen in mice. PMN number P10-0476.
Dow 2005b. The Dow Chemical Company. Charles, G; M; Kleinert, K. *Salmonella/E. coli* reverse mutation screening assay for [confidential substance] with mammalian S-9 activation. PMN number P10-0476.

Dow 2006. The Dow Chemical Company. Charles, G; Schisler, M; Kleinert, K. Evaluation of the alcohol and aqueous extracts of [confidential substance] in an in vitro chromosomal aberration assay utilizing rat lymphocytes. PMN number P10-0476.
Dow 2007a. The Dow Chemical Company. Marino, T; Hales, C; Najar J. An acute toxicity study with the daphnid, *Daphnia magna*. PMN number P10-0476.
Dow 2007b. The Dow Chemical Company. Dermal sensitization study in guinea pigs (Buehler method). PMN number P10-0476.
Dow 2007c. The Dow Chemical Company. Primary eye irritation study in rabbits. PMN number P10-0476.
Dow 2007d. The Dow Chemical Company. Primary skin irritation study in rabbits. PMN number P10-0476.
Dow 2007e. The Dow Chemical Company. Acute oral toxicity up and down procedure in rats. PMN number P10-0476.
Dow 2007f. The Dow Chemical Company. Yano, B; Zablotny, C; Murray, J. A combined repeated dose toxicity study with the reproduction/developmental toxicity screening test in CRL: CD (SD) rats. PMN number P10-0476.

4.2a Technical feasibility

See the details set out in Section 3.2 on selection of the alternative and Section 3 on availability of the alternative.

4.3a Reduction of overall risk due to transition to the alternative

According to the MSDS information and the industry hazard assessment the Polymeric FR is potentially very persistent, but has low potential for bioaccumulation and low potential for toxicity. On the basis of this, the pFR will not meet the criteria for PBT/vPvB.

The evaluation of the substance in terms of its health, safety and environmental profile is set out in Section 3.2; specific details of a risk assessment conducted on the pFR substance were not available, due to legal restriction on the information.

4.4a Economic feasibility

It is known that the pFR costs more than HBCDD, but it is assumed that this will be economically feasible, since the applicants intend to phase-in the pFR, although no full price comparison data are available.

4.5a Availability

The discussion and argumentation on availability of the pFR is key in this application. Detail is given in Section 5 of this document and in the accompanying SEA document (Section 2.3 of the SEA report).

4.6a Conclusion on suitability and availability for Alternative 1

This is the alternative that has been selected by the EPS manufacturers to replace HBCDD. However, there is expected to be insufficient supply for continued production of EPS in the short term following the sunset date for HBCDD. See section 4 and SEA.

b) ALTERNATIVE 2

Pyroguard SR-130 (CAS #97416-84-7), 1,1’-(1methylethyleidene)bis[3,5-dibromo-4-(2,3-dibromo-2-methylpropoxy)], is a brominated molecule which is understood to be being developed by Dai-Ichi Kogyo Seiyaku Co, Ltd (it is subject to a European Patent along with other BFRs for use in EPS and other plastics). Because of its size (it is not a polymer, for structure see Table 3.2), Pyroguard SR-130 is likely to behave in a similar manner to HBCDD in the environment. No information about this chemical is currently publicly available (Subsport 2013, HBCDD report 2013).

4.1b Substance ID and Properties

Chemical Name(s): Benzene, 1,1'- (1-methylethylid ene)bis[3,5-dibromo-4- (2,3-dibromo-2-methylpropoxy)]
Trade Name(s): Pyroguard SR-130, SR 130

CAS Number: 97416-84-7

4.2b Technical feasibility

The substance has been indicated as potentially suitable for EPS (see Table 3.2), however a research and development programme (as described in Section 3 of this document) considered a number of brominated substances as alternatives and found them not to be technically feasible. As mentioned in Section 3.2.1 above, within the R&D programme it was not possible to identify a manufacturer prepared to produce the substance for the European market and so this material has not been made commercially available. The substance is understood to be used in Japan as an alternative to HBCDD. This substance was not made available commercially to European EPS producers despite the offer of the EPS industry (via Plastics Europe) to work with the Japanese Producers Daiichi to develop the product: Plastics Europe has stated that "SR130 has been tested by EPS Alternative group .It is seen as an insurance policy in case there is any difficulty on the polymeric alternative side. EPS MC did approve the proposal to undertake the Bio accumulation test on the Daiichi material. This is the most critical step along the Reach registration of the product. Daiichi thanked us for our interest but did not want to send a sample for now." (Plastics Europe January 2012)

4.3b Reduction of overall risk due to transition to the alternative

According to ESIS[41], the substance is not classified in the Annex I of Directive 67/548/EEC. There are no data presented for self-classification of this substance in the Classification and Labeling Inventory (http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database).

There is not sufficient information on this substance to conduct an assessment of the risks, however as stated above, it could behave in a similar manner to HBCDD in the environment and given the general concern for brominated organic compounds (that are not polymers), which are used as flame retardants, it is not considered a suitable to replace HBCDD with a substance that is likely to be similar in environmental fate and behavior.

4.4b Economic feasibility

Given that this substance is considered to not be technically feasible, it is not relevant to investigate the economic feasibility of the substance.

4.5b Availability

This substance does not appear to have been registered under REACH in Phase 1 (>1000 tpa production/import) or Phase 2 (100 – 100 tpa) http://echa.europa.eu/en/information-on-chemicals/registered-substances.

This substance is listed in EINECS (European Inventory of Existing Commercial chemical Substances) meaning that it is a 'phase-in' substance under REACH.

Assuming that the substance could be registered in phase 3 of REACH, this means that the substance is currently only being supplied by each manufacturer/importer at less than 100 tpa.

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[41] European chemical Substances Information System, http://esis.jrc.ec.europa.eu/

The substance is listed on the REACH pre-registration list; however the envisaged registration deadline was for phase 1. That has not happened.

4.6b Conclusion on suitability and availability for Alternative 2

As stated in Section 3 of this document, it is known that this substance is not suitable as an alternative for HBCDD in EPS, since investigation of alternatives has been subject to a nine year research programme, in which a number of brominated compounds were rejected as possible alternatives on a technical and hazard profile basis and ultimately on the ability to commercialise. In addition, as summarized above, this substance is unlikely to have a health and safety profile that is better than HBCDD or the pFR and, given that the substance does not appear to be available at sufficient quantities for EPS manufacturers, it is not available to the EPS supply chain even if it were technically feasible today.

c) ALTERNATIVE 3

4.1c Substance ID and Properties

Chemical Name(s): Tetrabromobisphenol A bis (allyl ether)
Trade Name(s): BE 51, FG 3200, Fire Guard 3200, Flame Cut 122K, Pyroguard SR 319, SR 319
CAS Number: 25327-89-3

Table 4.2 Properties of tetrabromobisphenol A bis (allyl ether), CAS 25327-89-3 (reproduced from SUBSPORT Specific Substances Alternatives Assessment – Hexabromocyclododecane June 2013)

Chemical Properties	Characteristics of Chemical	Source(s) of Information
Physical Hazards		
Explosivity	No information available	
Flammability	No information available	
Oxidizing	No information available	
Human Health Hazards		
Acute toxicity	No information available	
Skin or eye corrosion/irritation	H319 (causes serious eye irritation)	ECHA C&L[1]
Chronic toxicity		
Carcinogenicity	Not classified by IARC	IARC 2013[2]
Mutagenicity	No information available	
Endocrine disruption	No information available	
Respiratory or skin sensitization	No information available	
Neurotoxicity	Not listed by Vela et al.	Vela *et al*. 2003[3]
Immune system toxicity	No information available	
Systemic toxicity	No information available	
Toxic metabolites	Has been shown to break down in estuarine sediments to bisphenol-A, which is known to be toxic and shows effects on the endocrine system.	Maag *et al*. 2010[4]
Environmental Hazards		
Acute/chronic aquatic toxicity	Inherently toxic to aquatic organisms; aquatic chronic: H413 (may cause long lasting harmful effects to aquatic life)	USEPA ACToR[5] ECHA C&L
Bioaccumulation	Not bioaccumulative	USEPA ACToR
Persistence	Persistent	USEPA ACToR
Greenhouse gas formation potential	No information available	
Ozone-depletion potential	Not found on Scorecard Montreal Protocol List of Ozone Depleting Substances; not listed on UNEP trade names of chemicals containing ozone depleting substance	Green Media Toolshed 2010 UNEP Ozone Action Branch[6]
Monitoring - has the substance been found in human or environmental samples?	No information available	

Note – The chemical properties are those listed by Subsport and do not necessarily relate to specific hazards as identified in EU classification.

References to the SUBSPORT table:

1. ECHA C&L Inventory database:
http://clp-inventory.echa.europa.eu/SummaryOfClassAndLabelling.aspx?SubstanceID=80879&HarmOnly=no?fc=true&lang=en

Accessed 23rd September 2013

2. International Agency for Research on Cancer (IARC). 2013. Agents Classified by the IARC Monographs, Volume 1-107. Accessed at http://monographs.iarc.fr/ENG/Classification/ClassificationsAlphaOrder.pdf

3.) Vela, M.M., Laborda, R. and Garcia, A.M. 2003. Neurotoxins: Classification Criteria and Provisional Listing. Arch Prev Riesgos Labor; 6 (1): 17 – 25.

4). Maag, J., Brandt, U.K., Mikkelsen S.H. and Lassen, C. 2010. Inclusion of HBCDD, DEHP, BBP, DBP and additive use of TBBPA in annex IV of the Commission's recast proposal of the RoHS Directive. Danish Environmental Protection Agency (DEPA), Environmental Project No. 13172010. Accessed at http://www2.mst.dk/udgiv/publications/2010/978-87-92617-52-1/pdf/978-87-92617-53-8.pdf

5). United States Environmental Protection Agency (USEPA), ACToR. Accessed at http://actor.epa.gov/actor/faces/ACToRHome.jsp

6) Green Media Toolshed. 2011. Scorecard: Regulations: Environmental Hazard Lists: Ozone Depleting Substances List (Montreal Protocol). Accessed October 27, 2011 from http://scorecard.goodguide.com/chemical-groups/one-list.tcl?short_list_name=ods

4.2c Technical feasibility

It is understood to be possible for use as a flame retardant for EPS manufactured by the 'two-step' process. The assumption therefore is that it is not technically feasible for the one step process. As stated in Section 2.1.3, in the two-step process the flame retardant is added after polymerization. This gives potentially wider possibilities of possible alternatives in the two-step process because there is less potential for the flame retardant molecule to interfere with polymerization of the styrene to polystyrene. For the reasons stated in Section 2.1.3, the two-step process is not used in Europe and therefore possible options for flame retardants are only relevant for the single step process. In addition a comprehensive research and development programme (as described in Section 3 of this document) considered a number of brominated substances as alternatives and found them not to be technically feasible.

4.3c Reduction of overall risk due to transition to the alternative

The substance is a derivative of TBBPA. Little information is available on hazardous properties. According to the information reviewed in KLIF (2009), it can be characterised with low toxicity, it is a potential immunotoxin, not easily hydrolysed and may be resistant to environmental degradation.

The substance is not classified in the Annex I of Directive 67/548/EEC. According to the ECHA Classification and Labeling portal[42] the self-classification for the substance is as follows:

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[42] http://clp-inventory.echa.europa.eu/SummaryOfClassAndLabelling.aspx?SubstanceID=80879&HarmOnly=no?fc=true&lang=en Accessed 23rd September 2013

Aquatic Chronic 4 H413 H413 (20 notifiers)
Eye Irrit. 2 H319 H319 – pictogram GHS07Wng (2 notifiers)
Eye Irrit. 2 H319 H319- pictogram Wng (1 notifiers)
Not Classified - (20 notifiers)

Consortium members have indicated that this alternative was not selected over the polymeric alternative due to its environmental profile. Indeed the research programme (as described in section 2 of this document) considered a number of brominated substances as alternatives and found them not to be technically feasible.

4.4c Economic feasibility

Given that this substance is considered to not be technically feasible, it is not relevant to investigate the economic feasibility of the substance.

4.5c Availability

This substance does not appear to have been registered under REACH in Phase 1 (>1000 tpa production/import) or Phase 2 (100 – 100 tpa) http://echa.europa.eu/en/information-on-chemicals/registered-substances.

This substance is listed in EINECS (European Inventory of Existing Commercial chemical Substances) meaning that it is a phase-in substance under REACH. According to ESIS, this substance is not classified in the Annex I of Directive 67/548/EEC.

Assuming that the substance could be registered in phase 3 of REACH, this means that the substance is currently only being supplied by each manufacturer/importer at less than 100 tpa.

The substance is listed on the REACH pre-registration list; however the envisaged registration deadline was for phase 1.According to the information available on substances registered in Phase 1[43], this substance was not registered in that phase.

4.6c Conclusion on suitability and availability for Alternative 3

As stated in Section 3 of this document, it is known that this substance is not suitable as an alternative for HBCDD in EPS, since investigation of alternatives has been subject to a nine year research programme in which a number of brominated compounds were rejected as possible alternatives. The possible use in the two-step process is not relevant to the one step process, as explained above. In addition, as summarized above, this substance is unlikely to have a health and safety profile that is better than HBCDD or the pFR (there are possible concerns for aquatic toxicity

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[43] http://echa.europa.eu/en/information-on-chemicals/registered-substances

and persistence in the environment – see also Table 3.2). Given that the substance does not appear to be available at sufficient quantities for EPS manufacturers it is not available to the EPS supply chain even if it were technically feasible today.

d) ALTERNATIVE 4

4.1d Substance ID and Properties

Chemical Name(s): 1,2,5,6-Tetrabromocyclooctane (TBCO)
Trade Name(s): Saytex BC-48
CAS Number: 3194-57-8

4.2d Technical feasibility

It is understood to be possible for use as a flame retardant for EPS manufactured by the 'two-step' process. The assumption therefore is that it is not technically feasible for the one step process. As stated in Section 2.1.3, in the two-step process the flame retardant is added after polymerization. This gives potentially wider possibilities of possible alternatives in the two-step process because there is less potential for the flame retardant molecule to interfere with polymerization of the styrene to polystyrene. For the reasons stated in Section 2.1.3, the two-step process is not used in Europe and therefore possible options for flame retardants are only relevant for the single step process.

As with other brominated non polymer compounds the R&D process eliminated these possible compounds on the grounds of technical infeasibility and/or hazard profile. This is also substantiated by other reports which indicate that tetrabromocyclooctane does not provide the functionality required for current EPS and XPS manufacturing processes (Weil 2009).

4.3d Reduction of overall risk due to transition to the alternative

A report by the UK Environment Agency (Fisk *et al*. 2003) indicates that TBCO is hazardous to the aquatic environment (i.e. chronic NOEC < 0.1 mg/l or acute L(E)C_{50}s < 10 mg/l), and potentially PBT/vPvB.

This substance is listed in EINECS (European Inventory of Existing Commercial chemical Substances) meaning that it is a phase-in substance under REACH. According to ESIS, this substance is not classified in the Annex I of Directive 67/548/EEC.

4.4d Economic feasibility

Given that this substance is considered to not be technically feasible, it is not relevant to investigate the economic feasibility of the substance.

4.5d Availability

According to a report of the Norwegian Climate and Pollution Agency, tetrabromocyclooctane seems to be no longer in production (KLIF 2011).

This substance does not appear to have been registered under REACH in Phase 1 (>1000 tpa production/import) or Phase 2 (100 – 100 tpa) http://echa.europa.eu/en/information-on-chemicals/registered-substances.

Assuming that the substance could be registered in phase 3 of REACH, this means that the substance is currently only being supplied by each manufacturer/importer at less than 100 tpa.

The substance is not listed on the REACH pre-registration list; however the envisaged registration deadline was for phase 1. According to the information available on substances registered in Phase 1[44], this substance was not registered in that phase.

4.6d Conclusion on suitability and availability for Alternative 4

As stated in Section 3 of this document, it is known that this substance is not suitable as an alternative for HBCDD in EPS, since investigation of alternatives has been subject to a nine year research programme in which a number of brominated compounds were rejected as possible alternatives. The possible use in the two-step process is not relevant to the one step process, as explained above. In addition, as summarized above, this substance is unlikely to have a health and safety profile that is better than HBCDD or the pFR (there are possible concerns for aquatic toxicity and persistence and bioaccumulation in the environment – see also Table 3.2). Given that the substance does not appear to be available at sufficient quantities for EPS manufacturers it is not available to the EPS supply chain even if it were technically feasible today.

e) ALTERNATIVE 5

4.1e Substance ID and Properties

Chemical Name(s): 2,4,6-Tribromophenyl allyl ether
Trade Name(s): Pyroguard FR 100, Great Lakes PHE-65, Bromkal 64-3AE
CAS Number: 3278-89-5

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[44] http://echa.europa.eu/en/information-on-chemicals/registered-substances

4.2e Technical feasibility

This substance is understood to be possible for use in the ‘two-step’ EPS manufacturing process. The assumption therefore is that it is not technically feasible for the one step process. As stated in Section 2.1.3, in the two-step process the flame retardant is added after polymerization. This gives potentially wider possibilities of possible alternatives in the two-step process because there is less potential for the flame retardant molecule to interfere with polymerization of the styrene to polystyrene. For the reasons stated in Section 2.1.3, the two-step process is not used in Europe and therefore possible options for flame retardants are only relevant for the single step process. In addition a comprehensive research and development programme (as described in Section 3 of this document) considered a number of brominated substances as alternatives and found them not to be technically feasible.

4.3e Reduction of overall risk due to transition to the alternative

Substance is not classified in the Annex I of Directive 67/548/EEC, there is no self-classification of the substance presented in the ECHA Classification and Labeling Inventory http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database).

The substance was proposed as one of the 120 HPV chemicals structurally similar to known Arctic contaminants (Brown &Wania 2008). It is considered likely to be bioaccumulative and subject to long range transport since the substance is found in Arctic seals in both blubber and brain (Von der Recke & Vetter 2007).

4.4e Economic feasibility

Given that this substance is considered to not be technically feasible, it is not relevant to investigate the economic feasibility of the substance.

4.5e Availability

This substance does not appear to have been registered under REACH in Phase 1 (>1000 tpa production/import) or Phase 2 (100 – 100 tpa) http://echa.europa.eu/en/information-on-chemicals/registered-substances.

This substance is listed in EINECS (European Inventory of Existing Commercial chemical Substances) meaning that it is a phase-in substance under REACH. According to ESIS, this substance is not classified in the Annex I of Directive 67/548/EEC.

Assuming that the substance could be registered in phase 3 of REACH, this means that the substance is currently only being supplied by each manufacturer/importer at less than 100 tpa.

The substance is listed on the REACH pre-registration list; however the envisaged registration deadline was for phase 1. According to the information available on substances registered in Phase 1[45], this substance was not registered in that phase.

4.6e Conclusion on suitability and availability for Alternative 5

As stated in Section 3 of this document, it is known that this substance is not suitable as an alternative for HBCDD in EPS, since investigation of alternatives has been subject to a nine year research programme in which a number of brominated compounds were rejected as possible alternatives. The possible use in the two-step process is not relevant to the one step process, as explained above. In addition, as summarized above, this substance is unlikely to have a health and safety profile that is better than HBCDD or the pFR (there are possible concerns for persistence and bioaccumulation in the environment – see also Table 3.2). Given that the substance does not appear to be available at sufficient quantities for EPS manufacturers it is not available to the EPS supply chain even if it were technically feasible today.

f) ALTERNATIVE 6

4.1f Substance ID and Properties

Chemical Name(s): Tetrabromobisphenol A bis(2,3- dibromopropylether) (TBBPADBPE) (with dicumyl peroxide for EPS, as usual synergist.)
Trade Name(s): GC SAM 55 E: powder blend for EPS
CAS Number: 21850-44-2

4.2f Technical feasibility

This substance is indicated as potentially suitable for EPS as a flame retardant. It is reported to have good thermal stability, be easily dispersible and compatible with polystyrene. It is insoluble in water and soluble in toluene and xylene. However, a comprehensive research and development programme (as described in Section 3 of this document) considered a number of brominated substances as alternatives and found them not to be technically feasible.

As mentioned in Section 3.2.1.1, the suppliers of SAM 55, Green Chemicals claim that the product is suitable for XPS, however suppliers MPi Chemi supply SAM 55 for XPS and for EPS. The EPS version SAM 55E is as described in Table 3.2 above, the XPS version SAM 55 is with the additive dicumene (CAS 1889-67-4) rather than dicumyl peroxide (CAS 80-43-3) .

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[45] http://echa.europa.eu/en/information-on-chemicals/registered-substances

4.3f Reduction of overall risk due to transition to the alternative

According to the KLIF (2009) review, TBBPADBPE has low toxicity with no endocrine effects have been observed. The information from the manufacturer suggests that TBBPADBPE has low biodegradability; it appears to be susceptible to hydrolysis and bioaccumulation is not expected. Contradicting conclusions on bioaccumulation are reported in Washington State (2006) and KLIF (2009), however. According to information in the dossier disseminated for the phase 1 registration under REACH, the substance is considered as vP (hydrolysis half-life > 1 year), and is not readily biodegradable.

The National Toxicology Program (NTP) indicates that the substance might have a carcinogenic potential since it was positive for mutagenic activity (NIEHS 2002).

This substance is not classified in the Annex I of Directive 67/548/EEC. Self-classification in the dissemination dossier also indicates that the substance is not classified.

The dissemination dossier reports environmental hazards identified for the substance are for aquatic sediment (PNEC for freshwater sediment is 927 mg/kg sediment dry weight,) and secondary poisoning (PNEC oral is 55.3 mg/kg food); *cf* HBCDD; PNEC for freshwater sediment is 0.86 mg/kg sediment dry weight and secondary poisoning PNEC oral is 5.0 mg/kg food.

According to a study done by Arcadis/EBRC for the European Commission[46] in 2011, much of their assessment of the risks to human health and environment were read across from tetrabromobisphenol A (TBBPA) because of a lack of available date on the substance. These authors report that the substance seems to be of low toxicity. In addition, although tetrabromobisphenol A bis (2,3-dibromopropyl ether) is under evaluation of the NTP[47] for potential carcinogenic effect, there is no evidence from *in-vitro* mutagenicity and repeated dose toxicity studies with tetrabromobisphenol A of concerns for carcinogenicity. These authors did not consider environmental effects or risks in any detail.

4.4f Economic feasibility

According to the manufacturer the substance is comparable to HBCDD in EPS and costs around 6.5 €/kg, this is slightly more expensive than HBCDD. However, given that this substance is considered to not be technically feasible, it is not relevant to investigate the economic feasibility of the substance further.

4.5f Availability

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[46] European Commission Health & Consumers DG Contract number 17.020200/09/549040

Identification and evaluation of data on flame retardants in consumer products FINAL REPORT

[47] US National Toxicology Programme (Department of Health and Human Services) - http://ntp-server.niehs.nih.gov/

For EPS only laboratory scale experience is reported and the substance is not yet in wide use. All raw materials, however, are worldwide commodities and thus GC SAM 55 E is reported to be immediately available for up-scaling on a commercial scale. For XPS the alternative is already in use at commercial scale. This substance has been registered under REACH in Phase 1 (>1000 tpa production/import) http://echa.europa.eu/en/information-on-chemicals/registered-substances.

This substance is listed in EINECS (European Inventory of Existing Commercial chemical Substances) meaning that it is a phase-in substance under REACH. According to ESIS, this substance is not classified in the Annex I of Directive 67/548/EEC.

4.6g Conclusion on suitability and availability for Alternative 6

As stated in Section 3 of this document, it is known that this substance is not suitable as an alternative for HBCDD in EPS, since investigation of alternatives has been subject to a nine year research programme in which a number of brominated compounds were rejected as possible alternatives. In addition, as summarized above, this substance is unlikely to have a health and safety profile that is better than HBCDD or the pFR (there are possible concerns for persistence in the environment – see also Table 3.2).

g) ALTERNATIVE 7

4.1g Substance ID and Properties

Chemical Name(s): 1,2-dibromo-4-(1,2-dibromoethyl)cyclohexane
Trade Name(s): SAYTEX BCL 462
CAS Number: 3322-93-8

Table 4.3: Properties of tetrabromobisphenol A bis (allyl ether), CAS 25327-89-3 (adapted from SUBSPORT Specific Substances Alternatives Assessment – Hexabromocyclododecane June 2013)

Chemical Properties	**Characteristics of Chemical**	**Source(s) of Information**
Physical Hazards		
Explosivity	No information available	
Flammability	No information available	
Oxidizing	No information available	
Human Health Hazards		
Acute toxicity	No information available	
Skin or eye corrosion/irritation		Subsport reports H319 (causes serious eye irritation), but the seems to be no record on the ECHA C&L inventory
Chronic toxicity		
Carcinogenicity	Not classified by IARC	IARC 2013[1]
Mutagenicity	No information available	
Endocrine disruption	No information available	
Respiratory or skin sensitization	No information available	
Neurotoxicity	Not listed by Vela et al.	Vela *et al.* 2003[2]
Immune system toxicity	No information available	
Systemic toxicity	No information available	
Toxic metabolites	No information available	
Environmental Hazards		
Acute/chronic aquatic toxicity	Not inherently toxic to aquatic organisms	USEPA ACToR[3]
Bioaccumulation	Bioaccumulative	USEPA ACToR
Persistence	Persistent	USEPA ACToR
Greenhouse gas formation potential	No information available	
Ozone-depletion potential	Not found on Scorecard Montreal Protocol List of Ozone Depleting Substances; not listed on UNEP trade names of chemicals containing ozone depleting substance	Green Media Toolshed 2010 UNEP Ozone Action Branch[4]
Monitoring - has the substance been found in human or environmental samples?	No information available	

Note – The chemical properties are those listed by Subsport and do not necessarily relate to specific hazards as identified in EU classification.

References to table:

1. International Agency for Research on Cancer (IARC). 2013. Agents Classified by the IARC Monographs, Volume 1-107. Accessed at http://monographs.iarc.fr/ENG/Classification/ClassificationsAlphaOrder.pdf

2.) Vela, M.M., Laborda, R. and Garcia, A.M. 2003. Neurotoxins: Classification Criteria and Provisional Listing. Arch Prev Riesgos Labor; 6 (1): 17 – 25.

3). United States Environmental Protection Agency (USEPA), ACToR. Accessed at http://actor.epa.gov/actor/faces/ACToRHome.jsp

4) Green Media Toolshed. 2011. Scorecard: Regulations: Environmental Hazard Lists: Ozone Depleting Substances List (Montreal Protocol). Accessed October 27, 2011 from http://scorecard.goodguide.com/chemical-groups/one-list.tcl?short_list_name=ods

4.2g Technical feasibility

The substance has been indicated as potentially suitable for EPS (see Table 3.2), however a research and development programme (as described in Section 3 of this document) considered a number of brominated substances as alternatives and found them not to be technically feasible.

4.3g Reduction of overall risk due to transition to the alternative

The substance is potentiality persistent and bioaccumulative in the environment (see Table 4.3). Results from a PubChem[48] search revealed an estimated BCF of 2200 had been calculated using an estimated log Kow of 5.24[49] and a regression-derived equation[50]. According to a classification scheme[51], this BCF suggests the potential for bioconcentration in aquatic organisms is very high.

In addition, there is some evidence of reproductive toxicity to birds; a study on American kestrels indicated effects on fertility and reproduction[52].

4.4g Economic feasibility

Given that this substance is considered to not be technically feasible, it is not relevant to investigate the economic feasibility of the substance.

4.5g Availability

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[48] http://pubchem.ncbi.nlm.nih.gov/

[49] Maylan and Howard. J. Pharm Sci 84: 83-92, 1995

[50] Maylan *et al.*, Environ. Tox and Chem. 18: 664-72, 1999

[51] Franke *et al.*, Chemosphere 29:1501-14, 1994

[52] Marteinson SC, Letcher RJ, Graham L, Kimmins S, Tomy G, Palace VP, Ritchie IJ, Gauthier LT, Bird DM, Fernie KJ. The flame retardant β-1,2-dibromo-4-(1,2-dibromoethyl)cyclohexane: fate, fertility, and reproductive success in American kestrels (*Falco sparverius*). Environ Sci Technol. 2012 Aug 7;46(15):8440-7.

This substance does not appear to have been registered under REACH in Phase 1 (>1000 tpa production/import) or Phase 2 (100 – 100 tpa) http://echa.europa.eu/en/information-on-chemicals/registered-substances.

This substance is listed in EINECS (European Inventory of Existing Commercial chemical Substances) meaning that it is a phase-in substance under REACH. According to ESIS, this substance is not classified in the Annex I of Directive 67/548/EEC.

Assuming that the substance could be registered in phase 3 of REACH, this means that the substance is currently only being supplied by each manufacturer/importer at less than 100 tpa.

The substance is listed on the REACH pre-registration list; however the envisaged registration deadline was for phase 1. According to the information available on substances registered in Phase 1[53], this substance was not registered in that phase.

4.6g Conclusion on suitability and availability for Alternative 7

As stated in Section 3 of this document, it is known that this substance is not suitable as an alternative for HBCDD in EPS, since investigation of alternatives has been subject to a nine year research programme in which a number of brominated compounds were rejected as possible alternatives. In addition, as summarized above, this substance is unlikely to have a health and safety profile that is better than HBCDD or the pFR (there are possible concerns for persistence and bioaccumulation and effects on the reproduction of birds in the environment). Given that the substance does not appear to be available at sufficient quantities for EPS manufacturers it is not available to the EPS supply chain even if it were technically feasible today.

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[53] http://echa.europa.eu/en/information-on-chemicals/registered-substances

5 OVERALL CONCLUSIONS ON SUITABILITYAND AVAILABILITY OF POSSIBLE ALTERNATIVES FOR USE 1 AND USE 2

5.1 Conclusions on steps needed in order to make the suitable alterative available

The conclusion of this analysis of alternatives is that there are no alternatives that are suitable and available.

This results from several alternatives not being suitable as it would not lead to an overall reduction in environmental and/or human health risks. No alternative is considered to be technically feasible. The intention of the consortium is to move as soon as possible to the pFR once a number of technical issues are resolved (see table 5.1) and it is available in sufficient commercial quantities.

As can be seen from this analysis of alternatives, a nine year research programme has been deployed involving both the substance manufacturers and the EPS producers in order to identify a technically feasible alternative to HBCDD. The phased programme that involved the initial screening of possible existing alternatives and testing in EPS foams showed that no suitable alternatives existed.

The development of a brominated polymer as an alternative was done by the Dow Chemical Company and is now being manufactured under license by the manufacturers that currently supply HBCDD to the EPS manufacturers (i.e. Chemtura (product ‘Emerald 3000’), ICL (product ‘FR-122P’) and Albemarle (product ‘GreenCrest’).

As stated earlier, the premise for this present application is that the EPS manufactures foresee that there will not be enough supply of the pFR to ensure continuity of the supply of their product, and it is therefore concluded that the alternative is not available to them. This being the case, ECHA requests (in the template for analyses of alternatives) the presentation of a *list of actions that you will undertake to identify and develop a suitable and available alternative*. The actions to identify and develop the alternative have been successfully made, as set out in Section 3 of this present document.

The implementation of the polymeric alternative is a managed process and subject to uncertainties. This includes uncertainties on the full technical feasibility and customer acceptance of the product as well as the availability of sufficient commercial volume of the polymeric alternative for the whole EPS and XPS supply chain. Initially each EPS manufacturer would try to use the alternative (pFR) in exactly the same way as HBCDD, however there may need to be changes the balance of other additives to ensure suspension stability, pellet size distribution (this is especially important for suspension process as the bead size determines the production of the various grades, which in turn is driven by market demand) and fire performance, amongst other things. The physical shape and size of the pFR is also important for loading into the reactor. For example it is known that the suppler Chemtura has changed their product from a powder to a compacted powder which has different loading requirements and potentially different handling requirements and/or equipment. It is yet to be known what form the other producers will supply. Testing and iterations all take time and the final testing has to be done on the full scale reactors fitting in between regular production for a commercial business.

Set out below are the steps and timings that are reasonably foreseen in order to allow the EPS manufacturers (those making this application) to phase-in the pFR, as it becomes available in sufficient commercial quantities. This includes the commercial-scale testing and product acceptability steps[54]. It should be noted that the full commercialization of the use of the pFR in EPS, requires testing with the commercially-produced pFR and the EPS manufactures' customers (i.e. the converters) need to ensure their acceptability of the products and also their customers acceptability of their products in turn. Such a plan is set out below; it is based on a Plastics Europe/EBFRIP/Exiba document from September 2007 (which has been updated to allow release to this Consortium without bridging confidentiality requirements). It includes the steps already taken to identify and develop a technically feasible alternative, which have been done for the pFR (note that it would take this time again to implement any other possible alternative); these steps are greyed out in Table 5.1. The on-going actions are indicated in Table 5.1.

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[54] It is known that one manufacturer of the pFR has a commercially available product; however other producers' products are in earlier stages of product development.

Table 5.1 Steps/Timing for Commercialisation of a FR Alternative

Step/action	Timing	Comment
1. Project Definition	1 day	Done
2. Identify partner(s) amongst customers for each application. Put secrecy agreements in place.	3 months	Done
3. Define a series of model structures that would have the technical advantages of HBCDD without the problematic features.	1 week	Done
4. Compare the models with commercially available chemicals and identify possible alternatives to HBCDD - in own portfolio - in literature	1 month	Done
5. Obtain or prepare samples of each potential candidate	6 months	Done
6. Evaluate in-house the possible alternatives(s) in each application - screening for technical performance - toxicity profile through software predictions - business assessment on availabilities and costs	3 months	Done
7. Present alternative(s) to customer partner(s) for their evaluation	1 month	Done
8. Prepare samples for partner(s) evaluation	2 months	Done
9. Evaluation by partner(s) in each application [a)]	6 months	Done
10. Review results - if technically and economically feasible - go to step 13 - if not technically and/or not economically feasible go to step 11	1 day	Done
11. Synthesis program for novel compounds	> 12 months	Done
12. Repeat steps 5 to 10 until a technically suitable alternative is found	n x 12 months	Done
13. Initiate toxicity testing for REACH registration - if testing OK go to step 14 - if testing is not OK, repeat steps 5 to 13 until a technically and HSE suitable alternative is found	n x 12 months	On-going (alternative substance is a polymer so not currently under REACH).
14. Assess sourcing of raw materials and manufacturing options for alternative	3 months	Done
15. Manufacturing pilot plant trials product for industrial trials	3 months	Done
16. Obtain product and process orientated research and development (PPORD) exemption from REACH registration for each country and customer where the product will be tested	3 months	On-going (alternative substance is a polymer so not currently under REACH).
17. Application pilot and industrial trials at partner(s)[b)]	6 months	To be initiated
18. Technical and organisational modifications of EPS production plants (e.g. equipment changes, tuning of process control and production parameters, training of personnel)	6 months	To be initiated
19. Build plant and start-up	12-18 months	To be initiated

Step/action	Timing	Comment
20. Contingency for unexpected delays/problems/product tuning. *(Chemtura experience for pFR indicates that this can be 15-18 months)*	15-18 months	To be initiated
21. Iteration between pFR and EPS manufacturers and between the EPS manufacturer and converters – necessary to ensure product commercial viability	2 x 6 months	To be initiated
22. Commercialisation after full registration in each country *(e.g. 24 month IVH programme for Germany*[55]*)* – it is not known if other members states will initiate similar programmes at member state level.	24 – 36 months	Initiated (in Germany only to date)
	Total time for initiated and on-going tasks c.4 -6 years	Total time for all steps ca. 7- >11 years

Table notes: a) Item 9 - timing will differ from company to company. It is possible that some partners will have to undertake several iterations of trialing to arrive at a satisfactory result whilst others will not.

b) It is known that one manufacturer of the pFR has a commercially available product; however other producers' products are in earlier stages of product development.

c) Full market implementation will depend upon the availability of an alternative to meet the market demand even if all technical, HSE, certification, etc. requirements are fulfilled. Hence the timing can be longer than that indicated.

Figure 5.1 below, gives and illustration of the ideal introduction of the pFR to replace HBCDD for the EPS manufacturers. This is intended to give a picture of all the EPS manufacturers that are part of this application and assumes a phased transition with some manufactures being quicker than others to switch to the pFR, because the rate of change depends on competition of the initiated and on-going tasks in Table 5.1 and this will not be exactly the same for all EPS manufacturers. In addition, the phase-in of the pFR is heavily dependent on the availability of sufficient commercial product from the manufacturers. Figure 5.2 illustrates the differences in the supply from the three main suppliers and shows that there estimated to be a short-fall in the amount supplied until around 2018 at the earliest. This is based on information from the main suppliers of pFR.

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[55] The IVH industry Hartschaum, Heidelberg, is the umbrella association for manufacturers of insulation materials made of polystyrene. It has 18 members that represent more than 90 per cent of the German market for polystyrene foam. In addition, raw material and machinery manufacturers and associated organizations are connected to the IVH as guest members.

The IVH promotes the environmental and economic importance of energy conservation through insulation with polystyrene. At the beginning of 1990, the Association first formulated his "Heidelberg principles" its environmental guidelines, which contained among other things a tightening of heat-protective regulation involving the old buildings and the introduction of building energy passport.

The IVH is currently undertaking a programme of research to investigate the insulating properties of EPS with the pFR in order to test and ensure that the insulating properties of the product are similar to HBCDD flame retarded foams. This is part of the product acceptability for EPS with the pFR and it is expected that other member states will have similar programmes.

Figure 5.1 Illustration of ideal timing for phase-out of HBCDD and phase-in of the polymeric alternative.

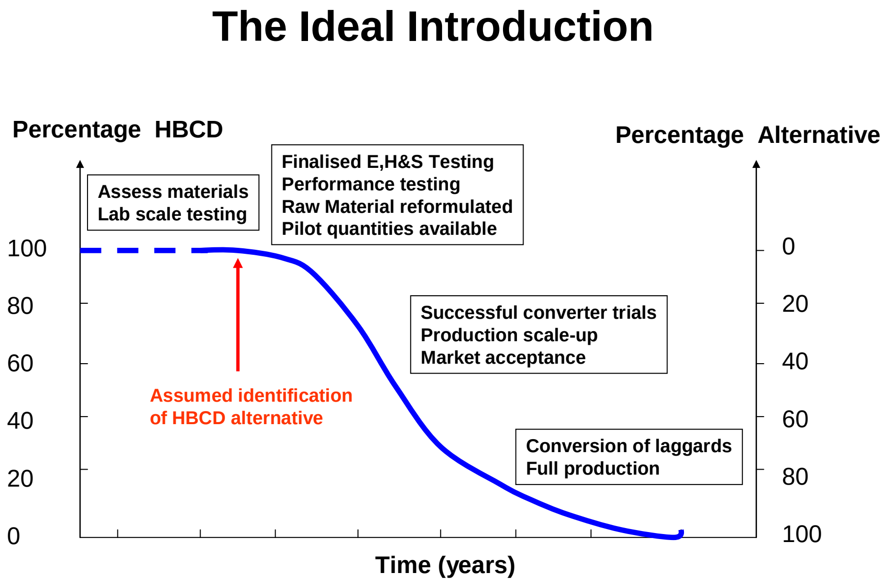
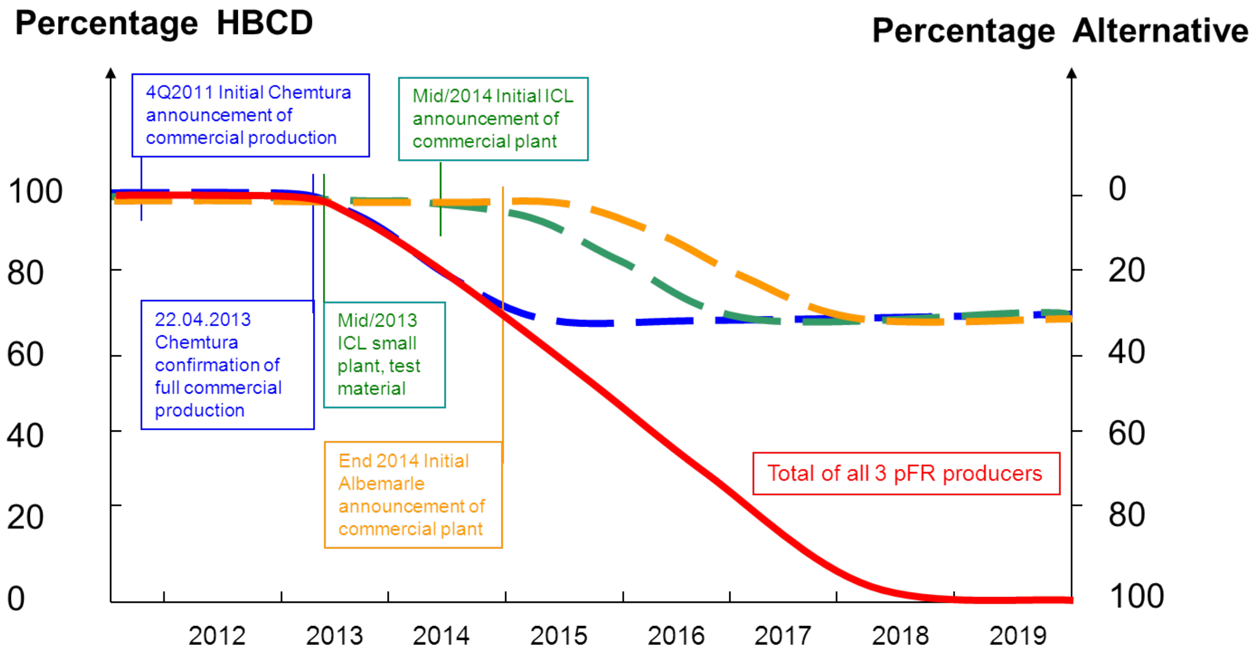


Figure 5.2 Illustration of ideal timing for phase-out of HBCDD and phase-in of the polymeric alternative, taking into account the planning of the three main suppliers of HBCDD and pFR.



It should be noted, that there is a strong possibility of delays to this and it is likely that the shortfall in supply will go beyond 2018. The possible reasons for delays are explained below.

What can cause delay?

The key determinants on timing for phase-in of the pFR are:

- The availability of the pFR,
- Technical testing of pFR from different producers by the various ESP pellet producers,
- Re-iterations of product between producers and users to fine-tune,
- Testing at converters (manufacturers of EPS articles).
- Final certification of EPS products by converters and their customers.

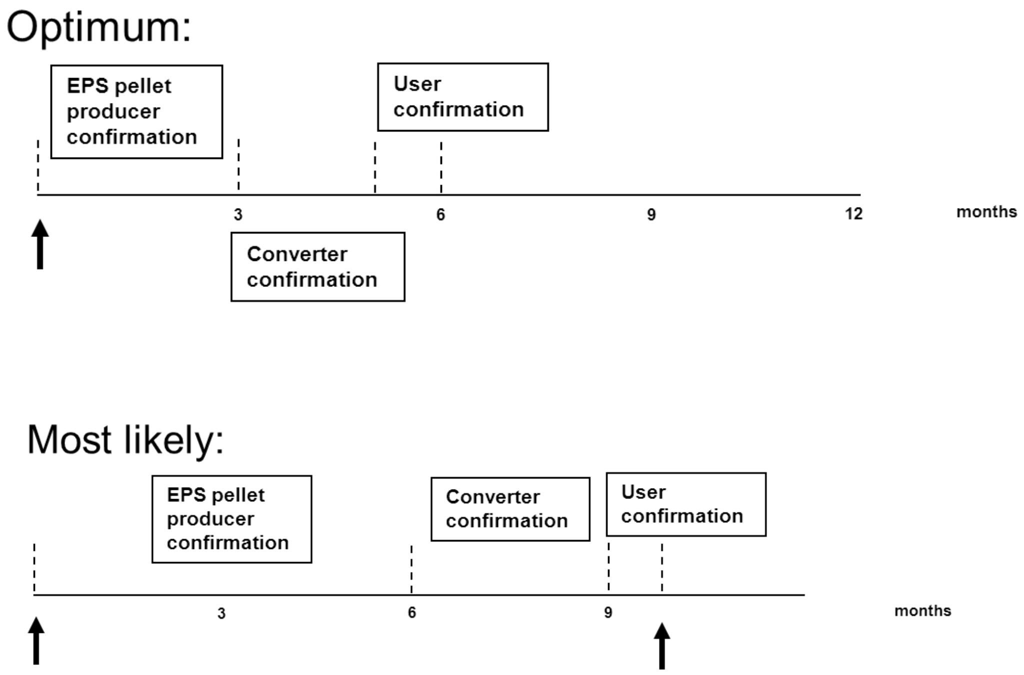
It is already known that supplier Chemtura is between 15-18 months behind schedule from their initial announcement. As a worst-case it has to be assumed that ICL and Albemarle could also be delayed by the same margin. Only once pFR production plants have steady-state, consistent product can the EPS manufacturers finalise their production. This is needed for each supplier as follows:

- If there are no production problems, then final testing can take *ca.* 3 months.
    - If there are production problems this can take considerably longer.
- Once the EPS manufacturers have approved product, then this can be finally approved by the converter (manufacturers of EPS articles). This is needed for each supplier:
    - If there are no production problems this can take 2 months
- If there are production problems this can take considerably longer.

Final testing at converters can only be done once there is a final EPS pellet to be tested. There can be some earlier work/testing at converters on pre-final product as orientation, but essentially these two elements do not overlap. Final certification is still yet to be fully defined. For example the IVH programme covers Germany, but other member states may yet come forward with similar programmes and it is still not clear if other countries will insist on testing by their own institutes. This is the case then there could be a considerable time delay owing to the limitation of official testing institutes and overloading of testing (this is in fact the case in Germany today, some 6-9 months for fire testing is required).

The timing from commercial availability of the pFR to EPS pellet producers, converters and end-users (for each pFR supplier), is illustrated in Figure 5.3 below.

Figure 5.3 Illustration of optimum and most likely timings for product confirmation (with pFR) by EPS manufacturers, EPS article manufacturers and EPS insulation board users.



5.2 The possibilities for identification of EPS with HBCDD and pFR going forward for recycling and waste purposes

It is desirable to be able to identify whether EPS foam contains HBCDD or not, so that at end-of-life the foam containing HBCDD is not recycled.

The identification of EPS foam containing HBCDD from the sunset date for the limited time of Authorisation would not be practicable or useful. There is a *ca.* 50 year history of foams containing HBCDD without identification. Therefore, for recycling or waste purposes there would be considerably more EPS with HBCDD already in buildings that is not specifically identifiable as such, compared to EPS marked as containing HBCDD from August 2015 onwards. That is only a fraction of the EPS waste would be marked as containing HBCDD. In addition, labelling EPS foams as containing HBCDD would be detrimental for the use of EPS and the legacy for all the foam already installed in buildings.

A declaration of performance requirements of the Construction Products Regulation, which came into force on July 1st 2013, mandates the identification of HBCDD. This means that there is a relevant documentation – a ‘paper trail’- for identification; however, a practical visual identification is also needed. A more positive approach would be to label EPS foams not containing HBCDD with the international recyclable symbol for PS (as below). In that way it indicates that the EPS not containing HBCDD is recyclable and all other EPS not so marked recovered from building uses in the EU could be considered to contain HBCDD and therefore not to be recyclable, unless it can be demonstrated that it does not contain HBCDD. This is currently under discussion within the EPS industry.

APPENDIXES AND ANNEXES

REFERENCES:

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APPENDIX 1

Economie
Eindhovens Dagblad Zaterdag 27 januari 2007 | 19

Iso Bouw maakt piepschuim onbrandbaar

Somerens bedrijf werkt in alle stilte aan uitvinding.

door **Henk van Weert**

SOMEREN - Iso Bouw in Someren heeft geëxpandeerd polystyreen (piepschuim) ontwikkeld dat onbrandbaar is. Het bedrijf spreekt van een revolutionaire vinding op het gebied van isolatiemateriaal voor de bouw.

Iso Bouw denkt met deze onbrandbare piepschuim op den duur 15 procent van de isolatiemarkt in handen te krijgen.

Het product, Xire genaamd, is vooral bedoeld voor toepassing in fabrieken, kantoren, ziekenhuizen en andere grote gebouwen waar verzekeraars hoge eisen aan de brandveiligheid stellen.

Iso Bouw, eigendom van investeringmaatschappij Gilde, start binnenkort met de productie bij zusterbedrijf Ertecee in Oldenzaal. Ook Synprodo in Wijchen, eveneens onderdeel van Gilde, en Iso Bouw zullen op den duur Xire gaan produceren.

Iso Bouw heeft vijf jaar in alle stilte gewerkt aan de uitvinding. Dat gebeurde in een klein laboratorium in de fabriek, waar slechts een select groepje technici binnen mocht. Zelfs het eigen personeel wist tot afgelopen maandag niet van de vinding.

Directeur Will Kemperman van Iso Bouw zegt dat Xire gebaseerd is op het samengaan van gewoon geëxpandeerd polystyreen en zand in een bepaalde wateroplossing. Met die vloeistof wordt een hard laagje aangebracht op de polystyreenkorrels die in het productieproces omgevormd worden tot piepschuimplaten.

Gewoon piepschuim smelt onmiddelijk weg als het in contact komt met vuur. Xire blijft intact en hard, zelfs als er een vlam van 1000 graden op gericht wordt. Er ontstaat hooguit een schroeivlek. Er komen volgens Iso Bouw ook geen giftige stoffen vrij.

Net als gewone polystyreen is Xire gemakkelijk te zagen en bruikbaar in allerlei vormen.

„Een wereldinnovatie, de grootste uit de geschiedenis van ons bedrijf, die we onder de aandacht gaan brengen van de bouwwereld, maar zeker ook onder die van de verzekeraars," zo karakteriseert Kemperman de Somerense vinding.

„Dit gaat groot worden in de bouw, groter dan ons bedrijf nu is. Ook buiten de bouw zien wij mogelijkheden." Kemperman doelt op een proef die met gewoon papier is gedaan. Iso Bouw heeft papier bewerkt met de speciale vloeistof en vastgesteld dat het papier onbrandbaar is geworden.

Of Iso Bouw met deze afgeleide uitvinding zelf aan de slag gaat of licenties verstrekt aan andere ondernemingen is nog niet duidelijk.

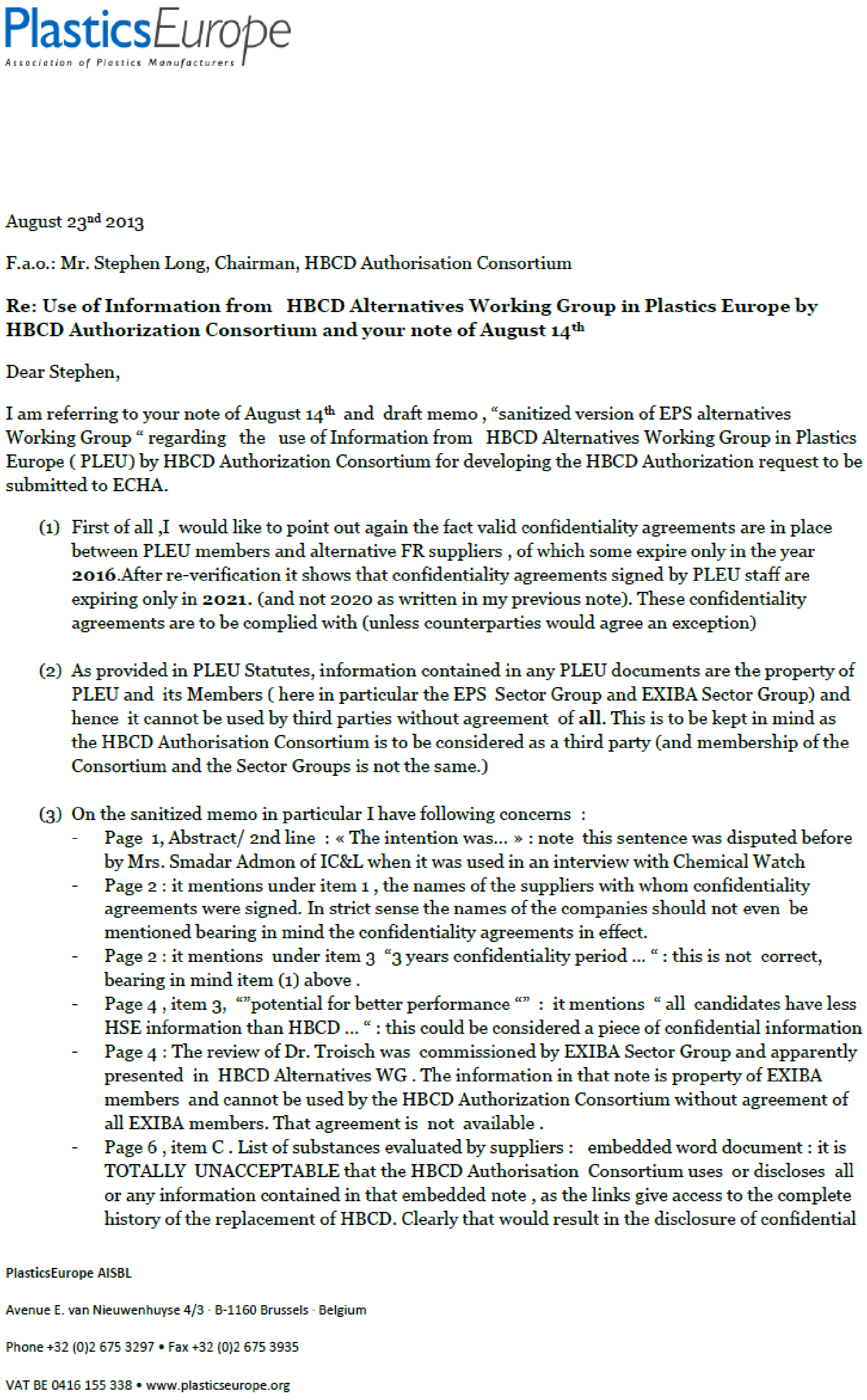
Xire is licht, duurzaam, recyclebaar, kan druk aan en voldoet aan de hoogste isolatie-eisen. Het materiaal is wel ruim twee keer zo duur als gewoon geëxpandeerd polystyreen. Daarom is het niet waarschijnlijk dat het in de reguliere woningbouw toegepast wordt.

Behalve in de bouw kan Xire gebruikt worden voor brandwerende systemen, bekleding van opslagtanks, isolatie van pijpleidingen en ontluchtingskoker. De toepassingen zijn nu nog niet aan de orde. In eerste instantie produceert Iso Bouw het materiaal voor vlakke daken. Na de zomer verschijnt Xire op de markt. Eerst in Nederland, daarna in de rest van Europa.

Xire smelt niet als er een vlam op gericht wordt. Hoofd productontwikkeling Peter Rensen kan er veilig zijn hoofd bij houden.

Met zijn uitvinding Xire denkt Iso Bouw in Someren een flink deel van de isolatiemarkt te veroveren. Dit nieuw type piepschuim is onbrandbaar.

APPENDIX 2



PlasticsEurope
Association of Plastics Manufacturers

August 23nd 2013

F.a.o.: Mr. Stephen Long, Chairman, HBCD Authorisation Consortium

Re: Use of Information from HBCD Alternatives Working Group in Plastics Europe by HBCD Authorization Consortium and your note of August 14th

Dear Stephen,

I am referring to your note of August 14th and draft memo , "sanitized version of EPS alternatives Working Group " regarding the use of Information from HBCD Alternatives Working Group in Plastics Europe (PLEU) by HBCD Authorization Consortium for developing the HBCD Authorization request to be submitted to ECHA.

(1) First of all ,I would like to point out again the fact valid confidentiality agreements are in place between PLEU members and alternative FR suppliers , of which some expire only in the year **2016**.After re-verification it shows that confidentiality agreements signed by PLEU staff are expiring only in **2021.** (and not 2020 as written in my previous note). These confidentiality agreements are to be complied with (unless counterparties would agree an exception)

(2) As provided in PLEU Statutes, information contained in any PLEU documents are the property of PLEU and its Members (here in particular the EPS Sector Group and EXIBA Sector Group) and hence it cannot be used by third parties without agreement of **all.** This is to be kept in mind as the HBCD Authorisation Consortium is to be considered as a third party (and membership of the Consortium and the Sector Groups is not the same.)

(3) On the sanitized memo in particular I have following concerns :
    - Page 1, Abstract/ 2nd line : « The intention was… » : note this sentence was disputed before by Mrs. Smadar Admon of IC&L when it was used in an interview with Chemical Watch
    - Page 2 : it mentions under item 1 , the names of the suppliers with whom confidentiality agreements were signed. In strict sense the names of the companies should not even be mentioned bearing in mind the confidentiality agreements in effect.
    - Page 2 : it mentions under item 3 "3 years confidentiality period … " : this is not correct, bearing in mind item (1) above .
    - Page 4 , item 3, ""potential for better performance "" : it mentions " all candidates have less HSE information than HBCD … " : this could be considered a piece of confidential information
    - Page 4 : The review of Dr. Troisch was commissioned by EXIBA Sector Group and apparently presented in HBCD Alternatives WG . The information in that note is property of EXIBA members and cannot be used by the HBCD Authorization Consortium without agreement of all EXIBA members. That agreement is not available .
    - Page 6 , item C . List of substances evaluated by suppliers : embedded word document : it is TOTALLY UNACCEPTABLE that the HBCD Authorisation Consortium uses or discloses all or any information contained in that embedded note , as the links give access to the complete history of the replacement of HBCD. Clearly that would result in the disclosure of confidential

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PlasticsEurope
Association of Plastics Manufacturers

> information and Sector Group information . Hence we urge you to remove the embedded word document in full and not use the information contained in it.

Bearing in mind in (1) the still valid confidentiality agreements , (2) the ownership of documentation of the PLEU EPS Sector Group and EXIBA (3) and the genuine concerns about the content of your draft memo, you will understand we are not in position to give clearance on behalf of PLEU / EXIBA for the use of it nor of its content by the HBCD Authorization Consortium. In conclusion it seems recommended that the HBCD consortium will have to limit itself to a high level description of the process that was followed for finding alternative FR's without using/disclosing information to which it has currently no legal /contractual access.

Eric Faes

Director Styrenics Chain

Manager EXIBA

Jacques Migniot

Technical Manager Styrenics Chain

Att : text note EF/JM August 14th 2013

Wednesday, August 14th 2013

Attention of: Mr. Stephen Long, Chairman, HBCD Authorisation Consortium

Re: Use of Information from HBCD Alternatives Working Group in Plastics Europe by HBCD Authorization Consortium.

Dear Stephen,

I am referring to your question regarding the use of Information from HBCD Alternatives Working Group in Plastics Europe by HBCD Authorization Consortium for developing the HBCD Authorization request to be submitted to ECHA.

We verified the files in Plastics Europe (PLEU) and it shows that:

(1) From the start of the HBCD Alternatives WG in 2004 , Plastics Europe and each of the PLEU EPS Sector Group Members that are equally members in that HBCD Working Alternatives WG, signed over time a several series of wide-ranging, complex and different confidentiality/non-disclosure agreements and/or renewal documents, with the suppliers of alternatives (such as Albemarle , Chemtura).
These confidentiality agreements are specified very tightly to prevent disclosure of information not only to any third parties, but equally to prevent disclosure of information between the suppliers of alternative products.
With signing of these agreements PLEU, its managers and the Members, have undertaken legal obligations on behalf of PLEU and their respective Companies.

PlasticsEurope
Association of Plastics Manufacturers

It is noted that some of these agreements will only expire in the course of the year **2016** (with even some obligations under US export control regulation being of an indefinite nature).

(2) Different and several managers of PLEU that were involved over time have equally signed confidentiality / non-disclosure agreements with same suppliers and these are valid till the year **2020.**

The information in the PLEU files is possibly incomplete, but from reviewing what was is available , it is clear that PLEU is neither in position to allow nor to agree that the information you compiled in a summary note is shared with the HBCD Authorization Consortium, its Members and or its Manager and neither can be disclosed to ECHA as this would constitute an infringement of the confidentiality agreements mentioned above.

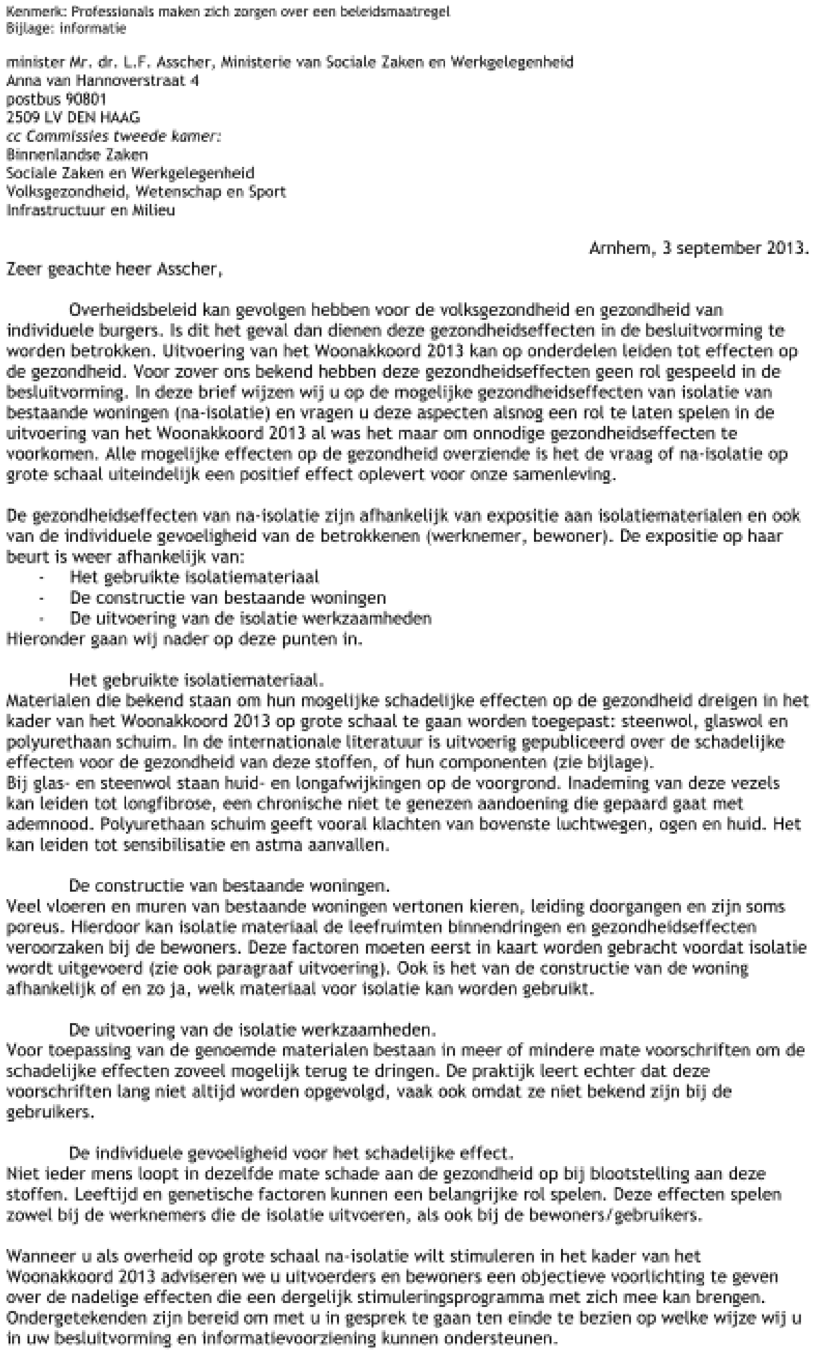
On behalf of Plastics Europe AISBL,

Eric Faes	Jacques Migniot
Director Styrenics Chain	Technical Manager Styrenics Chain

Cc : C.Oostens

APPENDIX 3

Letter from Netherlands health experts to Netherlands Ministry of Social Affairs and Employment regarding the use of insulation materials and associated health risks.



Kenmerk: Professionals maken zich zorgen over een beleidsmaatregel
Bijlage: informatie

minister *Mr. dr.* L.F. Asscher, *Ministerie* van Sociale Zaken en Werkgelegenheid
Anna van Hannoverstraat 4
postbus 90801
2509 LV DEN HAAG
cc Commissies tweede kamer:
Binnenlandse Zaken
Sociale Zaken en Werkgelegenheid
Volksgezondheid, Wetenschap en Sport
Infrastructuur en Milieu

Arnhem, 3 september 2013.

Zeer geachte heer Asscher,

Overheidsbeleid kan gevolgen hebben voor de volksgezondheid en gezondheid van individuele burgers. Is dit het geval dan dienen deze gezondheidseffecten in de besluitvorming te worden betrokken. Uitvoering van het Woonakkoord 2013 kan op onderdelen leiden tot effecten op de gezondheid. Voor zover ons bekend hebben deze gezondheidseffecten geen rol gespeeld in de besluitvorming. In deze brief wijzen wij u op de mogelijke gezondheidseffecten van isolatie van bestaande woningen (na-isolatie) en vragen u deze aspecten alsnog een rol te laten spelen in de uitvoering van het Woonakkoord 2013 al was het maar om onnodige gezondheidseffecten te voorkomen. Alle mogelijke effecten op de gezondheid overziende is het de vraag of na-isolatie op grote schaal uiteindelijk een positief effect oplevert voor onze samenleving.

De gezondheidseffecten van na-isolatie zijn afhankelijk van expositie aan isolatiematerialen en ook van de individuele gevoeligheid van de betrokkenen (werknemer, bewoner). De expositie op haar beurt is weer afhankelijk van:
- Het gebruikte isolatiemateriaal
- De constructie van bestaande woningen
- De uitvoering van de isolatie werkzaamheden

Hieronder gaan wij nader op deze punten in.

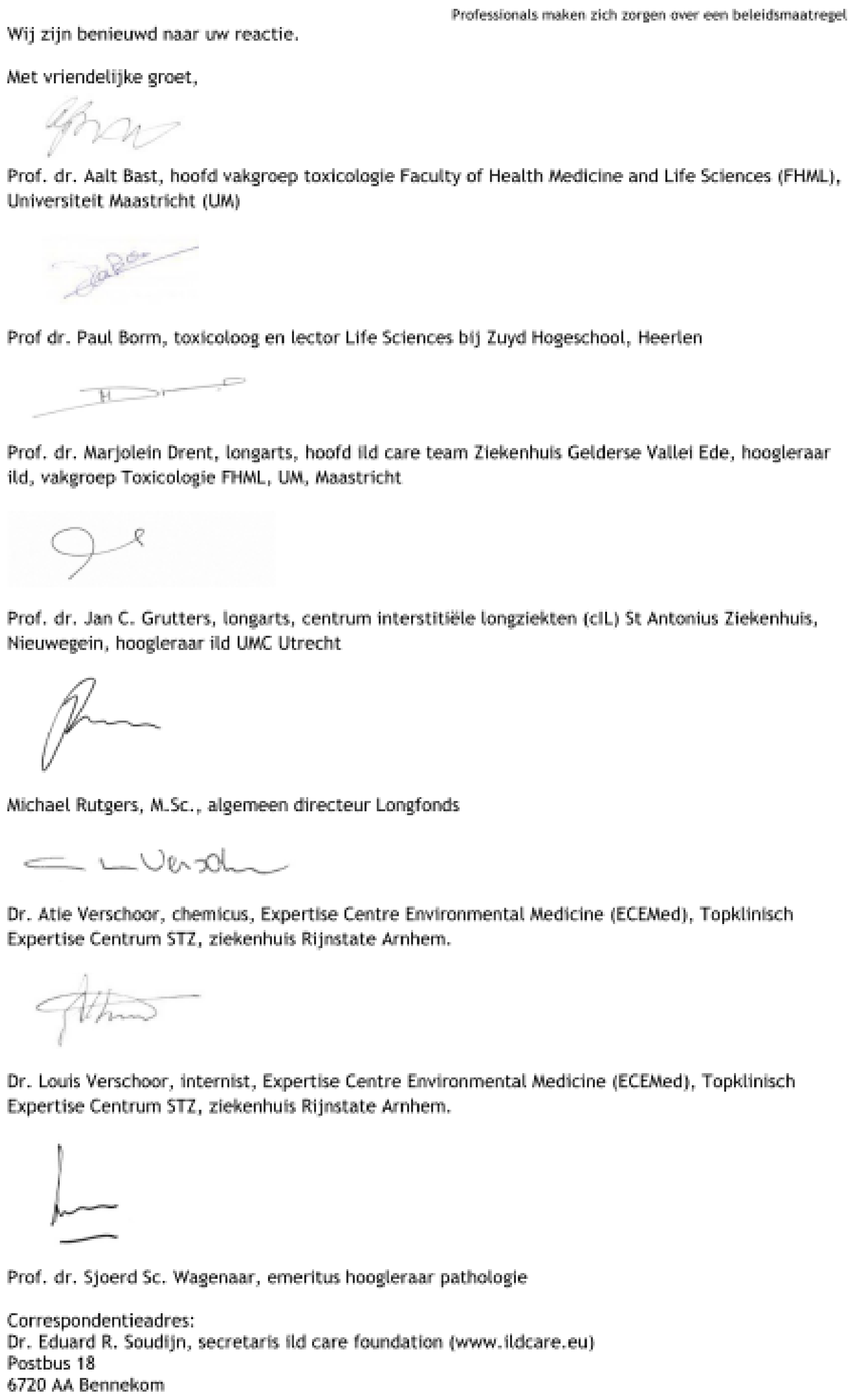
Het gebruikte isolatiemateriaal.
Materialen die bekend staan om hun mogelijke schadelijke effecten op de gezondheid dreigen in het kader van het Woonakkoord 2013 op grote schaal te gaan worden toegepast: steenwol, glaswol en polyurethaan schuim. In de internationale literatuur is uitvoerig gepubliceerd over de schadelijke effecten voor de gezondheid van deze stoffen, of hun componenten (zie bijlage).
Bij glas- en steenwol staan huid- en longafwijkingen op de voorgrond. Inademing van deze vezels kan leiden tot longfibrose, een chronische niet te genezen aandoening die gepaard gaat met ademnood. Polyurethaan schuim geeft vooral klachten van bovenste luchtwegen, ogen en huid. Het kan leiden tot sensibilisatie en astma aanvallen.

De constructie van bestaande woningen.
Veel vloeren en muren van bestaande woningen vertonen kieren, leiding doorgangen en zijn soms poreus. Hierdoor kan isolatie materiaal de leefruimten binnendringen en gezondheidseffecten veroorzaken bij de bewoners. Deze factoren moeten eerst in kaart worden gebracht voordat isolatie wordt uitgevoerd (zie ook paragraaf uitvoering). Ook is het van de constructie van de woning afhankelijk of en zo ja, welk materiaal voor isolatie kan worden gebruikt.

De uitvoering van de isolatie werkzaamheden.
Voor toepassing van de genoemde materialen bestaan in meer of mindere mate voorschriften om de schadelijke effecten zoveel mogelijk terug te dringen. De praktijk leert echter dat deze voorschriften lang niet altijd worden opgevolgd, vaak ook omdat ze niet bekend zijn bij de gebruikers.

De individuele gevoeligheid voor het schadelijke effect.
Niet ieder mens loopt in dezelfde mate schade aan de gezondheid op bij blootstelling aan deze stoffen. Leeftijd en genetische factoren kunnen een belangrijke rol spelen. Deze effecten spelen zowel bij de werknemers die de isolatie uitvoeren, als ook bij de bewoners/gebruikers.

Wanneer u als overheid op grote schaal na-isolatie wilt stimuleren in het kader van het Woonakkoord 2013 adviseren we u uitvoerders en bewoners een objectieve voorlichting te geven over de nadelige effecten die een dergelijk stimuleringsprogramma met zich mee kan brengen. Ondergetekenden zijn bereid om met u in gesprek te gaan ten einde te bezien op welke wijze wij u in uw besluitvorming en informatievoorziening kunnen ondersteunen.



Wij zijn benieuwd naar uw reactie.

Met vriendelijke groet,

Prof. dr. Aalt Bast, hoofd vakgroep toxicologie Faculty of Health Medicine and Life Sciences (FHML), Universiteit Maastricht (UM)

Prof dr. Paul Borm, toxicoloog en lector Life Sciences bij Zuyd Hogeschool, Heerlen

Prof. dr. Marjolein Drent, longarts, hoofd ild care team Ziekenhuis Gelderse Vallei Ede, hoogleraar ild, vakgroep Toxicologie FHML, UM, Maastricht

Prof. dr. Jan C. Grutters, longarts, centrum interstitiële longziekten (cIL) St Antonius Ziekenhuis, Nieuwegein, hoogleraar ild UMC Utrecht

Michael Rutgers, M.Sc., algemeen directeur Longfonds

Dr. Atie Verschoor, chemicus, Expertise Centre Environmental Medicine (ECEMed), Topklinisch Expertise Centrum STZ, ziekenhuis Rijnstate Arnhem.

Dr. Louis Verschoor, internist, Expertise Centre Environmental Medicine (ECEMed), Topklinisch Expertise Centrum STZ, ziekenhuis Rijnstate Arnhem.

Prof. dr. Sjoerd Sc. Wagenaar, emeritus hoogleraar pathologie

Correspondentieadres:
Dr. Eduard R. Soudijn, secretaris ild care foundation (www.ildcare.eu)
Postbus 18
6720 AA Bennekom

TRANSLATION TO ENGLISH

Feature: Professionals worry about a policy measure

Appendix: Information

Mr. Minister . Dr. L. F. Asscher , Ministry of Social Affairs and Employment

Anna Hanover Street 4

PO Box 90801

2509 LV THE HAGUE

cc Parliament Committees: Internal affairs/ Social Affairs and Employment/ Health, Science and Sport/

Infrastructure and Environment

Arnhem , September 3, 2013 .

Dear Mr Asscher ,

Public policy can have consequences for public health and health of individual citizens . If this is the case, then these health effects need to be taken into account when making the decision.. Implementation of parts of the Housing Agreement 2013 can lead to effects on health . As far as we know these health effects have played no role in the

decision making . In this letter, we point out the possible health effects of insulation of existing houses (post-insulation) and ask you to take these aspects still into account in the implementation of the Housing Agreement in 2013, if only to avoid that unnecessary health effects occur . Taking into account all possible health effects it is questionable whether widely applied post-insulation ultimately produces a positive effect for our society.

The health effects of post- isolation depend on exposure to insulation and the sensitivity of the individual involved (worker , resident) . The exposure is dependent on :

- The insulation material used
- The construction of existing homes
- The implementation of the insulation work

Below we elaborate on these points .

The insulation material used .

There is a threat that materials that are known for their possible harmful effects on health under the 2013 Housing Agreement are going to be widely applied : glass wool and polyurethane foam. In the international literature there has been extensively published on the harmful health effects of these substances , or their components (see Annex).

For glass and stone wool skin and lung abnormalities are in the foreground . Inhalation of these fibers can lead to pulmonary fibrosis , a chronic disease that cannot be cured which is accompanied by breathlessness . Polyurethane foam particularly leads to symptoms of upper respiratory tract, eyes and skin. This can lead to sensitization and asthma attacks

The construction of existing homes .

Many floors and walls of existing homes have cracks , pipe passages are sometimes porous . Through these the insulation material can penetrate the living spaces and cause health effects to the residents. These factors must first be mapped before insulation works are performed (see also section execution) . Also, it is depending of the structure of the dwelling

whether , and if so , what material can be used for insulation .

The execution of the isolation work .

For the purposes of the materials referred to exist to a greater or lesser degree requirements to reduce adverse effects as much as possible However, practice shows that these requirements are not always followed, often also because they are not known to the users.

Individual susceptibility to the harmful effect .

Not every man is equally damaged to health when exposed to these substances . Age and genetic factors may play an important role . These effects play a role for the employees who carry out the insulation , as well as for the residents / users .

If you as administration want to encourage wide application post- isolation as part of Housing Agreement 2013 we advise you to provide objective information to the users and residents about the adverse effects that such stimulation program can bring.

The undersigned are willing to enter into a dialogue with you to consider how we can support. in your decision making and information gathering.

Professionals worry about a policy measure

We look forward to your response .

Sincerely ,

Prof . Aalt Bast , head department of Toxicology Faculty of Health Medicine and Life Sciences (FHML)

Maastricht University (UM)

Prof. Paul Borm , toxicologist and Life Sciences lecturer at Zuyd University , Heerlen

Prof . Dr Marjolein Drent , lung , head ild care team Ede Gelderland Valley Hospital , Professor ild , FHML Department of Toxicology , Maastricht University , Maastricht

Prof . Dr. Jan C. Grutters , lung , heart interstitial lung diseases (CIL) St Antonius Hospital , Nieuwegein , professor ild UMC Utrecht

Michael Rutgers , M.Sc. , CEO Longfonds

Dr. . Ation Verschoor , chemist , Expertise Centre Environmental Medicine (ECEMed) Top clinical

Expertise Centre STZ , hospital Rijnstate Arnhem .

Dr. . Louis Verschoor , internist , Expertise Centre Environmental Medicine (ECEMed) Top clinical

Expertise Centre STZ , hospital Rijnstate Arnhem .

Prof . Dr. Sjoerd Sc . Wagenaar , emeritus professor of pathology

Correspondence Address :

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Annex [to above letter]

Stone and glass wool

Stone and glass wool consisting of fibers which, on inhalation give rise to accumulation in the body, an irreversible process. Once this material has entered the lung, it can never get out and acts as a disturbing element. Chronic lung problems, including asthma and pulmonary fibrosis may be the result. The last disease leads to severe disability, for which there is currently no adequate medical treatment. Irritation of the skin may occur when staying in rooms where these fibers are and / or the unprotected work with these materials.

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Polyurethane foam (PUR)

When insulating polyurethane foam is a mixture of substances isocyanates (often MDI) ,

polyols and neurotoxic substances as blowing gas in the cavity or on the ceiling of the crawl space sprayed . That this toxic substances, has been known for over 35 years . MDI has a limit of 0.05 mg / m 3 (NIOSH) . This means that in a house with a living area of 5 to 7 meters and a ceiling height of 3 meters (capacity 105 m 3), But 5 mg of MDI required to reach . limit Remember that in the insulation of cavity or crawlspace many pounds MDI may be used. Often the residents not warned during the work in-house and for adverse effects . The health effects involve many organ systems : respiratory , eyes , skin and gastrointestinal tract. Sensitization occurs mainly through the skin and leads to more violent reactions at ever lower blush count.

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