SUBSPORT Specific Substances Alternatives Assessment – Hexabromocyclododecane

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Table of content

1. Profile of hexabromocyclododecane 3
1.1 Chemical identification 3
1.2 Hazard characteristics 4
1.3 Source of exposures 5
1.4 Regulatory information 5
2. Function and uses of hexabromocyclododecane 6
2.1 Primary uses 6
2.2 Priority uses 7
3. Technical requirements of hexabromocyclododecane-containing materials 8
4. Preliminary identification of alternatives to hexabromocyclododecane 9
5. Screening out regrettable alternatives to hexabromocyclododecane 12
6. Characterization of alternatives to hexabromocyclododecane 13
6.1 Flame retardants and material/product redesign alternatives for HBCDD in EPS and XPS 14
6.1.1 Environmental, health and safety attributes 14
6.1.2 Performance attributes 20
6.1.3 Availability 21
6.1.4 Cost 22
6.1.5 Life cycle impacts 23
6.2 Flame retardants and material/product redesign alternatives for HBCDD in HIPS 24
6.2.1 Environmental, health and safety attributes 25
6.2.2 Performance attributes 30
6.2.3 Availability, cost and life cycle impacts 30
6.3 Material/product redesign alternative for HBCDD in textile back coating 30
6.3.1 Environmental, health and safety attributes 31

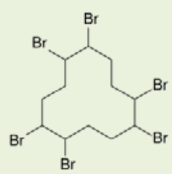
6.3.2 Performance attributes.. 32
6.3.3 Availability, cost and life cycle impacts.. 32
7. Comparison of alternatives to hexabromocyclododecane... 32
8. Conclusion.. 35
9. References 36
10. Appendices.. 43
Appendix A – SUBSPORT screening criteria for SVHC.. 43

1. Profile of hexabromocyclododecane

Characterizing the inherent hazards of hexabromocyclododecane (HBCDD) is an important component to conducting an assessment of its alternatives. This approach allows for assessment of its alternatives from an environmental, health and safety perspective. The hazard characteristics are intrinsic to the chemical, which means that regardless of the way that HBCDD is used, these characteristics do not change. The goal of the substitution processes is to advance inherently safer chemicals and products, consistent with the principles of green chemistry.

1.1 Chemical identification

Table 1.1: Chemical identification of HBCDD

Chemical Properties	Characteristics of Chemical	Source of Information
Chemical name (IUPAC)	Hexabromocyclododecane	
Identification number (CAS number, EC number)	• CAS No. 3194-55-6, **25637-99-5**, and 25495-98-1 • EC number: **247-148-4** and 221-695-9	ECHA 2011 (**bolded** numbers are those for which dossiers have been prepared under REACH)
Molecular Formula and Structure (general)	$C_{12}H_{18}Br_6$ 	ECHA 2011
Common names	HBCDD; HBCD; Hexabromcyclododecan; Hexabromociclododecano; Hexabromocyclododecane; 1,2,5,6,9,10-hexabromocyclododecane; Cyclododecane, hexabromo; Bromkal 73-6CD; Nikkafainon CG 1; Pyroguard F 800; Pyroguard SR 103; Pyroguard SR 103A; Pyrovatex 3887; Great Lakes CD-75P™; Great Lakes CD-75; Great Lakes CD75XF; Great Lakes CD75PC (compacted); (Dead Sea Bromine Group Ground FR 1206 ILM; Dead Sea Bromine Group Standard FR 1206 I-LM; Dead Sea Bromine Group Compacted FR 1206 I-CM); FR-1206; HBCD ILM; HBCD IHM	*ECHA 2008*
Names of the major diastereoisomers identified	• alpha-hexabromocyclododecane (CAS No 134237-50-6) • beta-hexabromocyclododecane (CAS No 134237-51-7) • gamma-hexabromocyclododecane (CAS No 134237-52-8)	ECHA 2008
Substance functionality	Flame retardant	

1.2 Hazard characteristics

Table 1.2: Hazard characteristics of HBCDD

Characteristics	Properties	Source of Information
Physical Hazards		
Explosivity	No information available[1]	
Flammability	No information available	
Oxidizing	No information available	
Other properties of reactivity	No information available	
Human Health Hazards		
Acute toxicity		
Highly toxic	No information available	
Skin or eye corrosion/ irritation	H315 - causes skin irritation; H319 - causes serious eye irritation	ECHA 2011
Chronic toxicity		
Carcinogenicity	Not listed under IARC	
Mutagenicity	No information available	
Reproductive toxicity (including developmental toxicity)	The European Commission has noted concerns about possible reproductive toxicity. Transient changes in learning and memory were observed in males, and delayed eye opening was observed in second generation offspring. There was high, dose-dependent pup mortality during lactation. H361 - suspected of damaging fertility of the unborn child; H362 - may cause harm to breast-fed children	EC 2008 ECHA RAC 2010 USEPA 2010 ECHA 2011
Endocrine disruption	In laboratory studies on mammals, HBCDD has been found to affect the thyroid	USEPA 2010
Respiratory or skin sensitization	H317 - may cause an allergic skin irritation	ECHA 2011
Neurotoxicity	No information available	
Immune system toxicity	No information available	
Systemic toxicity	No information available	
Toxic metabolites	No information available	USEPA 2010
Environmental Health Hazards		
Acute/chronic aquatic toxicity	Fish ChV = 0.00067 (HIGH); H400 - very toxic to aquatic life; H410 - very toxic to aquatic life with long lasting effects	USEPA OCSPP 2010 ECHA 2011
Bioaccumulation	BCF = 5,800 (HIGH)	USEPA OCSPP 2010
Persistence	Water = 60 d (MOD), Soil = 120 d (MOD), Sediment = 540 d (HIGH), Air =3.2 d (HIGH) The Canadian Government has conducted a preliminary assessment of HBCDD. In the draft assessment results, HBCDD was found to have the potential to remain in the environment for a long time, accumulate in organisms and	USEPA OCSPP 2010 ECA and HCA 2010

[1] "No information available" indicates that in the public literature or upon initial contact with manufacturers and suppliers sufficient data were not available to evaluate the hazard characteristic.

Characteristics	Properties	Source of Information
	cause harm to organisms.	
Greenhouse gas formation potential	No information available	
Ozone-depletion potential	No information available	
Monitoring - has the substance been found in human or environmental samples?	HBCDD has been detected in adipose tissue, human blood, breast milk and serum. Sampling and analysis in the home environment has shown detectable levels of HBCDD in household dust and indoor air. It has also been detected in fish and wildlife.	USEPA 2010 ECA and HCA 2010 EC 2008 TOXNET HSDB

1.3 Source of exposures

Release of HBCDD can occur during all stages of its life cycle. Information from the United Kingdom indicate that the primary sources of HBCDD in the environment are from fugitive emissions during its manufacture and use in ensuing products, potentially from leaching in landfills and from incinerator emissions. HBCDD is not chemically bound to the matrix of the materials in which it is incorporated and thus has the potential to enter the environment from finished products in use or after disposal. According to the European Chemicals Agency (ECHA), a significant quantity of products containing HBCDD will have very long service life and environmental releases will continue for a long time into the future (US EPA 2010).

People may be exposed to HBCDD from products and dust in the home and workplace, in addition to the presence of HBCDD in the general environment. Although it is typically manufactured as a powder of approximately 100 microns in size, a portion of the materials is micronized to 1 micron during manufacture which poses the potential for deep lung particulate exposure. Workers who fail to wear appropriate respiratory protection equipment have a high potential for deep lung exposure to micronized HBCDD. Particles 1 micron in size or smaller are capable of penetrating the alveolar sacs of the lungs and absorbed into the blood. Commercial workers may also be exposed to HBCDD through dermal contact or inhalation during chemical application. Exposure to the general population is likely to occur from its presence in food, outdoor air from near point sources, indoor air, as well as indoor dust (US EPA 2010).

HBCDD has been measured in air and sediment in Scandinavian countries, North American countries and Asia. It has been detected in marine and arctic mammals, freshwater and marine fish, aquatic invertebrates, birds and bird eggs and one plant species. It has also been detected in arctic fish, ringed seal and polar bears (US EPA 2010).

1.4 Regulatory information

HBCDD is subjected to several regulatory requirements, both nationally and internationally. Below is a summary of regulatory requirements associated with the use of HBCDD, primarily in building materials.

Table 1.3: Regulatory considerations associated with HBCDD

Country/ Region	Type	Specific Requirement/Restriction/Standard	Source(s) of Information
General Requirements			
EU	Indication of danger	N - dangerous for the environment	ECHA 2011
	Hazard statements (classification and labeling)	H361 - suspected of damaging fertility of the unborn child; H362 - may cause harm to breast-fed children	
	Risk phrases	R63/64 possible risk of harm to the unborn child; R64 - may cause harm to breast-fed babies; R50/53 - very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment	
	Safety phrases	S56 - dispose of this material and its container to hazardous or special waste collection point	
		S61 - avoid release to the environment. refer to special instructions/safety data sheets	
	Classification as Substance of Very High Concern	Subject to authorization under REACH	POPRC 2011
Japan	Designated as a monitoring chemical substance	Avian reproduction test required by March 2012	POPRC 2011
USA	Significant New Use Rule	Initiating rulemaking under TSCA Section 5(a)(2) to designate HBCDD for use in consumer textiles as SNUR	USEPA 2010
	Toxics Release Inventory	Initiating rulemaking to add HBCDD to TRI reporting requirement	USEPA 2010
Restrictions on Use			
EU	List of substances for priority action	OSPAR convention	POPRC 2011
	Recommended for Listing as Persistent Organic Pollutant	UNECE Convention on Long-Range Trans-boundary Air Pollution	UNECE 2009
Norway	National ban	Under consideration by Norwegian Ministry of Environment	KLIF 2011
Restriction on Other Products			
EU	Waste electrical and electronic equipment	Removal of brominated flame retardants from WEEE (2002/96/EC)	POPRC 2011

2. Function and uses of hexabromocyclododecane

2.1 Primary uses

Approximately 23,000 tons of HBCDD are produced annually; 9,000 to 10,000 tons in China, 13,426 tons by the Bromine Science and Environmental Forum (BSEF) member companies in Europe and the U.S. Available evidence suggests that use of HBCDD may be rising. There is also evidence that HBCDD may be replacing some polybrominated diphenyl ether (PBDE) flame retardants, notably the commercial decabromodiphenyl ether formulation (POPRC 2011).

HBCDD is used as an additive flame retardant, with the intent of delaying ignition and slowing subsequent fire growth during the service life of vehicles, buildings or articles, as well as while materials are in storage. The main uses of HBCDD globally are in flame-retarded expanded polystyrene (EPS)[2] and extruded polystyrene (XPS)[3] insulation foam boards. In Western Europe approximately 70% of EPS used for construction applications is flame-retarded, whereas more than 99% of flame-retarded EPS is used in Eastern Europe (ECHA annex XV dossier). HBCDD use in textile applications[4] and electric and electronic appliances (high impact polystyrene or HIPS)[5] is of a smaller scale. With respect to textile applications, it is used in textile back-coating in upholstery furniture and other interior textiles, including automotive applications (Japan 2011, LCSP 2006). Some other minor uses have also been reported by KemI (POPRC 2011).

Table 2.1: Function and uses of HBCDD

Characteristic	Description	Source of Information
Function	Flame retardant	
Uses	The primary use for HBCDD is for expanded polystyrene (EPS) and extruded polystyrene (XPS) foam insulation (more than 97%). Typical loading for EPS is between 0.5% and 0.7%. The average HBCDD loading in XPS is about 2% Its minor uses include textile back coatings (approximately 2-3% of total HBCDD use) and high impact polystyrene (HIPS) used in electronics housings (approximately 4% of total HBCDD use)	ChemSec 2011 EUMEPS 2002 POPRC 2011 US EPA 2011
Producers	Great Lakes Chemicals	ChemSec 2011a

2.2 Priority uses

Based on the above information, the vast majority (more than 97%) of HBCDD is used in EPS and XPS formulations. From the ECHA dossier database, which provides some insight into processes and uses that may lead to greater risk of exposure, the uses of HBCDD that result in dispersive environmental release potentials include EPS and XPS manufacture and use, HIPS and textile backing treatments (ECHA Registered Substances). While these are indicative of potential environmental or human health exposures, the potential for release is considered to be low. On the contrary, monitoring data show ubiquitous presence of HBCDD in the environment and in biota, even in arctic regions.

Given that a significant quantity of products containing HBCDD will have very long service life and environmental releases will continue for a long time into the future, the uses of HBCDD listed in **Table 2.1** are all of priority. Yet, because there is no evidence suggesting that release and exposure potentials associated with HBCDD use in HIPS and textile back coatings are more significant than its use in EPS and XPS, subsequent alternatives assessment work will focus primarily on EPS and XPS, except where other information is readily available.

[2] 0.5-0.7 % HBCDD w/w
[3] 0.8-2% HBCDD w/w
[4] 10-15% HBCDD w/w
[5] 1-7 % HBCDD w/w

3. Technical requirements of hexabromocyclododecane-containing materials

Expanded and extruded polystyrenes (EPS and XPS)

Technical properties that have been identified as key considerations for EPS building materials, (KLIF 2011, Morose 2006) include:

- Mechanical properties – compressive strength at 10% compression, compressive strength at 1% nominal strain, bending/flexural strength, dimensional stability;
- Moisture Properties – water vapor diffusion resistance factor, water vapor permeability, vapor resistivity, water absorption, fungus/bacteria resistance;
- Thermal Properties – thermal conductivity, thermal resistivity (R-value), maximum use temperatures;
- Nominal density; and
- Recyclability – EPS at end-of-life is typically incinerated.

EPS is produced in a variety of densities to match the required properties of its intended application. In Europe, the standard for EPS and XPS insulation materials for buildings and their test methods are defined in EN 13163, which is mandatory for all EU countries (KLIF 2011). A number of other standards and their respective test methods also exist for evaluating the fire performance of construction products. For example, EN ISO 1182, EN ISO 1716 and EN 13923 are the required tests used to demonstrate fire performance for construction products in Europe. Additional standards exist in the U.S. and Canada with respect to flame retardancy of construction materials (see **Table 3.1**).

Table 3.1: EPS and XPS building products requirements

Country/ Region	Type	Specific Requirement/Restriction/Standard	Source(s) of Information
EU	Required tests to demonstrate fire performance for construction products	EN ISO 1182, EN ISO 1716, EN 13923	POPRC 2011
	Insulation materials for buildings	EN 13163, test methods	KLIF 2011
USA	International building and residential code standards	ASTM C-578 (flame retardancy) and ASTM E-84 (flame spread and smoke)	POPRC 2011
Canada	National building code for foamed plastics in non-combustible construction	CAN/ULC S701 and CAN/ULC S102.2	POPRC 2011

High impact polystyrene (HIPS)

Typical technical properties of HIPS (Plastics International) include:

- Physical properties – specific gravity
- Mechanical properties – flexural modulus and strength, Rockwell hardness, gardener impact, izod impact strength, tensile elongation, tensile modulus and tensile strength

- Thermal properties – coefficient of thermal expansion, flammability rating (UL 94) and heat deflection temperature.

UL 94 measures a materials tendency either to extinguish or spread fire once it has been ignited, with a grade V-2 being the flammability rating for housing and similar parts not in direct contact with electricity bearing parts (Maag et al. 2010). HBCDD is generally used for UL 94 V-2 grade HIPS.

Textile back coating

The technical properties of textiles take into account a number of factors including the type of fabric, the fabric construction, their intended end uses, etc. For flammability or fire performance of textiles, multiple guidelines and their corresponding test methods exist for performance evaluation, depending on the intended end use of the textile. Below are the guidelines by the Association for Contract Textiles (ACT) to measure the fire performance of textiles when they are exposed to specific sources of ignition (ACT 2010):

- Upholstery: California Technical Bulletin #117 Section E – Class 1 (pass)
- Fabric wall covering/direct glue wall coverings and adhered panels: ASTM E 84 (Adhered Mounting Method) – Class A or Class 1
- Wrapped wall panels and upholstered Walls: ASTM E 84 (Unadhered Mounting Method) – Class A or Class 1
- Panel System Furniture: any one or combination of UL recognized component under Office Panel Fabrics category, UL 1286 Listed, ASTM E 84 (Adhered or Unadhered Mounting Method) – Class A or Class 1
- Drapery: NFPA 701 Method 1 – pass

4. Preliminary identification of alternatives to hexabromocyclododecane

Technically and economically feasible alternatives to different uses of HBCDD are currently available and on the commercial market for many of its uses. The alternatives identified are both alternative flame retardants and material/product redesign alternatives. **Table 4.1** includes information from the 2011 Persistent Organic Pollutants Review Committee (POPRC) Draft Risk Management Evaluation (POPRC 2011), which summarizes the technical feasible and commercially available halogen-free alternatives to the use of HBCDD, and also includes pertinent information from Norway's Climate and Pollution Agency (KLIF 2011) and a report by the Lowell Center for Sustainable Production (Morose 2006). For the purpose of this assessment, up to 5 alternative substances for each application of HBCDD were considered (see **Table 4.2**). Reasons for why the remaining alternatives were not considered in this assessment are provided in the subsequent paragraphs.

Table 4.1: Uses, applications and potential alternatives identified for HBCDD

Polymer Uses	Applications	Alternative chemicals	Alternative material & product redesign	Source(s) of information
EPS & XPS	• Insulation of foundation, walls and ceilings/roofs • Ground deck, parking deck etc.	Emerging possible alternatives: • Emerald 3000 • Pyroguard SR-130 • GreenCrest Previously identified possible alternatives: • Tetrabromobisphenol-A bis (allyl ether) • Tetrabromocyclooctane • Dibromoethyldibromo-cyclohexane	• Non-flame retarded EPS and XPS in combination with thermal barriers (e.g., concrete) • Phenolic foams • Blankets (fiber batts or rolls) that may contain rock wool, fiber glass, cellulose or polyurethane foam • Polyester batts • Loose fills that may contain rock wool, fiber glass, cellulose or polyurethane foam	POPRC 2011 KLIF 2011 DfE 2011 Morose 2006
HIPS	• Housings of electronic products • Wiring parts	Arylphosphates[6] such as: • Resorcinol bis (biphenyl phosphate) • Bisphenol A bis (biphenyl phosphate) • Polymeric biphenyl phosphate • Diphenyl cresyl phosphate • Triphenyl phosphate Other alternatives include halogenated flame retardants such as decabromodiphenyl ether in conjunction with antimony trioxide	Alloys of PPE/HIPS[7] treated with halogen-free flame retardant alternatives	POPRC 2011
Textile back coatings	• Protective clothing • Carpets • Curtains • Upholstered fabrics • Tents • Interior in public transportation • Other technical textiles	Intumescent systems[8] that contain: • A dehydrating component, such as ammonium polyphosphate (APP) • A charring component, such as pentaerythritol (PER) • A gas source, often a nitrogen component such as melamine		POPRC 2011

[6] Alternatives to HBCDD in HIPS applications typically used at considerably higher loadings (ECHA 2009).
[7] PPE/HIPS is an alloy of polyphenylene ether and high impact polystyrene
[8] Economic viability has been questioned (BSEF 2011).

According to representatives from European trade associations, it has proven to be difficult to develop substitutes for HBCDD in EPS and XPS insulation foams because alternative chemical flame retardants impair the structure and properties of the foam (ECHA 2009, BSEF 2011). Nonetheless, there are alternative chemicals that have the potential to replace HBCDD in EPS and XPS, including emerging alternative chemicals with promising applications.

The U.S. Environmental Protection Agency (EPA) Design for Environment (DfE) program is conducting a rigorous stakeholder research process to identify and evaluate potential alternatives to HBCDD for EPS and XPS applications. Two emerging chemical alternatives to HBCDD for EPS and XPS applications are being considered as part of the DfE program process (US EPA 2012); Emerald 3000 and Pyroguard SR-130. Emerald 3000 (CAS #1195978-93-8) is a large molecule polymeric brominated flame retardant developed by Dow Chemical Corporation and Chemtura. It is a block copolymer of polystyrene and brominated polybutadiene. Pyroguard SR-130 (CAS #97416-84-7), 1,1'-(1methylethyleidene)bis[3,5-dibromo-4-(2,3-dibromo-2-methylpropoxy)], is a smaller brominated molecule being developed by Dai-Ichi Kogyo Seiyaku Co, Ltd. Because of its size, 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, and therefore it was not further evaluated in this assessment. A third alternative is being developed by Albemarle, with the trade name GreenCrest. According to Albemarle, GreenCrest is a stable, high molecular weight polymeric flame retardant designed to gradually replace HBCDD for use in EPS and XPS applications. Albemarle plans to make the new technology commercially available in 2014 (Albemarle 2012). Like Pyroguard SR-130, GreenCrest was not further evaluated in this assessment due to its lack of currently available information. According to a report of the Norwegian Climate and Pollution Agency, tetrabromocyclooctane seems to be no longer in production (KLIF 2011)[9]. It is also understood that tetrabromocyclooctane does not provide the functionality required for current EPS and XPS manufacturing processes (Weil 2009). As such, this chemical alternative was also not further evaluated in this assessment.

As shown in **Table 4.1**, several material and product redesign alternatives to HBCDD for EPS and XPS insulation foam boards are available. The report of the Norwegian Climate and Pollution Agency stated that the dominating insulation materials that are alternatives for flame retarded EPS and XPS are non-flame retarded EPS and EXPS, polyurethane foams and rock wool (KILF 2011). For this assessment, non-flame retarded EPS and XPS in combination with thermal barriers and rock wool were the material and product redesign alternatives considered. This is because polyurethane foams used in the construction industry often contain the chlorinated flame retardant tris (1-chloro-2-propyl) phosphate (TCPP). TCPP has been found to be a chemical of concern due to its potential for long-range transport, persistence, toxicity and human exposure. It is a potential carcinogen, accumulates in the liver and kidneys, and may affect the developing nervous system based on cellular and animal studies (Babrauskas et al. 2012).

With respect to alternatives for HIPS application as identified in **Table 4.1**, polymeric biphenyl phosphate and decabromodiphenyl ether (decaBDE) in conjunction with antimony trioxide were the chemical alternatives not further evaluated in this assessment. There seems to be practically no publicly available information on polymeric biphenyl phosphate. DecaBDE, on the other hand, is likely to be commercially unavailable. As a result of negotiations with the U.S. EPA in 2009, two of U.S. producers

[9] A brief online search produced results indicating that tetrabromocyclooctane is marketed by the company Albemarle under the trade name SAYTEX BC-48. Albemarle was contacted twice by phone and email to confirm whether or not tetrabromocyclooctane is still produced and for hazard data on GreenCrest but the company failed to respond.

(Albemarle and Chemtura) and the largest U.S. importer (ICL Industrial Products Inc.) of decaBDE announced commitments to phase out the chemical (US EPA 2009). The companies committed to end production, importation and sale of decaBDE for most uses in the U.S. by December 31, 2012, and end all uses by the end of 2013. The use of decaBDE in certain electrical and electronic equipment sold in the European Union is also restricted (EU RoHS 2011).

A single alternative was identified for HBCDD application in textile back coating. This alternative represents an alternative approach to flame retardancy, intumescence. The intumescent systems contain a dehydrating and charring component and a gas source.

Below are the lists up to 5 alternatives for the various applications of HBCDD that were further evaluated in this assessment:

Table 4.2: List of up-to five alternatives for HBCDD uses evaluated in this assessment

EPS and XPS alternatives	HIPS alternatives	Textile back coating alternatives
1. Emerald 3000 2. Tetrabromobisphenol-A bis (allyl ether) 3. Dibromoethyldibromocyclohexane 4. Non-flame retarded EPS and XPS in combination with thermal barriers (e.g., concrete) 5. Rock wool	1. Resorcinol bis (biphenyl phosphate) 2. Bisphenol A bis (biphenyl phosphate) 3. Diphenyl cresyl phosphate 4. Triphenyl phosphate 5. Alloys of PPE/HIPS treated with halogen-free flame retardant alternatives	1. Intumescent systems containing a dehydrating component, a charring component and a gas source

5. Screening out regrettable alternatives to hexabromocyclododecane

The purpose of this section is to eliminate any alternative substance listed for further evaluation in **Table 4.2** above that would pose a high risk to human health and the environment. The Substance Database according to SUBSPORT Screening Criteria (SDSC)[10] was used to screen out such potentially high risk substances using the predetermined hazard endpoint categories: carcinogenic, mutagenic or toxic to reproduction (CMR); very persistent and very bioaccumulative (vPvB); endocrine disruption; neurotoxicity and sensitization (see **Appendix A**). Any substance that is listed substance in the SDSC was disregarded as an appropriate alternative substance (see **Table 5.1**).

Among the alternative substances listed for further evaluation, triphenyl phosphate is the only listed substance under SDSC. Consequently, this substance was eliminated from further consideration as a potential alternative to HBCDD for HIPS applications.

While not required as part of the SUBSPORT process, each alternative substance was also screened against the more than 30 list of substances in the SUBSPORT Restricted and Priority Substances Database[11]. Substances listed in this database are those that are legally or voluntarily restricted or are being recommended for restriction due to their hazards by international and national governments, non-governmental organizations and trade unions, and /or by individual companies. By using this database, tetrabomobisphenol-A (TBBPA) bis (allyl ether) and dibromoethyldibromocyclohexane would

[10] http://www.subsport.eu/listoflists?listid=31
[11] http://www.subsport.eu/listoflists

be screened out and not considered as appropriate alternative flame retardants for applications in EPS and XPS insulation foams. Similarly, intumescent systems would be disregarded as appropriate alternative for textile back coating applications because melamine, a component of intumescent systems, is a listed substance in the database. But for the purpose of this assessment, the SUBSPORT Restricted and Priority Substances Database was only reviewed and not used to screen out alternative substances. This information may be useful in prioritizing alternatives for a given application.

Table 5.1: Application of the SUBSPORT screening criteria for SVHC to identified alternatives to HBCDD

Alternative Substance	SDSC	Additional Information: SUBSPORT Restricted & Priority Substances Database
EPS and XPS applications		
Emerald 3000	Not listed	Not listed
TBBPA bis (allyl ether)	Not listed	**Listed**
Dibromoethyldibromocyclohexane	Not listed	**Listed**
EPS and XPS without FRs, using thermal barriers (i.e., concrete)	Not listed	Not listed
Rock wool	Not listed	Not listed
HIPS applications		
Resorcinol bis (diphenyl phosphate)	Not listed	Not listed
Bisphenol A bis (biphenyl phosphate)	Not listed	Not listed
Diphenyl cresyl phosphate	Not listed	Not listed
Triphenyl phosphate	**Listed**	Not listed
Alloys of PPE/HIPS treated with halogen free flame retardants	Not listed	Not listed
Textile back coating applications		
Intumescent systems containing APP, PER and melamine	Not listed	**Listed (melamine)**

6. Characterization of alternatives to hexabromocyclododecane

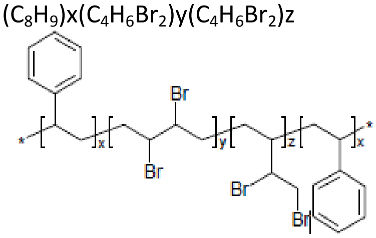
In this section, the environmental profiles as well as human health and safety attributes of the identified alternative substances which passed the SDSC are presented. Where available, information on their performance, availability, cost and life cycle impacts is also presented. Generally, questions related to the performance, availability and cost are often answered in the marketplace. It should be noted that substances listed in the SUBSPORT Restricted and Priority Substances Database were not disregarded as potentially feasible alternatives.

6.1 Flame retardants and material/product redesign alternatives for HBCDD in EPS and XPS

The following tables summarize the hazard characteristics for the alternative flame retardants (Emerald 3000, TBBPA bis (ally ether), and dibromoethyldibromocyclohexane) and material/product redesign alternatives (non-flame retarded EXP and XPS in combination with thermal barriers and rock wool) identified. Sources of information included primary sources (such as Federal or Member State governmental data, peer-reviewed scientific data and vetted compilations of data) in bold and secondary sources (such as industry claims, personal communications and unsubstantiated internet sources) in italics. Where possible, manufacturers were contacted directly for additional data. In some cases data on specific hazards may not be available in the public literature, even though studies have been conducted by manufacturers.

6.1.1 Environmental, health and safety attributes

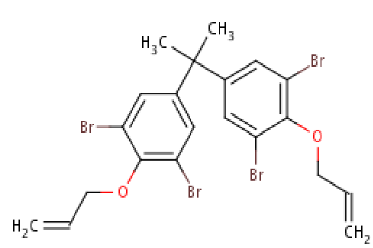
Table 6.1: Hazard characteristics of Emerald 3000

Chemical Properties	Characteristics of Chemical	Source(s) of Information
Chemical name (IUPAC)	Benzene, ethenyl-, polymer with 1,3-butadiene, brominated	**USEPA 2011**
Molecular Formula and Structure (general)	$(C_8H_9)x(C_4H_6Br_2)y(C_4H_6Br_2)z$ 	**USEPA 2011**
Common names	Polymeric FR; Block copolymer of polystyrene and brominated polybutadiene; Emerald 3000	**USEPA 2011**
Identification number (CAS number, EC number)	CAS #: 1195978-93-8	**USEPA 2011**
Physical Hazards		
Explosivity	No information available[12]	
Flammability	No information available	
Oxidizing	No information available	
Other properties of reactivity	No information available	
Human Health Hazards		
Acute toxicity		
Highly toxic	No information available	
Skin or eye corrosion/irritation	Slightly irritating to skin; mildly irritating to the eyes	*Chemtura MSDS 2013*
Chronic toxicity		
Carcinogenicity	Not classified by IARC	**IARC 2013**

[12] A determination of "no information available" for a hazard characteristic indicates that in the public literature or initial contact with manufacturers and suppliers that sufficient data were not made available to evaluate the hazard characteristic.

Chemical Properties	Characteristics of Chemical	Source(s) of Information
Mutagenicity	No genotoxicity observed (Ames, RLCAT)	**Davis 2011**
Reproductive toxicity (including developmental toxicity)	OECD 422 NOEL 1,000 mkd	**Davis 2011**
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**
Immune system toxicity	No information available	
Systemic toxicity	No information available	
Toxic metabolites	Carbon oxides and hydrogen halides	*Chemtura MSDS 2013*
Environmental Health Hazards		
Acute/chronic aquatic toxicity	EL_{50}>1000 mg/l, Water Accommodated Fraction (WAF) *Note, source also lists LL_{10} = 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 substances	**Green Media Toolshed 2010** **UNEP OzonAction Branch**
Monitoring - has the substance been found in human or environmental samples?	No information available	

Table 6.2: Hazard characteristics of TBBPA bis (allyl ether)

Chemical Properties	Characteristics of Chemical	Source(s) of Information
Chemical name (IUPAC)	1,1'-isopropylidenebis[4-(allyloxy)-3,5-dibromobenzene]	**EC ESIS**
Molecular Formula and Structure (general)	$C_{21}H_{20}Br_4O_2$ 	**USEPA ACToR**

Chemical Properties	Characteristics of Chemical	Source(s) of Information
Common names	Ally ether of tetrabromobisphenol-A; Benzene, 1,1'-(1-methylethylidene)bis(3,5-dibromo-4-(2-propenyloxy)-; Benzene, 1,1'-(1-methylethylidene)bis(3,5-dibromo-4-(propenyloxy)-; 2,2-Bis(3,5-dibromo-4-allyloxyphenyl)propane	**USEPA ACToR**
Identification number (CAS number, EC number)	CAS #: 25327-89-3 EC #: 246-850-8	**EC ESIS**
Physical Hazards		
Explosivity	No information available	
Flammability	No information available	
Oxidizing	No information available	
Other properties of reactivity	No information available	
Human Health Hazards		
Acute toxicity		
Highly toxic	No information available	
Skin or eye corrosion/ irritation	H319 (causes serious eye irritation)	**ECHA C&L**
Chronic toxicity		
Carcinogenicity	Not classified by IARC	**IARC 2013**
Mutagenicity	No information available	
Reproductive toxicity (including developmental toxicity)	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**
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**
Environmental Health Hazards		
Acute/chronic aquatic toxicity	Inherently toxic to aquatic organisms; aquatic chronic: H413 (may cause long lasting harmful effects to aquatic life)	**USEPA ACToR** **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 substances	**Green Media Toolshed 2010** **UNEP OzonAction Branch**
Monitoring - has the substance been found in human or environmental samples?	No information available	

Table 6.3: Hazard characteristics of dibromoethyldibromocyclohexane

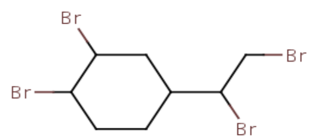
Chemical Properties	Characteristics of Chemical	Source(s) of Information
Chemical name (IUPAC)	1,2-dibromo-4-(1,2-dibromoethyl)cyclohexane	**EC ESIS**
Molecular Formula and Structure (general)	$C_8H_{12}Br_4$ 	**USEPA ACToR**
Common names	1-(1,2-Dibromoethyl)-3,4-dibromocyclohexane; cyclohexane, 1,2-dibromo-4-(1,2-dibromoethyl)-;	**USEPA ACToR**
Identification number (CAS number, EC number)	CAS #: 3322-93-8 EC #: 222-036-8	**EC ESIS**
Physical Hazards		
Explosivity	No information available	
Flammability	No information available	
Oxidizing	No information available	
Other properties of reactivity	No information available	
Human Health Hazards		
Acute toxicity		
Highly toxic	No information available	
Skin or eye corrosion/ irritation	H319 (causes serious eye irritation)	
Chronic toxicity		
Carcinogenicity	Not classified by IARC	**IARC 2013**
Mutagenicity	No information available	
Reproductive toxicity (including developmental toxicity)	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**
Immune system toxicity	No information available	
Systemic toxicity	No information available	
Toxic metabolites	No information available	
Environmental Health Hazards		
Acute/chronic aquatic toxicity	Not inherently toxic to aquatic organisms	**US EPA ACToR**
Bioaccumulation	Bioaccumulative	**US EPA ACToR**
Persistence	Persistent	**US EPA 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 substances	**Green Media Toolshed 2010 UNEP OzonAction Branch**
Monitoring - has the substance been found in human or environmental samples?	No information available	

Table 6.4: Hazard characteristics of concrete (a thermal barrier)

Chemical Properties	Characteristics of Chemical	Source(s) of Information
Chemical name (IUPAC)	N/A (concrete thermal barrier used in combination with non-flame retarded EPs and XPS	
Molecular Formula and Structure (general)	N/A	
Common names	Concrete	
Identification number (CAS number, EC number)	N/A	
Physical Hazards		
Explosivity	No information available	
Flammability	No information available	
Oxidizing	No information available	
Other properties of reactivity	No information available	
Human Health Hazards		
Acute toxicity		
Highly toxic	No information available	
Skin or eye corrosion/ irritation	Eye contact with wet concrete can cause moderate eye irritation, chemical burns and blindness; wet unhardened concrete and concrete dust may cause irritation, severe burns, and dermatitis	*Chandler Concrete MSDS 2008*
Chronic toxicity		
Carcinogenicity	Concrete is not listed as a carcinogen by IARC or NTP; however, concrete contains trace amounts of crystalline silica and hexavalent chromium which are classified by IARC and NTP as known human carcinogens	**IARC 2013** *Chandler Concrete MSDS 2008*
Mutagenicity	No information available	
Reproductive toxicity (including developmental toxicity)	No information available	
Endocrine disruption	No information available	
Respiratory or skin sensitization	Hexavalent chromium (chromate) present in concrete causes allergic contact dermatitis	*Chandler Concrete MSDS 2008*
Neurotoxicity	Not listed in Vela et al.	**Vela et al. 2003**
Immune system toxicity	No information available	
Systemic toxicity	Some have shown that exposure to respirable crystalline silica may be associated with the increased incidence of several autoimmune disorders such as scleroderma (thickening of skin), systemic lupus erythematosus, rheumatoid arthritis and diseases affecting the kidneys	*Chandler Concrete MSDS 2008*
Toxic metabolites	No information available	
Environmental Health Hazards		
Acute/chronic aquatic toxicity	No information available	
Bioaccumulation	No information available	
Persistence	No information available	
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 substances	**Green Media Toolshed 2010 UNEP OzonAction**

Chemical Properties	Characteristics of Chemical	Source(s) of Information
		Branch
Monitoring - has the substance been found in human or environmental samples?	Concrete in itself has not necessarily been found in humans but crystalline silica contained in concrete is a serious exposure concern for workers involved in construction activities such as concrete manufacturing and processing.	**OSHA 2002**

Table 6.5: Hazard characteristics of rock wool

Chemical Properties	Characteristics of Chemical	Source(s) of Information
Chemical name (IUPAC)	Rock wool	
Molecular Formula and Structure (general)	N/A	
Common names	Stone wool, mineral wool, mineral fiber	
Identification number (CAS number, EC number)	N/A	
Physical Hazards		
Explosivity	No explosive hazard exists	*CSR Building Materials MSDS 2007*
Flammability	Non-flammable	*CSR Building Materials MSDS 2007*
Oxidizing	No information available	
Other properties of reactivity	No information available	
Human Health Hazards		
Acute toxicity		
Highly toxic	No information available	
Skin or eye corrosion/ irritation	Can cause skin and eye irritation	**TOXNET HSDB**
Chronic toxicity		
Carcinogenicity	Classified as a Group 3 carcinogen according to IARC (not classifiable as to its carcinogenicity to humans).	**IARC 2013**
Mutagenicity	No information available	
Reproductive toxicity (including developmental toxicity)	No information available	
Endocrine disruption	No information available	
Respiratory or skin sensitization	Exposure to rock wool has been linked to allergic contact dermatitis.	**TOXNET HSDB**
Neurotoxicity	Not listed by Vela et al.	**Vela et al. 2003**
Immune system toxicity	No information available	
Systemic toxicity	No information available	
Toxic metabolites	When heated at high temperatures, the resin binder in rock wool decomposes and may release small amounts of carbon dioxide, formaldehyde and amines.	*CSR Building Materials MSDS 2007*
Environmental Health Hazards		
Acute/chronic aquatic toxicity	No adverse effect on the environment is expected if accidentally released into water sources.	*CSR Building Materials MSDS*

Chemical Properties	Characteristics of Chemical	Source(s) of Information
		2007
Bioaccumulation	No information available	
Persistence	No information available	
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 substances.	**Green Media Toolshed 2010** **UNEP OzonAction Branch**
Monitoring - has the substance been found in human or environmental samples?	During production, use and removal, man-made mineral fiber products (e.g., rock wool) can release airborne respirable fibers. Although exposures to these respirable fibers have been higher in the past, current average exposure levels are generally less than 0.5 respirable fiber/cm^3 (the permissible exposure limit based on an 8-hour workday is 1 respirable fiber/cm^3). Concentrations measured in outdoor and indoor air in non-occupational settings have been found to be much lower than in occupational settings related to their production, use and removal.	**IARC 2002** *NAIMA 2007*

6.1.2 Performance attributes

According to the manufacturer, Emerald 3000 has been designed to provide flame retardant properties at low loadings to polystyrene foam to meet industry fire norms such as ignition resistance (Davis 2011). Emerald 3000 is expected to provide comparable fire performance to HBCDD in flame retarded EPS and XPS. It is also expected to require minimal reformulation to use in existing production lines (Chemtura 2012). Some manufacturers of polystyrene foams, including BASF, anticipate that use of Emerald 3000 would result in a functionally equivalent product (Smock 2011). Extensive test series with Emerald 3000 on a small-to-medium scale have yielded promising results. BASF plans to test new product formulations on a larger scale as soon as sufficient amounts of the polymer become available.

A study on flame retardants listed TBBPA bis (allyl ether) and dibromoethyldibromocyclohexane as two possible alternative chemicals for HBCDD in EPS and XPS applications (Morose 2006). TBBPA bis (allyl ether) is marketed by Chemtura as a flame retardant for EPS insulation foams, providing indication that its performance attributes are similar to HBCDD is EPS applications (KLIF 2011).

Dibromoethyldibromocyclohexane is among the most common flame retardants used in EPS and XPS (Keml 2005). It is marketed by Albemarle under the trade name SAYTEX BCL 462 (Albemarle 2005). Dibromoethyldibromocyclohexane is therefore technically feasible.

Non-flame retarded EPS and XPS insulation foams in combination with other construction materials are used in several countries to protect the EPS and XPS from catching fire. For example in Sweden and Norway, national regulations allow the use of non-flame retarded insulation materials, provided the total building element meets fire safety requirements. In these countries, EPS in combination with thermal barriers (non-combustible materials with high heat thermal capacity such as concrete) are used as alternatives to flame retarded EPS and XPS. Use of EPS in combination with thermal barriers reduces the need for flame retarded EPS without compromising fire safety performance in constructions (KLIF 2011). In the U.S. and Canada, where it appears that there are material requirements for insulation materials, EPS and XPS in building applications would most likely contain flame retardants (Blomqvist 2010). The Norwegian Climate and Pollution Agency concludes that the best way to prevent the spread of fire is by adequately protecting insulation materials from any ignition source. Industry recommendations are that EPS should always be protected with facing materials including concrete, bricks, plasterboards, metal sheet, etc. Insulation materials should be covered during their use so as to provide the required fire performance and for mechanical and long-term insulation properties. By covering EPS and XPS insulation foams with concrete on all sides, the building element as a whole could be classified as non-combustible and used in construction. Non-flame retarded EPS insulation foams can also be covered with a layer on non-combustible insulation material such as mineral wool. This is particularly suitable for flat roofs. In all solutions involving non-flame retarded EPS and XPS, the layer of non-combustible material will have to fully cover the insulation material on all sides and precautions have to be taken to avoid openings and penetrations in the construction such as around windows (KLIF 2011).

Rock wool is marketed for most of the building application areas where EPS is traditionally used and has similar or slightly lower insulation efficiency or thermal conductivity. This provides an indication that the performance of this material may be similar to EPS for building applications. The compressive strength of the most compact types of rock wool is similar to that of the most widely used EPS types. Nonetheless, the compressive strength of rock wool cannot match that of EPS with higher compressive strengths greater than 100 kPA. Rock wool possesses some advantages over EPS. Unlike EPS, the softer types of rock wool allows it to fit and be affixed into the construction quickly. Rock wool maintains its form and flexibility over its lifetime. Despite the fact that some types are water repellent, rock wool is an open, wool-like material which allows water to penetrate it. After water is trapped in or behind the insulation, it can evaporate out through the insulation again to prevent accumulation of moisture (KLIF 2011). According to the North American Insulation Manufacturers Association (NAIMA), rock wool is naturally non-combustible (NAIMA 2010). As such, it does not contribute to the spread of fire and smoke development (ROCKWOOL Group 2012).

6.1.3 Availability

As of 2011, Emerald 3000 was not available in sufficient amounts for large scale new product formulations. BASF, a major manufacturer of polystyrene foams, plans to switch all product lines to the new flame retardant when Emerald 3000 becomes available and if large scale tests and customer trials prove as successful as small-to-medium scale tests. Several years will be needed to replace HBCDD completely (Smock 2011).

TBBPA is the most widely used brominated flame retardant and is produced in the largest volume (Groß et al. 2008). Yet, little information is available regarding the use of TBBPA derivative substances such as TBBPA bis (allyl ether) as commercial flame retardants. It is, however, estimated that about 25% of the total use of TBBPA is in TBBPA derivative flame retardants (ECA and HCA 2012). Based on this information and the fact that TBBPA bis (allyl ether) is marketed for use in EPS, TBBPA bis (allyl ether) can be expected to be commercially available.

Given that dibromoethyldibromocyclohexane is among the common flame retardants used in EPS and XPS applications, it can also be expected to be commercially available.

As stated in **Section 6.1.2**, non-flame retarded EPS and XPS insulation foams used in combination with thermal barriers for insulation are widely used in countries where regulation does not specify the use of flame retarded EPS or XPS in construction. As such, non-flame retarded EPS and XPS foams with thermal barriers as an alternative to flame retarded EPS and XPS are commercially available. In these countries, the performance of the whole building element is tested as opposed to that of materials (KLIF 2011).

Similar to non-flame retarded EPS and XPS insulation foams with thermal barriers, rock wool insulation is widely used in Europe and to a lesser extent in Asia. In Europe, rock wool accounts for about 25% to 30% of the insulation market while in Asia it accounts for about 8%. Eighty percent of the rock wool share of the insulation market in Europe is used in the construction of residential and commercial buildings (KLIF 2011). A publication by the Insulation Council of Australia and New Zealand (ICANZ) in 2004 stated that rock wool is among the mostly used insulation materials in Australia and New Zealand, and worldwide (ICANZ 2004). This alternative material is also commercially available.

6.1.4 Cost

For drop-in chemical alternatives, two main types of costs have to be considered concerning the switch from one flame retardant to another (Posner et al. 2009, POPRC 2011). First the switching cost, which is the cost of reformulation or the cost of the development work or equipment change. Manufacturing and processing facilities may need to invest in new equipment in order to shift to alternative flame retardants. This cost is difficult to estimate, and usually contains the cost of alternatives research and development endeavors including those that did not succeed in finding an efficient flame retardant alternative. This is a cost which is generated at the beginning of a product life cycle. Second is the operating cost associated with the price of the flame retardant (raw) material. In addition, daily operation costs may be different for any new process steps required to manufacture products using other flame retardant chemicals. To ensure economic viability, flame retardants must be easy to process. Typically, high-volume manufacturing conditions are necessary. The costs of manufacturing are heavily dependent on the costs of raw materials, but the degree of this dependency varies among the flame retardants and the current supply of each.

It is unclear at this point whether Emerald 3000 will be economically feasible. The manufacturer apparently considered “acceptable cost” as a primary characteristic for flame retardant replacements for polystyrene foam in its development process (Davis 2011). The cost of flame retardants is relatively small in comparison to the total cost of flame retarded EPS and XPS so that the cost of the alternative flame retardants may not have significant influence on the overall cost of the EPS and XPS insulation foams. For example, in 2011 it was reported that the cost of HBCDD nearly doubled due to efforts by the U.S. and European governments to restrict its uses (ICIS News 2011). In that same year, EPS producers in the U.S. and Canada sought to implement a $0.02 USD/lb price difference between flame retarded and non-flame retarded EPS, whereas producers in Mexico implemented a $0.04 USD/lb price difference (ICIS News 2011a). With the U.S./Canada and Mexico EPS prices in the range of $0.84 to $0.92 USD/lb and $1.03 to $1.05 USD/lb respectively, the price of flame retarded EPS would have rose to between $0.86 and $0.94 USD/lb in the U.S. and Canada, and between $1.07 and $1.09 USD/lb in Mexico. Taking into account that the proposed price increases were a direct result of the increased in the price of HBCDD by almost 100%, it can perhaps be assumed that flame retardants (if commercially available and appropriately priced) may not have significant effect on the price of EPS and XPS.

No information is available describing the cost of TBBPA bis (allyl ether) and dibromoethyl dibromocyclohexane in comparison to HBCDD for EPS and XPS applications. Given that these alternative chemicals are currently on the commercial market, they can be assumed to be economically feasible.

With respect to non-flame retarded EPS and XPS used in combination with thermal barriers, the costs of introducing thermal barriers have not been assessed. Nonetheless, the fact that this solution is widely used in some countries is an indication that the costs for some applications would not be higher than the cost of changing to alternative flame retardant materials (KLIF 2011).

The cost of rock wool varies depending on the intended application and the quality of products. For some applications (such as flat roofs, floors and outer facades), the cost of rock wool is higher than the cost of EPS, typically ranging between 10% and 30% higher. The cost is lower than EPS for cavity wall insulation. The cost is even lower for slaps for insulation of lofts and pinched roofs. For these applications, rock wool is highly competitive and one of the materials of choice in many countries (KLIF 2011).

6.1.5 Life cycle impacts

The life cycle impact assessments of the alternative flame retardants or materials in this section are primarily qualitative descriptions of the source materials for the alternatives, their impact on resource consumption, and their potential climate impacts.

There is no information available to present the life cycle impacts of Emerald 3000. As stated above, Emerald 3000 is a block copolymer of polystyrene and brominated polybutadiene. There are industry reports that provide information on the life cycle impacts of polystyrene. These life cycles impacts, particularly the cradle-to-gate impacts of polystyrene used in Emerald 3000 is likely to be similar to that of EPS and XPS insulation foams. As such, providing the life cycle impacts of polystyrene may result in an unfair comparison of Emerald 3000 to other the alternative chemicals and materials.

There is lack of information on the life cycle impacts of TBBPA bis (allyl ether) and dibromoethldibromocyclohexane.

In the case of non-flame retarded EPS and XPS used in combination with thermal barriers, some life cycle impacts of concrete (a thermal barrier) is presented[13]. Concrete is one of the most widely used construction materials in buildings and other infrastructures. Its primary components include cement (approximately 12%), aggregates (approximately 80%) and water. Production of cement accounts for about 5% of current global man-made carbon dioxide emissions into the atmosphere (Van den Heede 2012, WBCSD 2009). The main cement in use today, Portland cement, is one of the most energy-intensive materials of construction and a contributor of large amounts of greenhouse gases. Producing a ton of Portland cement requires about 4 GJ of energy and the cement clinker[14] manufacture also releases approximately a ton of carbon dioxide into the atmosphere. In addition, mining of cement raw

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[13] It should be noted that the life cycle impacts of concrete described relate to concrete in general and not necessarily that which is used as thermal barrier with non-flame retarded EPS and XPS insulation foams. There is no data on the quantities of concrete used as thermal barrier with non-flame retarded EPS and XPS and their contribution to energy and water consumption, and greenhouse gas emissions.

[14] Clinker is lumps or nodules, usually 3 to 25 mm in diameter, produced by sintering limestone and alumino-silicate (clay) during the cement kiln stage.

materials such as limestone and clay, and fuel such as coal often results in extensive deforestation and loss of top soils (Mehta 2001).[15] The mining, processing and transport of such large quantities of aggregate involves consumption of substantial amounts of energy and have adverse effect on the ecology of forested areas and riverbeds. Consumption of large amounts of fresh water also occurs in mixing and curing concrete. Moreover, concrete structures may lack durability. Despite being designed for a service life of 50 years, structures in urban and coastal environments begin to deteriorate in 20 to 30 years or less (Mehta 2001). Given the undesirable life cycle impacts of concrete and its component materials, a number of initiatives are underway to reduce their impacts on the environment. For example, a number of low-carbon or carbon-free cements are in the process of development by startup companies. According to the World Business Council for Sustainable Development (WBCSD), these cements appear to have comparable mechanical properties to Portland cement. They have yet to be shown to be economically feasible or sustainable in the long-term. They have also not been accepted by the construction industry where strong material and building standards exist. Other proposed initiatives to reduce carbon emissions from cement include deployment of existing state of the art thermal and electric efficiency technologies; use of less carbon-intensive and biomass fuels in cement production; substituting carbon-intensive clinker with lower carbon materials which has cementitious properties; and capturing carbon dioxide and storing it securely so it is not released in the future (WBCSD 2009).

According to an assessment of the life cycle impacts of rock wool commissioned by Flumroc AG, a rock wool producing company in Switzerland, the global warming potential[16] of rock wool production is dominated by direct emissions during the fabrication of the material, contributing over 60% of the total greenhouse gas emissions. The cumulative energy demand for the production of a kilogram of rock wool is 15.2 MJ, with non-renewable sources accounting for more than 90% of the energy used. The remaining 10% of energy used is from renewable energy resources including hydropower and biomass. The packing of rock wool also adds to the greenhouse gas emissions and demands an additional 16.7 MJ of cumulative energy. Estimate by Flumroc AG suggests that roughly 1% of deconstructed rock wool is recycled, while the rest is disposed in an inert material landfill (Flury and Frischknecht 2012). Another manufacturer stated that rock wool can be recycled when a building is deconstructed at the end of its life but provided no estimate regarding the percentage of the material that is actually recycled (ROCKWOOL Group 2010).

6.2 Flame retardants and material/product redesign alternatives for HBCDD in HIPS

The following tables summarize the hazard characteristics for resorcinol bis (biphenyl phosphate), bisphenol A bis (biphenyl phosphate), diphenyl cresyl phosphate and alloys of PPE/HIPS treated with halogen-free flame retardant. Hazard information obtained from primary sources (such as Federal or Member State governmental data, peer-reviewed scientific data and vetted compilations of data) is in

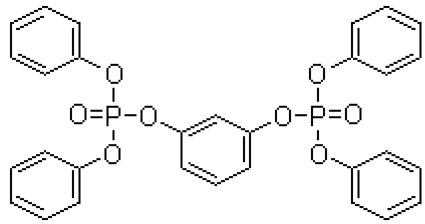
[15] The National Ready Mixed Concrete Association (NRMCA) has provided opposing conclusion with respect to the energy consumed in producing concrete. According to the NRMCA, the process of mining materials that make up the ingredients of concrete, combining the materials in a plant and transporting concrete to the construction site requires very little energy. In other words, a relatively small amount of carbon dioxide is emitted into the atmosphere (Lemay 2011).

[16] Global warming potential is a measure of the total energy that a gas absorbs over a particular period of time (usually 100 years), compared to carbon dioxide (USEPA Climate Change).

bold whereas those from secondary sources (such as industry claims, personal communications and unsubstantiated internet sources) are in italics.

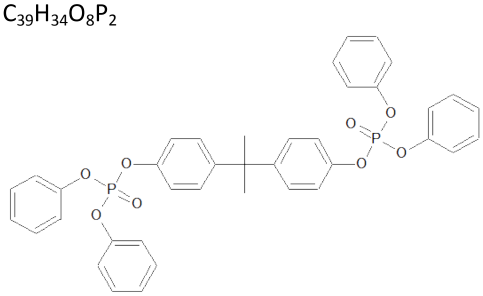
6.2.1 Environmental, health and safety attributes

Table 6.6: Hazard characteristics of resorcinol bis (biphenyl phosphate)

Chemical Properties	Characteristics of Chemical	Source(s) of Information
Chemical name (IUPAC)	Phosphoric acid, 1,3-phenylene tetraphenyl ester	
Molecular Formula and Structure (general)	$C_{30}H_{24}O_8P_2$ 	**USEPA SRS**
Common names	Tetraphenyl resorcinol diphosphate; phosphoric acid, 1,3-phenylene tetraphenyl ester; tetraphenyl m-phenylene bis(phosphate) and Fyrolflex RDP	**OECD eChemPortal**
Identification number (CAS number, EC number)	CAS #: 57583-54-7 EC #: 260-830-6	
Physical Hazards		
Explosivity	No information available	
Flammability	Not flammable	*CCC Limited 2011*
Oxidizing	No information available	
Other properties of reactivity	No information available	
Human Health Hazards		
Acute toxicity		
Highly toxic	Rat oral LD50: > 5000 mg/kg Rat dermal LD50: > 2000 mg/kg Rat inhalation LC50: > 4.14 mg/l (4-hr)	*CCC Limited 2011*
Skin or eye corrosion/ irritation	May cause mild irritation to the eyes	*CCC Limited 2011*
Chronic toxicity		
Carcinogenicity	Not classified by IARC	**IARC 2013**
Mutagenicity	Not mutagenic by the Ames Test	*CCC Limited 2011*
Reproductive toxicity (including developmental toxicity)	No adverse effects on reproductive or fertility associated with resorcinol bis (biphenyl phosphate) administration in the diets of rats	**Henrich et al, 2000**
Endocrine disruption	No information available	
Respiratory or skin sensitization	Not a sensitizer	*CCC Limited 2011*
Neurotoxicity	Not listed in Vela et al.	**Vela et al. 2003**
Immune system toxicity	No information available	
Systemic toxicities	No information available	
Toxic metabolites	No information available	
Environmental hazards		
Acute/chronic aquatic toxicity	Aquatic chronic 2: H411 (toxic to aquatic life with long lasting effects)	**ECHA C&L** **UK Environment Agency 2009**

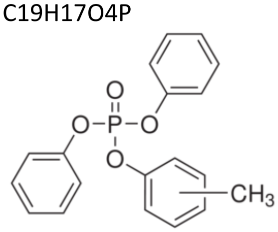
Chemical Properties	Characteristics of Chemical	Source(s) of Information
Bioaccumulation	Resorcinol bis (biphenyl phosphate) does not meet the criteria for a PBT or a vPvB substance.	**UK Environment Agency 2009**
Persistence	Resorcinol bis (biphenyl phosphate) does not meet the criteria for a PBT or vPvB substance.	**UK Environment Agency 2009**
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 substances.	**Green Media Toolshed 2010 UNEP OzonAction Branch**
Monitoring - has the substance been found in human or environmental samples?	The risks to air, secondary poisoning (freshwater and marine food chains and terrestrial food chains) and to humans exposed through the environment from production and all uses are considered to be low	**UK Environment Agency 2009**

Table 6.7: Hazard characteristics of bisphenol A bis (biphenyl phosphate)

Chemical Properties	Characteristics of Chemical	Source(s) of Information
Chemical name (IUPAC)	(1-methylethylidene)di-4,1-phenylenetetraphenyl diphosphate	**ECHA Registered Substances**
Molecular Formula and Structure (general)	$C_{39}H_{34}O_8P_2$ 	**ECHA Registered Substances**
Common names	Phosphoric acid, P,P'-[(1-methylethylidene)di-4,1-phenylene] P,P,P',P'-tetraphenyl ester; Phosphoric acid, (1-methylethylidene)di-4,1-phenylene tetraphenyl ester;	**OECD eChemPortal**
Identification number (CAS number, EC number)	CAS #: 5945-33-5 EC #: 425-220-8	
Physical Hazards		
Explosivity	No information available	
Flammability	Non-flammable	**ECHA Registered Substances**
Oxidizing	No information available	
Other properties of reactivity	No information available	
Human Health Hazards		
Acute toxicity		
Highly toxic	No information available	
Skin or eye corrosion/ irritation	Non-irritating to the skin and eyes of rabbits	**ECHA Registered Substances**
Chronic toxicity		
Carcinogenicity	Not classified by IARC	**IARC 2013**

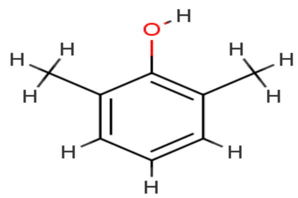
Chemical Properties	Characteristics of Chemical	Source(s) of Information
Mutagenicity	No information available	
Reproductive toxicity (including developmental toxicity)	No information available	
Endocrine disruption	Bisphenol A bis (biphenyl phosphate) is not listed as an endocrine disruptor. However, it degrades to bisphenol A which is an endocrine disruptor in animal toxicity studies.	**WA State 2008**
Respiratory or skin sensitization	Non-sensitizing to the skin of guinea pigs	**ECHA Registered Substances**
Neurotoxicity	Not listed in Vela et al.	**Vela et al. 2003**
Immune system toxicity	No information available	
Systemic toxicity	No information available	
Toxic metabolites	Degrades to bisphenol A, an endocrine disruptor in animal toxicity studies.	**WA State 2008**
Environmental Health Hazards		
Acute/chronic aquatic toxicity	Aquatic chronic 4: H413 (may cause long lasting effects to aquatic life)	**ECHA C&L**
Bioaccumulation	Bisphenol A bis (biphenyl phosphate) is neither a PBT or vPvB substance.	**ECHA Registered Substances**
Persistence	Bisphenol A bis (biphenyl phosphate) is neither a PBT or vPvB substance.	**ECHA Registered Substances**
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 substances.	**Green Media Toolshed 2010 UNEP OzonAction Branch**
Monitoring - has the substance been found in human or environmental samples?	Not likely to be exposed to either workers or public population.	**ECHA Registered Substances**

Table 6.8: Hazard characteristics of diphenyl cresyl phosphate

Chemical Properties	Characteristics of Chemical	Source(s) of Information
Chemical name (IUPAC)	Diphenyl cresyl phosphate	
Molecular Formula and Structure (general)	C19H17O4P 	**OECD SIDS**
Common names	Diphenyl tolyl phosphate	**OECD SIDS**
Identification number (CAS number, EC number)	CAS #: 26444-49-5	
Physical Hazards		
Explosivity	No information available	

Chemical Properties	Characteristics of Chemical	Source(s) of Information
Flammability	No information available	
Oxidizing	No information available	
Other properties of reactivity	No information available	
Human Health Hazards		
Acute toxicity		
Highly toxic	Acute toxicity 4: H302 (harmful if swallowed); H312 (harmful if contact with skin)	**ECHA C&L**
Skin or eye corrosion/ irritation	Moderately irritating (patch test)	**TOXNET HSDB**
Chronic toxicity		
Carcinogenicity	Not classified by IARC	**IARC 2013**
Mutagenicity	Not a mutagen	**TOXNET HSDB**
Reproductive toxicity (including developmental toxicity)	According an environmental risk evaluation report by the UK Environment Agency, a Category 2 R60 (may impair fertility) classification is appropriate for diphenyl cresyl phosphate due to observed effects in an animal model and supporting evidence on the site of action of spermatogenesis	**UK Environment Agency 2009(a)**
Endocrine disruption	No information available	
Respiratory or skin sensitization	Non-sensitizing (patch test) in humans	**TOXNET HSDB**
Neurotoxicity	Not listed in Vela et al.	**Vela et al. 2003**
Immune system toxicity	No information available	
Systemic toxicity	Specific target organ toxicity: H371 (may cause damage to organs)	**ECHA C&L**
Toxic metabolites	When heated to decomposition it emits toxic fumes of phosphorus oxides	**TOXNET HSDB**
Environmental Health Hazards		
Acute/chronic aquatic toxicity	Aquatic acute 1: H400 (very toxic to aquatic life); Aquatic chronic 1: H410 (very toxic to aquatic life with long lasting effects)	**ECHA C&L**
Bioaccumulation	Diphenyl cresyl phosphate does not meet the criteria for a PBT or vPvB substance	**UK Environment Agency 2009(a)**
Persistence	Although diphenyl cresyl phosphate does not meet the criteria for a PBT or vPvB substance, it is considered not readily biodegradable. However, its predicted environmental concentration is lower than the predicted no effect concentration. Therefore, it is considered of low potential risk.	**UK Environment Agency 2009(a) OECD SIDS**
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 substances.	**Green Media Toolshed 2010 UNEP OzonAction Branch**
Monitoring - has the substance been found in human or environmental samples?	Frequency of exposure is very limited and the very few workers involved wear personal protective equipment. The human health risks for the public from indirect exposure via the environment and consumer use are also low.	**OECD SIDS**

Table 6.9: Hazard alloys of PPE/HIPS treated with halogen free flame retardant alternatives[17]

Chemical Properties	**Characteristics of Chemical**	**Source(s) of Information**
Chemical name (IUPAC)	PPE: 2,6-dimethylphenol	
Molecular formula and structure (general)	$C_8H_{10}O$ 	**USEPA ACToR**
Common names	Phenol, 2,6-dimethyl-, homopolymer	**USEPA ACToR**
Identification number (CAS number, EC number)	PPE CAS #: 25134-01-4	
Physical Hazards		
Explosivity	No information available	
Flammability	No information available	
Oxidizing	No information available	
Other properties of reactivity	No information available	
Human Health Hazards		
Acute toxicity		
Highly toxic	No information available	
Skin or eye corrosion/ irritation	No information available	
Chronic toxicity		
Carcinogenicity	Not classified by IARC	**IARC 2013**
Mutagenicity	Not classified	
Reproductive toxicity (including developmental toxicity)	Reproductive toxicity 1A: H360 (may damage fertility or the unborn child)	**ECHA C&L**
Endocrine disruption	No information available	
Respiratory or skin sensitization	No information available	
Neurotoxicity	Not listed in Vela et al.	**Vela et al. 2003**
Immune system toxicity	No information available	
Systemic toxicity	No information available	
Toxic metabolites	No information available	
Environmental Health Hazards		
Acute/chronic aquatic toxicity	PPE is not inherently toxic to aquatic organisms	**CCR**
Bioaccumulation	PPE is not bioaccumulative	**CCR**
Persistence	PPE is persistent	**CCR**
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 substances.	**Green Media Toolshed 2010 UNEP OzonAction Branch**
Monitoring - has the substance been found in human or environmental samples?	No information available	

[17] Hazard characteristics presented in **Table 6.9** pertains only to polyphenylene ether (PPE).

6.2.2 Performance attributes

Specific information is unavailable to describe the performance of resorcinol bis (biphenyl phosphate), bisphenol A bis (biphenyl phosphate) and diphenyl cresyl phosphate in HIPS. Nonetheless, in view of the fact that HBCDD is not widely used in HIPS and these alternatives were preliminary identified to be technically feasible, it is possible that these substances are being used and that their performance attributes are similar to that of HBCDD (Maag et al. 2010).

With respect to PPE/HIPS, major European manufactures of television sets appear to be using alloys including PPE/HIPS with non-halogenated flame retardant. This is an indication that alloys of PPE/HIPS with non-halogenated flame retardant also perform to required industry standards. Alloys of PPE/HIPS are known to have relatively higher inherent resistance to burning and spreading fire because they form an insulating char foam surface when heated. They also have higher impact strength and give similar design opportunities for parts with fine structural details. In addition, alloys of PPE/HIPS require fewer changes to the expensive molds and tooling used in the molding process (Maag et al. 2010).

6.2.3 Availability, cost and life cycle impacts

Based on the information presented in **Section 6.2.2** above, resorcinol bis (biphenyl phosphate), bisphenol A bis (biphenyl phosphate), diphenyl cresyl phosphate and alloys of PPE/HIPS may be commercially available. There is, nonetheless, lack of information to describe the extent of their use as alternatives to HBCDD.

The information presented in **Section 6.2.2** above also indicates that resorcinol bis (biphenyl phosphate), bisphenol A bis (biphenyl phosphate), diphenyl cresyl phosphate and alloys of PPE/HIPS may be economically feasible. Alternatives currently used in the commercial market can be assumed to be economically feasible.

There is lack of information on the life cycle impacts of resorcinol bis (biphenyl phosphate), bisphenol A bis (biphenyl phosphate), diphenyl cresyl phosphate and the polyphenylene ether (PPE) component of alloys of PPE/HIPS.

6.3 Material/product redesign alternative for HBCDD in textile back coating

As described above, intumescent systems may contain ammonium polyphosphate, pentaerythritol and melamine. The hazard characteristics of these components of intumescent systems are presented in **Table 6.10**. Information obtained from primary sources (such as Federal or Member State governmental data, peer-reviewed scientific data and vetted compilations of data) is in bold whereas those from secondary sources (such as industry claims, personal communications and unsubstantiated internet sources) are in italics.

6.3.1 Environmental, health and safety attributes

Table 6.10: Hazard characteristics of intumescent systems

Chemical Properties	Characteristics of Chemical	Source(s) of Information
Chemical name (IUPAC)	N/A	
Molecular Formula and Structure (general)	N/A	
Common names	N/A	
Identification number (CAS number, EC number)	Several components	
Physical Hazards		
Explosivity	No information available	
Flammability	No information available	
Oxidizing	No information available	
Other properties of reactivity	No information available	
Human Health Hazards		
Acute toxicity		
Highly toxic	Melamine is harmful in contact with skin (H312) and harmful if inhaled (H332)	**ECHA C&L**
Skin or eye corrosion/ irritation	Pentaerythritol is not considered a skin or eye irritant; melamine causes severe skin burns and eye damage (H314) and serious eye irritation (H319)	**OECD SIDS(a)** **ECHA C&L**
Chronic toxicity		
Carcinogenicity	Melamine is classified as a Group 3 carcinogen	**IARC 2013**
Mutagenicity	No information available	
Reproductive toxicity (including developmental toxicity)	No information available	
Endocrine disruption	No information available	
Respiratory or skin sensitization	Melamine may cause allergic skin reaction (H317)	**ECHA C&L**
Neurotoxicity		
Immune system toxicity	No information available	
Systemic toxicity	Melamine may cause damage to organs (H373)	**ECHA C&L**
Toxic metabolites	No information available	
Environmental Health Hazards		
Acute/chronic aquatic toxicity	Ammonium polyphosphate is inherently toxic to aquatic organisms; pentaerythritol toxicity to aquatic organism is very low; melamine is very toxic to aquatic life and has long lasting effects (H400 and H410)	**USEPA ACToR** **OECD SIDS(a)**
Bioaccumulation	Pentaerythritol is neither a PBT nor vPvB	**ECHA Registered Substances**
Persistence	Ammonium polyphosphate is persistent; pentaerythritol is neither a PBT nor vPvB	**USEPA ACToR** **OECD SIDS(a)** **ECHA Registered Substances**
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	**Green Media Toolshed 2010**

Chemical Properties	Characteristics of Chemical	Source(s) of Information
	of chemicals containing ozone depleting substances	**UNEP OzonAction Branch**
Monitoring - has the substance been found in human or environmental samples?	No information available	

6.3.2 Performance attributes

Intumescent systems have successfully shown their potential. Several intumescent systems for textile applications have been on the market for about 20 years (Posner et al. 2010). They are based on the formation of expanded coal tar, which partly acts as an insulating barrier against heat and as a smoke-fume trap. Intumescent systems for textile back coating require special handling in application to ensure that the systems work as intended. It is important that the best conditions and combinations of the 3 different components of the systems are in an evenly and well distributed dispersion in the textile application for the desired flame protection to be achieved (Posner 2004).

6.3.3 Availability, cost and life cycle impacts

Despite being on the market for about 20 years, the extent of intumescent systems use in textile back coating is unclear. Nonetheless, intumescent systems are likely to be commercially available and as such possibly economically feasible. There is lack of information on the life cycle impacts of intumescent systems.

7. Comparison of alternatives to hexabromocyclododecane

The following tables present the Pros and Cons associated with the identified alternatives for the various applications of HBCDD.

Table 7.1: Comparison of alternative substances for EPS and XPS

Alternative Substance	Pros (Compared to HBCDD)	Cons (Compared to HBCDD)
Emerald 3000	• Anticipated to provide similar fire performance levels in products • Expected to require minimal reformulation when used in existing production lines	• Lacks comprehensive hazard data • Currently not commercially available • Lack of information to access economic feasibility and life cycle impacts
TBBPA bis (allyl ether)	• Not bioaccumulative • Likely to have similar performance attributes • Likely to be commercially available and economically feasible	• Degrades to bisphenol A, an endocrine disruptor • Inherently toxic to aquatic organisms with long lasting effects • Persistent in the environment • Lacks data to assess other hazard characteristics • Lacks data to assess life cycle impacts
Dibromoethyldibromo cyclohexane	• Not inherently toxic to aquatic organisms • Technically feasible (among most common flame retardant used in EPS and XPS) • Commercially available and likely to be economically feasible	• Bioaccumulative • Persistent in the environment • Lacks data to assess other hazard characteristics • Lacks data to assess life cycle impacts
Non-flame retarded EPS and XPS with thermal barriers	• Eliminates the use of HBCDD and other flame retardants • Maintains fire safety performance in construction • Commercially available (used in countries where regulation does not specify the use of flame retarded EPS and XPS in construction) • Widely used in the EU and therefore assumed to be proven effective	• Concrete (a thermal barrier) contains trace amount of known human carcinogens (silica dust and hexavalent chromium) • Crystalline silica in concrete is a serious exposure concern for workers involved in concrete manufacturing and processing • Lack of information on cost (but likely not higher than the cost of replacing HBCDD with another flame retardant) • Concrete is associated with significant impacts on energy consumption, greenhouse gas emissions, etc.
Rock wool	• Technically feasible (marketed for most applications where EPS is traditionally used) • Commercially available (widely used in Europe and to a lesser extent in Asia) • Durable, as it maintains its form and flexibility over its lifetime	• Small amount of formaldehyde may be released when resin binder in rock wool is heated at high temperatures • Cost for some applications (flat roofs, floors and outer facades) may be 10% to 30% higher (cost is, however, lower for other applications such as cavity wall insulation) • Production contributes significantly to greenhouse gas emissions • Major sources of energy used may be non-renewable

Table 7.2: Comparison of alternatives for HIPS

Alternative Substance	Pros (Compared to HBCDD)	Cons (Compared to HBCDD)
Resorcinol bis (biphenyl phosphate)	• Not a PBT or vPvB substance • Likely to be technically and economically feasible, and commercially available	• Toxic to aquatic life with long lasting effects • Lacks data to assess other hazard characteristics • Lacks data to assess life cycle impacts
Bis phenol A bis (biphenyl phosphate)	• Not a PBT or vPvB substance • Likely to be technically and economically feasible, and commercially available	• Degrades to bisphenol A, an endocrine disruptor • May cause long lasting effects to aquatic life • Lacks data to assess other hazard characteristics • Lacks data to assess life cycle impacts
Diphenyl cresyl phosphate	• Not a PBT or vPvB substance (however, considered not readily biodegradable) • Likely to be technically and economically feasible, and commercially available	• May impair fertility and cause damage to organs • Very toxic to aquatic life with long lasting effects • Lacks data to assess other hazard characteristics • Lacks data to assess life cycle impacts
Alloys of PPE/HIPS with halogen free flame retardant alternatives	• Technically feasible (used by major European TV set manufacturers) • Commercially available • Probably economically feasible (currently being used in the commercial market)	• Lacks comprehensive hazard data • Lacks data to assess life cycle impacts of PPE

Table 7.3: Comparison of alternatives for textile back coating

Alternative Substance	Pros (Compared to HBCDD)	Cons (Compared to HBCDD)
• Intumescent systems containing ammonium polyphosphate, pentaerythritol and melamine	• Pentaerythritol is not a PBT or vPvB substance • Likely to be technically and economically feasible, and commercially available (have been on the market for about 20 years)	• Melamine causes severe skin burns and eye damage; may cause allergic skin reaction; may cause damage to organs and is very toxic to aquatic life with long lasting effects • Ammonium polyphosphate is persistent and inherently toxic to aquatic organisms • Lacks data to assess other hazard characteristics • Requires special handling during application to ensure desired performance • Lacks data to assess life cycle impacts

8. Conclusion

Alternative chemical substances and materials have been identified for HBCDD use in EPS and XPS insulation foams, HIPS and textile back coating applications. With the exception of triphenyl phosphate for HIPS application, the substances that were considered in this alternatives assessment all passed the Substance Database according to SUBSPORT Screening Criteria (SDSC). From a safety perspective, no clearly safer alternatives for the various HBCDD applications were identified. Either the chemical and material alternatives are associated with hazard characteristics of concern or they lack data to allow for assessment of their hazards.

The chemicals alternatives identified for EPS and XPS, HIPS and textile back coating applications are judged to be technically feasible and commercially available. They can therefore be assumed to be economically feasible as well. Similarly, the material alternatives identified for EPS and XPS and HIPS are technically and economically feasible, and commercially available, as they are currently in use in some countries in Europe. Non-flame retarded EPS and XPS with thermal barriers are used in countries where regulation does not specify the use of flame retarded EPS and XPS insulation foams without any reduction in the fire safety performance of construction and rock wool is marketed for most applications where EPS is traditionally used. Alloys of PPE/HIPS treated with halogen-free flame retardant are used by major European TV set manufacturers.

There is limited data available to assess the life cycle impacts of the alternative chemical substances and materials. Only non-flame retarded EPS and XPS with thermal barriers and rock wool which are both material alternatives for HBCDD in flame retarded EPS and XPS insulation foams application have some information describing their respective life cycle impacts.

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10. Appendices

Appendix A – SUBSPORT screening criteria for SVHC

Criteria	Definition
Carcinogenic, Mutagenic or Reproductive Toxicants	CLP Regulation[18] Category 1A, 1B (Dir. 67/548, Category 1 and 2)
	IARC[19] Category 1, 2A, 2B
Very Persistent and Very Bioaccumulative Toxicants	REACH Regulation[20] – Annex XIII
	EC PBT Working Group[21]
	OSPAR List of substances of possible concern[22]
Endocrine Disruptors	OECD Report[23]
	EU Endocrine disruptors database[24] Category 1, 2
	SIN list database[25]
Neurotoxicants	Vela, Laborda, Garcia Study , 2003, categ. 2-4
Sensitization Agents	CLP Regulation[8] for H334, H317 (Dir. 67/548, for R42,R43)

[18] http://www.subsport.eu/wp-content/uploads/2011/01/61-clp-regulation-11.pdf
[19] http://monographs.iarc.fr/ENG/Classification/ClassificationsAlphaOrder.pdf
[20] http://subsport.eu/wp-content/uploads/2011/01/67_reach.pdf
[21] http://ecb.jrc.ec.europa.eu/esis/index.php?PGM=pbt
[22] http://www.ospar.org/content/content.asp?menu=00950304450000_000000_000000
[23] http://www.oecd.org/dataoecd/48/14/44439745.pdf
[24] http://ec.europa.eu/environment/endocrine/strategy/short_en.htm
[25] http://w3.chemsec.org/