CLIMATE AND POLLUTION AGENCY

Assessment of the consumption of HBCDD in EPS and XPS in conjunction with national fire requirements

TA 2819 2011

Prepared by Stefan Posner, SWEREA IVF/AB

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Swerea IVF AB Final Report 10/25

Preface

Norway nominated Hexabromocyclododecane (HBCDD) for considerations of a global ban under the Protocol for Persistent Organic Pollutants (POPs) under the Stockholm Convention in 2008. HBCDD was identified to be a persistent organic pollutant (POP) of global concern by the POP Review Committee (POPRC) under the Stockholm Convention in 2010. The committee decided to start the work on the global management evaluation for HBCDD in 2011.

The Climate and Pollution Agency (KLIF) have commissioned Swerea IVF to perform a compilation study in an attempt to assess current consumption of HBCDD in expandable polystyrene (EPS) and extruded polystyrene (XPS) in the building sector in different countries and world regions, to satisfy national fire requirements. EPS and XPS are used as rigid insulation panels or boards in building constructions and constructions underground. The project was issued by the Climate and Pollution Agency in Norway to support the global management evaluation for HBCDD by the POPRC. The project have been conducted by Stefan Posner at SWEREA IVF and financed by the Climate and Pollution Agency in Norway.

This background report is based on two parts. The Swerea IVF report 10/25 (the main report) in which data on HBCDD consumption is presented and assessed in relation to fire requirements on EPS/XPS products for the building sector. The second part is SP Technical Note 2010:10 (Annex) which is a detailed report on fire requirements in International building regulations for EPS/XPS products written by SP Fire Technology.

Mölndal, May 2011

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Swerea IVF – An assessment study of the consumption of HBCDD in EPS and XPS in conjunction with fire requirements.

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1 Introduction

1.1 Polystyrene

Polystyrene is a thermoplastic resin. Because of its process ability, it is used in many applications such as disposables, packaging, toys, construction, electronics and household wares. There are three basic types of polystyrene resins: general-purpose (GP), high-impact (HI) and expandable beads (EPS).

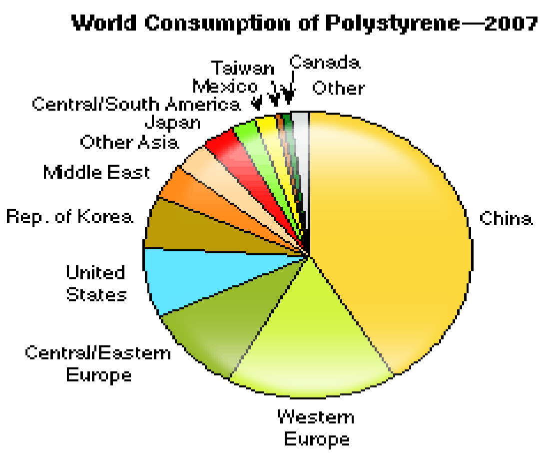
These resins are formed into intermediate or final products via processes such as injection molding, extrusion and thermoforming. The majority of extruded resins are consumed in sheet production that is sold as sheet stock or used internally by the sheet producer in thermoforming.

In thermoforming applications, a large amount of resin, which can range from 30% to 80% and averages 40–50%, is recycled as scrap. Foam molding and extrusion of resins use blowing agents such as pentane, butane and hydrochlorofluorocarbons (HCFCs).

1.2 EPS demand

EPS is among the biggest commodity polymers produced in the world. In 2007 the total world demand was 3.06 million tons and it is expected to grow at 6 percent per year. EPS is solid foam with a combination of characteristics such as lightness, insulation properties, durability and easy process ability. EPS is used in many applications like thermal insulation boards in buildings, packaging, cushioning of valuable goods and food packaging.

The following pie chart shows world consumption of polystyrene:



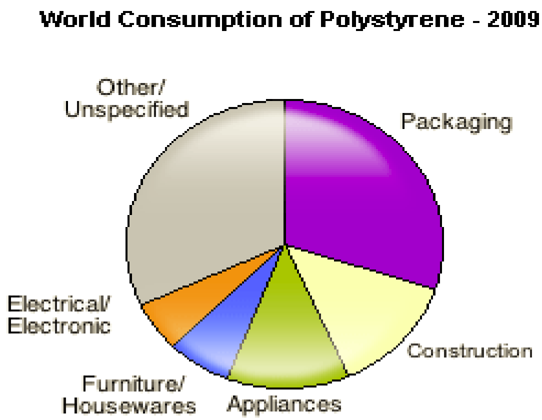
The regional markets for polystyrene with the highest growth potential include Asia, Central and Eastern Europe, and the Middle East. All of these regions will see increased capacities and rising demand for polystyrene. Particularly within Asia polystyrene the demand is projected to increase at a rate of almost 5% compounded annually; Central and Eastern Europe is expected to see a growth of almost 6% per year and the Middle East is projected to increase on the order of about 5% annually in 2007–2012.

1.3 The global polystyrene market

In 2009 global production and consumption of polystyrene (all grades) were approximately 14.4 and 14.9 million metric tons, respectively. Global capacity utilization was 66.7% in 2009, slightly lower than in 2008. Polystyrene consumption is estimated to have decreased by just over 2.5% in 2009. It is predicted to an average growth of 3.2% per year from 2009 to 2014, and 2.6% per year from 2014 to 2019. Average global utilization rates are expected to increase to the low or mid-80s range by the end of the forecast period.

Together, general purpose (GP) and high impact (HI) polystyrene account for about 70% of total global polystyrene consumption. The largest end use for GPPS and HIPS is in packaging applications, followed by appliances, and electric/electronic uses. EPS is mainly used in packaging and construction applications, especially for building insulation, where it provides energy reduction in heating and cooling buildings.

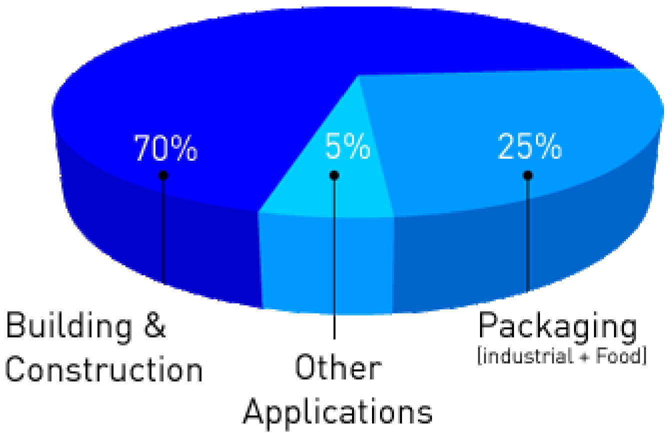
The following pie chart shows world consumption of polystyrene (EPS, GP and HIPS together) by end use:



1.4 The European EPS market

Western Europe contributes 27 percent of the global demand for EPS, which was approximately 840 000 tons in 2007. The corresponding value of this volume is approximately 3 billion Euros. The average annual growth is expected to be 2.5 percent per annum up to 2010.

The pie chart below demonstrates the main EPS market applications for Europe. The major applications are building / insulation and packaging.



2 Use of HBCDD

HBCDD can be used on its own or in combination with other flame retardants e.g. antimony trioxide and decabromodiphenyl ether.

HBCDD is used in four principal product types, which are:

- Expandable Polystyrene (EPS)
- Extruded Polystyrene (XPS)
- High Impact Polystyrene (HIPS)
- Polymer dispersion for textiles

The main use (around 90 %) of HBCDD is in polystyrene (PS) where the predominant use is in rigid insulation panels/boards for building construction (EPS and XPS).

3 The flame retardant market

In 2005, the total market for flame retardants in the United States, Europe and Asia was about 1.5 million metric tons and was valued at about 2.9 billion USD (see table 1). In 2008 this market had expanded to about 1.8 billion metric tons at about 4.2 billion USD. The market of FR is expected to grow at an average annual rate of about 3.7% in the next five years.

Table 1: *Global consumption of FRs in 1000 tons and their geographical distribution 2005 and 2008*

Category	**United States**		**Europe**		**Japan**		**Other Asia incl. China** *(figures for China in brackets)*		**Total volume [1000 metric tons]**		**Value [million USD]**	
Year	**2005**	**2008**	**2005**	**2008**	**2005**	**2008**	**2005**	**2008**	**2005**	**2008**	**2005**	**2008**
Aluminium hydroxide (ATH)	315	345	235	280	47	49	48	61 *(50)*	645	735	424	559
Organo phosphorous FRs	65	72	95	83	30	32	14	22 *(9)*	205	208	645	838
Brominated FRs	66	64	56	45	50	56	139	246 *(77)*	311	410	930	1428
Antimony trioxide	33	33	22	20	17	18	44	70 *(40)*	115	141	523	697
Chlorinated FRs	33	33	35	40	5	5	10	53 *(50)*	82	131	146	291
Other FRs	51	75	47	61	11	14	14	44 *(36)*	123	194	197	424
TOTAL	**564**	**622**	**489**	**529**	**160**	**173**	**269**	**495** *(222)*	**1481**	**1819**	**2865**	**4236**

Brominated flame retardants account for about 23% of the world market, which may be regarded as a significant proportion of total world production of flame retardants. TBBPA and decaBDE are the most common brominated flame retardants on the global market, followed by HBCDD which is the third most used brominated flame retardant worldwide - with a global market demand of 21 000 metric tons in 2008. In Europe the corresponding consumption of HBCDD is estimated to 11 000 metric tons in 2008.

The differences between the different regions' flame retardant consumption in volume are shown in figure 1. There are several reasons behind the regional differences. Asia (Japan, China and Other Asia) has the biggest demand for flame retardants. Besides the expected growth rate of flame retardants, sales are also expected to be the highest in Asia (excluding Japan) with about 6-7% compared to other regions. The growth in this region is due to the transfer to production (electronic manufacturing) to these areas, especially to China, Thailand and Malaysia. So far, due to the lack of strong regulation on FRs, almost half of Asia's flame retardant consumption still mainly consists of brominated flame retardants.

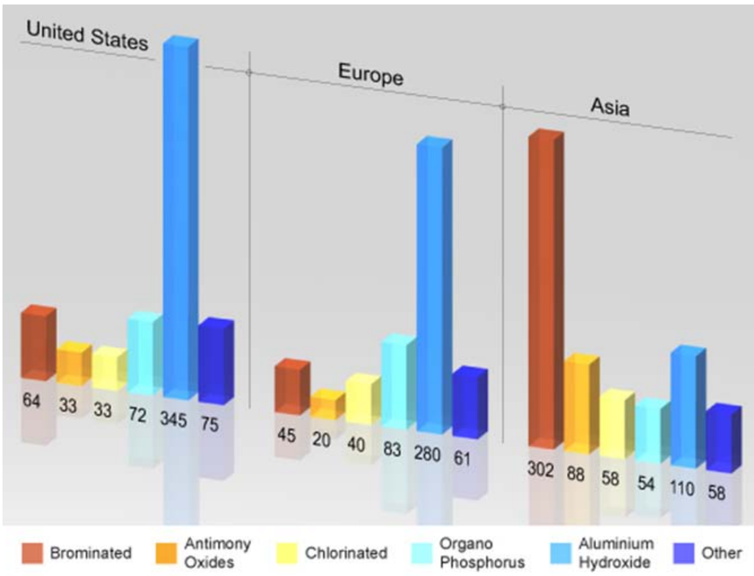


Figure 1: *Flame Retardant Consumption by Region in 2007*

In the United States the current economic uncertainties are reflected on the *flame retardant* market, which is expected to grow at an average annual rate of 2-3% through 2012. The major driving force for the US flame retardant business is the existence of government regulations; in addition, industry segments such as electronics have been self-regulating. USA is aware of existing and pending international regulations and wishes to use FR systems that will be accepted worldwide.

4 Assessment analysis of the consumption of HBCDD in EPS and XPS

As previously mentioned the world production and consumption of polystyrene is approximately 14 million tons annually. EPS/XPS are responsible for approximately 30% of this global consumption; approximately 65% of this share is used for packaging and approximately 35% for construction. This would mean that the global consumption of EPS/XPS for construction, mainly as insulation boards, is around 1.5 million tons per year.

It is important to take into consideration that insulation boards are bulky products and they are not transported over long distances. They are most likely manufactured for the market where the flame retarded insulation boards are actually used. This means that there is a current HBCDD consumption in close conjunction to production sites of EPS/XPS insulation boards.

A range of countries have been investigated concerning their practice of using flame retarded (FR) EPS/XPS on their national construction market, with possibly local manufacturers of HBCDD. In particular, one can note that in those countries where only the performance of the final product is tested the use of EPS/XPS as insulation material does not result in a formal requirement that the EPS/XPS used is flame retarded. In those countries where material performance is required, e.g. Germany, EPS/XPS that is used must be flame retarded.

This would mean that the consumption and possibly production of HBCDD is strongly located to those countries with a usage of FR-treated EPS/XPS. However, it is important to mention that some of the countries that practice usage of FR treated EPS/XPS may as well apply alternatives to insulation panels flame retarded with HBCDD on their national markets.

However, fire regulations in a number of countries do require flame retarded EPS/XPS in their construction industry, and flame retarded EPS/XPS is used even in countries where fire regulations do not require this see table 2 and 3 below. UK is an example of a country where requirements from insurance companies has resulted in that the majority of EPS/XPS is flame retarded.

Table 2 gives a summary of the requirement areas and practices of using flame retarded EPS/XPS in Europe. The description of the fire requirements in the different European countries is described in Chapter 3 and 4 in the annex of this report.

Table 2: *Summary of the requirement areas for fire performance in European countries and information on the practice of using flame retarded (FR) EPS/XPS in each country where available***.**

European country	General for materials	Insulation materials	Sandwich panels	Facades	FR-treated EPS/XPS Usage*
Sweden	No	No	No	Yes	**No**
Denmark	Yes	*n.i.*	*n.i.*	*n.i.*	*Likely*
Finland	No	Yes	No	No	*Likely*
Norway	No	No	Yes	No	**No**
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.*	Yes	*n.i.*	**Yes**
UK	No	Yes	*n.i.*	*n.i.*	**Yes**

n.i. = No specific information available.

* = the country specific application of the Eurocodes will determine whether material performance will be required.

The countries outside Europe that have been studied were selected either based on the significance of use of EPS/XPS or on the availability of information. Table 3 contains a summary of the findings and their implications for the use of flame retardants (FR) in each country. The description of the fire requirements in the different countries is described in Chapter 3 and 5 in the annex of this report.

Table 3: *Summary of the requirement areas for fire performance in selected non-European countries and information on the practice of the use of flame retarded EPS/XPS in each country where available.*

Country	General for materials	Insulation materials	Sandwich panels	Facades	FR-treated EPS/XPS Usage
USA	Yes	Yes	Yes	Yes	*Likely*
Canada	Yes	Yes	*n.i.*	*n.i.*	*Likely*
Australia	Yes	Yes	*n.i.*	*n.i.*	**Yes**
Japan	Yes	Yes	*n.i.*	*n.i.*	**Yes**
Korea	Yes	*n.i.*	No	*n.i.*	*Likely*
Egypt	Unclear*	Yes	Yes	*n.i.*	*n.i.*

n.i. = No specific information available

4.1 National fire requirements and the national consumption of HBCDD

The European fire classification system for construction products and material does not set requirements on individual material in a building product, but on the fire performance of the complete product in its intended mode of use.

In Europe the highest volume demands for flame retardants is in Germany, followed by France, Italy and UK (BizAcumen 2009). Table 4 gives the percentage break down of volume demands of flame retardants for different countries in Europe in 2008, together with the volume demand for flame retardants in million pounds converted into tons.

Table 4. *Estimated volume demand for flame retardants in Europe in 2008 in % and in millions pounds and converted into tons (BizAcumen 2009[1]).*

European Country	%	Volume demand (million pounds)	Volume demand (tons)
France	17.47	187.57	85081
Germany	22.18	238.29	10808
Italy	17.07	183.29	83139
UK	17.12	183.81	83375
Spain	4.86	52.15	23655
Russia	3.37	36.18	16411
Rest of Europe	17.93	192.54	87335
Total	100	1073.82	487076

The situation is a bit different for the volume demand for brominated flame retardants in the region. Germany is still on top followed by Italy and UK, while the demand in France is less than expected. Table 5 gives the percentage break down of volume demands for brominated flame retardants in different countries in Europe in 2008, together with the volume demand for brominated flame retardants in million pounds converted into tons.

[1] Flame retardant chemicals. A world market review. November 2009. BizAcumen.

Table 5. *Estimated volume demand for Brominated flame retardants in Europe in 2008 in % and in millions pounds and converted into* tons *(BizAcumen 2009).*

European Country	**%**	**Volume demand (million pounds)**	**Volume demand (tons)**
France	9.1	17.20	7802
Germany	23.8	45.05	20434
Italy	18.6	35.1	15921
UK	18.6	35.20	15966
Spain	5.4	10.16	4609
Russia	3.9	7.36	3338
Rest of Europe	20.6	38.92	17654
Total	**100**	**188.99**	**85724**

Germany has the most stringent fire requirements in Europe and has the highest consumption of flame retardants in general and brominated flame retardants in specific.

This also applies to the national fire requirements for buildings that are more stringent than the other European countries, as well. In Germany, they have national requirements that specify the fire performance on an individual material level in a building product. The implication for the use of EPS/XPS in such applications is that flame retardant products are required. They also have specific national regulations for the fire performance of insulation materials. Requirements on insulation materials will exclude the use of non-flame retarded EPS/XPS in many applications, especially for public buildings and other buildings with a high safety class, as e.g. high-rise buildings. There are also special requirements for sandwich panels in Germany. The requirements exclude the use of non-flame retarded EPS/XPS.

France, Italy and UK have specific national regulations for the fire performance of insulation materials. For most applications in these countries flame retarded EPS/XPS should be required. There could be exceptions, e.g. for applications of insulation materials in buildings with a lower safety level, such as single family dwellings. Although it is unclear whether these exceptions actually mean that a small portion of the market is non-flame retarded or whether all the market in these countries uses flame retarded EPS/XPS by default. France also has special requirements for facades. The requirements exclude the use of non-flame retarded EPS/XPS.

The volume demand in France for brominated flame retardants is less than in UK and Italy. This could mean that other materials that are less flammable than EPS/XPS are used in many applications and buildings in France. In UK there are no formal regulations that would exclude the use of non-flame retarded EPS/XPS, however, according to the UK plastic industry, almost the entire market share for EPS/XPS in UK is flame retarded products due to requirement from the insurance sector. This may partly explain the high volume demand for brominated flame retardants in the country. But since we do not have the volume demand for HBCDD for UK, France and the other countries it is not possible to conclude on this.

Countries like Sweden and Norway with a performance approach to the final product in their regulations use much less brominated flame retardants than countries with more specific fire requirements on a material level. The volume demand for brominated flame retardants in Norway have been estimated to [2]450 tons (Klif 2010) . Norway has special fire requirements for sandwich panels. The Norwegian requirements would require flame retarded EPS/XPS for some of those applications, but other insulation materials are usually used instead.

Table 6. *Estimated volume demand for Brominated Flame Retardants (BFRs) in the different world regions (and some countries) in 2008 and use of Flame Retardants (FRs) in the building and construction segment in millions pounds and converted into* thousand tons *(BizAcumen 2009).*

World region	**BFRs (million pounds)**	**BFRs (million kilograms)**	**FRs in the building and construction segment (million pounds)**	**FRs in the building and construction segment (tons)**
Asia-Pacific	917.92	416.361	329.05	149254
Japan	132.7	60.1917		
North America	192.92	87.5070	399.05	181006
Europe	188.99	85.7244	341.80	155037
Rest of the	74.1	33.6111	43.11	19554

[2] Miljøgifter i Produkter – data for 2007. Klima og forurensningsdirektoratet. TA 2622/2010.

world				
Total	**1506.8**	**683.472**	**1113.01**	**504852**

In North America (USA; 75840 tons BFRs and Canada; 11670 tons of BFRs), it seems that there are material requirements which mean that flame retarded EPS/XPS would be most common in building applications. In North America other brominated alternatives to the use of HBCDD in EPS are on the market, and the consumption of HBCDD is lower than in EU.

The low volume demand of brominated flame retardants and use of flame retardants in building and constructions for the rest of the world implies that other alternatives may be used here. In Australia there are very low formal requirements concerning fire performance of materials which would not necessarily require the use of flame retarded EPS/XPS. It seems however that if EPS/XPS is used instead of other materials it is flame retarded voluntarily.

The use in the Asian region of brominated flame retardants is dominated by use in electronics and electrical industry (BizAcumen 2009; 298-323 tons). Most of this is used in China (BizAcumen 2009). The use of flame retardants in the building and construction segment in Asia is on the same level as in Europe and North America, but this sector is heavily growing in China (BizAcumen 2009). In Japan, it would appear that EPS/XPS would need to be classified as flame retardant material as it would not be able to attain any of the other classes without the use of flame retardants which would automatically mean that it would be included in this class. This implies also that the majority of EPS/XPS for use in Japan would be expected to be flame retarded. Korea appears to have a similar situation as that in Japan. There have been limited information on the fire safety requirements in China, but flame retarded EPS is reported from the Chinese government to be important in new constructions and buildings. Considering the population in the Asian region compared to the European and North American populations, the use of other alternatives than EPS is likely.

4.2 Assessment of flame retarded EPS/XPS, based on reported HBCDD consumption

As previously mentioned HBCDD is used in four principal product types, which are:

- Expandable Polystyrene (EPS)
- Extruded Polystyrene (XPS)
- High Impact Polystyrene (HIPS)
- Polymer dispersion for textiles

According to industry information, the main use (90 %) of HBCDD is in polystyrene (PS) The predominant use of PS is in rigid insulation panels/boards for building construction (EPS and XPS). About 2 % of the total use of HBCDD is in “high impact polystyrene” (HIPS).

Table 7: *Consumption figures of HBCDD for 2006 in Europe supplied by the HBCDD Industry Users Group. The data for textiles use estimates for 2007.*

Use Category	**Consumption (tons/year)**
Insulation boards	11 160
Electronic devices	210
Textile coatings	210
Total	11 580

Since a textile back coating may contain approximately 25% HBCDD which corresponds to approximately a load of 7 to 9 % on the back coated fabric (70 to 90 kg HBCDD per ton of fabric), the consumption of 210 tons HBCDD, as mentioned in table 4 above, would only last for 2300 to 3000 kg of back coated fabrics in Europe, which sounds unlikely for the whole back coated textile consumption in EU, which could indicate that there is a major import of back coated textiles into EU27 or that the real HBCDD consumption for textile back coatings is higher than reported in table 6 above.

Figure 2 below illustrates the vast dominance of textile import from China to EU27 that are in quantities much higher than exported quantities from EU2 which are illustrated in figure 3.

However the statistics in figure 2 and 3 covers all categories of textiles and not specifically coated FR treated textiles, which may aggravate the assessment of accurate traded quantities of back coated textiles to and from EU27[3].

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3 http://madb.europa.eu/mkaccdb2/statistical.htm?from=form&format=0&cb_reporters=EU27&cb_partners=all&list_years=2004&ahscode1=5907000000&submit=Search+HS+code’

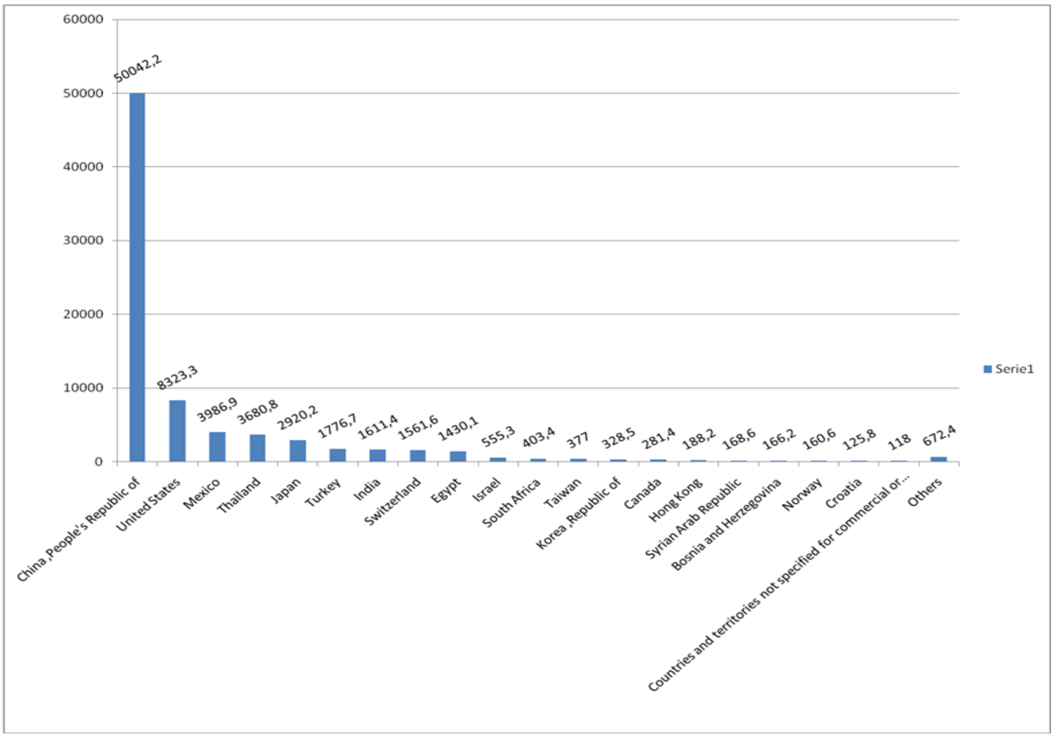

Figure 2: *Textile import to EU27 from countries outside the EU-region in 2004 (EU – Commission DG Trade, market access database)*

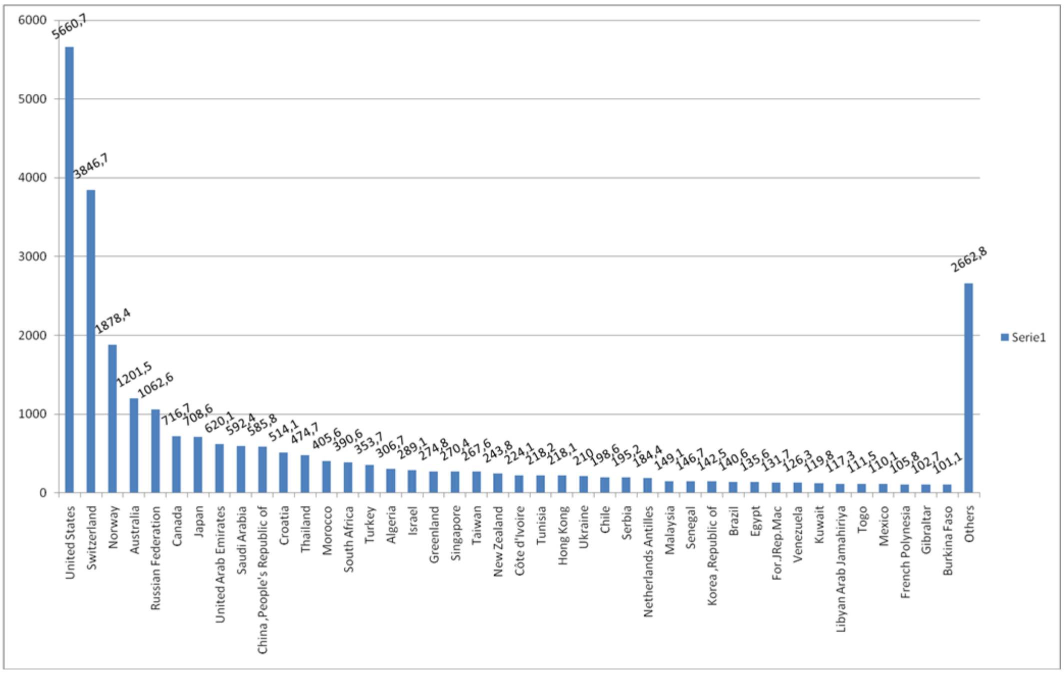

Figure 3: *Textile export from EU27 to countries outside the EU-region in 2004 (EU – Commission DG Trade, market access database)*

In 2008 the total global consumption of HBCDD was estimated to 21 000 tons. Since flame retarded EPS/XPS contains around 0, 5 – 1% HBCDD, these 21 000 tons would at least account for the production of 1500 000 tons of HBCDD treated EPS/XPS, which is in line with the total amount of EPS/XPS produced worldwide which is around 14 to 15 million tons annually. It is not likely that all EPS/XPS used worldwide are treated with HBCDD due to different fire regulations and market requirements and their implementation in various countries and regions in context to various regulatory environmental enforcement of HBCDD

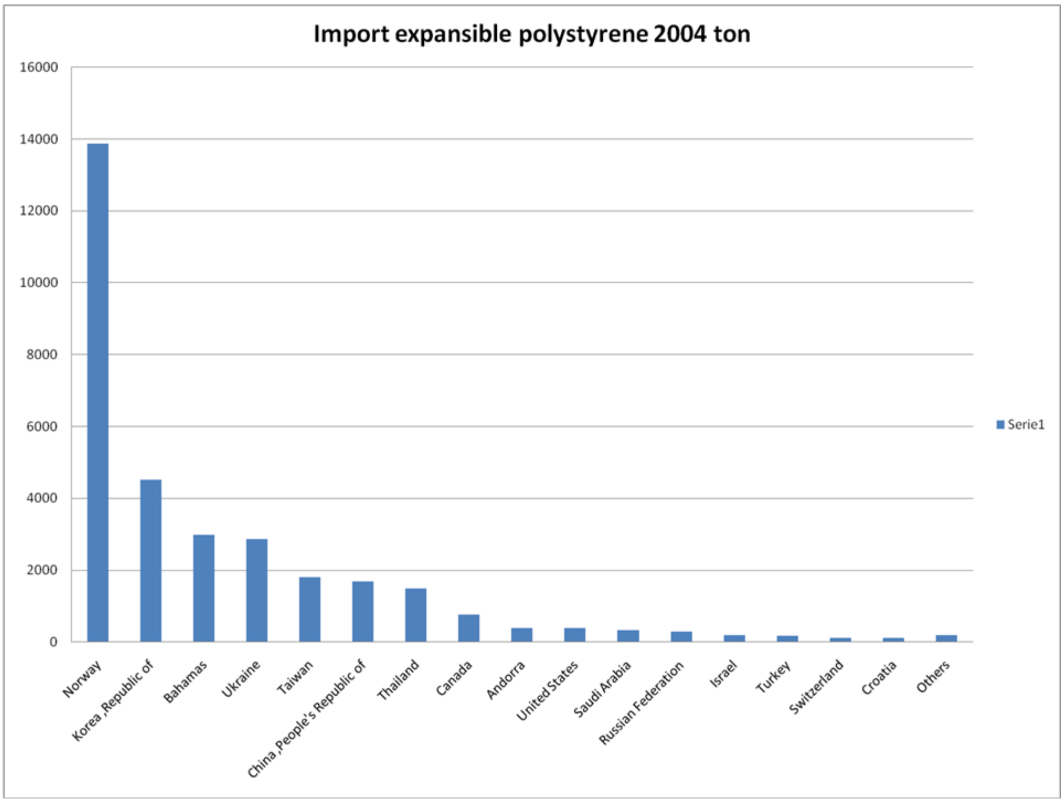

Figure 5: *Import of EPS to EU27 in 2004 from countries outside the EU-region (EU – Commission DG Trade, market access database)*

As earlier mentioned there is little trade over national borders with EPS insulations construction blocks mainly due to their size. This is a logistic problem.

Figure 5 and 6 illustrates the total trade between EU27 and countries outside EU. As for Europe Norway dominates the import of EPS to EU of all countries worldwide. The main part of the EPS is exported to Sweden and Denmark (see table 8). Most of this is assumed to be without a flame retardant. The producers of EPS in Norway are obliged by law to report their import, export and production of HBCDD to the national register for products. In 2009 21 tons of HBCDD was exported to other countries, as flame retarded EPS granulate. The volume of the

EPS granulate with HBCDD was 35 000 tons. There is no production of EPS with HBCDD for the internal market in Norway. This has been a voluntary agreement between the producers of EPS and the environmental authorities since the beginning of 2000.'

Table 8: *Trade Statistics (Imports - Exports) for EU27 and Member States in Trade with Norway for EPS in 2009 (EU – Commission DG Trade, market access database)*

Indicators	Import Value to the EU/MS (1000 EURO)	Import Qty to the EU/MS (1000 kg)	Export Value from the EU/MS (1000 EURO)	Export Qty from the EU/MS (1000 kg)
Partners	Norway	Norway	Norway	Norway
Years	2009	2009	2009	2009
EU Member State(s)				
Belgium	-	-	23.480	24.200
Denmark	7 068.390	6 521.300	0.120	0.200
Estonia	-	-	5.320	0.800
Finland	118.490	63.400	-	-
France	-	-	3 820.010	4 006.000
Germany	1 012.120	919.000	-	-
Greece	356.930	312.000	-	-
Ireland	49.470	0.000	-	-
Italy	15.000	12.000	-	-
Netherlands	-	-	49.580	48.000
Poland	-	-	5.840	3.500
Spain	139.080	144.000	-	-
Sweden	14 849.820	13 851.100	165.140	114.000
United Kingdom	1 756.460	1 576.700	26.180	4.000
EU25	25 365.760	23 399.500	4 095.670	4 200.700
EU27	25 365.760	23 399.500	4 095.670	4 200.700

Estimated use of HBCDD is approximately 33 tons in 2009 (Klif 2011)[4]. The consumption is a rough estimate based on an anticipated Norwegian share of the global consumption, and the proportional distribution between the different brominated flame retardants on the global market (the consumption of pentaBDE and OktaBDE is assumed to be zero, because of a national ban). The consumption includes HBCD in EPS, XPS, HIPS in cabinets and in isolation pipes. Table 8 above reports an import of 4200tons of EPS into Norway from EU27 in 2009. If we assume that 70% of all this EPS is used for the construction industry this would mean that approximately 2800 tons of imported EPS from EU27 is used in the Norwegian construction industry, and that some of these insulation boards may be flame retarded with HBCD.

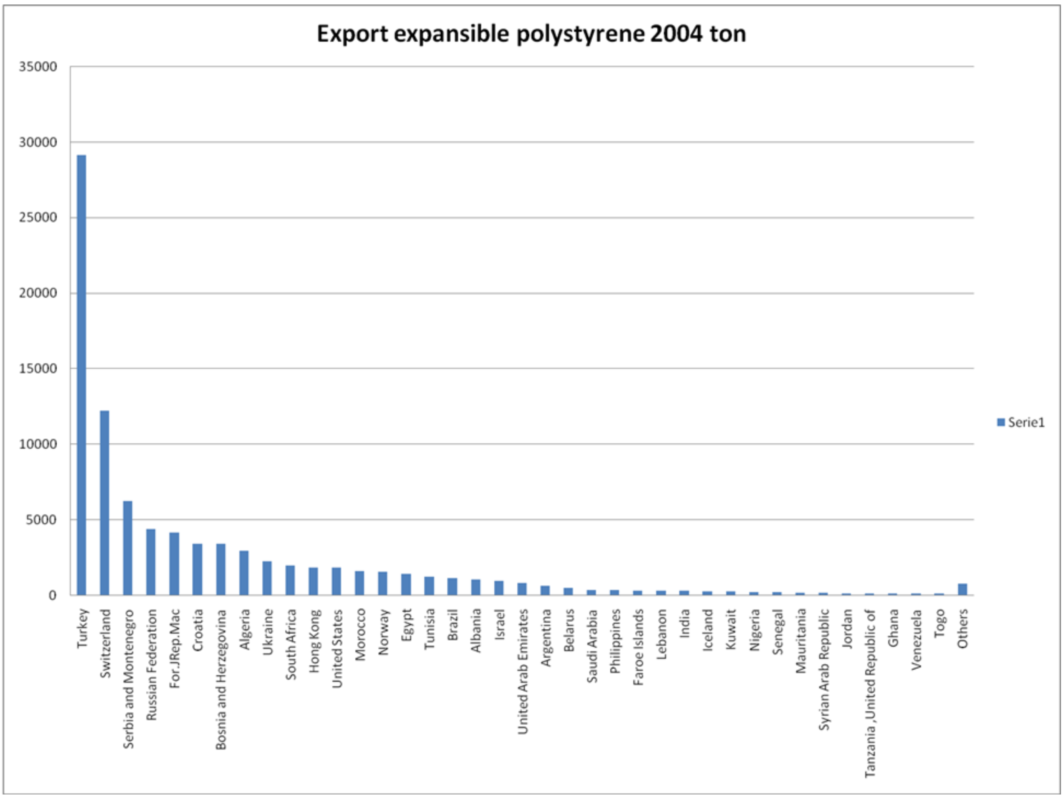

Figure 6: *Export of EPS from 2004 EU27 in 2004 (EU – Commission DG Trade, market access database)*

Figure 6 above show that Turkey followed by Switzerland is the major exporters of EPS into EU27. Switzerland is one of the countries that allow performance based solutions in specific applications meaning that they apply alternative materials on their national market instead of EPS. There is no further data for Turkey at hand concerning their use of

[4] Miljøgifter i Produkter – data for 2007. Klima og forurensningsdirektoratet. TA 2622/2010

HBCDD treated ESP or alternative materials as well as the potentially HBCDD treated EPS exported from Switzerland.

As shown earlier in this report from statistics, China (approx. 6 million tons per year) is the largest EPS/XPS consumer in the world followed by Europe. Unfortunately we do not have any specific production and consumption data of EPS/XPS available for China nor do we know their annual HBCDD consumption. However new statistics data from China has been issued, that indicate that the Asian markets are fast growing due to flourishing economies and that China is growing as a global production base for significant end-use markets of flame retardant chemicals (BizAcumen 2010).The developing construction and building sector in China make them the largest consumer of EPS/XPS in the world, and maybe also the largest consumer of HBCDD. In EU the market for flame retardants is more restricted by regulations, and halogen-free alternatives are on the rise due to the end-users concern for more eco-friendly or green products (BizAcumen 2009). HBCDD is now placed on the authorisation list with an aim of phasing out the use under the REACH-directive in EU. However, producers and users can apply for specific uses of HBCDD, but have to be able to document strong reasons for an authorisation by the EU Commission. They have to apply before February 2014, and the sunset date is August 2015.

Asia is emerging as a major importer of flame retardant chemicals worldwide. Burgeoning real estate and automobile sectors have set the tone for this development. China, Taiwan and South Korea are the most active markets for flame retardants, and China is topping the demand charts. Growing demand in the end-user markets as well as flourishing economy in China have led to growth in several markets, the electronics industry, the construction and building sector and the automotive industries. Another important drive for the increasing demand of flame retardants in the electronics and automotive industries are the extensive adoption of plastics and intricate device miniaturisation, in turn demanding greater amount of additives to prevent sparking. There are an increased usage of plastics in electronics, replacing glass and metals in various products. In the automotive industry new age cars are deploying larger volumes of plastic components, and electronics. Plastics are now common in aircraft, motor vehicles, and electrical products. In recent past plastics have also replaced other materials in construction products. As a consequence of this and lack of regulations brominated and chlorinated flame retardants dominate the market in China.

However, the restrictions in Europe also influence the use of flame retardants in electric and electronic appliances in China. Since the production flows to different markets are connected and very costly to divide, it is not possible to use a different production process for the products aimed for the European market. There are also indications of rising concern and demands to the industry from the authorities in China (BizAcumen 2010). The Chinese authorities are now considering introducing a similar restriction as the European RoHS- directive.

Another important factual you can conclude from the use of flame retardants in cars is that the automotive industry can be a larger sector for the usage of HBCDD, than expected. HBCDD can be used in plastic cabinets, and casings, as well as in isolation panels and automotive textiles. The amount of HBCDD in this industry is not investigated in depth on an international scale. The production flow is more complicated than for EPS panels, and the knowledge of the amounts of hazardous substances in cars is very limited, especially when imported from regions with less restrictions. In an Norwegian impact assessment of a total national ban of HBCDD, the amount of brominated flame retardants in the Norwegian park of transport vehicles was estimated to be 30 -50 tons, 10 – 15 tons of this was estimated to be HBCDD (Vista 2010). There are almost none transport industries in Norway, only production of smaller parts for export. All transport vehicles in Norway are imported.

In Europe a consumption of 11000 tons of HBCDD was reported in 2008. If we assume that all HBCDD consumption in Europe is addressed to local EPS/XPS insulation board production (with an average content of 0,7% HBCDD) for the regional construction, it would result in a consumption of approximately 1,6 million tons of HBCDD-treated EPS/XPS in Europe. That may seem a bit high in the context of the total consumption of EPS/XPS, estimated at 3 to 4 million tons for construction industry worldwide based on data available.

4.3 Conclusions

Based on the assessments made in this report, there is either an underestimate of the real global consumption of HBCDD in the EPS/XPS construction industry, or there is a far more common use of alternative materials for insulation that do not require HBCDD. However we cannot exclude Non Chemical alternative materials and solutions such as

- Phenolic foams
- Blankets (fiber batts or rolls) or as loose fills that may contain rock wool, fiber glass, cellulose or polyurethane foam
- EPS/XPS without flame retardants, together with alternative construction techniques, and thermal barriers

It is unclear to what extent these alternative solutions are used in those countries that require FR-treated EPS/XPS for their national construction industry since no market data of consumption and use have been found in statistics available to the public.

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Annex: SP Technical Note 2010:10 -

Compilation of International Building Regulations (Fire) Relevant for EPS/XPS

Per Blomqvist, Margaret Simonson McNamee and Per Thureson

Abstract

Compilation of International Building Regulations (Fire) Relevant for EPS/XPS

A compilation of international building regulations has been attempted. An undertaking of this kind is, by its very nature, nebulous and difficult to say the least due to the minutiae of differences in interpretation of seemingly similar regulations in their individual application. We have attempted to approach the topic in a systematic manner that has at times posed questions which have defied a single answer. This is particularly true in the EU where the CPD and associated harmonized Euroclass system seems straightforward at first glance, at least for those products where product standards exist (which is true for insulation materials). As the project has proceeded it has become painfully clear that the devil is in the detail, with application of the harmonized European approach differing significantly in the different member states, e.g. from essentially no material requirements in Sweden to stringent material requirements in Germany.

Nonetheless, it is clear from the compilation that the use of flame retardants in EPS/XPS is widespread, both in cases where this is a strict regulatory requirement (e.g., Germany) and in those where it is not (e.g., Australia).

The report is presented divided into European countries and non-European countries for the simple reason that the European countries have an overriding system (the CPD and Euroclass system) upon which they base their national regulations while those outside of Europe each have national codes.

The regulations themselves are summarized in Chapter 3 while their implications for European countries and non-European countries are summarized in Chapters 4 and 5, respectively.

Key words: Polystyrene, EPS, XPS, flame retardant (FR), building regulations, fire requirements

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Contents

1 Introduction

Hexabromocyclododecane (HBCDD) was nominated for inclusion in the POP protocol by Norway in 2008. The Task Force on POPs (UN ECE) finished the Track A review at its 7th meeting, and at the 26th session of the Executive Body the Parties to the POP Protocol it was determined that HBCDD should be considered as a POP as defined under the Protocol. The Task Force on POPs was requested to continue its work, to proceed with the review of the substance, explore management options for HBCDD and complete the Track B review. As part of this work it is clear that an understanding of building regulations and their impact on the use of HBCDD is an important factor.

In September 2010, Swerea IVF received a commission to investigate whether building fire regulations have an impact on the use of HBCDD in EPS/XPS in building applications in UN ECE lands. As part of this project, SP Fire Technology was commissioned to collate international fire regulations with a focus on Europe, North America, Australia, and Japan.

The time available for this compilation has been short and the data presented in this report while not exhaustive does give an overview of the fire regulations as a basis for discussion of their impact on the use of HBCDD in EPS/XPS. The data compiled in this report is based both on in-house expertise at SP Fire Technology, in particular in relation to European Building legislation, and on replies to a questionnaire distributed to a selected group of colleagues internationally, and subsequent discussions with these colleagues. The subjects and the question posed in the questionnaire are given in Appendix 4. As part of the questionnaire, subjects have been asked to comment on whether existing regulations have an impact on the use of EPS/XPS in building applications in their country/countries of expertise. This information has been included where available. If not available, no additional investigation has been possible to ascertain this within the scope of this project.

It is important to state that all non-referenced information and conclusions given in this report is ultimately based on the knowledge and judgement of the authors.

2 Building applications of EPS/XPS

Expanded polystyrene (EPS) is a rigid and tough, closed-cell foam. It is usually white and made of pre-expanded polystyrene beads. Familiar uses include molded sheets for building insulation and packing material for cushioning fragile items inside boxes.

Extruded polystyrene foam (XPS) is a similar rigid, closed-cell foam which offers improved surface roughness due to higher stiffness and reduced thermal conductivity. Due to the extrusion manufacturing process, XPS does not require facers to maintain its thermal or physical property performance. Styrofoam is a trademarked name for XPS.

In building applications EPS/XPS can generally be used interchangeably, although XPS has better mechanical properties and higher moisture resistance which makes it suitable for demanding underground applications. Building and construction applications are the largest outlet for EPS accounting for around two-thirds of demand [[i]]. Common building applications include: insulation underground (tunnel linings, under road surfaces, as insulation between surrounding ground and a cellar structure), floors, walls and ceilings. In many cases the EPS/XPS is found as part of a complex structure, e.g. a facade system (as insulation) or sandwich panel.

This project will not specifically consider underground uses of EPS/XPS (which generally have less stringent, or no, fire performance requirements) but will focus on uses of EPS/XPS as building insulation and sandwich panels.

3 International Codes and Standards

3.1 Overview and Scope

Building fire regulations relate both to *Fire Resistance* and *Reaction-to-Fire*. Fire Resistance relates to the integrity of a fire compartment under the influence of a given fire. Fire Resistance testing assesses integrity, insulation and stability of the construction under well defined conditions. Regulations on fire resistance are put on construction products and building elements with a fire separating function. These type of construction do not normally contain EPS/XPS as polystyrene would not contribute positively to the integrity or the insulation properties of the construction during a fully developed fire. In this project we have interpreted the scope of the project to exclude a full compilation of regulations for fire resistance as this has no clear bearing on the use of flame retardants in EPS/XPS.

The Reaction-to-Fire of a product deals with characteristics such as ignition, flame spread, heat release rate, smoke and gas production, the occurrence of burning droplets and parts. This project will focus on the building fire regulations related to Reaction-to-Fire classification of EPS/XPS.

3.2 European Fire Regulations

3.2.1 Construction Products Directive (CPD)

The European Commission published the building products directive (89/106/EEG) in 1989, to promote free trade of building products within the European Union (and those countries outside the EU having an agreement with the EU to abide by the CPD, 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

Indeed, the entirety of the European activities concerning fire classification and fire standardization for building products rests on the single 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 are developed within CEN, the European Committee for Standardisation, which call on standards also developed within CEN (or in some cases through ISO according to the Vienna Agreement).

The implication of the CPD is that building products must have a fire classification based on the same standards throughout Europe. The important issue is then how the classification standard is applied in each member country, i.e., the system itself is performance neutral. The European Classification Standards identify product performance but make no comment on what the performance should be for any given application. The level of safety a product must have in a building application in any member state is then the prerogative of building regulations in the specific member state.

A member state that regulates for a certain safety level will be able to identify the fire properties of a building product corresponding to that level according to the European classification standards. Products complying with the essential requirements of the directive are labelled c. An overview of the system is given in Figure 1.

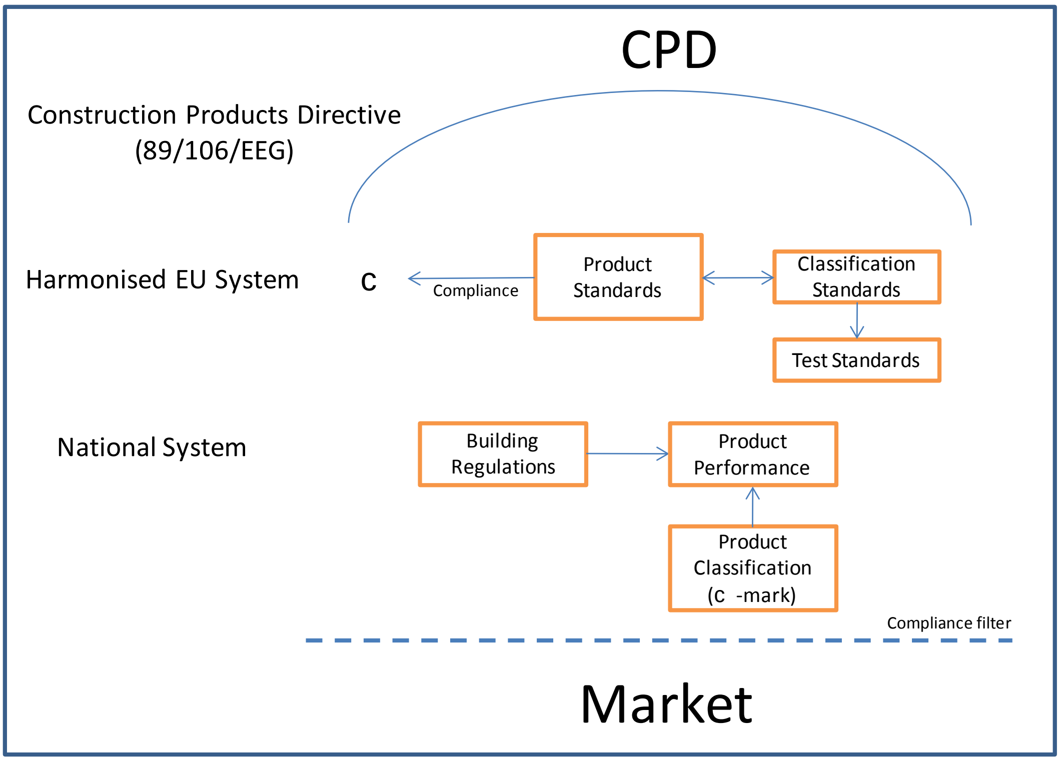

Figure 1: Schematic showing relationship between the CPD and the Market place for building products.

Once a product standard has been developed there is a continuous need for quality assurance associated with that standard. This can include interpretation of test procedures, extended application (EXAP) of test data, technical co-operation between test laboratories, agreements of praxis between certification bodies etc. The Fire Sector Group, consisting of notified bodies[5] for testing and certification throughout Europe, is responsible for discussing these issues and defining solutions if problems arise. Technical work such as the development of good technical practice in testing relies heavily on EGOLF, the European Group of Official Fire Laboratories, and various European industrial or trade organisations.

3.2.2 The Euroclass System

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

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[5] A notified body is a body, for example a test laboratory or a certification organisation, which a member state has *notified* to the European Commission as suitable for performing testing/certification under the European system.

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. Appendix 1 shows an example of the various Euroclasses for the reaction-to-fire performance of construction products excluding floorings and linear pipe thermal insulation products.

In many cases the test methods used are developed within ISO, the International Standardisation Organisation and later adopted within CEN through the Vienna Agreement. 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 methods included in EN 13501-1 are described in Appendix 2.

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. In particular, correlation has been made between EN 13823 (SBI) [[iii]], the main test method in EN 13501-1, and ISO 9705 [[iv]]/EN 14390 [[v]] which is a room scale test for surface lining products.

Class B in EN 13501-1 represents materials that do not give flashover in the reference room test, whereas Class C - Class E do 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 instead different degrees of limited combustibility of a product. Class F signifies that no Reaction-to-Fire performance has been determined.

3.2.3 Product Standards relevant for EPS/XPS

3.2.3.1. European product standard for sandwich panels EN 14509

A specific European product standard for sandwich panels, EN 14509 Self-supporting double skin metal faced insulating panels - Factory made products – Specifications, was published in December 2008. Since January 2009, sandwich panel manufacturers can chose to c - mark their products accordingly. From October 2010, CE marking will be compulsory for all sandwich panels sold in the EU.

The Reaction-to-Fire classification derived from the provisions in this standard provide 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 this annex.

Note that the specific class required for the use of a sandwich panel in Europe is the prerogative of regulators in the specific country of use within the EU.

3.2.3.2 European product standard for EPS EN 13163

This European Standard specifies the requirements for factory made products of expanded polystyrene (EPS), with or without facings or coatings, which are used for the thermal insulation of buildings. The products are manufactured in the form of boards or rolls or other preformed ware.

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.

3.2.3.3 European product standard for XPS EN 13164

This European Standard specifies the requirements for factory made products of extruded polystyrene (XPS), with or without facings or coatings, which are used for the thermal insulation of buildings. The products are manufactured in the form of boards, which are also available with special edge and surface treatment.

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 EN13164 refers to EN 13501-1 with information on required testing frequencies but with no additional testing instructions.

3.2.4 Euroclass testing of EPS/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 [vi] and/or the criteria concerning heat of combustion in EN ISO 1716 [vii].

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 [viii]. EN 13823 is an intermediate scale test where two vertically oriented sheets of the product are placed in a corner arrangement and a burner is applied to the base of the corner. ISO EN 11925-1 is a small-scale test where a small flame is applied to a vertically oriented test specimen. More details of these methods are given in Appendix 2.

The applications of the Euroclass tests for the main type of EPS/XPS product categories are summarized in Table 1. The expected ranges of classification results for non-flame retarded (non-FR) and flame retarded (FR) EPS/XPS, respectively, are indicated in the table.

Table 1: Euroclass test requirements for EPS/XPS products and estimates of classification results.

Product	Application of Euroclass tests	Non-FR product Euroclass	FR product Euroclass
EPS/XPS (EN 13163, 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-E*
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*

* An exposed FR-EPS/XPS sample specimen would only in rare cases pass the Euroclass B requirements in EN 13823.

The interpretation of the indicative classification results in Table 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 true independent of whether the EPS/XPS has been flame retarded.

The relevance of testing sandwich panel products using EN 13823 (SBI) and the link to the reference room test has been discussed previously [ix], as sandwich panel products are often used as self supporting building elements or mounted on a supporting frame. This has lead to the development of special large-scale tests for sandwich panels [x-xi]. These tests are not part of the European system but can have a role as demonstration tests in performance based fire safety engineering.

3.2.5 Compliance with the CPD and the Euroclass system

Compliance with the CPD requires that products, where a product standard exists, are tested and c-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 c-mark is a prerequisite for access to the European market for EPS/XPS in building applications but the fire performance cited in the c-mark may be as low as F (no testing required). Thus, potentially non-flame retardant products can be c-marked and sold within the EU. Indeed, this is the case for many building applications in Sweden where, provided the insulation material is not exposed in the final product, no further fire testing of the product is required.

The specific classification requirements in each country determine what performance is needed in order for the product to be marketed in the country of choice. This is discussed in more detail in Chapter 4.

The CPD has been in existence since 1989 as a *Directive* that is non-mandatory. There is a move in recent years to change the Construction Products Directive into the Construction Products Regulation which would essentially be mandatory in all EU-member states. The present projection for the implementation of this Regulation is 2013.

3.2.6 Additional informal requirements

In addition to the Directive and the associated Euroclass system there are numerous informal national systems in effect. In Sweden the “Pitch Fork”-mark[6] (t) is a national mark indicating type approval. In Sweden the Pitch Fork is largely disappearing as it is not legally allowed in Sweden once a product standard allows the implementation of the c-mark.

In Germany, the “Ü-mark” is widely used to signify acceptable performance of building material for use on the German market. This symbol signifies that not only are the EU-requirements met but also the specific German requirements which allow use of the product in German construction. This mark is very strong in the building market in Germany and while non-mandatory, is so well established that it is to all intents and purposes mandatory.

3.3 North American Fire Regulations

3.3.1 US

Building codes in the United States have developed over the years principally by locality and region. Local municipalities can choose to adopt their own building code version.

Three different Model Building Codes have, however, been in effect since about 1940. Their use has been preferred in the following regions:

- The West: The Uniform Building Code (CBC) issued by the International Conference of Building Officials (ICBO).
- The Midwest and Northeast: The BOCA National Building Code issued by Building Officials and Code Administrators International, Inc.
- The South: The Standard Building Code issued by the Southern Building Code Congress International, Inc. (SBCCI).

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[6] This mark is regulated by The National Board of Housing, Building and Planning (Boverket) in Sweden.

These model building codes are favoured in the areas where they originated and are adopted in full or in part in state or city building regulations, although this is not mandatory. Local or regional variations in building code acceptance deal with issues and concerns peculiar to that specific area. Localities can adopt a model building code but with specific changes or provisions needed in their particular location.

Fire precautions are dealt with comprehensively in these model building codes. Many of the fire standards referenced in the codes are issued by the American Society for Testing and Materials (ASTM). Many building authorities also use the nationally available NFPA 101 Life Safety Code of the National Fire Protection Association (NFPA) [xii], which also covers fire precautions. In addition, certain building regulations issued by the federal agencies apply nationwide. Minimum property standards have also been established by the Department of Housing and Urban Development (HUD) and the Department of Health and Human Services (HHS).

On December 9, 1994, the **International Code Council (ICC)** was established as a non-profit organization dedicated to developing a single set of comprehensive and coordinated national codes to promote code uniformity throughout the country. The ICC founders BOCA, ICBO, and SBCCI created the ICC in response to technical disparities between the three sets of model codes in use within the United States. This single family of codes has received widespread public support from leaders in the building community in the United States. The ICC issued their first **International Building Code (IBC)**, in 2000.

The IBC is not mandatory but it does appear to have met fairly broad acceptance across the US. This means that while the IBC may not be formally adopted, a particular state will have something similar in force. Further, if it is adopted it is often adopted with specific modifications for the state or municipality in question. The code, like the other three model codes has one primary chapter on expanded foam plastics, which includes most of the flammability regulations. It was agreed that standards adopted by the code would be based on consensus processes, for example, ASTM or NFPA.

The IBC essentially defines that expanded foam plastics used in building applications must be tested according to ASTM E84 (the Steiner Tunnel) for Reaction-to-Fire (for details, see Section 5.1).

In 2000, the **International Residential Code (IRC)** replaced the International One- and Two-Family Dwelling Codes (formerly CABO). Designed as a companion to the IBC and other International Codes, the IRC concentrates on one- and two-family dwellings, as well as townhouses up to three stories high. Flammability resistance of plastics in residential housing is no more stringent than in other constructions.

3.3.2 Canada

The regulation of buildings in Canada is the responsibility of provincial and territorial governments. Each of the 10 Provinces and 3 Territories have their own building code. All of the provincial and territorial building codes, however, are based on a single model code, the National Building Code of Canada (NBC). Although the NBC is intended to establish a minimum standard of fire safety for the construction of new buildings or the renovation of existing buildings, several provinces make amendments to the NBC that render their codes somewhat more demanding.

There are requirements both on material level and on the finished product. The test methods relevant for EPS/XPS insulation are: CAN/ULC-S124, “Test for the Evaluation of Protective Coverings for Foamed Plastic” and CAN/ULC-S101, “Fire Endurance Tests of Building Construction and

Materials”.

3.4 Other regions

3.4.1 Japan

In 1998, a revision of the main parts of the BSL (Building Standard Law), including the fire safety design systems, was published and came into effect in 2000. This revision has started a process of changing from a specification-based (i.e. prescriptive) to a performance-oriented design regulation.

The new version of the BSL places *Basic Requirements* and *Performance criteria* on building parts and materials. These are divided into fireproof, fire preventative construction, non-combustible materials, quasi-combustible materials and fire retardant materials. Based on the performance of tested materials, a “performance evaluation report” is issued and can be used to obtain approval for use.

Non-combustible materials are classified based either on ISO 1182 [vi] where a temperature rise of no more than 20 °C is allowed, or using the Cone Calorimeter (ISO 5660-1[[xiii]]) at 50 kW external heat flux, where the total heat release is not allowed to exceed 8 MJ and the maximum heat release must be less than 200 kW/m^2 during the whole 20 minute test period. Clearly EPS/XPS cannot meet these test requirements even when treated with flame retardants.

Quasi-combustible materials are classified either based on ISO 5660-1 or in the Box Heat Test, ISO 17431 [[xiv]]. The classification requirements are the same in ISO 5660-1 with the exception that the test period is only 10 minutes. In the Box Test a total heat release of 30 MJ is allowed with a maximum heat release rate of 140 kW. Further, no burn-through is allowed.

Flame retardant materials are also classified using the Cone Calorimeter or the Box Test. In this case the test period is only 5 minutes and the same classification criteria apply.

3.4.2 Australia

The Commonwealth of Australia consists of six states - New South Wales, Queensland, South Australia, Tasmania, Victoria, and Western Australia - and two Territories - the Australian Capital Territory where the capital, Canberra, is situated, and the Northern Territory. Building regulations are the responsibility of the states and territories. All the State and Territory Building Regulations call up the Building Code of Australia (BCA).

The BCA is published by the Australian Building Codes Board (ABCB). The BCA is performance based. It contains Objectives, Functional Statements, and Performance Requirements. The Performance Requirement for materials is that they must resist the spread of fire and limit the generation of smoke, heat, and toxic gases to a degree appropriate to the building type. The BCA also contains prescriptive Building Solutions that are “deemed-to–satisfy” the Performance Requirements without further testing.

The test methods used to ascertain whether building materials or components meet the deemed-to-satisfy provisions of the ABCB are described in AS 1530 (Parts 1-4). AS(NZ) 1530-3 (Early Fire Hazard Test) applies to all building materials other than thin flexible materials and is therefore the relevant standard for determining the fire performance of EPS/XPS in building applications.

Two other standards are commonly used to assess the fire performance of plastic materials in buildings but as these standards are not referenced in the ABCB they are not mandatory. The first, AS 2122-1 assesses the flame propagation properties of rigid and flexible cellular plastics in the form of bars and is similar to ASTM D 3014. The second, AS 2122-2 assesses the minimum oxygen concentration required for flame propagation on small specimens and is not relevant for EPS/XPS.

3.5 Fire Safety Engineering (FSE)

Fire Safety Engineering is the application of science and engineering principles to protect people and their environments from the destructive effects of fire and smoke. *Prescriptive* fire safety regulations are regulations which in detail specify the design and classification of building components. These will, for some applications, exclude the use of products containing combustible materials which do not conform to the required fire rating. A performance based approach to comply with the overall fire safety level of the building can be a valid alternative for such applications.

Fire safety regulations are basically prescriptive in many countries. However, a performance based approach is allowed in several countries. A few European countries have their regulations based on a performance based approach and some countries allow performance based solutions in specific applications. FORUM[7] have reported [[xv]] that the European countries that can be classified as performance based are: the United Kingdom, Sweden, and Norway. Other European countries allowing performance based alternatives include: Belgium, France, Italy, Luxembourg, Netherlands, Germany, Denmark, Ireland, Greece, Portugal, Spain, Austria, Finland, and Switzerland.

Internationally, New Zeeland and Australia have performance based codes. Japan generally allows performance based alternatives and both the US and Canada allows performance based alternatives in their regulations to a certain degree.

Generally, *performance based* regulations allow the building contractor to choose an appropriate design method to accomplish fire protection in accordance with the safety level defined in the regulations.

For most buildings there are two alternative methods that can be used in performance based fire safety work:

- prescriptive design or
- analytical design.

Prescriptive design is, in principle, the same method as was used prior to the introduction of performance based requirements. Prescriptive design assumes that all the requirements and general recommendations for the object in question are set out to be fully met. When using prescriptive design it is not possible to make any technical exchanges in addition to those already given in the published regulations. If any other technical exchanges are made the design is considered to be an analytical one.

One reason to abandon prescriptive design is that a more cost effective design might be possible using analytical design through a technical exchange. An even more common reason to use analytical design

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[7] The International Forum of Fire Research Directors (FORUM) is a group of the Directors of fire research organizations throughout the world which aim to reduce the burden of fire (including the loss of life and property, and effects of fire on the environment and heritage) through international cooperation on fire research.

is that fire safety according to prescriptive standards places limitations on the design regarding, for example, architectural objectives or building activity.

A comprehensive requirement when using analytic design is that the fire safety accomplished in a building should be as good as or better than if all the prescriptive requirements were set out to be met. A disadvantage when using analytic design is that this method requires a more knowledgeable designer than prescriptive design.

When using prescriptive design the requirements to verify the results are low. This design method is simple, well known and is in most cases results in a conservative fire safety solution.

When using analytical design, however, the need to verify the results is higher. This is due to the fact that the need to verify the results is high when the starting point for the design is the prescribed risk level. The verification of an analytical design solution concerns the choice of method, the acceptance criteria and the way the uncertainties are managed. Figure 2 illustrated the different sources of data when using Fire Safety Engineering to design a building.

The extent of changes made compared to prescriptive design and the complexity of the building, determines the need for verification. When the deviations from a prescriptive design are small, it is not reasonable to require a complete safety evaluation, considering the time and resources that would be needed to make one. It is, however, necessary to study all the relevant cases that will be affected by the deviations from the prescribed requirements in order to prove that the fire protection accomplished through the analytic design is equivalent to or better than that which would have been defined using prescriptive design.

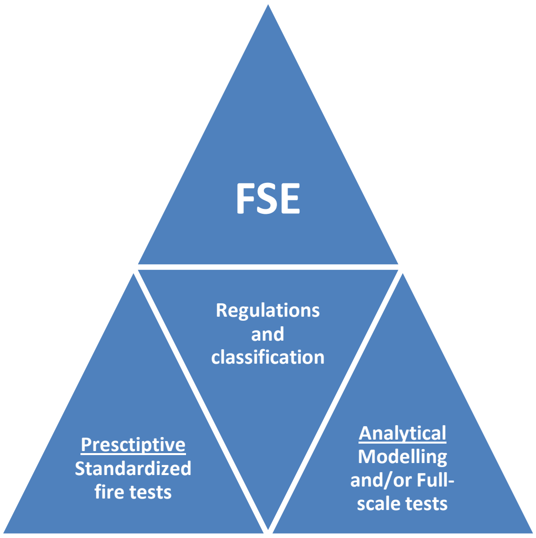

Figure 2: Pyramid diagram illustrating different sources of input used in Fire Safety Engineering (FSE).

The application of analytical design is typically used for fire safety design of large complex buildings and is not the preferred methodology for simple applications. For EPS/XPS products one could imagine analytical design to be used for larger building where sandwich panels are used and in some cases have a load bearing function.

However, it is not possible to quantify the extent of application of analytical design specifically to EPS/XPS products. Further, it is unclear whether the application of analytical design would necessarily change the fire performance requirements of these products in any given application as the fire safety design in an analytical design must be equivalent to or better than that using a prescriptive design.

4 Requirements in Europe

4.1 The Nordic countries

On a Nordic basis the NKB (Nordic Committee for Building Regulations) previously had the task of harmonising the Nordic Building Regulations. Since the Construction Products Directive came into practical use, the NKB Product Rules have increasingly been replaced by the new European system for testing and classification. The level of harmonization of the Nordic Building Regulations has been described and analysed in a SP-report [xvi].

The general principles and levels of regulatory tools concerning fire safety are described in Figure 3. The highest level defines the overall objective: safety in the case of fire. The next level includes two possible routes: Pre-accepted Design using fire classes and numerical values (prescriptive rules) or Performance Based Design utilising fire safety engineering (FSE). Finally, at the third level, either European test and classification methods or engineering methods can be used to define the required classes or performance of materials, products and building elements.

Only the test and classification methods and essential requirements in the case of fire are harmonised. On the design level there are a lot of differences between the Nordic countries [xvi]. For Reaction-to-Fire classification, EN 13501-1 is the basic classification document in all Nordic countries in accordance with the Euroclass system.

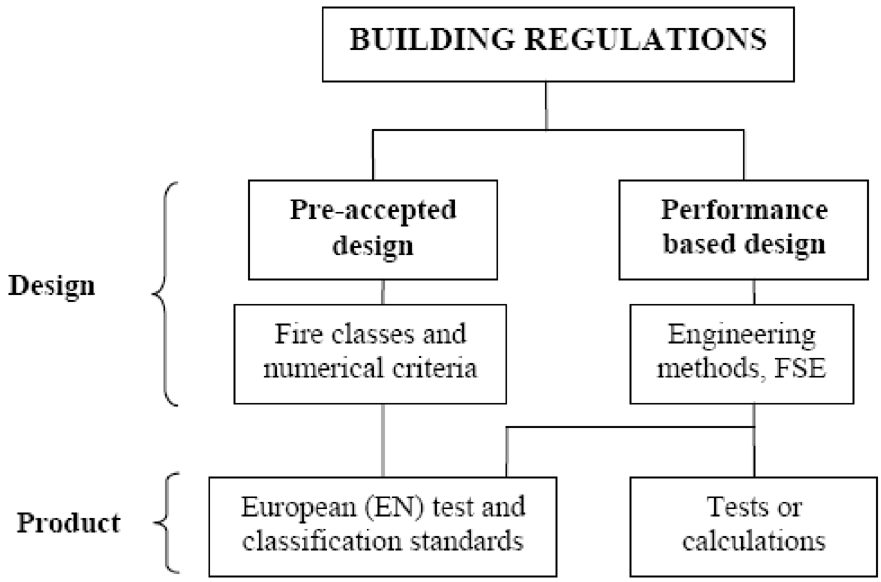

Figure 3: Schematic presentation of regulatory tools in the Nordic countries [xvi].

4.1.1 Sweden

The Euroclass system is fully implemented in Sweden and the Swedish building code (BBR) [xvii] sets requirements using the Euroclasses. BBR further sets requirement on façades for multi storey buildings according to SP FIRE 105 [xviii] (see A5.1). There is presently no large scale European fire test method for facades; but, a national large scale test method is used in Sweden. No other Nordic country requires such large scale façade testing at present, although Denmark and Norway are considering its introduction in the future. Sweden will continue to use the national test while there is a regulatory need to assess fire spread along facade systems in multi-storey buildings and no European equivalent is available.

Sweden has a performance based building code which implies that analytical fire safety design can be use for certain types of buildings. There are no informal requirements that restrict the use of EPS/XPS products.

The test requirements for EPS/XPS products in Sweden are summarized in Table 2. The classification requirements according to BBR are summarized in a simplified manner in Table 3. For full detail see BBR [xvii]. The more stringent requirements given for Br2 and Br1 buildings in Table 3 are for evacuation routes. Further, there are special requirements for escape routes in hotels etc. and for places of assembly and premises which present a fire hazard.

Table 2: Test requirements in Sweden for common applications of EPS/XPS products.

Product	Euroclass tests (see Table 1)	National tests
EPS/XPS sheets etc.	Yes	No
Building elements including EPS/XPS	Yes	SP FIRE 105 (façade systems on BR1 buildings)
Sandwich panels	Yes	Full scale test in certain cases

Table 3: Requirements of fire safety classes for various applications in Sweden.

Application	**Br3 building**	**Br2 building**	**Br1 building**

	1- and 2- storey no special circumstances	1- and 2- storey incl. institutional and places of assembly	3- storey and more, and 2- storey for disabled etc.
Wall	D-s2,d0	C-s2,d0 – B-s1,d0*	C-s2,d0 – B-s1,d0*
Ceiling	D-s2,d0	C-s2,d0* – B-s1,d0*	B-s1,d0*
Floor	-	Dfl-s1	Cfl-s1 (escape route)
Façade	D-s2,d0	D-s2,d0	Pass SP FIRE 105

* Surface lining shall be mounted on A2-s1,d0 product.

There are no reaction-to-fire requirements on testing that exclude the use of non-flame retarded EPS/XPS products in buildings in Sweden, except as exposed surface linings.

The requirement of SP FIRE 105 for facades of multi storey buildings does not exclude the use of non-flame retarded EPS in e.g. plaster-on-insulation wall systems.

4.1.2 Denmark

The Danish rules as summarised in the “Collection of examples for fire protection of buildings” imply reaction-to-fire requirements on a material level for materials, coverings and building elements. Therefore when the Danish regulations prescribe a certain Euroclass this implies, simplified, that each of the components in the product must fulfil the stated reaction-to-fire requirements on a material level.

DBI Method FIRE01:2007 [[xix]] give specifications for testing and classification for the reaction-to-fire properties on a material level in relation to the Euroclass tests, i.e. by a characterization testing and classification procedures giving results which are independent of the concept “end use application”.

Table 4: Test requirements in Denmark for common applications of EPS/XPS products.

Product	Euroclass tests (see Table 1)	National tests
EPS/XPS sheets etc.	Yes	DBI Method FIRE01
Building elements including EPS/XPS	Yes	DBI Method FIRE01
Sandwich panels	Yes	DBI Method FIRE01

The requirement for testing all materials in a product according to DBI Method FIRE01 should have a major impact on the classification of products containing EPS/XPS and probably prohibits the use of non-flame retarded EPS/XPS in many applications (although we have not been able to confirm this).

4.1.3 Finland

EN 13501-1 is the test method used to assess fire performance for most applications in Finland and there are generally few requirements on a material level. There are, however, some exceptions where material type requirements are related to minimum performance levels in some applications or to certain conditions or materials used. Examples relevant to the application of EPS/XPS products include:

- The framework of external walls of buildings of class P2 with 3-4 storeys may be made of building materials of class D-s2,d2. The insulation material and other filling material shall in this case be of at least class A2-s1,d0.

  This requirement essentially prohibits the use of EPS/XPS in this case.

- Building materials used in external walls in buildings of class P1 shall be mainly of at least class B–s1,d0.

  This requirement essentially prohibits the use of non-flame retarded EPS/XPS in this case.

- Thermal insulation which is inferior to class B–s1, d0 shall be protected and positioned in such a manner that the spread of fire into the insulation, from one fire compartment to another and from one building to another building is prevented.

  This requirement essentially means that non-flame retarded EPS/XPS can be used provided it is properly protected against being involved in the spread-of-fire.

- Internal wall and ceiling surfaces in buildings of class P2 shall be provided with a protective covering made of building materials of class A2–s1,d0 if the construction is made of materials of class C–s2,d1 or worse.

  This requirement allows the use of non-flame retarded EPS/XPS in this case.

4.1.4 Norway

EN 13501-1 is the test method used to assess fire performance for most applications in Norway and there are generally few requirements on a material level.

There are specific classification requirements for sandwich panels in Norway. The Euroclasses required in this case are B-s1,d0 or D-s2,d0, depending on application. It is not clear whether it would be possible for a sandwich panel containing EPS/XPS to pass this classification, even if it were flame retarded. It would definitely not be possible for a non-flame retarded EPS/XPS material to obtain such a classification.

There are no reaction-to-fire requirements on testing that exclude the use of non-flame retarded EPS/XPS products in buildings in Norway, except if these are used as exposed surface linings. Therefore non-flame retarded EPS/XPS is allowed as insulation material in buildings in Norway.

4.1.5 Iceland

Reaction-to-fire classification is based on EN 13501-1, but in the Icelandic building regulation there are a number of examples for fire protection in buildings which imply reaction-to-fire requirements on a material level for materials, coverings and building elements.

There are specific classification requirements for sandwich panels in Iceland. The Euroclasses required in this case are A2-s1,d0 or B-s2,d0, depending on application. It is not clear whether it would be possible for a sandwich panel containing EPS/XPS to pass this classification, even if it were flame retarded. It would definitely not be possible for a non-flame retarded EPS/XPS material to obtain such a classification.

4.2 Germany

Germany has traditionally applied a system with reaction-to-fire requirements on a material level. The national requirements are still used in parallel with the Euroclass system. There is further an informal product certification system, the “Ü-mark”, which is required for insulation products on the German market. The “Ü-mark” sets requirements on materials and products that refer to the old National fire safety classification.

DIN 4102-1 (see Annex 3.2) is equivalent to EN ISO 11925-2, the small flame test in EN 13501-1. The German requirements for application of the small flame test to cut-edges of EPS/XPS for any building product results in the application of these requirements on a material level when testing according to the Euroclass system

The minimum requirement for EPS/XPS is class E or DIN 4102 B2. However, in practice all EPS/XPS sold in Germany today meats DIN 4102 B1. Flame retarded EPS/XPS is therefore needed in all applications, at present and most likely in the future.

Table 5: Actual test requirements for common applications of EPS/XPS products.

Product	Euroclass tests (see Table 1)	National tests	Informal requirements
EPS/XPS sheets etc.	Yes	DIN 4102, part 15/16 DIN 4102, part 1	Ü-mark
Building elements including EPS/XPS	Yes, but cut-edges for all applications	DIN 4102, part 15/16 DIN 4102, part 1	Ü-mark
Sandwich panels	Yes, but cut-edges for all applications	DIN 4102, part 15/16 DIN 4102, part 1	Ü-mark

Table 6: Requirements of fire safety classes for various applications.

Application	Current requirements	Future requirements
EPS/XPS	German B2	Euroclass E
Complete product	German B2 – B1	Euroclass E – higher class

4.3 Poland

The European classifications have been introduced in Poland meaning that the test methods for reaction-to-fire as required in EN 1351-1 are applied. Euroclass E is the general requirement for EPS/XPS in Poland.

Two basic documents regulate the fire safety of buildings: the “Decree of the Minister of the Interior on the fire safety of buildings, other building structures and sites, and the “Decree of the Urban Planning and Building Minister on the technical requirements for buildings.”In multiple dwellings and public buildings, where over 50 persons are present, fixed finished materials must be made of at least hardly ignitable materials. Hardly ignitable would be at least Euroclass E. Ceiling covering and suspended ceilings must be made of non-combustible or non-ignitable materials (Euroclass A1, A2 or B), which will not fall down in case of fire (not valid for dwellings).

There are special requirements involving classification based on the national test method PN-90/B-02867 for fire spread on external walls of buildings. There are three classes: 1. Non-spreading fire, 2. Low spreading fire, and 3. Easy spreading fire. Additionally, if the core material of the wall is of EPS/XPS the material must be of Euroclass E or better.

Also for sandwich panels there is a requirement of Euroclass E for the core material.

In summary for Poland, flame retarded EPS/XPS foam grades are used in most applications.

4.4 France

In France, building products are tested for reaction-to-fire performance following EN 13501-1. There are no material-related requirements specific for EPS/XPS. In addition to prescriptive rules, performance-based building solutions are used in some cases which can be relevant for EPS/XPS products.

4.4.1 Public buildings

Insulation materials - internal applications:

There are specific requirements for the fire attack from the inside of a building on insulation materials for public buildings, which are given in article AM8 of the public buildings safety regulation [xx][xxi][xxii]. These requirements are summarised in Table 8. The regulations further allow performance based solutions including a risk analysis as an alternative.

Table 7: Requirements on insulation materials for public buildings in France.

Euroclass of protective material (minimum)	Requirements on building component
No protection	A2-s2, d0 for walls, ceilings and roofs $A2_{FL}$-s1 for floors
A2-s2, d0 Protection thickness is defined according to the temperature providing less than 5% of mass loss of the insulation in a TGA test	EN 1365-1 / ISO 834-1, EI15* (wall & floors) EN 1365-2 / ISO 834-1, EI30* (ceiling) No degradation of the insulation
No pre-defined protection	Risk-based approach (FSE study) to ensure that the construction system do not affect tenability conditions inside the building during evacuation

* Fire resistance classification according to EN 13501-2 [xxiii].

If the risk-based approach is used, the study has to be accepted by the central fire safety authority (Official commissions: CECMI, then CCS). By now (2010), only one construction system containing XPS has passed by this approach. That was a construction system based on wood-framed metallic-faced sandwich panels.

Insulation materials - external applications:

The requirements for the fire attack from the outside of a building on insulation materials are given in references [xxiv] and [xxv] of the Public buildings safety regulation [xx], and detailed in an additional text (IT249) modified recently to consider an increase of insulation thicknesses from 120 mm to 300 mm [xxvi].

The CO20 article [xxiv] specifies that all façade elements have to be classified as, at least, **D-s3, d0**. However, there are additional rules called "C+D", described in reference [xxvi] related to vertical and horizontal distances between windows of the façade, and a limitation of calorific value of the façade limited to 130 MJ/m² (CO21 article, ref [xxv]). If these requirements are not fulfilled, all materials have to be classified as **C-s3;d0**.

In reference [xxvi], there are different requirements to prove that safety exigencies are fulfilled, depending on insulation thickness, constructive system, substrate, etc. The following list tries to summarize these rules:

1) Insulation thickness can be increased from 120 mm to 300 mm without considering calorific load when fire stops are present horizontally every 2 storeys (no sleeping places in the building) or 1 storey (sleeping places in the building).

2) All materials are conform to requirements cited previously and respect pre-accepted constructive assemblies (solutions P1 to P6 for various cases in the text).

3) The façade system passes a façade test called LEPIR II , detailed in reference [xxvii]. This can be used in replacement of rule 2).

4) Performance-based construction solutions are further allowed in replacement of rules 2) and 3). The aim of the regulation is that fire penetration into the building from a façade fire is not accepted, according to a fire risk analysis based on tests and modelling. Ad-hoc tests or façade tests coming from other countries are required for a such study.

If the system is based on a EPS/XPS insulation, it has to be protected by a A2-s3; d0 surface material reinforced with fibreglasses, and respecting solution P1 of the text. EPS and XPS insulations have to be CE-marked and of **Euroclass E**. Producer of raw material has to prove flame retardancy to reach **Euroclass D** level for raw XPS in 60 mm and for raw EPS in 40 mm. This applies also to sandwich panels made of B-s1; d0 wood-wool skins and EPS/XPS core. The facade test will not restrict the use of EPS/XPS if the constructive system protects it enough from the fire.

4.4.2 Other buildings

For domestic applications [xxviii], there is no specific requirement for reaction-to-fire in individual houses and small collective buildings limited to 3 storeys (1st and 2nd families). However, for buildings of more than 3 storeys (3rd and 4th family, under 50m), rules applicable for common parts of the building (corridors, etc) and façade are close to those for public buildings. IT249 [xxvi] is not applicable, and the current version of the safety regulation [xxviii] does not take into account an increase of insulation thickness.

For high-rise buildings (both domestic and public usages), specific drastic regulation applies [[xxix]] [[xxx]][[xxxi]], including control of calorific load inside the building (except for privative part of domestic high-rise buildings, type IGHA). The AM8 article is not applicable and insulation materials requires classification as, at least, **A2-s2,d0**. Façades have to respect additional restrictive rules as stated in [xxvi].

4.5 Belgium

Requirements are on products in their end use application, i.e. on finished products, although local fire brigades sometimes require classes for individual components.

The Euroclass system is gradually replacing the former national classes based on NF P92-501 and/or B 476 Part 7. There is no specific classification for EPS/XPS other than for all other construction products. No direct requirement that they are flame retarded, although the reaction to fire requirements result in the use of flame retardants where reaction to fire requirements are imposed. For XPS sold to the construction market this means that 100% is FR-retarded. The use of non-FR EPS is less than 10% in the construction sector.

4.6 Italy

The building regulations in Italy has adapted the European CPD and there are no National requirements in addition to the Euroclass testing of reaction-to-fire performance according to EN 13501-1. There are, however, special requirements for insulation materials.

The requirements for EPS/XPS are ruled by the application and if the EPS/XPS material is uncovered or covered with a material with a better reaction-to-fire performance. Classification requirements for different applications are given in Table 8.

Table 8: Requirements on Insulation materials in Italy.

Euroclass of protective material (minimum)	Euroclass of EPS/XPS
No protective covering	B-s2,d0 or B-s1, d1
A2-s3, d0 or A2fl-s2 (floor)	C-s2,d1 (wall) / Cfl-s2 (floor) / C-s2,d0 (ceiling)
A1 or A1fl (floor)	D-s2,d1 (wall) / Dfl-s2 (floor) / D-s2,d0 (ceiling)
EI 30*	E

* Fire resistance classification according to EN 13501-2.

The information that we have received is that EPS/XPS for the Italian market is normally flame retarded, except for the use in Euroclass E applications. However, our experience is that also Euroclass E products requires flame retardant treatment.

4.7 Spain

The building regulations in Spain has adopted the European CPD and all requirements involves finished products and systems. It is unclear if old national tests are still required or alternatively used. National tests relevant for EPS/XPS products include UNE 23727, UNE 23724 and UNE 23725.

In most application Euroclass E is required. For sandwich panels containing EPS/XPS the requirements are Euroclass B-s2, d0 or C-s2, d0, depending on application. It is unclear if non-flame retarded products are actually used in some applications, but for applications where Euroclass E or higher classes are required the EPS/XPS would be flame retarded.

4.8 UK

The United Kingdom is comprised of England, Wales, Scotland and Northern Ireland. The Building provisions required in the various parts of the UK may differ slightly but are largely the same despite the fact that it is the prerogative of each part to define autonomously which Building Regulations they will adopt.

Technical provisions for the use and fire performance of building materials and components are given in the supporting documents to the Building Regulations, e.g. Approved Document B for England and Wales. The technical provisions for England/Wales and Northern Ireland are virtually identical. Those for Scotland differ in minor aspects only.

The provisions in Approved Document B are given as guidance only and provide one method of showing compliance with the Regulations. There is no obligation to follow that method provided compliance with the Regulations can be satisfactorily demonstrated.

National test standards for surface linings in buildings includes BS 476, part 6 and part 7. However, as the Harmonised European Fire Testing System has been established corresponding UK standards have been removed and the Euroclass system adopted.

There are generally no requirements on material level in UK. Regarding reaction-to-fire properties the provisions in the regulations are related to surfaces of walls and ceilings so when the thermal insulation is covered there is no requirement. There are, however, specific applications where only non-combustible insulation is allowed. In these applications PS foam would not be used. However, safety requirements from insurance companies regulates the use of EPS/XPS in the construction phase which has resulted in that most EPS and all XPS for the UK market is flame retarded. When flame retarded the PS foam is meeting **Euroclass E** according to EN 13501-1.

4.9 Summary Europe

Although the European countries 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 in applications and requirements in the individual countries. There can further exist requirements concerning fire performance for specific areas of applications such as insulation materials and sandwich panels in some countries. **Feil! Fant ikke referansekilden.** gives a summary of those applications where EPS/XPS products are affected and if there are special regulations in the individual European countries. The table also contains information concerning whether the majority of EPS/XPS used in each country in building applications is flame retarded (FR) or not. A "Yes" or "No" in **Feil! Fant ikke referansekilden.** signifies that information has been available as confirmation, this may be based on formal (mandatory) or informal (voluntary) requirements. In cases when information has not been available an assessment based on test requirements has been made and is written in italics.

Table 9: Summary of the requirement areas for fire performance in European countries and information on the practice of usage of FR EPS/XPS in each country where available.

European country	General for materials	Insulation materials	Sandwich panels	Facades	FR-treated EPS/XPS Usage*
Sweden	No	No	No	Yes	**No**
Denmark	Yes	*n.i.*	*n.i.*	*n.i.*	*Likely*
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.*	Yes	*n.i.*	**Yes**
UK	No	Yes	*n.i.*	*n.i.*	**Yes**

n.i. = No specific information available.

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

It is more common to have specific national regulations for the fire performance of **insulation materials**. The European countries with such regulations are: Finland, Germany, Poland, France, Italy and UK. We have no direct information on this from Denmark, Iceland, Belgium and Spain, but the general requirements on a material level applies for Denmark and Iceland and it is likely that insulation materials would have special requirements in these countries. Requirements on insulation materials will exclude the use of EPS/XPS in many applications, especially for public buildings and other buildings with a high safety class, as e.g. high-rise buildings. For most applications in these countries flame retarded EPS/XPS should be required. There could be exceptions, e.g. for applications of insulation materials in buildings with a lower safety level, such as single family dwellings. Although it is unclear whether these exceptions actually mean that a small portion of the market is non-flame retarded or whether all the market in these countries uses flame retarded EPS/XPS by default.

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

Sweden, Poland and France have special requirements for **facades**. To our knowledge it is possible to pass the Swedish test with a wall construction containing protected non-flame retarded EPS. Indeed, it appears that the majority of EPS/XPS that is used in Sweden is non-flame retarded.

In UK there are no formal regulations that would exclude the use of non-flame retarded EPS/XPS, however, according to the UK plastic industry, almost the entire market share for EPS/XPS in UK is flame retarded products due to requirement from the insurance sector.

5 Requirements in Non-European countries

5.1 USA

The general requirements in US apply to finished building products and not on the separate materials in a product. There are fire resistance requirements on construction assemblies and reaction-to-fire requirement on exposed materials. The rating or classification required is dependent on application and given in relevant NFPA standards.

Table 10: General test requirements on products and surface linings in US.

Material application	Test method
Exposed surface lining	ASTM E84 (flame spread etc, see Annex 3.3)
Construction assembly	ASTM119 (fire resistance)

The International Building Code (IBC) has regulations for foam plastic insulation in chapter 26, section 2603 [[xxxii]].The general requirements are that foam plastic insulation and foam plastic cores of manufactured assemblies shall have a flame spread index of not more than 75 and a smoke-developed index of not more than 450 where tested in the maximum thickness intended for use in accordance with ASTM E 84. For complete listing of requirements and exceptions see [xxxii].

Table 11: Requirements in ASTM E84 testing of foam plastic insulation and core materials according to IBC.

Parameter	Requirement (index)
Flame spread	< 75
Smoke	< 450

The IBC contains additional requirements and alternatives for applications of foam plastic insulation:

- Foam plastic shall be separated from the interior of a building by an approved thermal barrier. There are some exceptions from this requirement, e.g. for masonry and concrete construction where the insulation is covered.

- Exterior walls of buildings have requirements on fire resistance (ASTM E 119) and ignition (NFPA 268). Exterior walls of cold storage buildings required to be constructed of non-combustible materials.

- Foam plastic insulation meeting the flame spread and barrier requirements are permitted as part of a roof-covering assembly, provided the assembly with the foam plastic insulation is a Class A, B or C roofing assembly where tested in accordance with ASTM E 108 or UL 790.

- Foam plastic insulation shall not be used as interior wall or ceiling finish in plenums except when complying with special requirements or when protected by a thermal barrier.

- Special approval can be based on large-scale tests such as, but not limited to, NFPA 286 FM 4880, UL 1040 or UL 1715. Such testing shall be related to the actual end-use configuration and be performed on the finished manufactured foam plastic assembly in the maximum thickness intended for use. Foam plastics that are used as interior finish on the basis of special tests shall also conform to the flame spread requirements.

The consequence of the IBC regulation for EPS/XPS insulation in building products is that the ASTM E84 reaction-to-fire test is required in all applications, which must exclude the use of non-fire retarded EPS/XPS.

5.2 Canada

The general requirement for foamed plastics is that they must be protected. Special requirements depend on application and how they are protected.

There are requirements both on material level and on the finished product. The test methods relevant for EPS/XPS insulation are: CAN/ULC-S124, "Test for the Evaluation of Protective Coverings for Foamed Plastic" and CAN/ULC-S101, "Fire Endurance Tests of Building Construction and Materials".

The requirements are depending on applications and how the foam plastic is protected. The flame spread rating can range from below 25 up to 500. In small buildings, such as single family houses, there is no limit on flame spread rating for foam plastic insulation as long as it is protected (such as by interior finish).

The code does not explicitly require the use of flame retardant but applications that require a flame spread rating of 25 obviously warrant the use.

5.3 Australia

The test methods used to ascertain whether building materials or components meet the deemed-to-satisfy provisions of the ABCB are described in AS 1530 (Parts 1-4). AS(NZ) 1530-3 (Early Fire Hazard Test) applies to all building materials other than thin flexible materials and is therefore the relevant standard for determining the fire performance of EPS/XPS in building applications.

Although the test method is a small scale method which would not strictly require that EPS/XPS for building applications be flame retarded to obtain an acceptable classification it seems that EPS/XPS in building applications in Australia is generally flame retarded voluntarily by industry as this is deemed necessary for safety.

5.4 Japan

The Japanese system of test methods was recently changed and one of the major test methods is the cone calorimeter as described in ISO 5660. In addition ISO DTS 17431, an intermediate test, and ISO 1182 are used as described below.

Non-combustible materials are classified based either on ISO 1182 (Furnace Test) where a temperature rise of no more than 20 °C is allowed or using the Cone Calorimeter (ISO 5660-1) at 50 kW external heat flux, where the total heat release is not allowed to exceed 8 MJ and the maximum heat release must be less than 200 kW/m^2 during the whole 20 minute test period. Clearly EPS/XPS cannot meet these test requirements even when treated with flame retardants.

Quasi-combustible materials are classified either based on ISO 5660-1 or in the Box Heat Test ISO 17341. The classification requirements are the same in ISO 5660-1 with the exception that the test period is only 10 minutes. In the Box Test a total heat release of 30 MJ is allowed with a maximum heat release rate of 140 kW. Further, no burn-through is allowed.

Flame retardant materials are also classified using the Cone Calorimeter or the Box Test. In this case the test period is only 5 minutes and the same classification criteria apply.

EPS/XPS in building applications could potentially pass as quasi-combustible with flame retardants but would in that case need to be classified as flame retardant materials where additional toxicity testing is required over and above the fire performance testing. This implies that EPS/XPS in building applications is probably flame retarded, and it has been confirmed that this is the case.

5.5 Korea

The building law of Korea is issued by the Land, Transportation and Sea Ministry of Korea. Korean standards are prepared by KATS, the Korean Agency of Technology and Standards. There are evaluation criteria (classification requirements) for interior materials in building in the Building Law of Korea, the 52th directive. There are no specific criteria for e.g. sandwich panels at present. The criteria for interior materials are based on reaction-to-fire tests and toxicity tests and are divided in the following classes:

- Non-combustible material, KS F ISO 1182 and “mouse test, 9 min”.
- Semi-combustible material, KS F ISO 5660-1 (10 min) and “mouse test, 9 min”.
- Flame retardant material, KS F ISO 5660-1 (5 min) and “mouse test, 9 min”

For sandwich panels the Product standard KS F 4724 applies and relevant test methods includes KS F ISO 5660-1, KS F ISO 13784-1 (specific reaction-to-fire test for sandwich panels) and KS F ISO 9705 (room-corner test). Of these tests is only KS F ISO 5660-1 adapted in the Building law presently.

The requirements in the Korean building law reminds of that in Japan. It has not been confirmed, but it seems reasonable that EPS/XPS on the Korean market should be flame retarded.

5.6 Egypt

The building regulations regarding fire safety are currently under development in Egypt. The intent is to adopt the European testing standards, i.e. the Eurocodes.

Concern has recently been raised regarding the fire safety of construction with sandwich panels with a combustible core. US fire resistance standards have been applied for these products.

5.7 Summary for Non-European Countries

There are many countries internationally that have not been covered in the cursory summary of building regulations relevant to EPS/XPS use in building applications outside Europe. The countries that have been studies were selected either based on the significance of use of EPS/XPS or on the availability of information. **Feil! Fant ikke referansekilden.** contains a summary of the findings and their implications for the use of flame retardants (FR) in each country. A “Yes” in **Feil! Fant ikke referansekilden.** signifies that information has been available as confirmation. Note that the use of FRs may be based on formal (mandatory) or informal (voluntary) requirements. In cases when information have not been available an assessment based on test requirements have been made and is written in italics.

Table 12: Summary of the requirement areas for fire performance in selected non-European countries and information on the practice of the use of FR EPS/XPS in each country where available.

Country	General for materials	Insulation materials	Sandwich panels	Facades	FR-treated EPS/XPS Usage
USA	Yes	Yes	Yes	Yes	**Yes**
Canada	Yes	Yes	*n.i.*	*n.i.*	*Likely*
Australia	Yes	Yes	*n.i.*	*n.i.*	**Yes**
Japan	Yes	Yes	*n.i.*	*n.i.*	**Yes**
Korea	Yes	*n.i.*	No	*n.i.*	*Likely*
Egypt	Unclear*	Yes	Yes	*n.i.*	*n.i.*

n.i. = No specific information available

* = the country specific application of the Eurocodes will determine whether material performance will be required.

6 Summary and Conclusions

A compilation of international building regulations has been attempted. An undertaking of this kind is, by its very nature, nebulous and difficult to say the least, due to the minutiae of differences in interpretation of seemingly similar regulations in their individual application. We have attempted to approach the topic in a systematic manner that has at times posed questions which have defied a single answer. This is particularly true in the EU where the CPD and associated harmonized Euroclass system seems straightforward at first glance, at least for those products where product standards exist (which is true for insulation materials). As the project has proceeded it has become painfully clear that the devil is in the detail, with application of the harmonized European approach differing significantly in the different member states, e.g. from essentially no material requirements in Sweden to stringent material requirements in Germany.

In summary, the overlying regulations in Europe do unify the method for testing EPS/XPS products in building applications although the specific performance requirements differ significantly in the different member states. In particular, one can note that in those countries where only the performance of the final product is tested the use of EPS/XPS as insulation material does not result in a formal requirement that the EPS/XPS used is flame retarded. In those countries where material performance is required, e.g. Germany, EPS/XPS that is used must be flame retarded. UK is an example of a country where requirements from insurance companies has resulted in that the majority of EPS/XPS is flame retarded.

In North America (USA and Canada), it seems that there are material requirements which mean that flame retarded EPS/XPS would be most common in building applications.

In Australia there are very low formal requirements concerning fire performance of materials which would not necessarily require the use of flame retarded EPS/XPS but verbal information received by the authors indicates that EPS/XPS generally used in Australia in building applications is flame retarded voluntarily.

In Japan, it would appear that EPS/XPS would need to be classified as flame retardant material as it would not be able to attain any of the other classes without the use of flame retardants which would automatically mean that it would be included in this class. This implies also that the majority of EPS/XPS for use in Japan would be expected to be flame retarded. Korea appears to have a similar situation as that in Japan.

Finally, in Egypt it is unclear how the Eurocodes will be applied and therefore not possible to determine whether EPS/XPS in insulation is typically flame retarded or not. The reference to US codes (IBC) in the case of sandwich panels would, however, imply that at least in this application flame retarded products are used.

Despite the short time available and the difficulty in determining definitive answers to the interpretation of building regulations in some cases, it is clear from the compilation that the use of flame retardants in EPS/XPS is widespread, both in cases where this is a strict regulatory requirement (e.g., Germany) and in those where it is not (e.g., Australia).

Appendix 1: EN 13501-1 tables of Euroclasses

Table 13: Table for Euroclasses for fire performance for construction products excluding floorings and linear pipe thermal insulation products.

Class	Test method(s)	Classification criteria	Additional classification
A1	EN ISO 1182 (1); *and*	$\Delta T \leq 30°C$; *and* $\Delta m \leq 50\%$; *and* $t_f = 0$ (i.e. no sustained flaming)	-
	EN ISO 1716	PCS ≤ 2.0 $MJ.kg^{-1}$ (1); *and* PCS ≤ 2.0 $MJ.kg^{-1}$ (2) (2a); *and* PCS ≤ 1.4 $MJ.m^{-2}$ (3); *and* PCS ≤ 2.0 $MJ.kg^{-1}$ (4)	-
A2	EN ISO 1182 (1); *or*	$\Delta T \leq 50°C$; *and* $\Delta m \leq 50\%$; *and* $t_f \leq 20s$	-
	EN ISO 1716; *and*	PCS ≤ 3.0 $MJ.kg^{-1}$ (1); *and* PCS ≤ 4.0 $MJ.m^{-2}$ (2); *and* PCS ≤ 4.0 $MJ.m^{-2}$ (3); *and* PCS ≤ 3.0 $MJ.kg^{-1}$ (4)	-
	EN 13823 (SBI)	FIGRA ≤ 120 $W.s^{-1}$; *and* LFS < edge of specimen; *and* $THR_{600s} \leq 7.5$ MJ	Smoke production(5); *and* Flaming droplets/ particles (6)
B	EN 13823 (SBI); *and*	FIGRA ≤ 120 $W.s^{-1}$; *and* LFS < edge of specimen; *and* $THR_{600s} \leq 7.5$ MJ	Smoke production(5); *and* Flaming droplets/ particles (6)
	EN ISO 11925-2(8): *Exposure = 30s*	Fs ≤ 150mm within 60s	

C	EN 13823 (SBI); *And*	FIGRA ≤ 250 $W.s^{-1}$; *and* LFS < edge of specimen; *and* THR_{600s} ≤ 15 MJ	Smoke production(5); *and* Flaming droplets/ particles (6)
	EN ISO 11925-2(8): *Exposure = 30s*	Fs ≤ 150mm within 60s	
D	EN 13823 (SBI); *And*	FIGRA ≤ 750 $W.s^{-1}$	Smoke production(5); *and* Flaming droplets/ particles (6)
	EN ISO 11925-2(8): *Exposure = 30s*	Fs ≤ 150mm within 60s	
E	EN ISO 11925-2(8): *Exposure = 15s*	Fs ≤ 150mm within 20s	Flaming droplets/ particles (7)
F	No performance determined		

(*) The treatment of some families of products, e.g. linear products (pipes, ducts, cables etc.), is still under review and may necessitate an amendment to this decision.
(1) For homogeneous products and substantial components of non-homogeneous products.

(2) For any external non-substantial component of non-homogeneous products.

(2a) Alternatively, any external non-substantial component having a PCS ≤ 2.0 $MJ.m^{-2}$, provided that the product satisfies the following criteria of EN 13823(SBI) : FIGRA ≤ 20 $W.s^{-1}$; *and* LFS < edge of specimen; *and* THR_{600s} ≤ 4.0 MJ; *and* s1; *and* d0.

(3) For any internal non-substantial component of non-homogeneous products.

(4) For the product as a whole.

(5) **s1** = SMOGRA ≤ $30m^2.s^{-2}$ *and* TSP_{600s} ≤ $50m^2$; **s2** = SMOGRA ≤ $180m^2.s^{-2}$ *and* TSP_{600s} ≤ $200m^2$; **s3** = not s1 or s2.

(6) **d0** = No flaming droplets/ particles in EN13823 (SBI) within 600s; **d1** = No flaming droplets/ particles persisting longer than 10s in EN13823 (SBI) within 600s; **d2** = not d0 or d1; Ignition of the paper in EN ISO 11925-2 results in a d2 classification.

(7) Pass = no ignition of the paper (no classification); Fail = ignition of the paper (**d2** classification).

(8) Under conditions of surface flame attack and, if appropriate to end–use application of product, edge flame attack.

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EN 13501-1 additionally includes a classification tables for floorings and thermal insulation products.

Appendix 2: Test methods referred to in EN 13501-1

A2.1 EN ISO 1716, Calorific potential

EN ISO 1716 [vii] determines the potential maximum total heat release of a product when completely burning, regardless of its end use. The test is relevant for the classes A1, A2, $A1_{fl}$ and $A2_{fl}$.

The calorific potential of a material is measured in a bomb calorimeter. The powdered material is completely burned under high pressure in a pure oxygen atmosphere.

A2.2 EN ISO 1182, Non-combustibility

EN ISO 1182 [vi] identifies products that will not, or significantly not, contribute to a fire, regardless of their end use. The test is relevant for the classes A1, A2, $A1_{fl}$ and $A2_{fl}$.

EN ISO 1182 is a pure material test and a product cannot be tested in end use conditions. Therefore only homogenous building products or homogenous components of a product are tested. The test apparatus is shown in Figure 4 and the test specifications are given in Table 14.

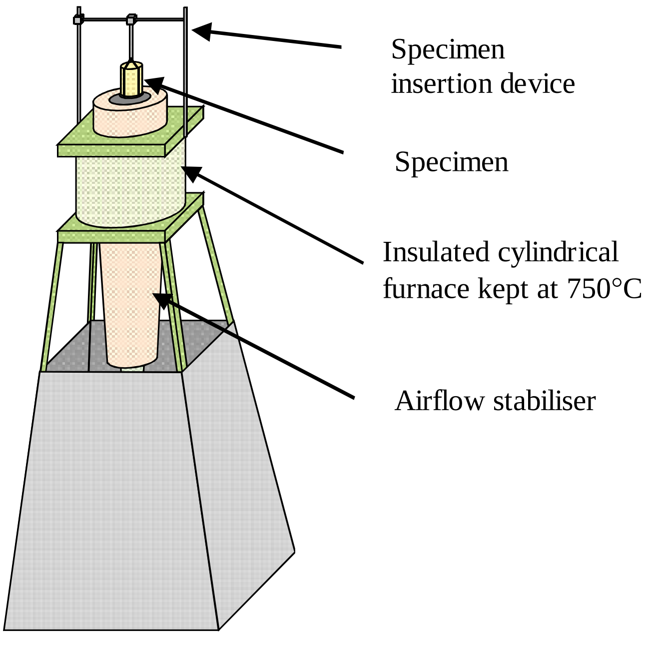

Figure 4: EN ISO 1182 test for Non-combustibility.

Table 14: EN ISO 1182 test specifications.

Specimens	5 cylindrical samples, diameter 45 mm, height 50 mm

Specimen position	Vertical in specimen holder in the centre of the furnace
Heat source	Electrical cylindrical furnace at 750 °C (measured by the furnace thermocouple)
Test duration	Depends on temperature stabilisation
Conclusions	Classification is based on temperature rise as measured by the furnace thermocouple, duration of flaming and mass loss of the sample. Details are given in Table 13.

A2.3 EN ISO 11925-2, Small flame test

EN ISO 11925-2 [viii] evaluates the ignitability of a product under exposure to a small flame. The test is relevant for the classes B, C, D, E, B_{fl}, C_{fl}, D_{fl} and E_{fl}.

The small flame test is quite similar to the DIN test used for the German class B2. Variants of this procedure are also found in other EU member states regulations. The test rig is shown in Figure 5 and the test specifications are summarized in Table 15.

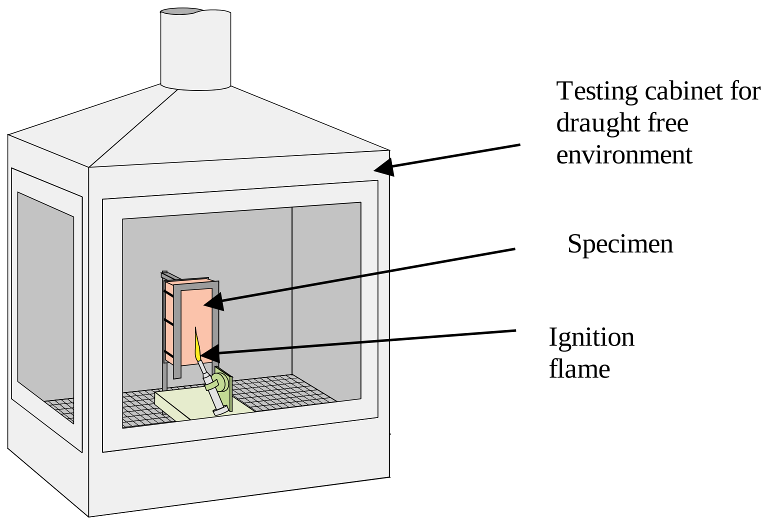

Figure 5: EN ISO 11925-2 Small flame test.

Table 15: EN ISO 11925-2 Small flame test specifications.

Specimens	250 mm long, 90 mm wide, thickness 60 mm
Specimen	Vertical

position	
Ignition source	Small burner. Flame inclined 45° and impinging either on the edge or the surface of the specimen
Flame application	30s for Euroclass B, C and D. 15s for Euroclass E
Conclusions	Classification is based on the time for flames to spread 150mm and occurrence of droplets/particles. Details are given in Table 13.

A2.4 EN 13823, SBI

EN 13823 SBI [iii] evaluates the potential contribution of a product to the development of a fire, under a fire situation simulating a single burning item in a room corner near to that product. The test is relevant for the classes A2, B, C and D. The SBI is the major test procedure for classification of linings.

The test rig is shown in Figure 6. Test specifications are summarised in Table 16.

The SBI is of intermediate scale size. Two test samples, 0,5 m x 1,5 m and 1,0 m x 1,5 m are mounted in a corner configuration where they are exposed to a gas flame ignition source. As for ISO 9705 a direct measure of fire growth (Heat Release Rate, HRR) and light obscuring smoke (Smoke Production Rate, SPR) are principal results from a test. Other properties such as the occurrence of burning droplets/particles and maximum flame spread are observed.

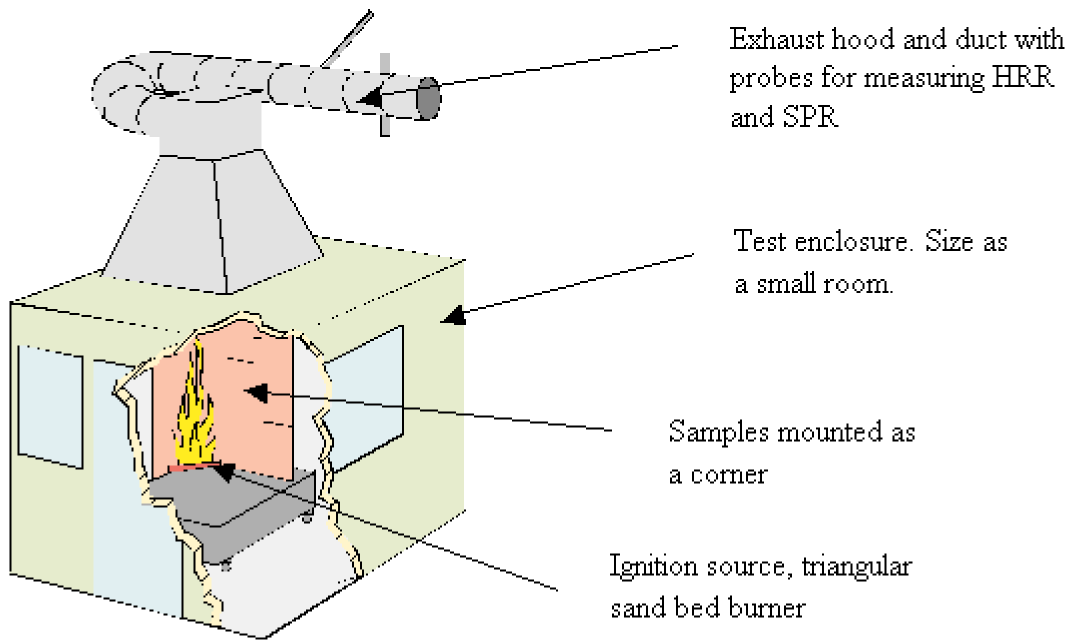

Figure 6: EN 13823, SBI, the Single Burning Item.

The index FIGRA, FIre Growth RAte, is used to determine the Euroclass. The concept is to classify the product based on its tendency to support fire growth. Thus FIGRA is a measure of the biggest growth rate of the fire during a SBI test as seen from the test start. FIGRA is calculated as the maximum value of the function (heat release rate)/(elapsed test time), units are W/s. A graphical presentation is shown in Figure 7.

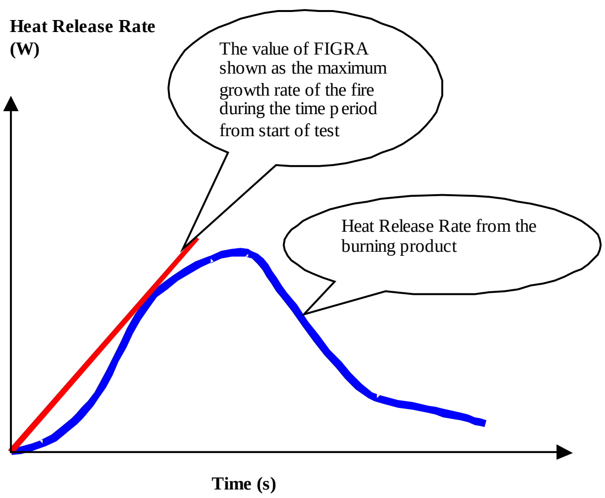

Figure 7: Graphical representation of the FIGRA index.

To minimise noise the HRR data is calculated as a 30s running average. In addition certain threshold values of HRR and the total heat release rate must first be reached before FIGRA is calculated.

The additional classification for smoke is based on the index SMOGRA, SMOke Growth RAte. This index is based on similar principles as FIGRA is. SMOGRA is calculated as the maximum value of the function (smoke production rate)/(elapsed test time) multiplied by 10 000. The data on smoke production rate, SPR, is calculated as a 60s running average to minimise noise. In addition certain threshold values of SPR and integral values of SPR must first be reached before SMOGRA is calculated.

The detailed definitions of FIGRA and SMOGRA can be found in EN 13823 (SBI).

Table 16: EN 13823 SBI test specifications.

Specimens	Samples for 3 tests. Each test requiring one sample of 0,5x1,5m and one sample of 1,0x1,5m
Specimen	Forms a vertical corner

position	
Ignition source	Gas burner of 30 kW heat output placed in corner
Test duration	20 min
Conclusions	Classification is based on FIGRA, THR_{600s} and maximum flame spread. Additional classification is based on SMOGRA, TSP_{600s} and droplets/particles. Details are given in Table 17.

Appendix 3: National test methods (selected)

A3.1 Sweden

SP FIRE 105, External wall assemblies and facade claddings – reaction to fire:

SP Fire 105 [xviii] specifies a procedure to determine the reaction to fire of materials and construction of external wall assemblies or facade claddings, when exposed to fire from a simulated apartment fire with flames emerging out through a window opening. The behaviour of the construction and material and the fire spread (flame spread) in the wall/cladding can be studied.

The test method is applicable to: - external wall assemblies - and facade claddings added to an existing external wall. The test method is only applicable to vertical constructions.

The method is not applicable for determination of the structural strength of an external wall assembly or facade cladding construction when exposed to fire.

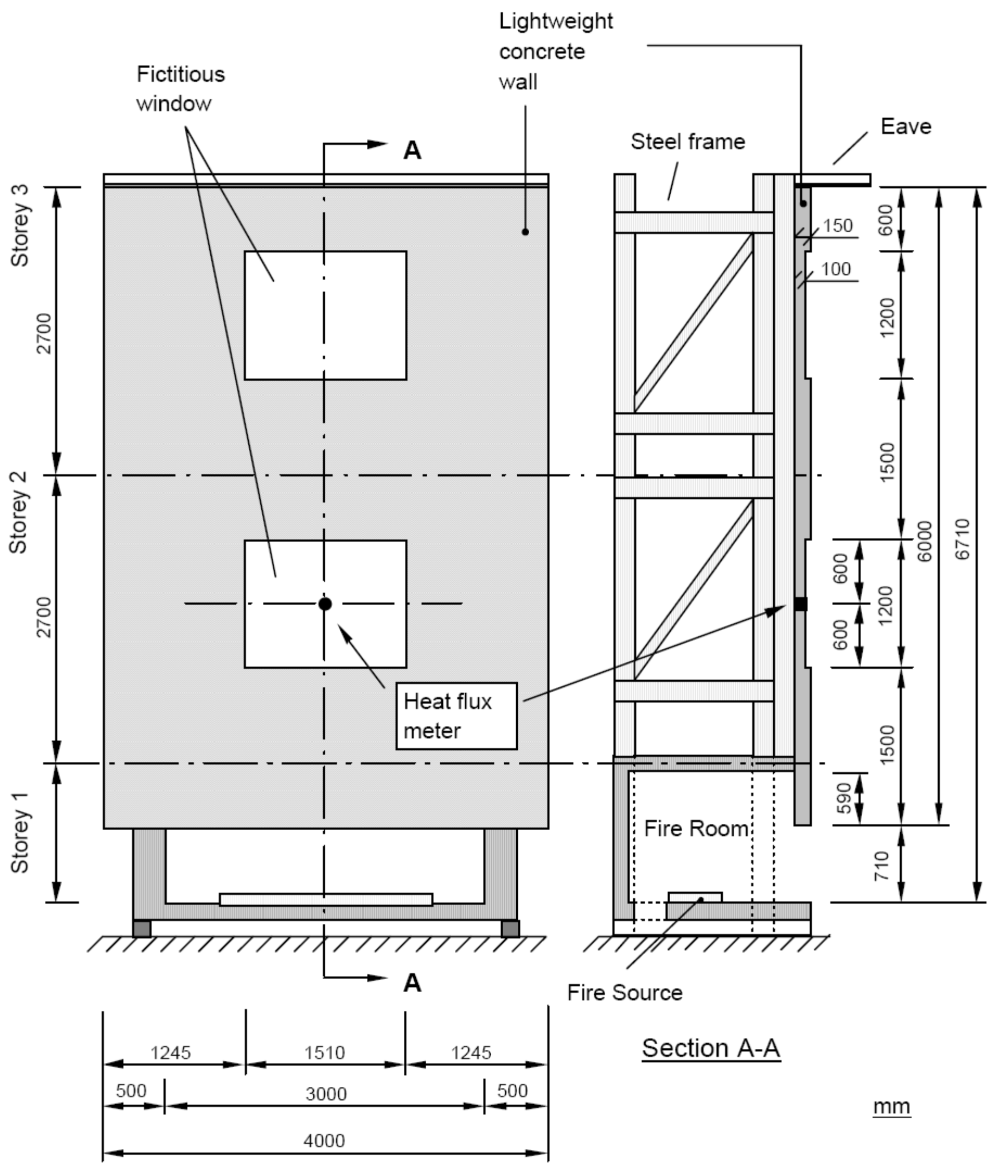

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Figure 8: The test rig used in SP Method 105.

A3.2 Germany

The National German test standard for fire testing of building products is DIN 4102. This standard contains several parts of which Part 2 and Parts 15/16 are relevant for reaction-to-fire properties of EPS/XPS materials and products.

DIN 4102 Part 1 – "Kleinbrenner"

This is a small flame test and is essentially the same test method as EN ISO 11925-2 (see Annex 2). The test is used for determining the B2 requirement.

The test specimen is suspended vertically and a 20mm high flame is applied for 15 seconds to both the specimen surface and edge. Reference lines are marked on the specimen, which achieves B2 classification if the tip of the flame does not reach the reference marks within 20 seconds on any sample. 5 samples are tested with filter paper being placed below each to determine the production of flaming droplets.

DIN 4102 Parts 15/16 – "Brandschacht"

This is the main test method in DIN 4102 which measures reaction-to-fire. The term Brandschacht, refers to the testing apparatus which consists of a square-shaped vertical housing equipped with a gas burner. Four 1000 mm × 190 mm test samples are held vertically in a supporting frame and are subjected to flames for 10 minutes. A constant, uniform flow of air is blown into the Brandschacht from below during the test. The test apparatus is shown in Figure 9.

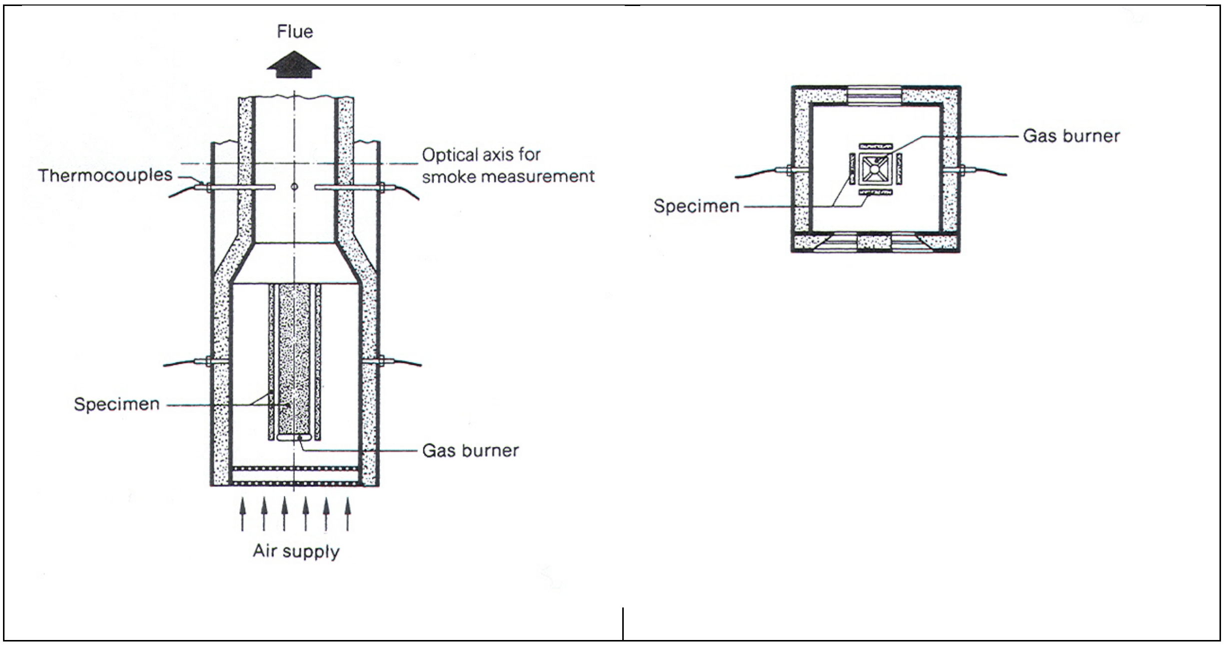

Figure 9: Schematics of test set-up of German "Brandschacht (DIN 4102 Parts 15/16).

In evaluating the test, smoke gas temperature and the mean residual length of the sample are taken into account (residual length = the part of the specimen which has escaped burning). In order to be classified as B1, the tested product must show: 1) A mean residual length of not less than 150mm, with no specimen being burned away completely. 2) A mean smoke gas temperature of less than 200ºC.

A3.3 US

Within the US the major test method for wall and ceiling linings is ASTME84 which is an intermediate scale test for interior finishes. In a number of cases also a full scale test is required such as NFPA 286 and UL1715. These full-scale tests are rather similar. Besides this also requirements from the insurers are used. ASTM E84 is described below.

ASTM E 84-00a Surface Burning Characteristics of Building Materials

ASTM E 84 is probably the most used or referenced fire test standard and the generally most important in the US building codes to characterize flammability of plastics. The test fixture is known as the Steiner Tunnel and was developed by Underwriters Laboratories. The standard is used to assess the comparative surface burning behaviour of building materials and is applicable to exposed surfaces such as walls and ceilings, although building codes rely on data for most cellular product insulation materials, even if behind other barriers.

The test is conducted with the specimen in the ceiling position with the surface to be evaluated exposed face down to the ignition source. The material, product, or assembly must be capable of being mounted in the proper test position during the test. Thus, the specimen must either be self-supporting by its own structural quality, held in place by added supports along the test surface, or secured from the back side. The purpose of this test method is to determine the relative burning behaviour of the material by observing the flame spread along the specimen. Flame spread and smoke developed indices arc reported.

Two preliminary tests are carried out after the apparatus is calibrated. A first run is made with a standard red oak specimen to obtain numerical values of 100 for flame spread and smoke density. In the second preliminary test, an inorganic reinforced cement board specimen is tested in order to obtain zero values for these same parameters.

In the actual main test, the contribution of the material under test to smoke development and flame spread is measured and the material classified on the basis of the results. Test specifications are given in
Table **17**

Table 17: ASTM E 84 test specifications.

Specimens	Sample size 0.51 m × 7.32 m x thickness of use up to a maximum
Specimen position	Horizontal
Ignition sources	Two gas burners, 5.3 MJ/min output located 190 mm below the specimen at a distance of 305 mm from and parallel to the fire end of the test chamber
Test duration	10 min

Conclusions	Flame spread index and smoke-developed index (smoke density)

Appendix 4: Questionnaire

A4.1 Introduction

As described above, fire regulations internationally are often based on Model Codes. This term implies that a code has been developed for the classification of material but that the application of this code, i.e., which material is allowed in which building application, is then specific to the building codes in the individual state or country. This means that compilation of how building regulations impact on the use of a specific chemical or material is not just a matter of identifying the relevant Model Code but also how it is implemented into national or state regulations.

At SP Fire Technology there is detailed knowledge of the Model Codes for fire safety employed in Europe and to a certain degree in North America but only patchwork knowledge of how this is applied in each individual state or country. To add detailed knowledge of the application of the Model Code in the various states and countries included in this compilation, a number of colleagues were contacted with a small number of questions. This chapter contains a summary of those included in the questionnaire and the questions posed. Specific details of the individual answers are given in Appendix 4. The information provided through the questionnaire has been incorporated into both the preceding chapter on Building Regulations and the next chapter on Compliance.

A4.2 Subjects

The subjects for inclusion in the questionnaire were selected based on their experience of building fire regulations in their country of origin or (in some cases) across a number of different markets.

Some of the subjects were representatives of the building industry, others were research scientist working for organisations like SP internationally, yet others were consultants. Table 18 summarises the subjects included in the questionnaire and whether they provided and answer or not.

Table 18: Summary of participants in Questionnaire.

Country	**Employment**	**Relevant Expertise**	**Provided an answer**
Germany	BASF	Building regulations, Standardisation	Yes
UK	DOW	Building regulations, Standardisation	Yes
UK	Exova Warringtonfire	Test Lab, Research Lab	Yes
France	LNE	Research Lab, Building regulations, Standardisation	Yes
Poland	ITB	Test Lab, Building regulations	Yes
Italy	LAPI	Test Lab, Building regulations, standardisation	Yes
Spain	Cidemco	Research Lab, Building regulations, standardisation	Yes
Belgium	Ghent University	Research Lab, Building regulations, standardisation	Yes
Canada	National Research Council	Research Lab, Building regulations, standardisation	Yes
USA	NASFM	Building Regulations	Yes
USA	NIST	Research Lab, Building regulations, standardisation	Yes
USA	SwRI	Research Lab, Building regulations, standardisation	Yes
Egypt	NIS	Research Lab, Building regulations, standardisation	Yes
Australia	Consultant (previously CSIRO)	Building regulations, standardisation	Yes
Japan	NMRI	Research Lab, Building regulations, standardisation	Yes
Korea	Fire Insurers Laboratories of Korea	Research Lab, Building regulations, standardisation	Yes

A4.3 Questions posed

The following set of questions was sent to each of the identified subjects:

“1. Do your building regulations place requirements on individual materials (e.g. EPS) or on finished products (e.g. sandwich panels with EPS) or both?

2. Which test methods are used to assess compliance of insulation materials such as EPS/XPS or products containing these in your country?

3. Which classification must EPS/XPS attain to be used in different building applications?

4. Do these building regulations require that EPS/XPS used in construction is flame retarded?

Note that the Questions relate to reaction-to-fire rather than fire resistance.

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[3] EN 13823:2010, Reaction to fire tests for building products - Building products excluding floorings exposed to the thermal attack by a single burning item.

[4] ISO 9705:1993, Fire tests -- Full-scale room test for surface products.

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[21] Article AM8. Last version of AM8 can be found in notification 2004/0124/F. (Chapter of Public buildings safety code related to insulants used inside the buildings - in reference [xx].)

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[24] Article CO20 - Réaction au feu des composants et équipements de façades. (Chapter of Public buildings safety code related to fire-reaction of facades - in reference [xx].)

[25] Article CO21 - Résistance à la propagation verticale du feu par les façades comportant des baies. (Chapter of Public buildings safety code related to penetration of fire from the facade when facade is equiped with windows - in reference [xx].)

[26] Instruction technique 249 relative aux façades, prévue par la circulaire du 3 mars 1982 relative aux instructions techniques prévues dans le règlement de sécurité des établissements recevant du public, et modifiée par l'arrêté du 24 mai 2010 portant approbation de diverses dispositions

complétant et modifiant ce même règlement (parution au journal officiel le 6 juillet 2010).

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[29] Articles R123 du Code de la Construction et de l'Habitation. (specific parts of the Building Code.)

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Tittel

Assessment of the consumption of HBCDD in EPS and XPS in conjunction with fire national requirements

Sammendrag – summary
Dette er en studie av forbruk av HBCDD i isolasjonspaneler i bygningsbransjen for å oppfylle nasjonale brannforskrifter i ulike land og verdensregioner. Et høyt nasjonalt forbruk av bromerte flammehemmere ble funnet å være en konsekvens av nasjonale brannkrav basert på brannegenskapene til selve materialene, til forskjell for krav basert på bruken og det ferdige produktet.

This is an assessment of the current consumption of HBCDD in expandable polystyrene (EPS) and extruded polystyrene (XPS) in the building sector to satisfy the national fire requirements in different countries and world regions. A clear relationship was found between high national consumption of brominated flame retardants and national fire requirements based on the performance of the material and not the performance of the final product.

4 emneord	4 subject words
HBCDD	HBCDD
Bromerte flammehemmere	Brominated flame retardants
Stockholmkonvensjonen	Stockholm Convention
Brannforskrifter	Fire safety regulations

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- reduce the harmful effects of air pollution and noise

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